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Planning, Management and Organizational Aspects of the Decommissioning of Nuclear Facilities

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PLANNING, MANAGEMENT AND ORGANIZATIONAL ASPECTS OF THE DECOMMISSIONING OF NUCLEAR FACILITIES

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PLANNING, MANAGEMENT AND ORGANIZATIONAL ASPECTS OF THE DECOMMISSIONING OF NUCLEAR FACILITIES

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2013

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FOREWORD

Many old reactors and other nuclear facilities worldwide are being actively dismantled or are candidates for decommissioning in the near term. A significant number of these facilities are located in Member States having little experience or expertise in planning and implementing state of the art decommissioning projects. Planning, management and organization are critical for the success of such projects.

The main objective of IAEA technical activities related to decommissioning is to promote the exchange of lessons learned, thereby contributing to successful planning and implementation of decommissioning projects. Imperative for success is a better understanding of the decision making process, the comparison and selection of decommissioning plans and organizational provisions, and relevant issues affecting the entire decommissioning process.

Topics addressed in this publication include details on development of the decommissioning plan, structuring of key project tasks, organizing the project management team, identifying key staffing positions and determining required workforce skills, and managing the transition from an operational phase to the decommissioning phase. It is expected that this project, and in particular the papers collected in this publication, will draw Member States' attention to the practicality and achievability of timely planning and smooth management of decommissioning projects, especially for smaller projects.

Concluding reports summarizing the work undertaken under the aegis of a coordinated research project (CRP) on planning, management and organizational aspects in the decommissioning of nuclear facilities, and presented at the third and final research coordination meeting (RCM) held in Đa Lat, Vietnam, 5–9 September 2011, are included in this publication. Operating experience and lessons learned during full scale applications, as well as national programmes and plans, are among the most significant achievements of the CRP and have been highlighted.

The IAEA would like to thank to all project participants and to acknowledge the cooperation and hospitality of the institutions that hosted the RCMs. The IAEA officers responsible for this publication were M. Laraia and V. Michal of the Division of Nuclear Fuel Cycle and Waste Technology.

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CONTENTS

1. INTRODUCTION

For nuclear facilities, decommissioning is the final phase in their lifecycle after siting, design, construction, commissioning and operation. It is a complex process involving early, preliminary and later on, detailed planning, and operations such as detailed surveys, decontamination and dismantling of plant, equipment and facilities, demolition of buildings and structures, site remediation, and the management of resulting waste and other materials, whilst taking into account aspects of health and safety of the operating personnel and the general public, and protection of the environment. Experience to date has clearly shown that the technological components of decommissioning are sufficient to assure its completion in a safe, timely and cost effective manner. To this end, careful planning, organization and management are essential.

Until the mid-1990s decommissioning experience was scarce, but much has been learned in the intervening period in all aspects of the discipline. Sometimes the scope of the projects was overestimated and projected costs were believed to be very high. This often gave rise to a slowdown, or even failure to start the decommissioning process while on other projects the tasks were underestimated, resulting in some mistakes being made. With the growing experience in decommissioning of large nuclear facilities, including the completion of some large scale decommissioning projects over the last few years, confidence has been gained and there has often been an incentive to publish and make much information available, typically in the form of lessons learned.

There is a growing volume of information including lessons learned from decommissioning projects being published by several organizations. One such example is a TECDOC published by the IAEA in 2004 [1]. These documents present mainly good experiences; sometimes mistakes and mishaps are also included. There appears to be an increasing recognition that lessons learned should be reported. However, it should be noted that published information on planning, organizational and management aspects of decommissioning is still scarce in comparison with that on technological aspects. Reasons for this situation may be due to overemphasizing the technical aspects of decommissioning to the detriment of the organizational ones, or due to specific political or socioeconomic conditions in any given country. Guidance on organizational aspects may lead to better decision making, reductions in time and resources, lower doses to the workers and reduced impact on public health and the environment.

An old IAEA technical report [2] dealt with planning and management aspects for decommissioning research reactors and other small nuclear facilities. In other IAEA publications [3–5], planning and management were dealt with as one part of the overall decommissioning project. Eventually, the experience available globally on organizational aspects of decommissioning was gathered and consolidated in [6]. More recently, certain non-technological aspects of decommissioning were investigated by the IAEA in ad hoc reports [7–10].

Most important, real time information gathering on actual case histories is minimal. The collected body of international experience in decommissioning planning, organization and management needs to be assembled and published for use and interpretation by those engaging in these activities. This Coordinated Research Project (CRP) is designed to meet this need as will be described in the following sections.

2. COORDINATED RESEARCH PROJECTS ON DECOMMISSIONING

Although the state of the art for decommissioning nuclear facilities is probably adequate to cope with most difficulties associated with the dismantling of such facilities, it is generally necessary to improve, adapt or optimise approaches for the specific needs of the facility to be dismantled. Learning from others rather than reinventing the wheel makes sense in today’s global context. This approach would probably match the needs of many developing Member States. In general, research and development on decommissioning technologies, strategies and management is an active research field. Exchanging conceptual information and knowhow is the very raison d’être of a CRP.

This CRP on Planning, Management and Organizational Aspects in Decommissioning of Nuclear Facilities represents the continuation of three CRPs conducted earlier, in 1989–1993, 1997–2001, and 2004–2008 in the field of decontamination and decommissioning of nuclear facilities. The main results of these CRPs were collected in TECDOCs for distribution to Member States [11–13].

As decommissioning covers a broad, multidisciplinary field, it is widely accepted that to be cost effective, a CRP should be focussed on specific technical topics, such as non-technological aspects of decommissioning, as in this case, and/or specific types of nuclear installations (such as research reactors [11]). The time when decommissioning was viewed as one "package" is over.

3. SCIENTIFIC SCOPE AND PROJECT GOALS

Experience has shown that decommissioning can be undertaken without any deleterious effect on the safety of the workers, the public, or any identifiable impact on the environment, provided decommissioning activities are undertaken in accordance with a properly formulated plan. In addition, a dedicated decommissioning organization, including any needed contractors, should be in place to ensure timely and cost effective management of the decommissioning project.

The objective of the CRP is to promote research and development (R&D) activities, as well as the exchange of information on the planning, organizational and management experience of Member States in decommissioning of their nuclear facilities, in order to pave the way to its smooth planning and implementation. This should be achieved through a better understanding of the decision making process in the comparison and selection of decommissioning options; and planning, organizational and management issues affecting the entire decommissioning process. Special emphasis is given to the gradual development of decommissioning plans (from preliminary to detailed) and decommissioning oriented management techniques. The results are used to improve understanding of specific characteristics of the decommissioning project that are important in the planning and implementation of decommissioning. The information will be particularly useful to Member States that are currently planning or implementing decommissioning of their nuclear facilities.

This CRP directly refers to planning and implementation of nuclear decommissioning projects. Although managerial and organizational techniques were originally developed for the non-nuclear industry, they have been long adapted to the regulations, constraints and specifics of the nuclear industry. Further developments – such as those that took place during the CRP – are typical of a nuclear component alone.

The specific objective of the CRP includes the following components:

- To establish methodologies and data needs for developing concepts and approaches relevant to the comparison and selection of planning, organization and management strategies in decommissioning;
- To improve and expand the database on applications and performance of various types of decommissioning planning approaches and organizational and managerial techniques;
- To address specific issues for individual plans/strategies and generate data relevant to their solution.

In general, the following typical activities have been addressed by the CRP and are reflected in the papers given in this TECDOC:

- Planning of decommissioning activities (preliminary, detailed plans) with a focus on interactions with relevant stakeholders (regulators, public opinion groups);
- Identifying needs, constraints and priorities;

- Gathering experience on planning, organization and management from other decommissioning projects;
- Evaluating costs and financing including processes and tools, project budget, cost control, cash flow;
- Identifying infrastructure requirements and their impact on the decision making;
- Conducting cost—benefit or multi-attribute analyses of specific case histories;
- Evaluating the role of decommissioning staff, organization structure, responsibilities, lines of communications, use of contractors vs. in house work;
- Conducting R&D of innovative/adaptive planning, organization, control and management techniques including sequencing of operations, scheduling, milestones, work packages;
- Identifying training requirements and performing training in the above mentioned areas;
- Elaborating on operating experience and lessons learned.

Immediately following approval of the CRP, prospective participants were invited to propose research contracts or agreements on relevant topics. The process of selecting and awarding agreement/contracts was completed by mid–2008. According to a rough categorization, the CRP involves four institutions from fully industrialized Member States (Denmark, Finland, Norway, the United Kingdom), three institutions from Member States with limited resources, but gradually gaining experience in decommissioning (Bangladesh, Ukraine and Vietnam) and five institutions from Member States presenting a mixed picture from the viewpoint of national decommissioning programmes development and implementation (Czech Republic, Hungary, Russian Federation with two distinct contracts, and Slovakia). As illustrated by Table 1 below, some of these institutions have an interest in decommissioning planning, others in organization and management of ongoing decommissioning projects, yet others in both. The facilities in question also vary widely. Four contracts were awarded, the rest being research agreements (RA).

TABLE 1. DISTRIBUTION OF REFERENCE FACILITIES AND PROJECT OBJECTIVES AMONG CRP PARTICIPANTS

Legend: DP = Decommissioning Planning O&M= Organization and Management
NFC= Nuclear Fuel Cycle NPP= Nuclear Power Plant RR= Research Reactor

RRs	Czech R (DP)	Bangladesh (DP)	Ukraine (DP)	Vietnam (DP)
NPPs	Slovakia (DP, O&M)	Hungary (DP)	Finland (DP)	
NFC facilities	Denmark (DP, O&M)			
Various facilities, generic	United Kingdom (DP, O&M)	Russian Federation Contribution from A.F. Nechaev (DP)	Russian Federation Contribution from S.V. Mikheykin (DP, O&M)	Norway (DP, O&M)

Soon after proposal selection, UKAEA Ltd (now Babcock International Group PLC) in Dounreay was contacted and kindly accepted to host the first RCM. Dounreay is the venue of a number of decommissioning activities of various kinds, as the entire nuclear research centre is being decommissioned, a task which will last decades. The workshop included two technical tours to the

Dounreay Centre, including: the Prototype Fast Reactor; the Dounreay Fast Reactor, both under active decommissioning; and Caithness Horizons, a multimedia place incorporating the functions of archaeological museum, heritage centre, centre of genealogical studies, stakeholder forum, and information centre on state and progress of the Dounreay decommissioning. Caithness Horizons exemplifies UKAEA Ltd and other donors' endeavours to mitigate socioeconomic impacts of Dounreay closure and decommissioning by stimulating tourism and creating jobs.

Soon after the first RCM, FORTUM of Finland was contacted and kindly accepted to host the second RCM. FORTUM is institutionally tasked, among other things, with the drafting of preliminary decommissioning plans for Loviisa NPP. In Finland, there is already decades of experience of such periodic revisions to NPP decommissioning plans, and it was extremely instructive for the CRP team to be acquainted with these activities as they happen. The timing of FORTUM's participation in the CRP was ideal. At the time of the first RCM, a decommissioning plan for Loviisa NPP had just been completed (late 2008). The next update is planned for 2012 which made the third RCM in late 2011 almost the best time to see how the decommissioning plan evolves and why. (Incidentally almost the same updating schedule applies to Hungary's Paks NPP decommissioning plan, Hungary being another CRP participant).

The third RCM was held in Đa Lat, Vietnam. This RCM offered the opportunity to visit ageing facilities in Đa Lat and have a first hand view of issues and the progress in planning for the decommissioning of the Dalat research reactor in a national context of little experience on this topic.

4. SUMMARY OF MAJOR PROJECT ACHIEVEMENTS

According to IAEA guidance [4] "three stages of planning for decommissioning are envisaged: initial, ongoing and final. For a given facility, the degree of detail will increase from the initial to the final decommissioning plan. This planning process will result in the production of a decommissioning plan". "An initial plan for decommissioning should be prepared and submitted by the operating organization in support of the licence application for the construction of a new reactor." The CRP in question highlighted that many research reactors do not have yet a decommissioning plan, but are moving towards having one, consistent with IAEA recommendations [4] "In cases where an operational plant does not have an initial plan for decommissioning, a decommissioning plan reflecting the operational status of the installation should be prepared without undue delay". This is the case of Bangladesh and Vietnam reactors as highlighted in the CRP.

Quoting further from ref [4] "During the operation of a reactor, the decommissioning plan should be reviewed, updated and made more comprehensive with respect to technological developments in decommissioning, incidents that may have occurred, including abnormal events, amendments in regulations and government policy, and, where applicable, cost estimates and financial provisions". As far as the CRP was concerned, this was the case of Finland, Czech Republic, Slovakia and Hungary. In these countries, updating decommissioning plans has been a legal requirement for many years. During the CRP, information was provided for the Loviisa NPP and as detailed above in Section 3, it was shown what impact the change of boundary conditions may have on decommissioning provisions and costs. Concerning the Czech Republic, new circumstances having wide impact on the decommissioning planning of the research reactors operated by the Nuclear Research Institute Řež included:

- Shipment of spent fuel to the Russian Federation for reprocessing;

- Preparation of processing of radioactive waste from reconstruction of the VVR-S research reactor.

Hungary has legal provisions similar to Finland. For all these countries it is praiseworthy that decommissioning plans are being updated although the planned final shutdown is far away in time.

For Hungary, shortening of the protected conservation period is the main issue of the decommissioning plan revision. Reasons for this change include:

- The national radioactive waste management agency (PURAM) which is in charge of decommissioning in Hungary realises that the long term availability of skilled workers and of a national waste management infrastructure will be an issue;

- The expected reduction of the workforce after final shutdown could be compensated by engaging the workers in the decommissioning tasks.

It should be noted that the move towards accelerated decommissioning is in line with the preference for immediate dismantling specified in IAEA Safety Requirements [14].

Another project regarding decommissioning of a research reactor is being carried out in Ukraine. Its main aspects consist of the following. Planning for decommissioning started as *Decommissioning Concept* in 2001. This document contains a generic decommissioning approach and measures. The next step of decommissioning planning was the development of the detailed *Decommissioning Program*, which was drafted during 2007–2009 and approved by the regulatory authority on 4 November 2009. This document determines and substantiates the main technical and organizational measures for decommissioning preparation and implementation, the sequence of works and measures, necessary conditions for their execution and provisions. Special attention is given to the safety of the public, due to the reactor location in the capital city of Ukraine.

The two Russian projects were complementary in that they adopted two different approaches to a similar objective which can be summarized as "Critical review of Russian infrastructure and conditions related to planning for and organization of decommissioning and waste management activities, including unsolved issues, sensitive areas, possible changes and necessary improvements". The vast extent of the country, the spreading of institutional responsibilities, and the huge legacy from nuclear activities have made it difficult so far not only to have a clear picture of the overall problem, but also to prioritize and look for optimized resources.

The Danish project focuses on the role of the project managers at decommissioning projects. The following summarizes the key lessons learned during the decades of decommissioning activities at Risoe:

- The project managers should be involved at an early stage in the project;

- They should be involved in the development of the:

    - Project schedule;

    - Its cost estimation;

    - Development of the risk logs.

- Their early involvement in the project will ensure ownership of these documents by the project manager;

- The organizational structure should be such that the project manager has access to all resources necessary to deliver the project;

- If these resources are not within his or her direct management control then it is recommended that there is a formal agreement between the project and the line management of the resources concerned;

- If this form of matrix management is employed then that staff who are seconded into the project must feel that they are an integral part of the project team.

The above statements are in line with the guidance given by the IAEA in [6].

The role of human factors is well recognized in [6] as an important component of organization and management of decommissioning projects. This is due, among other factors, to decommissioning being in itself dynamic and changing (as opposed to routine operation). The key factors investigated in the Norwegian project can be enumerated as follows:

- Maintaining a motivated workforce becomes more challenging during decommissioning;
- Work tasks and procedures also change;
- This puts requirements on internal communication and communication and collaboration technologies chosen by organizations to enable new work processes and practices;
- Sometimes new procedures must be made and remade in cooperation between the plant and the regulators.

Most reference publications including [6] decline to deal with organizational measures for a facility that has undergone a serious accident. This is due to the difficulty of predicting the radiological and physical conditions prevailing after an accident. Therefore the research study pursued by a Slovak organization is particularly significant. Slovakia has two decommissioning projects underway: one for a prototype NPP with a seriously damaged reactor (A1), the other for a NPP shut down under planned conditions (V1). The Slovak study compares organizational and management provisions between these NPPs.

A recent report by the IAEA deals with performance indicators [15] broadly. The study from Dounreay, UK, expands on a project management technique called Earned Value Management (EVM), which is a performance indicator and also a means to closely control progress and any deviation. In particular it aims:

- To define the principles, methodologies and benefits of the application of EVM to nuclear decommissioning;
- To define the principles, methodologies and benefits of an integrated programme control system in managing scope, schedule and cost.

5. STATE OF THE ART AND PENDING ISSUES

This CRP has assessed the processes involved during the decommissioning of nuclear facilities with respect to planning, organization and management. A non-exclusive list of aspects important for the implementation of successful decommissioning programme is as follows:

- A decommissioning project is subject to continuous change. Procedures for the management of change are therefore essential. A timely plan to deal with the social impacts that can occur during plant shutdown is often vital.
- Clearly defined end states of the decommissioning activities are established. The end states are derived from the objectives of the organization charged with completing the work and are in compliance with the requirements of the regulatory body and other organizations. Further, the agreed upon end states will be readily verifiable, independently measured, and reported in a quantitative way.
- Even if the facility owner selects a decommissioning operations contractor(s), the owner, as licensee, remains responsible from a regulatory perspective. Well written contracts with sufficient detail and comprehensive procurement packages are necessary.

- For all the recent advances in cost estimation, actual decommissioning costs can vary substantially from the estimates during planning. Contingency planning and proper management of the decommissioning funds are necessary.

- It is important that the decommissioning project manager be identified and the decommissioning team established in adequate time to allow the development, approval and reviews as need of the decommissioning plan. It is important to use a dedicated organization with the necessary responsibilities and qualifications.

- Key personnel from the operating facility staff are normally part of the decommissioning management team due to their familiarity with the facility and its systems.

- Maintain emphasis on quality throughout the project. Data gathering must be thorough and must meet the data quality objectives early in the project for the characterization, and during the final stages of the project when acceptance of the site for release is to be demonstrated to the regulators.

- The actual organization of the decommissioning team can vary greatly and should be tailored based on the competencies of individual team members, the type of facility, decommissioning strategy and Member State's policies. The team composition may change during the progress of the decommissioning project.

- Management of interfaces with organizations external to the decommissioning team is important. Continuous communication with regulators is essential.

In terms of learning from the shortcomings in past projects, the following issues can be identified:

- Belated/poor planning for decommissioning including inadequate characterization, lack of proper resources, lack of long lead planning for waste storage and/or disposal;

- Unclear roles and responsibilities;

- Inadequate definition of tasks, scope, schedule, and budget;

- Ineffective project organization and project management;

- Lack of strict change control process leading to increased costs;

- Inadequate quality assurance;

- Lack of adequate training for staff;

- Lack of early interface with regulators and with local community;

- Ineffective supervision in monitoring worker performance;

- Lack of corrective action when needed.

6. PROJECT OUTCOME

Implementation and execution of the CRP promoted the exchange of information on ongoing R&D activities in the participating Member States on the various topics relevant to planning, organization and management strategies in decommissioning. The results of the CRP will be useful to Member States in their planning for and implementation of decommissioning of their nuclear facilities. Material collected and elaborated at RCMs (this publication, progress reports and presentations) will remain available to the international community for many years to come.

It is considered that the following outcomes from the CRP will be achieved:

- There will be enhanced understanding among the participants and their organizations of the need for early planning for decommissioning and the establishment of effective organizations and management structures for the decommissioning process;

- An improved understanding of the specific impacts of planning, organizational and managerial factors onto the overall decommissioning strategy;

- A better understanding of how to compare and select organizational and management techniques in an optimal manner taking into account the above factors.

In more detail, it is expected that this project, and in particular the papers collected in this TECDOC, will draw Member States' attention to the need for timely planning and implementation of decommissioning. In some Member States there are nuclear facilities which are kept in an extended state of shutdown, pending decisions on continued operation, extensive refurbishment or decommissioning. This situation, which frequently lasts for many years, weighs heavily on staff morale and motivation, impacts on mobilization of resources and entails deterioration of structures and components, which may in the longer term, have very serious safety implications.

The results of this IAEA project will offer many Member States the opportunity to move forward in their evaluation of the financial and other impacts of decommissioning their nuclear facilities, so that decommissioning actions can be initiated and continued without undue delay. Aspects such as fuel and waste management and provisions for other technical, administrative and financial resources require timely preparation and control. The main target group for this publication are those responsible for the planning and implementation of nuclear decommissioning projects. The information contained herewith may also be useful to policy makers, regulatory bodies, contractors and waste managers involved in nuclear decommissioning.

Additionally, the results of the project will contribute to enhancing Member States' overall project organizational capabilities. As decommissioning is a multi-disciplinary process, the project's results will stimulate Member States to develop an integrated approach to decommissioning by making optimal use of resources available both domestically and internationally. In this regard, the project impact may go far beyond the scope of nuclear decommissioning. A recent statement from the technical literature fully supports the objectives and achievements of the CRP "…from the company perspective current advances in technology do not bring about big changes in decommissioning, but rather changes in management approaches and regulatory approaches that offer then greatest opportunity to improve the efficiency of decommissioning" [16].

7. CONCLUSIONS

Beyond the need for early planning, which is now generally endorsed worldwide, organization and management of decommissioning projects require great attention. Hindrances to smooth progress of decommissioning may include inter alia lack of information on technologies/experience/strategies available in a given country. These aspects may require considerable organizational efforts prior to commencement of decommissioning, and during its execution. Both the transition from operations to decommissioning and the decommissioning phases of a project requires a disciplined approach to management. In the interests of improved efficiency it is necessary to adopt the techniques of modern project management, monitor performance, control costs and feedback lessons learned. Decommissioning requires a different 'mind set' from operations – the transition from R&D or process type operations will not necessarily be easy for the workforce.

Nuclear decommissioning – especially with severely constrained resources – requires an ability to select applicable experiences gained in the wider decommissioning context and apply them in a pragmatic way to enable 'fit for purpose' and cost effective solutions. Such experiences must be used selectively and optimized for the project in hand —– there is no universal panacea. Key to the process is getting the existing messages over to those in nuclear environments which do not have the benefit of access to a developed nuclear infrastructure. Fortunately, the decommissioning community is 'close knit' and benefits from the sharing of experiences via international collaborations and the conference scene. Additionally, organizations such as IAEA have recognized the requirement for support to these areas by developing assistance programmes where the wider experiences of others can be shared effectively.

One significant development in this context is the IAEA International Decommissioning Network (IDN), which provides a vehicle to sustain the benefits described in this paragraph [17]. As detailed in the accompanying national papers, a CRP is also a means for participating institutions to establish bilateral or multilateral contacts bound to bear fruit in parallel to and beyond the CRP framework.

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Annex

EXAMPLES OF NATIONAL EXPERIENCES

The examples provided in this annex cover a variety of topics, from simple, standardized technical practice to complex computer programs, covering the overall decommissioning process. It is believed that all these aspects are useful for providing practical guidance and information on how decommissioning projects are planned and executed in various Member States with a view to illustrating how strategies and methods can be adapted from one decommissioning project to another. The examples given are not necessarily best practices, nor has their consistency with the IAEA's guidance been tested in detail. Rather they reflect a wide variety of national policies, social and economic conditions, nuclear programmes and traditions. Although the information presented is not considered to be exhaustive, the reader is encouraged to evaluate the applicability of these cases to a specific decommissioning project. Data and statements provided by national contributors are not necessarily endorsed by the IAEA.

PLANNING, MANAGEMENT AND ORGANIZATIONAL ASPECTS OF THE DECOMMISSIONING OF NUCLEAR FACILITIES IN BANGLADESH

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Abstract

This report summarizes the main results obtained by the Bangladesh Atomic Energy Commission in the decommissioning of spent ^{60}Co gamma irradiator at GammaTech Limited, Chittagong, and preparation of decommissioning plan of the 3 MW TRIGA Mark-II research reactor in Bangladesh.

1. Introduction

Radioactive materials and radiation sources are widely used in Bangladesh in medicine, industry, and research. For different reasons some of these facilities had reached the end of their useful life and consequently they required decommissioning. Major radiation and nuclear facilities in Bangladesh are as follows:

(A) Radiation facilities

- ~14 kCi spent ^{60}Co gamma irradiator at Chittagong;
- ~75 Ci spent ^{60}Co gamma irradiator at Bangladesh Institute of Nuclear Agriculture;
- ~25 Ci spent ^{60}Co gamma irradiator at Bangladesh Atomic Energy Centre (BAEC).

(B) Nuclear facility

- 3 MW TRIGA Mark-II research reactor at Atomic Energy Research Establishment (AERE).

Decommissioning is the last phase in the life cycle of a nuclear radiation facility. Time schedule and costs in decommissioning /dismantling projects are mainly influenced by:

- Type and size of the nuclear/radiation facilities;
- Decommissioning/dismantling strategy/policy;
- Regulatory and legal conditions.

For decommissioning planning and implementation it is necessary to have:

- Govermental support and commitments;
- Responsibility for decommissioning determinated;
- Commitments for financial resources;
- Financing schemes;
- Radioactive waste management strategy;
- Coordination at all levels — especially of the nuclear regulators / regulatory authorities.

The paper describes the actions taken for planning and implementation of decommissioning of the following facilities:

- Spent ^{60}Co source at GammaTech Limited facility;
- 3 MW TRIGA Mark-II facility.

2. Decommissioning policy

Draft regulatory guide “Decommissioning of Nuclear Facilities and Radiation Sources” (2004) requires to address following aspects of decommissioning process:

- Scope, aims and definitions;
- Basic principles;
- Prerequisites of successful decommissioning activity;
- Socioeconomic requirements;
- Financial opportunities;
- Research and development priorities;
- Responsibilities of operating organizations.

3. Plan for dismantling of ^{60}Co gamma irradiator at Chittagong

GammaTech facility was visited in May 2008 by US DOE team for the upgrade of physical protection system with prior permission from High Court under GTRI (Global Threat Reduction Initiative) programme. The source was found risky.

A time bound action plan was prepared in collaboration with US DOE team for dismantling of the spent ^{60}Co gamma source of GammaTech Ltd. and submitted to High Court in August 2008. High Court permission for source dismantling was issued in November 2008 (dismantling work should be finished by 22 August 2009 and report to High Court by 30 August 2009).

Decision on dismantling method was taken in March 2009 in cooperation with US DOE and Russian counterpart after the site visit. Preparatory works were done from April to July 2009.

3.1. History of spent ^{60}Co gamma irradiator at Chittagong

The plant (Fig. 1) was in operation from 1994. Purpose of the facility was food preservation and irradiation of other products. License for operation expired in December 2001 and the plant was closed down in December 2002.

Later on the plant was declared bankrupt by the High Court decision on 26 October 2004, but unfortunately the source was kept without any security measures. Nominal activity of the source was 110 kCi in 1993. The source was stored in a dry mode with water cooling system (underground pit with 56 holes).

Documents prepared for the implementation of dismantling and source removal were as follows:

- Dismantling procedures;
- Radiological preparedness;

- Radiation monitoring report;
- Training arrangement for dismantling and transport workers;
- Accidental consequence analysis with computer code;
- Transport pathways analysis.

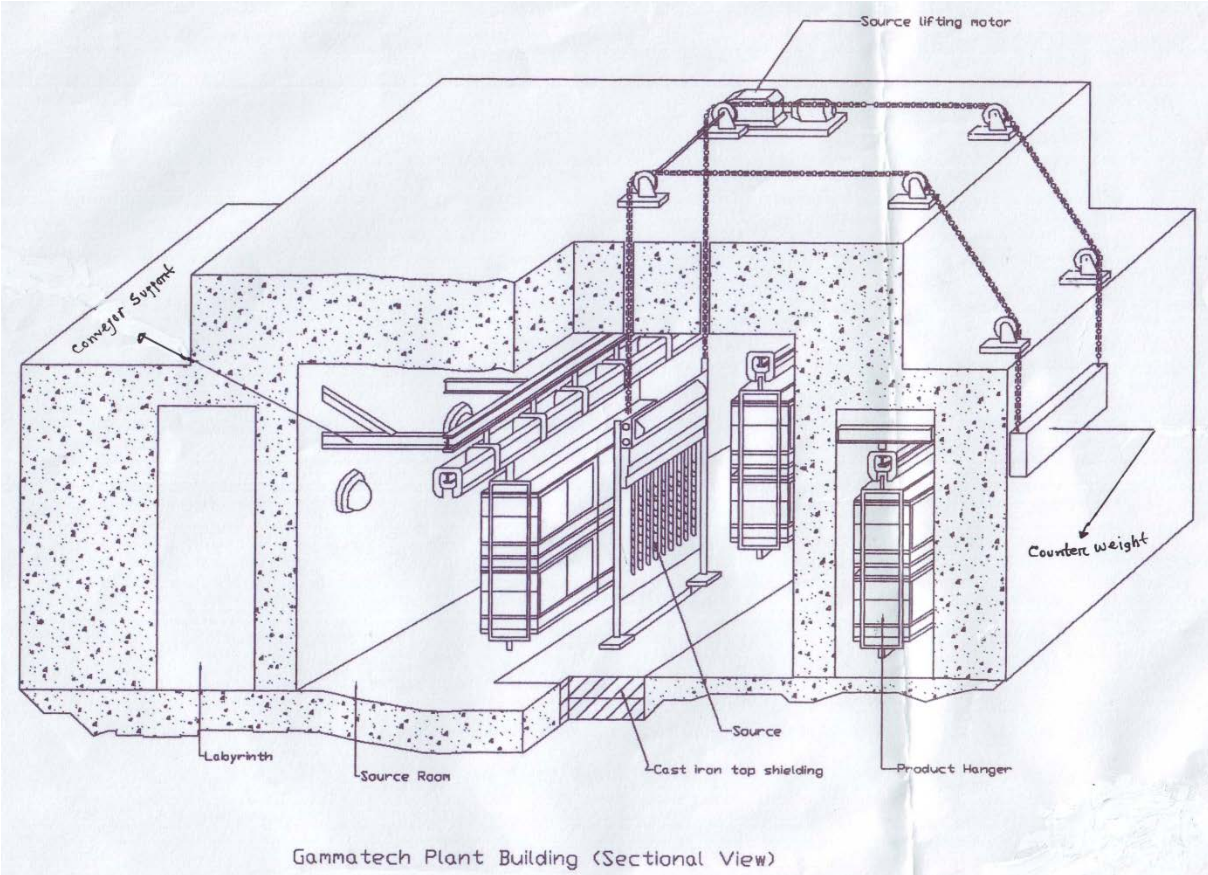

FIG. 1. General layout of the gamma irradiator plant.

Following dates were important for the project implementation:

- Fabrication of transport container and source transfer container: order for the Russian Federation by US DOE in May 2009;
- Technical committee formation: June 2009;
- Technical committee's meeting with Regulatory body: June 2009;
- Regulatory consent for dismantling: July 2009;
- Arrival of Russian experts: 6 August 2009;
- Site preparation: 7–18 August 2009;

- Arrival of transport and source transfer containers at site location: 20 August 2009 (late arrival due to a lot of various problems);

- Source dismantling task: 21–22 August 2009;

- Transfer of source container to AERE storage facility: 23 August 2009;

- Final report to High Court and Regulatory Authority: 30 August 2009.

Spent ^{60}Co source transportation was implemented as follows:

- Transportation of spent ^{60}Co source was carried out in container by the specialized vehicle;

- The convoy of the trucks move used specially developed pathways and it was supported by police and fire brigade.

3.2. Final report

After completing of dismantling works and transport (documented in Fig. 2–13 in Annex) the final radiation survey/contamination was carried out. The results were used for preparation of final report to High Court & Regulatory Authority. On the basis of the report regulatory body accepted decision about the opportunity for the removal of the facility from regulatory control.

3.3. Lesson learned

Dismantling task was successfully completed in collaboration with US DOE and the Russian Federation under GTRI programme. Based on these experiences, further works on dismantling of other radiation sources are being planned under GTRI programme. The GammaTech facility can be used for other purposes.

4. Status of research reactor

TRIGA Mark-II research reactor (see Figs 14–16 in the Annex to this paper) with thermal power 3 MW is operated by BAEC. Pool type reactor is cooled by light water and moderated by zirconium hydride. The reactor was first made critical on 14 September 1986.

The reactor serves as a radiation source for physics experiments, radioisotope production, activation analysis and irradiation purposes.

5. Preliminary decommissioning planning for research reactor

In accordance with the existing legislation the decommissioning planning must be performed at the operation stage of nuclear installation. Initial decommissioning planning for the research reactor was performed in the framework of Final Site Safety Report (FSAR) issued in 1996. The further development of this document is the **Decommissioning Plan** for research reactor in the FSAR (2006). Elaboration of necessary decommissioning documents is in progress now.

Tentative schedule for the research reactor decommissioning is as follows:

- Shut down: 2030;
- Start of decommissioning: 2032;
- End of decommissioning: 2035;
- Site use after decommissioning: will be determined based on regulatory decision.

Main steps to achieve planned decommissioning goals are as follows:

(1) Establishment of work areas;

(2) Procedure for removal of peripheral systems;

(3) Access arrangement to research reactor hall;

(4) Decontamination of different items;

(5) Dismantling of installation and secondary structures;

(6) Cleaning and clearance of the research reactor building;

(7) To ensure implementation of ALARA principle.

6. Plan for decommissioning

The term 'decommissioning' refers to administrative and technical actions taken to allow removal of some or all of the regulatory controls from a nuclear safety. These actions involve decontamination, dismantling and removal of radioactive materials, waste, components and structures. The initial plan would address the following main points:

(1) A proposal of decommissioning of research reactor along with an estimate of costs for decommissioning shall be prepared;

(2) Description of the nuclear installation, including both technological and constructional parts, before termination of operation;

(3) Planned date of starting the decommissioning activities, reasoning of the proposed method and extent of decommissioning and used technological procedures, including their availability and verification in practice, time schedule of the decommissioning activities and their objective will be developed;

(4) Estimation of type and quantity of generated radioactive waste and description of proposed handling with radioactive waste including release of waste into the environment;

(5) Description of handling with spent nuclear fuel and other nuclear materials. Method of securing physical protection during the decommissioning;

(6) Method of securing emergency preparedness and analysis of possible extraordinary situations and their initiation events, including analysis of radiation risks and impact assessment of the decommissioning activities on the staff, public and environment;

(7) Proposal of organizational preparations and staffing of the decommissioning process. Planned use of the area of the nuclear installation during and after the decommissioning, including description of changes in the surroundings of the nuclear installation resulted from its operation and supposed effects on the surroundings caused by the decommissioning;

(8) The schedule of decommissioning activities shall include a description of the considered decommissioning activities, costs of such decommissioning activities etc.

7. Conclusions

The spent gamma irradiator plant was successfully dismantled, transported and safely stored in collaboration with US DOE and Russian experts under GTRI programme. A programme is under process for dismantling of other risky spent gamma radiation sources.

Research reactor facility in Bangladesh is in operation and will not be decommissioned in the near future. Preliminary decommissioning plans for research reactor are in progress [3, 4]. Computer software will be developed for management of all decommissioning activities. Exchange of the information and knowledge related to the decommissioning planning and management [1, 2, 5, 6] are very valuable and mutually beneficial under this CRP.

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Annex

FIG. 2. Source transfer cask.

FIG. 3. Transfer cask before loading of spent ^{60}Co pencil source from the source pit.

FIG. 4. Manipulation with the transfer container for lifting the spent ^{60}Co source.

FIG. 5. Transfer cask with spent ^{60}Co pencil source from the source pit.

FIG. 6. Transfer cask with spent ^{60}Co pencil source from the source pit.

FIG. 7. Unloading spent ^{60}Co source from the transfer cask.

FIG. 8. Unloading spent ^{60}Co source from the transfer cask.

FIG. 9. Contamination/Leaking test.

FIG. 10. Lifting of ^{60}Co transport container.

FIG. 11. Transport container with truck.

FIG. 12. Truck accompanied by police/fire brigade.

FIG. 13. Stored of dismantled ^{60}Co source at the waste storage facility.

FIG. 14. View of the TRIGA Mark-II research reactor.

FIG. 15. Control panel.

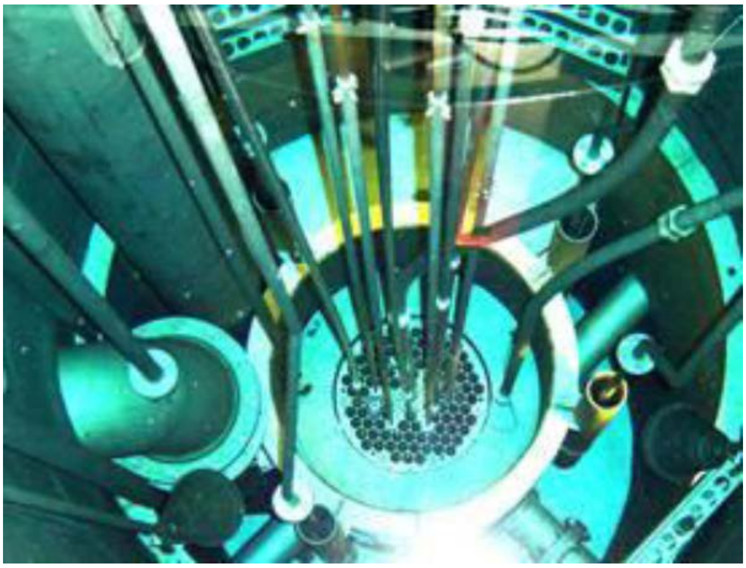

FIG. 16. View into the research reactor core.

PLANNING THE DECOMMISSIONING OF RESEARCH REACTORS

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Abstract

In the Czech Republic, three research nuclear reactors are in operation. According to the valid legislation, preliminary decommissioning plans have been prepared for all research reactors in the Czech Republic. The decommissioning plans shall be updated at least every 5 years. Decommissioning funds have been established and financial resources are regularly deposited. Current situation in planning of decommissioning of research reactors in the Czech Republic, especially planning of decommissioning of the LVR-15 research reactor is described in this paper. There appeared new circumstances having wide impact on the decommissioning planning of the LVR-15 research reactor: (1) Shipment of spent fuel to the Russian Federation for reprocessing and (2) preparation of processing of radioactive waste from reconstruction of the VVR-S research reactor (now LVR-15 research reactor). The experience from spent fuel shipment to the Russian Federation and from the process of radiological characterization and processing of radioactive waste from reconstruction of the VVR-S research reactor (now the LVR-15 research reactor) and the impact on the decommissioning planning is described in this paper.

1. Introduction

In the Czech Republic, three research nuclear reactors are in operation. According to the valid legislation, preliminary decommissioning plans (PDP) have been prepared for all research reactors in the Czech Republic. The decommissioning plans shall be updated at least every 5 years. Decommissioning funds have been established and financial resources are regularly deposited.

In 2008, the preliminary decommissioning plan for the LVR-15 research reactor operated by the Nuclear Research Institute Řež was updated. The next update was performed in 2010; it was also connected with the process of changeover of the owner and operator of the research reactors.

There appeared new circumstances having wide impact on the decommissioning planning of the LVR-15 research reactor:

- Shipment of spent fuel to the Russian Federation for reprocessing;
- Preparation of processing of radioactive waste from reconstruction of the VVR-S research reactor (now LVR-15 research reactor).

2. Planning of decommissioning of research reactors in the Czech Republic

2.1. Research nuclear reactors operated in the Czech Republic

In the Czech Republic, three research nuclear reactors are in operation. Two research reactors LVR-15 a LR-0 are operated by the Centre of Research Řež and the educational reactor VR-1 is operated by the Faculty of Nuclear Sciences and Physical Engineering of Czech Technical University of Prague. One research rector has already been decommissioned as shown in Table 1.

2.1.1. LVR-15 research reactor

The LVR-15 reactor is a light water moderated and cooled tank nuclear reactor with forced cooling. It has 10 MWth power and it has been in operation since 1957 as the VVR-S reactor and since 1989 as the LVR-15 reactor after reconstruction. The reactor serves as a radiation source for several experiments, activation analysis and irradiation purposes.

TABLE 1. RESEARCH NUCLEAR REACTORS IN THE CZECH REPUBLIC

Nuclear Installation	Type of reactor	Operator	Year of start up	Year of Shut down	Status
Research reactor LVR-15	tank reactor 10 MW_{th}	Research Centre Řež	1957 (VVR-S) 1989 (LVR-15)*	2018	in operation
Experimental reactor LR-0	zero power reactor	Research Centre Řež	1972 (TR-0) 1982 (LR-0)*	2008	in operation
Training Reactor VR-1	zero power reactor	CTU Prague	1990	2020 or later	in operation
Research Reactor SR-0	zero power reactor	ŠKODA Nuclear Machinery	1970	1989	decommissioned (1997)

* After reconstruction

The reactor was operated at 2 MWth maximum output from 1957 until 1969 when the power was increased to 4 MWth. The Russian type EK-10 fuel made up of 16 rods of a 10% enriched uranium dioxide–magnesium alloy in aluminium cladding was used during this period. In 1974, the IRT-2M fuel with 80% enrichment was introduced. This consisted of 3 or 4 concentric square tubes of uranium/aluminium alloy fuel/metal clad on either side with aluminium. The power output of the reactor was increased to 10 MWth. In the years 1988 – 1989 the reactor was reconstructed into the LVR-15 reactor. It was essentially a complete rebuild of the reactor vessel and internals, primary circuit, control room and ventilation system. In 1996, the IRT-2M fuel with 36% enrichment used uranium dioxide was introduced. Since 2010, the IRT-4M fuel with 20% enrichment is used. The maximum output of the LVR-15 research reactor is 10 MWth.

2.1.2. LR-0 experimental reactor

LR-0 is an experimental light water zero power reactor for determination of the neutronphysical characteristics of VVER type reactor lattices and shielding. LR-0 originated from the reconstruction of the reactor TR-0.

Reactor TR-0 was commissioned in 1972 as a heavy water zero power reactor. It served for the research of the reactor core of the energetic reactor ILS-150 installed in NPP A-1. Reactor TR-0 was operated until 1979. In years 1979–1982 it was reconstructed into light water reactor LR-0. Reactor LR-0 started its operation in 1982 and is operated until now.

The basic types of fuel assemblies used are the shortened dismountable models of the VVER-1000 and VVER-440 assemblies. All LR-0 assemblies are loaded with fuel elements of one type. The height of the fuel filling in the element is 1250 mm, the total length of the element is 1357 mm. The fuel enrichment varies from 1.6 to 4.4% of ^{235}U. Several fuel elements may be opened at both ends and fuel pellets may be removed.

2.1.3. Training reactor VR-1

The VR-1 training reactor is a pool type light water reactor based on enriched uranium as fuel. Its core contains fuel assemblies which are submerged in water.

IRT-4M type fuel in the shape of rectangular concentric tubes with enrichment of 20% is used in the reactor. The tube contains fuel in the form of a dispersion of uranium with aluminium. Owing to the low reactor power the fuel remains physically fresh for entire lifetime of the reactor, no measurable burnup taking place. Hence, virtually no fission products accumulate in the fuel, whereby the spent fuel disposal problem is eliminated.

2.1.4. SR-0 research reactor

In 1971 the SR-0 light water assembly with zero output was put into operation at ŠKODA Plzen. Original allowed output of the system of 100 Wt was increased in 1975 to 2 kWt. In 1989 the SR-0 reactor was put out of operation. The reconstruction of the reactor was supposed, namely the reconstruction of the reactor vessel and the shielding. Nevertheless, in 1990 it was decided to decommission the reactor. The SR-0 reactor has been completely decommissioned in years 1995–1997.

2.2. Legislation requirements on preliminary decommissioning planning

The SÚJB (State Office for Nuclear Safety) is an independent central state administration body for the area of nuclear safety and radiation protection. It has its own budget item approved by the Parliament of the Czech Republic within the state budget. The SÚJB is headed by a Chairperson appointed by the Czech government.

The Act No. 18/1997 Coll. as amended later (Atomic Act) defines conditions for peaceful utilization of nuclear energy and ionizing radiation, including activities requiring a license. The Atomic Act is followed up by decrees, e.g.:

- Decree No. 307/2002 Coll., on radiation protection, as amended by Decree No. 499/2005 Coll.
- Decree No. 185/2003 Coll., on decommissioning of nuclear installations and workplaces in categories III and IV.

Pursuant to the Atomic Act, a Radioactive Waste Repository Agency (SÚRAO) was established by the Ministry of Industry and Trade. It functions as a State organization responsible for ensuring the safe disposal of RW and the monitoring and control of repositories during their operation and after their closure. The Agency is funded through levies imposed on RW producers. It is charged with organizing the disposal of all RW and of SF, if it has been declared as RW.

According to the Atomic Act, decommissioning of a nuclear installation is one of activities associated to utilization of nuclear power, and decommissioning is defined as a set of activities aimed to clear nuclear installations or workplaces, where radiation activities were performed, to be utilized for other purposes.

The preparation for decommissioning shall (in accordance with the Act) be included in each stage of the lifecycle of a nuclear installation. The sitting license documentation for a nuclear installation shall include within the Initial Safety Report a draft concept for safe termination of the operation. The licensing documentation for construction of a nuclear installation shall include as part of the Preliminary Safety Report the concept of safe termination of operation and decommissioning of nuclear installation or workplace being licensed, including disposal of RW. The licensing documentation for each commissioning stage of a nuclear installation for the initial fuel load shall also include the proposed method of decommissioning of installation approved by the SÚJB, as well as the estimated costs of decommissioning verified by SÚRAO.

The operating license documentation for a nuclear installation shall include the proposed method of decommissioning (preliminary decommissioning plan) approved by SÚJB, as well as the estimated costs of decommissioning verified by SÚRAO. The scope and method used to realize the proposed strategy of decommissioning as approved by SÚJB.

For decommissioning of a nuclear installation, the holder of the operating license is liable under the provisions of Atomic Act, Section 18, and based on the estimated total cost of decommissioning, as verified by SÚRAO, to steadily create a provision so that monetary funds deposited in a dedicated and “blocked” account (as defined below) are available for the preparation and execution of decommissioning in a timely manner and in a sufficient amount in compliance with the proposal of decommissioning of nuclear installation approved by the SÚJB. Decree No. 360/2002 Coll. stipulates the method of creating the provision for decommissioning of a nuclear installation or workplace in category III or IV. The funds kept in such a "blocked" account shall only be used for the preparation and execution of decommissioning and drawing on such money is subject to approval by SÚRAO. This Act also defines exceptions to the obligation to create the provision, specifically state organizations, public universities or local government bodies, where decommissioning costs shall be born by the state.

3. LVR-15 research reactor decommissioning planning

3.1. Decommissioning planning

Decommissioning planning of the LVR-15 research reactor is described here as an example of planning of decommissioning of research reactors in the Czech Republic.

According to the Czech legislation the operator of a nuclear facility must prepare a proposal of decommissioning of nuclear installation method (i.e. preliminary decommissioning plan – PDP) along with a cost estimate of decommissioning. This documentation is periodically updated (every 5 years).

In 2008, the PDP for the LVR-15 research reactor was updated [1]. The next update was performed in 2010; it was connected with the process of changeover of the owner and operator of the research reactor.

Since July 2010, the research reactors is owned and operated by Research Centre Řež, a daughter company of NRI Řež. The reason is that all research activities are being transferred from NRI to the Research Centre Řež.

3.2. Update of PDP

The "deferred decommissioning" strategy for decommissioning of the LVR-15 research reactor, i.e. dismantling after the safe enclosure, has been elaborated in the Preliminary Decommissioning Plan of the LVR-15 Research Reactor. The shutdown and removal of SF is considered as a milestone of the operation – the finish point. All following activities are included in the decommissioning phase.

The main scope of decommissioning activities as decontamination, dismantling and radioactive waste processing, will be done after safe enclosure.

The decommissioning process is divided into the following phases:

- Post-operation phase;
- Preparation for a period of facility enclosure;
- Period of the facility enclosure;
- Dismantling of the facility.

The time schedule is given in Table 2.

TABLE 2. THE TIME SCHEDULE OF THE LVR-15 REACTOR DECOMMISSIONING PROCESS

Step	Date
Final shutdown	2018
Post-operation phase (including transfer of spent fuel from the fuel storage pool to the High Level Waste Storage)	2018–2019
Preparation of the facility safe enclosure	2019–2020 *(2021)*
Period of the facility safe enclosure	2021 *(2022)* – 2031
Dismantling of the facility	2032 – 2035
End of decommissioning activities	2035

Note: The dates in brackets are from the previous PDP (2008)

The reasons for choosing this strategy of decommissioning can be summarized as follows:

- The amount of contaminated material and the level of contamination;
- Presumed conditions of technologic equipment and buildings after the end of operation;
- Specific conditions given by location of a nuclear facility (presumed area utilization, competence of the staff, environmental impacts, etc.);
- Radioactive waste disposal and storage capacity and availability;
- Exposition of the staff;
- Financial resources availability;
- Conception of release of wastes into the environment.

The cost of decommissioning will be 145 mil. CZK (in 2010 prices, without spent fuel management); it corresponds to 5.71 mil. EUR.

4. Spent fuel management

4.1. History of spent fuel management

It was understood in the past that all spent nuclear fuel (SNF) produced in the VVR-S reactor would be transported to the Soviet Union for reprocessing, but no such transport has been realized. Therefore it was necessary to enlarge the SNF storage capacity. In addition to the original at reactor (AR) pool, new away from reactor (AFR1) pools were constructed close to the reactor hall and then also new AFR2 pools were constructed in the High Level Waste Storage Facility (HLWSF).

In the years 1969–1975, EK-10 SNF was transferred from the reactor site to temporary storage. SNF was held in dry storage drums. The SNF was then transferred to the HLWSF between the years 1996–1997 (Figs 1 and 2). According to the storage period length, the character of the drum construction materials (carbon steel drum filled with concrete, carbon steel liner) and their possible interaction with aluminium cladding, as well as corrosion of the cladding had to be taken into consideration. It was decided to repack all EK-10 SNF into canisters. A new hot cell was built in HLWSF, and EK-10 SNF was repacked between the years 2006 and 2007 into stainless steel canisters, hermetically welded, put into a cask basket and then stored in a storage facility located close to the hot cell. Additionally, some leaked IRT-2M FAs were also repacked.

FIG. 1. Temporary storage of drums with EK-10 SNF in the HLWSF.

FIG. 2. View inside one EK-10 storage drum after plug removal.

Most of the IRT-2M SNF was moved out of the initial AFR pool in the reactor building into the HLWSF pool between the years 1996–2003. A ŠKODA 1xIRTM transport cask was used for each FA.

In total, 252 pcs. of IRT-2M (80%) and 91 pcs. of IRT-2M (36%) FAs and 206 canisters with EK-10 FAs / fuel rods (10%) have been accumulated.

4.2. Transportation of spent fuel to the Russian Federation

In 2005, NRI joined the Russian Research Reactor Fuel Return (RRRFR) programme under the US-Russian Global Threat Reduction Initiative (GTRI) and started the process of SNF shipment from the LVR-15 research reactor back to the Russian Federation (RF). SNF shipment from NRI to the The Russian Federation represents a very complex and complicated scope of work, technically, legally and contractually.

The SNF shipment has been realized under several specific conditions:

(1) High capacity ŠKODA VPVR/M casks were used for transportation for the first time, which enabled the shipment of both high and low enriched SNF (about 550 fuel assemblies) in one shipment, resulting in substantially reduced risk.

(2) For the first time, high enriched uranium SNF from a research reactor has been sent to the RF from a European Union country under the appropriate intergovernmental agreements, legal regulations and conditions.

(3) Combined road (ADR) and railway (RID) transport of the dangerous material was used, with several reloadings of goods.

The ŠKODA VPVR/M storage and transportation cask (see Figure 3) was used for transportation of SNF. The ŠKODA VPVR/M cask is a type B(U) and S cask system designed and licensed for the transport and storage of SNF from research reactors of Russian origin. 16 ŠKODA VPVR/M casks were used for SNF transportation.

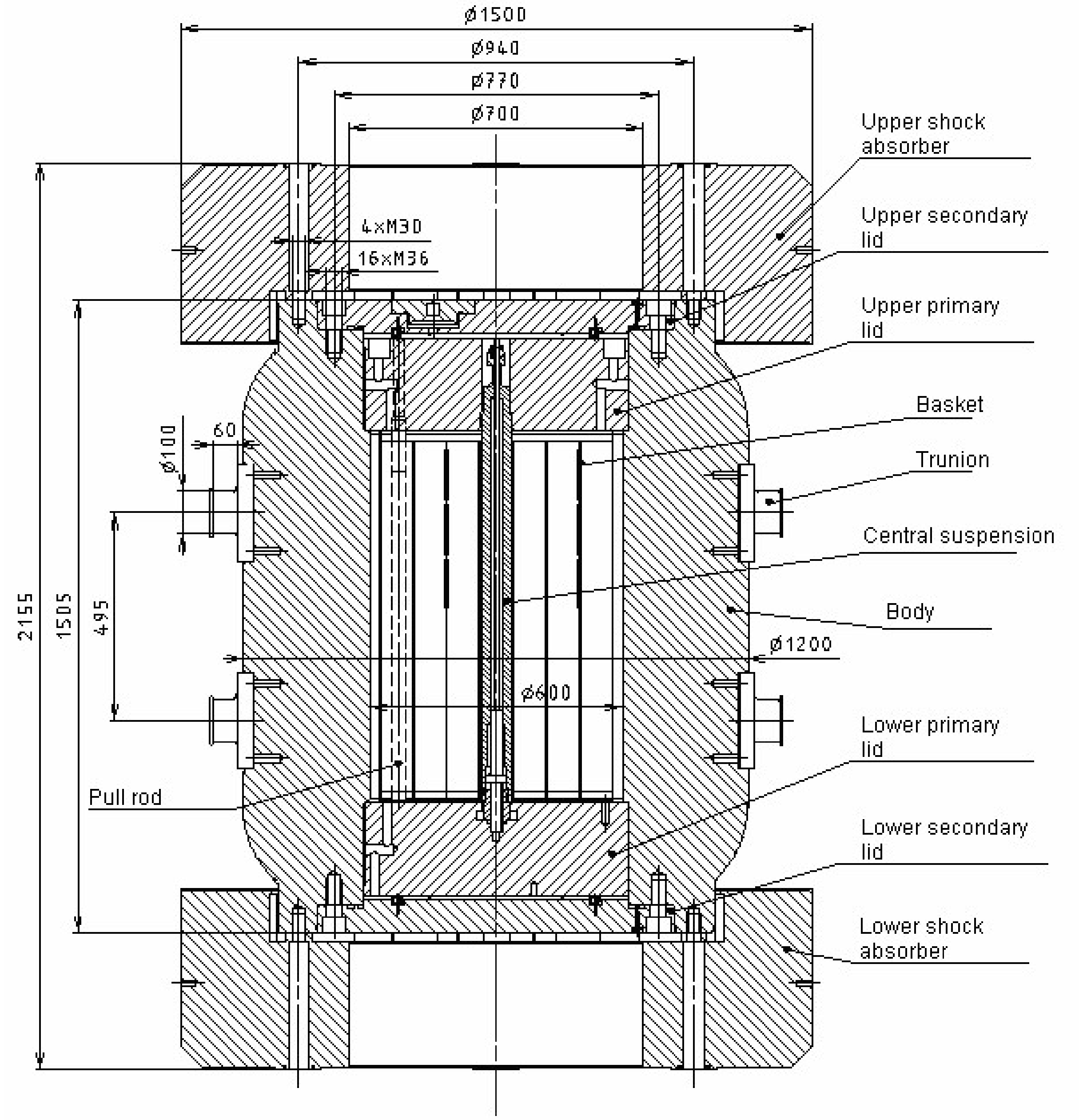

FIG. 3. Scheme of the VPVR/M cask.

In Figures 4–6 the manipulation with the ŠKODA VPVR/M cask and its loading with spent fuel is shown.

FIG. 4. Manipulations with the cask.

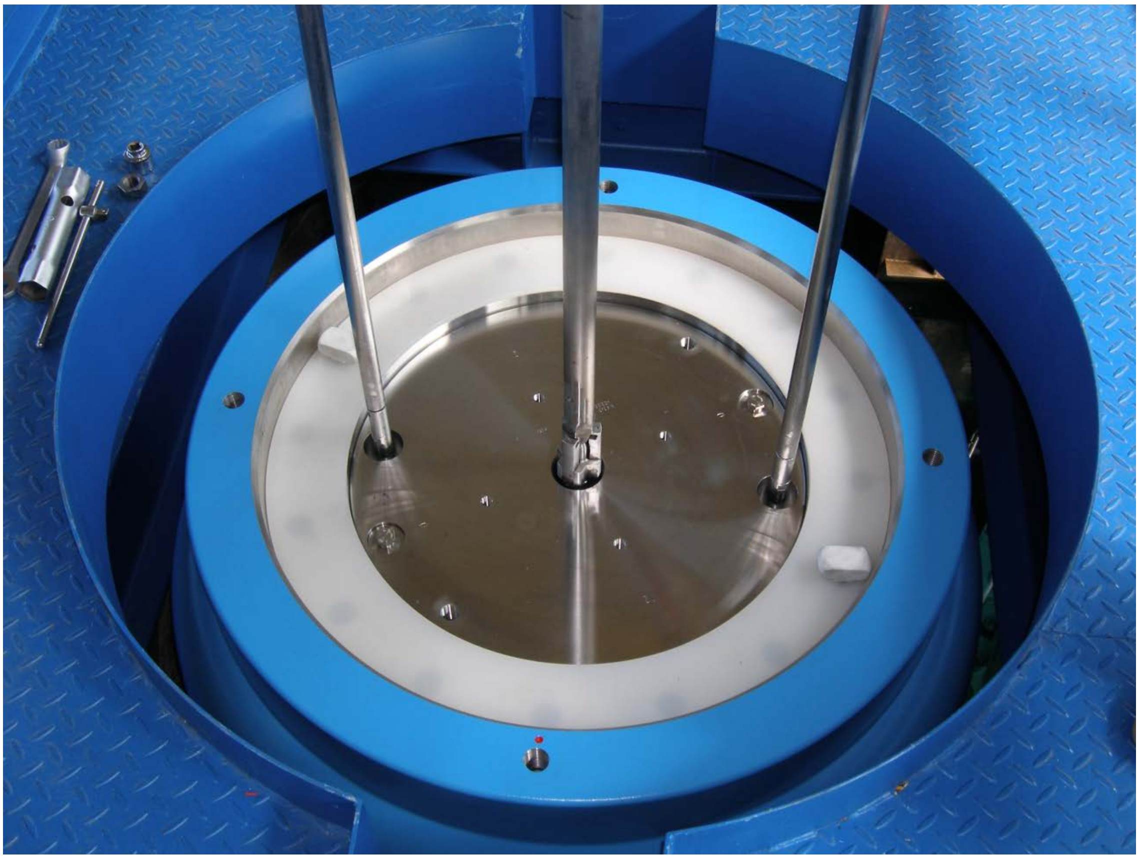

FIG. 5. Lowering of the basket.

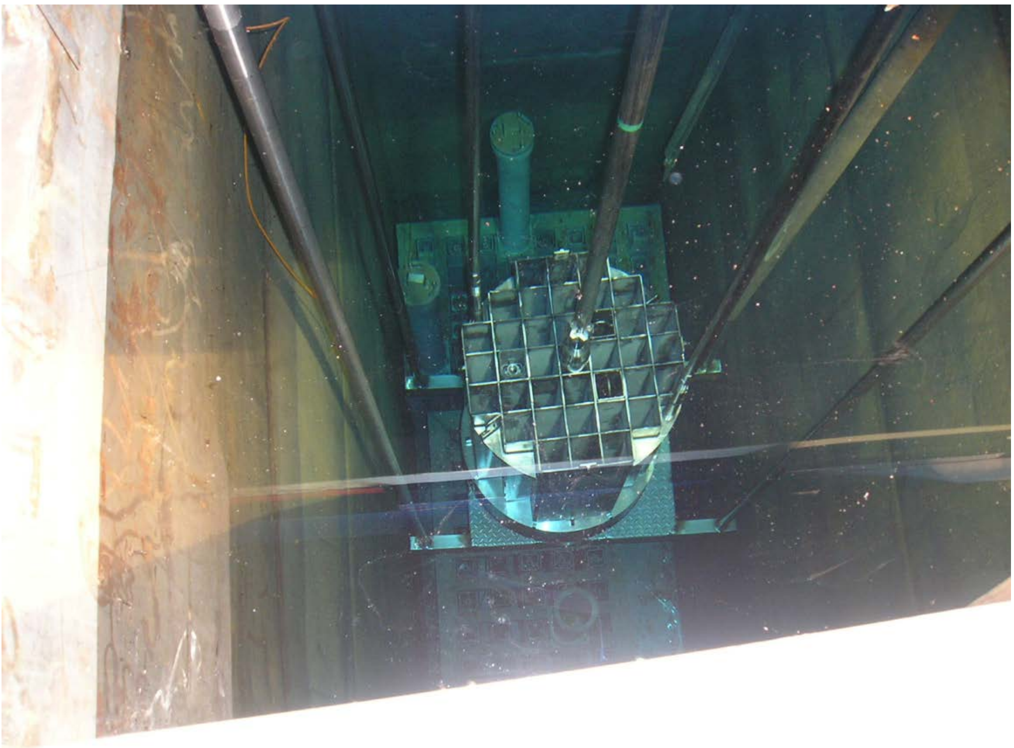

FIG. 6. Basket in the storage pool.

Before transport, the transportation documentation had to be prepared and assembled and all necessary transport licenses had to be acquired. The transport of SNF from the Czech Republic to the RF took place across the transit countries of Slovakia and Ukraine by combined rail and road transport. The transport was performed in December 2007. The VPVR/M casks were loaded from the HLWFS storage area into the ISO containers (Fig. 7). The ISO containers were transported to the railroad station on trucks and were then transferred onto the railroad carriages. Physical protection and emergency preparedness were ensured during transport.

FIG. 7. ISO container with the VPVR/M cask.

5. Management of old radioactive waste from reconstruction of the VVR-S research reactor

In years 1988–1989, the VVR-S reactor was reconstructed. It was essentially a complete rebuild of the reactor vessel and internals, primary circuit, control room and ventilation system. Radioactive waste from the reconstruction has not been processed yet and is stored on the temporary storage site. Processing of this waste started in 2009. Information obtained from the processing (character of waste, radioactive contamination and activation, methods for processing, release into the environment, etc.) will be very important for the decommissioning planning of the LVR-15 reactor, and can be also useful for planning of decommissioning of the other Russian type research reactors.

Approximately 210 m^3 of solid RAW resulting from VVR-S research reactor are expected for processing. Maximum of RAW will be decontaminated and released into the environment. The rest will be processed and sent for disposal. The standard system of solid RAW conditioning consists of segmentation and conditioning by cementation into 200 l drums. Then the drums are sent for disposal into the repository. The new concept has been prepared for disposal of big segments of contaminated technological equipment directly into the disposal cells of the repository. It will be advantageous from the point of view of radiation protection because it will require less segmentation operations. It will be also less time consuming and many resources will be saved. RAW from reconstruction is stored at two storage sites:

- Reloading site (VVR-S reactor vessel);
- Red Rock Storage Site.

5.1. VVR-S reactor vessel

The VVR-S reactor vessel was used from 1957 to 1987. It is made from aluminum alloy SAV-1 (98.5% Al). The dimensions of the vessel are: 2 300 mm (diameter) and 6 260 mm (height). The weight of the vessel is 3.5 t, including internals. In Figures 8 and 9, the removal and storage of the VVR-S vessel into the temporary storage site (Reloading site) is shown.

FIG. 8. Removing of VVR-S reactor vessel.

FIG. 9. Putting the VVR-S reactor vessel into the Reloading site.

The Reloading site was initially constructed as a temporary reloading site to handle conditioned RAW but later was used also for storage of various RAW before treatment. The bases of the boxes are 4 m below ground level and are drained to four closed sumps. The building has a steel roof.

The Reloading site (see Figure 10) consists of 8 concrete boxes each with dimensions of 5.5 x 8 x 4 m (1 400 m^3 total capacity). The hall above the Reloading Site with a crane and auxiliary technology was constructed in 2004. In Figure 11, the Reloading site with a new hall is shown. The reactor vessel is stored in the box No. 7 (Fig. 12).

FIG. 10. Reloading site before reconstruction.

FIG. 11. Reloading site with a new hall.

FIG. 12. VVR-S research reactor vessel.

In 2008, the radiation measurement of the vessel was performed after 20 years of the first measurement [2].

The measurement of equivalent dose rate was performed in the distance of 25 cm from the external surface of the vessel in two axes (horizontal channel No. 9 and thermal column). The data are presented in the Table 3 and compared with the data obtained in 1988. The distance of measuring points is from the top of the vessel.

TABLE 3. EQUIVALENT DOSE RATE IN THE DISTANCE OF 25 CM FROM THE EXTERNAL SURFACE

distance [cm]	Axis of horizontal channel No. 9		Axis of thermal column	
	dH/dt [mSv/h] 1988	dH/dt [mSv/h] 2008	dH/dt [mSv/h] 1988	dH/dt [mSv/h] 2008
100		0.055		0.055
128	0.960		0.960	
178	1.480		1.040	
200		0.102		0.123
228	2.350		2.000	
278	4.000		3.480	
300				0.230
328	6.700			
350		0.520		0.410
378	10.870		8.350	
420	13.910	0.540	19.130	0.750
458	11.740			
470		0.535		0.520
498	11.130			
520		0.370		0.200
543	8.690			
588	5.650			

The maximum equivalent dose rate is between the distances of 350 – 470 cm, that corresponds to the location of the active zone.

Especially at the graphs (Figs 13 and 14) the decrease of equivalent dose rate is evident.

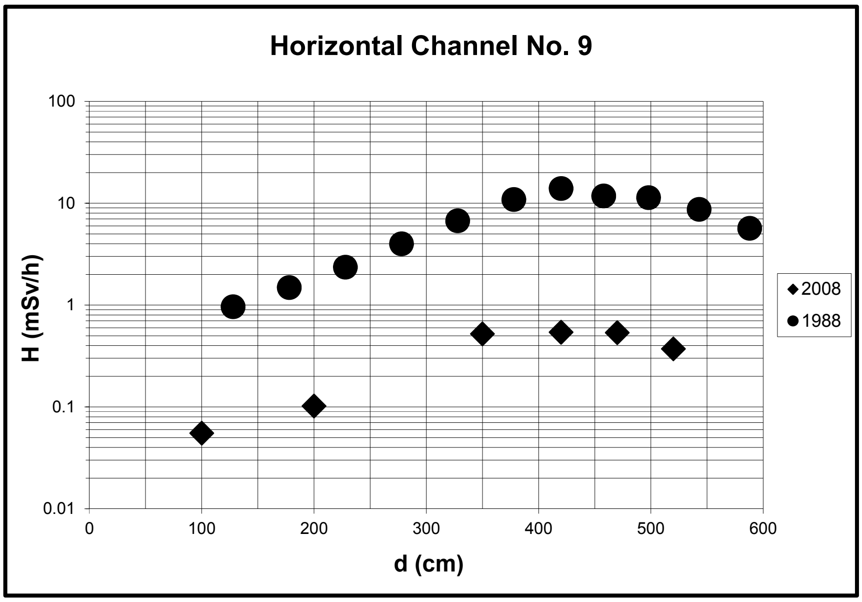

FIG. 13. Comparison of measurements in 1988 and 2008 (axis of horizontal channel No. 9)

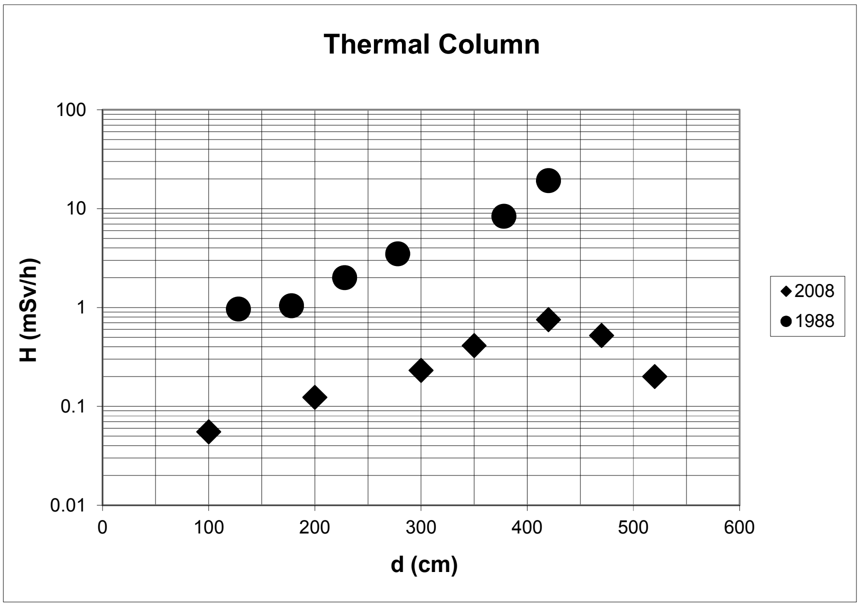

FIG. 14. Comparison of measurements in 1988 and 2008 (axis of thermal column).

The decrease corresponds to the decay period of 20 years. The activity of ^{60}Co decreased 15 times, the remaining radionuclides decayed practically fully.

The measurement with gamma camera was performed in 2010 (Fig. 15) [3].

FIG. 15. Measurement with gamma camera.

In Figures 16 and 17, the results of measurements are shown (measurement for ^{60}Co and ^{137}Cs). The maximum dose rate corresponds to the measurement described above.

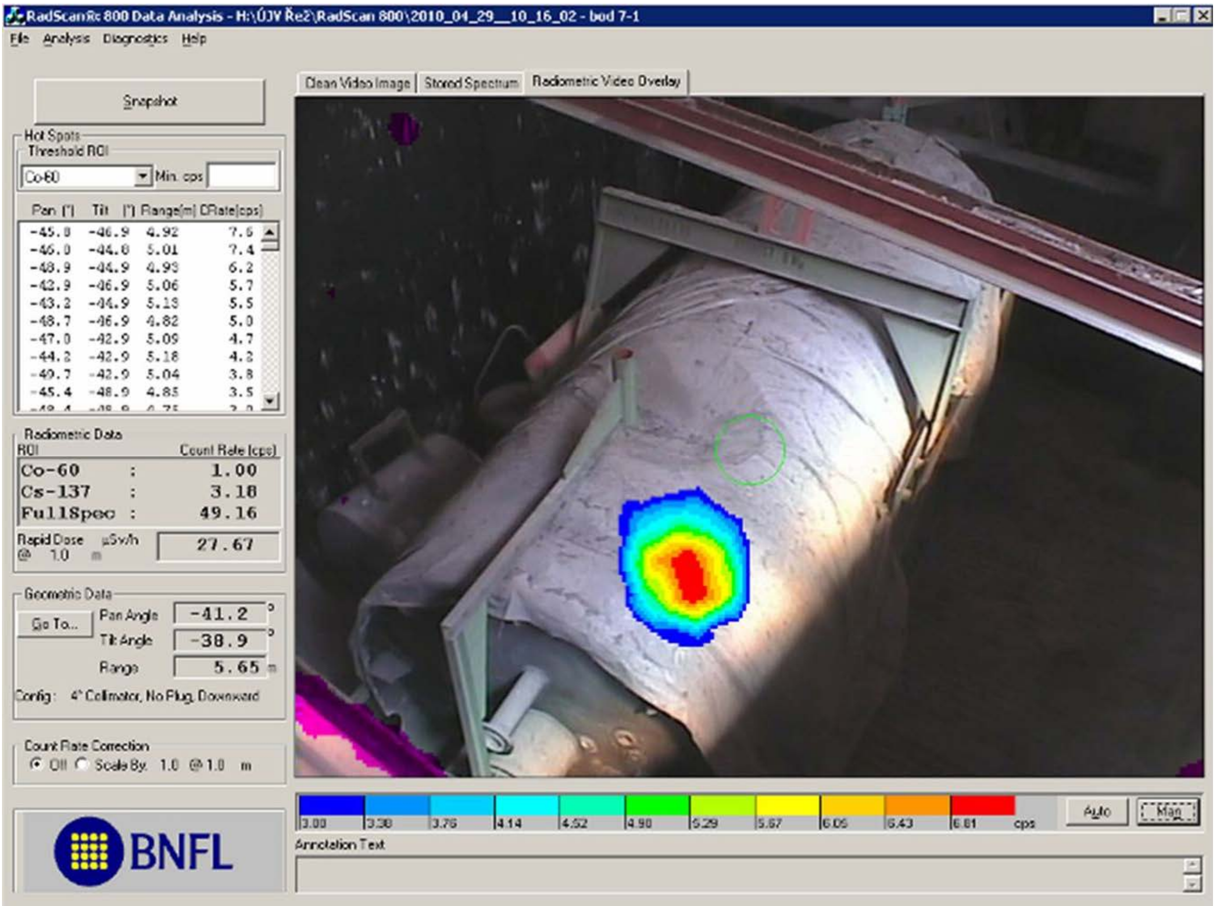

FIG. 16. Measurement with gamma camera — result for ^{60}Co.

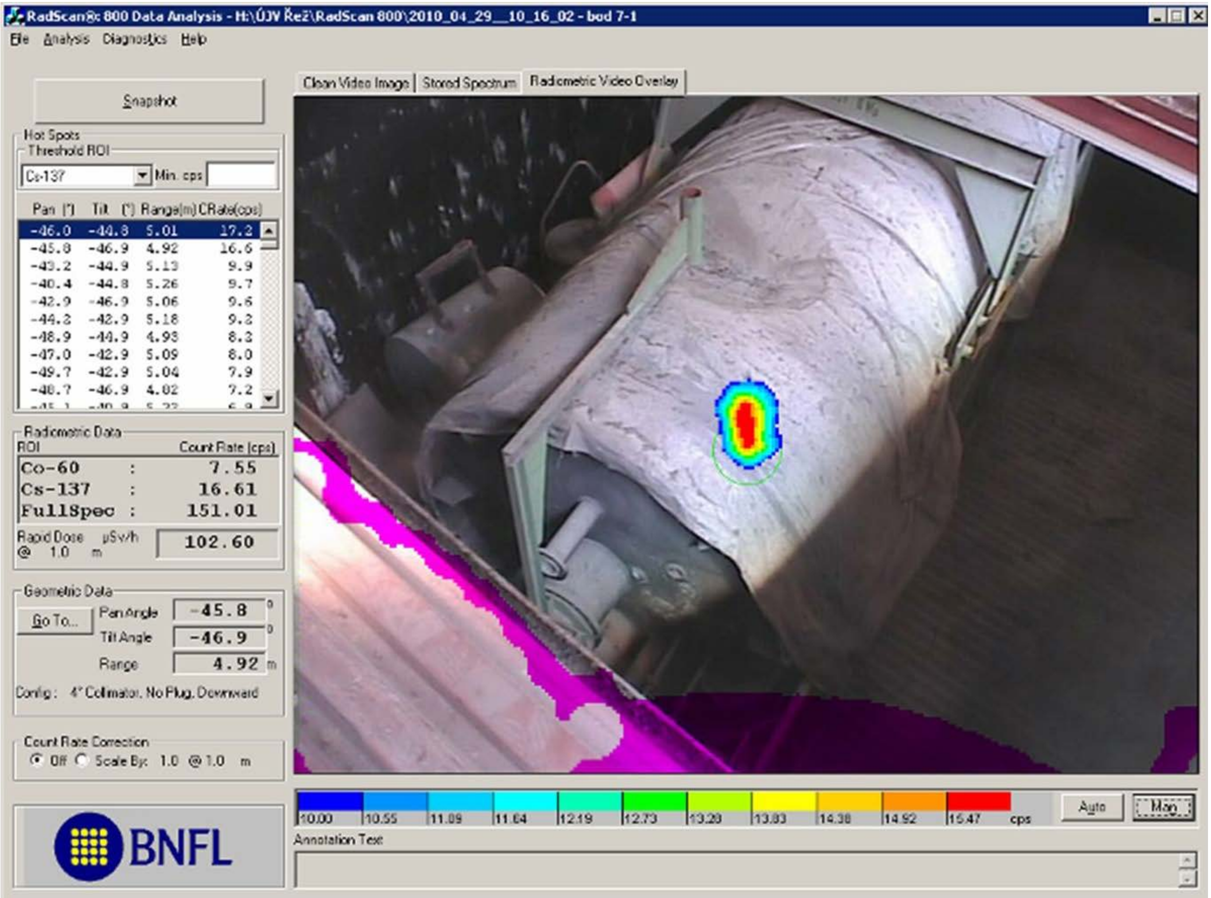

FIG. 17. Measurement with gamma camera – result for ^{60}Cs.

The visualization of the dose rate distribution will also serve for planning of safe processing of the vessel.

5.2. RAW stored in the Red Rock Storage Site

Storage of RAW at the "Red Rock Storage Site" (Fig. 18) started in 1988. The stored waste includes RAW arising from reconstruction of the VVR-S research reactor (primary circuit, ventilation system, etc.) stored in ISO shipping containers and old technology equipment for RAW processing (heat exchangers, tanks, filters). The total storage area is 300 m^2. The total amount of RAW is approx. 90 metric tons. The amount of RAW from VVR-S reactor reconstruction corresponds to approx. 180 m^3 (60 t).

The RAW is contaminated mainly with ^{137}Cs, ^{60}Co and ^{90}Sr. Rain wash off from contaminated equipment to soil and groundwater and irradiation from in situ material were identified as the main risks to the environment and/or to employees.

RAW will be transported for processing (segmentation, decontamination and conditioning). RAW will be disposed or released into the environment. The processing of RAW started in 2009 and will be finished in 2014.

FIG. 18. Red rock storage site.

In Figures 19–20, the content of ISO storage containers No. 3 and 4 is shown.

FIG. 19. RAW in ISO container No. 3.

FIG. 20. RAW in ISO container No. 4.

6. Experience from the process of updating the preliminary decommissioning plan

6.1. Update of PDP

There were no significant changes between the 2008 and 2010 updates instead of shortening the period “Preparation of the facility enclosure” for 1 year and extension of the period “Safe enclosure” of 1 year without affecting the total duration of decommissioning.

This time, the process of long term operation of the LVR-15 reactor started. The goal of this process is to extend the reactor operation to 2028.

6.2. Spent fuel management and its consequence on the decommissioning planning

In 2007, almost all spent fuel was transported to the Russian Federation for reprocessing in the frame of the Russian Research Reactor Fuel Return (RRRFR) programme under the US–Russian Global Threat Reduction Initiative (GTRI).

In 2010, the conversion of the LVR-15 reactor to IRT-4M fuel with enrichment of 20% started. Now, the IRT-4M fuel with enrichment of 20% is used in the reactor. Next transport of the rest of the high enriched SNF will be realized in 2013 in the frame of the RRRFR programme.

There are two potential solutions of the spent fuel elimination after the LVR-15 reactor decommissioning:

(1) Fuel reprocessing;

(2) Final disposal together with spent fuel arising from the operation of nuclear power plants in any of the planned deep geological repositories.

The preferred solution is the fuel reprocessing because it is a direct way of the spent fuel elimination. The HLW from the reprocessing would be returned to the Czech Republic after a certain cooling period. This solution is connected with some problems, mainly with the transportation to the place of reprocessing and management of the RAW from SF reprocessing.

According to the deep geological repository programme in the Czech Republic, deep geological repository is planned to be put in operation in 2065. That means there is a long period requiring further temporary spent fuel storage; the sufficient storage capacity is available. The main factor influencing the option selection will be financing.

The available storage capacity is sufficient for all SNF produced from the operation of the LVR-15 reactor. Use of AR pool or AFR1 pools during decommissioning is not possible because of the location (reactor hall or vicinity to the reactor building). Special measures from the point of view of technological feasibility and physical protection would be applied. The HLWSF can be used for storage of SNF during and after decommissioning of the LVR-15 reactor. Its capacity (450 + 300 FAs in the pools, 576 FAs in ŠKODA VPVR/M casks) is sufficient.

That means that the spent fuel management is not a limiting factor for decommissioning.

6.3. *Management of old radioactive waste from reconstruction of the VVR-S research reactor and its consequence on the decommissioning planning*

6.3.1. Research reactor vessel

The results from the measurement of the old VVR-S reactor vessel is presented in chapter 5.1. The maximum equivalent dose rate corresponds to the location of the active zone. In 1988 it was from approx 14 to 19 mSv/h, after 20 years of storage it was below 1 mSv/h. The decrease corresponds to the decay period of 20 years. The activity of ^{60}Co decreased 15 times, the remaining radionuclides decayed practically fully.

In 2007, measurement of radiation situation of the new vessel (with water inside) was performed during operation inspection [4]. The new LVR-15 vessel was installed in 1988 and is in operation since 1989. The vessel is made of stainless steel, the internals from aluminium. The dimensions of the vessel are: 2 300 mm (diameter) and 5 760 mm (height). The weight of the vessel is 7.9 t.

The fuel and internals (except of active zone and horizontal channels) were removed during measurement. On Figure 21, the view inside the reactor vessel levels during measurement is shown.

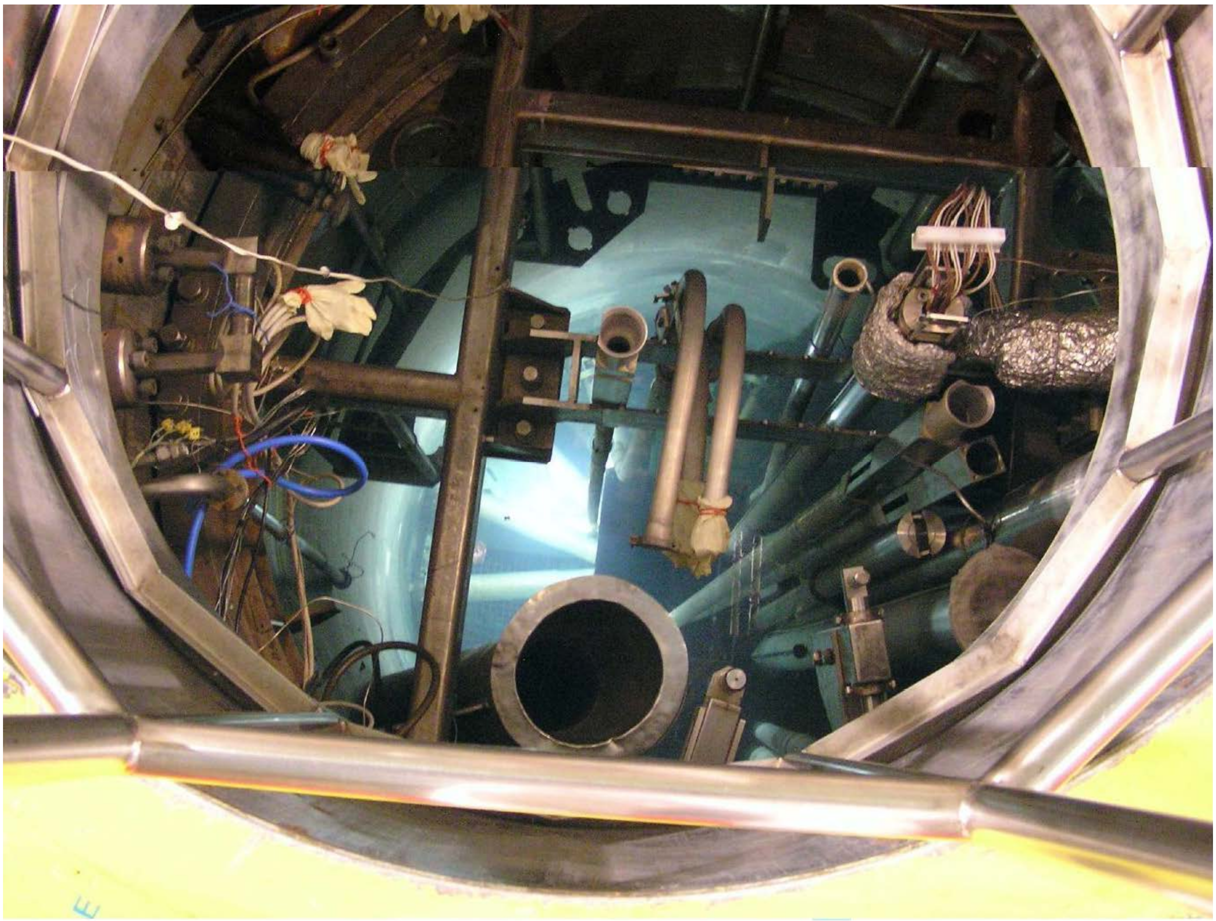

FIG. 21. View inside the reactor vessel.

In Figure 22 the levels of equivalent dose rate at the level of the fuel rack are shown.

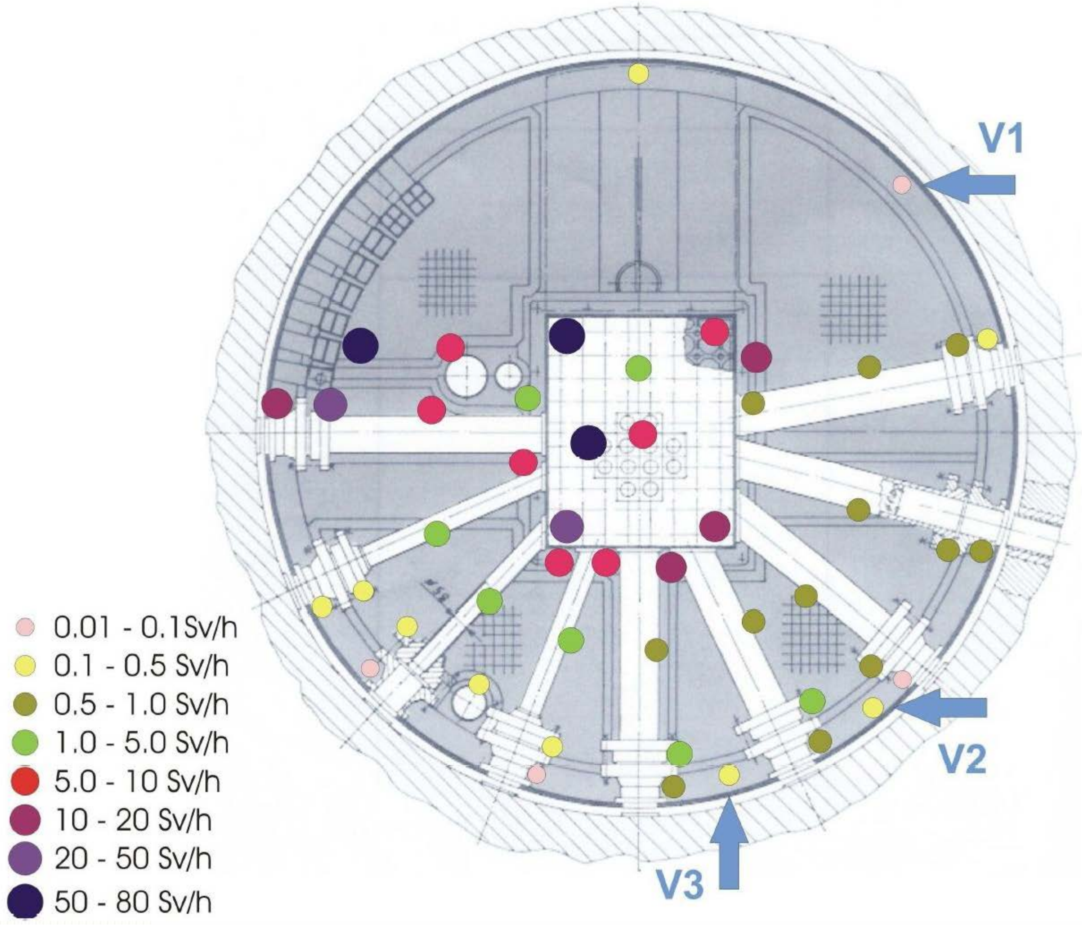

FIG. 22. Equivalent dose rate at the level of the fuel rack.

In Table 4 and Figure 23 the levels of dose rate in three axes in various distances from the fuel rack are shown.

TABLE 4. DOSE RATES IN THREE AXES FROM THE FUEL RACK TOP

Height [cm]	Equivalent dose rate [mSv/h]		
	Axis 1	Axis 2	Axis 3
0	44.0	50.0	60.0
50	43.0	130.0	165.0
100	10.0	9.0	10.0
150	1.0	0.6	0.9
200	1.0	0.3	-
250	0.5	0.1	-
300	0.2	-	-

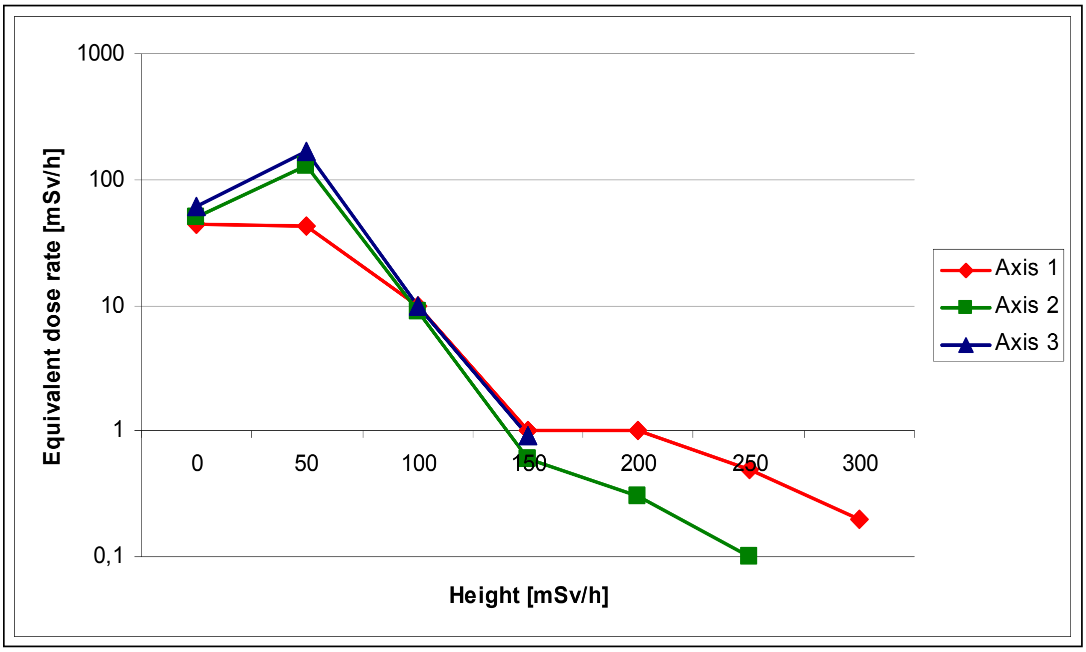

FIG. 23. Dose rates in three axes from the fuel rack top.

The maximum values of dose rate are in the active zone and in the horizontal channels flanges. The presence of water partially eliminated the contribution of other components in the vessel.

It is evident that the activity of the steel vessel will be higher than the activity of the aluminium one (at least in two orders). The vessel will be stored after removal from the reactor and will be processed after decrease of its activity. The time of storage will be defined according to the actual radiation situation after vessel removal.

6.4. Processing of RAW stored in the Red Rock Storage Site

The amount of RAW from VVR-S reactor reconstruction corresponds to approx. 180 m^3 (60 t). The RAW is contaminated mainly with ^{60}Co.

According to the fact that the waste was preliminary decontaminated after the VVR-S research reactor reconstruction and the period of storage, the contamination of the waste is low and a big part of the waste will be after decontamination released into the environment.

In Figures 24–28 the process of processing of RAW from the ISO container No. 3 is shown.

FIG. 24. RAW in ISO container No. 3 (during RAW removal).

FIG. 25. RAW in ISO container No. 3 (during RAW removal).

FIG. 26. RAW from ISO container No. 3 before decontamination.

FIG. 27. RAW from ISO container No. 3 before decontamination.

FIG. 28. RAW from ISO container No. 3 after decontamination.

In Figures 29 and 30 the storage of RAW before the release measurement is shown.

FIG. 29. Storage of RAW from the ISO container No. 3 before the release.

FIG. 30. Storage of RAW from the ISO container No. 4 before the release.

To the end of the 2010, 15.5 t of metal were decontaminated and 15 t are waiting for final release measurement. On the base of experience with processing of RAW, there is an assumption that minimally 80% of RAW from the VVR-S reactor reconstruction can be released into the environment after decontamination.

This experience can be used during planning of decommissioning of the LVR-15 research reactor. The activity of the equipment will be much lower after the safe enclosure period and it will ensure that more contaminated material will be released into the environment as inactive waste or recycled.

7. Collaboration with other CRP members

Shortly after the first RCM in Dounreay in January 2009, the participants of the CRP from the Czech Republic and Slovakia found useful to organize site visits of their nuclear sites and to discuss possible cooperation in the field of decommissioning and RAW management.

The reciprocity visits were organized during 2010. Colleagues from the Czech Republic (NRI Řež) visited the VUJE company and nuclear sites in the Bohunice (NPP A1 and RAW treatment facility) and in Mochovce (National RAW Repository Facility).

Colleagues from Slovakia (company VUJE) visited the Nuclear Research Institute Řež:

- Facilities for RAW management (Centre for RAW Management, Pilot Bitumenation Unit, hot cells in the Radiochemistry Building, High Level Waste and Spent Fuel Storage);

- Facilities being decommissioned (Reloading site, RAW surface store, building with old technology for RAW management).

Discussions organized were very open and can serve as basis for possible future cooperation in the field of decommissioning and RAW management.

8. Publications resulting from the CRP

PODLAHA, J., “Decommissioning of Nuclear Facilities at the Nuclear Research Institute Řež plc.” Nuclear Technology & Radiation Protection, 2010, Vol. 25, No. 2, pp. 143–151.

TARASOVA J., “Preliminary Decommissioning Plan of the LVR-15 Research Reactor”, Internal report, Centre of Nuclear Research, Řež, 2010. (in Czech)

9. Conclusion

Decommissioning planning is a very important part of the operation of nuclear facilities. For successful decommissioning of nuclear installations the effective decommissioning planning is necessary. All nuclear facilities in the Czech Republic are in operation and will not be decommissioned in the near future. Preliminary decommissioning plans have been prepared and are regularly updated.

Preliminary decommissioning plan of the LVR-15 research reactor has been prepared and is regularly updated.

The spent fuel management is not a limiting factor for decommissioning of the reactor because of sufficient storage capacity. The spent fuel can be sent for reprocessing or disposed in the future.

RAW management has big impact on decommissioning. For decommissioning planning, the experience from management of RAW from the VVR-S reactor reconstruction is used.

During the LVR-15 operation, important information which can influence the decommissioning process, are collected.

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[3] LONDYN, P., ”Report of gamma camera measurement in the Building No. 211/6” (in Czech) Envinet a.s., April 2010.

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PLANNING, MANAGEMENT AND ORGANIZATIONAL ASPECTS OF THE DECOMMISSIONING OF A HOT CELL FACILITY

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Abstract

This CRP project document — Planning, Management and Organizational Aspects in Decommissioning of a Hot Cell Facility — aims to describe the establishment of a management organization that ensures that the DD Hot Cell Project is properly and safely conducted and that staff members, who are seconded to the project, have a strong feeling of ownership and being an integral part of the project.

The objectives of the decommissioning project of the hot cell facility is to decontaminate the facility and to remove items that cannot be decontaminated on site, in order for the entire hot cell building to become useable for other purposes without any radiological restrictions. The project requires proper communication and coordination with all stakeholders on-site, comprehensive work plans and strict control of the individual working areas and operations.

A project of this type obviously requires a strong and well managed and coordinated project organization. DD has established a management system – KMS. The purposes of the KMS are twofold. The system aims to secure the fulfilment of the conditions and requirements of quality set by the nuclear authorities. The system also aims to provide the basis for a rational and economically feasible operation with a high level of safety.

One of the main lessons learned in this project is clear that is to ensure that the necessary resources are available and the required expertise is allocated timely for the performance of the project(s) a strong coordination and great flexibility within the DD organization is required.

This document describes the approach and considerations from the project management point of view. The document initially gives an introduction to the hot cell decommissioning project followed by issues of the general considerations and planning of the project within the DD, including aspects on organisation, quality assurance and coordination.

1. Introduction

Danish Decommissioning (DD) has the task of decommissioning the nuclear facilities formerly operated by Risø National Laboratory in Denmark. As a member of the IAEA DD participating in the Coordinated Research Project (CRP) on Planning, Management and Organizational Aspects in Decommissioning of Nuclear Facilities[1], this document has been developed as a technical document, forming part of the contribution to the Research Coordinating Meetings (RCM) held during the project. DD has selected its hot cells facility decommissioning project to be the physical basis for the technical contribution to the CRP project, with emphasis on the management organization.

2. The hot cell decommissioning project

2.1. Project objective

The objectives of the decommissioning project of the hot cell facility is to decontaminate the facility and to remove items that cannot be decontaminated on site, in order for the entire hot cell building to become useable for other purposes without any radiological restrictions.

The hot cell project will be carried out as a decommissioning project in Danish Decommission. The responsibility for the management and performance of the project lies with the Project Manager assigned to the project.

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[1] IAEA ref.: Research Agreement No. 14861

2.2. General description

The hot cell facility is located in Building No. 227 at the Risø site. When the facility was in operation the whole building was used for hot cell activities. After a partial decommissioning carried out by Risø National Laboratory in 1990–94, a row of six concrete cells remains inside the building (Fig. 1). The remaining part of the building is now being used for other purposes, as described below.

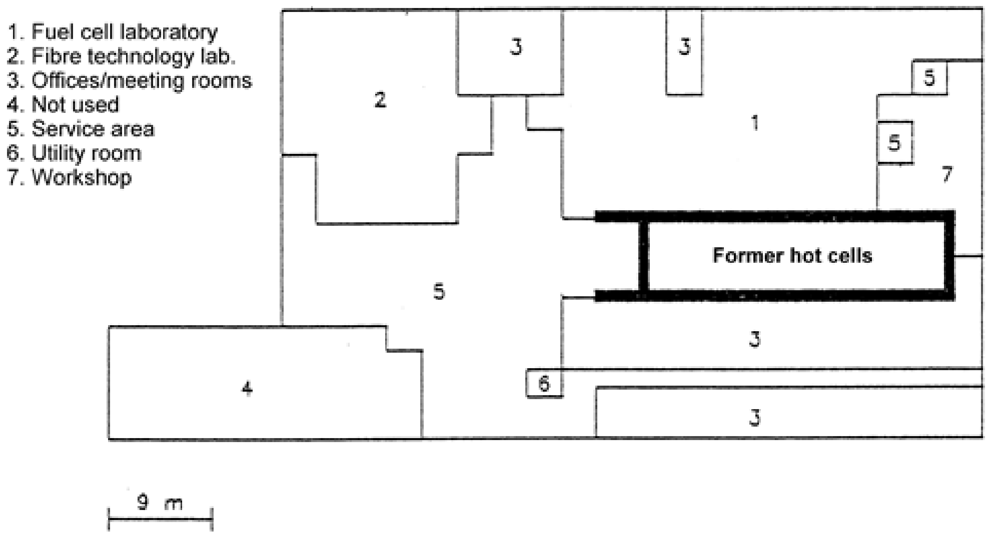

FIG. 1. Location of the cells in the building (ground floor) and the former use of adjoining areas.

Figure 2 shows a horizontal cross section of the cells.

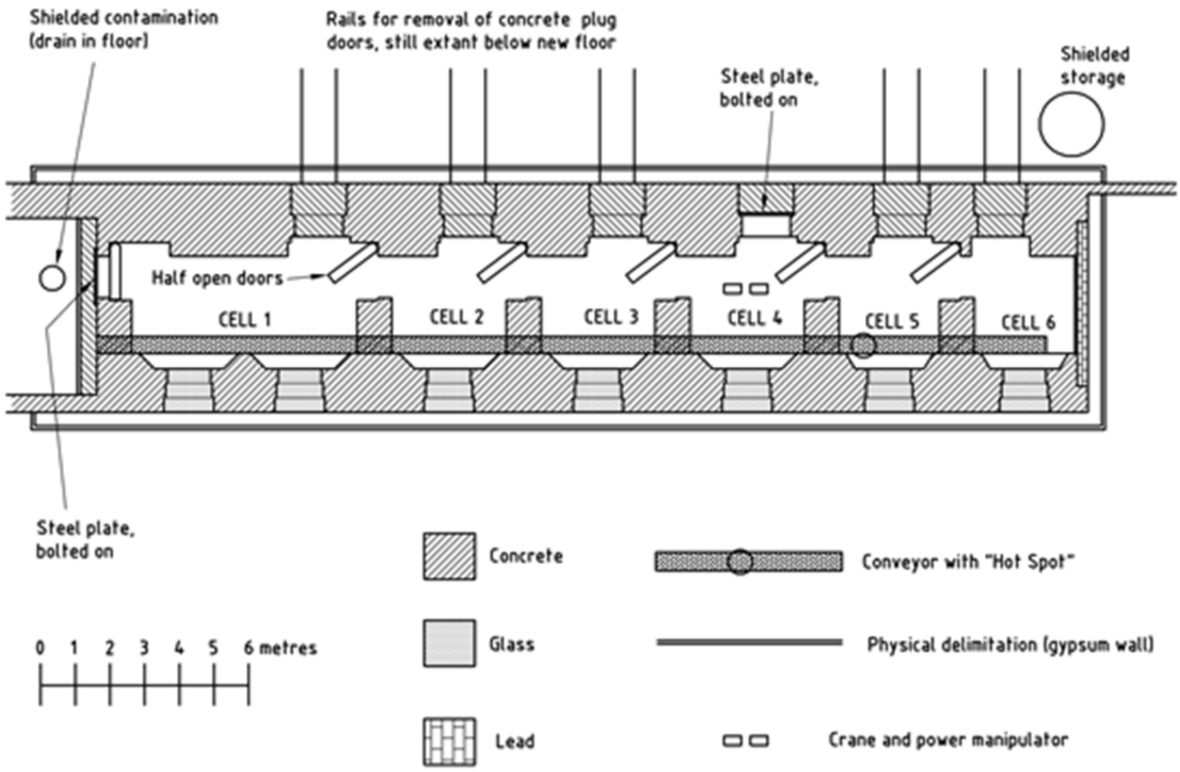

FIG. 2. Horizontal cross section of the row of concrete cells.

The line of six concrete cells comprises an entrance bay (cell airlock) and the cells 1–6. Each cell is lined with 8 mm mild steel plate, completely welded along all joints. It acts like one big steel box, which made it possible to operate with a vacuum in order to avoid contaminating the concrete.

Each cell contains a workbench of cast iron. Its surface is varnished and holds much contamination, e.g. ^{60}Co pellets that have burned into the varnish.

The hot cell building is now used for offices and laboratories for two of Risø National Laboratory's departments. The Risø research working areas, including meeting rooms, offices and extensive laboratory facilities are immediately adjacent to the areas required for the decommissioning works and to be used by DD. The research carried out is high profile Risø research and the laboratory facilities would have been very expensive to move to another location. Therefore, DD and Risø have agreed on an approach to the decommissioning that will require as little as possible intervention in the work of Risø[2].

2.3. Introduction to the decommissioning project

The hot cell decommissioning project can in short be described as follows. The purpose of the project is to decontaminate the facility and to remove items that cannot be decontaminated on site, in order for the entire former hot cell building to become useable for other purposes without any radiological restrictions. The project was planned for implementation during 2008–2011.

The main object for the project is a row of six concrete cells that remains in the building. Therefore, the decommissioning of the hot cell facility includes mainly decontamination work as it has been decided that the main structures of the cells shall remain.

A particular challenge to this decommissioning project is the fact that Risø will maintain offices and working laboratories in the building while DD performs the decommissioning work. This involves requirements to information and coordination activities as well as noise reduction precautions and, of course, special radiation protection considerations. A number of specific areas around the hot cells will have to be temporarily occupied by DD during the decommissioning work.

The hot cell project is aimed to be performed primarily with the use of DD's own personnel. The individual departments within DD and groups of experienced and skilled labour will be involved in the development of the detailed planning, work plans and instructions for the decommissioning works.

A number of activities and works are foreseen to be performed by external and specialized contractors. the work to be performed by external staff will be conducted under the supervision and control of the project manager.

Based on the project proposal by DD the hot cell decommissioning project received approval by the nuclear regulatory authorities in spring 2008 and the financial funding was made available by the Parliament's Finance Committee in June 2008.

2.3.1. Decommissioning approach

The general approach includes initial clearing of the peripheral systems on the top of the cells, i.e. removal of redundant ventilation components etc. and establishment of various work areas (see later). It was initially the intention to enter the hot cells and adjoining areas through an opening to be established in the eastern wall of the building as the normal entry points to the cells from the back side of the row of cells (via plug doors) would not be available to DD until 2010. The main decontamination work would be performed via the established opening in the eastern lead wall or via penetrations from the cell top or from the cell front, e.g. via the wall penetrations for the master slave

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[2] Ref.: Project Description Hot Cells, DD-32 (EN)

manipulators. However, as described later, the approach and method had, during the CRP period, been changed due to a number of delays. It is now in the planning to perform the decontamination work from the back side of the cells now available to DD.

Decontamination will start with cell 6 (to the right hand side in Figure 1), which contains the lowest measured contamination level and dose rate, and end with cell 1 (to the left in Figure 1).

In principle the general decommissioning approach includes the following main steps:

(1) Establishment of work areas;

(2) Removal of peripheral systems;

(3) Remotely controlled decontamination of cells;

(4) Providing access to cells;

(5) "Manual" decontamination of cells;

(6) Dismantling of installation and secondary structures (inside cells);

(7) Cleaning and clearance of the building.

Firstly the work was detailed and planned. The requirements for supplies and logistics was also assessed and defined in the initial stages, including the supply of electricity, water, sewage system, ventilation and others. The main part of the work – and all work on radioactive/contaminated parts – is performed by DD staff. A number of activities and operations are planned to be performed with the support of external specialized service providers. The hot cells project includes a number of work areas around the cells for various operations. It has therefore been considered purposeful to divide the project work into six main work areas as follows (Figs 3–8).

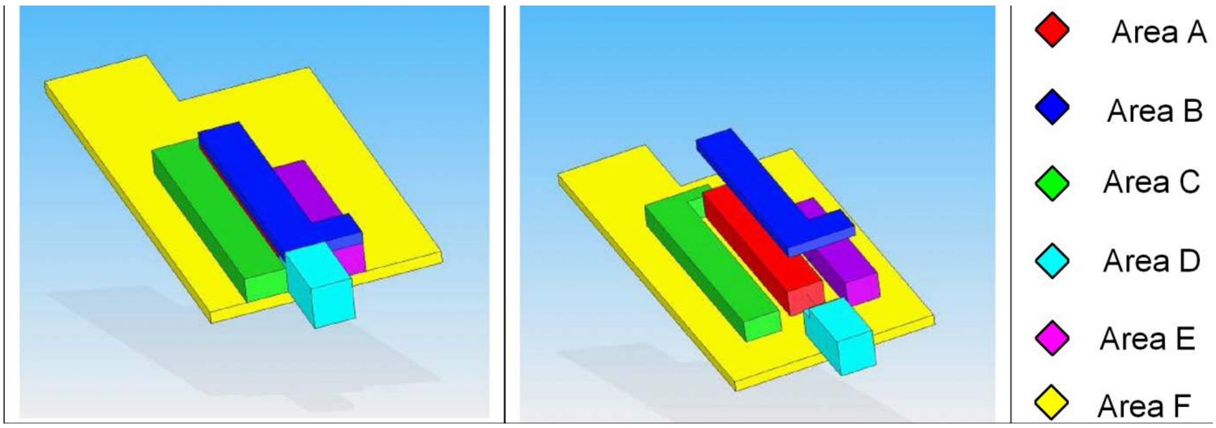

FIG. 3. Work areas principle.

(A) Hot cells (ground floor level);

(B) Top of hot cells (first floor level);

(C) Adjoining area (south) around hot cells (ground floor level);

(D) Access and handling area (ground and first floor level);

(E) Adjoining area (north) around hot cells (ground floor level);

(F) Basement and underground installations (underground level).

Areas A–C and E are all placed inside the Risø building No. 227. Area D has been erected outside the building with the main purpose of providing access to area A, B, C and E, and providing the necessary work space for the handling and management of components and waste to be removed. Area F includes the piping installations in the basement and the underground storage tanks for active waste water placed outside the building No. 227. The principal sketch below shows the work areas and their interrelations (building No. 227 not shown, but the extent of area F corresponds to the extent of the building).

FIG. 4. Working areas inside building occupied by DD, ground floor (red=A, green=C, blue=D, purple=E).

Area A covers the actual six hot cells to be decontaminated. The surface of approximately 680 m^2 steel liner inside the cells is contaminated with γ emitters, such as ^{60}Co and ^{137}Cs, as well as α emitters, such as ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{243}Am and ^{244}Cm. The contamination stems from the various operations performed in the cells during its operational lifetime. The general radiation levels inside the cells are in the range 0.1–10 mSv/h with a number of hot spots with considerably higher levels. Decontamination of the surfaces of the cells will be by use of remote operated sand blasting techniques.

FIG. 5. Area A, inside the hot cells (view: cell 2»1).

FIG. 6. Area B, top of hot cells, typical picture before start of work.

Area B includes former ventilation and service installations supplying the cells during the operational period. The area and all remaining systems (ventilation channels, filters, shutter doors and so forth) are found to be contaminated with a similar mix of radionuclides as the cells; however the contamination on external surfaces is moderate. The area also contained a large amount of unexpected waste items stored in the room and inside the ventilation channels. All items have been removed and the surface of the area shall be decontaminated. The shutters dividing the cells and the shutter housings remain and shall be used during the work inside the cells. The Area B gives only limited vertical access to the cells through ventilation shafts.

Area C includes the former operators' area of the cells and the lock for bringing in materials to the cells. All equipment in this area was removed during the former preliminary decommissioning, including e.g. the manipulator arms. However, the front of the cells provides a number of openings of various sizes allowing for access to the cells. It is the intention to use these openings in support of the decontamination work inside the cells by e.g. bring in cameras and monitoring equipment in to the cells through these openings from the area C. So far a number of hot spots have been removed from the cells by use of remote operated equipment through the openings.

FIG. 7. Area C, front of hot cells, work area fully established ready to commence real decommissioning work.

FIG. 8. Area E, back front of hot cells, alpha seal doors (with plug doors).

The access and handling area D provides access points to all the other areas of A–C, E and F, including stairs and lifts for access to area B. The area has been established as a new erected air lock building, providing access to the other classified areas and providing the necessary work space and facilities for the handling and management of equipment and materials, packaging, registration and labelling of waste, control measurements of radiation levels from components, as well as the required health physics and safety facilities to be provided for the working staff. The area also includes the entrance facilities for personnel. Access to area D will be directly from the outside.

From the area E access to each cell can be made through the concrete plug doors. The doors are operated on rails. Additional work includes the decontamination of the shielded storage facility placed in the flooring structure. Before access to the back side alpha seal doors could be obtained the area housed Risø laboratory facilities that had to be removed before the work area could be established in 2010.

Area F includes the piping installations in the basement and the active waste water storage tanks and cooling water tanks (4 units in all) placed underground outside the building No. 227. All pipe penetrations through the concrete or embedded pipes will be controlled for contamination. The work of area F is scheduled for the later stages of the project.

The division into the six work areas also allows for separation and varying classification of areas during the project. This will, for instance, give the possibility of downgrading the classification of areas up until the actual operations in the specific area will be carried out. It also allows for establishment of separate ventilation systems for the individual working areas and the possibility of creating different air pressures between the areas, hereby limiting the risk of cross contamination during operations. This setup is believed to allow a flexible management of the individual operations and activities.

The project requires proper communication and coordination with all stakeholders on-site, comprehensive work plans and strict control of the individual working areas and operations. A project of this type obviously requires a strong and well managed and coordinated project organization. A strong involvement and ownership to the project is also considered as essential to support this organization.

3. Overall project management strategy

3.1. The DD organization

Danish Decommissioning is an organisation under the Ministry of Science, Technology and Innovation and is responsible for decommissioning, i.e. dismantling of the nuclear facilities formerly belonging to Risø DTU — National Laboratory for Sustainable Energy. DD organizational structure is shown in Fig. 9.

DD took over the responsibility for the nuclear facilities on 15 September 2003, after thorough preparatory work that investigated all aspects of the organisation's impending task.

DD places strong emphasis on openness. This will be achieved through dialogue with organizations, neighbours, local politicians and other stakeholders, as well as via the formal processes and hearings that the decommissioning work has to undergo. Both local and national authorities will be involved in the various phases of the decommissioning work.

DD has taken on a difficult and exciting task that has not previously been carried out in Denmark. Many of the staff members have previously been employed at Risø DTU and have considerable experience and expertise regarding the nuclear facilities, though, as the hot cell facility was closed back in the eighties and partially decommissioned in 1994, the expertise is mainly on the operating of the DR 3 reactor.

DD strives to establish and maintain a workplace with a clear personnel policy based on mutual respect and openness in a professional environment.

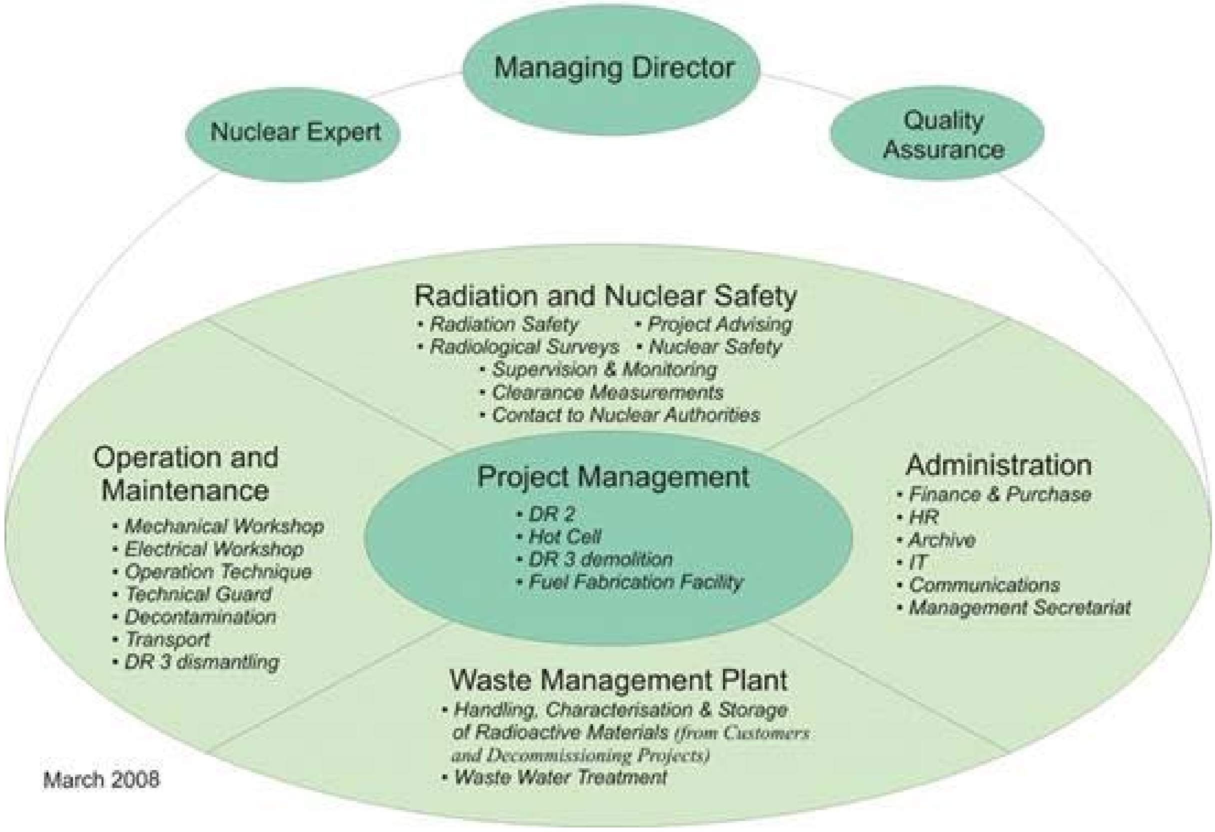

FIG. 9. DD organization.

3.2. Project management in general

DD's overall objective is to:

- Decommission the nuclear facilities;
- Maintain the nuclear facilities until fully decommissioned;
- Receive, treat and store radioactive waste until a Danish final repository is available;
- Help prepare the base for a parliamentary decision about a Danish final repository.

The decommissioning will bring the facilities to the state of greenfield, which means that all buildings and surrounding land can be used for other purposes without any radiological restrictions attached.

Safety for employees, neighbours and the environment is given priority and will be in accordance with international standards.

3.2.1. Detailed planning and project management in DD

The decommissioning requires thorough planning and specialized equipment and facilities. The first couple of years will, therefore, be spent on characterization of the levels of radioactivity in the facilities, establishing new facilities to handle and store radioactive items and waste, purchase of equipment, and the development of working methods, etc.

It is necessary to characterize the level of radioactivity in each facility before the actual planning can be initiated. What are the levels of activity, what is the precise location of the activity, and which isotopes are we dealing with? Once that is done, a number of parameters must be taken into account: the risk posed, personnel resources available as well as the economic aspects.

The overall plan is to start with the facilities and the parts that contain the least radioactivity. In this way, the more radioactive facilities and parts will, to some extent, have time to reduce the level of radioactivity. Also, it is possible to make use of the experience obtained from the minor projects.

Six main facilities are to be decommissioned:

- DR 1 (fully decommissioned by 2006) [1];
- DR 2 (fully decommissioned by 2008) [2][3];
- DR 3 (planning and dismantling of non-active systems in progress);
- Fuel fabrication facility (planning in progress);
- Hot cell (ongoing);
- Waste management plant (in operation).

The decommissioning of all facilities is scheduled to finish by 2018.

Radioactive waste will be deposited at the waste management plant's storage facilities until a Danish final repository has been established.

3.2.2. Project reports and financing

Before each project can begin, a project description (*Project Plan*) must be written and approved by the Nuclear Regulatory Authorities. Project descriptions include descriptions of the facility and its operational data, methods applied, assessment of health physics and conventional risks. The format and content of the project descriptions follow the recommendations given in IAEA's Safety Guide WS-G-2.1 [3].

In the process of developing the project an international committee of experts on decommissioning is involved. The committee comments on the methods and process proposed by DD. The committee also makes recommendations to alternatives and new solutions. The use of an expert group in the planning process is a requirement set by the regulatory authorities, but it has also proven beneficial to DD.

Once the project description has been approved, the Parliament's Finance Committee must grant appropriation, before decommissioning can begin. As a final stage of the decommissioning works, the facility and surrounding area will undergo clearance measurements. At the end, a final decommissioning report must be produced and approved by the nuclear regulatory authorities. An important issue to report in this final report is lessons learned that can be of use in future projects.

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[3] More information on this project can be found in: IAEA-TECDOC-1602, Innovative and Adaptive Technologies in Decommissioning of Nuclear Facilities, October 2008

3.3. *Organizing the project management*

3.3.1. The challenge

To ensure that the necessary resources are available and the required expertise is allocated for the performance of the project(s) a strong coordination and great flexibility of the DD organization is required.

3.3.1.1. "The project manager is king"

Quote by A. Neal, United Kingdom Atomic Energy Authority (UKAEA) [5]:

- The project managers should be involved at an early stage in the project;
- They should be involved in the development of the:
  - Project schedule;
  - Its cost estimation;
  - Development of the risk logs.
- The early involvement in the project will ensure ownership of these documents by the project manager;
- The organisational structure should be such that the project manager has access to all resources necessary to deliver the project;
- If these resources are not within his or her direct management control then it is recommended that there is a formal agreement between the project and the line management of the resources concerned.

A. Neal concludes in his paper:

- If this form of matrix management is employed then the staff who are seconded into the project must feel that they are an integral part of the project team.

3.3.2. Organising the project set up

The DD main organization is established on the basis of the technical tasks and the operational tasks performed on a running basis. The resources — staff and equipment — are all placed in the main DD organization. A project organisation is established individually for each decommissioning project. The managing director together with the Head of Departments (HoDs) has the responsibility for the prioritizing of projects and coordination of resources and expertise across the main organisation. The overall responsibility for the project belongs to the HoD. The HoD appoints a project manager for the project performance. The project manager (PM) identifies the required project organisation and staffing. The HoDs allocate the staff available to the project.

3.3.3. Job description for the PM

A memo was developed in 2009 with the aim to clarify the role and responsibility of the internal "stakeholders" in DD.

"Responsibilities and job description for project managers of decommissioning projects and other cross organizational projects" (DD Management memo June 2009).

The memo defines the job description for the PM and the interrelations with the other departments of DD and the division of responsibilities.

Responsibility of the PM:

- Planning;
- Establishment of the project organisation;
- The execution of the work;
- Conclusion of the project and reporting.

3.3.3.1. Planning

- The project manager (PM) is in charge of planning the project, including preparing the project plan which after internal investigation in DD is presented to The International Expert Panel for commenting and finally sent to the nuclear regulatory authorities for approval;
- Furthermore, the PM must prepare a detailed budget for the purpose of preparing a document directed to the Finance Committee (Parliament);
- Relevant experts from other departments of DD shall assist in the planning, including the preparation of the project plan and the document;
- The planning process is described in the process network "Project Management" in the quality assurance system (KMS), cf. Chapter 4.

3.3.3.2. Establishment of the project organisation

- Prior to initiating the work itself the PM must ensure that the necessary staffing resources and professional competences for the execution of the project are present;
- When DD staff shall be involved agreements are made with the HoD that provides the relevant staff;
- If it is not possible to find a solution directly between the departments involved, the Managing Director is drawn in. When external staff is involved, contracts are made in accordance with DD's rules;
- The PM must, furthermore, ensure that the project group is ready and well defined and in accordance with the project needs for decision authorisation and resource management;
- The DD management formally approves the composition of the project group after recommendation from the PM;
- Similarly, arrangements are made with the HoDs about use of other resources, such as facilities, tools and machines, which the department shall provide for the project;
- It is the PM's responsibility that the cooperation between the parties involved takes place purposive and constructive and in accordance with the ground rules for good cooperation in DD.

3.3.3.3. The execution of the work

- The PM has the responsibility for organizing and managing the execution of the work. The responsibility for subassignments may, if possible, be delegated to other employees; but the PM carries the overall responsibility towards DD's management for the work being carried out safely and in accordance with the time schedule and budget;

- The project manager functions as supervisor for the assisting staff and delegates the assignments to the employees. In regard to the employees from the technical support functions (Radiation & Nuclear Safety and Quality Assurance) the management is limited with deference for these functions' independence in the execution of supervisory control etc.;

- The project manager continuously monitors the assignments and communicates information to interested parties, both internal and external. The DD management in particularly is informed at each milestone and if changes are foreseen which are presumed to have relevance for the time schedule and economy;

- If it is necessary to increase or decrease the staff during the execution of the project, the changes are agreed upon with the relevant HoD. If it is not possible to obtain sufficient staff resources internally in DD, the possibility for external recruitment or internal reallocation is considered; this occurs in consultation with the DD management;

- The project manager is as supervisor, legally responsible for the staff safety during the execution of the work;

- The execution of the work is described in the process "Dismantling of Nuclear Facilities" in the Quality Assurance System (KMS, see later). Follow-up assignments are described in the process "Project Follow-up".

3.3.3.4. Conclusion of the project and reporting

The project manager must:

- Be in charge of the preparation of the final report according to the requirements form the nuclear authorities (given in the "Operational Limits and Conditions for Operation and Decommissioning", BfDA), incl. ensuring that satisfactory contributions are provided by the other participants in the project;

- If necessary revise the final report after comments from the nuclear authorities;

- Together with the person responsible for accounting work out the final account of the project;

- Ensure archiving of material from the project in accordance with the rules and make sure that clearing out in the project documentation takes place (on paper and on servers and other computers).

4. Quality assurance of the management system

4.1. Document structure

DD is a Quality Assurance certified government company in accordance to the DS/EN ISO 9001:2008.

In order to meet the demands of the ISO system a structure has been defined for the main documents and the office procedures. The document structure includes the following:

- The overall plan for decommissioning in DD that defines the overall framework *directive* for DD in the whole of the decommissioning life of DD [4];

- The five year rolling strategy including the identification of the main goal for this period;

- Outcome contract with line ministry covering a four year period;

- Annual plan identifying milestones, manpower and resources;

- Safety documentation, identifying the actual safety situation at the nuclear facilities. Also includes the organizational task and responsibilities as well as job description for key staff. The safety documentation also includes the conditions for the maintenance and operation programme of the nuclear facilities (BfDA);

- Descriptions of the office procedures (processes) and directions – the main management system called KMS.

4.2. The management system — KMS

In Danish the acronym KMS stands for Quality, Environment and Safety (Kvalitet, Miljø og Sikkerhed). The purposes of the management system KMS are twofold. The system aims to secure the fulfilment of the conditions and requirements of quality set by the nuclear authorities. The system also aims to provide the basis for a rational and economically feasible operation with a high level of safety.

The DD Management System — KMS — includes the legal and authoritative requirements, that DD shall follow and also includes the following main tasks:

(1) Decommissioning, including dismantling and decontamination down to clearance of the nuclear facilities;

(2) Handling and storing of radioactive waste;

(3) Operation of the nuclear facilities until decommissioning;

(4) Receiving and storing radioactive waste from Danish companies and institutions.

All the required office procedures are defined and described in the KMS system as further shown in the following. The system also includes directions and instructions for specific operational and maintenance systems as well as blank forms for data registration and reporting systems.

4.3. The process network

The process network KMS is electronic based. Through the DD intranet all employees can enter the system and find any specifically required process, blank forms and templates from decision of starting a decommissioning project, acquiring approval from authorities, initiating of work, follow-up and reporting, just to mention a few. In the following further descriptions are given on the process network for decommissioning projects.

The main processes include:

- Project management;

- Decommissioning;

- Waste Management;

- Clearance.

These main processes are then again subdivided in to a number of technical supporting processes:

- Operation and maintenance;
- Measuring and analysis;
- Radiation safety;
- Nuclear safety;
- Quality and Conventional Safety (workers’ health and safety).

A few processes are also defined for administrative purposes, including:

- Economy;
- Management/staffing.

4.3.1. The decommissioning process network

Herein a number of selected processes of the KMS system are further described including the main decommissioning process and succeeding processes for issuing of work plans, dismantling/size reduction and finally processes for classification of activity and accept of classification[4].

The process network for decommissioning is shown below as two separate diagrams.

The first part represents the process at the level of main management and administration with interaction to the main strategy of the company. This process also shows the proceeding steps for describing the project (proposal), review of the project proposal by DD’s International Panel of Experts and finally obtaining approval from the nuclear authorities and the necessary funds for execution of the project. In DD the project manager is typically attached to the process when drawing up the project description for the project is initiated.

The second part of the process describes the succeeding steps for execution of the project. All processes here described involve the project manager.

For each process step described hereafter there is the possibility (not shown here) of electronically linking to relevant templates available, and the relevant and/or specific requirements set out in the ISO9001 system is given as well as the latest issuing date of the process in question and name of the responsible editor.

In the process diagrams below the square boxes (by clicking) contain descriptions of the specific actions to be taken and work to be done at the specific stage as further detailed in the following subsections.

4.3.1.1. Prepare the work plan

Action: Prepare work plan

For each work task defined in the project, project management shall ensure that detailed work plans are issued and considerations have been done regarding:

[4] In the following the term ”activity” = radioactivity (activated or contaminated item)

- Likely and unlikely risks connected to the task;
- Appropriate and sufficient tools and equipment;
- Personal Protection Equipment – PPE;
- Other preventive means e.g. access control, additional training etc.;
- Expected radiation exposure at the workplace;
- Expected individual dose impact;
- Estimated resources, personnel and time / man hours;
- Type of dosimeters for the job;
- Appropriate type of waste containers;
- Expected type and amount of non-radioactive waste;
- Expected type and amount of radioactive waste;
- Compliance to rules and legislation;
- Check of radiation and contamination level at the workplace before, during and after the job has been performed;
- Quality Assurance.

The Project Manager shall ensure that all relevant information from all sections (including health physics) and the Working Environment Manager has been gathered for this task.

Action: Review project specific WPA

The Working Environment Manager is reviewing and commenting the project specific Work Place Assessment (WPA).

Action: Evaluations regarding working environment

The Project Manager evaluates the need for a WPA (legally required).

Are conditions the same as for the last project, or is it necessary to update, e. g. including other issues into a new WPA?

Action: Create project specific WPA

The Working Environment Group(s) responsible for the area and/or participating in the decommissioning task prepares a project specific WPA covering only this specified project.

Action: Create final work plan

The Project Manager organizes all input into a final work plan.

The Working Environment Group receives a copy for their information.

The work plan is submitted to the Section Manager for approval.

Action: Approve final work plan

The Section Manager approves / rejects with additional comments, if any.

A copy of the approved document will be addressed to the Working Environment Manager.

4.3.1.2. Dismantling

Action: Instruction of work force

The PM instructs all participants in the work plan about administrative and safety related topics in the plan.

It is very important to make sure that everybody who is participating in the project has sufficient knowledge about the special safety precautions, which shall be applied during the work handling radioactive material.

Action: Apply for HPT (health physics technician) services

Before commencing the work, the technical worker consults the Laboratory Manager or HPT about how measurements and surveillance at the worksite shall be conducted.

Action: Prescribe HP (health physics) precautions

The Laboratory Manager and the HPT evaluate the need for additional equipment or e.g. extra shoe facilities, special clothing etc.

Action: Documenting the work

The different tasks shall be documented.

This will be done in e.g. a diary, logbook, or minutes from project meetings.
The documentation is used for reporting and transferring knowledge and lessons learned for future projects to come.

The documentation should include photos and/or video sequences of particularly interesting or critical operations.

Action: Surveillance of the working Environment

The Working Environment Representative (WER) surveys the worksite at all times in order to prevent accidents or dangerous incidents to arise.

The WER can stop the job, if needed, and demand additional preventive elements to be implemented, before the job can continue.

Action: Prepare equipment and worksite

The workplace is prepared for the job.

This includes:

(1) Proper shielding from radiation;

(2) Walls, dust preventive measures, noise etc. and sufficient access control to the worksite.

Approved equipment — approved/checked equipment are present and (tasks that requires) certified personnel, are present.

Action: Surveillance of radiation in the working environment

The HPT surveys the radiation- and contamination levels during execution of the task.

The HPT advises the personnel during operation, concerning radiation level, exposure time and distances to radioactive sources.

Action: Dismantling and reduction

The dismantling and reduction are carried out according to approved plans and procedures.

Action: Register HPT measurements

The HPT registers data from the measurements in the specified form.

The HPT is responsible for collecting and returning additional dosimeters (including dosimeters for external handling of data).

Action: Surveillance of the work

The Project Manager or his Deputy, surveys the project on a regular basis.

Action: Register waste item ID

The Technical Assistant to the Project Manager is registering the item in the Waste Management System (ADS) and adds information about the item's physical data.

The dismantled material will then be transferred to a suitable container.

Action: Prepare the building for clearance

When dismantling has been completed, the building will be cleaned thoroughly.

Action: Measure radiation and contamination

Radiation and contamination are measured on the waste items.

Action: Records of waste items

Radiation and contamination measurements are registered in the Waste Management System (ADS).

4.3.1.3. Classification of activity

In general[5]:

All waste from the decommissioning process shall apply to a specific activity classification[6].

---

[5] Health assistant = Health physics technician

[6] Waste categories colouring: Radioactive = RED, Feasible to Decontaminate = YELLOW, Potentially not Radioactive = BLUE and Free Released = WHITE.

Action: Measure radiation

Dose rate measurement. The dose rate is measured around the item at a 10 centimetres distance. The background dose rate must be less than 0.2 microSv/h.

If the maximum measured dose rate is more than 0.5 microSv/h the item must be activity classified as red.

The measurement result is registered in the waste management system.

Action: Evaluate waste

The measurement schedule with instruction corresponding to the instrument that is to be used for the assignment is brought or printed. It is to be evaluated if the item can be measured for contamination.

Action: Measure contamination

The task is performed as described in the instruction on the measurement schedule:

- If the result is below the clearance level the item is classified as white;
- If the result is above the clearance level the item is classified either yellow or red.

The measurement result is registered in the waste management system.

Action: Prepare clearance report

A clearance report is prepared.

4.3.1.4. Accept of classification

In general:

Based on measurements on the waste (ADS) — and economic considerations — the waste is packed in transport containers corresponding to categories Radioactive (RED), Feasible to Decontaminate (YELLOW) and Potentially Not Radioactive (BLUE) and Free Released (WHITE).

Action: Acceptance of white classification

The project manager accepts the classification and ensures that a clearance report is available.

If the project manager does not accept the classification it has to be considered whether the item has to be classified as blue, yellow or red waste.

Action: Pack white item

The waste is packed with a view to disposing of it as conventional waste.

Action: Acceptance of blue classification

The project manager accepts the classification.

If the project manager does not accept the classification it is considered if the item has to be classified as yellow or red waste.

Action: Pack blue item

The blue waste is weighed and the result is registered in the waste management system, after which it is packed according to instructions from the clearance laboratory. Transport to the buffer storage facility or clearance laboratory is ordered.

Action: Acceptance of yellow classification

The project manager accepts the classification.

If the project manager does not accept the classification it is considered if the item has to be classified as red waste.

Action: Decide method

The project manager decides which method is to be used in the further treatment of the waste — is it to be decontaminated or further subdivided in preparation for a division in a blue and a red fraction?

Action: Pack yellow item

The yellow waste is weighed and the result is registered in the waste management system, after which it is packed according to instructions for the decontamination facility. Transport to the buffer storage facility or the decontamination facility is ordered.

Action: Fragmentation of item

The item is subdivided according to instructions from the project manager.

Action: Acceptance of red classification

The Project Manager accepts the classification.

Action: Pack red item

The red waste is weighed and the result is registered in the waste management system, after which it is moved to the relevant waste container. Transport to the buffer storage facility or the intermediate storage facility is ordered.

5. Lessons learned

5.1. Planning, management and organizational aspects

Delays are inevitable in decommissioning projects or at least they should come as no surprise. With reference to the above mentioned quote "the project manager is king" all kinds of delays in the project are of concern to the PM.

In DD the PM does get involved in the project at an early stage as it is typically the PM that is lead contributor to the development of the Project Proposal including the overall time schedule. It is also the PM that estimates the costs that forms the basis for the application for funding. The PM is also involved in the analysis of risk to the project as this is e.g. an integral part of the estimation of the budget. From the start of the execution of the project the PM is of course a part of the executing team on a daily basis.

As such the PM does feel ownership to the project and great responsibility for timely and safe execution. However, the most challenging are typically the unforeseen delays caused by other stakeholders internally as well as externally to DD. This being delays in other departments of DD, administrative and bureaucracy related hinders and similar. Examples can be accreditation of new procedures to be implemented in the department in accordance to the quality assurance system, or obtaining of training and/or certification legally required for operating and handling specific equipment. The delays are typically due to late start (read: prioritization) in the department in question.

A specific lesson learned in DD is – as a government institution — not to underestimate the resources and time required for procurement and public tendering of specialized tool and equipment.

The organisational structure in DD is not as such that the project manager has ready access to all resources necessary to deliver the project. The resources are in fact not within his or her direct management control. All staffing on the project are delivered by other departments. To allow some possibilities for the PM to execute his project DD has tried to establish the basis for a formal agreement between the project and the line management of the resources concerned (DD Management memo June 2009). However, the sometimes contradicting priorities between the individual departments (each having their own projects and annual plan) are of great challenge to DD. As a relatively small organisation (number of staff around 80 divided into five departments) key expertise and key staff are always limited. Therefore, the responsibility given to the PM (in the memo) for establishing the project organisation is in fact not possible.

As mentioned earlier, prior to initiating the work itself the PM must ensure that the necessary staffing resources and professional competences for the execution of the project are present and agreements are made with the HoD that provides the relevant staff. However, often it has shown difficult to find a solution directly between the departments involved, and the Managing Director was drawn in.

From the point of view from middle management level (PM, Operations Manager, Laboratory Manager and similar) the problem relates to the lack of communication between the different managing levels in the organisation. On the recommendation from the middle management level a coordinating group was established in 2011 and a formal forum of communication between upper and lower managing levels. On a weekly basis all middle management staff of the departments meet to discuss ongoing and upcoming projects and to coordinate related needs for resources. At the same time formal meetings between the coordination group and the management board (including Managing Director) have been established and meetings are now held regularly on a monthly basis.

The decommissioning network is now a detailed and complex system that requires reviews and updating regularly on a yearly basis made by the HoD and PM and other managerial staff. This also assures in depth knowledge of the processes. The use by the technical staff, engineers and others is typically limited to the use of ready available templates.

5.2. Unknowns and particular challenges in the project

The decommissioning of (old) Research Reactors and related facilities often involves “Working with Unknowns”. This has been a particular challenge in the planning and execution of the hot cell project.

This can in general be divided in to the following areas of unknowns:

- Technical matters as further described below;
- The need for special tools and unforeseen problems as mentioned above regarding the procurement;
- Time scheduling and budgeting.

The present Risø research working areas in the building, including meeting rooms, offices and extensive laboratory facilities are directly adjacent to the areas used by DD. It has been argued that the research carried out is high profile Risø research and the laboratory facilities would have been very expensive to move to another location. Therefore, DD and Risø at an early stage prior to the planning of the decommissioning work agreed on an principal approach to the decommissioning that will require as little as possible intervention in the work of Risø. This has enormous impact on the economical, resource and time aspects of the project. This requirement is a great challenge to the planning and execution of the project.

Of particular challenges to the execution of the project the following should be mentioned:

- Decontamination of α contamination and the risk of cross contamination;
- Remote operation execution;
- Work including heavy lifting in small areas/space;
- Access to necessary working areas to be available in separate phases due to the agreement made with Risø;
- First time — Project type all new to DD/Denmark;
- All equipment to be new supplied;
- The Nuclear authorities have expressed their particular attention to this project;
- Hot spots not known. The characterisation has shown that some hot spots are not located as was expected, and a number of additional hot spots are found in the cells;
- Limited documentations on drawing;
- Limited documentation of the closing of the facility, what happened, what is stored on 1st floor, channels, why and where?'

Compared to previously performed projects in DD the workers' Health and Safety programme needed also to be increased. This included among other things:

- Extended urine sample taking programme (α) (*new to DD*);
- New staff entrances and air locks to be erected;
- Full body monitor to be used by exit from work areas (*new to DD*);
- Additional/extra change areas for shoe covers and protective gear between working areas and sub-areas;
- New full body suits and protective air breathing gear (*new to DD*).

It has also happened that workers rightly expressed their concerns due to no experience in entering cells and the use of new types of protective equipment.

6. Collaboration with other CRP members

Through the Norwegian CRP member DD has established a formal co corporation with the Halden Reactor Project in Norway. The corporation is formalised in a Memorandum of Understanding (MoU) and aims at practical use of a visualization software in decommissioning works. The MoU project also aims at the further development of the software through the inclusion of the experiences and lessons learned from the use of the software in DD.

7. Conclusions

Administrative procedures, regulations and legal requirements to procurement and tendering procedures and the consequential resource — and time consumption related hereto should not be underestimated.

Communication — as always — is essential to communicate the goals and milestones and clarify the need of resources between the different projects and "stakeholders" within the organization. The time consumption needed for this purpose should not be underestimated.

The established processes and decommissioning network system is useful for overall planning and management purposes. Further development and dissemination of the system within DD may be purposeful.

The organization in DD may not be the most optimal and improvement is a continuing challenge. However, the hot cell decommissioning project is progressing, though not according to the original time schedule but a new revised version. Work is being done, waste produced and progress made on-site and no accidents have occurred, the latter being the most important.

Finally, in the department of Project Management we have acknowledged the fact:

- Unknowns are a part of the challenge of the project.

We have extensively made use of the already existing knowledge of similar or related projects/problems within the international decommissioning community (e.g. IDN, IAEA TecDocs, experts).

In particular regarding special tools we have taken time to looking into other special working fields involving high risk operations, e.g. offshore, subsea, high voltage/power, aerospace, power lifting, medical/pharmaceutical and related industries.

We can conclude with the recommendation to always be prepared. And do not be afraid to overestimate time and budget — double up!

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DECOMMISSIONING PLANNING DURING THE OPERATION OF THE LOVIISA NPP — PLANNING, MANAGEMENT AND ORGANIZATIONAL ASPECTS

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Abstract

The first decommissioning plan for Loviisa nuclear power plant was written already in 1980's, when the plant had just started operation. The plan has been updated in 5–6 years intervals and this work still continues towards the final decommissioning plan. The decommissioning plan is based on immediate dismantling option and final disposal of decommissioning waste to the extension of the on site final disposal facility for low and intermediate level waste. The decommissioning planning has been organized as an independent project, which is realised in close cooperation with Fortum's research programme on radioactive waste management. The plant personnel are involved in the planning work through providing operating experience on contamination and activation of systems, structures and components. Later in the decommissioning phase the plant personnel will form the main part of the decommissioning organization.

1. Introduction

Loviisa Nuclear Power Plant (NPP) is located in the city of Loviisa, about 100 km east from Helsinki, Finland. Fortum Power and Heat Ltd own the plant, which includes two VVER-440 type pressurized water reactors (Loviisa 1 and Loviisa 2). The plant is operated by Fortum Power Division, which has about 600 employees on-site.

Loviisa 1 and 2 plant units started operation in February 1977 and November 1980, respectively. The gross electric power of the plant units is 510 MW (net 488 MW) leading to annual electricity generation of about 8 TWh. This is approximately 10 % of the total annual electricity consumption in Finland. The plant units have been operating with high load factors. The cumulative capacity factors calculated for the complete operating history of the plant units are 86% and 88%, respectively. The current operating license of Loviisa NPP is valid for 50 years i.e. until 2027 (Loviisa 1) and 2030 (Loviisa 2).

Like all the other VVERs, Loviisa reactors have horizontals steam generators. The reactor core has 313 fuel rod bundles arranged in hexagonal channels. The primary circuit has six loops. During the 30 years of operation the Loviisa NPP has been modernized and refurbished, and, hence, it includes some specific features differing from the other VVERs. One of them is the ice condenser containment, which is not part of the original Russian design. The plant is also equipped with systems for severe accident management, which allow external cooling of the reactor pressure vessel in the case of a core melt accident. Currently the plant automation and control systems are under modernization. This work will be done during the normal outages in several phases. Figure 1 shows an overview of the Loviisa NPP.

2. Legislative framework for decommissioning planning in Finland

The main legislative documents in Finland are the Nuclear Energy Act (issued in 1987 and somewhat modified since that) and Nuclear Energy Decree (issued in 1986 and somewhat modified since that). Decommissioning was only briefly mentioned in the original legislative documents, but new paragraphs about decommissioning were added to the Nuclear Energy Act in 2008. The two main principles included in these paragraphs are:

- The design of a nuclear facility shall provide for the facility's decommissioning, the related decommissioning plan being kept up to date as provided in section 28 herein.

- When the operation of a nuclear facility has been terminated, the facility shall be decommissioned in accordance with a plan approved by the Radiation and Nuclear Safety Authority (STUK). Dismantling the facility and other measures taken for the decommissioning of the facility may not be postponed without due cause.

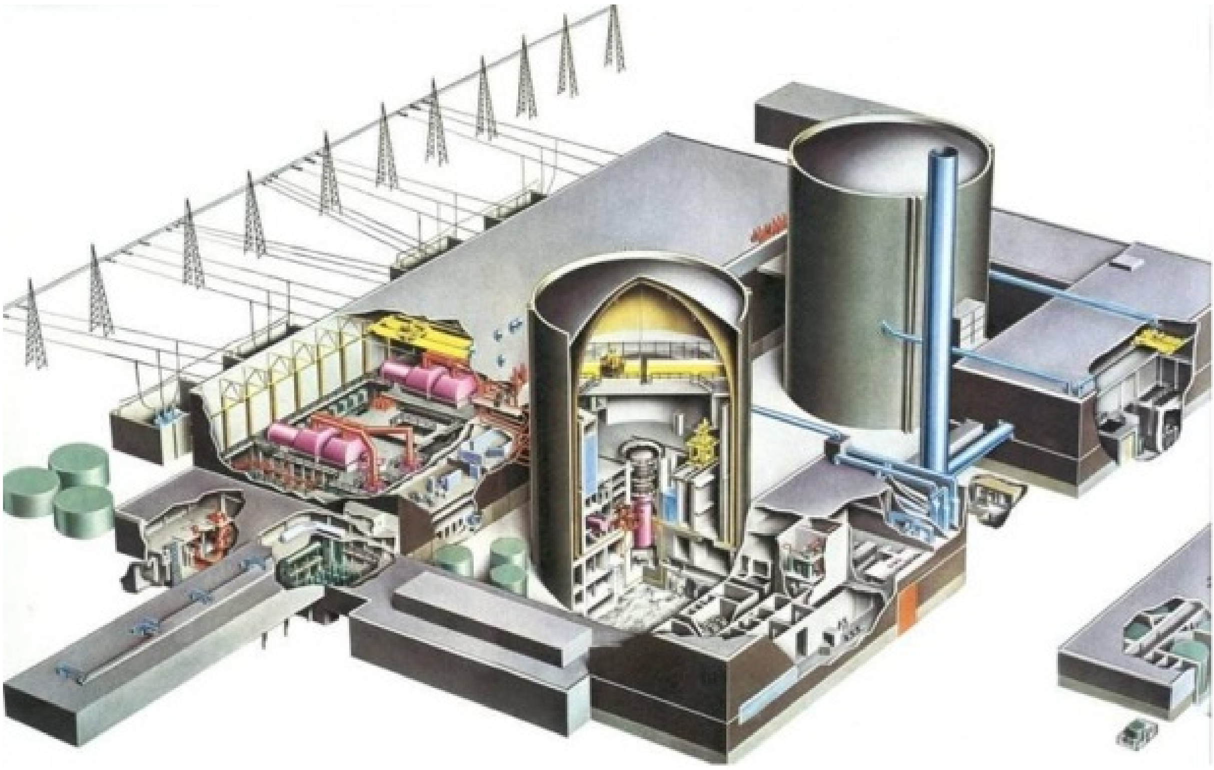

FIG. 1. General view of the Loviisa NPP.

The Nuclear Energy Act also requires, that the waste management plan is updated every 3rd year and the decommissioning plan every 6th year:

- For the duration of the operations subject to a licence, the plan for carrying out nuclear waste management shall be presented regularly at three year intervals, unless otherwise provided in the licence conditions. The plan shall also include a general plan for the following six years. Unless otherwise provided in the licence conditions, a plan for the decommissioning of the nuclear facility shall be presented regularly, at six year intervals, for the duration of the operations subject to a licence.

In the Nuclear Energy Decree, the requirements for construction and operating licence applications are specified. The construction and operation license applications shall include:

- A description of the quality and maximum amounts of the nuclear materials or nuclear waste that will be fabricated, produced, handled, used or stored at the nuclear facility;

- A description of the applicant's plans and available methods for arranging nuclear waste management, including the decommissioning of the nuclear facility and the disposal of nuclear waste, and a description of the timetable of nuclear waste management and its estimated costs.

Statute of the Government VNA 736/2008 on the final disposal of nuclear waste covers all types of radioactive waste; hence, there are no specific requirements for decommissioning only in this document. In the requirements about safety culture, safety and quality management, decommissioning is mentioned. In addition to that the requirements for near surface disposal set limits for the use of this type of facilities for disposal of decommissioning waste:

- When designing, constructing, operating and decommissioning or closing a nuclear waste facility, a good safety culture shall be maintained.
- Organisations participating in the design, construction, operation and decommissioning or closure of a nuclear waste facility shall employ a management system for ensuring the management of safety and quality.
- If nuclear waste, as referred to in the Nuclear Energy Act, will be disposed of in a facility constructed in the ground, said disposal shall be planned and implemented in compliance with the requirements laid down in sections 3–9 and 13–21 herein. Only very low level waste, the average activity concentration of which does not exceed the value of 100 kBq per kilogram, and the total activity of which does not exceed the limits laid down in section 6(1) of the Nuclear Energy Decree, can be placed in a facility constructed in the ground.

The Finnish Nuclear and Radiation Safety Authority STUK have published, for comments, a new draft regulatory guide "YVL D.4 Handling of low- and intermediate- level waste and decommissioning of a nuclear facility" (available in the Internet in https://ohjeisto.stuk.fi/YVL/?en=on). This regulatory guide sets more detailed requirements for the decommissioning of nuclear facilities, including regulations on radiation protection, design requirements, operation of the facility, demonstration of compliance with safety requirements and regulatory control. The document also includes general clearance levels for unlimited material amounts, general clearance levels for limited material amounts, and monitoring of activity in the waste. This guide is expected to be published in 2012.

The main legislation framework for licensing procedure for decommissioning and dismantling includes the Nuclear Energy Act, Nuclear Energy Decree, and also the Environmental Impact Assessment (EIA) Act, and the Euratom treaty. Since there have been no real decommissioning projects in Finland so far, and the need for detailed legislation in this area has been limited to decommissioning planning, it is possible that the Nuclear Energy Act will be revised in this respect before the decommissioning projects.

3. Decommissioning licensing procedure and schedule

In 2009, Fortum prepared a preliminary study of licensing of the Loviisa NPP for and during the decommissioning [1]. According to this study the licensing of the Loviisa NPP for decommissioning and final disposal of decommissioning waste includes at least the following steps:

- Environmental impact assessment (EIA) for decommissioning and final disposal of the decommissioning waste;
- New operating license to cover the decommissioning and dismantling works;
- Decision in principle (DIP) for final disposal of the decommissioning waste to the on site repository;
- Announcement about the termination of the operation of the plant units;
- Final decommissioning plan;
- Construction license (CL) application for the on site final disposal facility, and
- Operation license (OL) application for the on site final disposal facility.

This means that separate licences for the NPP under decommissioning (operation licence) and for the final repository for the decommissioning waste (DIP, CL, OL) are needed.

A preliminary licensing schedule for Loviisa NPP decommissioning is presented in Figure 2. The critical path in the licensing is determined by the licensing of the final disposal facility. The final disposal of the decommissioning waste in an on site repository is included in the decommissioning plan as an integral crucial part of it, which enables the optimization of the entire waste management chain from the dismantling of the plant all the way to the final disposal of the waste.

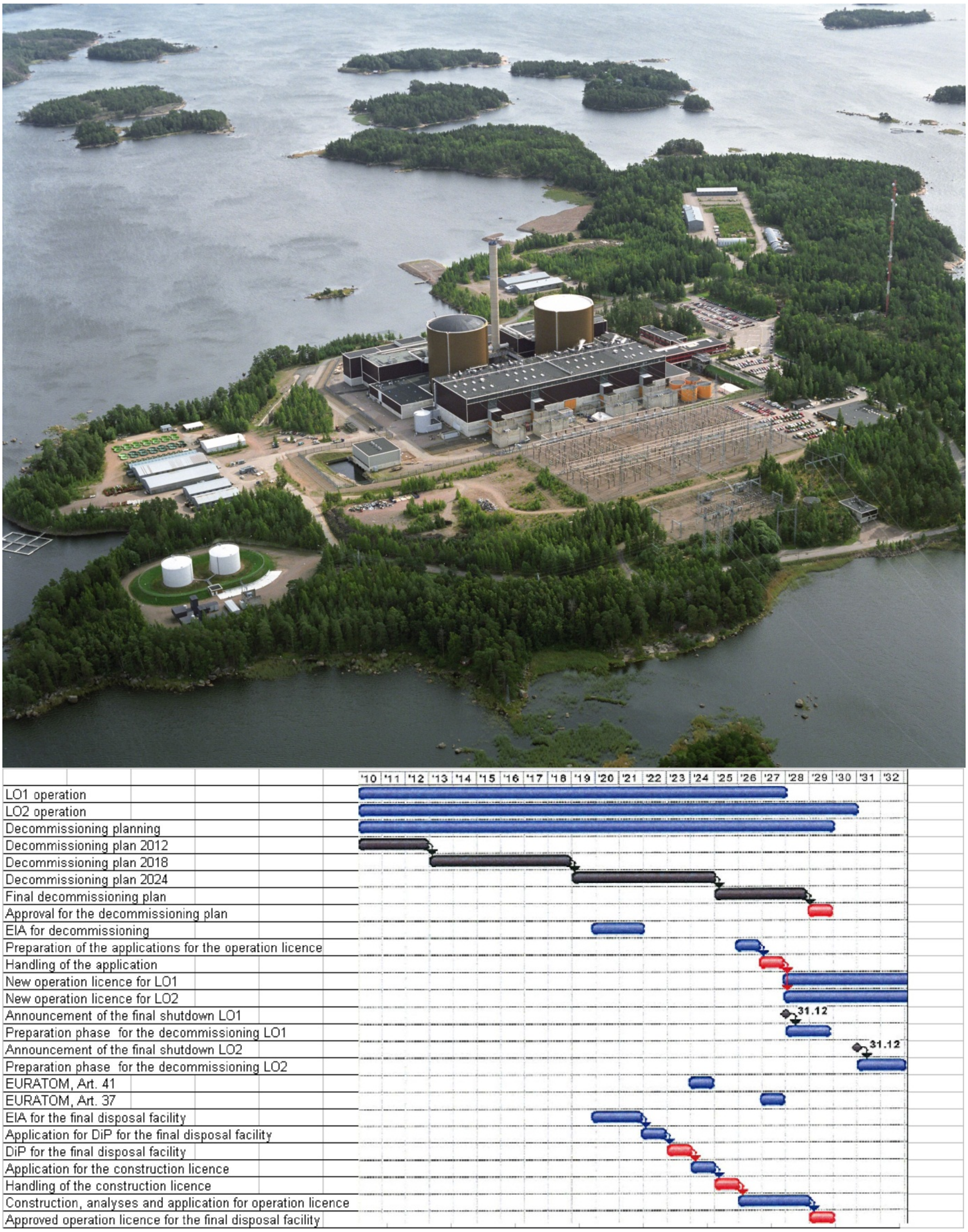

FIG. 2. Preliminary licensing schedule for decommissioning of the Loviisa NPP.

4. Decommissioning planning for Loviisa NPP

4.1. History and background

Decommissioning planning for Loviisa NPP is a continuous process, which started already in 1980s. In this process the level of details has been enhanced gradually. The work has involved follow-up of development of contamination and activation in the plant systems and structures. The process has taken into account the numerous changes in the plant processes and systems during the 30 years of operation. At the same time, the effects of changing legislation environment have been followed and reflected in the plans.

The decommissioning plan forms the basis for funding, which is collected into the national nuclear waste fund. Financial calculations are updated simultaneously with the technical design work included in the decommissioning planning.

The decommissioning plans were originally updated every 5th year (1987, 1993, 1998, 2003, 2008), but this was changed recently to every 6th years. The next update, however, will be made already in 2012 i.e. four years after the previous one. The reason is that in this way the decommissioning planning is synchronized with the preparations of the overall waste management plan and cost estimate, which is updated every 3rd year. The final goal of the work is a sufficiently detailed decommissioning plan available at the end of the plant operation, which is needed when applying permission to start the actual dismantling works.

Decommissioning planning for Loviisa NPP is based on immediate dismantling option and 50 years operating lifetime. The other assumptions and boundary conditions for Loviisa NPP decommissioning planning are the following:

- The plan covers the dismantling of radioactive systems, structures and components;
- No requirements for green field — area will be used for power production;
- Dismantling with currently available technology;
- Disposal of large components (RPV, SGs) without cutting;
- Final disposal of the waste to the extension of the existing repository for operating waste on-site; and
- No recycling or re-use of material assumed in the cost calculations.

4.2. Decommissioning plan 2008

The latest update of the Loviisa NPP decommissioning plan was done in 2008 [2]. This update included the following major modifications:

- More detailed plans for dismantling of certain systems;
- More detailed plans for independence of some systems;
- New safety case for the final disposal of decommissioning waste;
- Updated occupational exposure estimates;
- Updated cost calculations, and
- Other updates due to the operation experience.

The total volume of decommissioning waste from the Loviisa NPP was estimated to be about 30 000 m^3 (including the waste packages). The manpower needed in the dismantling work is about 3 000 man years. The estimated collective radiation dose to the plant personnel from the decommissioning and dismantling works will be about 10 manSv. The estimated decommissioning costs for the two Loviisa NPP units will be about 312 M€, including all the final disposal costs of the decommissioning waste. The preparatory decommissioning works can be started in 2027 at the Loviisa 1 unit, and 2030 at the unit number 2. The dismantling of activated and contaminated material starts in 2029 in the Loviisa 1 unit. The decommissioning will be completed around 2060, when the spent fuel storage will be dismantled, the waste from there will be disposed of, and the repository will be closed. Dismantling of the spent fuel storage at Loviisa is possible only after all the fuel has been transported to Olkiluto for final disposal. See Figure 3 for the overall schedule for the decommissioning of Loviisa NPP.

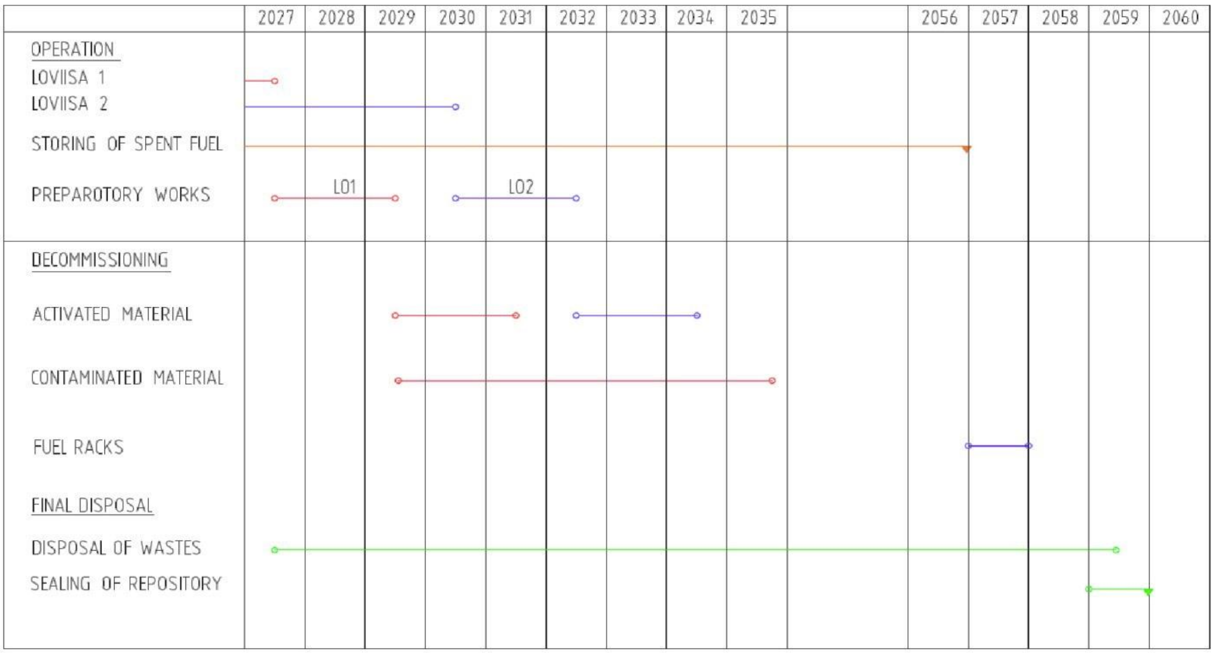

FIG. 3. Schedule for decommissioning of Loviisa NPP.

4.3. Decommissioning plan 2012

The next update of the Loviisa NPP decommissioning plan is included in Fortum's nuclear waste research programme. The update shall be ready before the end of 2012. This time the decommissioning planning is organized as a project, which has an ultimate goal in the final decommissioning plan in the 2020's. The project plan for the period 2009–2012 was issued in 2009, and it included an action plan, resource plan, time schedule, cost estimate and risk assessment. A support group of 7 persons follow the work. Further time periods are sketched in a similar way.

The new plan will take into account the work done at Fortum during the years 2009–2012:

- Higher burn up of the fuel and its impact on decommissioning schedule;
- Overall study of final disposal of very low active solid waste;
- C-14 issues (included in the national research programme on nuclear waste (KYT) ; to be completed in 2013) and research on durability of engineered barriers (concrete);

- More detailed design of closing and sealing of the repositories (backfill materials, barrier structures and migration of gases);
- Studies on fault and emergency conditions in decommissioning and their consequences;
- More detailed assessment of dose rates and radiation doses during the detachment and removal of large power plant components, such as the reactor pressure vessel;
- Positive values relating to a decommissioned power plant, such as the value of equipment or metal in terms of recycling and re-use;
- Risk assessment of the situation with one unit in operation and one unit under decommissioning has been done;
- Study on the licensing of Loviisa NPP for decommissioning, and
- A preliminary risk analysis of the decommissioning and dismantling works.

There are also some continuous activities in Fortum, which will be taken into account:

- Collection of operating experience at Loviisa plant (e.g. repair and replacement of components, working hours, work methods and contamination);
- Monitoring of the activity of systems, equipment and structures at the plant;
- Maintaining preparedness for decommissioning and long term safety case competence;
- Following possible changes in the legislation framework;
- Monitoring international research.

4.4. Final plan

According to the Finnish regulations, the final decommissioning plan shall be submitted to the regulatory body STUK not later than two years after the closure of the plant. At the same time, all necessary studies on safety of decommissioning and final disposal of the decommissioning waste shall be submitted to STUK. The decommissioning works can be started after STUK has approved these documents.

4.5. Responses from the regulatory body

The last decommissioning plan 2008 was submitted to the Ministry of Employment and the Economy in December 2008. The Radiation and Nuclear Safety Authority STUK evaluated the plan and prepared a statement in 29.6.2009. According to STUK's opinion:

> "*The decommissioning plan for the Loviisa NPP is in the current stage sufficiently extensive and detailed. The decommissioning and the financial provision can be realized according to the plan*".

STUK's statement included, however, some detailed comments for the future work, which has been taken into account in the work plan discussed above. Fortum's decommissioning plan was also evaluated by the Technical Research Centre of Finland, VTT, who prepared a statement in 2. 7. 2009. VTT's main emphasis was on the long term safety case, into which it had some detailed comments. Finally, the Ministry of Employment and the Economy (TEM) accepted the updated decommissioning plan in its decision dated on 17. 12. 2009. The ministry stated, that the current plan is detailed enough for this moment of time, and provided some comments, which have to be taken into account in the next updates.

5. Management and organizational aspects in the decommissioning of Loviisa NPP

5.1. Organization of decommissioning and dismantling in the current decommissioning plan

The current decommissioning plan includes an estimate of the manpower needed for the decommissioning project. The general principle of implementation of the Loviisa NPP decommissioning project is that the power plant's own personnel will be responsible for project administration linked with the decommissioning, the planning work, operation of the necessary processes and certain decommissioning tasks that require good knowledge on the plant and particular expertise. Other clearly definable tasks linked with the decommissioning will be contracted out separately to subcontractors.

As the decommissioning progresses, the operating organization of the Loviisa Power Plant will change in stages to a pure decommissioning organization. When the preparatory phase of the decommissioning of Loviisa 1 begins, Loviisa 2 continues to be in full operation. The organization of the Loviisa 1 preparatory phase will be mainly formed from the operating personnel of Loviisa 1. The organization of the preparatory phase will be responsible for the following tasks:

- Operation and maintenance of the necessary process systems;
- Treatment of the maintenance waste and treatment and solidification of the liquid waste;
- Dismantling of the reactor internals and transfers of the spent fuel to the interim stores;
- Decontamination of the primary circuit;
- Clearance of the segment area;
- Radiation protection;
- Accounting and office services;
- Dining and accommodation services.

The strength of the organization required for the preparatory phase has been estimated at 189 people. Some of the people will be in charge of tasks linked with both the operation of Loviisa 2 and preparations for the decommissioning of Loviisa 1. In the preparatory phase, the most important contracts to be carried out by subcontractors will include construction of the access ramp outside the reactor buildings, construction of the packaging and cutting station for the decommissioning waste, and extension of the repository for decommissioning waste.

When the actual dismantling of Loviisa 1 begins, the organization will be changed so as to meet the requirements set by the decommissioning. The tasks of the power plant's own decommissioning organization will include, for instance, the following:

- Planning of the decommissioning measures;
- Supervision of and guidance for the contractors concerning the detachment and treatment of activated and contaminated material;
- Operation and maintenance of the necessary process systems;

- Storage and transports of the spent fuel, and related safety arrangements;
- Radiation protection;
- Transports and final disposal of the decommissioning wastes;
- Accounting and office services;
- Dining and accommodation services.

The strength of the power plant's own personnel required for the decommissioning phase has been estimated at 156 people. Some of the people will be in charge of tasks linked with both the decommissioning of Loviisa 1 and the operation and, subsequently, the decommissioning of Loviisa 2. In the decommissioning phase, the contracts to be carried out by sub contractors will include the dismantling, cutting and packaging of the process systems and constructions that contain radioactive substances, and the necessary cleaning.

Upon termination of the operation of Loviisa 2, the changing of the operating organization to the decommissioning organization will be similar to the process at Loviisa 1. The guarding of the plant has been planned to be included in the decommissioning operations from the shutdown of Loviisa 2. The maximum strength of the decommissioning staff will be almost 430 people. Three distinct peaks can be recognized in the manpower demand. They will fall on the beginning of the preparatory phase of Loviisa 2, the launching of the actual decommissioning of Loviisa 2, and the dismantling of the contaminated auxiliary systems after all spent fuel has been taken away from the plant.

5.2. Management and organization issues for decommissioning planning

The basic principle for organizing the decommissioning and dismantling of Loviisa NPP is to use the existing work force from the site as much as possible. This is done since the existing organisation on-site, as well as the management of the operating plant, is committed to high safety culture during the operation of the plant. The management system has recently been updated to correspond to the new structure of Fortum's Power Division's nuclear operations. The new organisational unit Nuclear Competence Centre (NCC) is now responsible for operation of Loviisa NPP as well as its technical support. All together about 700 nuclear experts work in NCC in two sites, Loviisa and Espoo.

The decommissioning planning works have been closely connected with Fortum's long term waste management research and development programme. The decommissioning planning has been communicated with the plants operators through plant life management (PLIM) workshops, which are organized twice a year. In 2009 PLIM seminar a general presentation about the updated decommissioning plan was given. In 2010, a presentation about the final disposal and long term safety of the waste was given. Key messages relating to the operation of the plant:

- All activated or contaminated waste items have to be disposed of, and
- All stored waste items are to be disposed of, if not earlier, at the latest during the decommissioning.

The age structure in Fortum's nuclear is such that the generation change is right now going on. The people who were involved in the construction of the plant are retiring and young people are taking their place. Continuation of nuclear activities at the site i.e. the construction of a new Loviisa 3 plant unit has been postponed, since the government did not grant a decision in principle (DIP) for Fortum. The detailed decommissioning organisation shows the career possibilities and time schedule for decommissioning works, hence, shows that activities on-site continue for more than the next 20 years.

6. Decommissioning as part of the Research, Technology and Development (RTD) programme for nuclear waste

The Finnish Nuclear Energy Act requires, that "...the licensee under the waste management obligation shall present, for assessment by the body granting the licence, a plan for carrying out nuclear waste management. For the duration of the operations subject to a licence, the plan for carrying out nuclear waste management shall be presented regularly at three year intervals, unless otherwise provided in the licence conditions. The plan shall also include a general plan for the following six years. Unless otherwise provided in the licence conditions, a plan for the decommissioning of the nuclear facility shall be presented regularly, at six year intervals, for the duration of the operations subject to a licence".

The RTD plan includes all types of nuclear waste, although the majority of the pages are dedicated to the management of spent fuel. The latest research plan "TKS-2009" (RTD-2009) was published in 2009 [3]. This document includes a detailed research plan for 2010–2012, and a more generic one for 2013–2015. The next plan is currently under preparation, and it covers the years 2013–2015 (detailed plan) and 2016–2018 (generic plan).

The focus in the new plan will be slightly different than in the previous one, since the waste management organization POSIVA, responsible for the management of Fortum's and TVO's spent fuel, is about to file a construction license application for the final disposal facility for spent fuel. The application is scheduled to be filed in 2012.

7. Collaborations with other CRP members

The decommissioning planning has included the following international cooperation:

- Participation in the organisation of a Nordic seminar on decommissioning (see http://www.nonuclear.se/files/NKSDecom2010-invitation.pdf). Some CRP members took part in the seminar;

- Participation in the OECD/NEA/WPDD work. Some CRP members and the IAEA take part in the work.

In addition, Fortum's representatives have participated in international seminars and training courses on decommissioning area.

8. Conclusions

This paper has given an overview of the status of the Loviisa NPP decommissioning plan, and system for updating the plan towards the final decommissioning plan. The latest decommissioning plan was submitted to the authorities in 2008. Fortum received positive statements from the ministry, regulatory body and the evaluators of the plan.

The work is under way in Fortum to prepare the next update of the decommissioning plan. The work done during the last three to four years has shown that the licensing procedures need to be started about 8 years before the decommissioning begins. The first licensing activity will be the preparation of an Environmental Impact Assessment (EIA) for the final disposal facility. The updating of decommissioning plan is organized as a project in Fortum. A project plan has been written for the future decommissioning planning. The planning period for decommissioning is 6 years whereas it is 3 years for the overall nuclear waste management planning (RTD programme).

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HUNGARIAN EXPERIENCE IN DECOMMISSIONING PLANNING FOR THE PAKS NUCLEAR POWER PLANT

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Abstract

Preparations for the decommissioning planning, and the legal background are described in the first part, followed by a review of possible decommissioning strategies and the present reference scenario. Specific issues of financing the future decommissioning and the anticipated radioactive wastes and their activities are described in the latter part of the report.

1. Introduction

1.1. Brief history

There are 4 nuclear facilities in Hungary:

- Paks NPP with its four WWER-440 units, commissioned between 1982 and 1986, and providing about 40% of the country's domestic electricity production;
- The Interim Spent Fuel Storage Facility (ISFS), located adjacent to the NPP;
- The Research Reactor of the Hungarian Academy of Sciences KFKI Atomic Energy Research Institute (AEKI);
- The Training Reactor of the Budapest Technical and Economical University.

No nuclear facility is in the stage of decommissioning. The timing for the shut down of the Paks NPP will be influenced by the feasibility of extending the plant life. A life extension application is being processed by the regulator, and the decision regarding Unit 1 is expected within months and for the other Units within a year.

Hungary has put in place a quite classical system for the preparation of future decommissioning of nuclear facilities. The necessary organization — the Public Agency for Radioactive Waste Management (PURAM) — has been set up in similar way as in many other European countries.

Up to now 4 Preliminary Decommissioning Plans (PDP) were prepared for the NPP, 2 PDPs for the Interim Spent Fuel Store, and 1 PDP each for the research/training reactors. The last PDP for the NPP — as the update of the third revision — was prepared according the table of content of the "Standard Format and Content for Safety Related Decommissioning Documents" issued by the International Atomic Energy Agency, in 2008.

According to the Hungarian Nuclear Safety Standards (NBSZ) a Final Decommissioning Plan (FDP) needs to be submitted to the regulator a year before final shutdown commences. The lifetime extension request for all Paks units has been submitted but not approved yet; therefore a FDP is due in by December 2011.

1.2. Regulatory system

In Hungary, Act CXVI of 1996 on Atomic Energy expresses Hungary's national policy in the application of atomic energy. Among other aspects, it regulates the management of radioactive waste and authorises the Government and the competent Ministers to issue executive orders specifying the most important requirements in this field. The legal background for the decommissioning of nuclear facilities is also the Act on Atomic Energy and the newly issued Government Decree 118/2011 (VII. 11.), specifying the role of the Hungarian Atomic Energy Authority (HAEA). A particular issue is that the Act establishes a so called divided authority and regulatory system. It means that the principal licensing and supervising authority for nuclear applications is the HAEA; with regard to radioactive waste management it is an organisation appointed by the minister responsible for health (at present, it is the State Public Health and Medical Officer Service — SPHAMOS).

The Government provides for the execution of the governmental tasks described in this Act through the HAEA and the Ministers concerned. The Act on Atomic Energy and the decrees relating to its implementation also assigned the responsibilities for the various ministries: the Ministry of Health, the Ministry of Environmental Protection, the Ministry of Interior, the Ministry of Transportation and Water Management, the Ministry of Agriculture and Regional Development and the Ministry of Economy.

In matters related to the peaceful use of atomic energy, the HAEA is a central administrative body with national jurisdiction that is directed by the Government and having independent duties and regulatory authorisations. It is supervised by a minister appointed by the Prime Minister [1].

2. General principles

The Nuclear Safety Regulations (NSR) were promulgated as Appendices to the newly issued Government Decree 118/2011, (VII. 11.) [2]. The NSR considers the complete clearance of a site for unlimited re-use as a free non-nuclear area. Future modifications envisage release of the site as a “brown field” for further industrial use.

Relevant international guidelines (IAEA documents, WENRA Decommissioning Safety Reference Levels) or advisory publications (OECD NEA decommissioning publications, e.g. on strategy) were used as reference materials.

3. Special situation with unit 1 decommissioning

There is no explicit definition for the starting point of the decommissioning process. One year prior to final shut down of the reactor, documentation shall be available, serving as a basis for the licence applications to be submitted to the Authority and containing the final version of the Decommissioning Plan and the way of its execution.

This requirement results in a particular situation for Unit 1 of Paks NPP, because the 30 years design lifetime expires in 2012. The operator submitted a plant lifetime extension submission with all the required supporting reports and studies for all 4 Units. The review of this application is in progress. Since there is no decision yet for Unit 1, the general requirement of a Final Decommissioning Plan will become valid at the end of 2011, and a corresponding document would be required until December 2011.

4. Safety regulation on decommissioning [3]

Decommissioning is not a current issue for the Hungarian nuclear facilities, so there are no exact/final clearance criteria for the nuclear sites. Nevertheless the licensing process of decommissioning has been covered in regulations. For decommissioning, a multi step licensing procedure is established, where the first step is to obtain the authorities’ consent to terminate operation.

A further requirement is a valid environmental protection licence based on environmental impact assessment and public hearing. As in all phases of the life cycle of a nuclear facility, radiation protection authorities are involved in these licensing procedures, and they license separately the appropriate radiation protection programme and radiation protection organization of the facility.

In Hungary, decommissioning activities cannot be carried out under an operating license. They have to be implemented under a specific decommissioning license. Licenses for decommissioning nuclear installations are issued by the Nuclear Safety Directorate (NSD) of HAEA and the SPHAMOS on behalf of the Ministry of Health.

During the decontamination, dismantling, and other steps, an ongoing task of the authority is the control of the radiation situation within the facility and around it, and the monitoring of personal doses and the discharges and the radiation in the environment. The Central Nuclear Financial Fund is liable for the costs arising after the shut down of the plant as well as for the management of all radioactive wastes. The Licensee determines when decommissioning should start. The license procedure covers 4 phases:

- Final shutdown;
- Period of preparation for decommissioning (can include a period of safe enclosure);
- Period of decommissioning;
- End of regulatory control.

For the phase I and II a Final Shutdown License is necessary, for the phase III a license for Decommissioning issued by HAEA NSD is required. There is no specific licence between the final shutdown licence and the start of dismantling. The legally binding final shut down licence allows the owner of the operational licence to perform activities related to liquidation/termination of operational activities on the unit that is to finally shut down the reactor and to execute activities necessary for preparation of decommissioning.

Content requirements of the application are detailed in the Nuclear Safety Codes. A decommissioning licence is needed to start decommissioning. If decommissioning starts immediately after shutdown, the two licences may be combined. The newly issued document [2] is providing guidance for decommissioning planning purposes.

4.1. Final shutdown permit

The permit authorizes ceasing of operations and preparations for decommissioning activities (the latter includes also removal of nuclear materials and fuel from the plant). The permit is issued for a period of maximum 10 years, but in case of decommissioning reparations, which include a period of Safestore, this period can be further extended. The request should also be supported with an updated issue of the Final Safety Analysis Report (FSAR) and an Emergency Plan.

4.2. Decommissioning permit

Decommissioning works can only be carried out in possession of a valid decommissioning licence. The permit authorizes the Licensee to dismantle and decommission systems and components of the Plant, and to perform activities necessary to release the site for unconditional or conditional use. It contains the required end state to be reached after performing of the above activities.

The permit is issued for a period of maximum 10 years, but in case of decommissioning preparations, which include a period of Safestore, this period can be further extended with the Safestor period. The request should also be supported with the first (preliminary) issue of the Decommissioning Safety Analysis Report (DSAR) and an Emergency Plan for decommissioning.

4.3. *Regulations for the period of decommissioning*

The process of decommissioning of the systems and components of the NPP create an ever changing situation where the state of the facility warrants an ongoing follow-up with changes e.g. in the DSAR, or in the classification of the systems.

During the period of decommissioning the following should be provided — these also need a licence:

- Emergency planning;
- Radioactive waste management;
- Dosimetric control;
- Maintenance, testing and servicing;
- Feedback of decommissioning experience.

4.4. *End of regulatory control*

After the process of decommissioning ends, a formal request needs to be submitted to the NSD, asking termination of regulatory control. The request should also be supported with the updated issue of the Decommissioning Safety Analysis Report.

Nuclear regulatory control of a site can be terminated when:

- The desired end state of decommissioning has been reached;
- No new nuclear facility is planned for the site;
- The decision about releasing the site for further use has been issued by the competent regulator.

Contrary to earlier regulatory opinion, the requirement that the necessary end point is unrestricted use of the site (removal of contamination and radioactive sources above clearance levels, or “green field”) is no longer in the Nuclear Safety Codes, and will be a subject of a unique decision at a later stage, therefore unrestricted use, restricted use or use for a new nuclear facility are all viable options in the Decommissioning Plan.

5. Decommissioning strategy

The completed versions of the decommissioning study for Paks NPP were aiming to help choose the best option for NPP decommissioning [4].

The first 3 studies investigated the following three options:

- Immediate dismantling;
- Closing under surveillance of the units for 70 years;
- Safe enclosure of reactor pressure vessels and their internals in the reactor shafts for 70 year (target value), 50 and 100 years.

In the latest PDP the following four options were considered in connection with the decommissioning strategy:

- Immediate decommissioning;

- Protected conservation of reactors for:
  - 50 years;
  - 70 years;
  - 100 years.
- Protected conservation of the primary circuit for 50 years;
- Protected conservation of the primary circuit for 20 years.

The option of protected conservation of reactors for 50 years was chosen on the basis of the study, and costs of this option were taken into account for payments into the central nuclear financial fund (fund) in the last years. In addition, the Licensee requested preparation of a separate PDP for the safe enclosure for 20 years of active buildings, which are allocated to the controlled zone.

6. Financing the decommissioning

6.1. Legal conditions

The Act on Atomic Energy, provided for the government to take steps aimed at setting up a financial system to implement a coherent and comprehensive solution for the following tasks:

- Back end of the nuclear fuel cycle;
- Final disposal of radioactive waste;
- Interim storage of the spent fuel;
- Decommissioning of nuclear facilities.

According to the Act, financing the tasks mentioned above shall be provided from a fund, and all costs must be paid by the licensees (with exception of the budget institutions, in which case by the central State budget).

The member of the government, who supervises the HAEA, is responsible for the operation of the fund and through the HAEA — as the manager of the fund — controls the implementation of the management tasks associated with the operation of the fund. The fund is a separate State fund pursuant to the Act on Public Finance. Payments into the fund by licensees of nuclear facilities are determined in a way that the fund will fully cover all the costs arising as a result of the final disposal of radioactive waste, the interim storage and final disposal of spent fuel and the decommissioning operations.

In the case of the Paks NPP, payments made by the licensee to the fund are taken into account as expenditure when pricing electricity. This needs to be negotiated also with the Hungarian Energy Office. In order to ensure the stability of the value of the fund, a certain amount of money is provided from the Government budget (presently 2% above the average basic interest rate of the Hungarian Central Bank). Payments into the fund started in 1998.

PURAM has to submit a proposal for the long and intermediate term, as well as for the annual plans. These are evaluated by a special committee created by the Hungarian Atomic Energy Authority and chaired by the director general of the HAEA. The plans negotiated in this way have to be approved by the Minister supervising the HAEA who submits the plan for inclusion and approval within the annual budgetary act. Following approval by the Parliament, the tasks may be implemented.

As a result of the calculations of decommissioning costs and safestore periods in the latest revision of the PDP, these are differing from the previously applied costs and expenditure profiles.

the "mid and long term plan of PURAM for the activities to be financed from the central nuclear financial fund" [4] is issued every year and it contains the calculations based on what the payments made by the biggest licensee to the fund (NPP Paks) are to be made. A decision about the changes in the strategy and the resulting new costs will be incorporated in the calculations after a thorough review of the alternatives.

7. Cost estimation for decommissioning

The decommissioning cost estimation should include all activities, reaching from the planning and transition (from shutdown to decommissioning) phases, performing the decontamination and dismantling and management of resulting waste up to the final remediation of the site. All supporting activities like management of the project, maintenance, surveillance, physical protection, research and development etc., should be included. The decommissioning plan which includes all relevant decommissioning activities is an inevitable prerequisite for reliable estimation of decommissioning cost.

The decommissioning costing methodologies for the PDP were developed based on experience derived from real decommissioning and the developed methodologies were then used for similar facilities after adjustment of unit factors and other elements of cost methodologies for the differences in facility size and inventory, local and other factors. The quality of results for calculations for other NPPs depends on quality of adjustment of unit factors for differences in NPPs and involving all relevant decommissioning activities.

The way to overcome these drawbacks is to use the facility specific approach which identifies and evaluates the activities of a decommissioning project at the lowest level of details available, relevant to the level of the project (starting from the conceptual plan through preliminary stage up to the final detailed decommissioning plan) and to use the locally adapted calculation specific data. This principle recommended in IAEA-TECDOC-1476 "Financial aspects of decommissioning" [5], is known as the "bottom up principle" and is considered as the most accurate costing approach.

Another basic principle is the application of the standardised structure of decommissioning cost as presented in the document "A Proposed Standardised List of Items for Costing Purposes" which was issued by IAEA, EC and OECD/NEA in 1999 as an interim technical document for promoting the harmonisation in decommissioning costing. Experience shows that application of this standardised structure is very efficient in comparing the decommissioning costs of various NPP's even when comparing the cost developed using different costing approaches. Example of this can be found in the IAEA-TECDOC-1322 benchmarking costs for NPP's of WWER 440 type [6].

The cost estimate, as applied in the Preliminary Decommissioning Plan, implements the "bottom up principle" as the base for cost estimate approach and the standardised cost structure as the template structure for identification of decommissioning activities and additionally, the elements of the systematic material flow and waste management in decommissioning.

The cost estimation was performed in the computer programme developed in Excel software. Based on review of procedures and methods for implementation of recommended decommissioning cost approaches, experience in practical costing and selected elements of advanced decommissioning costing, the following principles were applied in costing for the Preliminary Decommissioning Plan of Paks NPP:

- Definition of decommissioning strategy and extent of decommissioning options;
- Implementation of standardised cost structure as the base of executive calculation structure;
- Implementation of "bottom up" principle;
- Implementation of costing procedure based on international experience;

- Development of facility specific data;
- Development of facility and site specific unit factors;
- Development of facility specific waste management system and data;
- Development of compact Excel calculation package.

The implementation of the “bottom up” principle means that for every identified decommissioning activity a separate calculation item was created in the executive calculation structure and the decommissioning data was calculated at this lowest level. The calculated data was then grouped in order to develop the overall data presented in standardised formats.

The facility specific data was developed in the form of the inventory database of systems and structures and the database of rooms of the Paks NPP, including the radiological data and specific data needed for calculation of costs and other decommissioning parameters. The database is in the modules of the Excel program.

The facility and site specific unit factors were developed in extent needed for calculation of decommissioning parameters. The database is one of the modules of the Excel program.

The facility specific waste management system and data was developed to cover all types of waste generated during decommissioning and also all relevant data needed for calculation of decommissioning parameters. Waste management system and data are included in one of the modules of the Excel program.

The Excel calculation program was developed as a modular system, which involves the modules with input data, three executive calculation structures for each calculation option and modules with calculated data formatted in standardised structure and graphs.

As an example, results for the calculated necessary man hours, and yearly decommissioning expenditures are presented as Figures 1 and 2 for the option of “Protected conservation of reactors for 50 years”.

The calculation algorithms were developed for the following cost categories:

- Activity dependent costs, related to the extent of “hands on” work like dismantling;
- Period dependent costs, proportional to duration of individual activities/phases;
- Collateral costs and costs for special items which can neither be assigned to hands on work activity nor to period dependent activity, typical as fixed costs.

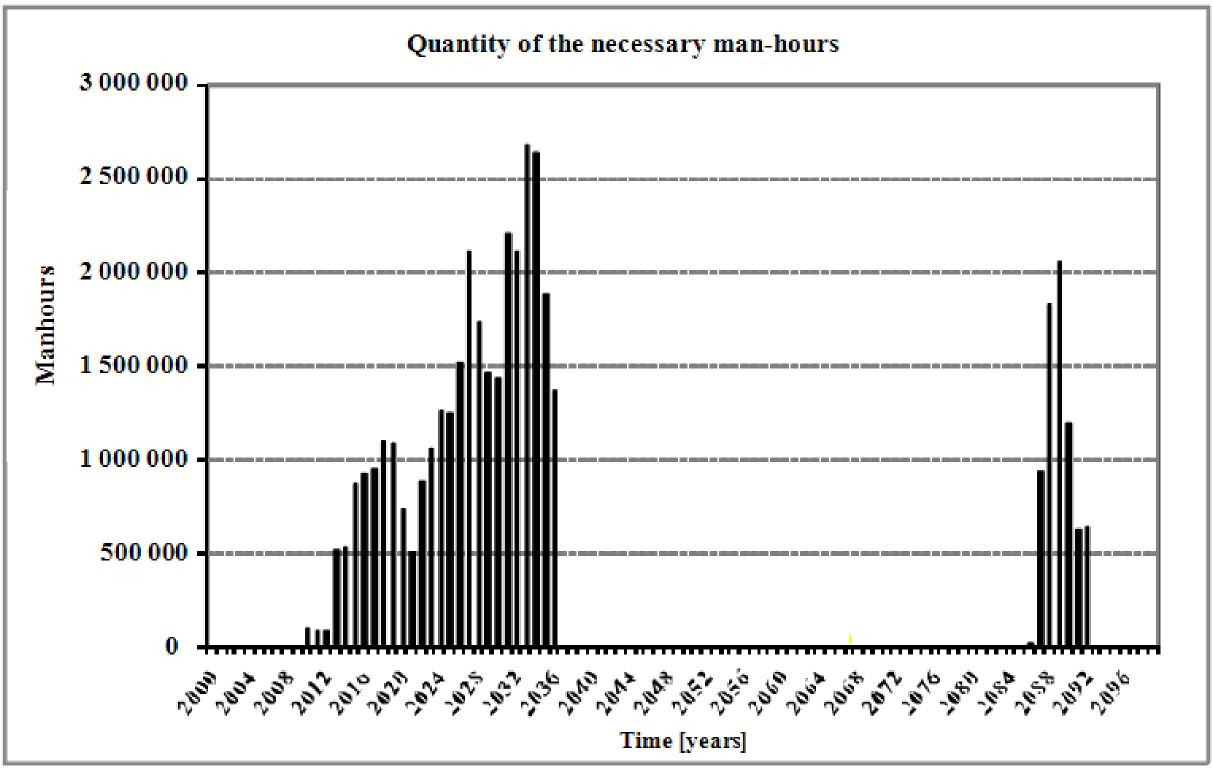

FIG. 1. The decommissioning man hours in the reference case (50 years PC).

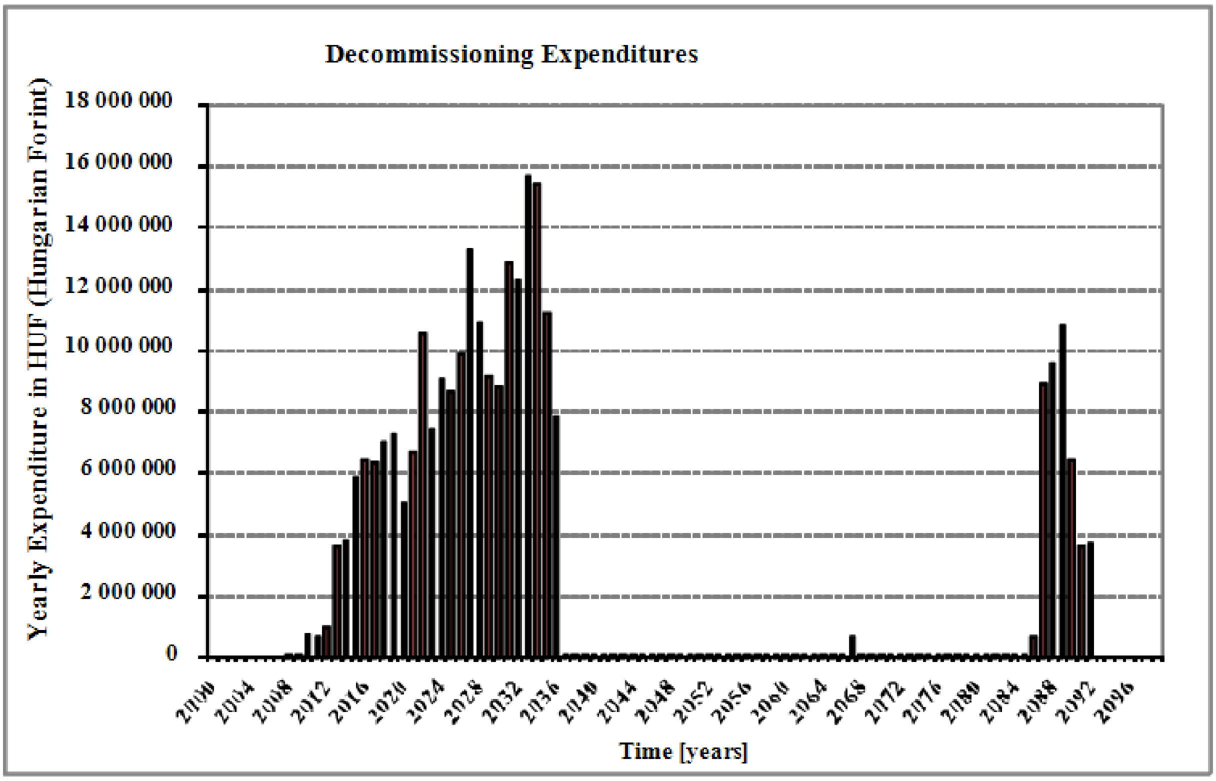

FIG. 2. The yearly decommissioning expenditures in the reference case (50 years PC).

8. Decommissioning wastes

There was an initial evaluation of the decommissioning wastes and their isotopic content in all versions of the Preliminary Decommissioning Plan. Disposal of decommissioning LLW and short lived ILW is planned at the same site and in the same depth, where the operational waste are disposed of. Long lived ILW will be disposed of together with the HLW in a planned deep geological repository.

8.1. Amount of wastes

The total amount of wastes has been calculated for each building and contaminated plant structure (e.g. Reactor Hall, Auxiliary buildings, stacks, waste management building, etc), and according to the type of materials to be decommissioned (e.g. stainless steel, carbon steel, coloured metals, etc.).

The totals were calculated for the investigated decommissioning options separately. As an enveloping condition, data for immediate decommissioning are shown in the following Table 1. The data shows the total for the 4-unit plant. Since decommissioning is planned only for parts of building above the1m mark, and the rest is planned to be filled back and buried, a separate account is taken of the building parts above this level.

TABLE 1. TOTAL AMOUNT OF WASTE

Waste type	Amount, kg
Total amount of solid radioactive wastes (RAW)	65 681 000
Total amount of solid RAW discharged	51 239 000
Total amount of remelted carbon steel	4 100 000
Total amount of remelted stainless steel	0
Total amount of decontaminated carbon steel	2 155 000
Total amount of decontaminated stainless steel	1 544 000
Weight of dismantled carbon steel in controlled area	21 899 000
Weight of dismantled stainless steel in controlled area	20 710 000
Weight of dismantled non-ferrous metals in controlled area	6 939 000
Weight of dismantled non-metals in controlled area	16 133 000
Metals for fragmentation above 3 kBq/cm^2	10 882 000
Total amount of concrete (m^3)	15 881 000 m^3
Weight of stainless steel to deep geological repository	350 000
Weight of stainless steel to surface repository	9 452 000
Weight of carbon steel to surface repository	2 583 000

8.2. Activity calculations

According to different studies, 99% of the total activity in a WWER-440 reactor during decommissioning can be found in the reactor vessel, its internals and the surrounding concrete.

The inventory for one reactor vessel has been calculated, using the ORIGEN Code with the following assumptions, the reactor is loaded with all internals, control rod drives, etc.

- Activation period: 30 years;
- Decay time: 0 days;
- Activation height: 3 m;
- Steel density: 7 860 kg/m^3;
- No water content.

The calculation was reviewed in the framework of the IAEA RER/3/005 Project by an expert from Finland. Taking into account his comments, and new information becoming available a new calculation has been performed. The output data is now used for the review of Waste Inventory for the dose calculations of the waste disposal process.

Similarly, an inventory for the concrete surrounding the reactor vessel has been calculated, using the SCALE-4.3, XSDRNPM and TORT Codes. From the long list of isotopes calculated, the dominant are ^{41}Ca, ^{45}Ca, ^{55}Fe and ^{14}C, after 1 month decay, with ^{55}Fe and ^{45}Ca providing 90% of the total.

8.3. Review of the amount of decommissioning wastes

The option of protected conservation of reactors for 50 years was chosen on the basis of the study, and costs of this option were taken into account for payments into the Central Nuclear Financial Fund (the fund) in the last years. Therefore it was surprising both for the Operator and for PURAM that the last edition predicted much lower amounts of L/ILW decommissioning wastes to be disposed of, independently from the chosen decommissioning option.

A separate review is initiated, and PURAM plans to involve foreign (Belgian) consultants in evaluating the common features of the NPP waste generation during operations and decommissioning, needless to say that this issue plays an important role in the design and licensing of the L/ILW radioactive waste repository.

9. Decommissioning plan for the interim spent fuel store

The initial Preliminary Plan for the Interim Spent Fuel Store (ISFS) was prepared in 2002. A revision and update was prepared in 2010. The comments of the regulator and Licensee to the original plans as well as those made to the latest PDP of the NPP were all collected and taken into account.

An important consideration was the issue of lifetime of the ISFS. Although the design lifetime of the ISFS is 50 years, and thus the first Modules, which were commissioned in 1997, should be emptied in 2047, this date does not tie with the present plans of PURAM regarding repository operations and temporary closure. It was a request of PURAM and the Operator that in the PDP updates the dates of the NPP and ISFS decommissioning should be synchronized.

For the period since the first (last) issue of the ISFS PDP was prepared there were also other events/documents to be considered in the next revision:

- PURAM’s decommissioning strategy has changed;
- A new Nuclear Safety Standard on decommissioning exists in draft form;
- Various IAEA documents were published;
- WENRA Working Group on Waste and Decommissioning (WGWD) published the “Decommissioning Safety Reference Levels Report”;
- HAEA provided some guidance on the decommissioning principles.

The Table of Content of this document followed the general principles applied to the NPP PDP. Detailed weight and material data were generated from the Workshop drawings of the facility. The ISFS PDP end state assumed a free release of the site with all the auxiliary buildings, services demolished/removed.

10. Collaboration with other CRP members

(1) The activity calculations for the Reactor Vessel were reviewed in the framework of the IAEA Technical Co-operation project RER/3/005 "Support in Planning for Decommissioning of Nuclear Power Plants and Research Reactors" by an expert from Fortum, Finland.

(2) The latest version of the PDP was reviewed in the framework of the IAEA TC project RER/3/009 (next phase of previous TC project RER/3/005) by an expert from Nuvia, UK.

(3) Presentations and discussions have been held with the CRP members during the Research Coordination Meetings.

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PROCEDURES AND PRACTICES — CHALLENGES FOR DECOMMISSIONING MANAGEMENT AND TEAMWORK

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Abstract

The mental and practical approach to a decommissioning project is often not the same at all levels of an organization. Studies indicate that the early establishment of a decommissioning mindset throughout an organization is an important and frequently overlooked process. It is not enough to establish procedures, if practices and mental approaches are overlooked; and for decommissioning projects that are more often than not dominated by one of a kind problem solving, procedure design is challenging, and new requirements are put on communication. Our research considers stakeholder involvement in these processes in the wider sense of the term; however the main stakeholders in focus are regulators and the work force that will perform or lead the tasks related to decommissioning. Issues here treated include: Decommissioning mindset and the manifestation of mindset issues in decommissioning projects, including challenges and prospective solutions; trust building and trust breaking factors in communication and collaboration relevant to transition and decommissioning; new technologies for collaboration and communication and how these may impair or empower participants — experiences from several domains. This paper is based on work done in collaboration with the OECD NEA Halden Reactor Project.

1. Introduction

Around the world, a large number of Nuclear Power Plants (NPPs) are now several decades old, and many of them are nearing the time for decommissioning. Furthermore, by international agreements, all nuclear facilities under design or under operations shall today have a preliminary decommissioning plan prepared. Thinking about decommissioning is thus timely for most of us.

The main focus in preliminary decommissioning plans is normally funding and waste management issues. This is rightly so, all though other challenges do exist, and some of these have traditionally not been much addressed in a decommissioning context: the human and organisational factors of decommissioning.

To most plants and communities, decommissioning is a severe change. Several international organisations, including the IAEA, recommend including staff with much experience from the operational phase of a facility in its decommissioning organization. For these people the daily work and even the purpose and motivation of their work become very different from what they have been used to.

Several managers have found that leadership challenges in decommissioning are different from leadership challenges of managing and operating a plant. The focus moves from well established operational performance indicators and routine into project based Decommissioning and Dismantling (D&D), with more unknowns, more complex employee management, and, for many team leaders, more empowerment (and demand) for making own decisions.

Many of the new challenges — and opportunities that tend to manifest themselves with the start of a decommissioning project have similarities to challenges and opportunities encountered in other industries. In this paper, all though the decommissioning community is often reluctant to employing new and unproven methods and technologies, a few lessons learned in other industries are outlined, mainly concerning tools for collaboration and communication.

As stated in [1], sufficient technology does in general exist to ensure that decommissioning projects can be completed within a regulatory framework without any significant effect on the safety of the workforce and the public, or any significant radiological impact on the environment. However, reasons for closing down or deciding to decommission previously closed down sites can be many. The conditions under which transition and decommissioning projects are conducted thus also vary, and all decommissioning projects do not have similar resources for acquiring state of the art technology or the related knowhow. In projects with limited resources, challenges are often related to making do and inventing alternative methods.

Further, ibid. p. 2:

"It has been noted on several occasions that the major weakness in decommissioning projects is poor or inadequate planning and management, including unclear identification of roles and responsibilities. This is unfortunately true in both developing and industrialized countries."

A significant challenge to take on is thus related to the human and organisational factors of preparing for and performing a decommissioning process. Here we focus in particular on factors related to motivational aspects and collaboration.

As stated in [2]:

"Human factors is at the heart of decommissioning since it is all about people, for example the skills of people to undertake the work, the safety of people, motivation of people, and ultimately the redeployment of people."

As found in a series of usability studies for outage support tools [3], many decommissioning challenges are not unlike those of outage; they are mainly more pronounced versions of typical challenges in outage or maintenance situations. We therefore expect that especially for safety assurance, emergency preparedness and motivational aspects, findings from decommissioning will be highly applicable also in operational settings.

2. The challenges and opportunities of decommissioning

To many people, decommissioning is about change. Change of scope, change of purpose and change of motivational aspects. In general, we often tend to resist change, and if a change is radical, it is even not unusual that people need to go through a grieving process before they are able to come to terms with their new situation.

Change may often have a silver lining, however, and many factors influence on how a person reacts to change; are the threats more dominating in the mindset than the opportunities? First we need to discuss what the main changes are on the way from operations to a successful decommissioning project. The IAEA has provided a very useful Nuclear Energy Series report on training requirements for decommissioning [1] and building on this, the table in Figure 1 was developed for another IAEA publication [4].

The first experience related to a new decommissioning project is for many stakeholders a feeling of insecurity. Local companies working for the operator of the NPP are uncertain of the future need for their staff and competence, the operator staff wonder whether their work places will remain safe after the project starts. Many nuclear facilities are located away from the larger cities, and so the work places in the area are to a large degree based on or associated with the facility operation. In the early stages, when decommissioning to many is still an option and not a fact, starting at the bottom of this table, the first change many people experience is thus job insecurity or doubt about their job security. Where previously the nuclear power plant was always there, and jobs would be found, now the end of employment is visible to all staff. People react differently. Some expect to be needed for quite a few years more in connection with decommissioning, and foresee new and interesting challenges. Others do not see much chance of further employment, or worry that the decommissioning project is likely to end long before their retirement. And when the decommissioning starts focus is no longer on keeping up production and profits to ensure continued employment, but on completing a project that will be removing a workplace for good.

Operations	Decommissioning
Predominant risk is nuclear and radiological	Reduced nuclear risk, changed radiological risk, significant industrial risk
Repetitive activities	One-time activities
Well known working environment	Unknowns possible
Routine communications with external partners	New communication requirements
Relying on permanent physical structures	Introducing dynamic physical structures
Relying on permanent organisational structures	Introducing dynamic organisational structures
Safety management based on routine	Safety management based on tasks
Management objectives production oriented	Management objectives project completion oriented
Fixed employment with routine objectives	Visible end of employment – refocused staff work goals

FIG. 1. What is the change? [4].

As the project starts, safety management also changes. During operations good safety management implies a strong focus on establishing and keeping good routines. And while there is certainly also need for good safety routines in D&D, many of the safety concerns relate to one of a kind tasks, or to hazards and uncertainties that are different than they were before. Many good habits need to be replaced by a constructive questioning attitude. The risk also changes, from predominant nuclear and well known radiological risk, to a more complex radiological risk combined with significant industrial risk.

During dismantling physical structures will change, and new practical ways of working need to be implemented to compensate. A previously familiar working environment has more unknowns than before as walls and shielding are torn down, and previously inaccessible areas and equipment is being cleaned out and removed. Organizational structures change as well, to meet the new needs associated with moving from a production facility to a dismantling project. Finally, communication and collaboration requirements change, formally, but also in less formal ways as a result of new work practices and targets.

As people, this sort of change does something to us, and we need to work on it. New work processes are needed that suit the new workflow and the new work practice. New organizational functions are needed, others need to be changed or taken out. And the way we approach and think about our job usually needs to change too. This can be a problem — or it can be an opportunity for a more creative job, new and interesting leadership challenges and more empowerment; and mindset will be important for how this is seen.

3. A mindset for decommissioning

3.1. Definitions of mindset

A mindset can be described as:

Our (established) way of thinking through which we view the world and our work environment.

The mindset of an individual is based on our knowledge, skills and attitudes, and on our willingness to learn and to change. To have a useful decommissioning mindset we need to both understand and accept what a decommissioning process is about.

As decommissioning is much about change, a decommissioning mindset requires a change or an expansion of existing mental models. Moving from producing research or power into producing waste will require a change in the how we think about our jobs and targets. Moving from a routine job with fixed and well rehearsed procedures and guidelines, into a new setting where solving new problems is a significant part of ones task work will require a new approach. Moving from working with well known teammates into ad hoc or short lived teams, composed of people from ones original company in combination with contractors will require a new outlook on teamwork, and on leadership.

3.2. Mindsetting

A common denominator for decommissioning projects that have failed to tackle mindsetting from early on seems to be that they get delayed. People will resist change, be it consciously or not, and work according to old habits often turns counterproductive.

Then how do successful decommissioning management teams work on mindset?

There are several approaches, but while the first step is usually realizing that a decommissioning mindsets is not established over night, the next is planning for how to address this part of the decommissioning tasks just as thoroughly as one will address the selection of the best cutting tools or the right cost management systems.

In general, achieving a fruitful decommissioning mindset and working culture in an organization can be addressed by:

- Training;
- Coaching, most typically of middle management;
- Recruitment, especially team leaders and managers;
- Establishing reward mechanisms;
- Focus on good communication of targets and the way to get there.

As in all change processes visible managers are important, and they need to communicate the new targets and ways of working clearly. In many projects, managers putting on the working gear and being present on the floor or being present to talk in the canteen have had a strong impact. So has the endorsement of the new project by the informal leaders when these are communicating the opportunities of change by walking ahead. This is what Kotter [5] calls the guiding coalition of change; and then there is paying attention to communication, communication and — collaboration.

4. Communication and collaboration

In decommissioning, many different tasks need be completed simultaneously by different workgroups. These tasks will often compete for priority and staff, or they will depend on each other with delays in one seriously hampering another. This is different from a regular operating situation.

Additionally, unlike an operating situation, work is seldom repetitive. The work that needs to be undertaken will comprise formal sequences of non-routine, one of a kind tasks [6] with considerable hazards to be addressed. Safety cases and analyses for this complex setting need to be produced and communicated.

Further, the teams or workgroups will have high diversity, consisting of previous operating staff, employees hired specifically for dismantling and decommissioning activities, and contractors, very often with backgrounds from other areas, such as construction and demolishing. The mindsets and skills of these team members will thus be different, and it can be challenging to harness and utilize these complementarities. Decommissioning tasks are of limited duration, and though many team members know each other of old, the teams themselves are often not long lasting.

These factors put requirements on collaboration approaches, including collaboration tools.

4.1. Communication — breaking news or breaking trust

Already in the early stages, when decommissioning to many is still an option and not a fact, communication is vital to maintaining trust. The work force trust in management, the management trust in regulators and authorities, the publics trust in the industry, and several other vital trust relationships are strongly influenced by what is communicated and how, and by what is omitted.

When people worry about losing their jobs or of other consequences connected to a probable decommissioning of a nuclear facility, what they crave is often verified information. When such information is not available, human nature tends to supply us with other types of information such as rumors, wishful thinking and worst case scenarios.

The key managers and leaders of an organization facing decommissioning will often need to have communication skills a bit out of the ordinary. They need the ability to communicate about uncertainties, and to build trust through their communications. Establishing trust requires management presence both with their workforce and with their other stakeholders; the local community, the regulators, the media and the environmental organizations. It also requires a high level of integrity (Fig. 2).

Building trust in a work environment is not just about managers doing or saying the right things to make people trust them. Trust needs to be built between team members, managers need to trust their staff, and trust also needs to be maintained between actors such as operator company–contractor company/operator company–regulator.

Furthermore, trust needs to be calibrated, as pointed out in [7]. Especially in high risk environments, such as a decommissioning site usually is, over confidence or unfounded trust can be not only unproductive, but even hazardous.

As demonstrated through discussions in the press and on various Internet forums after the Fukushima accident, communication about radiological risk is difficult. The population at large lacks even the terminology to talk about it, and people often get stuck mixing micro Sieverts and Becquerel or confusing radiological contamination with activation. For the public it is often challenging to appreciate or compare risk levels.

Despite some very good efforts from the nuclear community, more pedagogics still is required in this type of communication. Furthermore, visualization tools, if used well, can play an important role in bridging some of these gaps in the future.

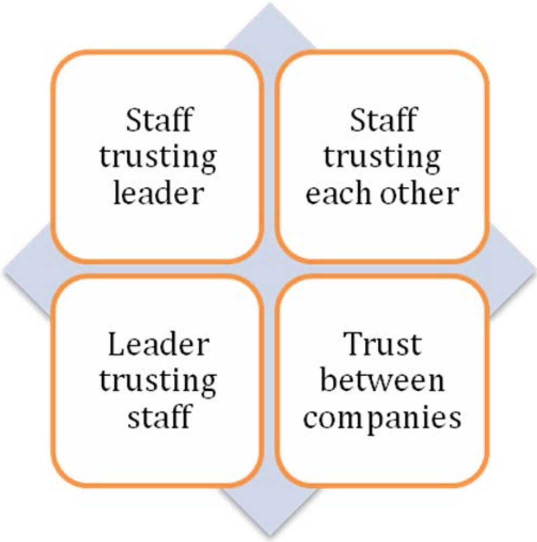

FIG. 2. Trust at different levels [7].

4.2. Tools and ways of working for involving external expertise

The uniqueness of many of the tasks encountered in a decommissioning project means that all expertise required in not necessarily available in the local workforce at all times. Many efforts are made to share expertise, through workshops or hands on training, or through bringing experts physically into the teams, either on own budget or with the help from international actors, such as the IAEA. Here some of the advances in another industry are likely to be of great help in the near future: Integrated Operations (IO).

4.2.1. Integrated operations

With the advances in collaboration technology during the past decade, further opportunities are available. The petroleum industry on the Norwegian Continental shelf has with their concept of IO broken ground in employing distributed teams for highly technical problem solving and decision making [8]. Unlike the average distributed teams studied in teamwork research, the IO teams work in a high risk industry, they are multidisciplinary and multi cultural, and team members often have (or feel like they have) conflicting agendas and timeframes [9]. Many of these characteristics also apply to a number of decommissioning teams.

IO teams are also typically built up as teams of teams, and with frequent team–team interactions; and they are often distributed. Some team members will be offshore in two week shifts, actually wielding the wrench or building the scaffold required to maintain some pump or compressor, others will be onshore, having the detailed expertise on the equipment and providing the continuity of knowledge and information between the offshore shifts. For especially complex problems, expert centres are added to the team, either with helpdesk type of function, or if experience is rare, involving a particular expert.

The technology supporting this type of work is information sharing, through video conferencing and shared work surfaces [10–12]. Through the use of this technology, the IO team is no longer the particular crew of mechanics exchanging that tricky component today, but rather the mechanics and their team leader together with their onshore support team, and the expert from another offshore installation who solved the same type of problem there two years ago.

FIG. 3. Collaboration in a distributed team, here made possible by video conferencing and a shared surface.

In Figure 3, a typical work session is illustrated. The collaborating parties on the left hand screen, their shared work surface on the right hand screen. In the shared work surface not only equipment documentation or SAP tables are shown, but also just as likely a photo of some problematic situation or equipment, a 3D model of the work area or a risk profile for a certain combination of jobs to be performed.

These technologies now constitute one of the new opportunities also for sharing decommissioning expertise. However, it is important to benefit from some of the lessons learned on their way by the petroleum industry to avoid the most central pitfalls.

At the outset of IO, several oil companies invested in advanced video conferencing facilities and expected their staff to embrace the new possibilities and crowd into the rooms to collaborate. For the first couple of years, however, the rooms stood mostly empty. The threshold for using the new technology was too high. The rooms were in several cases designed by the companies' most technology literate staff ("computer geeks" in clear speak), and many of them would liberally add a wide range of "nice to haves" and elements for increasing a facility's so called "wow factor". Though such solutions went down well with visitors and some of management on tours of the facilities for a short time, the concept was not easy to sell in to technical people who felt more at home with their wrench or crane controls. As one nuclear operator stated in a usability study: "Actually, I do not use computers much. I find them most suited for playing solitaire, and this new technology will take quite some time getting used to".

It really took some time to simplify the rooms and to get working in an holistic manner with people, organisation and technology issues so that the rooms fitted the actual needs, the meetings and collaboration sessions felt natural and fitted in the right place on a busy workday spent mostly in the field, and the work surfaces as well as the work processes were fine tuned to embrace and exploit the new possibilities for safer an more efficient work [13].

4.2.2. Applying IO principles in decommissioning

In designing distributed collaboration solutions for decommissioning, focus needs to be put on accessibility, collaboration type, frequency and purpose.

While many nuclear facilities, and thus their decommissioning projects are located in areas with access to high bandwidth, this is not always the case, and different equipment is required for lower bandwidth lines. Furthermore, working between a low end system in one site and a high end system in another can be challenging for creating meetings where participants experience being on an equal footing. If participants know each other well and are confident with using their collaboration technologies, technology differences is usually not a problem. In other settings, balancing technology issues in advance and designing systems for handling each type of collaboration situation will pay off in both information flow and teamwork quality.

In addition to technical issues, distributed meetings require extra focus on shared expectations and thorough preparations. Is the purpose of a meeting to share information or to solve a problem? If this is a regular meeting, who is the 'meeting owner', the person who is main responsible for the meeting being facilitated and the results becoming what they need to be? What kind of information can we share in advance to make sure that everyone is able to contribute at his or her best?

In cross-disciplinary distributed collaboration, failing to address such questions in advance can even lead to people "collaborating against each other" from their different sites. "We could not solve the problem today, but it is their fault." With good preparations, proper training in use of equipment, and regular attention to challenges in distributed collaboration, however, teams have even experienced that they work better and more focused in mediated collaboration [12].

In the last couple of years, low end collaboration solutions, such as WebEx ™, Skype ™ and GoToMeeting ™ have made a leap in usability and functionality, and one on one conferences or work sessions can now very often be run from a desktop, no longer requiring a full scale Video Conferencing (VC) facility for adequate quality. For regular meetings with several participants at one or more of the sites, VC is still normally the preferred solution.

5. ALARA

The drive towards efficient work must be counterbalanced with HSE (health safety and environment) requirements, and in decommissioning a strong focus must be kept on safety planning. There is also a significant use of contractors in decommissioning work, and clear communications about hazards, threats and risks is important.

By facilitating improved planning and communication, many unwanted incidents might be avoided. Among the types of planning tools that seek to accomplish this are ALARA (As Low As Reasonably Achievable) support tools. 3D ALARA tools, as illustrated in Figure 4, from [14], appear to have the potential to be useful for minimising doses but also for improving communication between involved parties, and thus safety.

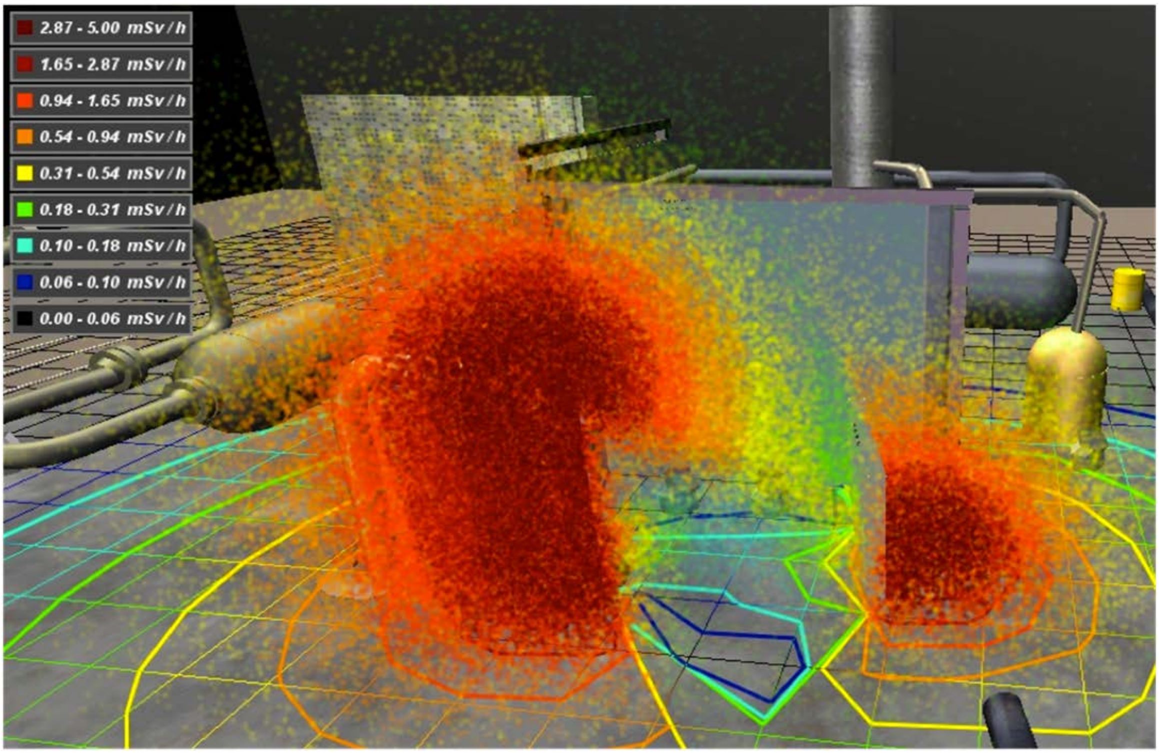

FIG. 4. Visualization of total gamma radiation from three different sources in a simple 3-D environment with two shields [14].

Interactive visualisation tools can be used to relate a plan for a high risk work task to the environment in which it will take place, even when this environment is not physically available during planning. Risks that may be visualised this way include, among others, the risk of radiation exposure, the risk of mechanical accidents (cranes, large equipment etc), and risks arising from multiple teams working in the same area.

Studies performed in the Halden Reactor project [3] indicate that one may be able to reduce the risk of procedure misinterpretations if the planners' intentions and understanding of the procedure is illustrated in an unambiguous way in a 3D plan.

The impact of good visualisations will however only be significant if the data visualised are sufficient and of high quality. Impressive visualisation of poor data may lead to false confidence, so may visualisations that offer too much room for interpretation.

Figure 5, also from [14], shows how knowledge about the main radioisotopes in the sources present in an environment can be visualised so that a team can make better decisions on shielding. This is discussed further in [15]. The isotopes in Figure 5 will together make up the entire dose rate picture as illustrated in Figure 4.

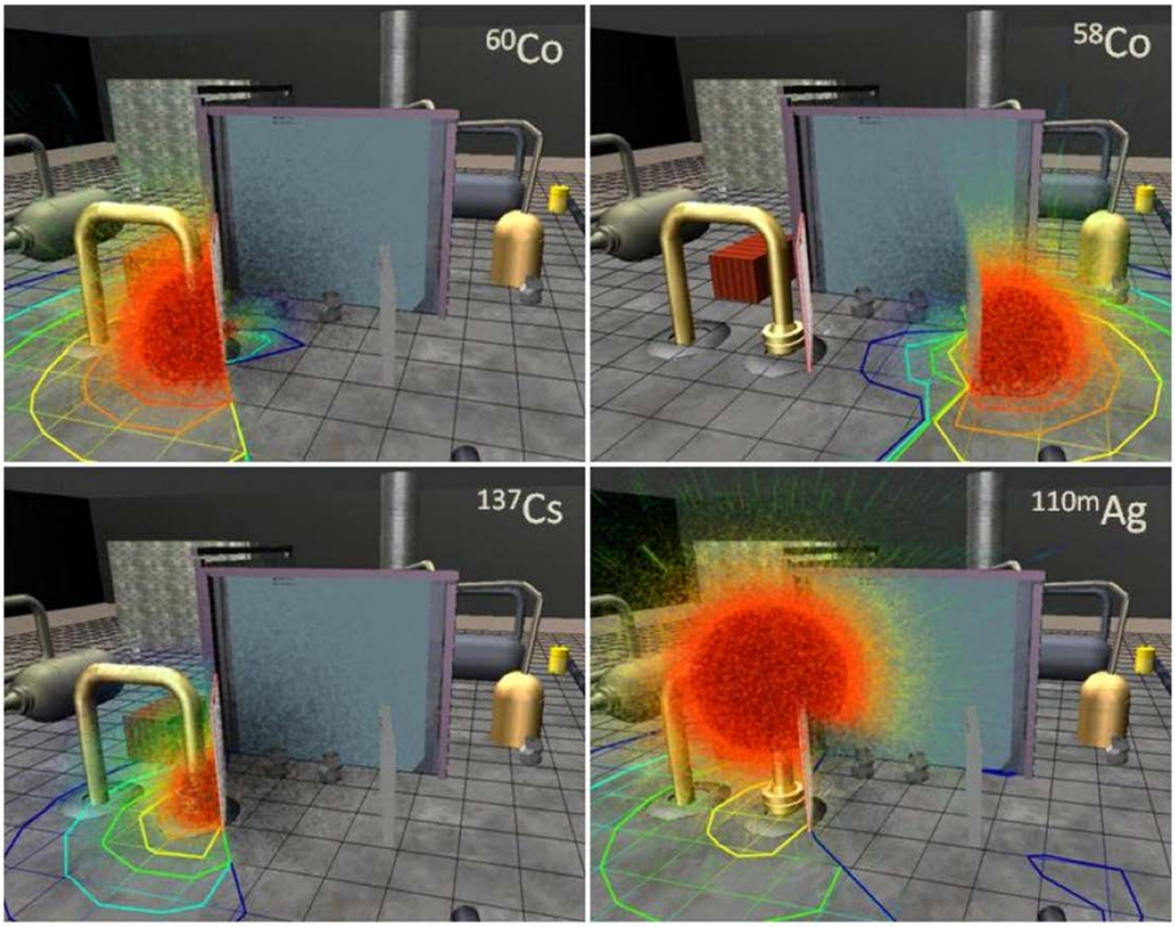

FIG. 5. Radioisotopic maps for the four different radioisotopes ^{60}Co, ^{58}Co, ^{137}Cs and ^{110m}Ag where only ^{60}Co and ^{137}Cs are located in the same source [14].

Visualisation tools can also be used for outreach, public acceptance and teaching. Simulator training is well known from the aviation and defence industries, and is now also increasingly used for training (or planning) procedures and building radiation awareness for work in high radiation areas.

Several large decommissioning projects have used the establishment of training or visualisation facilities actively to mark the change of targets and tasks coming with the decommissioning project as a new and exciting challenge. An example of this approach is illustrated in Fig. 6.

Visitors centres are used to help communicate to the public that the project in well in hand, often also addressing “touchy” issues such as waste management, radiation protection and environmental impacts.

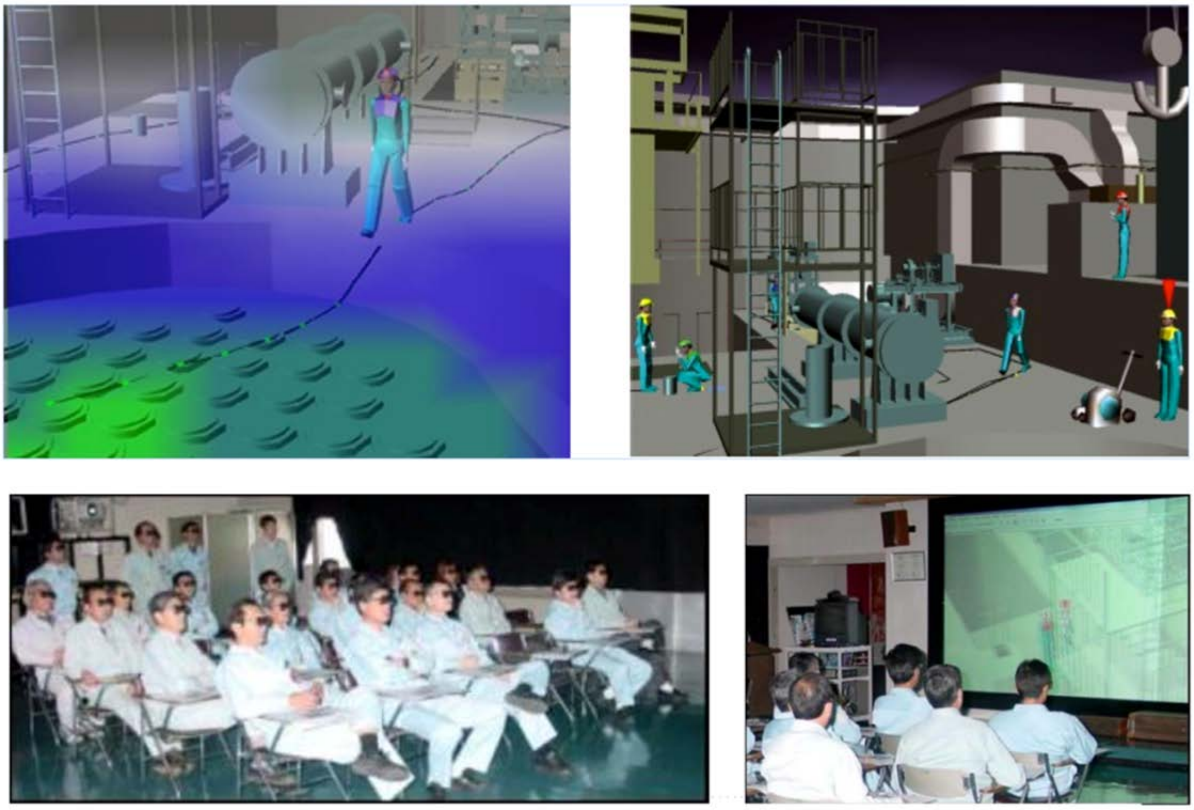

FIG. 6. Example of using advanced visualization technology for stakeholder involvement: The Fugen decommissioning project, VR dose Virtual Reality tools [16].

6. Collaboration with other CRP members

The topical sessions of the CRP, along with the CRP itself have been very useful for working on these issues. The diversity and complementarities of the CRP team has helped view issues from several different angles.

7. Publications resulting from the CRP

The Halden Work Report HWR-1000, "Stakeholder communication and motivational aspects in decommissioning processes" benefited greatly from working with this CRP.

8. Conclusions

We have discussed some of the challenges involved in decommissioning, with particular focus on those arising when moving from an operational situation into a decommissioning project with much of the original staff onboard.

Furthermore we have outlined some emerging technologies and working concepts that may be of help in addressing some of these human and organizational challenges, along with lessons learned also in other industries.

ACKNOWLEDGEMENTS

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MAIN PRINCIPLES OF THE ORGANIZATION OF DECOMMISSIONING ACTIVITIES FOR LEGACY SITES

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Abstract

As a result of more than 60 years development of nuclear industry in the former Soviet Union and in the Russian Federation there has accumulated a number of unresolved problems associated with contamination of facilities and environment during the early stages of research and industrial activities. Prior to the year 2000 most of the problems were solved slowly; the main decisions were postponed for the future. During that time were done the local works for the rehabilitation of contaminated sites. The Federal Target Programme "Nuclear and Radiation Safety for 2008 and for the period to 2015" was adopted in 2008. Analysis of accumulated experience as result of previous work on decontamination to develop new project management system for the rehabilitation of the nuclear legacy is needed. This CRP contribution is aimed at solving the tasks of the rehabilitation of the nuclear legacy.

1. Introduction

Since the beginning of development of Soviet Nuclear Programme in the end of 1940s, it had a higher priority and as result was under schedule driven deadlines to deliver products. Man hours, environment contamination etc. were secondary to delivering results. Knowledge about safety of nuclear materials was at "zero" point. Facilities commissioned and operated in record breaking speed with one purpose to produce final product. A lot of temporary, pilot installations was built and shut down after finalization of key tasks. Old facilities were often unfunded and abandoned, as additional facilities were built for newer missions and changes in technology. The former USSR met the end of Cold War with a lot of old research, pilot and industrial facilities, which was shutdown and in the transmitted period of Russian economy these sites lost governmental funding, changed owners, partially lost regulation control and degraded to "legacy sites".

Term "legacy sites" are radioactively contaminated facilities or territories which operated from the end of 40-s till middle of 90-s and are not operating now. These sites didn't come through normal procedure of shutdown and as rule has an insufficient control or even a loss of control.

Why radioactive anomalies happened in the Russian Federation:

- There was not enough knowledge, law and strong sanitary and safety norms in 1940–1960s;
- Using industrial wastes, ashes with high content of natural radionuclides in building industry;
- Albescence of special waste management service and practice up to 1961;
- Legacy sites just stopped and closed, i.e. switch off. It means that there are no archives, or any information about construction, processing equipment, contamination and accidents;
- Insufficient control resulted in insufficient conditions from the point of view of safety standards and requirements;
- A lot of data and records were lost.

As result of insufficient control buildings, constructions, equipment and infrastructure are in insufficient conditions from the point of view of safety standards and requirements. Main differences in present state of Legacy Sites (LS) and Normally Operated Facilities (NOF) are in the Table 1.

TABLE 1. THE MAIN DIFFERENCES BETWEEN NORMALLY OPERATED FACILITIES (NOF) AND LEGACY SITES (LS)

##	NOF	LS
1	Facility is under regulation control during all operational time	Lost control as result of changes of owners or insufficient closeout
2	Records keeping	No records
3	Need development of Decontamination plan at 1–5 years before shutdown [10]	Closeout without development of decontamination plan
4	Control of constructive materials, process and main equipment	No control, partially demolished constructions and shields
5	Decommissioning plan should be developed by the owner of the Facility	No regular owners

Initial condition of the decommissioning system was as follows:

(1) Incompleteness of regulations base of the decommissioning;

(2) Absence of a developed management system;

(3) Absence of stimulation mechanisms in completing of the decommissioning works for local enterprises;

(4) Absence of effective financial mechanisms for conducting works and the economic conditions stimulating of the decommissioning activity;

(5) Absence of the register of the objects which are subject of the decommissioning;

(6) Absence of the unified approaches to the decision of the decommissioning problems for nuclear sites;

(7) Absence of modern information support of the decommissioning works;

(8) Absence of the mechanisms excluding duplication of works on working out and a substantiation of technologies and the decommissioning projects.

To solve the problems of nuclear legacy there has been developed and approved the Federal Target Programme "Nuclear and Radiation Safety for 2008 and for the period to 2015". It aims to address the most critical issues of nuclear heritage sites, which were necessary to create nuclear weapons, nuclear industry and energy, and is now largely in demand [1].

2. Categorization of legacy sites in the Russian Federation

A lot of sites and facilities have been contaminated as a result of the work to develop nuclear weapons, conducting various studies, as well as the use of radioactive isotopes in medicine and industry. These problems have not been solved for decades for the following facilities in the Russian Federation [2]:

(1) Combines for the production of weapons grade plutonium
Federal State Unitary Enterprise "PO" Mayak
JSC "Siberian Chemical Combine"
Federal State Unitary Enterprise "Mining and Chemical Plant"

(2) Mining of uranium and radium
The State hydro plant "Almaz"
JSC "Priargunskoe Mining and Chemical Production Association"
Novotroitsk Enricment Facility

(3) Processing of uranium
JSC "Kirovo-Chepetsk Chemical Plant"

(4) Nuclear weapons testing and use of nuclear explosions for peaceful purposes
Nuclear test site "Novaya Zemlya"

A total of 124 peaceful nuclear explosions in the USSR was held for the national economy. Three of them ("Globe-1", "Kraton-3" and "Crystal") followed by accidents in which there was a leak of decay products.

(5) The consequences of exploitation and utilization of nuclear ships
SevRAO: Andreeva Bay (22000 spent fuel assemblies, 17650 m^3 of solid radioactive waste, 3480 m^3 of liquid radioactive waste), Gremikha (778 spent fuel assemblies, 1500 m^3 of solid radioactive waste and 200 m^3 of liquid radioactive wastes).

DalRAO: Sysoeva Bay (5000 spent fuel assemblies, 19347 m^3 of solid radioactive waste, 1407 m^3 of liquid radioactive waste).

In total the three accidental submarines under preparation for long term storage [3].

(6) Scientific and technological institutions
State Scientific Center of Russian Federation "Physico Energy Engineering Instituite named after A.I. Leypunsky" (PhEI);

State Scientific Center of Russian Federation "Scientific Research Institute of Atomic Reactors" (NIIAR);

Open Joint Stock Company "Leading Research Institute of Chemical Technology" (VNIIChT);

Open Joint Stock Company "VNIINM named after A.A.Bochvar".

(7) Nuclear legacy in the institutes of the Russian Academy of Sciences
At the time many institutions have stopped experiments with radioactive materials and problem of decommissioning, disposal of contaminated equipment and istallations has become particularly acute. This is illustrated by the following figures:

- Academy of Sciences has 470 institutions;

- Have previously worked with the sources of ionizing radiation — 150 institutions;

- Currently employed or have nuclear materials, radioactive materials, radiation installations waste, etc. (according with records of the System of State Accounting and Control) — 78 institutions;

- Require immediate action on the decommissioning and disposal of radiation sources — more than 30 institutions;

- The main problems associated with contaminated buildings and territories:

- Stopped, but not decommissioned nuclear facilities;

- Large amounts of waste in poor conditions of storage;

- The total activity of the sources of hundreds of thousands of curie. In some institutions, equipment storage is in an inoperable condition, the premises themselves require decontamination.

(8) The consequences of accidents in the nuclear weapons complex and nuclear power

- Tank with liquid radioactive wastes PA "Mayak" containing 20 million curie of a radioactivity had blown up on 29 September 1957. The radioactive cloud formed the East Ural radioactive trace (EURT) with the area over 20 thousand of sq. km. In liquidation of consequences of accident participated from 25 thousand to 30 thousand soldiers during the period from 1957 to 1959. The general extent of EURT is about 300 km at length and width from 5 to 10 kilometers.

- Chernobyl NPP accident, 26 April 1986 [4].

TABLE 2. DISTRIBUTION OF CONTAMINATED TERRITORIES IN THE RUSSIAN FEDERATION, ^{137}CS, (10^3 HA)

Region	Area	<1 Ci/km^2	1–5 Ci/km^2	5–15 Ci/km^2	15–40 Ci/km^2	>40 Ci/km^2
Bryansk	175.1	4.1	103.1	39.7	26	2.2
Kaluga	70.3	7.5	48.1	14.7	-	-
Tula	21.2	10.1	10.2	0.9	-	-
Orel	12.8	1.1	11.6	0.1	-	-
Total	279.4	22.8	173	55.4	26	2.2

Note: 1 Curie = 3.7×10^{10} Bq

(9) Accidental contamination of industrial facilities with spent sources

As an example, Podolsk Plant of Nonferrous metals and Togliatti Plant "Phosphor".

(10) NORM contamination: thermal power plants and oil processing factories

Many thousands tons of ashes contaminated with NORM buried in the area of big coal power plants. The problems of contaminated dust and migration of radionuclades with water streams are here. Also NORM contaminated areas happened as result of leakage of oil transporting systems and oil industrial facilities.

Types of nuclear and radiation facilities to be decommissioned are shown in Fig. 1.

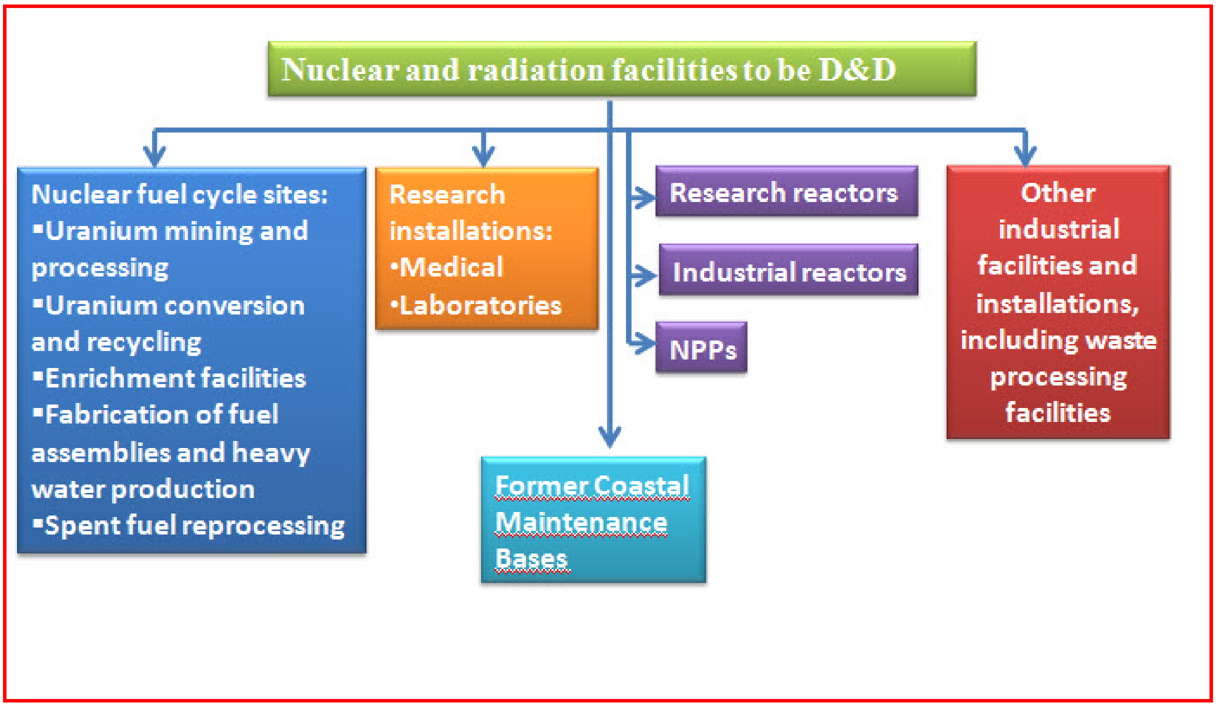

FIG. 1. Facilities to be decommissioned.

The majority of radioactive wastes and contaminations (up to 94%) in the Russian Federation is located in "Mayak" combine neighborhood, that is connected with its foregoing activities as main Soviet nuclear site in the 40-s. The production complex of "Mayak" includes:

- Production reactors: operated from 1948;
- Radiochemical plant: operated from 1948;
- Radioisotopes production;
- Chemical and metallurgical production works;
- Chemical production works.

2.1. Classification of radiation facilities depending on its potential hazards

The potential danger of radiation of the object is determined by the possible radiation impact on the population as radiation accident. Potentially more dangerous are the radiation facilities, as a result of which irradiation in the accident may not only impact employees of the object, but also the population. The least dangerous radiation facilities are those which exclude the possibility of exposure of persons, not related to personnel. By potential radiation hazard shall be four categories of objects.

Category I: include radiation facilities in an accident which their radioactive may impact on the population and may take steps to protect it.

Category II: radiation facilities where the impact of the accident is limited to the sanitary — protective zone.

Category III: are facilities, radiation exposure during an accident which are confined to the object.

Category IV: includes objects that radiation exposure from the accident is confined to rooms where work is with radiation sources.

Category radiation facilities should be set at the design stage in consultation with state oversight field of radiation safety. For existing facilities shall be provided Authority in consultation with the state sanitary — epidemiological supervision.

2.2. Criteria for categorization of radiation facility

In establishing the categories of radiation facility to determine the extent of the potential disaster of radiation exposure to the various categories of exposed individuals, the following levels (hygienic criteria) of effective doses of potential exposure [5]:

- A group of staff — 20 mSv/year;
- For staff in group B — 5 mSv/year;
- To public — 1 mSv/year.

3. Key principles and factors in management of legacy sites in the Russian Federation

After 50+ years of operations with radioactive materials, a number of decontamination techniques, tools and machines for dismantling, techniques and equipment for site remediation developed. Also positive and negative results of national wide experience received. Many problems were associated with specific conditions of legacy sites: absence of initial information, problems with records keeping, insufficient conditions of constructions and equipment, unpredictable distribution of radioactive materials and unknown locations of dumping sites for radioactive wastes.

Government of the Russian Federation and Rosatom created complex legislative base for the decommissioning and environmental remediation for liquidation of problems accumulated on old nuclear sites. It based on:

- The Federal Law “about use of atomic energy” [6];
- The Federal Law No. 317 “about the State corporation on Atomic Energy Rosatom” [7];
- Federal Law “About radioactive waste management and about modification of separate acts of the Russian Federation in radioactive waste management” (11 July 2011, No. 190-FZ) [8];
- Updated sanitary rules (NRB-2009, SPORO-2002 and OSPORB-2010) [9–11];
- The Federal target programme “Nuclear and Radiation Safety for 2008 and for the period to 2015” [12];
- Rosatom corporate system on decommissioning of nuclear and radiation hazardous facilities;
- Local norms and requirements.

Financial aspects of performance of the decommissioning are defined by the Governmental orders of the Russian Federation from 30 January 2002, No. 68 and from 21 September 2005, No. 576 according to which the institutions which are working with dangerous radioactive materials, should do annual deductions in special funds. Deducted funds included in cost of production and are released from the taxation. For accumulation of funds according to Federal Act No. 317 (Article 20) State Corporation “Rosatom” creates the special reserve funds intended, including, and for financing of the decommissioning works.

Main principles and directions of the decommissioning works are fixed in the concept of State Corporation “Rosatom” from 30th June 2008, No. 232. According to the given order the Corporate System of the Decommissioning was developed.

3.1. Target Federal Programme (TFP) “Nuclear and Radiation Safety for 2008 and for the Period to 2015”

The specific conditions in development of nuclear industry in the former Soviet Union and the Russian Federation are responsibility of government to all activity in this area. In accordance with this position special Target Federal Programme developed for solution of old problems with radioactive wastes, spent nuclear fuel, contaminated areas, research institutions and industrial facilities accumulated within more than 50 years. The following objectives are listed in FTP as the main tasks set by the Programme:

(1) Decommissioning of shutdown facilities;

(2) Environmental remediation of sites;

(3) Decommissioning of radiation installations that have outlived their design service periods and of exhausted sources of ionizing radiation;

(4) Creating basic sites for the management of spent nuclear fuel and radioactive waste;

(5) Enhancing measures of protection against radiation exposure for personnel, general population, and the environment;

(6) Providing support for the activities undertaken in the field of nuclear and radiation safety.

Main goals of the Programme are:

(1) Development of basic infrastructure for waste management;

(2) Elimination of the problems connected with nuclear legacy;

(3) Transfer to safe conditions (transportation and processing of spent fuel and radioactive wastes);

(4) Decommissioning of old nuclear facilities;

(5) Reconstruction of waste treatment and storage facilities, decommissioning of old storages of liquid and solid wastes;

(6) Decommissioning and remediation of former coastal maintenance bases;

(7) Removal and safe transportation and processing of spent fuel from research reactors;

(8) Decontamination and remediation of contaminated territories.

The key drivers for the decommissioning of “legacy sites” are reduced environmental hazards or liability, and the reduction in facility and infrastructure footprint to reduce the associated surveillance and maintenance costs. The longer these facilities sit, the further they degrade and the more dangerous and costly they are to maintain and/or disposition. Currently, there are more than a few facilities in such disrepair as to prohibit access to workers and as such requiring remote/robotics decommissioning approaches to be used.

The goal for decommissioning is establishing the radiological facility end of life disposition path and removing facilities from the regulatory inventory. The general goal is the same for decommissioning project: reduce and ultimately eliminate risks, maintenance costs and foot print.

3.2. Impact of regulatory requirements

Regulatory requirements applied to decommissioning activities from the planning of decommissioning and environmental remediation activities to the end state. The final paper in act is about full scale completion of the Project and achieving decontamination criteria.

In general (and usually) for decontamination criteria can take the basic limits of doses in accordance with Radiation safety standards 2.6.1.2523-09 "Norms of radiation safety (NRB-99/2009)" [9]. For different sites, depending on the end state of the site there are two main dose limits:

- 20 mSv/year for the personnel (group A-nuclear professionals);
- 1 mSv/year for population (citizens, industrial workers etc.).

As decontamination criteria applied to residual contamination in accordance with Sanitary Rules of radioactive waste management SP 2.6.6.1168-02 (SPORO-2002) [11]. In this case at the unknown radionuclide composition residual contamination with specific activity should be less than:

- 100 kBq/kg for beta;
- 10 kBq/kg for alpha;
- 1 kBq/kg for TRU.

The Rosatom concept "decommissioning of nuclear installations, sources and storage facilities" (2008) [13]

Rosatom considers as one of the priority purposes performance of works on maintenance of a safe decommissioning, including old facilities which are not meeting modern safety requirements. The concept is prepared on the basis of positions of the legislation of the Russian Federation and expresses a policy of Rosatom on decommissioning taking into account the functions of controls assigned to it by use of basic variants for the decommissioning:

- Liquidation of nuclear site — a variant of the decommissioning, providing decontamination of equipment, buildings and constructions, liquidation of radioactive contamination to comprehensible level according to norms, dismantle of the equipment, systems, designs and the building constructions containing radioactive substances and materials, removal of all radioactive waste from site, and also rehabilitation of site from the point of view of it further use.
- Creation of on site final storage is conservation of site or facility, providing localization is radioactive contamination, equipment, building designs or RW with creation of necessary safety barriers against unapproved access and to protection against distribution radioactive substances in environment.
- Conversion — a complex of the organizational and technical actions directed to change of a designation of the basic constructions, buildings, engineering systems and equipment for other kinds of practical activities, including atomic energy use.
- For complex sites as a final state combinations and updating of base variants can be used. The final choice of a variant is defined and proved by set of engineering, economic, ecological and other factors.

The Rosatom decommissioning system includes:

(a) Management system;

(b) Financing mechanisms;

(c) Regulation base;

(d) Information system;

(e) Centres of excellence;

(f) Operators;

(g) Engineering institutions for decommissioning (subcontractors).

3.3. Use of typical technologies

- Typical techniques of safety assessment (3D, dynamic calculation models, etc.);
- Systems for design, planning and support of the decommissioning (training tools, modeling of sequence of works, etc.);
- Typical technologies and tools for dismantling, decontamination and radioactive waste;
- The special equipment and tools for decommissioning (a robotics, manipulators, gages, etc.).

3.4. Development of unique technologies and equipment

- Technologies and equipment (including remote) for dismantling and cutting of irradiated and contaminated equipment, buildings, constructions and others elements;
- The equipment and technologies allowing as much materials as possible to free release to reduction of the decommissioning cost;
- Technologies of monitoring and characterization of RW;
- Technologies for protection of costructive materials during decommissioning operations;
- Decontamination and cutting techniques for contaminated materials.

3.5. The conventional approaches to the decommissioning

Orientation to universal approaches to the organization of decommissioning works:

- Application of international experience;
- Application of the approved and proved technologies of dismantle and decontamination, packaging and transportation of RW;
- Development of alternative decisions on optimum methods of the decommissioning wastes disposal/recycling;
- Costing of the decommissioning operations for typical projects.

4. Decision making process depending on various influencing factors

Choosing of the decommissioning strategy is multivariate procedure. It is starting from an understanding of acceptable end state of site. Preferable variants in accordance with basic requirements are:

- Liquidation: a variant of decommissioning, providing decontamination of equipment, buildings and constructions, liquidation of radioactive contamination up to a levels comprehensible according to norms, dismantling of the equipment, systems and building constructions containing radioactive substances and materials, removing of all radioactive wastes and remediation of site for new use;

- Creation of objects for final isolation on site: a variant of a decommissioning, providing localization is radioactive contamination of the equipment, building designs or radwaste on site with creation of all necessary barriers which will exclude non-authorized access and spray of radioactive substances in an environment;

- Conversion: a complex of the organizational and technical actions directed to change of a special purpose designation of the basic constructions, buildings, engineering systems and equipment for new activities, including of use for nuclear energy.

The next key procedures for full scale remediation of site should compare and combine for multi variant procedure during decision making process:

- Stabilization procedure may be needed for facilities with surface contamination of soil / equipment / building constrictions, for sites with degraded infrastructure;

- Preparation for decommissioning procedures which serve to safe operation of personnel during all Decommissioning Project execution and included all preliminary stages;

- Decontamination with removal of contaminants to reduce the safety and health risks of staff or public. The extent and costs of removing contamination influences the disposition alternatives and the subsequent decommissioning work methods. Decontamination can be only process or can combine with other procedures;

- Decommissioning is the procedure of removing items necessary to maintain original mission purpose or to take out of service. Resulting facility is ready for final disposition end state in accordance with accepted criteria;

- Demolition/fragmentation is procedure of complete or partial removal of the facility processing and supplied equipment and its infrastructure. Debris is either recycled or disposed as waste depending on the type of contamination or material cost. This procedure may leave bare ground, the concrete foundation, or the core structure based on end state agreements or transition to environmental remediation projects;

- Disposition is the end state established for the facility such as Federal re-use, release to public use, in situ decommissioning (entombment), or demolition.

To solve the problem of choosing technologies and tools for decontamination and dismantling contaminated equipment and structures, as well as to prepare waste for transportation it should have as much information about methods, tools and technologies available. Selected tools and technologies to ensure the safe conduct of work in preventing the formation and distribution of radioactive aerosols that can contaminate the working space and environment during the work. Clean materials must meet the criteria for free release and waste should be prepared for transportation in accordance with the requirements for safe transportation and in accordance with the acceptance criteria treatment facilities and storage or disposal criteria. The decision making process for the decommmissioning of non-nuclear legacy sites is illustrated in Fig. 2.

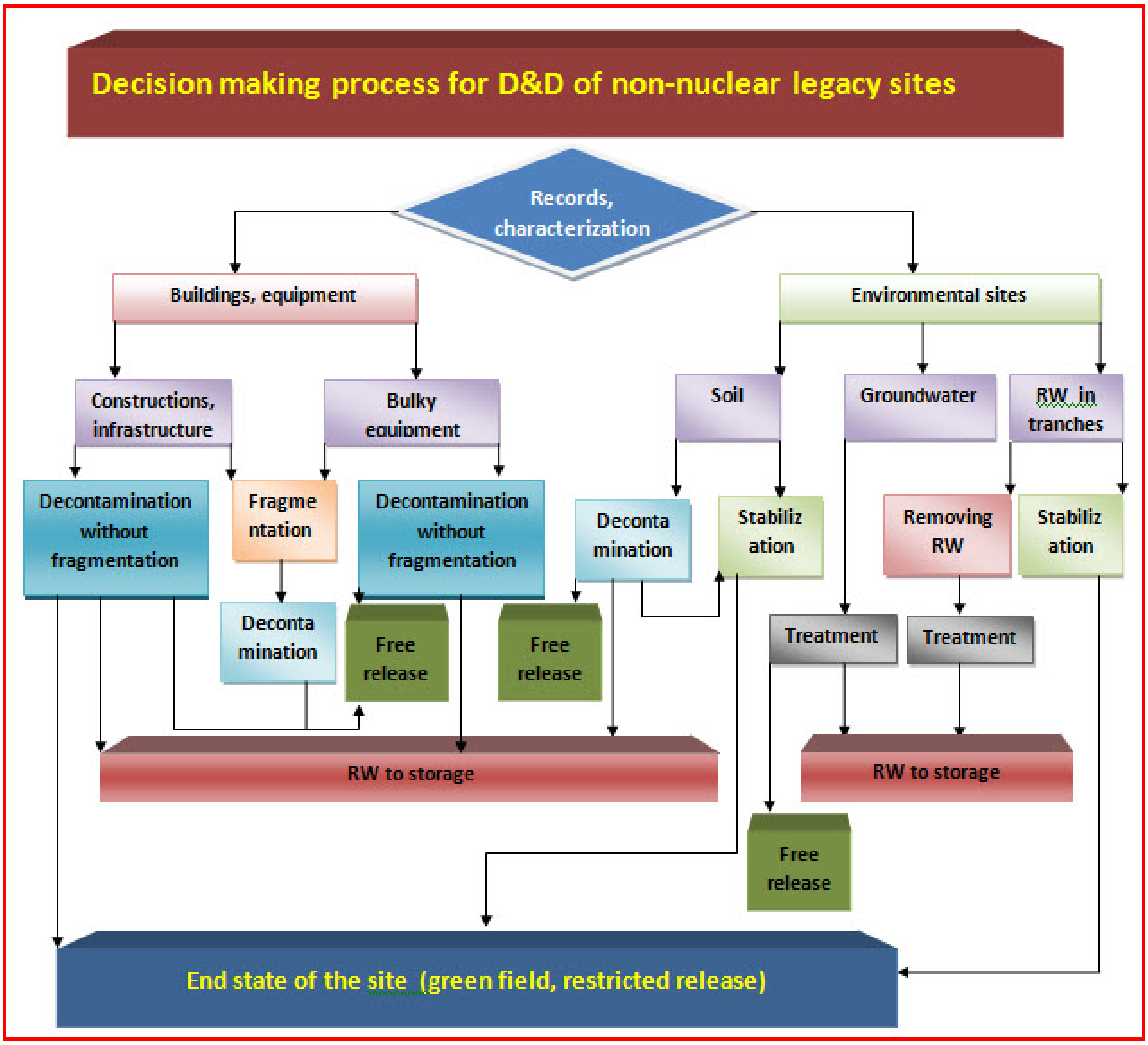

FIG. 2. Decision making process for the decommissioning of non-nuclear legacy sites based on technological flow sheet.

Main factors which influent to decision making process:

(1) A condition of the State Contract — the key point is the end state of the site (Fig. 3);

(2) Radiation and engineering characterization, data treatment, archive data treatment.

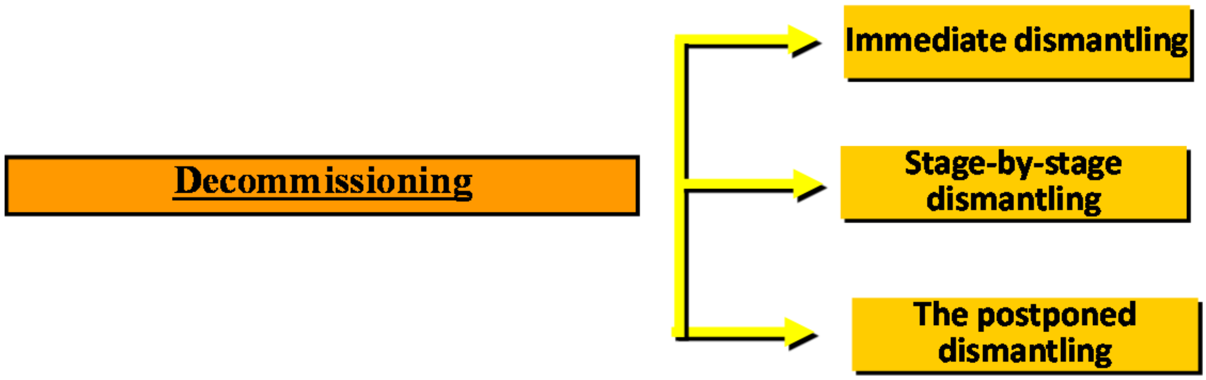

FIG. 3. Variants of decommissioning.

The special attention should be paid for characterization of site in the case of legacy site. It is connected with absence of records and data for this site. Treatment of information about contamination levels and radionuclide content, distribution of radioactive contamination, stability/non-stability of constructive materials should result a basic elements for development of technological part of decontamination plan.

- Radionuclide content influent to decontamination criteria, technologies for decontamination and waste treatment;
- Dose rate indicate what kind of safety barriers should be for protection of personnel, also estimation of needs in remote control tools;
- Amount and content of RW influent to choose of waste management strategy;
- Stability/or non-stability of constructive materials of building (by result of engineering control) influent on safety of personnel and needs to use remotely controlled equipment.

For correct decision ideal result of initial data treatment should contain:

- Detail map of the building or room;
- List of equipment to be decontaminated (types, amount, levels, size);
- Maps of contamination and results of spectrometry of contaminated materials and samples received in result of routine monitoring during operation period;
- List of contaminated rooms, bulky equipment etc. (levels of contamination, size, etc.);
- Knowledge of future plans (restricted or unrestricted use, "green field"). Decontamination criteria and limits for future using of this subject depend on these plans.

4.1. Tender for subcontractors

Preferences which decontamination teams are to satisfy should be as follows:

- Regulations requirement (licenses);
- Has enough good references;
- Will able to develop and agreed with regulators detailed work plan;

- Has personnel category A;
- Will able to use a specific tools and equipment;
- Ask a reasonable costs.

4.2. Development of decontamination plan

Decontamination Plan is handbook for decommissioning project so it should develop carefully and cover all levels of activity up to reach of end state. Main paragraphs should describe:

- Preparation of site to decontamination and dismantling. Creation of stationary or mobile sanitary post for personnel which will work in contaminated zone. Design of safety barriers for subdivision of building to “clean” and “hot” zones, repair/renovation of ventilation system and water/electricity supply in accordance with safety requirements. Design of on site temporary RW storage.

- Decontamination and dismantling. Developed by operator or design company and agreed with regulator. It should contain decontamination criteria depending on end state of site. Different decontamination techniques analysis and choosen in accordance with initial and end state of site, amount and parameters of RW, contamination levels of equipment and constructive material. More simple contamination can remove with simple handy tools for mechanical treatment of surface. These tools should be supplied with industrial vacuum cleaner or other special equipment for evacuation of radioactive dust. Polymeric strippable coatings or gels widely used for removal of surface contaminations from metals or painted materials. For heavy contaminations can use aggressive chemicals or electro chemical techniques. Depending of state and parameters (material, contamination, type of equipment etc.) of processing equipment different dismantling tools or special equipment should be indicated.

- Radioactive waste collection, preparation to transportation. The simplest is collection of RW and packaging in containers. More difficult is sorting of RW on site in the area of high dose rates. Special procedures should be developed for liquid wastes. Remotely operated equipment can use in the case of high irradiation levels. Design and capacity should be agreed with transporting company and waste treatment facility.

- RW Transportation. For small projects, located not far from RW storage facility can be used for small trucks (for 1–2 m^3 containers). In the case of hundreds cubic meters of RW or long distance to RW storage facility it is needed to use trucks for 10 or more containers, or to use 20–40 ft containers certified for RW transportation.

- Site remediation. Site remediation may be required to satisfy requirements of end state of the site and regulation standards. For this kind of activity it may use removal and decontamination of soil, covering of surface with geomembranes or other protective covers, clean soil, vegetation.

5. Elaboration of lessons learned from the decommissioning and remediation projects

5.1. Beginning: modernization of technologies and radioactive waste management

The first stage:

- Decommissioning was necessary for development of nuclear industry with possibility of use of available old buildings and constructions for other application, i.e. decommissioning was considered as subsection of modernization. An exception — rehabilitation of the Lake Karachay which accumulated great activity of RW with risk of a wind transfer of contamination. In this period R&D works on for decontamination techniques, mainly liquid were conducted.

- Absence of legislative and regulations was typical. The main target was liquidation of the most dangerous sources.

To separate plutonium, generated in nuclear reactors, from uranium and fission products, a radiochemical plant was built at the “Mayak” in the end of 1948. The solution, containing uranium, plutonium and fission products, was processed by using the acetate–fluoride technology. The gained experience allowed, commencing in 1952, design of three new radiochemical plants, where irradiated uranium slugs were processed after the improved acetate scheme. Due to lack of proper technological systems for the radiochemical liquid wastes and an easy going approach to the problem of disposal of such wastes dumped into the natural aquatic systems 1949–1956. Medium and high level liquid radwaste discharged directly to the lake Karachay from 1951. Stage by stage liquidation of the water reservoir was started in 1988.

There are many nuclear facilities which were reconstructed during their operation and modernization of technologies. It was not decommissioning, but first experience in decontamination and dismantling of contaminated equipment was learned. All these operations used different aggressive acid and alkali chemical decontamination solution with potassium permanganate and complexions. Very simple handy tools and mechanisms used for cutting of equipment. For many pilot installations and small industrial facilities “entomb” options were chosen. There are no special national wide activity in decommissioning and environment restoration in the former Soviet Union. Relatively simple sanitary requirements applied.

First industrial scale works on decontamination/remediation of territories and buildings were executed after accidents at PA “Mayak” in 1957 and in Chernobyl in 1986. Specific experience showed that industrial equipment and military machines successfully modified for work in conditions of heavy irradiation (additional protection from lead). Typical military decontamination compositions and techniques and techniques developed for nuclear industry applied for decontamination of trucks, constructions and equipment.

5.1.1. East Ural radioactive trace (EURT)

Tank with liquid radioactive wastes PA “Mayak” containing 20 million Curie of a radioactivity has blown up on 29 September 1957. The radioactive cloud has formed the East Ural radioactive trace (EURT) with area over 20 thousand sq. km. In liquidation of consequences of accident participated from 25 thousand to 30 thousand soldiers during the period with 1957 for 1959. The general extent of EURT is about 300 km at length and width from 5 to 10 kilometers. In territory with contamination over 2 Curies on square kilometer of ^{90}Sr across more than 20 villages. They have been evacuated, the property have been destroyed and buried. Agriculture fields are plowed up and withdrawn from an agricultural use. Government of the USSR has formed the forbidden closed zone in 1959. It included the territory limited to an isoline of 2–4 Curies of ^{90}Sr on square kilometer, the total area is about 700 sq. km. The East Ural reservation was created on this territory in 1968 [14–15].

5.1.2. Chernobyl, 1986

Detail descriptions are in the number of specialized publications. In summary [16]:

- Billions of monitoring and sampling data were collected for all former Soviet Union territory, especially for Chernobyl exclusion zone;

- For decontamination of trucks, equipment and buildings all available techniques developed for military purposes and for nuclear facilities were used and tested (water, surfactants, liquids with aggressive chemicals, polymeric films etc.);

- Soil decontamination was removing mainly by contaminated surface with layer from 5 to 20 cm and storing it on special near surface facilities;

- Demolishing of contaminated wooden houses and storing it on special near surface facilities;
- Sanitary rules were based for development of protection and time limits for staff.

5.2. Development — pilot testing of decontamination and remediation techniques for old facilities

From 1980s to 1990s the main attention was given to development of new effective techniques with minimization of secondary RW production.

- First experience in application of unique equipment and skills in operations with robotics received;
- Works were carried out according to the Federal Law “On the Use of Atomic Energy”, sanitary rules (NRB-99/2009, OSPORB-99/2010, SPORO-2002, etc.).

Experience accumulated on main Soviet nuclear sites as result of decontamination and modernization works starting from first days of nuclear era till 90’s was used as base for development of more effective and safe operations for two institutions located in Moscow. These projects are demonstration of application of new scientific knowledge and approaches to the decommissioning and environmental remediation.

The beginning of 2000’s was characterized by:

- Rapid deployment of work on utilization of nuclear submarines and rehabilitation of former Navy coastal bases;
- A practical starting work on the nuclear legacy of RRC “Kurchatov Institute” and other research institutions;
- Elaboration and launching of the Comprehensive Plan to environmental restoration and protection on PA “Mayak”.

These studies have allowed accumulation of considerable experience, which, along with foreign ones, clearly testified:

- Principal possibility of liquidation of nuclear legacy;
- The complexity of the scientific and engineering problems, including the choice and justification of the final state of nuclear facilities heritage;
- Expenses should be paid by State.

Decontamination activities on first plutonium installation in VNIINM, rehabilitation of the territory “Kurchatov Institute” and industrial facility of “Kolchugino Plant of Non-ferrous Metals” are described in Annex 2.

5.3. Present: Decommissioning and environmental remediation within the Federal Target Programme “Nuclear and radiation safety for 2008 and for the period to 2015”

The main attention is given to works in the framework of FTP which means the fixed financing of decommissioning and environmental remediation remediation.

- Sufficient experience of work on decontamination, dismantling and environmental remediation were accumulated up to now. In this connection foreground problems are choice of decontamination criteria, optimal equipment and techniques (decision making process), collection of the exact data about contamination, technical condition of contaminated subjects, development of good decommissioning or environmental remediation project, a choice of professional and effective subcontractor.

- Special attention is given to problems of management and modelling. For operations are used special equipment and decontamination/cutting means, modernization of the equipment for special tasks and, to a lesser degree — development of new means and techniques for decontamination and environmental remediation.

- In connection with fast increase in quantity of the decommissioning and environmental remediation projects there was a necessity of a choice of professional subcontractors. In spite of the fact that works are carried out after carrying out of competition (tender), it is necessary to carry out training as the personnel working directly on object, and engineers and designers developing technologies and projects of the decommissioning and environmental remediation.

- Works are carried out in accordance with the Federal Law "On the Use of Atomic Energy" and the Federal Law "About radioactive waste management and about modification of separate acts of the Russian Federation in radioactive waste management" (11 July 2011, No. 190-FZ), updated sanitary rules (NRB-99/2009, SPORO-2002 and OSPORB-99/2010), FTP "Nuclear and Radiation Safety for 2008 and for the period to 2015".

The typical flow sheet for realization of the Project (detailed working plan developed in accordance with this flow sheet) (Fig. 4):

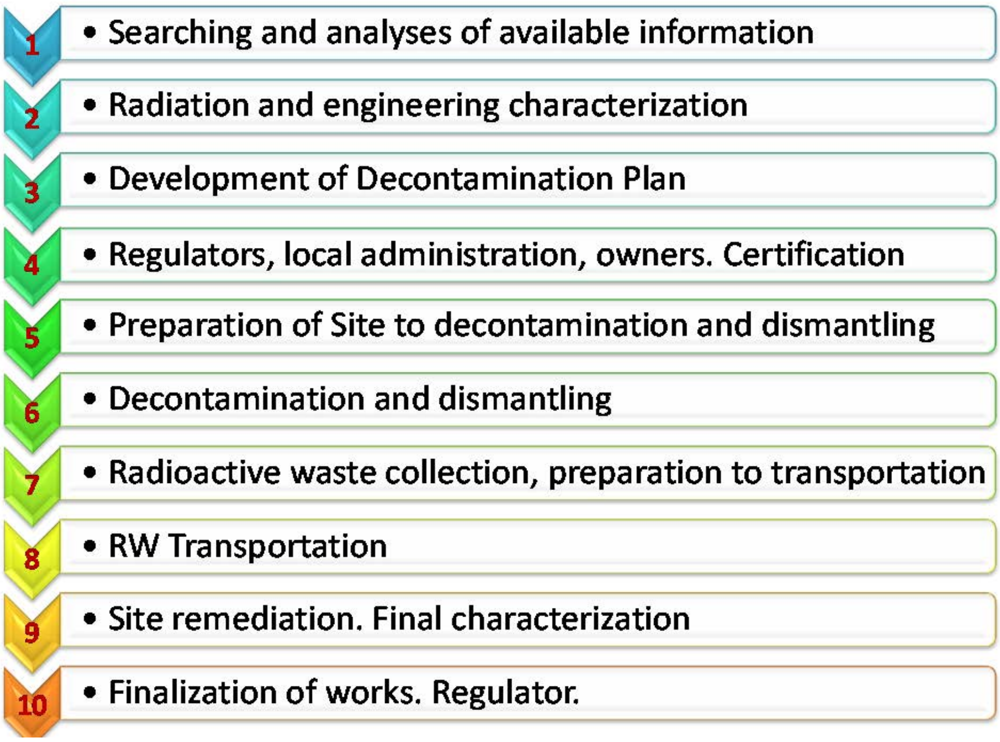

FIG. 4. The flow sheet of decommissioning and environmental remediation projects.

Two decommissioning projects of FSUE "RosRAO" are as examples. See Annex 3.

6. Establishment of training for managers of the decommissioning and remediation projects

The great volume of forthcoming operations in the decommissioning assumes presence of a considerable quantity of the qualified personnel, capable to perform all works according to modern requirements of radiation safety. Besides, the personnel performing such works should have skills of work with modern mechanisms, equipment and technologies of decontamination and dismantling.

Representatives of State Corporation "Rosatom", profile universities and experts mark an acute shortage of highly skilled personnel for the decommissioning operations in the Russian Federation and setup the basic problems:

(1) Now there is no technical university preparing experts in field of the decommissioning and environmental remediation of contaminated sites;

(2) Decommissioning and environmental remediation activities will demand involving of subcontractors — the specialized organizations having the highly skilled personnel;

(3) Working technical specialities (technicians), field engineers, designers, managers with knowledge of economic bases, IT experts should be the most demanded;

(4) It is necessary to conduct not only basic education at universities, but also improvement of professional skill or conversion training of employees of other nuclear fields.

In 2011, State Corporation Rosatom began preparation to create training centre for personnel of nuclear industry to work on RWM, decommissioning and environmental remediation. Because the IAEA has worldwide training experience on various aspects of Safety, RWM, decommissioning and environmental remediation, creation of the educational centre with participation of the IAEA is planned.

6.1. Draft proposal for a training centre on environmental remediation in the Russian Federation (drafted by H. Monken Fernandes, WTS, IAEA)

Education and training should involve elements related to project management — planning, costing, financing, contracting and procurement. It will deal with scientific disciplines as geosciences (geochemistry), civil engineering (hydrology, geotechnical engineering, electronic engineering), chemistry (radioanalytical chemistry), engineering, computational sciences (mathematical modeling), economics and communication.

There are many excellent projects within IAEA Member States and it may be good examples for training and education in the Russian Federation; so training/educational facilities will be needed in cooperation with IAEA.

6.2. The role of the IAEA

The Agency has undertaken a wide range of activities for education and training in radiation protection that can be summarized as follows:

- Post graduate educational courses in radiation protection and safety of radiation sources;
- Practice specific specialized training courses;
- Fellowships and scientific visits;
- Distance learning.

The Post Graduate Educational Course in Radiation Protection and Safety of Radiation Sources (PGEC) is a comprehensive training programme aimed at training young professionals at graduate level or the equivalent for initial training to acquire a sound basis in radiation protection and safety of radiation sources, some of them would be expected to become the trainers in due time. PGEC is designed to provide both theoretical and practical training in the multidisciplinary scientific and / or technical bases of international recommendations and standards on radiation protection and their implementation. The Agency has been assisting the organization of the regular PGECs in different Regional Centres and in different Agency's official languages. These include Argentina (Spanish), Syria (Arabic), Malaysia and Greece (English), Morocco (French) and Belarus (Russian).

During the ENVIRONET Workshop on Remediation of Nuclear Legacy Waste Facilities and Sites: Challenges, Lessons Learned and Path Forward — that took place in Moscow on the margins of the IV Conference and Exhibition “AtomEco 2010” — representatives of the Russian Federation demonstrated a clear demand that the IAEA could help organizing a training centre on environmental remediation in the country. This centre would attend the national demand for the qualification of professionals to work in the various remediation projects in the Russian Federation but could also serve the neighboring Russian speaking countries that need to deal with environmental remediation (e.g. Ukraine, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Belarus, Georgia, and Lithuania). The training activities would be supported/complemented by the different types of services and products to be made available by the ENVIRONET that will include long distance training material, educational videos, discussion forum and other training events to be organized by the network.

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- Post graduate educational courses in radiation protection and safety of radiation sources;
- Practice specific specialized training courses;
- Fellowships and scientific visits;
- Distance learning;
- The Post Graduate Educational Course in Radiation Protection and Safety of Radiation Sources (PGEC).

6.3. The road map

In the establishment of the Training Centre on Environmental Remediation (TCER) in the Russian Federation, the first step would involve the elaboration of a curriculum that would encompass the range of topics and disciplines that would be adequate (needed) as a background for a professional to work in Environmental Remediation. This curriculum would them serve as the basis for structuring a 6 week training course. That would be termed the basic course on Environmental Remediation. This course would cover the essential elements for a manager (decision maker) of environmental remediation projects. Some specific courses on elements of environmental remediation would then be structured as to include, site characterization, monitoring, groundwater modeling, dose assessment, engineering design of remediation solutions, etc.

Draft of training/educational programme “Decommissioning of contaminated sites” is in Annex 4.

7. Collaboration with other CRP members

(1) Meeting and discussions with CRP Members at the International Conferences: “Decommissioning Challenges”, Avignon, France (2008);

(2) Discussions within framework of IAEA IDN annual meetings 2009–2011;

(3) Preparation to cooperation with Nechaev (Russian Federation) in new edition of handbook on decontamination techniques for universities;

(4) Discussions with CRP Members during RCM in Dounreay, UK (2009), Espoo, Finland (2010) and Dalat, Vietnam (2011).

8. Publications resulting from CRP

(1) BARINOV, A.S., SAFRONOV, V.G., MIKHEYKIN, S.V., “MosSIA “Radon”: Experience in D&D of legacy sites”, International Conferences “Decommissioning Challenges” Avignon, France (2008).

(2) BARINOV, A.S, SAFRONOV, V.G., SALIKOV, V.A., MIKHEYKIN, S.V., Remediation Activity at SUE SIA “Radon”, WM 2009 Conference, paper No. 9156, Phoenix, AZ, USA (2009).

(3) MIKHEYKIN, S.V., “The Federal State Unitarian Enterprise “RosRAO” — RW management operator”, WM 2010 Conference, Session 48, Phoenix, AZ, USA (2010).

(4) MIKHEYKIN, S.V., “Environmental Remediation Challenges in the Russian Federation”, WM 2010 Conference, Session 70, Phoenix, AZ, USA (2010).

9. Conclusions

(1) The analysis of different types of contaminated sites "nuclear legacy", it is shown that the main problems in preparing of remediation works is the lack of baseline records and in some cases in poor condition of these sites;

(2) An overview of the main factors influencing the choice of strategy for the rehabilitation works prepared. Discussed the main steps in the preparation work on the rehabilitation plan requirements for the content of decontamination;

(3) The analysis of the most typical works on decommissioning of the Russian Federation made. It is shown that the experience of rehabilitation can be divided into 3 phases:

- Starting when decontamination was performed in the framework of the modernization of production;
- Development and testing of new technologies and tools;
- Present status of works within the Federal Target Programme “Nuclear and Radiation Safety for 2008 and for the period to 2015” in accordance with modern safety requirements.

(4) Due to the fact that intensive development of remediation works for "nuclear legacy" requires the use of specialized enterprises and high professional staff, basic elements of special training centre has developed.

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Annex 1

SANITARY STANDARDS

Radiation safety standards “Norms of Radiation Safety NRB-99/2009” [A–1]

Art. 2.5. For maintenance of radiation safety at normal operation it is necessary to be guided by the following main principles:

- Not excess of allowable limits of individual doses of an irradiation of citizens from all sources of radiation (**a principle of normalization**);
- Prohibition of all kinds of activity on use of sources of radiation at which the benefit does not exceed risk of the possible harm caused by an additional irradiation for the person and a society (**a principle of a substantiation**);
- Maintenance on possible a low and achievable level individual doses of an irradiation and number of irradiated persons at use of any source of radiation in view of economic and social factors of (**a principle of optimization**).

The basic limits of radiation doses are summarized in Table A–1.

TABLE A–1. THE BASIC LIMITS OF DOSES

	Dose Limits	
	The personnel (group A)	The population
Effective dose	20 mSv per year on the average for any consecutive 5 years, but no more than 50 mSv per year	1 mSv in a year on the average for any consecutive 5 years, but no more than 5 mSv per year
Equivalent dose per year in a crystalline lens of an eye	150 mSv	15 mSv
Skin	500 mSv	50 mSv
Hand and stop brush	500 mSv	50 mSv

Sanitary rules of radioactive waste management SP 2.6.6.1168-02 (SPORO-2002) [A–2]

Art. 3.6. At the unknown radionuclide composition solid radioactive wastes with specific activity is more:

- 100 kBq/kg for beta;
- 10 kBq/kg for alpha;
- 1 kBq/kg for TRU.

Art. 3.7. Gamma — contaminated materials with unknown radionuclide composition are radioactive wastes if its absorbed dose at their surface (0,1 m) exceeds 0,001 mGy/h above a background.

Classification of liquid and solid radioactive wastes by specific activity is shown in Table A–2.

TABLE A–2. CLASSIFICATION OF LIQUID AND SOLID RADIOACTIVE WASTES (*by specific activity*)

Category	Specific activity, kBq/kg		
	Beta	Alpha (except TRU)	TRU
LLW	Less than 10^3	Less than 10^2	Less than 10
ILW	10^3–10^7	10^2–10^6	10–10^5
HLW	More than 10^7	More than 10^6	More than 10^5

Rules of maintenance of radiating safety, Sanitary rules 2.6.1.799-99 (OSPORB-99/2010) [A–3]

Art. 3.6. Decommissioning planning

3.6.2. On radiating objects I of a category not later than 5 years up to the appointed shutdown the detailed decommissioning project for object or its separate part, coordinated with bodies of the state supervision of radiating safety should be developed. For objects of II category not later than 3 years, and for objects of III category-1 year.

3.6.3. In the decommissioning project safety at various stages should be stipulated.

3.6.4. The decommissioning project should contain:

- Preparation of the necessary equipment for carrying out of dismantling works;
- Methods and means of Decontamination and demolishing;
- The order of recycling of radioactive wastes.

3.6.5. During decommissioning activity it is necessary to estimate expected individual and collective doses of an irradiation of the personnel and the population.

Annex 2

DECOMMISSIONING EXPERIENCE

Decommissioning of the Pu extraction facility in VNIINM

Old Pu extraction facility was decontaminated and decommissioning in VNIINM in 1999–2000. This facility is a system of interconnected working areas housing process equipment located in 4 floor building and includes more than 20 laboratories rooms, two “hot cells”, few sealed contaminated rooms and two extraction shaft. Industrial separation technologies have been tested on the facility for 20 years since 1947. The first USSR Pu was obtained here. U-5 pilot facility was prototype for radiochemical facility at Mayak. In the mid-1960s the equipment was partially decommissioned and sealed. Some areas were put into prolonged storage. Some areas were adapted for laboratories. Practically all rooms were contaminated with Pu, Cs, Sr etc. In 1965 U-5 was put into a prolonged storage: it was preliminarily decontaminated and isolated by blocking doors and windows with bricks. But a few laboratories and hot cells have been used until recently to collect, store and condition VNIINM’s radioactive waste and to perform decommissioning research. Figure A–1 shows an external view of the facility building [A–4].

FIG. A–1. External view of the U-5 building.

Approaches:

Based on the radiation monitoring, safety precautions to be taken to protect the personnel, routes for movements and waste transportation, permissible occupancy time were identified. The preliminary stage outlined general decommissioning approaches based on our experience gained. A technology, tools and decontamination and localization polymeric coats has been developed for decontamination and decommissioning process equipment and further rehabilitation of working areas.

Based on laboratory research effective decontamination processes and agents have been developed and selected. The decision was made for a dry decontamination method with strippable PVA coatings.

First stage:

The floor and stair surfaces along the transportation paths were covered with protective polymeric films with sackcloth or gauze under it to add strength. Prior to removing contaminated equipment and decontaminating glove boxes the room surfaces of 300 m^3 were covered with polymeric coatings.

As a result of first stage of activity in decontamination, which also used for training of personnel, 16 rooms decontaminated were accepted and certified by the Sanitary Epidemic Service (SES) for use as laboratory rooms.

Second stage:

At the second decommissioning stage the door openings leading to the shafts were unblocked. In shift 1 the surface of the areaway canyon lined with stainless steel was most contaminated. ^{235}U and ^{239}Pu were the main contributors to radioactivity, but ^{237}Np, ^{226}Ra, ^{234}U, ^{241}Am, ^{238}Pu and ^{222}Rn were also detected. Three tanks with the total capacity of 700 l and 400 kg of other equipment were decontaminated, dismantled and enclosed in polyethylene. The total amount of collected metallic scrap (stainless steel) to be disposed of was 800 kg. The interior of the shift (above 50 m^2) was decontaminated by easily strippable polymeric coatings.

FIG. A–2. Application handy tools for cutting of pipes.

FIG. A–3. Demolishing of contaminated plaster.

FIG. A–4. Preparation of wastes to transportation.

FIG. A–5. Demolishing of metering tank shield.

The second stage includes decontamination and dismantling of hot cells, control and service rooms, metering tank compartment.

As a result of the decommissioning activities all rooms and “hot cells” were decontaminated, which generated waste (more than 10 000 kg of lead, more than 10 000 kg of another solid radioactive waste) sent for disposal. Examples of several decommissioning activities are shown in Figs A–2 to A–5.

Results:

- The first Soviet pilot ^{239}Pu extraction facility located within a thickly populated region was decommissioned.
- A multipurpose technology was developed for the decommissioning of U-5, methods and polymeric compositions were created for decontamination and immobilization of contaminated surfaces.
- Radiation monitoring showed no abnormal events or radioactive releases into the environment during the decommissioning work.

- The surface of the shafts (160 m^2) was decontaminated to produce 1 735 kg of solid waste. The shafts decontaminated were certified.

- The experimental equipment of two hot cells was decommissioned. The surface (63 m^2) of hot cells, control and service rooms were decontaminated and certified. The waste amount was 2 226 kg.

- The dissolution equipment was decommissioned and removed to produce above 500 kg of waste.

- The equipment of the metering tank compartment was decommissioned to produce 2 768 kg of solid waste. The compartment room (20 m^2) was rehabilitated.

- Sixteen laboratory rooms with a total area of 300 m^2 were rehabilitated and certified. The amount of waste removed exceeded 7 000 kg.

- All rooms rehabilitated were certified and accepted by regulators (Sanitary Inspection) further use.

Remediation of waste storage area at RCC "Kurchatov Institute" [A–1 to A–6]

The project provided a consistent solution of the following major tasks:

- The elimination of old trenches that contained mostly low and intermediate level waste;

- The elimination of the old trenches with cemented wastes and high level wastes;

- Decontamination of soils at the site of the old contaminated trenches;

- Removal and disposal of waste from temporary storage facilities;

- Reconstruction of pipelines and other elements of special sewage;

- Cleaning and rehabilitation of contaminated sites.

Defined in the project materials technology, engineering, and design solutions ensure performance of these works, subject to the rules of radiation safety and preservation of normal environmental conditions. Operations included:

- Opening storages and removal of radioactive wastes. Preparation of temporary shelters if it is necessary for protection;

- Wide use of remote means of search and diagnostics of sources of ionizing radiation, remotely operated robotics;

- Using of dust suppression polymers for preventing of aerosol formation;

- Continuous control of the maintenance of radionuclides in air of working zones;

- Realization in working zones and on external perimeter of a platform of storage facilities;

- Constant remote control of capacity of dose γ radiations.

Technologies:

In view of the absence of accurate data on design features of the old repositories and composition of the RW they contained, their disposition was performed in accordance with the following standard sequence of steps:

- Drilling of exploratory boreholes in repository boundary areas and radwaste mass followed by radiation survey;
- Removal of artificial ground from the repositories, dismantling and removal roofs from the repository;
- Evacuation of waste from the repositories, waste sorting and loading into certified containers;
- Inspection and disposition of repository constructions;
- Removal and sorting of contaminated soil from repository;
- Final radiation survey of repository;
- Backfilling with clean soil.

The remediation works were accompanied by application of dust suppression means and control of volume aerosol activity in the working area air. The presence of high level waste in repository No. 4 made it necessary to construct an additional radiation shielding around it. Removal of radioactive wastes from the old repositories was performed using conventional wheeled and crawler construction machines as well as “Brokk-110” and “Brokk-330” robots.

To protect operators against ionizing radiation, the construction machine cabs were shielded with lead sheets and provided with protective lead glasses. Both construction machines and robots were equipped with collimated detectors for measurement of activity of the RW being evacuated. During operations on the high level waste repository, monitoring colour video cameras were installed inside the radiation shielding structure, and their signal was received by monitors located in the excavator cabs. Intermediate level waste and fragments of high level waste were extracted by robots. To warn personnel about radiation hazard, working areas were equipped with threshold collimated detectors that produced audible and light alarms when the allowed gamma dose rate level was exceeded**.** One of the gamma locators was used for continuous monitoring of changes in the radiation situation in working areas at repository No. 4, with the measured data displayed on the PC screen via internet. The other gamma locator scanned the entire radwaste disposal site and measured gamma spectra from it individual areas.

Remediation of repository site needs in removal of approximately 10 x 10^3 m^3 of contaminated soils. Direct transportation of these soils was expensive and not optimal. For reduction of volumes of radioactive wastes for transportation technologies for decontamination of radioactive soil was developed by Bochvar Institute (VNIINM). The pilot facility for decontamination of soil was developed. The basic unit of this pilot facility was fabricated at the Gormashexport enterprise in Novosibirsk and has a modular design consisting of the following three basic modules: a disintegration module; a classification module; and a thickening module. This pilot facility for water gravity separation of contaminated soil was installed at the radwaste disposal site (Fig. A–6).

FIG. A–6. Pilot facility for soil decontamination.

The specific activity of the major portion (70–80%) of the initial soil reduces 4–5 times; on the average, from 180 to 200 kg of each processed ton of the initial soil are removed for long term storage; return water remains virtually uncontaminated throughout several facility operation cycles. Contaminated metals decontaminated using hydro abrasive decontamination and cutting machine (1 500 atm). The use of the hydro abrasive equipment allowed decontaminating about 170 m^3 of metal RW that was further shipped to “Ecomet-S” enterprise for remelting.

Radioactive residues packaged to containers and transported to MosSIA “Radon” storage facility near Moscow.

Kolchugino factory of non-ferrous metals [A–7]

Former industrial facility located in two building levels totaling 1 220 m^2, included 900 m^2 of ground level and 320 m^2 of second level (Figs A–7 to A–8). Contamination with ^{226}Ra detected inside and outside of building. The building commissioned in the beginning of 50’s for fabrication of luminescent compositions using of soluble bromide of ^{226}Ra and sulfide of zinc activated by copper. Building equipped with system of local exhaust ventilation and clearing of air on filters FPP; the mobile protection devices; wells storehouses (2 m depth) for storage of raw material, semi finished and finished production; systems of horizontal and vertical transportation.

At the end of 1980s manufacturing has been closed. Contaminated areas of 210 m^2 with dose rate up to 28 000 µR/h; alpha contamination up to 17 700 particles /cm^2 x minute detected inside the building.

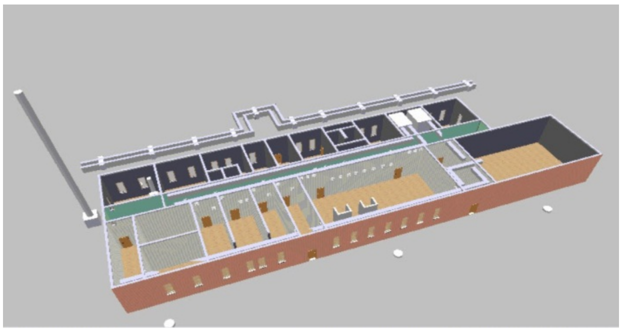

FIG. A–7. 3-D model of building.

FIG. A–8. View of contaminated building.

The contaminated materials are metal pipes, ventilation boxes, wooden items and constructions (battens, ceilings), building designs (concrete, a brick, a ceramic bar, ferro concrete locking etc.), the equipment (fans, mobile protection devices, exhaust boxes), the linoleum, the contaminated ground, a pipes of exhaust ventilation, stack. The decontamination criteria are summarized in Table A–3.

TABLE A–3. DECONTAMINATION CRITERIA

№	Criteria	Unit	Contamination levels	
			territory	rooms
1	Level of gamma radiation	µSv/h	0,54	0,54
2	Surface beta contamination, fixed	Bq/cm^2	none	50
3	Surface beta contamination, non-fixed	Bq/cm^2	none	none
4	Surface alpha contamination, fixed	Bq/cm^2	none	5
5	Surface alpha contamination, non-fixed	Bq/cm^2	none	none

All decontamination and dismantling activity provided by MosSIA "Radon"

Preparation stage:

Development of decontamination plan. Preparation of modernized tools. Subdivide of contaminated and clear rooms to "hot" zone and "clear" zone equipped with sanitary/dosimetry control, cloakrooms for protective clothes and showers. Carrying out of primary decontamination/fixing of radioactive contamination. Removal of non-fixed contamination, protection of the equipment, walls, floors are carried out for reduction of risk of contamination distribution and to exclude of risk contamination of personnel during work. Surface protected with special colors with application of a first coat of deep penetration such with use of sprays a two layer covering with intermediate drying 30 minutes.

Fixation of walls executed with acrylic front paints with use of sprays a two layer covering with intermediate drying 30 minutes. Contamination limits for application of such fixators are more than 5 alpha particles /min x cm^2.

Decontamination and dismantling/cutting of processing equipment:

Firstly the mobile protection devices was decontaminated and cut. Special barriers from polyethylene films and polyurethane foam are created for prevention of spread of contaminated water and solutions.

Decontamination and dismantle of glove boxes and other equipment:

Fragmentation of metal equipment and constructions have made with plasma cutting torch Plasma cutting torch and cutting tool completed with industrial vacuum cleaner. Wooden parts are cut by the manual tool, decontaminated with portable planers.

Decontamination of equipment and dismantling/cutting of building constructions:

Firstly the mobile protection devices was decontaminated and cut. Decontamination of linoleum have made with hot air guns and cutter tools (removal of contaminated linoleum); decontamination without removal made with sandblaster and high pressure equipment. Special barriers from polyethylene films and polyurethane foam are created for prevention of spread of contaminated water and solutions.

Annex 3

EXPERIENCE OF FSUE "ROSRAO"

The Refining Plant of the Podolsk Plant of Non-Ferrous Metals (PPNFM)

The refining plant is in territory of the Podolsk Plant of Non-Ferrous Metals (PPNFM). The main problem is that this plant never worked with radioactive materials and it is in operation now with personnel which can't contact with radioactive materials. As a result of melting of source ^{137}Cs in furnaces in 1989 the territory, buildings and equipment of factory were contaminated with ^{137}Cs.

Primary decontamination has been done, the building is preserved. There are 6 contaminated objects on this territory. The building, equipment and territory of Refining Plant contaminated with ^{137}Cs up to 8 mSv/h (levels in May 2010). Three dimensional model of the plant is shown in Fig. A–9.

Absence of supervision of a technical condition of a building within almost 20 years has led to that, it is in an unsatisfactory condition, on a floor there is a building garbage, the slag rests, fragments of a metal ware. Surfaces of walls, building designs, equipment are covered by a considerable layer of corrosion and contaminated dust. The indoor infrastructure is completely destroyed (see Fig. A–10).

In accordance with federal law the European Engineering Corporation Ltd. (EEC) was successor in competition and sigh Governmental Contract with FSUE "RosRAO". EEC developed detailed decommissioning plan, agree it with regulators, recruited and trained personnel for works with radioactive materials. Main goal is decontamination of refining plant without demolishing of building, for further use of territory for industrial purposes. Organizational chart of the project sees in Fig. A–11. Taking into account industrial end state of the building, decontamination criteria with gamma dose rate 0,4 µSv/h over background agreed with regulators.

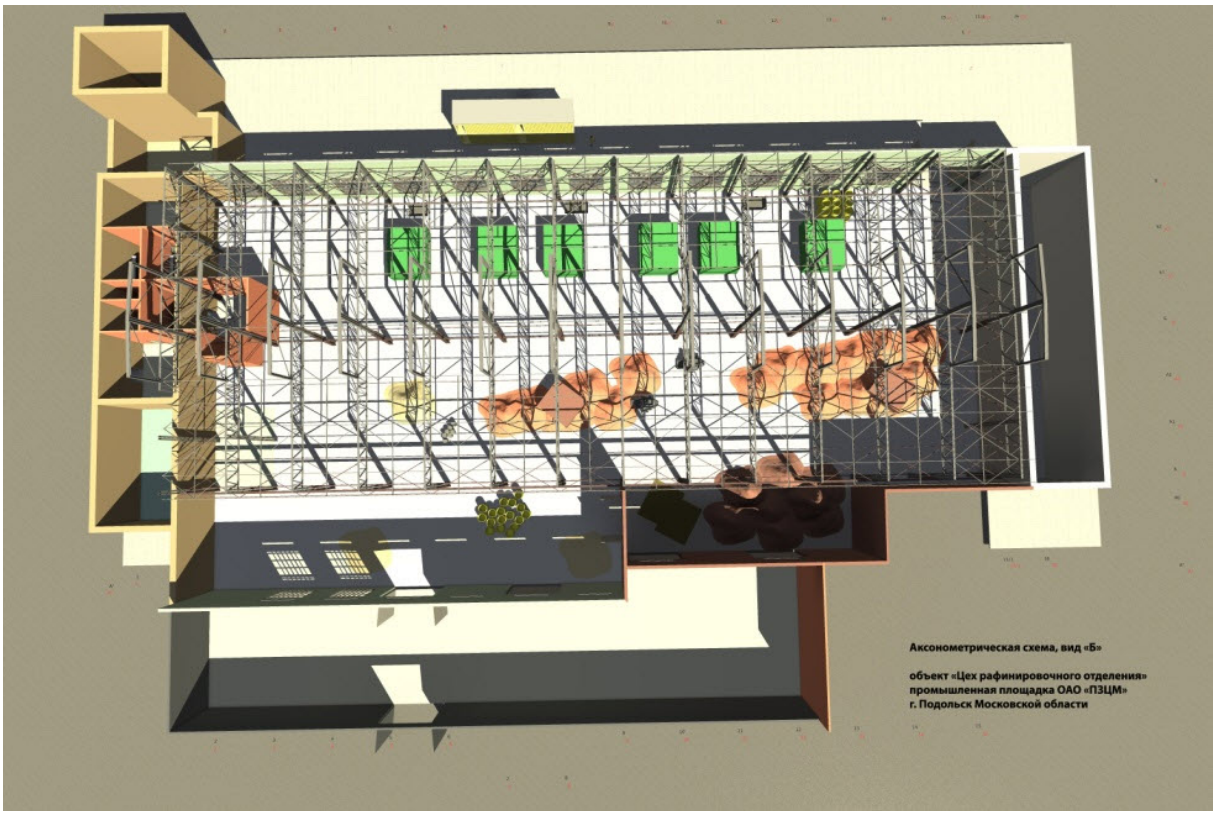

FIG. A–9. 3-D model of refining plant.

FIG. A–10. Status of building before beginning of the project and after removing of contaminated materials.

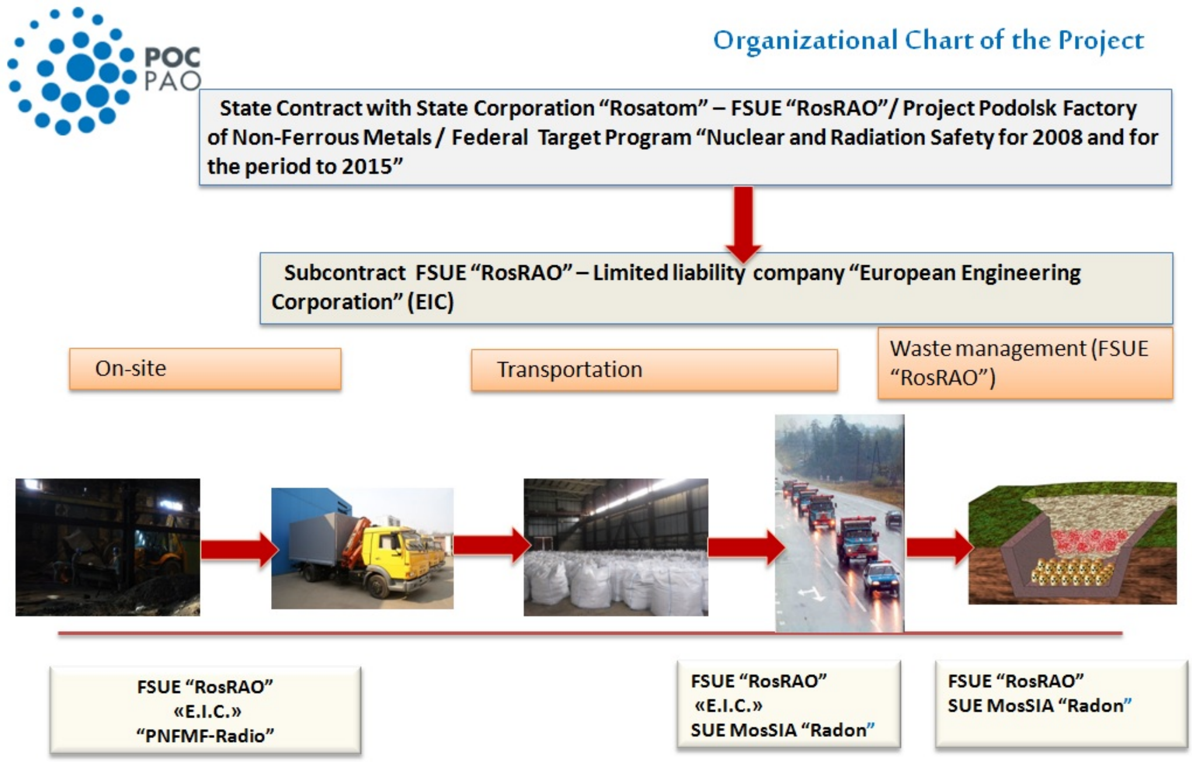

FIG. A–11. Organizational chart of the project.

The following strategy of decontamination works is chosen:

- Preparation of a building equipment of a sanitary post, subdivision of building into "clean" and "hot" zones, the equipment of on site temporary storage of RW packaged in primary pickings;
- Dismantle of not contaminated bulky equipment and its removal in scrap metal after radiating control;
- Sorting of wastes — a brick, slag, etc. on-site, packing of RW in primary packing "big bag" type;
- Removal of dangerous industrial wastes (contamination is less than RW, but higher than maximal possible for free release) on a dumping area at factory territory;
- Packing of "Big Bag" in transport containers KRAD-1.3 type;
- Transportation of RW in containers to "RosRAO" storage facility for long term storage;
- Carrying out of final radiometric inspection, preparation of the report and finalization of the regulation control.

The main problems of the project are:

- Short term of performance (from June to December 2010);
- A bad condition of bearing designs of a building;
- Great volume of solid RW (more than 1000 m^3);

- Small distance to other buildings which operated with non-radioactive production;

- RW sorting on site in presence of high dose rates need to developed a special methodology of measurement and sorting;

- Great volumes of the RW treated in short terms, demand working out of a detailed logistical chain of gathering, containerization and transportations to storage facility of “RosRAO”.

Kirovo-Chepetsk Chemical Combine (KCChC)

The Kirovo-Chepetsk Chemical Combine named after B.P.Konstantinov was built in the 1940s to produce uranium fluorides and it operated until 1990s. At the moment all contaminated objects are transferred to FSUE “RosRAO” as a branch. The former uranium fluorides processing buildings has volume of 102 000 m^3. Tailings and RW burial sites contain approximately 440 000 tons of RW with total activity 3 400 Ci. Scheme and location of contaminated sites on the territory of KCChC are shown in Fig. A–12. Main tasks and the concept of decommissioning are illustrated in Figs A–13 and A–14.

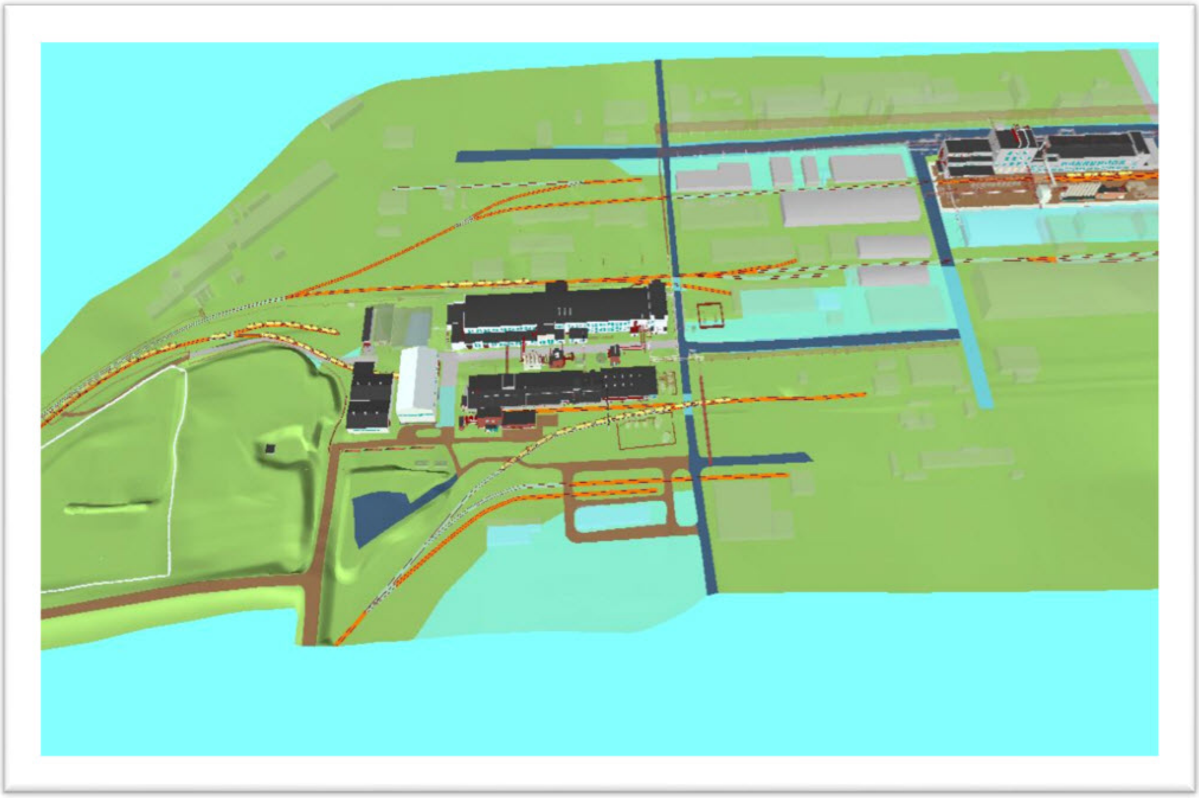

FIG. A–12. Scheme and location of contaminated sites on the territory of KCChC.

FIG. A–13. Main tasks in remediation of the plant.

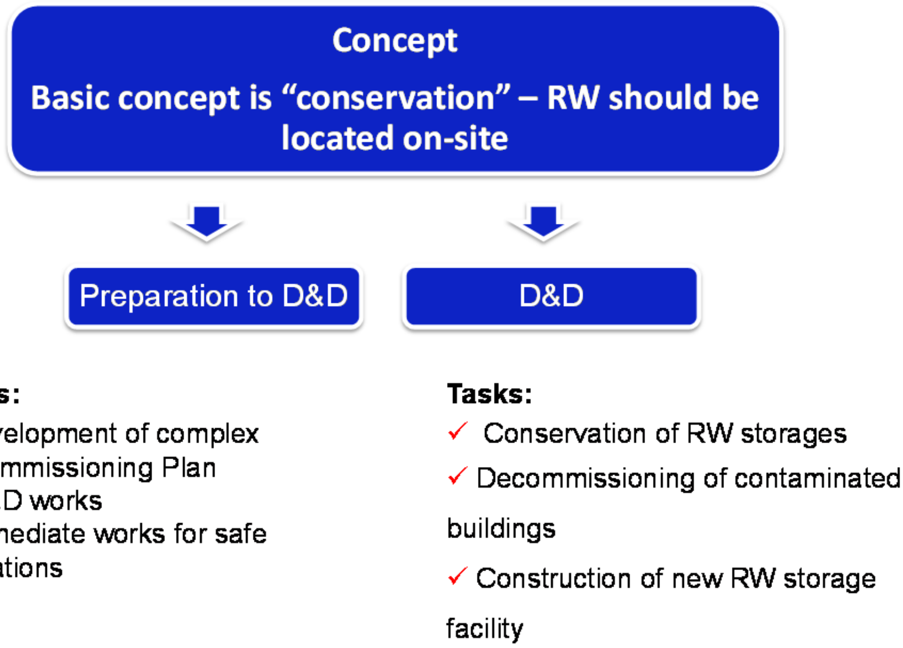

FIG. A–14. The concept of work on KCChC site.

List of main activities:

- Hydrogeological study evaluation of organizing the near surface disposal facilities RW;
- An engineering survey of building designs and building protective engineering barriers of six storages for solid radioactive wastes;
- Environmental impact assessment (EIA) of activities for the decommissioning;
- Assessment of soil contamination, soil, groundwater and surface water, ground water monitoring;
- Development of the decommissioning project and certification;
- Conservation and protection of RW storages and tailings;
- Decommissioning of contaminated buildings;
- Construction of the on site temporary storage.

All works are scheduled for the period from 2012 to 2025.

Annex 4

DRAFT OF TRAINING/EDUCATIONAL PROGRAMME "DECOMMISSIONING OF CONTAMINATED SITES"

Background information:

- Objectives and overview of the course;
- Basic approaches, Russian and international experience, role of IAEA IDN and ENVIRONET networks;
- Responsibilities and functions of stakeholders.

Regulations in decommissioning:

- Safety and radiating protection criteria;
- Requirements and recommendations;
- Final state of object;
- Methods of an estimation and safety assessment of contaminated site.

Development of the Decommissioning plan:

- The analysis of the initial data
- The purposes of complex engineering and radiating inspection (KIRO);
- The equipment for engineering and radiating inspection;
- Inspection/characterisation of contaminated objects;
- Development of decontaminated and remediation criteria;
- Development of the Decommissioning project and working plan.

Decontamination techniques and tools:

The main principles, targets and efficiency of decontamination:

- Chemical methods:
  - The liquids/chemicals;
  - Polymers, gels;
  - Electrochemistry;
  - Ultrasound.
- Abrasive/mechanical methods;
- Thermal;
- Principles of decision making.

Dismantling of contaminated equipment and constructions

The general requirements to dismantling of contaminated materials

- Cutting of metal and concrete:
  - Hydraulic tools;
  - Diamond saws.
- Demolition of concrete structures;
- Dismantling of large components;
- Concrete removal;
- Remotely controlled operations;
- Selection of optimal technique.

Remediation of contaminated areas and sites

- Safety assessment;
- Methods for site remediation;
- Dismantling of buildings/constructions;
- Decontamination of soils;
- Restoration of a vegetative cover;
- Monitoring of territory after the decommissioning and environmental remediation;
- The purposes and characterization and monitoring;
- Monitoring means;
- Mathematical models.

Radioactive waste management

- The general principles of RW management in Russian Federation and international experience;
- Assessment of amounts and characteristics of decommissioning waste;
- Compliance with radioactive waste management standards and disposal site requirements;
- Recycling/re-use of decommissioning materials;
- Waste minimization/pollution prevention;
- Categories of RW, regulations;
- Characterization and acceptance criteria for RW;
- Procedures for conditioning, packaging, storage, transport and disposal.

Financial planning

- Elements of decommissioning costs;
- Cost estimating guidelines;
- Financing approaches;

Environment safety and health issues

- Environment safety and health;
- Unexpected occurrences;
- Environmental issues (permits);

Management of a decommissioning project

- Organization and staffing;
- Training;
- Quality assurance/quality control;
- Record keeping and reporting;
- Security;
- Completion of a decommissioning project;
- Post-decommissioning survey final reports;
- License termination.

Case studies on decommissioning

- Evolving technologies for decommissioning;
- Technical visit to a facility where decommissioning is implemented.

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THE NEEDS FOR AND THE BASIC ELEMENTS OF AN INTEGRATED APPROACH TO PLANNING, ORGANIZATION AND MANAGEMENT OF DECOMMISSIONING ACTIVITIES IN THE RUSSIAN FEDERATION

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Abstract

This report contains the principal results of analytical studies performed by Research Group of St.-Petersburg State Institute of Technology in the framework of the IAEA CRP on “Planning, Management and Organizational Aspects in Decommissioning of Nuclear Facilities”. The aims of the studies were to determine the adequacy of available tools and mechanisms for planning and organization of a large scale decommissioning and waste management activities; to define such elements of planning and management system that require changes and improvements; to elaborate recommendations on necessary actions; and to provide info analytical and methodical support for sustainable realization of decommissioning programme. Final report includes systematized information on a broad spectrum of issues related to CRP goals — from legislation, financing, subordination to concrete plans, projects, relevant manuals and guides addressed both to decision makers, technical executors and the public.

1. Introduction

The Russian Federation is now fully engaged in decommissioning, with the list of affected facilities reaching several hundreds. Shutdown and the necessity for proper management of various nuclear installations have required a broad spectrum of regulatory, financial, organizational and technical activities. Noticeable progress has already been achieved, although a significant number of issues still require realistic and carefully considered solutions. In early 2000s it was officially recognized (e.g. see “Foundations of the State Policy in the Field of Nuclear and Radiation Safety of Russia”, signed by President of Russian Federation on 04.12.2003) that the time for postponed decisions has expired, and decommissioning and radwaste management “is one of the most important issues of socioeconomic development and national security of the country”.

For successful accomplishment of the mission it was decided to establish a single national system for planning, organization and management of decommissioning and waste management activities. This required active and carefully coordinated efforts of various State authorities and non-governmental organizations. Launching the project “The needs for and the basic elements of integrated approach to planning, organization and management of decommissioning activities in the Russian Federation” Research Group of St.-Petersburg State Institute of Technology has planned to provide an independent examination of corresponding intentions, plans, documents and actions, and to exercise influence (within its power) on improvements in organization and management of decommissioning programme.

2. Some important steps on the way towards establishment of national system for planning, organization and management of decommissioning activities in the Russian Federation

In 2008 (the year of the project start) in the Russian Federation was the year of more than serious alterations in organizational, managerial and regulatory platforms of nuclear activity. In accordance with the Federal law “On the State Corporation for Atomic Energy “Rosatom” (N317-FL of 01.12.2007) the system of management, mechanism of financing, structure of subordination, form of property of nuclear power and fuel cycle companies and R&D institutions were radically changed with the aim:

- To increase effectiveness of direction and utilization of resources in nuclear field;
- To provide new impulse for accelerated and harmonious development of atomic power under the highest level of nuclear and radiation safety.

Active attempts have been undertaken in 2008 to improve legislative support for the “back end” activities — radioactive waste management and decommissioning of nuclear and radiation facilities. In specific:

(1) A bill “On Radioactive Waste Management” has been presented for discussion in October 2008 [1–4]. It contains a number of clauses that are (or better to say: would be) a matter of principle for planning and implementation of decommissioning projects. As an example one could mention the new category — “special (or non-retrievable) waste” defined in the draft law as “radioactive waste for which radiation and other risks and expenditures connected with retrieval, processing, conditioning and disposal of waste in dedicated repositories exceed the risks and costs connected with in situ disposal option”. Combination of this definition with the IAEA nuclear energy principle “benefit” [5] gives some legal grounds for the selection of in situ disposal variant for decommissioning of open storage ponds contained a few hundred million cubic meters of liquid radioactive waste.

(2) There was issued “Concept of Decommissioning of Nuclear Facilities, Radiation Sources and Storage Points” [6], and there was started Federal Programme “Ensuring of Nuclear and Radiation Safety of the Russian Federation in 2008 and for the Period up to 2015” [7] with the budget of 145.3 bln. roubles.

The first document formulates the policy of Rosatom for decommissioning of nuclear and radiation facilities. The Federal Programme can be considered as a combination of a national strategy and strategy implementation plan for the “back end” stages of atomic energy utilization, including decommissioning activity.

2.1. New structure of organization and top management in the “back end” of atomic energy utilization

In accordance with the Federal law N317-FL of 01.12.2007 and Decrees of the President of the Russian Federation in 2008 the Federal Agency for Atomic Energy was liquidated and new directing body — State Corporation for Atomic Energy “Rosatom” — was established. Rosatom is juridical “body” allotted with the following authorities to:

- Pursue a state policy;
- Carry out normative and lawful regulation;
- Manage the State property in the area of atomic energy utilization;
- Secure the development and safe functioning of organizations of atomic energy and industry cluster and nuclear weapons complex of the Russian Federation;
- Ensure nuclear and radiation safety and non-proliferation of nuclear materials and technologies;
- Favour the development of nuclear science, techniques and professional education;
- Accomplish international cooperation in the field of atomic energy utilization.

According to Clause 3 of the Federal Law N317-FL of 01.12.2007 *“Federal bodies of the State power, regional government bodies and local authorities don’t have a right to interfere in activities of*

Corporation and their officials on achieving the legislatively established objects excluding special cases envisaged by federal laws".

Thus, Rosatom — the largest nuclear profile organization and one of the largest hi-tech companies of the country — is allotted a wide range of powers, and it bears the responsibility for sustainable and safe development of nuclear power and technology including decommissioning of nuclear and radiation facilities and radioactive waste management. Corporation can command on its own by the means coming from production activities and, in addition, has *substantial budgetary financing*. It is important that safety and development oriented activity of Corporation is supported with special reserve funds (Fig. 1).

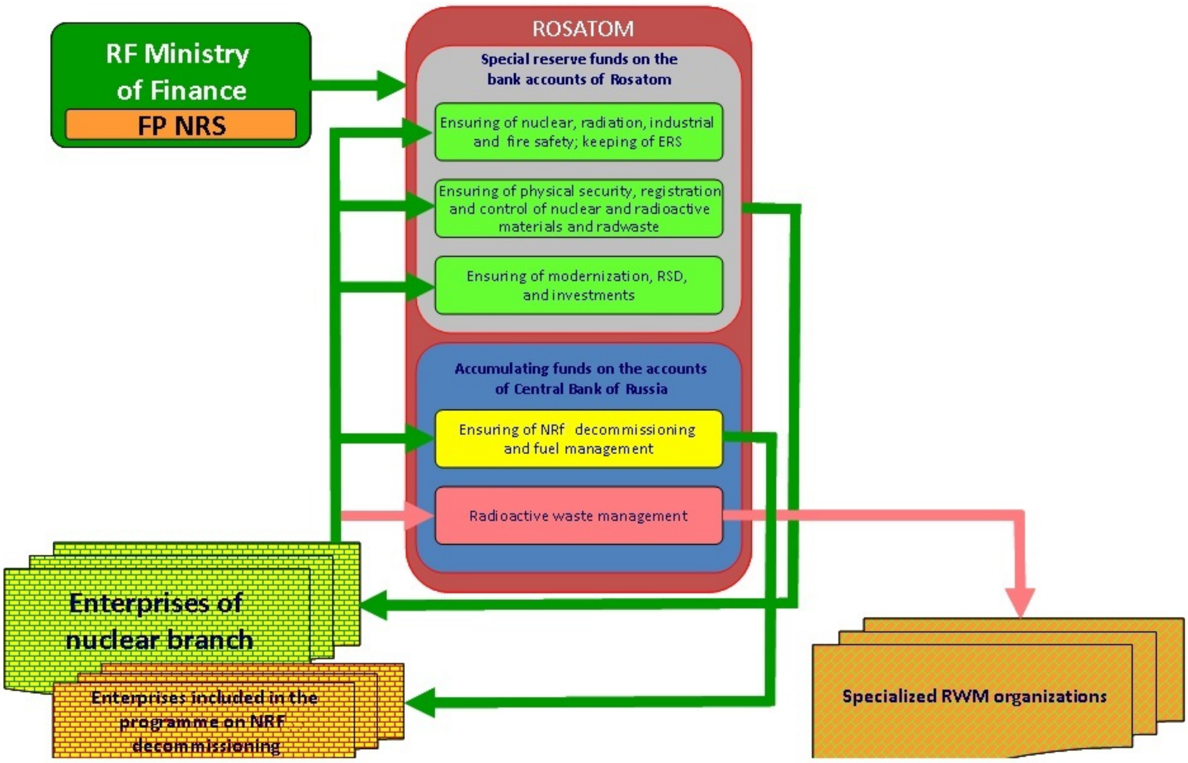

FIG. 1. Special funds of the State Corporation "Rosatom".

For planning, coordination and direction of decommissioning activity Rosatom has established Department of Spent Fuel and Radwaste Management and Decommissioning[7]. The Department of Nuclear and Radiation Safety plays an active role in organization and control of decommissioning programmes. This Department of Rosatom was an official manager of budgetary money (145 bln. roubles till 2015) allocated for solution of "nuclear legacy" problem (including decommissioning of shutdown facilities) in the framework of Federal Programme [7].

Planning and organization of NPPs decommissioning remains the responsibility of JSC "Atomenergoprom" that is constituent part of the State Corporation. For practical management of decommissioning projects four Testing and Demonstration Centres (TDC) are in the stage of organization. It is planned that TDCs will be responsible for elaboration and testing of methods and techniques for decommissioning of different types of nuclear facilities. In specific:

[7] Now it is divided into two Project Offices "Development of the System of Radioactive Waste Management" and "Development of the System of Spent Nuclear Fuel Management and Decommissioning of Nuclear and Radiation Dangerous Objects" in the structure of Direction on Radiation and Nuclear Safety.

- TDC located at Physics and Power Institute (Obninsk) — for research reactors;
- TDC located at Mining and Chemical Combine (Krasnoyarsk) — for nuclear fuel cycle enterprises;
- TDC located at Siberian Chemical Combine (Tomsk) — for uranium–graphite reactors, both industrial and RBMK type;
- TDC located at Novovoronezh NPP — for power reactors of WWER type.

In due course it is intended to reorganize TDCs in to service companies specialized in decommissioning of nuclear facilities. As concerns organizational structure of decommissioning waste management (on the level with operational one) the following institutions are or planned to be involved

(1) Active subdivisions of specialized enterprises of Rosatom:

- IA “Mayak” (Chelyabinsk);
- Siberian Chemical Combine (Tomsk);
- Mining and Chemical Combine (Krasnoyarsk);
- Newly organized company of Rosatom: RosRAO — has been established in 2008; amalgamates all regional “Radon” enterprises, SevRAO and DalRAO.

(2) Organization that is planned to be established under the aegis of Rosatom:

- National Operator (symbolic name) — institution of the State Corporation responsible for planning, organization and implementation of activities related to long term storage and final disposal of radioactive waste.

(3) Commercial companies:

- Ecomet-S (metallic waste);
- EcoAtom (Navy waste);
- RaoTech (NPPs’ waste), etc.

Besides Rosatom there are other Agencies involved in decommissioning of nuclear and radiation facilities. These governmental bodies are defined, by law, as *“directing organizations in the field of atomic energy utilization”*. Complete list of additional “directing organizations” includes eight positions:

(1) Federal Service on Environmental, Technological and Atomic Safety Supervision (FSETASS);

(2) Federal Medical and Biological Agency (FMBA);

(3) Federal Agency for Hydrometeorology (FAHM);

(4) Ministry of Emergency Situation (MES);

(5) Ministry of Industry and Trade (MIT);

(6) Ministry of Regional Development (MRD);

(7) Ministry of Education and Sience (MESc);

(8) Federal Agency on Marine and River Fleet (FAMRF).

Organizations enumerated in items 1–3 of the above list execute the functions of regulation. Ministry of Emergency Situations has a mandate to control fire safety (by licensing and periodical inspections of nuclear/radiation facilities) and to liquidate consequences of various possible accidents, if any, including nuclear and radiation ones.

Other organizations (items 5–8) operate nuclear and radiation facilities and/or radiation sources for which decommissioning is inseparable and inevitable stage of the life cycle. Obviously these organizations must be involved in decommissioning activities but as consumers of corresponding services rather than as active implementers of decommissioning related works. Summing up the results of analysis general organizational scheme of decommissioning activity can be presented as follows (Fig. 2).

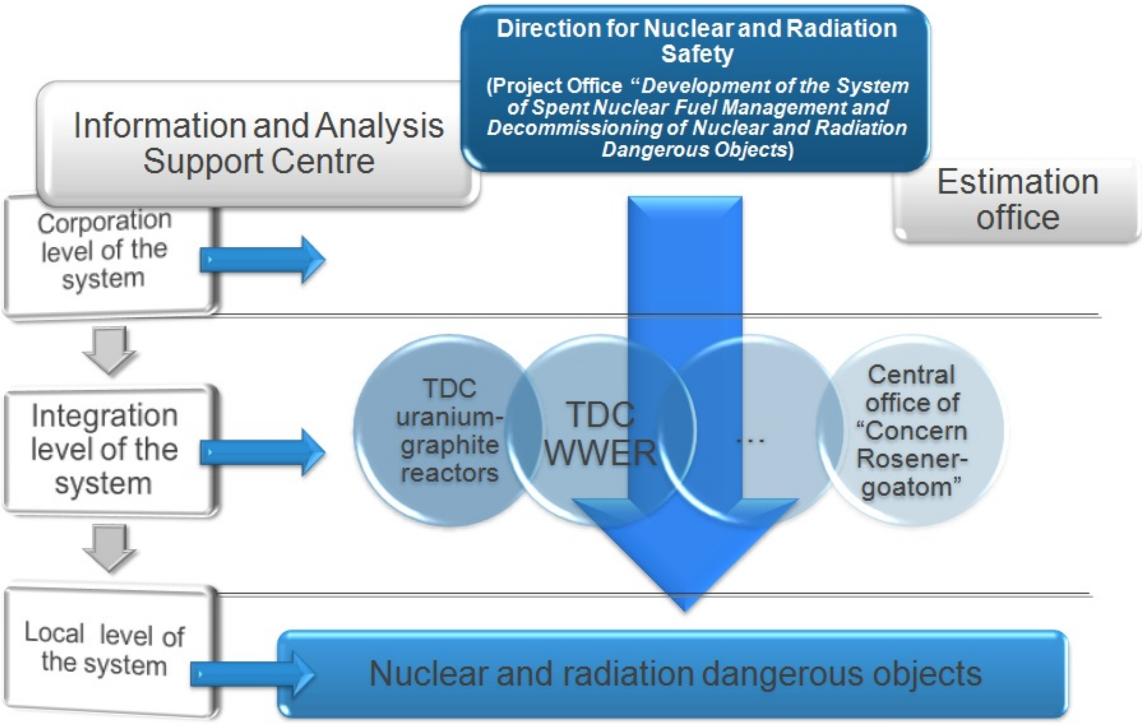

FIG. 2. General scheme of organization and coordination of decommissioning activity.

2.2. Rosatom policy of decommissioning

Effective planning, organization and management of the large scale decommissioning programmes, in a crucial way, depend on availability of relevant policy and strategy, where

- **A policy** is a set of goals and requirements established to control safe, effective and efficient decommissioning of nuclear and radiation facilities;

- **A strategy** is a plan for achieving the goals and requirements set out in the policy.

The policy is usually established by the national Government or Parliament but there may be situation where this is delegated to corporate bodies.

State Corporation "Rosatom" — directing organization in the field of atomic energy use according to the law N317-FL — has issued in February 2008 "Concept of Decommissioning of Nuclear Facilities, Radiation Sources and Storage Points" [6][8]. This Concept "…expresses the policy of Rosatom and envelops the period of time up to 2030".

2.2.1. *Goals and principal definitions*

Concept [6] formulates the principal end of decommissioning — *release of nuclear and radiation facilities (NRF) from nuclear and radiological regulatory control* (Section 1), and determines the basic options for decommissioning:

- **liquidation of NRF** — decontamination, dismantling and demolishing of equipment, constructions and buildings, removal of all waste and restoration of site for further use;
- **entombment (on site disposal)** — localization of radioactively contaminated elements of equipment, building structures and radioactive waste on the site with creation of necessary physical barriers excluding non-sanctioned access in zone of localization and release of radioactive substances in environment;
- **conversion** — alteration of initial destination of the main buildings, constructions, engineering systems and equipment of NRF for other purposes including those *related to atomic energy use*.

These decommissioning options differ from so called "standard decommissioning strategies" used in the IAEA vocabulary: *immediate dismantling, deferred dismantling, entombment* (e.g. see [8]). The choice between these two approaches is rather difficult. But, in any case, classification of Rosatom seems to be sufficient because definitions "immediate" and "deferred" characterize just a period of time between shutdown and physical liquidation of facilities *which is, in both cases, the principal end of this option/strategy*.

Conversion is reasonable and not infrequently practiced decommissioning option. However, as usual, term "conversion" is applied in order to describe transformation of nuclear/radiation facility in a "conventional" one. Conversion of one NRF in another one contradicts the ultimate goal of decommissioning postulated in the Concept [6] — *release of facility from nuclear and radiation control*. This paradox must be settled to prevent possible misunderstandings and erroneous interpretations of the top level document.

Decommissioning activity can be implemented in stage by stage mode including "safe store" period.

Practical object of Rosatom policy in the period 2008–2015 is to provide necessary conditions for the start of the large scale decommissioning programme and to prepare 116 facilities at 19 enterprises of the State Corporation for decommissioning.

2.2.2. *Basic principles of NRF decommissioning*

On the level with nuclear and radiation safety fundamentals the following principles have an importance during the NRF decommissioning (Section 4 of Concept [6]):

- NRF must be put in the state of nuclear safe object by the normatively fixed date (removal of nuclear materials, fresh and spent reactor fuel);
- NRF must be put in radiologically safe state in optimal period taking into account social and economic factors;

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[8] It should be said in all fairness that the first "Concept" has been prepared by VNIPIET and approved by Minatom 8 year before. However in [6] the previous document is not mentioned even in passing.

- Materials and equipment should be returned in industrial and economic cycle as completely and effectively as possible;

- Decommissioning operations should be organized so as to minimize the volumes of waste and irradiation of personnel;

- Radioactive decommissioning waste should be placed in the long term storage facilities and/or in dedicated repositories;

- Decommissioning activity should not be considered as a factor withstanding development of nuclear power and industry.

2.2.3. Priorities of Rosatom decommissioning activity

The main directions of Rosatom decommissioning activity during the period 2008–2015 are the following:

- Development and improvements in normative and legal frame on the basis of domestic and foreign experience and recommendations of international organizations;

- Effective use of scientific and technical innovations, advanced technologies and practical experience accumulated in decommissioning area;

- Use of effective organizational and financial schemes for practical realization of decommissioning, radwaste and spent fuel management projects, and for creation of necessary conditions for development of all kinds of services in the field;

- Organization and coordination of works on determination of scientifically substantiated criteria and indicators of decommissioning projects implementation taking into account social and economic factors;

- Creation of necessary conditions for the development of relevant infrastructure at operated and shutdown facilities aiming at ensuring of NRF decommissioning;

- International cooperation in the field of NRF decommissioning on the basis of concluded intergovernmental agreements.

The key elements of directing activity of Rosatom include:

- Development and confirmation of strategic programme on NRF decommissioning bearing in mind all the sources for financial provision of works;

- Analysis, coordination and confirmation of programmatic documents on decommissioning of various types of NRF or concrete facilities, including calculation of optimized expenditures;

- Determination and forming the list of Rosatom NRFs liable to decommissioning;

- Preparation of necessary information on the final shutdown and decommissioning of NRF for relevant governmental agencies;

- Development of the standard system of indicators for the assessment of decommissioning projects fulfilment;

- Centralized collection and analysis of information related to NRF decommissioning, creation of organizational and legal conditions for repeated use of technologies and facilities elaborated at the budgetary means for NRF decommissioning and radwaste and spent fuel management.

Decommissioning activity in the discussed period of time will be closely linked with the creation of the main objects for radwaste and spent fuel management including regional waste storage/disposal facilities.

2.2.4. Socioeconomic aspects

At the planning of NRF shutdown and decommissioning it is necessary to foresee a complex of measures for social protection of personnel, including:

- Creation of a new places for work in the area of NRF location;
- Retraining of NRF employees;
- Resettlement of NRF staff and the members of their families in the new places of work (if necessary and reasonably).

Important elements of decommissioning activities are understanding and support of the project by the local community and the organizations of self government. For these purposes Rosatom and operating organizations should provide active communication with the public, regional and territorial authorities and mass media informing stakeholders about the goals and the final results of NRF decommissioning.

2.2.5. Financial support

Timely and sufficient financing of decommissioning activity is one of the most important conditions for the safe use of atomic energy in peaceful and defence purposes.

The list of the sources for financing of decommissioning activity includes:

- Target means of Federal budget;
- Means of regional budget;
- Means of special funds established in the framework of existed legislation;
- Funds allocated for this purpose in the programmes of international cooperation and assistance;
- Other means utilization of which does not contradict legislation of the Russian Federation.

In accordance with legalization of the final responsibility of the State decommissioning of facilities operated in the past should be financed from the Federal and Regional budgets with possible involvement of additional non-budgetary resources.

For operated and new facilities that don't have "nuclear legacy" problems financing of decommissioning projects should be done from the special funds which are creating in accordance with existed legislation and the laws under development.

2.2.6. Research and development issues

R&D support of decommissioning activity is directed to provision of conditions for the most effective employment of known and innovative technologies and technical means with the aim to minimize costs, irradiation of personnel and to increase safety.

To achieve these goals it is planned to solve the following tasks:

- To subdivide shutdown and liable to decommissioning facilities into groups of similar objects;

- To elaborate standard decommissioning procedures and technologies for each group of NRF at Testing and Demonstration Centres (see 2.1);

- To develop special procedures and technologies for decommissioning of unique NRF.

Succession of decommissioning works (including priorities inside the group) is determined taking into account the level of risks and safety of NRF, the rates of protective barriers degradation, forecast of the costs increase[9] and other factors important for decision making.

2.2.7. Other goals and requirements

To ensure effective planning and organization of NRF decommissioning with proper solution of adjacent radwaste and spent fuel management problems operating organizations should prepare and regularly renovate the plans (programmes) for decommissioning of shutdown or intended to be decommissioned facilities in the time intervals up to 2010, 2015 and 2025.

In the period until 2015 for all NRF planned to be shutdown till 2020 corresponding decommissioning concepts, programmes and design documents should be developed and confirmed. Structure, form and content, sequence of preparation and confirmation of NRF decommissioning programmes are determined by the normative documents (e.g. see [9–13]).

Operating organization is also obliged to collect, to analyze and to keep information related to both operational and decommissioning stages of facility's life cycle.

Principal goal of Rosatom — as the main directing organization in the field of atomic energy use and in decommissioning area — is to establish in strategic perspective (until 2030):

- Necessary normative and legal basis;

- Financial mechanisms effectively working in the market economy;

- Infrastructure including national and regional storage facilities and repositories for radioactive waste, material and engineering basis for decommissioning, etc., *taking into account technical feasibility, economic expedience and social purposefulness of the problem*.

2.3. Rosatom strategy for NRF decommissioning

Strategy of decommissioning activity (*i.e. plan for achieving the goals and requirements set out in the Concept*) is stated in the Federal Target Programme "Ensuring of Nuclear and Radiation Safety of the Russian Federation in 2008 and for the Period until 2015" [7]. It is planned that the Programme will be continued with the second stage foreseen for 2016–2020.

The main goal of the Programme is *to transfer the objects of nuclear legacy in a safe state and to ensure the State guarantees of nuclear and radiation safety for a long period of time* including:

- Construction of the objects for radioactive waste and spent fuel management;

- Decommissioning of nuclear and radiation dangerous objects;

- Improvement of the State system for control and ensuring of radiation safety for man and environment;

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[9] As practice shows the cost of decommissioning may strongly depend on the timeliness of the actions undertaken. For example, in 2004 evacuation of RITEG from the cape Navarin has costed 500,000 roubles but in 2006 for this decommissioning operation it was required 100 mln. roubles [1].

- Development of science and technology basis and investment mechanisms for long term guarantees of nuclear and radiation safety.

For realization of programme [7] 145.3 bln. roubles (~5 bln. US$) are allocated from which 131.8 bln. roubles are the means of the Federal budget. In 2016–2025 expenditures can reach 1 200-1 400 bln. roubles.

It is important that programme [7] is coordinated with Federal Target Programme "Development of Atomic Power and Industry Complex of the Russian Federation in 2007–2010 and for the period until 2015" [14] with the budget of 1 500 bln. roubles.

This reflects clear understanding of the fact that dynamic and sustainable development of nuclear power and industry is impossible without proper and timely solution of the "back end" issues, and first of all — problems of spent fuel, radioactive waste and decommissioning of nuclear facilities (Fig. 3). Moreover, decommissioning and radwaste management are truly considered as inseparable links of the chain: many decommissioning projects all over the world are slowing down because of the shortage of capacities for long term storage and disposal of radioactive waste.

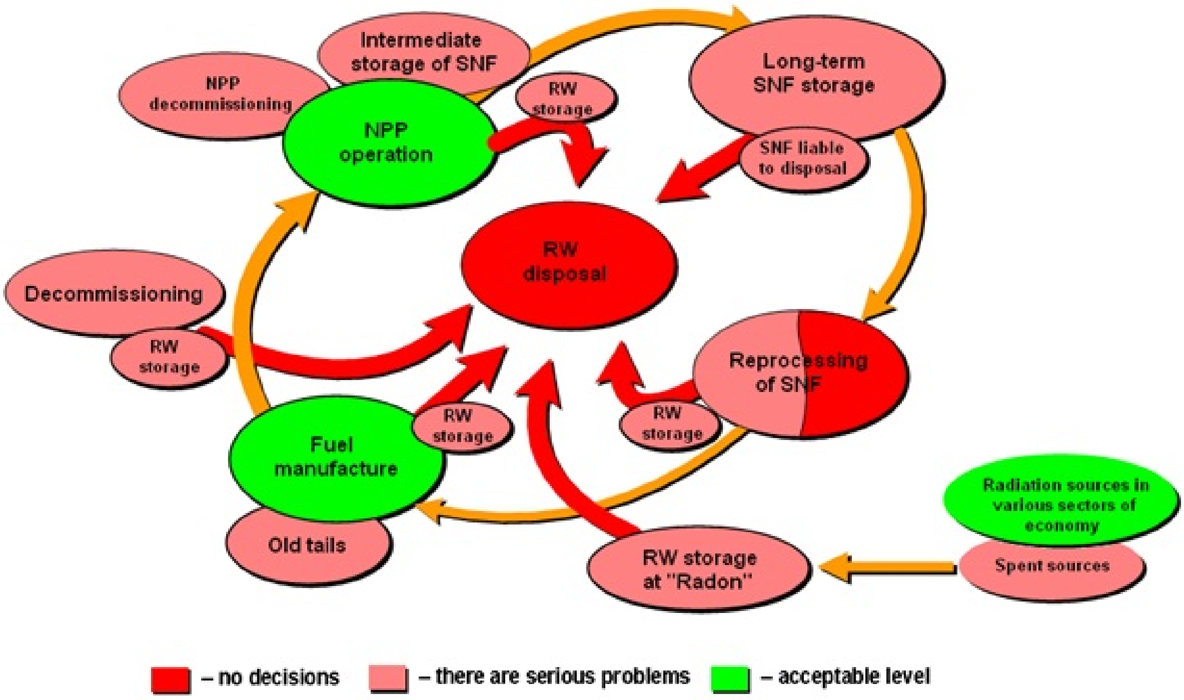

FIG. 3. Comparative assessment of the problems existed (as of 2006).

The programme [7] realizes the so called "strategy of intensive decision of accumulated problems" (one of the three strategies that have been considered at the stage of the programme discussion, including "strategy of postponed decisions" and "strategy of development ensuring" [15]).

In decommissioning area it is planned:

- To decommission or to increase the level of safety of Rosatom's "crucial" objects located at IA "Mayak", Siberian Chemical Combine and Mining and Chemical Combine (the largest radiochemical enterprises);

- To ensure long term safety of nuclear legacy objects belonging to other State agencies;
- To liquidate shutdown NRF of research centres including those located in megalopolises;
- To increase the level of safety (to decommission) of radiation sources used in various branches of the national economics;
- To liquidate negative consequences of the peaceful nuclear detonations — restoration of sites.

Directly for these purposes it is allocated about ¼ of the Programme's budget. The most share of money will be used for investments in building and reconstruction of corresponding objects (Figs 4 and 5).

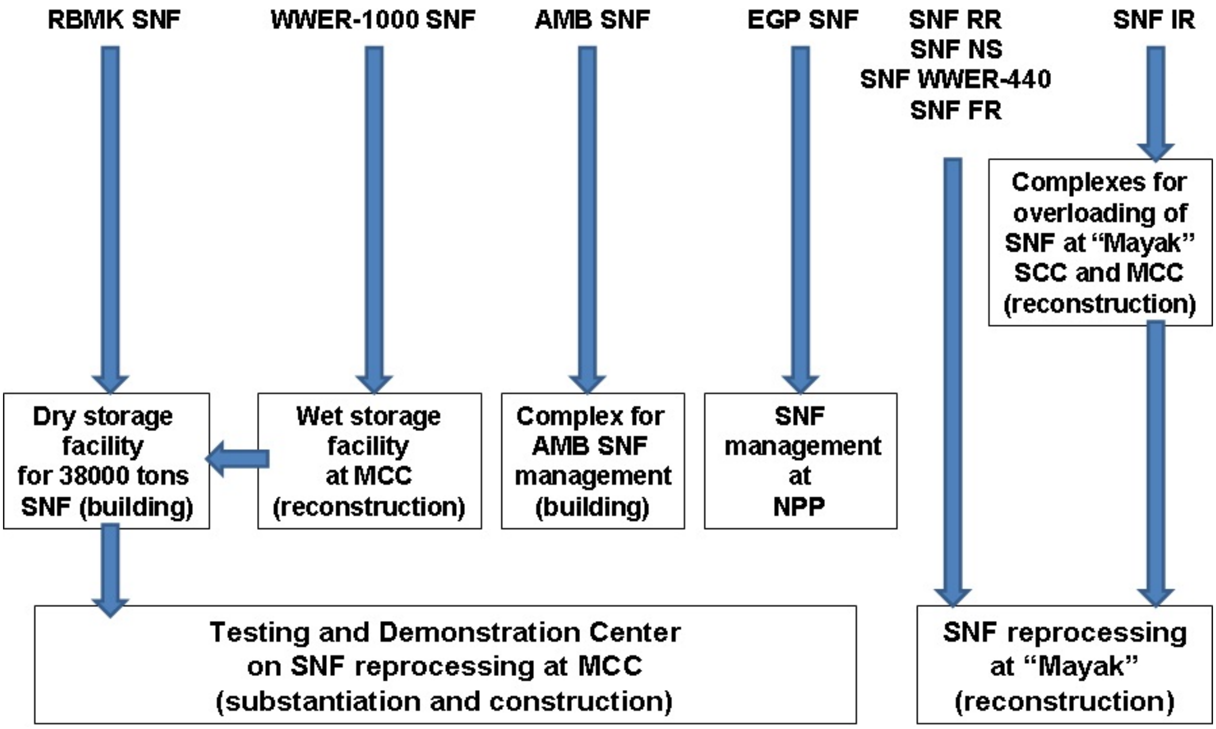

FIG. 4. Programme's measures for reconstruction and building of storage facilities and objects for SNF management (54.4 bln. roubles).

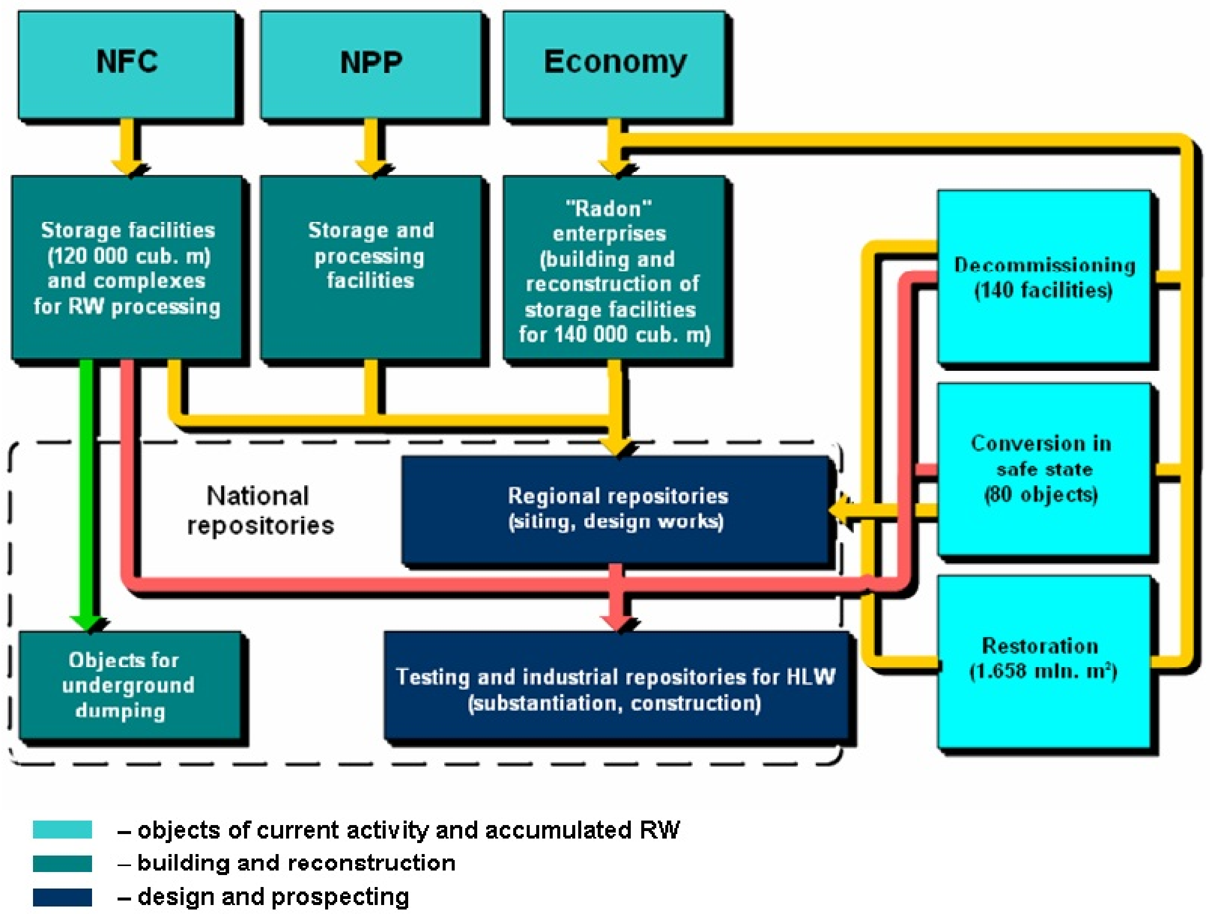

FIG. 5. Programme's measures for decommissioning and radioactive waste management (29.7 bln. roubles).

Expected effectiveness of the Programme [7] implementation is assessed as follows:

- Prevented economic detriment at the account of prevention of emergency situations at NRF with radiological consequences (up to 200 bln. roubles for the most dangerous objects);
- Saving of future expenditures at the account of timely solution of the problems accumulated (up to 1 000 bln. roubles for the period 2016–2025);
- Exclusion of the future budgetary expenditures for safe maintenance of NRF which are intended to be liquidated in the course of the Programme implementation;
- Raising the competitive attractiveness of nuclear facilities including export potential (up to 100 bln. roubles annually);
- Raising the investing attractiveness of the branch, as a whole, and enterprises and regions of their location at the account of guaranteed nuclear and radiation safety of objects at all the stages of their life cycle.

The strategy/programme discussed is intended to be reviewed and, perhaps, reconsidered in 2011 taking account the results of the first phase implementation.

3. Status and peculiarities of legislative platform

Legislative basis for peaceful use of atomic energy includes about ten Federal Acts. However there is no special law regulated decommissioning activity. In this context it is important to emphasize special role of Federal law N190-FL "On radioactive waste management and on amending of certain legislative acts of the Russian Federation" adopted in July 2011. This law can and will seriously influence planning, organization and implement of decommissioning activity.

According to Clause 9 of the law government of the Russian Federation is exceptional proprietor of accumulated (historical) radwaste. The Russian Federation is *responsible for financial provision of processing, long term storage and disposal of historical waste*, i.e. waste accumulated at the territory of the country before 2011. This includes *decommissioning of storage facilities contained specific waste*. Category "specific waste" is introduced by the Clause 4 of the law with the following definition: "specific waste is radioactive waste for which radiological and other risks and expenditures connected with retrieval, processing, conditioning and disposal operations exceed the risks and costs connected with in situ disposal option".

Incentives for such innovation are rather transparent. Nuclear legacy of the Russian Federation includes 22 open ponds filled with more than 400 mln. cubic meters of liquid radwaste. Decommissioning of these storage facilities with extraction, processing, conditioning, transportation and disposal of waste in dedicated repositories is the back breaking toil. On the other hand application of "entombment option" for open ponds may formally contradict existing regulations for radioactive waste disposal [16, 17].

Introduction of "specific waste" category on the level with all necessary stipulations, described in Clauses 4 and 26, gives legal grounds for reasonable solution of this issue.

It is also important that the law discussed creates necessary conditions for forming the market of services in radwaste management area (Clause 14), and envisages organization of special State company responsible for long term storage and disposal of radioactive waste — *National Operator* (Clause 20).

Thus organizational reforms, primarily aiming at deciding radwaste problem, may *provide reliable basis for mass decommissioning of nuclear and radiation facilities*.

4. Intermediate conclusions

Summing up the above described results of investigation one can conclude

(1) Formally all necessary elements of the system for proper planning, organization and management of decommissioning activities (legislation, policy, strategy, managerial mechanisms and financial opportunities) have been created in the Russian Federation in relatively short period of time.

(2) Such a large scale and complex process of organizational restructurization and renovations in legislative and normative area requires time for proper adjustment, and this objective circumstance should be admitted and adequately taken into account.

(3) It is important that decommissioning and the ultimate isolation (disposal) of radioactive waste are considered in the framework of one integrated strategy, because it is clear that:

- decommissioning of any NRF is a source of radioactive waste;
- in the absence of radwaste repositories and comprehensive (from cradle to grave) strategy of radwaste management decommissioning of one NRF (NPP for example) inevitably leads to creation of another one (radwaste storage facility) with indefinite future;

- the last one means that the principal end of decommissioning — liquidation/mitigation of potentially dangerous consequences of atomic energy utilization — is not achieved.

(4) To ensure clear, realistic and reliable routes for decommissioning waste “rendering” it is necessary, apart from everything else, to solve a number of rather complex organizational issues.

5. State system of radwaste registration and control

It is evident that one of the most important preconditions of successful decommissioning and radwaste management issues is the reliable registration and control of radioactive waste “from cradle to grave”. State system for on site registration of radwaste has been put into operation a few years ago. Necessity for further evolution of this system is dictated by the basic strategic approach formulated in “Fundamentals of the State Policy” [18] and in Federal Programme [7] — all radioactive waste, both already accumulated and newly generated, should be safely disposed of.

In terms of this strategy one should expect mass transference of radwaste from the sources of generation and/or from off site temporary storage facilities to the points of their final isolation. This process will be accompanied by the property rights transfer from the waste generators to specialized companies and/or to the National operator responsible for the waste disposal. For safety reasons all these operations must be carefully recorded and controlled.

Principal scheme of the radwaste transference and registration (Fig. 6) involves three main streams [19]:

(1) Preliminary inventory making of waste and waste storage points;

(2) Subdivision of accumulated waste on “special” (non retrievable) and retrievable ones with further on site disposal of SRW and disposal of treated and conditioned retrievable waste in the regional or federal repositories;

(3) Operational waste (including waste generated in the course of decommissioning operations) can be disposed of either in off site or on site repositories depending on results of safety assessment, plans in respect to the land utilization, socioeconomic and other factors.

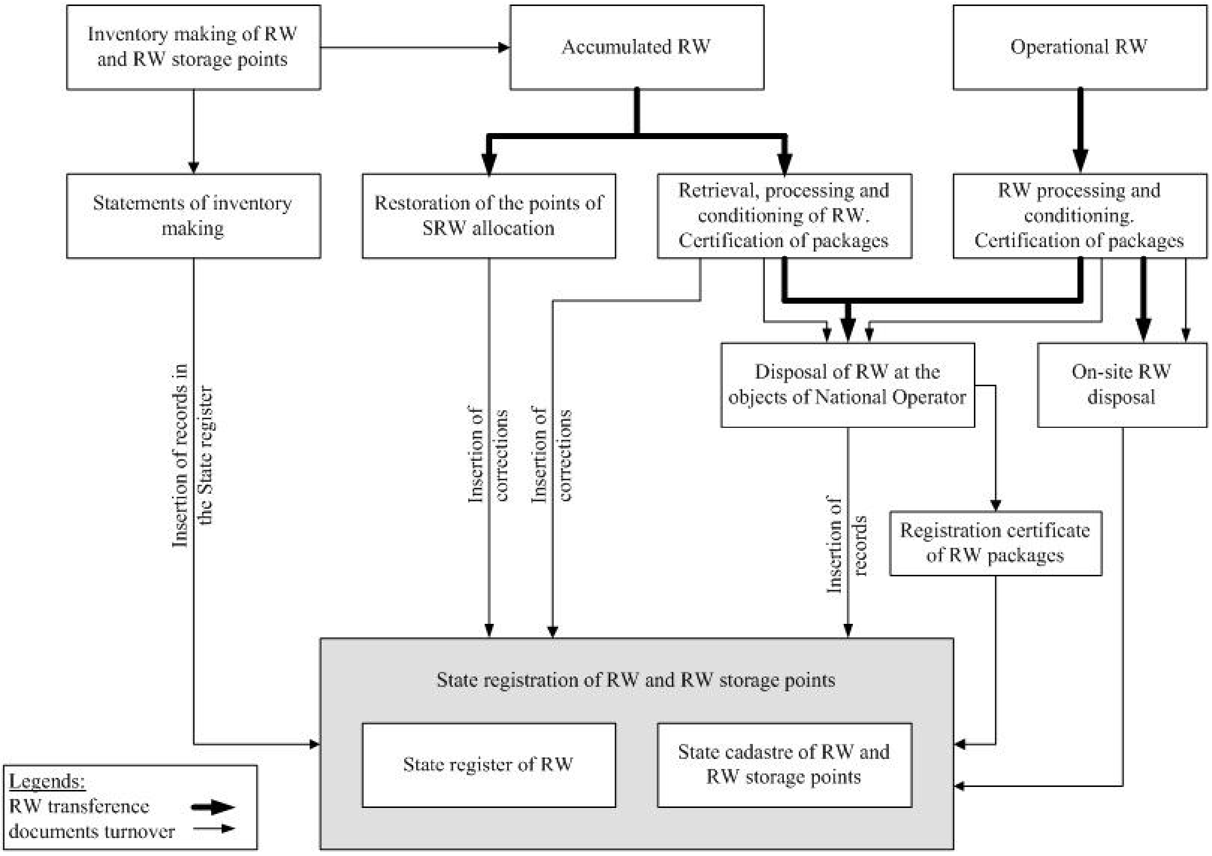

FIG. 6. Principal scheme of radwaste transference and registration.

All information regarding the quantities and characteristics of radioactive waste, and regarding the status and conditions of the waste storage/disposal facilities is planned to be directed to the State Register and State Cadastre.

The key function of the State Register (Fig. 7) is to fix momentary status of documented data on property rights (and, consequently — on final responsibilities of the waste owners) and on characteristics of radwaste in store. Furthermore Register is intended for tracing of any changes connected with development of decommissioning and radwaste management activities.

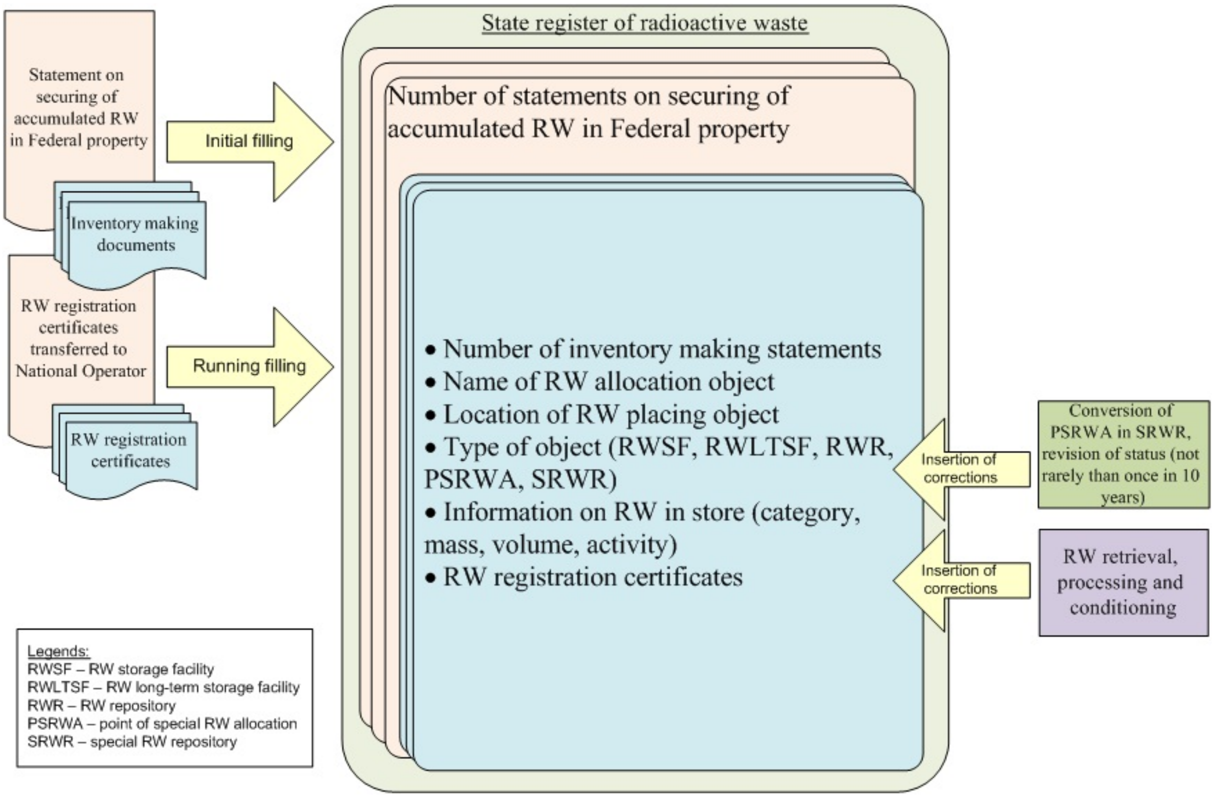

FIG. 7. State register of radioactive waste.

State Cadastre (Fig. 8) contains factual juristical, technical and economic information on waste storage/disposal points. In addition, this is reliable basis for establishment of long term institutional control over closed radwaste repositories.

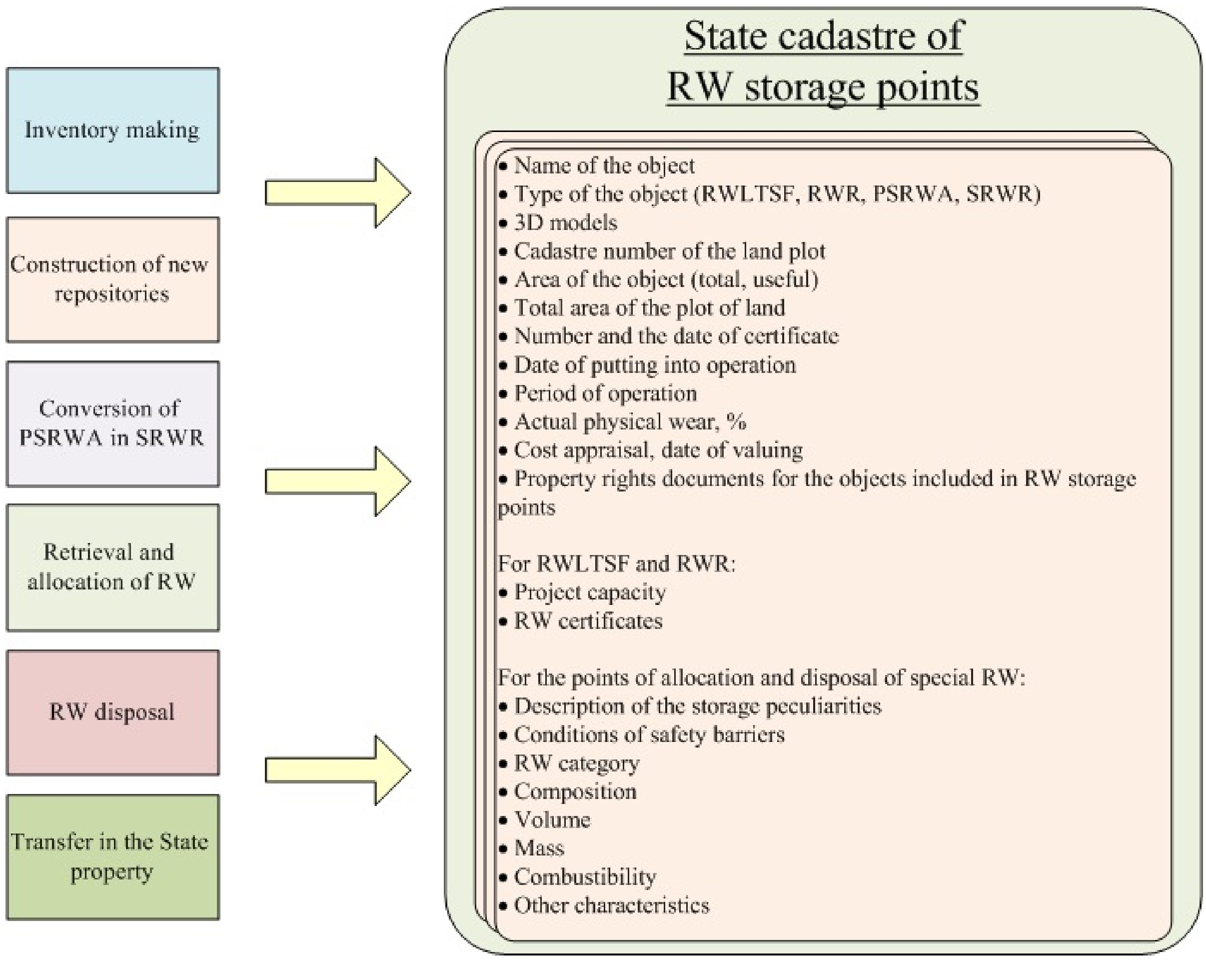

FIG. 8. State cadastre of radwaste storage/disposal points.

As it was mentioned before, according to regulatory requirements [20] all the "operators" must report yearly to "regulator" on the quantities, activities and conditions of the waste generated. Thus, planned activity on registration and control of RW and RW storage points should be considered as development/improvement of existed system rather than a new project.

6. Planning and organization of waste disposal routes

It is reasonable to emphasize here that because of the absence of repositories and deficiency of centralized storage facilities practically all accumulated waste can be removed from the site only during the decommissioning of facility, and therefore *this waste must be considered as decommissioning waste.*

An estimation of radioactive waste — already accumulated and expected from operation and decommissioning of NRFs — gives the following distribution of radwaste over the Federal regions (Fig. 9). According to the accepted strategy [7, 18] radwaste disposal is planned to be realized (depending on characteristics, state of waste and some other factors) by three main scenarios:

(1) In Federal deep geological repositories;

(2) In regional near surface repositories;

(3) In local objects (on site disposal of so called "specific" waste — see Progress Report 2009).

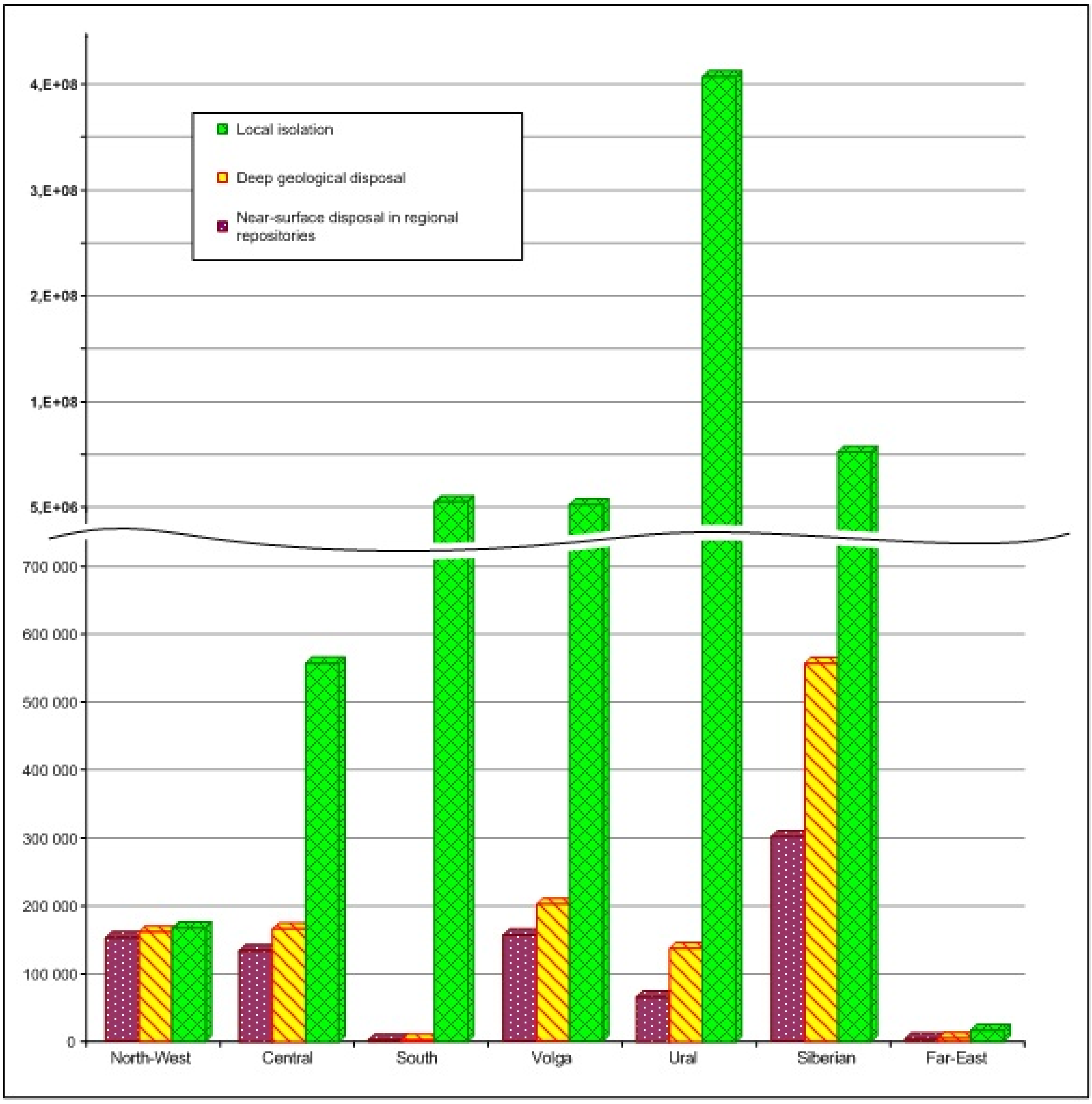

FIG. 9. Distribution of radwaste accumulated by the technologies of disposal [21].

Geographical distribution of waste disposal sites (Fig. 10) is based on the administrative and territorial division of the Russian Federation into seven Federal regions. In addition, it is expected that "territorial" approach will make it possible to optimize transport flows and to make the most of production potential and/or disposal capacities of specialized regional companies of former "Radon" system (now — divisions of Federal State Enterprise "RosRAO") [22].

FIG. 10. Supposed geographical distribution of infrastructural objects in the Russian Federation [21].

The data presented (Fig. 10) should be considered as just a first approximate draft of a general scheme of repositories siting. At present full clearness exists, perhaps, with respect to only one disposal site — deep geological repository for high level, long lived radioactive waste located in Krasnoyarsk region (Nizhnekansk massif) [23].

For any other region careful, multifactorial analysis is needed involving such aspects as real geological conditions, expected expenses, density of population, rates (of) and prospects for socioeconomic development, etc. Examples of analytical information necessary for the selection of optimal variants are presented in Figures 11 and 12.

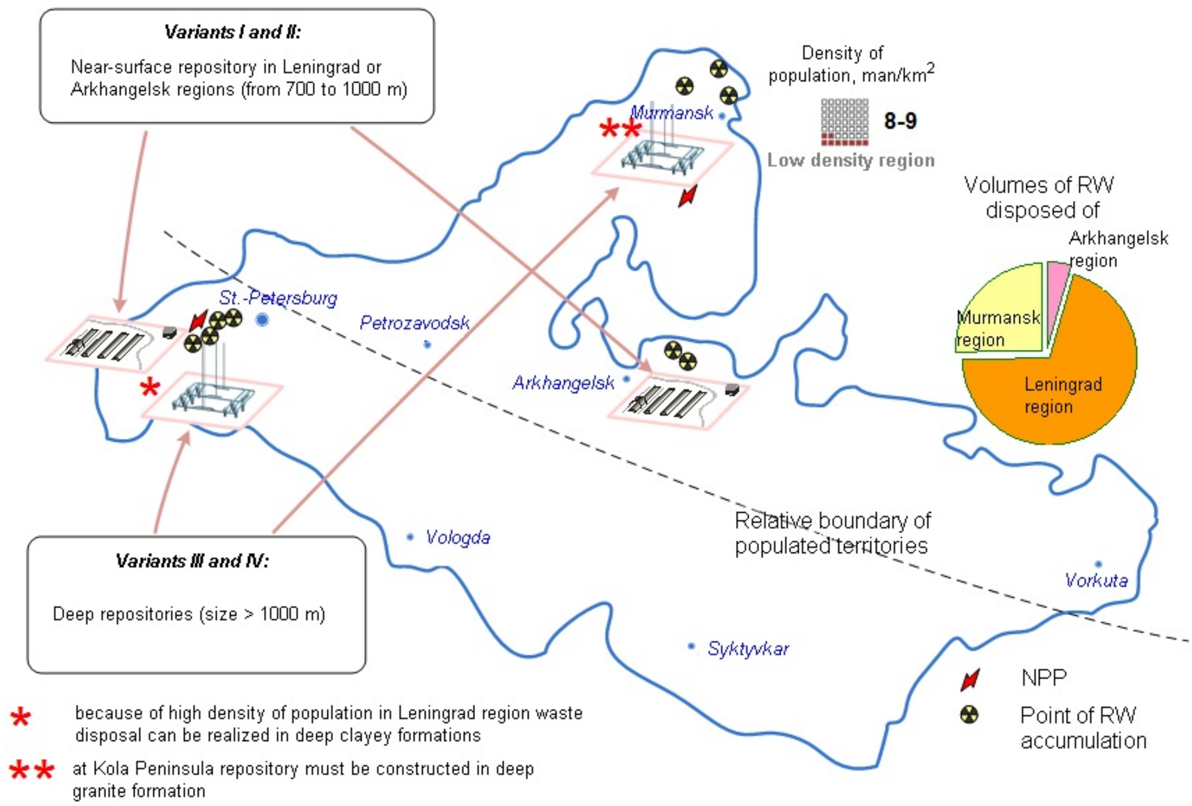

FIG. 11. Some variants of regional repositories construction in the North-West region.

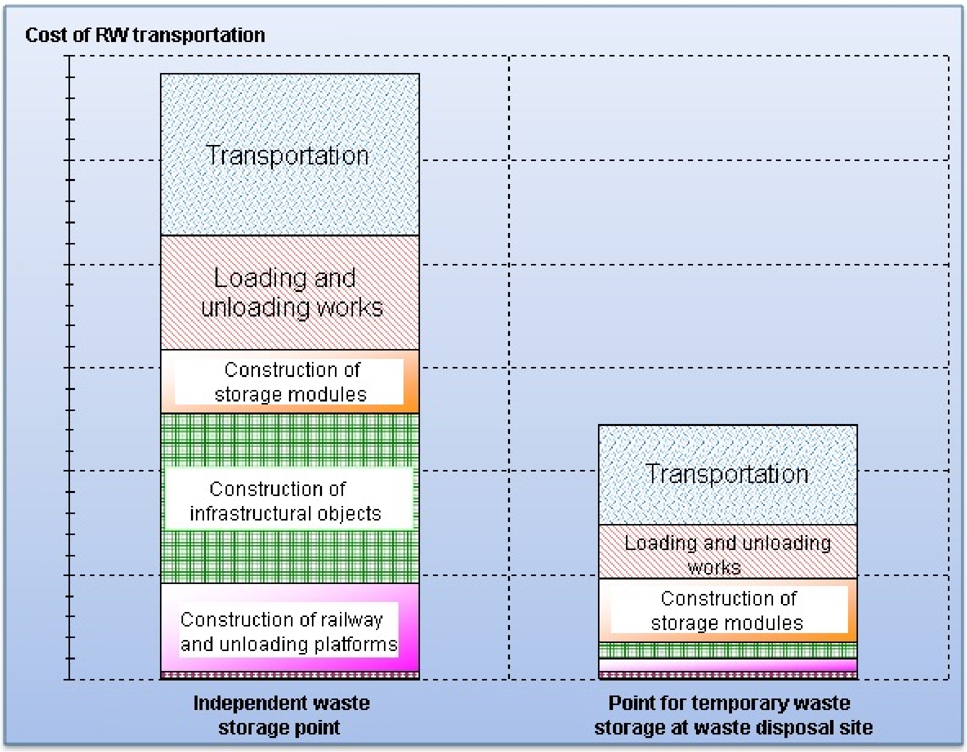

FIG. 12. Technical and economic analysis of transport–technological operations (for Volga region) [24].

In the first case (Fig. 11) there are some obvious opportunities for creation of radwaste repository in the area with low density of population and good geological conditions — clay formations in Arkhangelsk region [24]. However, in that case the most share of decommissioning waste and waste accumulated in the North-West region (~70%) must be transported on the distance of 400–1 200 km, and the transport expenses (including railway construction) may seriously exceed expenditures needed for construction of regional waste repository. According to our very rough estimation only construction of additional 100 km of railway require about 20 bln. roubles (~670 mln. US$), while investments in construction of near surface repository for ~600 000 m^3 of containerized radwaste total less than 3 bln. roubles [25].

Next example (Figure 12) demonstrated comparative costs of radwaste transportation and temporary storage within the different scenarios of logistic centres organization: independent facility for waste accumulation versus storage facility located directly at waste disposal site. As it is seen the difference is more than considerable, and this fact must be taken into account at the planning stage — when there determined the order of priority of waste removal from production/decommissioning sites and construction of waste repository.

It is important to stress here that there is much scope for further evaluation of real volumes of already accumulated and expected radioactive waste, and consequently — for proper planning of transportation and disposal capacities. Now in the publications of the same authors (see [21] and [24]) the volume of waste intended for disposal in the North-West region of the Russian Federation is estimated as ~550 000 m^3 (including 180 000 m^3 of “special” waste, see Figure 8) in one case [21], and about 180 000 m^3 of waste — in another one [24]? At the same time in [26] the volume of operational and decommissioning waste *only at Leningrad NPP* (4 units of RBMK-1000) is estimated as ~190 000 m^3 without containers, and more than 600 000 m^3 in containerized form. Obviously, such dramatic discrepancies must be eliminated as soon as possible.

It is important to define, as soon as practically possible, concrete status of RosRAO divisions (former “Radon” enterprises):

- Facility intended for immediate decommissioning;
- Logistic centre for temporary accumulation of radwaste;
- Long term storage facility;
- Radwaste disposal site (local or regional repository).

It is understandable that clear destination of company seriously influences financial policy, principles of management, possibility of long term planning of activity, criteria for selection and training of personnel, etc. In turn, sustainable development of RosRAO enterprises (taking into account peculiar position of these centres in existed structure of waste management tools and mechanisms) is one of the key factors of successful implementation of Federal Programme [7].

Thus, practical realization of the strategy of NRF decommissioning involves as an inseparable stages:

(1) Improvement of the State system of registration and control of radioactive waste and radwaste storage sites.

(2) Development of comprehensive database on radwaste management infrastructure: facilities for processing and conditioning of waste, containers for radwaste storage, transportation and disposal, radwaste transportation means.

(3) Development of the principles, criteria and the draft scheme of radwaste repositories siting. Accepted approach involves creation of “local” (for so called specific waste), regional and federal facilities for near surface or deep geological disposal of radioactive waste. Old storage

facilities (~1500) should be inspected and (depending on results of inspections) decommissioned or transformed in waste disposal points. The final selection of sites for regional repositories is rather difficult task since geological conditions are not the only factors that must be taken into account.

7. Achievements, uncertainties and open issues

Realistic assessment of situation gives a reason to conclude that, in principle and as a whole, decommissioning activity in the Russian Federation has rather good rates. The Russian Federation has now stopped the operations at all of its 13 reactors that were previously producing weapons grade plutonium. By the beginning 2011, out of 198 nuclear discharged submarines, 190 have been dismantled and 539 radioisotope thermoelectric generators (RITEGs) have been decommissioned. For the first time in domestic practice there was decommissioned an enterprise of a nuclear fuel cycle — chemical and metallurgical plant in Krasnoyarsk [27], and this experience is extremely useful for decommissioning of identical nuclear fuel cycle facilities in Electrostal, Glasov, Novosibirsk, Tomsk and Angarsk.

Activity on decommissioning of radwaste storage facilities at ship repair plants has essentially increased [28]; the conceptual project on decommissioning of high level waste vitrification units at IA “Mayak” is developed [29]; large scale and laborious work is carried out on complex engineering and radiation studies of nuclear facilities of various types with the development of recommendations on realization of concrete variants of decommissioning for each nuclear or radiation dangerous object [30], etc. Russian companies successfully work abroad. For instance, decommissioning of Hazaria and Balkanabat factories in Turkmenistan, highly contaminated with natural radionuclides, has been finished in 2010 with:

- Dismantling of equipment;
- Demolition of industrial and auxiliary buildings;
- Collection, containerization and disposal of about 20000 tons of radioactive waste;
- Restoration of industrial sites [31].

However, recognizing doubtless achievements in decommissioning of nuclear facilities and, particularly — in liquidation of the “cold war” legacy, it is necessary to draw attention to the following:

(1) Correct and thought over policy supported with reasonable strategy and a package of coordinated federal programmes on decommissioning and radioactive waste management yet does not give desirable results, basically, because of annoying failures in organization and management;

(2) Lacks of decommissioning programme organization are obvious — these are scandalous inconsistency of supervising documents, absence of unity in understanding of the problem by various Ministries and Agencies; too frequent and not always clear shifts in management personnel, languid position of Parliament concerning acceptance of necessary laws (see for details Progress Report 2010–2011);

(3) Understanding the essence of the problem and the ways of its solution it is necessary to concentrate efforts on improvement of *planning, organization and management system of decommissioning*. The decision of this issue demands well coordinated joint actions of the State Corporation “Rosatom” with the state structures forming economic policy of the country (Ministry of Finance, Ministry of Economic Development) and directly or indirectly involved in creation or use of nuclear facilities (Ministry of Defense, Ministry of Power, Russian Academy of Science and others).

Our comments and recommendations on the subject, based on the results of the study performed in the framework of coordinated research project (2008-2011), are in good agreement with newly formulated official position of Rosatom. In September 2011, at VI International Nuclear Forum this position has been stated in the paper "Concept of establishment of the branch system of nuclear and radiation dangerous objects decommissioning" [32]. Present status of the system is characterized in the paper as follows:

- Incompleteness of legal and normative basis;
- Absence of effective management system;
- Absence of mechanisms for getting enterprises interested in completion of decommissioning works;
- Absence of effective financial mechanisms;
- Absence of approved list of the objects liable to decommissioning;
- Absence of effective info analytical support for decommissioning projects.

Simple analysis of the views expounded in the paper clearly shows that some from the indicated deficiencies are the results of non-fulfilment of before accepted and approved in the policy and strategy plans, decisions and obligations. "Concept" contains a number of steps aiming, first of all, at improvements in planning, organization and management of decommissioning activity. It is planned that in the nearest 15 years more than 150 nuclear facilities should be decommissioned.

8. Publications resulting from the CRP

In 2010–2011 some important results obtained in the framework of Research Project "The needs for and the basic elements of integrated approach to planning, organization and management of decommissioning activities in the Russian Federation" have been systematized and published in form of a series of books and booklets addressed to the various groups of "stakeholders".

This is aiming at

- Informing the persons and organizations involved in decommissioning projects on international activities in this area coordinated by the IAEA;
- Providing the parties concerned with domestic and foreign experience in organization and management of decommissioning projects, and with criteria and algorithms of decision making as well;
- Acquainting the decision makers with existing techniques and technologies suitable for practical realization of decommissioning projects and predetermining the choice of realistic strategy;
- Raising the interest of youth to nuclear education with further involvement in various segments of practical nuclear activities including *decommissioning.*

The list of published materials includes:

(1) Monograph **"Technologies for Radiation Safety Ensuring on the Objects with Nuclear Installations"** [33].

This book provides the reader with a broad spectrum of verified information on the subject including basic positions of planning, organization and management of decommissioning activities (Chapter 3 and 4).

In addition, this book contains helpful information on normalization of radiation situation at nuclear facilities after accidents (IA "Mayak", Chernobyl NPP, nuclear submarines K-19, K-11, K-27, K-140, etc.; see Chapter 5). Valuable experience accumulated in this field can and must be taken into account at the stage of *planning, organization and management* of decommissioning projects as well as at the active stage of nuclear facilities decommissioning (when the safety barriers of decommissioned facility are consecutively liquidated during dismantling and demolition operations).

And, at last, the monograph contains the unique data on *new materials, technologies and techniques* suitable for employment in decommissioning projects (Chapter 6). This information provides *planning bodies and practical managers* with the knowledge on:

- What kinds of materials and technologies are available, in principle, for the decision of essential decommissioning issues (especially in the field of safe management of specific decommissioning waste);
- What is the present state of these materials/technologies — commercially available, R&D stage, laboratory investigation, etc.;
- How much efforts and resources are needed to involve innovations in routine practice of decommissioning.

Having this data, managers have an opportunity for well founded decision making on the optimum organization of decommissioning projects.

(2) Manual **"Decontamination"** [34].

The objective of manual **"Decontamination"**, prepared by the members of SPbSIT Research Group, is to provide information, experience and assistance on how to select proper technology for decontamination of operated or *decommissioned* nuclear facilities. This book is intended to be useful to students, operators and/or decommissioning contractors as practical guidance, as well as to policy makers, regulators, owners and the planners — as some kind of data base necessary for the thought over decision making.

This manual describes scientific bases for selection of relevant reagents, compositions of decontamination compounding, parameters of the process realization, special features of physico–chemical interaction for various materials, techniques and technologies of decontamination, and recommendations on the planning, preparation, organization and carrying out of decontamination works.

In domestic practice special monographs on the subject (e.g. Zimon A.D., et.al. "Decontamination"; Ampelogova N.I., et.al. "Decontamination in Nuclear Power") have been published 28–30 years ago. Therefore, it is timely and logically to update and add the information taking into account new knowledge and practical achievements. With the increase in experience of decommissioning topicality of such action is, apparently, evident.

(3) Manual **"Technologies of Restoration of Contaminated Territories and Industrial Sites"** [35].

This book describes the methods and technologies of soils and grounds decontamination with instructions on their practical availability, readiness for operation, reliability, estimated cost, processing time, efficiency for various types of pollutions and recommendations on formation of "technological trains". The great attention is given to methodology of working out and performance of contaminated territories rehabilitation: to planning, strategy working out, object's pilot survey, the account of such factors as availability of infrastructure, risks for personnel and the population, environmental impact, conformity to legislative requirements and public opinion. Carefully selected and systematized information provides reliable support not only to technical specialists involved in restoration activities, but to policy makers, planners and regulators responsible for the organization and safe performance the programmes on decommissioning of nuclear facilities.

(4) **Series of textbooks and booklets addressed to teachers and pupils of high school** [36–51].

For realization of large scale and long term decommissioning programmes it is necessary, first of all and without fail, to have sufficient contingent of competent, experienced and capable of optimal solutions specialists. Today, because of various reasons (e.g. see materials of SPbSIT presented at the IAEA RCM-2010 in Espoo, Finland), there is justified anxiety with respect to the potentialities of Russian Universities to provide nuclear complex with qualified specialists.

Therefore, we consider work on youth attraction in nuclear branch as an integral part of the IAEA project "Planning, Management and Organizational Aspects in Decommissioning of Nuclear Facilities".

With that end in view sixteen special booklets addressed to teachers and pupils of high schools have been prepared and published. These publications are devoted to various aspects of nuclear science and technology. The objective of these publications is to describe in the accessible, understandable and fascinating form history of nuclear technology development; spheres of nuclear energy applications; achievements, benefits and prospects of nuclear technologies; real and invented danger of radiation; prospects and working conditions in nuclear branch, etc.

The same idea underlies carrying out of all Russian competitions among the pupils for the best work on nuclear subjects. At the initiative of Public Council of Rosatom and with the assistance of SPbSIT Research Group such competitions were conducted already four times, and more than thousand pupils from ten regions of the Russian Federation have taken part in them. In 2011 at St.-Petersburg State Institute of Technology "The Information Centre for Atomic Energy" has been opened. This is a hi-tech specialized information complex focused on "nonprofessional" audience, and first of all — on pupils and their parents. For the first two weeks more than hundred persons has visited Centre. It points out the high interest of the public to nuclear power and allows hoping for the future rejuvenation of the branch.

9. Conclusion

Implementation of Research Project "The needs for and the basic elements of integrated approach to planning, organization and management of decommissioning activities in the Russian Federation" in the framework of the IAEA CRP on "Planning, Management and Organizational Aspects in Decommissioning of Nuclear Facilities" has resulted in the development of a set of analytical and methodical materials that are important for timely and well considered realization of a large scale decommissioning programmes in the Russian Federation. Some aspects of the problem, that are revealed and discussed in this IAEA supported study, have not even been taken into consideration up until now. At present these issues became the subject of discussions at representative scientific and technical forums, and in responsible authorities. Thus, participation of SPbSIT research group in joint investigations, initiated and coordinated by IAEA, to some extent allowed to stimulate "internal" activity in practically important area — decommissioning of nuclear facilities. This is one of the most significant results of Research Project successfully performed owing to the initiative and the aid of the International Atomic Energy Agency.

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COMPARISON OF PLANNING, MANAGEMENT AND ORGANIZATIONAL ASPECTS OF NUCLEAR POWER PLANTS A1 AND V1 DECOMMISSIONING

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Abstract

This contribution deals with planning, management and organizational aspects of decommissioning of NPP shut down due to the accident (prototype NPP A1) and NPP shut down after normal operation (NPP V1). The A1 and V1 NPPs are located very close in Bohunice nuclear site however both plants have very different technology and operational history. The preparation of A1 NPP decommissioning strategy and relevant decommissioning plans was long term process, because the plant was shut down after the accident in 1977 and decommissioning was implemented first time in Slovakia with many specific difficulties. The decommissioning planning of V1 NPP was shorter and easier, because the plant was shut down after normal operation, there were lessons learned from the A1 NPP decommissioning planning, available legislation, available financing etc.

Development of decommissioning strategies, preparation and planning for decommissioning, development of legislation for decommissioning, management of decommissioning projects and other aspects are described and compared. Lessons learned are formulated on the basis of analysis of past, ongoing and planned decommissioning activities in Slovakia.

1. Introduction

The first nuclear power plant operated in former Czechoslovakia is the NPP A1 (Fig. 1), located in Jaslovské Bohunice near the town Trnava and approx. seventy-five km from the capital of Slovakia, Bratislava. The A1 NPP (one unit reactor cooled by CO_2, moderated by heavy water and with natural uranium as fuel) is in the process of decommissioning. Nuclear power plant A1 was in operation from 1972 to 1977 and was finally shutdown after the accident (level 4 according to the international nuclear event scale) and therefore its decommissioning process is very specific. The accident had the following main technical consequences:

- Several technological reactor’s channels were overheated and consequently damaged;
- Coverage of all fuel assemblies in the active zone were also damaged;
- Primary circuit was contaminated and through leakages of steam generators some parts of secondary circuit were also contaminated.

FIG. 1. NPP A1 [1].

The first stage of the A1 NPP Decommissioning project successfully finished in 2008 and second one started in 2009. Customer is state owned Nuclear and Decommissioning Company (JAVYS), general contractor is VUJE and one of the subcontractors is company DECOM.

Decommissioning of the second Czechoslovak NPP V1 (two units with WWER-440/230 reactors) in Jaslovské Bohunice (Fig. 2) is in the very initial phase. The decision to shut down this NPP was clearly political, not a technical one. First unit of the V1 NPP was in operation from 1978 and it was shut down on 31^{st} December 2006. Second unit was in operation from 1980 and it was shut down on 31 December 2008. The first decommissioning stage will start in 2012 and second one in 2015. License for the V1 NPP decommissioning 1^{st} stage was issued by the Slovak Nuclear Regulatory Authority in July 2011.

FIG. 2. NPP V1 [1].

2. Comparison of planning, management and organizational aspects of NPP A1 and NPP V1 decommissioning

2.1. Comparison of development of decommissioning strategies for A1 and V1 NPPs

2.1.1. Development of the A1 NPP decommissioning strategy

Key aspect for the main direction of further activities after the A1 NPP accident on 22nd February 1977 was the decision made after discussion by Government of former CSSR on 17th May 1979. Government agreed, on the basis of detailed technical and economical analysis prepared by former Federal Ministry of Fuel and Energy, that operation of the A1 NPP would not be renewed and its primary active part would be shutdown.

Government also decided to formulate a new task focused on the A1 NPP decommissioning problem including possible use of secondary circuits. This task was elaborated within the state plan of science and technology development. The deadline for the preparation of the task was 31st December 1979 [2].

Preparation of required documents was very difficult, because the safe enclosure problem and decommissioning of nuclear facilities weren't taken into account before. Despite all problems, the project of state task of science and technology development was prepared by VUJE in cooperation with employees of NPP Jaslovské Bohunice. On 18 October 1979 the project was opposed and included into the plan of state tasks under the name A 01-125-104 "Termination of the A1 NPP operation" with the commencement date of 1 January 1980 and completion date of 31 December 1987. Task contained proposals of solutions from the assessment of state of the A1 NPP technology, evaluation of radioactive materials in locality of the A1 plant, review of barriers against leakages to analysis of liquidation options, related decontamination and radioactive wastes management. The problem of alternative utilization of secondary circuit was also solved within one of the subtasks.

Task A 01-125-104 was specified further in 1981 and from November 1981 it was changed to task A 01-125-109 with the same name, but one subtask (subtask 08 — see below) was added.

This task of science and technology development had following subtasks:

- Subtask 01: Basic approaches to solution of NPP decommissioning problems;

- Subtask 02: Analysis and assessment of status of the A1 NPP including barriers;
- Subtask 03: Preparation of the A1 NPP decommissioning;
- Subtask 04: Decontamination of the A1 NPP;
- Subtask 05: Treatment and disposal of radioactive waste;
- Subtask 06: Proposal of process of the A1 NPP selected equipment liquidation;
- Subtask 07: Using of secondary circuit equipment;
- Subtask 08: Termination of the A1 NPP spent nuclear fuel storage.

Solution of the above subtasks was done basically in accordance with the designed project. However it was necessary to specify and add more implementation outputs. Changes of the project were initiated in May 1985. The part of subtasks was shortened and the programme of the new subtask, focused on legislative and economical problems of liquidation, preparation of the safe enclosure of technology and establishment of related barriers, was prepared. Assessment of all technical aspects of the Project was done in cooperation with high number of specialists from the A1 NPP management and involved organizations. The new task was given a mark A 01-125-803, but the name remained the same.

Positive results of solution of the task A 01-125-109 were elaboration of the basic procedures and conception of the A1 NPP decommissioning as well as subsequent approval of conception by experts and relevant Authorities. From the viewpoint of further research activities following results were the most important:

- Technical solution of handling of slightly damaged nuclear fuel within its preparation for transport;
- Solution of high level RAW management from storage of spent nuclear fuel: so called chrompik — solidification to glass (vitrification) and dowtherm — fluid incineration;
- Detailed analysis of barriers against leakage of activity to environment;
- Detailed analysis and evaluation of large scale experiments with spent nuclear fuel in connection with creation of corrosion hydrogen and following pressuring of hermetical caskets;
- Termination of solution of problem with utilization of equipment and buildings of the A1 NPP for distribution of heat power from Jaslovské Bohunice to regional system of Central Thermal Supply.

Philosophy of preparation of a new state task of science and technology development was heavily affected by the acceptance of solution to decommission NPP after their lifetime by Czechoslovak side within the Council of Joint Economic Support (RVHP — theme KA11). The first proposal was to solve decommissioning issue of NPPs with WWER type of reactors separately from the A1 NPP decommissioning. It was decided later to prepare common solution of NPP decommissioning. Within the preparation of the research activities plan for the next 5 years a new task A 01-125-004 “Actuation of quiet state of the A1 NPP” was proposed.

Task A 01-125-803 was solved from 1986 and in principle had the same subtasks as previous task A 01-125-109. Its solution continued till the end of 1987. Final hearing confirmed successful execution of goals of task A 01-125-803 “Termination of the A1 NPP operation” despite the fact, that this problem was quite new in former CSSR. Process of solution of this task and previous ones show that there was no need to create a specialized capacity for the decommissioning problem in former CSSR. These solutions were continuously created during the course of tasks implementation only. Solution of the task was implemented in accordance with coordination plan and recommendations and conclusions of coordination commission. The NPP operators, which were in fact responsible for the solution of the task, directly used results of solution and thus relative connections between solution and implementation were ensured. This fact had positive influence on professional level of results.

Concurrently a new state task of science and technology development marked A 01-125-818 “Reconstruction and decommissioning of NPP” was prepared for the period 1988–1989. This project reflected requirements of the A1 NPP liquidation activities as well as CSSR participation in implementation of so called “complex programme of science and technology progress in member states of Council of Joint Economic Support” in task 3.1.7. — III^rd^ priority direction “Development of measures and technical means for NPPs reconstruction and decommissioning”. This task had following particular subtasks:

- Subtask 01: Basic principles of reconstruction and decommissioning of NPP;
- Subtask 02: Radiation safety during NPP decommissioning;
- Subtask 03: Decontamination and treatment of RAW;
- Subtask 04: Termination of the A1 NPP operation;
- Subtask 05: Procedures and tools for dismantling and assembly during NPP decommissioning and reconstructions;
- Subtask 06: Decommissioning of the A1 NPP.

Planned result of this task of science and technology development was to provide activities needed for specification of the A1 NPP decommissioning conception and for the implementation of given subtasks to 1995. Moreover, this task could ensure research and development basis for the elaboration of basic approaches to reconstruction and decommissioning of NPPs with WWER-440 type of reactor after their lifetime.

Despite some problems during solution of this task, it was concluded on the basis of presented results that all subtasks and requirements were fulfilled in planned terms. This conclusion was confirmed by opinion of the customer during its assessment and acceptance of results on regular working meetings. Solution of the task A 01-125-818 was finished in planned term and all results were in principle correspondent with planned goals. Invested costs were in due proportion to obtained results. Efficiency of using of invested financial costs was confirmed on the basis of more detailed calculation of economical efficiency, even though main contributions were in non-economical field.

After 1990 it was supposed that by sequential implementation of particular tasks results radiation safe condition of the A1 NPP would be achieved in 1995. Due to various objective reasons (more strict requirements of Authorities, changes of opinions on RAW treatment technologies, discussion with Russian side about transport of spent nuclear fuel, contamination of reactor hall by leaked chrompik etc.) conditions for achievement of the NPP A1 radiation safe (dry) state were more complicated and initial term was extended.

In this situation the Government of the Slovakia decided (Decree No. 266/93 from 14 April 1993, letter C) to elaborate “Comprehensive project of setting of the A1 NPP into radiation safe condition” with the term of preparation till 31st December 1994.

The first step in the preparation of the project was definition of the project submission by the group of experts from SEP-EBO (branch of state enterprise SEP in Jaslovské Bohunice), SEP, VUJE and DECOM. The project was understood in terms of comprehensive investment action as it is proposed, planned and implemented in western countries (project management).

Elaborated project was assessed and accepted by relevant supervisory and governmental bodies of SR. The project was elaborated into the form of a time schedule of achievement of radiation safe condition of the A1 NPP and accepted by the Government of Slovakia in Decree No. 649/95. This Decree also ordered to update objective, time and financial aspects of the schedule on the basis of obtained experience, available financial sources for the implementation as well as valid legislation. Governmental Decree ordered to achieve the NPP A1 radiation safe condition till the end of 2007. On the basis of the Act No.130/1998 Coll. on peaceful utilization of nuclear energy (so called Atomic Act), the term "radiation safe condition of the A1 NPP" was replaced by the term "Decommissioning of the A1 NPP — Stage I".

At the beginning of execution of the A1 NPP decommissioning process (Stage I) in compliance with the Project, completion of priority tasks — preparation and transport of remaining part of spent nuclear fuel to Russian Federation was very important. This first main task was completed in 1999, when all the remaining spent nuclear fuel was transported to RF. The next task was completion of construction and commissioning of Bohunice RAW Treatment Centre and National RAW Disposal Facility in Mochovce.

Project was reassessed from the objective, term and financial aspects at the end of 1997. The conclusion was, that for further implementation of the Project it was necessary to ensure external supplier, because branch utility of Slovenské elektrárne, SE-VYZ, did not have sufficient working capacity at that time.

Nuclear Power Plants Research Institute (now VUJE) was selected as a general supplier of the Project in international tender that was organized in 1998. The contract included time schedule, which respected schedule of the project "Decommissioning of the A1 NPP — Stage I" (till the end of 2008), approved by the Government of Slovakia on 9th June 1998.

Intent for the A1 NPP decommissioning after the termination of Stage I was elaborated in accordance with the Act No. 127/1994 Coll. on Environmental impact assessment in 2001. Continuous decommissioning of the A1 NPP was approved, according to which the A1 decommissioning is supposed to have been finished by the end of 2033. On the basis of new Atomic Law No. 541/2005 Coll. this time period was divided into the four shorter consequential periods (Fig. 3). A set of documentation required for the licensing of the Stage II was also specified.

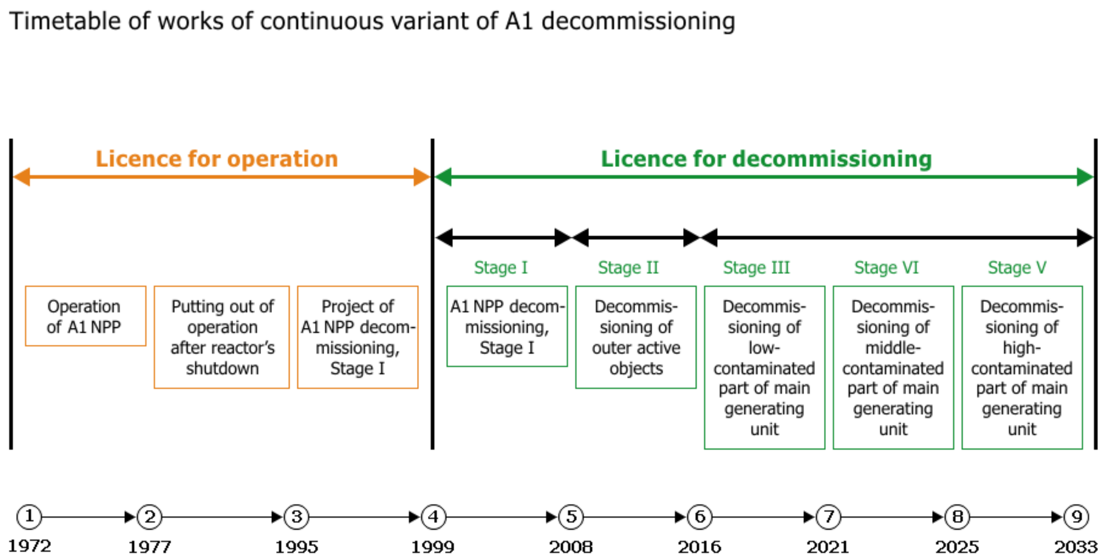

FIG. 3. Schedule of the A1 NPP decommissioning process [2].

The second stage of the A1 NPP decommissioning (2009–2016) follows continuously after activities performed in Stage I. The main goals of Stage II are decommissioning of the A1 NPP outside active buildings (objects) and some low contaminated parts of the main generating unit, radioactive waste management, contaminated soil management, technical support of planned decommissioning tasks and environmental protection during implementation of decommissioning activities.

Decommissioning of low contaminated parts of the main generating unit will be the main scope of Stage III. Following equipment will be decommissioned:

- Some parts of low contaminated smaller equipment within the transport technology system;
- Remaining equipment of auxiliary systems for D_2O a CO_2 management;
- Remaining equipment for the transport of fuel;
- Equipment for preparation of handled and non-handled spent fuel for transport.

Decommissioning of middle contaminated parts of the main generating unit with content of short lived radionuclides (mainly primary pipelines, section armatures, turbo compressors, high pressure gasholder and other parts of primary circuit) will be the main scope of Stage IV. Decommissioning of high contaminated parts of the main generating unit will be the main scope of Stage V.

From 1 August 2006 the A1 NPP decommissioning is managed and assured by Nuclear and Decommissioning Company (JAVYS), which was founded as a result of privatisation of company Slovenské elektrárne (Slovak Electric Utility). JAVYS is a successor of branch utility SE-VYZ, which ensured implementation of the A1 plant from 1996 to 2006.

2.1.2. Development of the V1 NPP decommissioning strategy

The Government of the Slovakia adopted the pledge to shut down units of the V1 NPP, gradually, Unit 1 in 2006 and Unit 2 in 2008. The decision was taken in 1999. The first of comprehensive studies dealing with decommissioning options of the V1 NPP were the studies elaborated during the years 1991 and 1992. The studies evaluated technical, organizational, economic and safety aspects (i.e. to some degree also environmental impacts) of the following five decommissioning options:

(1) Immediate decommissioning option, i.e. continuous decommissioning immediately after operation termination up to the site release for unrestricted use.

(2) Option with safe enclosure of hermetic compartments of main production buildings for a period of about 70 years with subsequent dismantling and demolition of civil structures and equipment up to the site release for unrestricted use.

(3) Option with safe enclosure of reactors in the reactor cavities for a period of about 70 years with subsequent dismantling and demolition of civil structures and equipment up to the site release for unrestricted use.

(4) Option with safe enclosure of the reactor building for a period of about 70 years with subsequent dismantling and demolition of civil structures and equipment up to the site release for unrestricted use.

(5) Safe enclosure under surveillance of constructions and buildings containing equipment with induced activity or contaminated equipment for a period of about 70 years with subsequent dismantling and demolition of civil structures and equipment up to the site release for unrestricted use.

The objective of the studies was to compare individual options and to recommend the most suitable one. For this purpose a multi-criteria method was used. On the basis of multi-criteria comparison of all five options, the option 2 was preliminary selected as the most suitable ones. However, this option was not discussed and reviewed in accordance with the valid legislation at that time and was not approved by regulatory authorities and so it can be changed whenever on the basis of further considerations of the V1 NPP decommissioning.

The first document dealing with environmental impacts of the V1 NPP decommissioning "Intention study in accordance with Act No. 127/1994 Coll." was elaborated in 1997. The document was based on previous studies and evaluated the impacts of options 1, 2 and 5. This document was also not submitted to appropriate regulatory bodies and was not reviewed or approved.

At the end of 1998, another document "Strategy of NPP decommissioning" was elaborated based on previous ones whose objective was to find, for strategic conceptions of WWER NPP decommissioning in Slovakia, an optimum extent of equipment to be placed under the safe enclosure and an optimum duration of the safe enclosure. While the study did not answer the question of optimum extent of the safe enclosure, the conclusion on its duration was that the safe enclosure should not be shorter than 30 years nor longer than 70 years and that the period of 50 years could be sufficient since its further extension will not result in a substantial change of parameters being decisive for the decommissioning process.

"Updating the V1 NPP decommissioning plan" and the "Conceptual plan of the V1 NPP decommissioning" were prepared in parallel in 2002. Following decommissioning options were considered:

- Immediate decommissioning option, i.e. continuous decommissioning immediately after operation termination up to the site release for unrestricted use;

- Safe enclosure under surveillance of constructions and buildings containing equipment with induced activity or contaminated equipment for a period of 30 years with subsequent dismantling and demolition of remaining civil structures and equipment up to the site release for unrestricted use;

- Option with safe enclosure of reactors in the reactor cavities for a period of 30 years with subsequent dismantling and demolition of remaining civil structures and equipment up to the site release for unrestricted use.

A fundamental difference in comparison with previous approaches was the reduction of deferring time for relevant decommissioning options.

Another document considering the V1 NPP decommissioning was prepared in 2004 "Redevelopment of V1 NPP" according to particular provision of the Governmental decision No. 974/2000, requiring "to ensure an analysis of economical utilization of V1 NPP civil structures and technological equipment and an analysis of use of the site after V1 NPP decommissioning". In its main conclusions, the study recommended to decommission the plant as soon as possible.

The important step of documentation preparation for the V1 NPP decommissioning was the elaboration of the Conceptual Plan of the V1 NPP Decommissioning in 2002 and its update in 2006. The plan provides general technical and financial information about selected possible and reasonably executable options of decommissioning, which are in compliance with Slovak legislation, in order to prove in this way that decommissioning process will be technically executable and, most of all, appropriate from the point of view of protection of health, nuclear and radiation safety, physical protection and preservation of environment. Four options were developed, see below Figure 4.

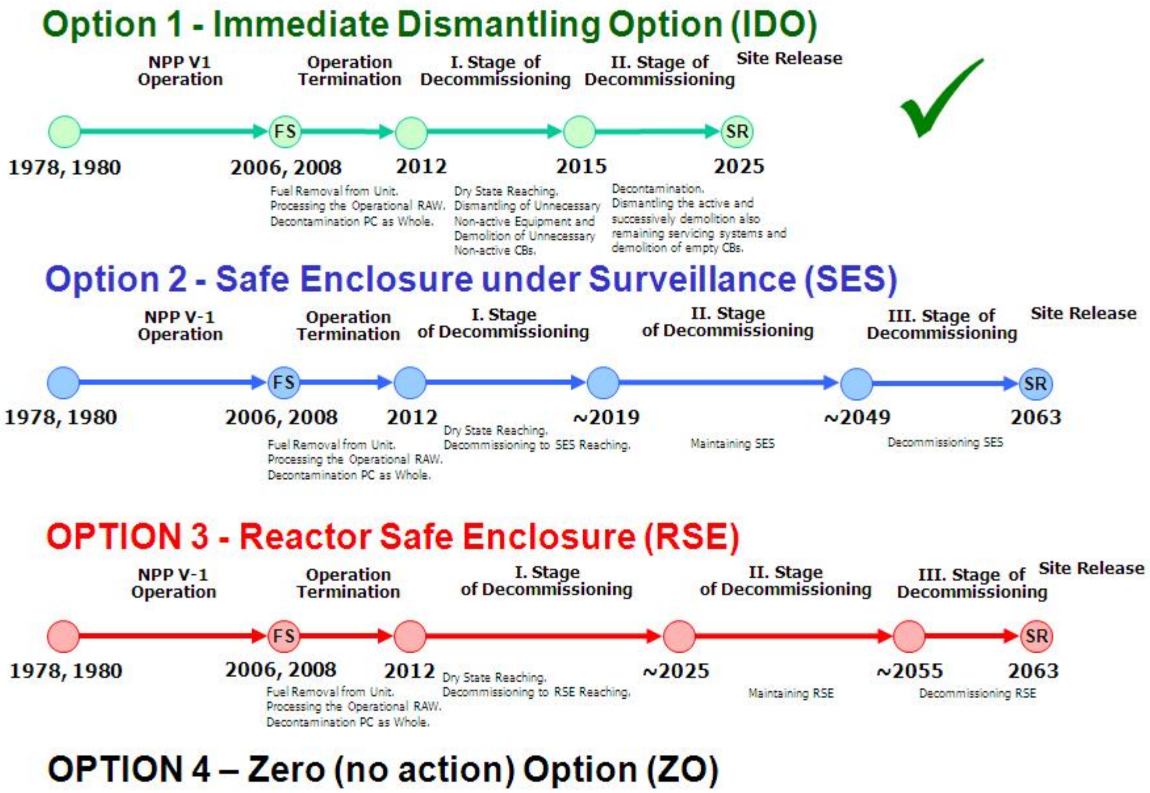

FIG. 4. Considered options of the NPP V1 decommissioning.

The main characteristic of Option 1 is decommissioning of reduced range of existing construction objects from object composition of the V1 NPP by immediate and continuous disassembly of facilities and technological units, demolition of construction objects up to the bottom of the shaft and preparation of locality for construction of new nuclear source.

In Options 2 and 3 a wider composition of construction objects is presupposed to be decommissioned to achieve unlimited locality utilization, however, construction objects will be demolished only up to elevation of 1 m. The whole decommissioning process is divided into two stages (for Option 1) and into three stages (for Options 2 and 3), which represent specific areas of decommissioning.

During the period of operation termination all the fuel will be taken away from unit and, consequently decontamination of the primary circuits carried out, after which the whole primary circuit is drained and dried. Remaining part of operational radioactive waste is processed and the other necessary preparation activities for decommissioning are performed. During termination of operation, documentation necessary for Stage I of decommissioning will be prepared and approved. Period of the operation enclosure is finished by taking fuel away from storing pool to intermediate storage of spent fuel and by issuing the permit for decommissioning by authorized Slovak bodies. It is supposed that permit for Stage I of decommissioning will be issued by the Nuclear Regulatory Authority of Slovakia by the end of 2011 and decommissioning itself would start in 2012.

With regard to the range of decommissioned technological facilities and objects and with regard to specific conditions of decommissioning, activities related to V1 NPP decommissioning will be substantially time demanding. Also when all the available technical resources for decontamination, disassembly, demolition and treatment of radioactive waste are used and optimal manner of their employment is applied, complete decommissioning will last for period of 14–22 years (Option 1).

Bohunice International Decommissioning Support Fund (BIDSF) was created as compensation by the European Union. Administrator of the fund is the European Bank for Reconstruction and Development (EBRD). Financing is executed in form of grant contracts, in which frame definitions of projects extents are introduced.

Projects financed/cofinanced from BIDSF are managed by the Project Managing Unit (PMU) that consists of JAVYS staff and PMU Consultant (consortium of four companies, which succeeded in international tender: Iberdrola Ingeniería y Consultoría, Empresarios Agrupados International, Soluziona Ingeniería, Electricité de France).

Conceptual plan of the V1 NPP decommissioning (project BIDSF B6.1 [3]) was negotiated in August 2006 in the Board of Directors of JAVYS resulting in decision to prefer variant of "continuous decommissioning". The main reason for this preference is maintenance of continuity of processing of radioactive waste on existing facilities. Assessment of the V1 NPP Decommissioning Plan from the point of view of influence on environment (project BIDSF B6.2 [4]) was finished in October 2006 and approved by the Ministry of Environment in March 2007. Consequently, the more detailed Decommissioning 1st Stage Plan (project BIDSF B6.3 [5]) that describes procedure and manners of execution of the process was developed for the Nuclear Regulatory Authority in order to obtain licence for the decommissioning stage. The license for the V1 NPP decommissioning 1st stage was issued on 19 July 2011.

Within the preparation and implementation of the V1 NPP overall decommissioning process the following groups of particular projects were defined:

- A projects that are focused on termination of operation activities;
- B projects that deal with preparation of decommissioning documentation, training of staff etc.;
- C projects that deal with radioactive waste management;
- D projects that will be focused on implementation of the decommissioning activities.

2.1.3. Comparison of development of decommissioning strategies for the A1 and V1 NPPs

NPP A1 is the power plant, in design of which part of its decommissioning was omitted. No decommissioning plan was developed before or during operation. The fact that decommissioning came about after a serious accident and inappropriate handling with spent fuel caused expressive troubles in the process of the A1 NPP decommissioning.

Development of the A1 NPP decommissioning strategy was long term and partially spontaneous process, mainly because decommissioning was a relatively new problem in former Czechoslovakia. Process of solution of decommissioning tasks shows, that there was no created need for a specialized capacity in the past. Complexity of many technical problems related to decommissioning of the A1 NPP after accident superimposed difficulty of the overall process.

Gradual development of opinions regarding the A1 NPP decommissioning strategy took about 15 years from the plant shutdown. Only after 1992 were developed basics for the current decommissioning strategy. Continuous decommissioning of the A1 NPP was approved, according to which the A1 plant decommissioning is supposed to have been finished by the end of 2033.

NPP V1 is the power plant, which was shut down after normal operation without any accident. This is the first and very important difference in comparison with the A1 NPP. The second difference is that no decommissioning documentation was prepared during operation of the A1 plant, however the first decommissioning documentation for V1 NPP started to be elaborated from early 1990s, i.e. during operation of both units of this plant. In the first decommissioning studies the implementation of long term safe enclosure was evaluated as preferred option however the today's strategy is the immediate (continuous) decommissioning of the V1 NPP.

Moreover, according to the Slovak legislation, particularly to provisions of the Act No. 238/2006 Coll. on National Nuclear Fund for decommissioning, the proposal of Strategy of back end of nuclear energy was recently elaborated. Proposal of the Strategy, together with the Report on the impact of given strategic document on environment (as required by provisions of the Act No. 24/2006 Coll. on environmental impact assessment), was prepared by the Board of Governors of the National Nuclear Fund.

According to the legislatively given structure, the Strategy can be divided onto two basic parts:

- Conceptual technical solutions for decommissioning of the Slovak nuclear facilities, storage and disposal of radioactive waste and spent fuel, their supposed schedules and interdependencies;
- Economical considerations where the long term income and needed withdrawal from the National Nuclear Fund is balanced, leading to conclusions regarding the price of electricity and corresponding issues.

The strategy considers the last updated conceptual decommissioning plans of the Slovak NPPs. It also includes plans of activities leading to decision on the final spent fuel management step based on the updated plan on deep geology development, as its integral part. The strategy has been already approved by the responsible ministry (the Ministry of Economy) and currently is waiting for the Governmental approval.

This is the first complete and complex Slovak Strategy for the back end of nuclear energy after 13–14 years. Therefore it considers in more details the oncoming activities in comparison with the middle and long time (100 years) conceptual plans. According the corresponding Act, the Strategy shall be updated with the periodicity 5 years.

2.2. Overview of some aspects related to preparation and planning for decommissioning of the A1 and V1 NPPs

Some aspects related to the preparation and planning for decommissioning in case of accidental A1 NPP and normally shut down (even though untimely) V1 NPP are summarized in Table 1. One can see significant differences in both plants decommissioning preparation and planning.

TABLE 1. OVERVIEW OF SOME ASPECTS RELATED TO THE PREPARATION AND PLANNING FOR DECOMMISSIONING OF A1 AND V1 NPPS

Evaluated Aspect	NPP A1	NPP V1
Funding of decommissioning	Funding was not established in the time of shut down at all. Funding of ongoing decommissioning activities is from Slovak sources only.	National fund was established during operation of plant, but sufficient financial sources were not accumulated. Additional funding through BIDSF is available now, but certain co-funding from Slovak sources is required.
Preliminary report on decommissioning process	Not prepared at all	Not prepared at all
Preparation of preliminary conceptual decommissioning plan	Not prepared at all	Not prepared before commissioning of plant, but later during operation period
Upgrade of conceptual decommissioning plan during operation of NPP	Not done at all	Done together with preparation of some other conceptual documentation
Preparation of decommissioning plan for licensing	Done, but only after the termination of operation	Done
EIA for decommissioning	Done, but only after the termination of operation	Done during operation of the plant
Preparation of decommissioning concept for period after termination of licensing validity	Done	Done
Realization of physical and radiological characterization for decommissioning	Done/will be done before the implementation of particular activities	Systematically done during the transition period from operation to decommissioning [6]
Preparation of decommissioning implementation documentation	Done / will be done in due time	Will be done in due time
Final description of decommissioned NPP site and all implemented activities	Will be done in due time	Will be done in due time

It is obvious, that in case of the accidental A1 NPP the decommissioning documentation was not available at all when its operation was terminated. The later preparation was long term process, mainly because of difficult technical situation of the plant itself as well as by reason that legislative requirements for decommissioning were not defined as it is today.

Preliminary decommissioning documentation of the V1 NPP was not prepared before the plant was commissioned, but it was done later during its operation in accordance with requirements of Atomic Law and its relevant decrees.

2.3. Particularities of the A1 and V1 NPPs decommissioning

2.3.1. Particularities of the A1 NPP decommissioning

Certain technology systems of the A1 NPP contain liquid radioactive waste with high specific activity that is in some cases close to 10^{11} Bq/dm^3. Moreover some types of waste have very specific physical and chemical properties including sludge phases in liquids or organic liquid waste. Significant restrictions for the treatment of A1 NPP radioactive waste are given by content of alpha radionuclides. Rate of alpha radioactivity to ^{137}Cs activity can be in accordance with history of particular stream of radioactive waste from 1:10^1 to 1:10^4. The A1 NPP reactor contains certain amount of radioactive graphite what is the only reactor's graphite in Slovakia. Extensive characterization was/is thus needed for historical waste.

Unique procedures and equipment are needed to manage the historical waste and to implement decommissioning activities. Complexity of many technical problems related to decommissioning of the A1 NPP after the accident superimposed difficulty of the overall process.

It should be also highlighted that comprehensive national system of RAW management did not exist up to 1999. Uniform decommissioning financing system did not exist up to 1994, where the first relevant legislation was issued. Decommissioning legislation was not available up to 1987, where the first regulation on RAW management was issued by former CSKAE. Development of the A1 NPP decommissioning strategy was long term and partially spontaneous process, mainly because decommissioning was a relatively new problem in former CSSR.

The ongoing A1 NPP decommissioning activities are managed through the general contractor approach. Current project management structure of the A1 NPP decommissioning project is clearly established on both sides of the Client (JAVYS) and the General contractor (VUJE).

The most experienced retired staff from the A1 NPP quite often accepted working proposals from private companies involved in the A1 decommissioning activities. Achieved unique experiences are in such way used for the A1 NPP decommissioning tasks implementation. Rejuvenation of the A1 NPP decommissioning staff is slow and not an easy process. One of the consequences of the certain lack of A1 NPP decommissioning staff is that the A1 (JAVYS) needs to use services of qualified general contractor subcontractors and to order implementation of specific decommissioning activities. Also some lack of knowledge and experiences transfer between older and younger staff could not be identified until recently. Direct transfer of the decommissioning knowledge and experiences between the staff of the A1 and V1 plants is questionable.

2.3.2. Particularities of the V1 NPP decommissioning

NPP V1 is the power plant, which was shut down after normal operation without any accident. The first decommissioning documentation for the V1 plant started to be elaborated from early 1990s, i.e. during operation of both units of this plant. Several comprehensive decommissioning studies and documents were elaborated from 1991 to 2006.

In the first decommissioning studies the implementation of long term safe enclosure was evaluated as preferred option; however today's strategy is the immediate (continuous) decommissioning of the V1

NPP. According to the Slovak legislation, particularly to provisions of the Act No. 238/2006 Coll. on National Nuclear Fund for decommissioning, the Strategy of back end of nuclear energy was elaborated (it includes also the V1 NPP decommissioning strategy).

Activities related to the transition from operation to decommissioning (so called pre-decommissioning activities) are implemented from both units shut down to beginning of the decommissioning 1st stage (2012–2014). The decommissioning 1st and 2nd stage activities are planned with BIDSF support. Project management structure of the V1 NPP decommissioning process will include combination of JAVYS own staff involvement and external subcontractors services. General contractor project management approach similar to A1 NPP one is not expected.

The political decision to shutdown the V1 NPP was accepted by the Slovak Government in 1999. The plant operational company was afraid that qualified staff needed for safe and reliable operation could give notice before time of the V1 shut down (12/2006, 12/2008), because of fear from loss of existence guarantees. It could have influence on the V1 NPP operational licence. Staff important from the viewpoint of nuclear safety was stabilized through so called "Compensation Agreement", where financial compensations (up to 60 average monthly salaries) for the staff (so called authorized persons) were agreed.

The "Compensation Agreement" had very positive influence on stabilization of authorized persons for period from decision to shut down the V1 NPP to shut down itself. Very high level of operational safety culture was achieved during this period. However the "Compensation Agreement" has now negative influence, because the authorized persons can not continue to work on the V1 NPP decommissioning after they received compensation. It can cause troubles with the V1 plant decommissioning implementation in near future.

2.4. Cost estimating and funding

2.4.1. Development of code OMEGA for the decommissioning costs estimating

The computer code OMEGA was developed in Slovakia in the period 1999–2004 as the universal tool for evaluation and optimisation of decommissioning costs for nuclear installations with any systems and structures and any radiological situation after shutdown including post accidental, as was the case of A1 NPP in Slovakia. The code was used for evaluation of decommissioning cost for NPPs in Slovakia and in several international cost studies.

The calculation structure of the code is based on standardised list of cost items which was issues jointly in 1999 by IAEA, the OECD Nuclear Energy Agency and the European Commission [7] to serve as a general basis for presentation of decommissioning costs and for promoting the harmonisation in decommissioning costing. The standardised structure has been currently updated by the same organisations as the International Structure for Decommissioning Costing (ISDC) based on the experience gained over ten years of use of the original standardised listing. The ORACLE based computer code OMEGA implement the ISDC structure directly as the cost calculation structure by extending the generic ISDC levels. Summary of lessons learned with the use of the code are presented in [8].

Main features of the code and the principal scheme of the code shwon on Figure 5 are as follows [9]:

- Calculation structure of the code implements in full extent the generic ISDC structure; it is one compact package which includes the waste management in full extent.
- Calculation process is sequentially linked up in such a way that it simulates real decommissioning process flow and relevant material/radioactivity flow.

– Calculation process is nuclide resolved and respects the radioactive decay of individual radionuclides. This approach supports the evaluation of waste management issues and exposure of personnel.

– The code generates the Gantt chart of the decommissioning project based on user defined WBS, on facility inventory database and allocate the cost and other used defined resources to the items of the Gantt chart.

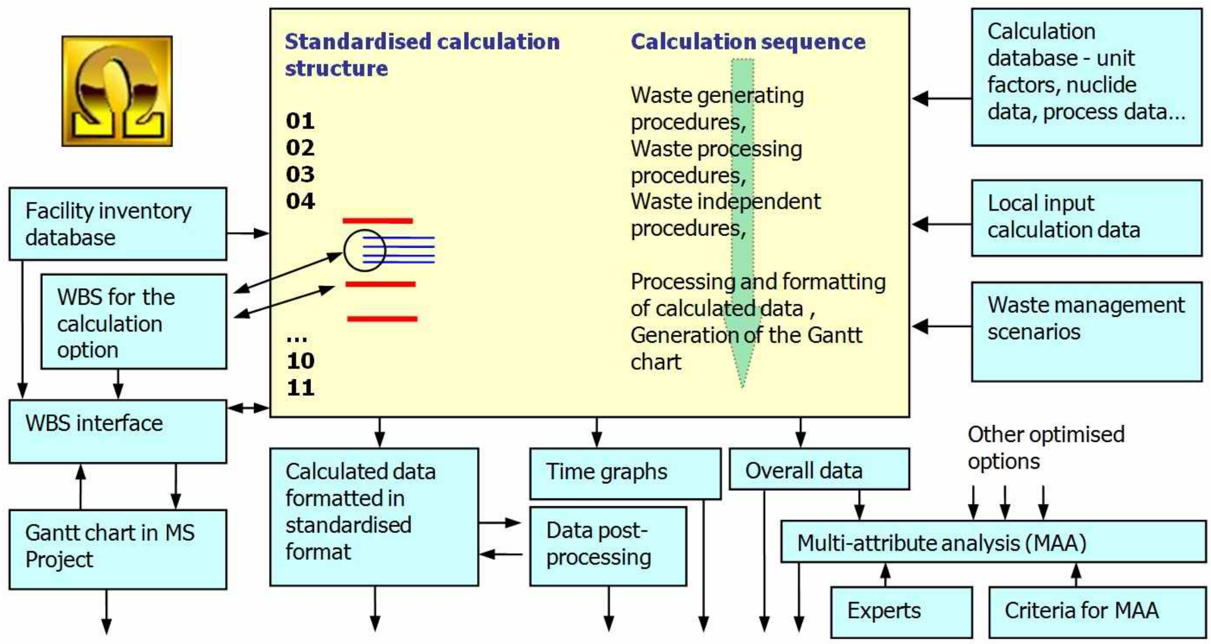

FIG. 5. Principal scheme of the calculation code OMEGA.

The base of the OMEGA code is a general ISDC template which consists of two types of extended segments. Items for period dependent activities and collateral cost were developed as fixed structures with redundant items. For inventory dependent activities were developed special segments which are extended to lower levels automatically by the code depending on the content of the facility inventory database with the object floor room equipment structure. Several modes of these dynamical segments were developed. The general ISDC template is allocated to the given decommissioning option and adapted by the user according the scope of the option. Adaption means deleting segments obsolete for the option and/or adding new segment. Option specific static ISDC template is developed at this step.

In the next step, the option specific ISDC template is used for generation of the ISDC cost calculation structure specific for a decommissioning option, by interaction of the option specific ISDC template and the facility inventory in order to develop the full list of elementary hands on activities for the project. The ISDC cost calculation structure involves static segments for period dependent activities and for collateral cost and dynamically generated segments for inventory dependent activities with room oriented or system oriented structure [9]. At the end, the extent of calculation is defined by involving the relevant calculation items and introducing the input data for period dependent activities and collateral cost. Using this approach, the ISDC cost calculation structure can be generated for any nuclear facility.

2.4.2. Evaluation and optimisation of waste management issues

The ISDC compact calculation package involves activities for managing of radioactive, hazardous and conventional waste. A system of internal data linking simulates the real flow of materials and of radioactivity linked to the individual material items. Input data for this system are one material items of primary and secondary waste which are generated by the code during dismantling based on the inventory data. System consists of sorting procedures, compartments for individual waste management techniques and systems for calculating the decay of individual radionuclides. In this way it is possible to evaluate various waste management scenarios with various techniques, disposal approaches, unconditional and conditional release of materials, etc.

2.4.3. Evaluation and optimisation of exposure

In the frame of calculation of labour cost for elementary activities, the manpower components are calculated as the first. Manpower components are at the same time the base for calculation of the exposure of personnel. Manpower components involve all productive and non-productive items and by allocating the dose rate components to individual items of the manpower components, the collective dose for working groups due to external exposure is calculated. As for the internal exposure, based on the manpower components, the code evaluates the level of radioactive aerosols generated at the working area during performing of dismantling activities depending on the level of contamination, radionuclide composition of contamination and ratio of releasing of radionuclides from contamination to working environment. Based on parameters of breathing, parameters of protective clothing and conversion factors Sv/Bq for individual radio nuclides, the code evaluates the risk of internal exposure.

The system was developed which evaluates the dose at the working area for elementary decommissioning activities and based on the limit value of the dose rate predefined by the user, the code switches from manual to remote techniques. By varying of the limit value, the optimal threshold for implementation of remote controlled dismantling techniques may be identified. System enables also the evaluation of individual effective dose for selected individual members of working groups and optimisation of exposure of these individuals in order to keep the annual limit of individual effective dose.

2.4.4. Management of decommissioning schedules

The code generates the Gantt chart of a decommissioning project based on the work breakdown structure (WBS) template defined by the user as the hierarchical structure within one of the modules of the code. WBS template is defined as the structure of decommissioning tasks, parallel to ISDC cost calculation structure. These structures are linked by the user according the principles of the second approach of implementing the ISDC. The WBS template involves also the information, which WBS tasks should be broken down into lower levels based on the content of facility inventory database. Based on the information involved in the WBS template, on the content of the facility inventory database (buildings, floors, rooms structure) and based on the linking between WBS and the ISDC cost calculation structure, the code generates the detailed Gantt chart of the decommissioning option and allocate the cost and other project management data, defined by the user, as resources to tasks of the Gantt chart.

The baseline Gantt chart can be optimised as for starts data and durations of selected tasks; the data are then reloaded to the OMEGA code for recalculation of costs and other data according the settings of the Gantt chart. An interface was developed for linking the WBS items, ISDC items and the facility inventory database to enable the iterative work in several optimisation cycles.

2.4.5. Funding of the A1 NPP decommissioning

Funding of the A1 NPP decommissioning is done only through National Nuclear Fund. The A1 NPP decommissioning costs (in price of year 2010) are as follows [10]:

- Total costs for the A1 NPP decommissioning will be about 930 M€:
- From that the relevant costs spent in period from the A1 NPP shut down (1977) to 2015 will be about 432 M€;

– From 2016 to the end of decommissioning (2033) the costs will be about 498 M€.

The A1 NPP never contributed to the National Nuclear Fund because no financial mechanism existed during the time of the A1 NPP operation. Therefore the financing of the A1 NPP decommissioning were done through state budget and after the creation of National Nuclear Fund in 1995 it was done from financial sources generated and accumulated there by other NPPs. The potential lack of financing of the A1 NPP decommissioning represents the financial risk and the issue has to be solved by the A1 NPP operator in cooperation with other relevant and responsible Slovak bodies (National Nuclear Fund, Ministry of Economy, Ministry of Finance etc.).

2.4.6. Funding of the V1 NPP decommissioning

Funding of the V1 NPP decommissioning is done from BIDSF (Bohunice International Decommissioning Support Fund) that is managed by European Bank for Reconstruction and Development as well as from the National Nuclear Fund and other national sources (co-financing of some particular decommissioning projects). The last estimations of the V1 NPP decommissioning costs (in price of year 2010) are as follows [10]:

– Total costs for the V1 NPP termination of operation stage are about 24 M€;

– Total costs for the V1 NPP decommissioning 1st stage will be about 212 M€;

– Total costs for the V1 NPP decommissioning 2nd stage will be about 546 M€.

2.5. Other non-technical factors of A1 and V1 NPPs decommissioning

Assessment of influence of radiation safety and radiation protection principles (ALARA) on the decommissioning implementation process is very important issue mainly for the A1 NPP. The radiation situation there is very different in various rooms and therefore any decommissioning activity has to be carefully planned taking account local radiation conditions. Alpha contamination complicate radiation situation as well. It can be expected that the V1 NPP decommissioning implementation will be easier from the viewpoint of the radiation safety assurance.

QA management system developed and implemented by company JAVYS includes ISO standards, Manual of Integrated QA Management System, particular QA programmes, internal QA procedures etc. Every subcontractor has to have own QA system that is compatible with the QA management system of JAVYS. The QA management system of external subcontractor can be audited by JAVYS QA managers in order to check current status of implemented QA system and improve it on the basis of QA audit findings and conclusions.

Training of personnel of A1 and V1 NPPs has two main parts:

(1) Theoretical training that is done in VUJE's Training Centre. The Training Centre has an authorization from Nuclear Regulatory Authority to provide training of several categories of decommissioning personnel. Theoretical training is terminated by test and issue of certificate.

(2) Practical training at particular working place on site at A1 or V1 NPPs. This part of training follows after the theoretical one.

According to Slovak Atomic Act is the responsibility for safe decommissioning fully on holder of decommissioning license. It is "owner" and operator of A1 and V1 NPPs — company JAVYS. It should be underlined that the decommissioning responsibility is indivisible and non-transferable.

3. Collaboration with other CRP members

Shortly after the first RCM in Dounreay in January 2009 the participants of the CRP from the Slovakia and Czech Republic found useful to organize site visits of their nuclear sites and to discuss possible cooperation in the field of decommissioning and RAW management.

The reciprocity visits were organized during 2010. Colleagues from the Czech Republic (NRI Řež) visited the company VUJE in Trnava and nuclear sites in the Bohunice (NPP A1 and Bohunice RAW treatment facility) and in Mochovce (National RAW Repository Facility).

Colleagues from Slovakia (companies VUJE and JAVYS) visited following facilities in the Nuclear Research Institute Řež:

- Facilities for RAW management (Centre for RAW Management, Pilot Bitumenation Unit, hot cells in the Radiochemistry Building, High Level Waste and Spent Fuel Storage);

- Facilities being decommissioned (Reloading site, RAW Surface store, Building with old technology for RAW management).

Discussions organized were very open and can serve as basis for possible future cooperation in the field of decommissioning and RAW management.

4. Publications resulting from the CRP

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HUTTA, J., MICHAL, V., PEKAR, A., ZATKULAK, M., "Development of decommissioning plans for A1 and V1 NPPs in Slovakia", EPRI 10th International Decommissioning and Radioactive Waste Management Workshop, 20–22 September 2011, Lund, Sweden (2011).

5. Conclusions

Despite the fact, that both A1 and V1 NPPs belongs to the same state owned organization (JAVYS) and are located in one nuclear site (Jaslovske Bohunice), the real particularities of both plants decommissioning were / are / will be very specific and quite different. Main differences, when comparing the A1 and V1 NPPs decommissioning, are as follows [11]:

- The total duration of the A1 NPP decommissioning will be about 35 years (after 5 years of operation). The total duration of the V1 NPP decommissioning is planned to be about 14 years (after 28 years of operation). The prolongation factor about 2.5 can be identified for the A1 NPP decommissioning in comparison with the V1 plant.

- Much more research and development activities and additional safety measures activities were needed for the A1 NPP as expected and planned for the V1 NPP. There is a long list of procedures, techniques, equipments which were developed as unique or adapted systems for the A1.

- The analysis of available cost data and estimated costs for decommissioning up to 2033 shows, that the total A1 NPP decommissioning costs (one unit, 150 MWe) are higher than estimated costs for the V1 NPP decommissioning (two units, 880 MWe).

Above is mentioned that both A1 and V1 NPPs belongs to the state owned company. It means that process of privatization which passed in Slovakia as well as in other countries of the former Eastern block had no influence on ownership of decommissioning and RAW management facilities. Both

NPPs in decommissioning are still owned by the government together with other facilities for treatment and disposal of radioactive waste.

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INTEGRATED PROGRAMME CONTROL SYSTEMS: LESSONS LEARNED

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Abstract

Dounreay was the UK's centre of fast reactor research and development from 1955 until 1994 and is now Scotland's largest nuclear clean up and demolition project. After four decades of research, Dounreay is now a site of construction, demolition and waste management, designed to return the site to as near as practicable to its original condition. Dounreay has a turnover in the region of £150 million a year and employs approximately 900 people. It subcontracts work to 50 or so companies in the supply chain and this provides employment for a similar number of people. The plan for decommissioning the site anticipates all redundant buildings will be cleared in the short term. The target date to achieve interim end state by 2039 is being reviewed in light of Government funding constraints, and will be subject to change through the NDA led site management competition.

In the longer term, controls will be put in place on the use of contaminated land until 2300. In supporting the planning, management and organisational aspects for this complex decommissioning programme an integrated programme controls system has been developed and deployed. This consists of a combination of commercial and bespoke tools integrated to support all aspects of programme management, namely scope, schedule, cost, estimating and risk in order to provide baseline and performance management data based upon the application of earned value management principles. Through system evolution and lessons learned, the main benefits of this approach are management data consistency, rapid communication of live information, and increased granularity of data providing summary and detailed reports which identify performance trends that lead to corrective actions. The challenges of such approach are effective use of the information to realise positive changes, balancing the annual system support and development costs against the business needs, and maximising system performance.

1. Introduction

1.1. Brief history

1.1.1. Dounreay

In 1954, the Government announces that Dounreay is to become the UK fast reactor research and development site. Agricultural land next to a disused wartime airfield in Caithness, Scotland was chosen to build and test the reactor and associated chemical plants. Since the start of the programme the Dounreay site has had three development reactors built, those being the Dounreay Fast Reactor (DFR), Dounreay Materials Test Reactor (DMTR) and the larger Prototype Fast Reactor (PFR). In addition, Dounreay also undertook research and development for reactor fuel reprocessing within a number of on-site laboratories.

In 1988, the Government announces a phased end of fast reactor research and development in the UK. The Dounreay reactors were shut down and all fuel fabrication was subsequently ceased. Dounreay Site Restoration Plan was established in 2000, laying out the 60 year plan to decommission the site at cost of £4.3 billion.

In 2005, the Nuclear Decommissioning Authority (NDA) was created through the UK Energy Act 2004. The Nuclear Decommissioning Authority is a non-departmental public body with the goal to deliver the decommissioning and cleanup of the UK's civil nuclear legacy in a safe and cost effective manner, and where possible to accelerate programmes of work that reduce hazard. This goal is to be achieved through introducing innovation and contractor expertise by competition.

In 2007, the NDA takes ownership of Dounreay [1] and with support from industry experts establishes its own processes and procedures to be complied with by the UK nuclear decommissioning sites. One set of procedures focuses on programme controls, in which a framework is provided on how decommissioning programmes are to be defined and managed. This framework is based on earned value management principles.

In 2008, Dounreay Site Restoration Limited (DSRL) was formed in accordance with the NDAs goals for competition. Operating under contract to the NDA, DSRL is the site licence company responsible for the site closure programme; DSRL holds the site licence, waste disposal authorisation and other necessary legal permits for managing the site. Before then, the site was managed by the UK Atomic Energy Authority (UKAEA).

In 2009, UKAEA Ltd was sold by the UK Atomic Energy Authority to Babcock International Group. DSRL itself has a turnover in the region of £150 million a year and employs approximately 900 people. It subcontracts work to 50 or so companies in the supply chain and this provides employment for a similar number of people.

By April, 2012 the NDAs led competition to manage and operate the Dounreay site decommissioning programme will be complete and a commercial partnership will have undertaken transition to manage and operate DSRL. Under this NDA contract the winning partnership will provide an accelerated and reduced cost site decommissioning programme in line with NDAs annual funding levels.

1.1.2. Earned Value Management (EVM)

Earned Value Management (EVM) emerged as a financial analysis speciality in the United States (US) Government programmes in the 1960s, but it has since become a significant branch of project management and cost engineering. The original concept was called PERT/COST, but it was considered overly burdensome by contractors who were mandated to use it, and many variations of it began to emerge among various procurement programmes. In 1967 in order to establish a consistent approach the US Department of Defence established a criterion based approach, using a set of 35 criteria, called the Cost/Schedule Control Systems Criteria (C/SCSC).

In the late 1980s and early 1990s, EVM emerged as a project management methodology to be understood and used by managers and executives, not just EVM specialists. EVM was quickly adopted by the National Aeronautics and Space Administration, United States Department of Energy and other technology related agencies. Many industrialized nations also began to utilize EVM in their own procurement programmes. The construction industry was an early commercial adopter of EVM. Closer integration of EVM with project management profession accelerated in the 1990s. The Project Management Institute (PMI) in 1999 included an overview of EVM in its first Project Management Body of Knowledge (PMBOK) which was expanded in subsequent editions. EVM is now a recognised project management methodology to identify cost and schedule variances within a programme of work and to forecast the final cost to complete the work.

The UKs Nuclear Decommissioning Authority has established procedures to be adopted by the UKs nuclear decommissioning site management teams. In particular the NDAs programme control procedures utilizes the EVM principles as the framework for best practice.

1.2. Research project outline

In accordance with the theme of this TECDOC on planning, management and organizational aspects in decommissioning of nuclear facilities, the UK led research has been focused on the application of EVM as applied to the Dounreay decommissioning programme. To support the application of EVM an Integrated Programme Controls (IPC) system has been established at Dounreay, in which its benefits and problems are analysed.

The objectives of the research are:

- To define the principles, methodologies and benefits of earned value management in the application of nuclear decommissioning;
- To define the principles, methodologies and benefits of an integrated programme control system in managing scope, schedule and cost.

The anticipated outcomes being:

- Documented principles of earned value management and its application within a real programme of nuclear decommissioning within the UK;
- Documented lessons learned from implementing earned value management principles which will include training/learning requirements, cultural/business changes, performance reports/data analysis, performance metrics, change control and business rules;
- Documented principles of an integrated programme control system with respect to capturing and managing scope, schedule and cost as applied within a real programme of nuclear decommissioning within the UK and in support of earned value management;
- Documented lessons learned from implementing an integrated programme control system which will compare Commercial Off The Shelf (COTS) versus bespoke development, data management, user interfaces, roll out and training, development and management of the tool set, security and data integrity.

2. Earned value management principles

Earned Value Management encompasses the main components of programme management, those being scope, time and cost. Through its structured approach it provides a method to establish a baseline plan from which performance can be measured. There are three fundamental elements used within EVM which are based upon cost, those being:

- **Budgeted Cost of Work Scheduled (BCWS):** This represents the estimated cost over time for the work.
- **Budgeted Cost of Work Performed (BCWP):** This represents the earned value of the work completed at a point in time.
- **Actual Cost of Work Performed (ACWP):** This represents the actual cost of the work completed at a point in time.

Example:

The scope of work is to process five drums of waste over a period of five months ie one drum to be processed in each month.

The estimated cost of processing one drum is say £10,000 (£10k). Therefore the baseline plan is to spend £10k/month, with an estimated total cost of £50,000 (£50k).

Baseline Plan to Spend £10k Each Month Processing One Drum in Each Month

At the end of the 2nd month of processing the **plan** was to complete two drums, therefore the BCWS is £20k.

On checking the physical progress made the processing team have actual processed three drums within the two month period. Therefore the earned value of the work completed is £30k. This represents the planned worth of the work and is termed the Budgeted Cost of Work Performed (BCWP).

Finally, when collecting the actual cost of the three drums processed, as opposed to the planned costs, it is determined that the Actual Cost of Work Performed (ACWP) is only £15k, significantly less then originally estimated and planned.

Therefore at the 2nd month we have identified the following data:

- Budgeted Cost of Work Schedule (**BCWS**) = **£20k**
- Budgeted Cost of Work Performed (**BCWP**) = **£30k**
- Actual Cost of Work Performed (**ACWP**) = **£15k**

By using this data we can determine a number of factors as follows:

- Schedule Performance Index (**SPI**) = BCWP / BCWS = £30k / £20k = **1.5**
- Cost Performance Index (**CPI**) = BCWP / ACWP = £30k / £15k = **2.0**

– Schedule Variance (**SV**) = BCWP–BCWS = £30k–£20k = **£10k**

– Cost Variance (**CV**) = BCWP–ACWP = £30k–£15k = **£15k**

By using this data, indices and variances provide a picture of the health of a package of work can be determined, in this example the positive results indicate a package of work which is ahead of plan and below estimated costs. This EVM approach can be taken one step further by producing the above data within a graph as shown below within Figure 1.

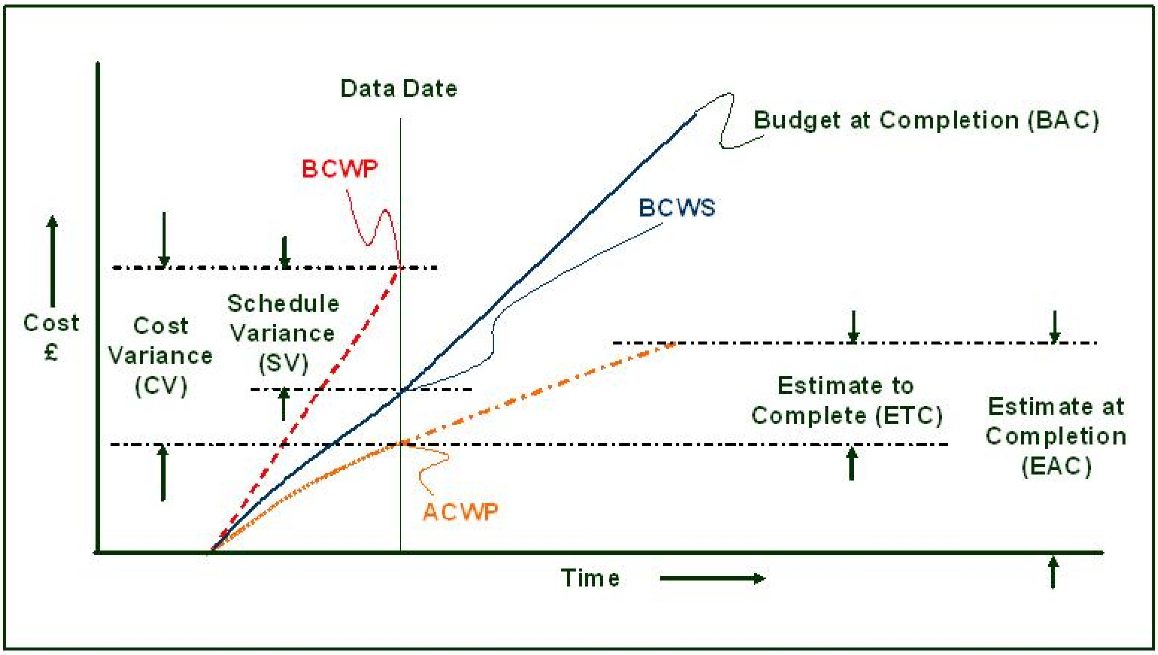

FIG. 1. Example of earned value management graph.

By collecting such data over time, trends in performance can be identified and the cost to complete the work can be estimated. By using such trending information realistic corrective actions can be planned and implemented as well as identifying projects which are performing well from which resources could then be used to assist failing projects.

This section contains only a brief consideration of the principles of EVM; the topic of EVM is extensive with a vast amount of literature available [2].

3. Dounreays earned value management data

EVM data is collated on a monthly basis at Dounreay, this data is then used to review schedule and cost variances and supports forecasting of the estimate to complete work packages and to identify areas which are under performing or over performing, since the latter could be used to help the former through the release of unutilised resources.

Table 1 details the DSRL EVM yearly data at the highest level, that being overall site performance for the last four years.

TABLE 1. DSRL EVM yearly data

Performance Year	Scheduled Work (BCWS)	Work Performed (BCWP)	Actual Cost (ACWP)	Schedule Performance Index–SPI (BCWP / BCWS)	Cost Performance Index–CPI (BCWP / ACWP)
2010/11	£151,912k	£152,765k	£137,939k	1.01	1.11
2009/10	£173,021k	£170,977k	£154,177k	0.99	1.11
2008/09	£160,760k	£148,981k	£142,951k	0.93	1.04
2007/08	£155,184k	£150,900k	£138,136k	0.97	1.09

Analysing the data in Table 1 identifies that DSRL has consistently completed the planned yearly work slightly below the estimated value as indicated in the CPI column where values ranging from 1.04 through to 1.11. However, DSRL completes slightly less work than planned as indicated in the SPI column where values range from 0.93 to 0.99, except in year 2010/11 when all of the planned work was completed as indicated by an SPI value of 1.01.

This high level summarised data provides an overall picture of the sites yearly performance. However, since this data is collected for each work package, the same indices can be viewed at any level as shown in Tables 2, 3 and 4.

Table 2 identifies the DSRL site decommissioning work broken down in to nine major groups. The table identifies differing SPI and CPI values for each line item. If we focus on schedule variance (SV) the first major group item, 10.1.15 Site Decommissioning — Active Facilities has the largest schedule variance of the group.

Table 3 shows EVM data for major group item 10.1.15 Site Decommissioning — Active Facilities broken down to the next level of detail, that being the project level. If we analyze this data in the same way, we can see that 10.1.15.D1193 FCA Fuel Buildings has the largest schedule variance of the projects under this major group.

Finally Table 4 shows EVM data for this project item 10.1.15.D1193 FCA Fuel Buildings broken down to the next level of detail, that being the control account. If we analyze this data in the same way, we can see that 10.1.15.D1193.02 D1203 has the largest schedule variance of the control accounts under this project.

Although a number of projects are contributing to the overall major group delay; by breaking down the detail we can identify the projects which are contributing the most and identify why and what mitigation actions can be taken.

TABLE 2. DSRL EVM DATA BY MAJOR GROUPING

Major Grouping	Description	Scheduled Work (BCWS)	Work Performed (BCWP)	Actual Cost (ACWP)	SPI : Schedule Performance Index (BCWP / BCWS)	CPI : Cost Performance Index (BCWP / ACWP)	SV : Schedule Variance (BCWP - BCWS)	CV : Cost Variance (BCWP - ACWP)
10.1.15	Site Decommissioning - Active Facilities	£12,540k	£9,498k	£9,078k	0.76	1.05	-£3,042k	£420k
10.1.20	DFR Decommissioning	£4,427k	£3,173k	£3,964k	0.72	0.80	-£1,254k	-£791k
10.1.25	Reactors Decommissioning	£1,691k	£1,565k	£1,640k	0.93	0.95	-£126k	-£75k
10.1.30	PFR Decommissioning	£4,052k	£3,790k	£3,429k	0.94	1.11	-£262k	£361k
10.1.48	Silo & Shaft Decommissioning	£495k	£345k	£284k	0.70	1.21	-£150k	£61k
10.1.55	Site Decommissioning - Non Active Facilties	£1,987k	£2,193k	£2,380k	1.10	0.92	£206k	-£187k
10.1.65	Waste Services	£6,420k	£6,464k	£5,182k	1.01	1.25	£44k	£1,282k
10.1.75	Site Closure & Enviromental Restoration	£2,731k	£4,222k	£3,308k	1.55	1.28	£1,491k	£914k
10.1.80	Support Project	£12,137k	£12,205k	£11,000k	1.01	1.11	£68k	£1,205k

TABLE 3. DSRL EVM DATA BY PROJECT

Project	Description	Scheduled Work (BCWS)	Work Performed (BCWP)	Actual Cost (ACWP)	SPI : Schedule Performance Index (BCWP / BCWS)	CPI : Cost Performance Index (BCWP / ACWP)	SV : Schedule Variance (BCWP - BCWS)	CV : Cost Variance (BCWP - ACWP)
10.1.15.D1190	Site Decommissioning - Active Facilities Programme Management	£1,804k	£1,804k	£1,664k	1.00	1.08	£0k	£140k
10.1.15.D1191	DMTR Area	£986k	£672k	£821k	0.68	0.82	-£314k	-£149k
10.1.15.D1192	LLW Pits	£93k	£95k	£88k	1.02	1.08	£2k	£7k
10.1.15.D1193	FCA - Fuel Buildings	£1,899k	£1,010k	£928k	0.53	1.09	-£889k	£82k
10.1.15.D1194	FCA - Reprocessing Plants	£2,002k	£1,552k	£1,390k	0.78	1.12	-£450k	£162k
10.1.15.D1195	FCA - Cells & Laboratories	£2,207k	£1,892k	£1,840k	0.86	1.03	-£315k	£52k
10.1.15.D1196	FCA - Support Facilties	£2,405k	£1,929k	£1,733k	0.80	1.11	-£476k	£196k
10.1.15.D1197	Ancillary Buildings	£1,140k	£541k	£611k	0.47	0.89	-£599k	-£70k

TABLE 4. DSRL EVM DATA BY CONTROL ACCOUNT

Control Account	Description	Scheduled Work (BCWS)	Work Performed (BCWP)	Actual Cost (ACWP)	SPI : Schedule Performance Index (BCWP / BCWS)	CPI : Cost Performance Index (BCWP / ACWP)	SV : Schedule Variance (BCWP - BCWS)	CV : Cost Variance (BCWP - ACWP)
10.1.15.D1193.02	D1203	£1,177k	£529k	£443k	0.45	1.19	-£648k	£86k
10.1.15.D1193.03	D1231	£18k	£19k	£14k	1.06	1.36	£1k	£5k
10.1.15.D1193.04	D2580	£26k	£28k	£22k	1.08	1.27	£2k	£6k
10.1.15.D1193.05	D2670	£677k	£433k	£447k	0.64	0.97	-£244k	-£14k

There are two further points of interest associated with Tables 2, 3 and 4. First, in Table 2 we can see that the major group item 10.1.20 DFR Decommissioning has the lowest schedule performance index (SPI) at 0.72. However, major group item 10.1.15 Site Decommissioning — Active Facilities has the largest schedule variance which is a more significant factor. It is therefore important that a number of different indicators are considered when analyzing the EVM data in order to understand the complete picture. Second, as mentioned, it is also important to consider which areas are performing well; in Table 2 we can see that major group item 10.1.75 Site Closure & Environmental Restoration has a schedule performance index (SPI) of 1.55. Therefore it is also worth considering any lessons learned from this area which may assist under performing areas of the programme and also consider if this over performing area could provide resources to assist other areas of the programme, even if this means that the over performing area looses some ground in performance, since consideration needs to be given to the whole decommissioning programme and not just individual areas.

The data shown in Tables 2, 3 and 4 is a snap shot of data after four months of progress for this financial year (2011/12) which commenced on the 1st April 2011. As well as analyzing the cumulative data, it is also important to look for trends in performance. By plotting the previous months data and the future forecast data for control account 10.1.15.D1193.02 D1203 (Figure 2) we can see that although the ACWP remains slightly below the BCWP, the BCWP is forecast to continue along an increasing negative trend in which the forecast end position in March 2012 is being predicted at an SPI of 0.4. The reason for this trend may be legitimate; since there is no forecast recovery it may well be that this work has been postponed to take place in the next year, say due to constraints such as funding, resources, or delays elsewhere in the programme which need to be completed first. When the work is completed then the SPI will revert to 1.0 since the BCWP will match the BCWS. It is an important rule that the BCWS is only changed under approved controlled procedures, since changing the BCWS would alter the original plan. Typically changes are made to the BCWS for agreed changes in the strategic approach to the work and/or an agreed change in the scope of the work, these changes must be undertaken through a change control process in which all changes to the BCWS are recorded for future reference. Under no circumstances should history be changed, even through change control; this is a fundamental rule of EVM. Whatever has been previously recorded (even in error) must remain unchanged such that an auditable record remains throughout. Any required change (say to correct a previous error) can be undertaken next month by entering the correct data, in which a step change will be recorded.

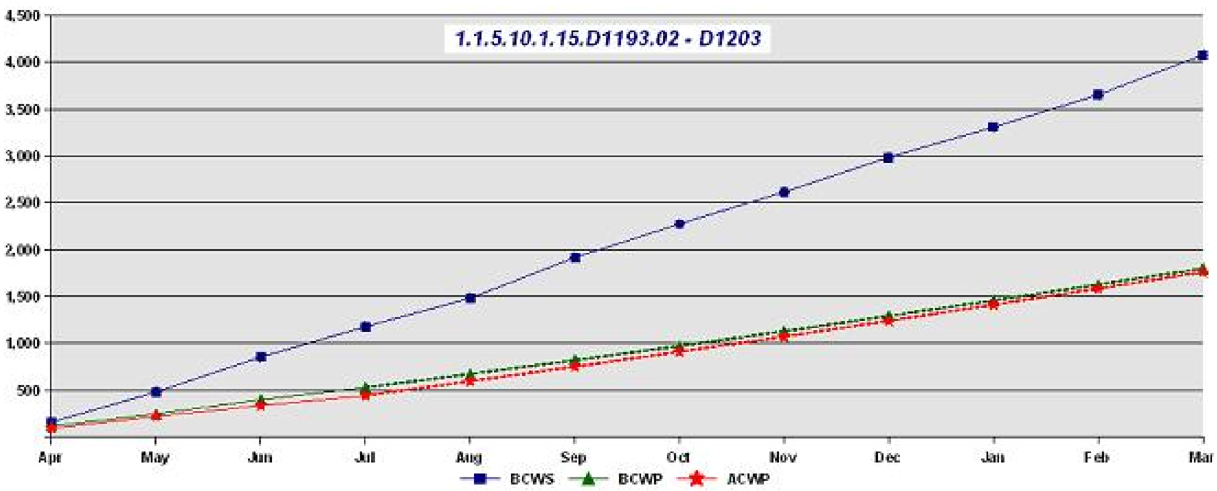

FIG. 2. Trend data for control account 10.1.15.D1193.02 D1203.

4. EVM lessons learned

Although EVM has many benefits, as discussed in this report, it does have some limitations. The main limitations that have been found through application are as follows:

- EVM has no provision to measure project quality, so even if you are ahead of schedule and under cost you may still have unsuccessful outcomes;

- EVM is not intended for non-discrete (continuous) effort. In EVM standards, non-discrete effort is called “level of effort" (LOE). If a project plan contains a significant portion of LOE, and it is intermixed with discrete effort, EVM results can be distorted;

- EVM relies on estimates of percentage complete, which are not always reliable, hence the need for discrete performance measurables/metrics;

- EVM relies on accurate and timely true actual cost data, this can be a challenge as there is a need to link to the financial system which requires accruals and receipting in order to capture the true actual cost;

- EVM forecasting is based on the assumption that future performance can be predicted based on past performance this is not always true and can give a distorted view;

- EVM historical data should never be changed; future BCWS should only be changed through an agreed change control procedure and for major reasons such as a strategic change in the approach to the future work and/or a change in the scope of work.

To address some of these limitations it is important to recognise that EVM is just one tool that a project manager has available in managing a work package. It is important that EVM data is verified by physical inspection and knowledge of the work package to ensure that reported progress is as accurate as possible. To support this approach it is essential that during the planning phase discrete milestone events, which represent performance indicators [3], are identified within the plans. A few examples of which are:

- Quantities of waste processed / recycled;

- Areas or equipment decontaminated;

- Buildings demolished;

- Design review gates passed;

- Equipment purchased;

- Drawings & documents approved;

- Surveys completed;

- Systems commissioned;

- Services isolated.

5. Integrated programme controls (IPC) system principles

Successful implementation of EVM relies on two key aspects, those being that a robust baseline plan has been developed and that performance against that baseline plan is maintained; in effect it is about *Planning the Work* and *Working the Plan*. In this respect an integrated programme controls system has proven to be a valuable asset in implementing EVM at the Dounreay site.

Dounreay started off with one financial system and many standalone project tools which drove the culture of focusing on financial management and minimal focus on project performance. By implementing an IPC system it supported a change in the culture to focus on project performance providing programme management capabilities underpinned by financial management. As shown in Figure 3, an IPC system supports all of the key components of programme management which are also essential to EVM.

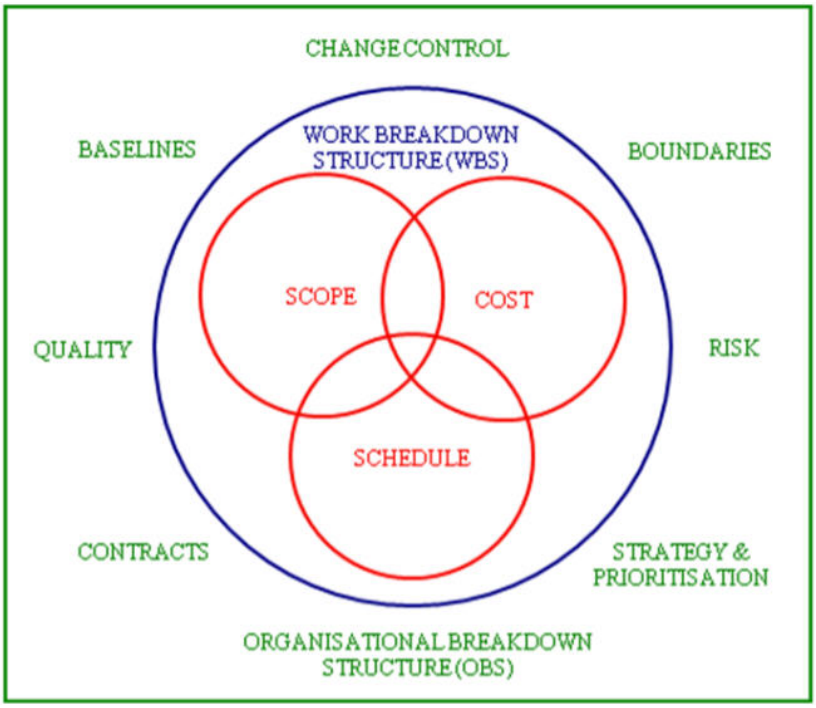

FIG. 3. Key components of programme management.

In essence an IPC system is a collection (or single tool) that supports the data management for each of the key components of programme management (Figure 3). It is an integrated system that ensures that data is consistent for each key component and that minimal user data entry is required. It also has the advantages of being able to communicate live data quickly to a large number of users; by which the application of EVM is made easier than through a number of standalone systems. Such an IPC system, if configured correctly, ensures that EVM is implemented correctly against defined procedures and business rules.

The IPC system developed and implemented at the Dounreay site is a mixture of commercially available software products and bespoke products. Each tool within the system has been careful chosen for its individual merits and combined together through the addition of bespoke integration software to ensure consistency of data.

The Dounreay IPC system (Figure 4) has a set of tools for managing the baseline plan and a set of tools for managing the performance measurement data. The whole IPC system is then combined to report the recorded EVM data based upon the three main criteria, those being BCWS, BCWP and ACWP. It is not particularly important as to which specific tools are chosen, as long as all the aspects of programme management (Figure 3) can be undertaken; that the three principle elements of EVM are recorded over time (BCWS, BCWP and ACWP) and that the system is integrated in order to ensure consistent data.

Our lessons learned for consideration when choosing individual software tools to be part of an IPC system are:

− Don't try and "reinvent the wheel" look for commercial software packages that provides the closest fit to the requirements — for example we did not write our own bespoke risk analysis programme or scheduling programme since it is far too complex;

− Review the requirements and challenge the need — must haves or nice to haves;

− Concentrate on the interfaces — how can we make them all work together as an integrated system;

− What have we already invested in — you may not have the luxury of starting from scratch;

− Consider the total life issues not just the short term, ie upgrades, customisation, licences, data migration, security, training, maturing organisation, number of users;

− Consider the level of suitable qualified and experienced resources available to support, develop, implement and train users on the IPC system;

− Remember once you start along a path it becomes more difficult and costly to make changes, particularly if a system is in use, so take time to plan and validate various software options.

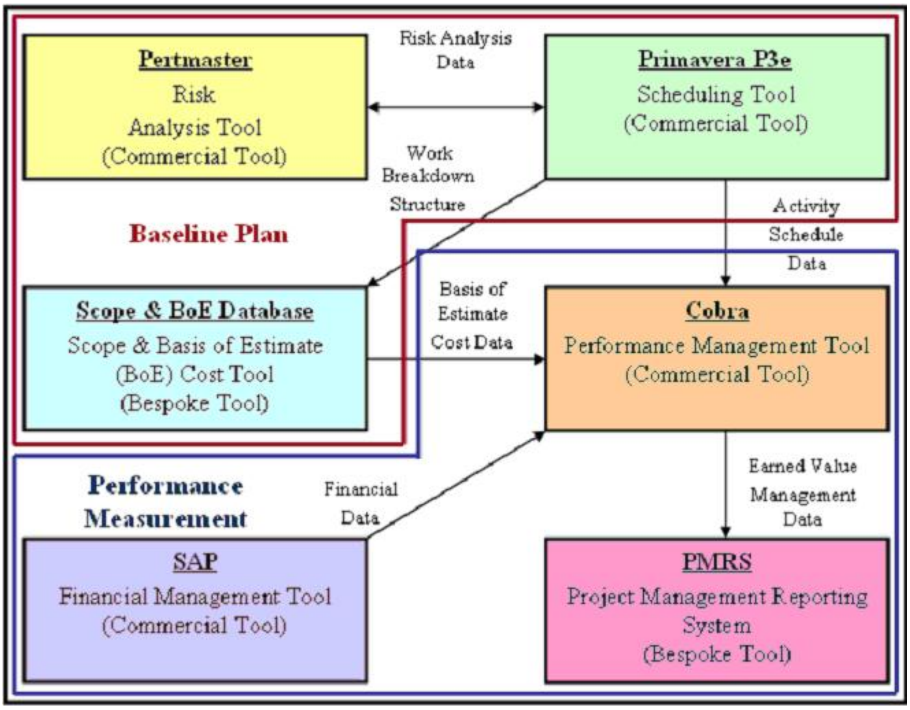

FIG. 4. Dounreays integrated programme controls system.

The Dounreay IPC system is a combination of commercially available tools and bespoke tools which have been developed by DSRL programmers specific to Dounreays requirements. In addition the integration between the tools has also been a bespoke development using the individual tools interface software. Our experience as to the main differences between commercial off the shelf (COTS) tools and bespoke tools are:

Commercial Off The Shelf (COTS):

− An instantly available solution, usually quick to install for use;

− Training courses/material readily available;

− Licence costs and tie in to software house upgrades/versions;

− Relatively fixed system configuration and performance;

− Can be expensive to customise and not always bug free.

Bespoke development:

− Development and implementation time required;

− Training courses and reference manuals need to be developed;

− In house and/or subcontract programming skill sets required;

− Developed to meet specific requirements;

− Upgrades relatively inexpensive with no licence costs.

Both options should be carefully considered when developing an IPC system, in particularly the through life costs of support, development, upgrades and licence costs as well as how much tailoring is required to a tool to meet existing business requirements.

When an IPC system has been successfully developed and implement it can be a very powerful system in supporting EVM practices; an example of the Dounreay IPC system outputs can be seen in Figure 5. This figure shows EVM data graphically and in tabular format together with the scheduled scope of work. Such outputs are readily available to authorised system users, showing the same consistent data, and allowing for both summary and detailed level data reports.

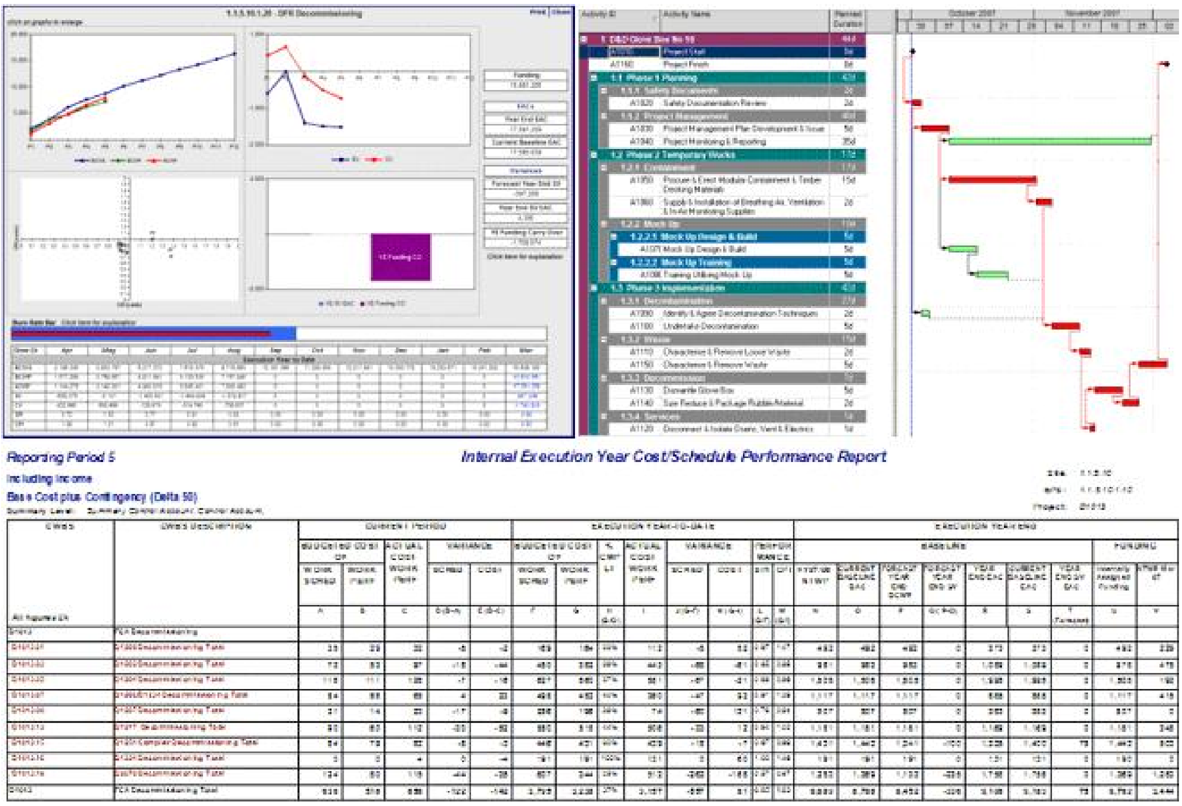

FIG. 5. Dounreays IPC system typical outputs.

6. Utilizing an IPC system

Since EVM is a measure of performance against a baseline plan it is important that the baseline plan is estimated as accurately as possible. This can be a difficult undertaking for a long term and complex nuclear decommissioning site. At Dounreay the baseline plan has been developed through top down bottom up review (Figure 6).

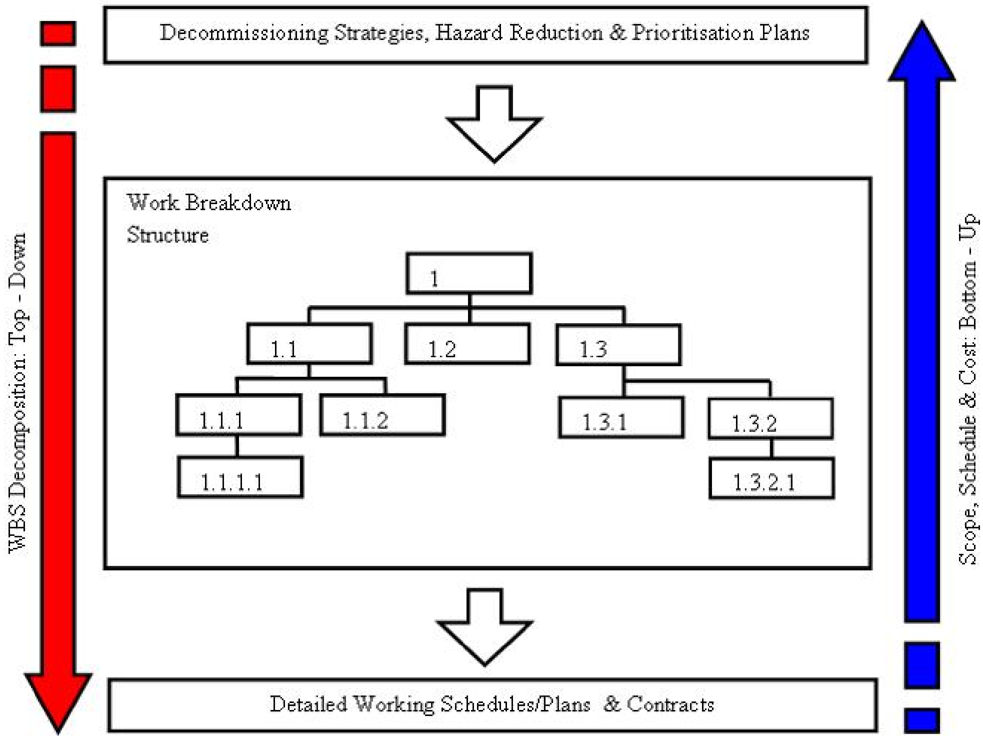

FIG. 6. Top down bottoms up baseline planning.

First we identify the main Decommissioning Strategies, usually based on hazard reduction these will then provide a prioritisation plan based on such things as company values (safety, environment, value for money), government and regulatory policies, radioactive decay, resources, funding and logistics. The work is then broken down in to smaller packages based upon the prioritisation.

Once there is a good understanding of the framework you can then work back up from the bottom by defining the scope, schedule and cost of each work package. It is easier to identify the scope, schedule and cost in small definable packages and then summarise these up the framework. In practice this is an iterative process, since you need to check relationships between activities and against the decommissioning strategies and prioritisation plans. A point will then be reached where there is a fully defined and robust estimated baseline plan to measure performance against.

A key feature of an IPC system is the integration of data, underlying this is a coding system between the various data elements such as scope, schedule and cost. This coding system is based upon the work breakdown structure (wbs), of which we can see an example in Figure 6 and also previously within Tables 2, 3 and 4; whereby for each lower level of detail an additional code is added to the wbs string. This string identifies the 'parent' information associated with the lower level detail. This code is then used consistently throughout the IPC system to link together the associated data elements such as scope, schedule and cost information.

At Dounreay the work breakdown structure starts be breaking down the site in to major groups of work based upon the planned decommissioning of the site geographically (Figure 7). With each major group identified the next level of definition is identified at the project level, again this is based upon defined areas for decommissioning within a major group. The projects are then broken down further in to control accounts which are typical based upon discrete facilities/rooms/laboratories. The work continues to be broken down until a level is reached by which a package of work is considered manageable in its own right. Each package of work is then defined in terms of scope of work, resource requirements, cost, time, deliverables, measurable, risks, assumptions and opportunities.

FIG. 7. Dounreays major grouping of work based upon geographical locations.

The baseline plan should be a reflection of the strategic approach and main priorities for decommissioning the site. It should not be a reflection of the organisational structure, since this should be mapped to the required work not driving the breakdown of the work.

Once the work has been broken down the organisational structure can be mapped to the work by identifying control accounts and control account managers (Figure 8). In this way the responsibilities and resource assignments can be defined and managed.

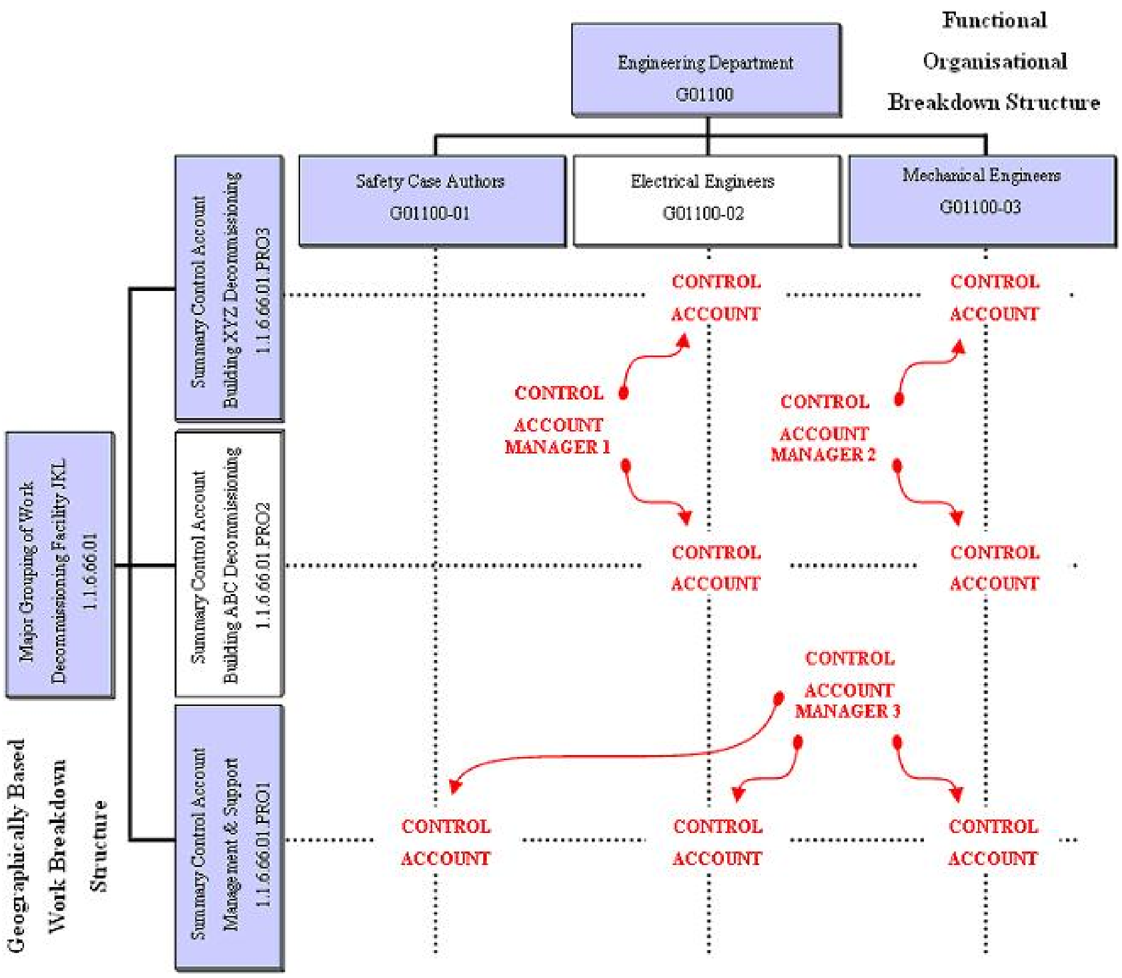

FIG. 8. Representation of control accounts to map organisational structure to work breakdown structure.

Since it is difficult to develop a detailed decommissioning plan for each year of the programme, since such a programme could last for ten's of years, then a rolling plan approach can be adopted. This rolling plan is the process followed at the Dounreay site and is graphically demonstrated within Figure 9.

In such a process the current year of execution and the following two years are planned in detail with robust estimated underpinning. Outside of this three year window the level of estimating detail reduces towards the end point. Whilst progressing the execution year's physical work, the fourth year of the plan is increased in estimating detail, such that when the current execution year completes, the fourth year of the plan, which now becomes part of the three year window, has been increased in detail. This continues throughout the plan such that in any given execution year there is both completion of the current years work and increasing the detail in the next year to fall within the rolling window. This ensures that the baseline plan continues to be maintained as accurately as possible whilst reducing potentially nugatory work in estimating the whole plan in detail.

It is important to state that this rolling window approach is neither changing history, which is a forbidden rule of EVM, or changing the baseline without an approved change control procedure, it is merely increasing the detail of the original plan in terms of breaking down the work packages and defining the required work package resources.

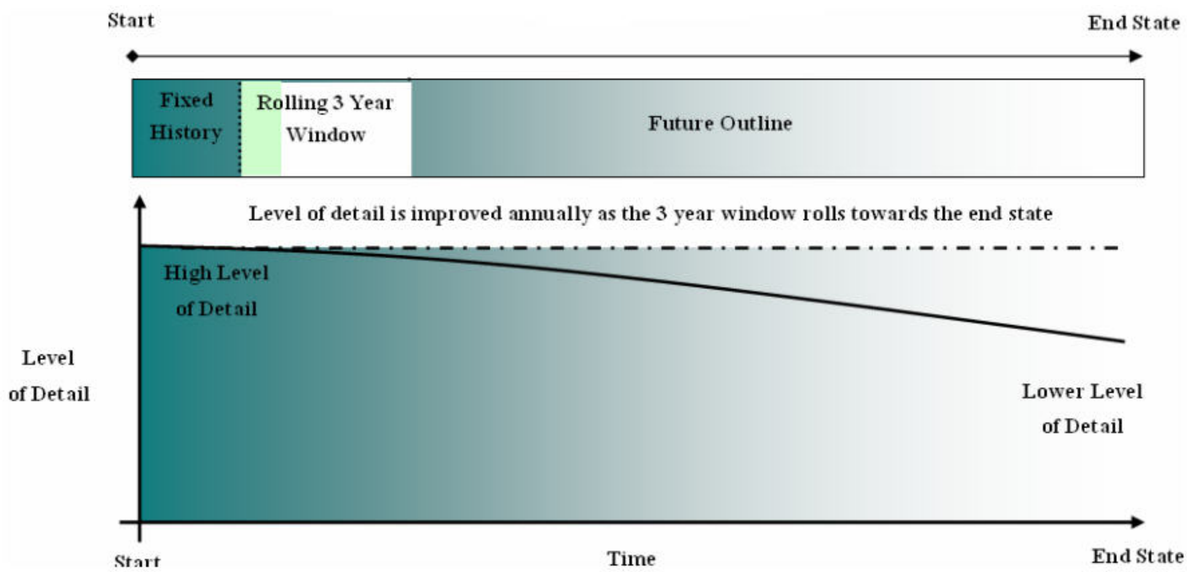

FIG. 9. Graphical representation of a rolling plan.

As always any significant change in the baseline plan should be undertaken only through an approved change control procedure, typically for agreed strategic changes and/or agreed changes in scope. It should not be used to 'hide' poor performance or to change history. Since EVM is fundamentally about learning to improve poor performance through lessons learned, it is important that lessons are indeed captured and not hidden away, as such a no blame culture needs to be adopted together with the application of EVM, whereby any issue that has caused poor performance or indeed positive performance should be equally discussed and lessons learned identified and carried out, since the main aim is performance of the whole decommissioning plan.

7. Collaboration with other CRP members

During the initial stage of the CRP significant interaction with the Lithuania representative and associated Lithuanian Ministry was being undertaken to identify the benefits and lessons learned based upon the UK experience of decommissioning management. Principally based upon the Dounreay site experience this interaction focused on the application of EVM through an IPC system amongst other areas of interest.

Presentations and discussion on EVM through an IPC system have been held each year with the CRP members during the coordinated research meetings.

8. Publications resulting from the CRP

Participating in the CRP has involved a review of the current Dounreay approach in order to capture the lessons learned and present the experience. Although no direct publications have been issued as a resulted from the CRP work, it has led to a greater understanding of the EVM approach, which will be beneficial in defining future training and system improvements.

9. Conclusions

There have been many lessons that have been learned through implementing an earned value management process supported by an integrated programme control system, particularly for a complex nuclear decommissioning programme.

Fundamentally, any new process, procedure or system should have the principle aim of improving the current position significantly beyond any disruption, cost, time and learning incurred to implement such changes. The following is a summarised list of the key lessons learned to reflect upon when considering implementing EVM through an IPC system. These are based upon the lessons learned and experiences of implementing such an approach at Dounreay.

- Ensure that the principles of earned value management are understood by those assigned to implement such process. From Dounreays experience those implementing such a process are significantly involved in ensuring that it was being followed correctly through the training of others and establishing the required business rules and tools;

- Consider how EVM data will be managed; if this is to be through an IPC system then undertake a review of the current organisations software tools and processes to identify how these can be enhanced to support EVM and be developed towards an IPC system. It is feasible to undertake a smaller scale trial within one project as a demonstration of the benefits and potential problem areas that could be encountered when implementing across the organisation;

- In developing an IPC system choose carefully between bespoke in house developments and commercial off the shelf software tools, since there are benefits and disadvantages to each. Once implemented it becomes more costly and disruptive to then later change a system. Take time to plan and validate on a smaller scale with defined review gates for IPC system development. Ensure in house development knowledge is retained within the organization through using standard industry coding and documentation of any bespoke developments. Consider how all aspects of programme management can be supported, however, also consider undertaking a phased approach to implementation, concentrating on the required EVM aspects first — scope, schedule and cost;

- When maintaining an IPC system, reliability and performance have been shown to be system user's main requirements as well as consistency of data and minimized data entry. Consider the cost, time and disruption for improvements in these areas; are development requests based upon 'must haves' as opposed to 'nice to haves'. An established steering group/committee, with the required authority for such decisions can provide a useful interface between the IPC system support and development team and the system users. A formal service level agreement also ensures that the organisation has agreed to the required systems support against which a support and development budget can then be agreed;

- EVM is based upon a robust baseline plan that has change controls in place to prevent any change to history and to record any agreed future changes. Consider developing such a baseline plan based upon a top down / bottom up approach, breaking the work down on geographical areas. Assign the organisational structure after the work breakdown has been developed by utilizing a control account approach. Consider a rolling plan approach to the level of detail required within a baseline plan, this can reduce nugatory work and ensure that detail is added to the plan in the execution and next couple of years;

- Once EVM has been implemented, and if through an IPC system, initial and continual training is essential to maximize benefits of such a system through understanding the data. Training courses, manuals, user guides, software help/prompts have all proven beneficial at Dounreay. Support to project managers in interpreting EVM data is important, the project managers need to own such a system, they need to understand both the input requirements and the output reported data, a culture of 'no blame' is important to ensure that trending information is used to improve the overall performance and equally learn from both the poorly performing areas as well as from the over performing areas.

In conclusion the Dounreay site has embraced EVM principles through an IPC system from early 2007. Partly due to the requirement to adhere to the NDAs procedures based upon EVM and partly due to the knowledge that a robust process needs to be implemented to manage such a complex environment. Prior to this approach the Dounreay Site Restoration Plan was laying out a 60 year plan to decommission the site at a cost of £4.3 billion, today that plan identifies a 39 year plan that commenced in 2000 at a cost of £2.3 billion. This is expected to be reduced even further, both in time and cost through the NDA commercial contract placement due to commence on the 1st April 2012 following announcement of the preferred bidder and subsequent site transition. We believe that implementing EVM through an IPC system has played some part in establishing these reductions; this approach has provided the detailed level of understanding within the baseline plan and supported performance improvement by identifying and understanding the project trends and implementing lessons learned.

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DEVELOPMENT OF THE DECOMMISSIONING PLANNING SYSTEM FOR THE WWR-M REACTOR

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Abstract

Kiev's research reactor WWR-M is in operation for more than 50 years and its continued operation is planned. At the same time the development of a decommissioning plan is a mandatory requirement of the national legislation and it must be performed at the operational stage of nuclear installation as early as possible. Recently, the Decommissioning Programme for the WWR-M reactor has been developed. The programme covers the whole decommissioning process and represents the main guiding document during the whole decommissioning period, which determines and substantiates the principal technical and organizational activities on the preparation and implementation of the reactor decommissioning, the consequence of the decommissioning stages, the sequence of planned works and measures as well as the necessary conditions and infrastructure for the provision and safe implementation. The programme contains the basic directions of further decommissioning planning aimed on the timely preparation for the reactor decommissioning. This paper describes the status of the WWR-M reactor decommissioning planning attained by the middle of 2011.

1. Introduction

The term "decommissioning" refers to the administrative and technical activity taken to allow the removal of partial or whole scope of the regulatory requirements from a facility. A facility means a building and its associated territory and equipment in which radioactive material is produced, processed, used, handled or stored on such a scale that consideration of safety is required. Decommissioning activities are performed within an optimized approach to achieve a progressive and systematic decreasing of the radiological hazards. Facility is considered decommissioned when an approved end state has been reached. Subject to national legal and regulatory requirements, this end state encompasses partial or full dismantlement, with or without restrictions on further use. At that, unconditionally, the safety and protection of human and environment against the radiological and man caused impacts should be provided. On account of any reasons leading to the reactor final shut down, the decommissioning is the mandatory stage of life cycle; it requires the thorough planning both the decommissioning process as a whole and its separate components on the base of a large volume of design and technical documentation. With the objective of safety provision and cost efficiency it is obvious that the decommissioning planning should meet the following main criteria:

- Transparency of all technological, ecological, social and economical decisions;
- Independence of the ecological and financial monitoring;
- Nuclear, radiation and ecological safety in accordance with the relevant norms and standards;
- Social protection of the reactor staff;
- Public involvement into decision making process.

In accordance with the international decommissioning experience such process requires huge intellectual and financial expenditures, the balanced planning, the special legal basis, the thoroughness of organization, the coordination and control of works, the creation of special infrastructure, the application of innovative engineering solutions and the high skilled staff.

Requirements for the provision of activity on the decommissioning of nuclear installations as well as the activities directly connected with the decommissioning (for example, the spent fuel and radwaste management, the licensing etc) are established by the acting legislation of Ukraine. In accordance with the Law of Ukraine "On the Licensing Activity", the decommissioning is a separate stage of a nuclear facility lifecycle and the operator is obliged to obtain a license for this stage. The operator of nuclear installation at the different stages of lifecycle should prepare oneself for the forthcoming decommissioning.

Research reactor WWR-M is the operational installation. The Institute for nuclear research (INR) is the reactor operator and has all required licenses and permissions for the reactor operation. Preliminary decommissioning planning was initiated in the document "Decommissioning Concept of the WWR-M reactor" issued in 2001 [1]. The next step of the decommissioning planning is the document "Decommissioning Program of the WWR-M reactor" (further: DP-2009 [2]), which was approved by the Regulatory Body at the end of 2009. DP-2009 is conforming to the *ongoing decommissioning planning*; therefore, it contains the basic directions of further decommissioning planning aimed on the timely preparation for the reactor decommissioning.

The following step of decommissioning planning foresees the development of the detailed decommissioning programme for WWR-M, which will conform to the *final decommissioning planning*. This programme will be developed on the basis of careful consideration of all site specific factors and taking into account of different combinations of technologies for the characterization, decontamination, and dismantling and radwaste management suitable for the different equipment, systems and elements. Special attention will be concentrated on the ecological safety of decommissioning due to the reactor location in the megapolis. A relevant organizational arrangement with the adequate infrastructure and distribution of resources should be established with the aim of timely preparation of all necessary documents for the planning and implementation of decommissioning process as the whole. The self consistent cost effectiveness detail decommissioning programme with the set of substantiating and supporting documents will be a result of present research project.

2. Overview of the regulatory framework

As a whole, the normative legal basis of Ukraine is sufficient for the decision on present day tasks connected with the provision of safety and protection of the personnel, population and environment at the decommissioning of NPPs and RRs in Ukraine. In this area the normative legal basis is corresponding to the international practice, accounting the recommendations of IAEA, ICRP and other international organizations [3–8]. Laws of Ukraine "On the Use of Nuclear Energy" and "On the Licensing Activity" are establishing the basic principles of radiation protection during the use of nuclear energy including for decommissioning. In accordance with the Law of Ukraine "On the Radioactive Waste Management", one of the principles of national policy in the field of radioactive waste management consists in: "storage of radioactive wastes on the radioactive waste generator's site for a limited time with further transfer to specialized radioactive waste management enterprises".

The normative document [9] contains the definition of term "decommissioning": *Decommissioning means such set of measures after removal of nuclear fuel that excludes the operation of the facility in purposes for which it was constructed and provides personnel and the public safety and the environment security***.**

Following to this definition, the goal, scope and possible ways are determined:

- Decommissioning of the facility is undertaken to exclude the possibility of further use of the given facility with the purposes for which it was constructed;

- Decommissioning of the facility is undertaken to achieve such site conditions that reduces any restriction on the site use. It provides for:

    - Stage by stage removal of the sources of ionizing radiation being subject to regulatory control;

    - Abolishment of the restriction regime and reduction of radiation monitoring in the supervision zone and sanitary protective zone of the facility.

The present document determines the following stages of decommissioning: **final closure, preservation, long term storage, dismantling**. Decommissioning of the facility is preceded by stage of **termination of operation**. The main objective of this stage is facility transformation to the condition, which corresponds to the absence of nuclear fuel on the site or storage of fuel within the site boundaries only inside nuclear fuel storage facilities, which are designed for a long term safe storage. The necessity of each separate stage and sequence of stage priorities should be defined and substantiated during development of the decommissioning strategy. The decommissioning stages can be implemented either completely or partially for different parts of the facility according to the chosen strategy.

The decommissioning license requires the obtaining of the separate permissions on implementation of each decommissioning stage. The operator should submit to the Regulatory Body three documents for the obtaining of permission, namely, the Decommissioning Stage Implementation Plan, the Safety Analysis Report and the Technological rules of decommissioning.

3. Description of facility

The WWR-M reactor is a heterogeneous water moderated pool type research reactor operating with the thermal neutrons at a power level of 10 MW_{th}, giving a maximum neutron flux of 1.5×10^{14} $cm^{-2}s^{-1}$ at the core center. The reactor is equipped with 9 horizontal experimental channels, a thermal column, and 13 vertical isotope channels inside the beryllium reflector. It is possible to install 10–12 vertical channels in the core. The WWR-M reactor was commissioned on 12 February 1960. The WWR-M reactor is located at the site of the Institute for nuclear research in the Goloseev district of Kiev (Fig. 1). For more than 50 years of operation there were no single accident situation which exceeded the norms or conditions of normal operation as well as no contamination above the established levels by radionuclides and aerosols for the free access premises.

Lifetime for the reactor vessel and primary circuit is not determined by design documentation. Surveys performed since 1988 until now provide an evidence that there are no negative changes beyond the design limits in the reactor vessel and primary circuit components. The part of the reactor elements, equipment and systems are in operation since the reactor commissioning in 1960. Upgrade of the reactor systems or replacement of the specific equipment was aimed at safety improvement during the reactor operation. All reactor systems were upgraded completely or partially at the time of reactor continued service.

Since May 2001 INR has the permanent license for the reactor operation, which will be in force till the reactor final shutdown. The reactor final shutdown term **isn't specified yet** and the reactor operation is carried out now in accordance with the separate permissions issued for several years. the basis of such extension for permission is the revised operational safety analysis report, which must be approved by the regulatory body.

The current timeframe of operation was continued by the decree of the SNRCU's Board (No.11 from 21 May 2009) and then a new permission for the reactor operation will be issued:

- To continue the reactor operation till 31.12.2013;
- To convert the reactor on the stage "termination of operation" from 01.01.2014;
- In the case of the operator's decision concerning the reactor's further operation, to prepare and agreed with the SNCRU the possibilities and conditions of the reactor operation.

The National Academy of Sciences of Ukraine has approved in 2004 The Strategic Plan for the use of research reactor WWR-M of the Institute for Nuclear Research [10]. The main goal of this Plan is the coordination of work between the operator, researchers and users from the different organizations; determination of the user's needs and installation capabilities; provision of the reactor sustainable operation by means of stepwise implementation of the planned strategic tasks. The Plan determines the strategic goal as the provision of the reactor operation till 2015, but now this timeframe is reconsidered towards the further extension.

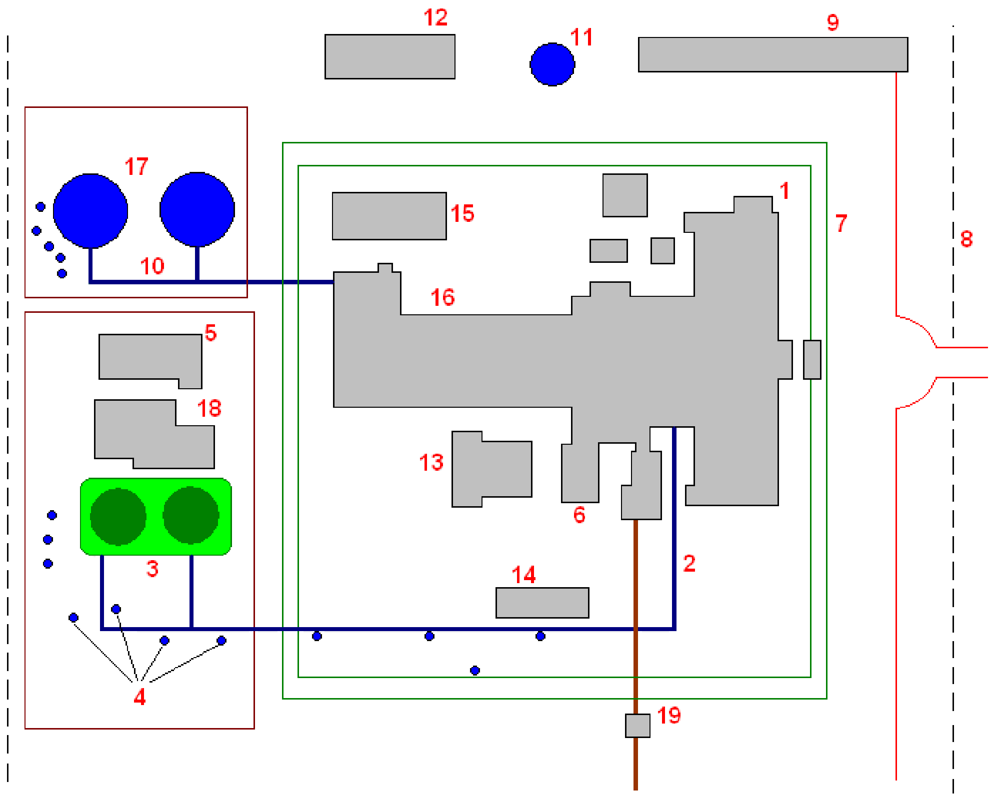


FIG. 1. Location of buildings and constructions at the reactor site:
(1) reactor building with the reactor hall; (2) pipeline of special sewerage system; (3) reactor reservoirs; (4) driven wells; (5) workshop; (6) reactor hall tambour; (7) physical protection fence; (8) reactor site enclosure; (9) warehouse; (10) pipeline of special sewerage system of "hot cells"; (11) water tower; (12) cooling tower; (13) reactor ventilation center; (14) gas-holder; (15) secondary loop pumps room; (16) "hot cells" building; (17) reservoirs for "hot cells"; (18) liquid radwaste treatment plant; (19) experimental building at the horizontal channel No. 9.

4. Plans for the site use

Currently, due to some objective reasons, it is impossible to plan further specific use of the site and reactor building. There are the isochronous cyclotron U-240 and electrostatic generator EG-10 on the INR site. The design lifetimes are not specified for these research facilities and, therefore, they will be in operation for a long time, even after the completion of decommissioning of research reactor WWR-M. A further operation of cyclotron and generator will require continuing the restriction regime on the institute's site independently on the state and conditions of the reactor's site.

The "hot cells" building is adjacent to the reactor building. These "hot cells" don't belong to the reactor administratively, but they are used by the radiation material science division of the Institute. It seems to be reasonable to continue the "hot cells" operation after completion of the reactor decommissioning.

Therefore, most likely, it is foreseen that the use of the reactor's building with the "hot cells" as the separate laboratory for the development and application of radiation technologies, after the transfer of the reactor building, the part of existing infrastructure for the reactor operation provision and the reactor auxiliary building to such laboratory. The directions of future use for this laboratory will be determined during next few years taking into account the specific needs of industry, in particular, the needs of nuclear power industry of Ukraine.

It is necessary to mention that some time back it was considered the possibility to construct a new research reactor at the existing site near the WWR-M reactor. In spite of the obvious advantages for such decision, the construction of new reactor is entirely impossible today due to the more strong restrictions of acting legislation concerning the location of new nuclear installations and, therefore, in the case of acceptance of decision for the construction, a new research reactor will be located outside Kiev [11, 12].

It seems to be worthwhile to consider the requirements for the future separate laboratory at the CERI (complex engineering and radiaition inspection) implementation as well as at the development of the reactor dismantling design, which will include the list of equipment, systems and rooms suitable for utilization by such laboratory. It is necessary to determine which systems are requiring the renovation / replacement / modernization. The necessary remodeling and reconstructions of rooms should be planned during the dismantling works in accordance with the future functional destination.

These requirements will be presented in the **Engineering Solution** on the laboratory creation, which is necessary and sufficient for the decommissioning planning. Further development of this Engineering Solution will be done in the technical and economic assessment (feasibility study).

5. Decommissioning strategy

DP foresees the strategy of the immediate dismantling reasoning from the plans of the further site use [13, 14]. In accordance with the selected decommissioning strategy, the sequence of decommissioning stages was established along with the content of works and measures at these stages, their durations as well as the necessary conditions and infrastructure for the timely and effective decommissioning execution. The ultimate goal of the reactor decommissioning is the unlimited site use with the transfer of the reactor building, the part of existing infrastructure for the reactor operation provision and the reactor auxiliary building to the separate laboratory for the development and application of radiation technologies.

The DP covers the whole decommissioning process and it is the main guiding document during the decommissioning period. The DP is a subject to revision by established order at least every 5 years in correspondence with the status of its practical implementation as well as when it will be necessary accordingly to the changes of requirements of the acting legislation, the development of technique and technologies, the changes of financial–economical and socioeconomical conditions. The various detailed decommissioning plans/projects will be developed from the strategy presented in the DP [15].

Considering the unique features of the WWR-M reactor, the DP is directed to the solution of the following tasks:

- Comprehensive and timely planning of all kinds of the decommissioning activity;
- Use of the modern methods for the management of all kinds of the decommissioning activity;
- Use of the novel decommissioning technologies and technical tools;
- Provision of the safety norms, rules and standards for the personnel protection;
- Use of the permanently operating system for the collection, treatment and storage of information which would have a significant impact on the decommissioning process;
- Provision of the impact gradual decreasing on the personnel, population and environment from the WWR-M reactor by means of the phased implementation of works;

– Minimization of the radwaste generation, treatment and final disposal;

– Consecutive release of the reactor site from the ionizing irradiation sources, which are a subject of regulatory control, to the free release levels;

– Provision of the social protection for the reactor's personnel;

– Public relations on the decommissioning problems with the goal of safety confirmation of measures, which are planned or carried out.

6. The sequence of decommissioning

6.1. Activity for the preparation of decommissioning during the reactor operation

At the reactor operation it will be performed the set of activities directed toward the preparation of decommissioning. The following measures are carried out permanently:

- Classification, accounting and forecast of the radwaste volumes, which will be generated during the reactor operation and decommissioning;

- Collection, processing and storage of information related to the buildings, the constructions and the reactor systems and elements, which will be required for the reactor decommissioning;

- Works aimed on the preparation and removal of the spent nuclear fuel;

- Gathering of the material and technical resources for the decommissioning;

- Development of the decommissioning documentation;

- Request and approval of the decommissioning license;

- Public relations on the decommissioning problems.

6.2. Termination of operation

The termination of operation stage is preceding the decommissioning, namely, the final stage of reactor operation, which will be performed after the decision making about the reactor final shutdown. Basic goal of activity at this stage is the conversion of reactor into the state when the spent nuclear fuel is absent on the rector site, i.e. SNF was removed from the reactor core and cooling pool for the safe long term storage.

After SNF removal, the operational license will be cancelled and cannot be renewed. The following decommissioning works will be carried out in accordance with the decommissioning license, which does not envisage the SNF management.

Thus, the following works and measures are foreseen during the termination of operation stage:

- Removal of the spent fuel outside the reactor site;

- Final shutdown of systems, which cannot be used; all reactor systems and elements will be shutdown excluding those that provide the regular operation, such as the ventilation, the radiation control, the cooling of the spent fuel storage etc;

- Extraction of the working mediums from the technological schemes and equipment;

- Discharge of the potentially hazardous substances, which are not required for the future utilization;
- Decontamination of the reactor systems and elements;
- Extraction and transfer to processing of radwaste, which was collected during the reactor operation or generated at the termination of operation stage;
- Execution of the complex engineering and radiation inspection (CERI) with the goal of data collection related to the engineering and radiation conditions at the reactor; this information will be used for the development of decommissioning documentation as well as at the planning and execution of decommissioning works;
- Implementation of measures directed on the life support and maintenance of the systems, which will be in operation at the next decommissioning stages;
- Gathering of the material and technical resources for the final closure and dismantling stages;
- Staff training for the decommissioning works;
- Development of decommissioning documentation, which is necessary for the permission on the beginning of final closure stage
- Implementation of administrative and organizational measures corresponding to the changed status of the reactor.

6.3. Final closure

The goal of the final closure stage is the reactor transformation into condition, which excludes its use as the neutron source. The reactor does not exist as the neutron source after the fuel removal from the core and the equipment of experimental channels will be dismantled. Thus, the main goal of the stage would be reached.

The following measures are planned at this stage:

- Execution of the additional radiometry and dosimetry surveys of the reactor premises; the creation of contamination maps;
- Creation of the more precise inventory of the radioactive contaminated and activated reactor systems;
- Dismantling of experimental installations located at the reactor horizontal channels.
- Dismantling of external reactor systems, which doesn’t have an impact on safety and cannot be used at the dismantling stage;
- Preservation and strengthening (if necessary) of the protective barriers assigned for the prevention of contamination spread; the reinforcement of protection around the biological shield, especially near the gate valves;
- Arrangement of the temporary storage places for the facilitation of equipment operation (the utilization of disengaged premises);
- Extraction, conditioning, storage and transfer to disposal of radwaste generated at the stage of final closure;

- Design, assembling, operation and maintenance (with the subsequent dismantling) of the additional equipment assigned for the extraction of radioactive and hazardous substances (if necessary);

- Gathering of the material and technical resources for the and dismantling stage;

- Development of decommissioning documentation, which is necessary for the permission on the beginning of dismantling stage;

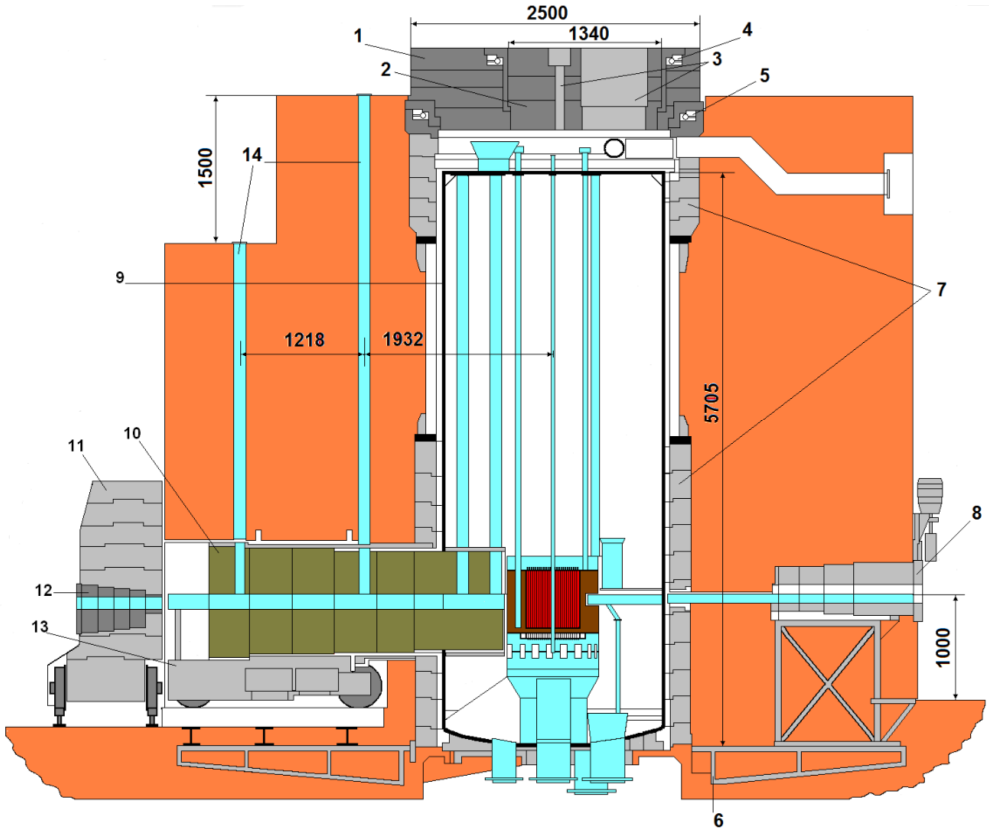
- Development of necessary design and technological documentation;

- Implementation of administrative and organizational measure corresponding to the changed status of the reactor;

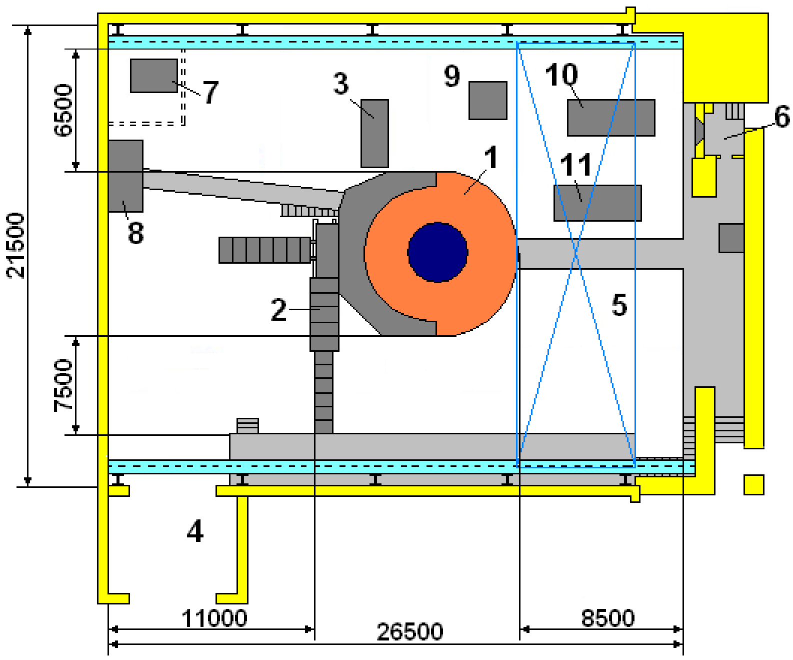
- Execution of other works and measures foreseen by the implementation programme for this decommissioning stage.

6.4. Dismantling

The goal of dismantling stage is the segmentation and removal of the reactor systems and components as well as removal of the radioactive substances outside the reactor site. From the technical point of view and existent radiation conditions, there are two most complex objects liable to dismantling, namely, the reactor with biological shield and the pump house of primary circuit. Their design and layout is shown on Figures 2 and 3; the composition is presented in Tables 1 and 2.

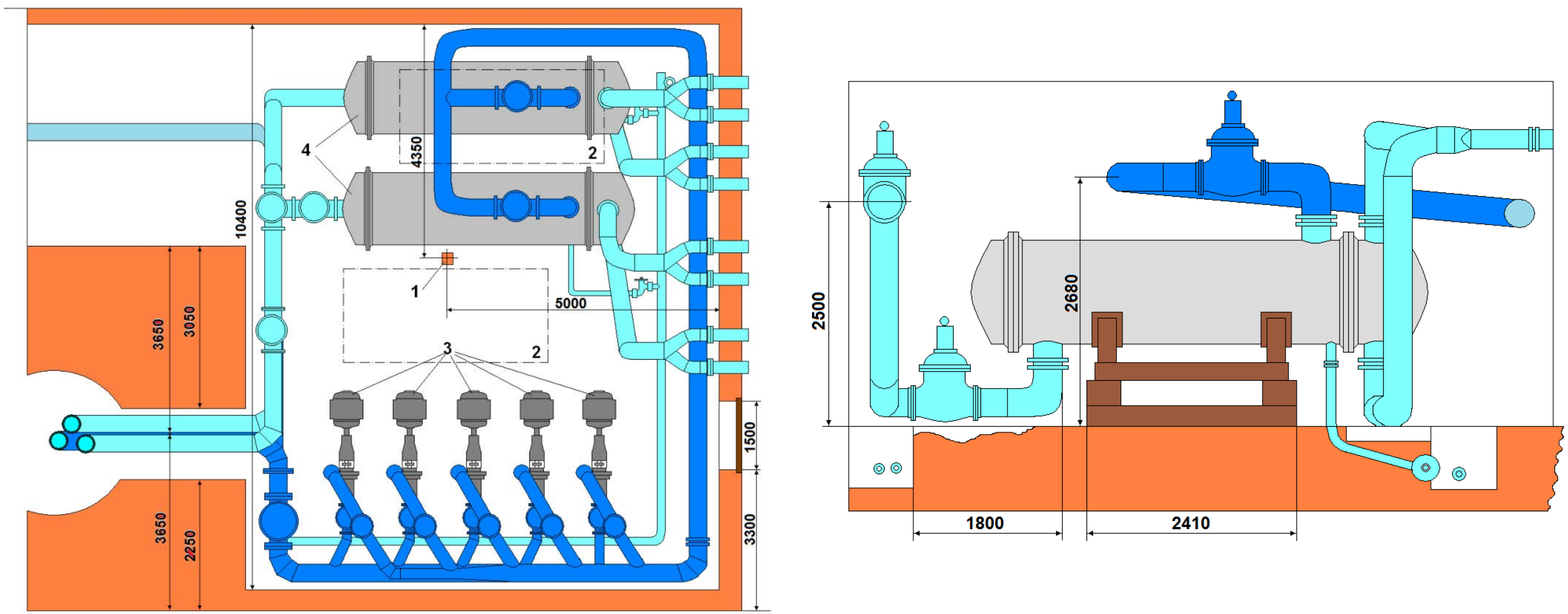


(a) *Reactor design drawing: (1) big rotating cover plate ; (2) little rotating cover plate; (3) protective plugs;(4) ball bearing of big plate; (5) ball bearing of little plate; (6) baseplate; (7) biological shielding (rings); (8) gates of horizontal experimental channels; (9) reactor vessel; (10) thermal column; (11) thermal column protection; (12) thermal column gate; (13) thermal column trolley; (14) thermal column channels.*



(b) *Reactor hall layout (below): (1) reactor; (2) thermal column protection; (3) SF cooling pond; (4) tambour to new SF storage facility; (5) bridge crane; (6) bridge crane control cab; (7–11) technological embrasures to the basement floor.*

FIG. 2. Reactor design drawings (a) and (b).



(1) ceiling pier; (2) projection of technological embrasures; (3) circulation pump units; (4) heat exchangers

FIG. 3. Pump house of primary circuit.

TABLE 1. COMPOSITION AND WEIGHT OF THE REACTOR COMPONENTS

No.	Component part	Weight (kg)	Material
1	Big rotating cover plate (4 segments of 4060, 5250, 5450 and 5680 kg)	20440	cast iron
2	Little rotating cover plate (3 segments of 2810, 2230 and 2330 kg)	7370	cast iron
3	Protective plugs	3571	cast iron
4	Ball bearing of big plate	791	steel-40
5	Ball bearing of little plate	482	cast iron
6	Baseplate	8500	steel-3
7	Biological shielding (rings)	45210	cast iron
8	Gates of horizontal experimental channels (9 pieces)	10560	steel-40
9	Reactor:		
	- vessel	3815	CAB-1
	- reactor internals (core, lattices)	256	CAB-1
	- reflector	335	beryllium
10	Thermal column (6 segments)	5940,5	graphite
11	Thermal column protection	30550	cast iron
12	Thermal column gate	698	cast iron
13	Thermal column trolley	6850	steel-40
14	Thermal column channels (4 pieces)	138	CAB-1

TABLE 2. COMPOSITION AND WEIGHT OF THE PRIMARY CIRCUIT

No.	Component part	Weight (kg)	Material
1	Main pipelines (different diameters and lengths)	5695	steel
2	Circulation pump units (5 pieces)	837×5=4185	steel
	Stop valves:		
	- Dn200 (10 pieces)	212×10=2120	
	- Dn300 (5 pieces)	650×5=3250	steel
	- Dn350 (1 piece)	600	
4	Heat exchangers (2 pieces)	7694×2=15388	steel
5	Cooling pipelines (different diameters and lengths)	1800	steel
6	Bypass purification system:		
	- pump unit	277	
	- pipelines O57	150	steel
	- stop valves Dn50	110	
	- housings of ion exchange filters	800	
7	Emergency cooling system:		
	- pump units (4 pieces)	200×4=800	steel
	- pipelines Dn50	300	

To complete scheduled dismantling tasks the following sequence of the works and measures is proposed:

- Decontamination of the areas and equipment for the facilitation of dismantling works;
- Preparation of the temporary storage areas for the location of dismantled and segmented parts;
- Dismantling of the technological equipment at the reactor upper part and in the reactor hall;
- Dismantling of metal layer of the thermal column rolling off mechanism and the thermal column shield;
- Dismantling of the thermal column’s first disk;
- Dismantling of Be reflector;
- Dismantling of reactor vessel (extraction of vessel as the whole piece, without segmentation);
- Dismantling of the armature rod drives;
- Dismantling of the ion exchange and electrophoresis filters;
- Dismantling of primary circuit;
- Dismantling of primary circuit’s embedding units;
- Dismantling of biological concrete shield;
- Dismantling of spent fuel cooling pool (CP-1);
- Removal of contaminated components, which can be extracted after dismantling of other components;
- Removal of clean auxiliary equipment for the final radiation survey;
- Dismantling of non-contaminated structures;
- Removal of contaminations from all areas and premises;
- Refinement of adjacent territory (where necessary);
- Characterization of the radioactive substances for the unlimited re-use or final disposal;
- Conditioning and transfer for the final disposal of the radwaste generated during the dismantling stage;
- Characterization of radwaste packages;
- Restoration of the reactor site (if necessary) depending on the plans of further use;
- Execution of the final radiation survey inside the reactor building and within the sanitary protective zone.

After completion of all works which are foreseen by DP:

- Implementation of procedures directed on the termination of radiation control (development of the final Safety Analysis Report) and the cancelation of the decommissioning license;

- Implementation of administrative and organizational measure corresponding to the changed status of the reactor site.

Final state after completion of the dismantling stage is matching the state, which should be achieved after the reactor decommissioning. This state is characterized by the release of reactor's site from the radiation control with the subsequent elimination of restriction conditions for the unrestricted use.

7. Decommissioning project management

The effective implementation of the WWR-M decommissioning will need the clear organizational structure and the precise definition of functional relationships and responsibilities of various entities and groups involved in decommissioning. The Institute for nuclear research as the reactor operator is responsible for the organization and implementation of the decommissioning.

At all decommissioning stages the reactor will be in another qualitative condition, which requires another management approach. Also, the significant change of planning system will be necessary. Main component of the effective planning and management in this changed state is the process of determination of full decommissioning work volume and division of this volume on the separate parts depending on the common goals and tasks**.** Project management includes planning, organization, implementation and control of resources (human, equipment, financial, materials etc.) for satisfying the technical, financial and timing constraints of the project.

The following tentative scheme for the project management is proposed. The principal responsibilities belongs to the project manager, who might be the Director of the Institute for Nuclear Research or another authorized person. He will assign three deputies: **technical management** (reactor chief engineer or deputy chief engineer); **scientific support** (head of the department of research reactor); **administrative management** (deputy on administration). Moreover, the head of **quality assurance** group will be assigned as well (chief of radiation protection department or deputy chief). The responsibilities for the high quality and safe decommissioning work execution are accounted by the head, their deputies, the chiefs of groups for dismantling, support, control, shift supervisors and head of quality assurance group.

Technical management. The deputy head on technical management has following duties:

- Participation in the development of decommissioning design;

- Analysis of possible contingencies;

- Provision the necessary staff radiation protection;

- Recording of changes in the work planes;

- Determination of the task specificity for the regular staff;

- Distribution of tasks between the regular staff and contracting personnel;

- Selection and assignment of groups for the decommissioning tasks;

- Selection and assignment of support groups;

- Selection and assignment of control group;

- Examination of personnel skill and conduction of trainings;
- Establishing of inspection order and approval of order;
- Determination of work places specificity;
- Control for preparation of the special procedures, distribution of works and checking of execution;
- Establishing the terms for the reports collection and registration;
- Renewal of necessary documents;
- Information on each specific task;
- Selection of special tools and instruments;
- Safety control and supervision;
- Participation in development of final report.

Scientific support. The deputy head on scientific support has following duties:

- Participation in the development of decommissioning design;
- Defining and testing of methods and technologies needed for the decommissioning tasks;
- Scientific support during the implementation of decommissioning;
- Analysis of possible contingencies;
- Coordination of the work plan changes;
- Participation in determination of the tasks and work places specificity;
- Participation in the conduction of trainings;
- Analysis of performed operations;
- Approval of special procedures;
- Public relations;
- Participation in development of final report.

Administration. The deputy head on administration has following duties:

- Approval of the decommissioning budget and financial provision of decommissioning;
- Recording and control of financing;
- Purchase of special equipment and instruments;
- Participation in development of final report.

Quality assurance group. The head of quality assurance group is the direct subordinate of the head of the reactor decommissioning. He has following duties:

- Quality provision at the dosimetry and radiometry investigations;

- Selective control on results of measurements and their analysis;

- Examination of compliance for measuring devices with the corresponding requirements (metrology);

- Personnel examination;

- Control of correspondence with the established rules and procedures of dosimetry investigations;

- Control of dosimetry investigations by means of selective examinations and observations.

8. Radwaste management

Decommissioning process generates significant amount of radwaste, which will be different when compared to the operational ones by variety and volumes. These radwaste can be classified in accordance with the radioactive contamination levels (high, intermediate and low level), the physical conditions (solid, liquid, gaseous), and the treatment process (combustible, compactable, melting etc.) [16]. The main part of radwaste will consist of liquid and solid ones, at that the liquid radwaste will be low and intermediate active, the solid ones will be high, intermediate and low level.

The following radwaste are belonging to the mentioned above ones:

Liquid radwaste:

- Those, which were generated directly while performing the dismantling operations (water flushing, dust suppression, gas cleaning) along with the decontamination solutions from the cleaning of dismantled segments of constructions and equipment before its further treatment;

- Secondary liquid radwaste from the treatment of different radwaste;

- Polluted water from the sanitary gate, waste from the laboratories.

The treatment and hardening of these radwaste are foreseen during the decommissioning.

Solid radwaste:

- Main technological equipment (entire or segmented), including the reactor's elements, primary circuit pipelines etc;

- Non-metal waste from the dismantled auxiliary equipment and pipelines;

- Metal building constructions after dismantling of premises;

- Facing materials (sheet steel, elastron), plasterwork and broken concrete from the mechanical decontamination of premises;

- Ventilation and technological filters, filter cotton cloth, heat insulation;

- Concrete from the dismantling of biological shield and other premises;

- Construction and household rubbish, organic waste (special clothes, footwear, cleaning materials).

Gaseous radwaste:

The decommissioning operations imply the existence of the mobile radioactive particulates, thus the main gaseous radwaste are in the form of aerosols. Consequently, all decommissioning operations will be carried out in the ventilated premises and the workers will be protected by the proper equipment.

Non-radioactive waste:

The non-radioactive waste results from the areas in which the contamination doesn't spread as well as from the decontamination of superficially contaminated surfaces. The non-radioactive waste is to be taken by the common waste collection system. The main materials resulted from decommissioning which are considered dangerous are the followings: cadmium, lead, mineral wadding, asbestos, oils and lubricants, plastics from the wire dismantling. The non-radioactive waste will be managed in accordance with the national standards. Such materials will be so sorted to recover the valuable metals, namely, stainless steel, copper as well as other materials that can be re-used.

It is planned to use an ***existing infrastructure*** for the collection, treatment and transportation of decommissioning radwaste. However, taking into account big volumes and availability of large scale elements, it is necessary to develop the technologies for the radwaste fragmentation (including the metal and concrete) as well as the technologies for the treatment of contaminated constructions (mainly metallic).

Treatment and conditioning. Collection of solid radwaste is carried out immediately at the places of their generation separately from the usual domestic, technological and building wastes taking into account following:

- Nature of waste (organic, inorganic, biological);
- Aggregative state (solid, liquid);
- Lifetime of radionuclides in the waste;
- Dangerously explosive and fire risk;
- Requirements of UkrSA "Radon" for the treatment process.

The list of the reactor system's weight of components is following:

WWR-M reactor	-	149 609 kg
primary circuit	-	31 774 kg
secondary circuit	-	49 204 kg
auxiliary systems	-	81 564 kg
	TOTAL:	**312 151 kg**

After the packaging, the solid radwaste are transported to the premise, which is assigned for the temporary solid radwaste storage. These wastes, prepared for disposal in accordance with the acting norms and rules, are transported to the Kiev's regional enterprises "Radon" in accordance with the contract between this enterprise and institute for nuclear research. The solid radwaste transportation is executed by the special cars of "Radon" only.

Liquid radwaste treatment. Liquid radwaste treatment is based on the ecologically clean method of evaporation up to the concentrate. Evaporated water after the ion exchange cleaning, chemical and gamma spectrometry analysis is used for the reactor technical needs, the concentrate (residue) containing the radioactive substances is extracted from the apparatus for the treatment (immobilization) and transported in solid form to the enterprise “Radon’. Operating apparatus for radwaste evaporation was commissioned in 2003, the facility heat power — 400 kWt, capacity — 12 m^3/day, residue: 900–1000 mg/l.

9. Support infrastructure for the decommissioning

Succesful implementation of the planned decommissioning tasks will require a relevant supporting infrastructure. The available infrastructure components are sufficient for this goal.

Power supply of the reactor’s site is provided by the Kitaevsky high voltage substation 35/10 kW by means of the cable lines 10 kW to TP-1429 and then to three transformer 10/0.4 kW 560 kWA. Reserve power supply is providing by the cable lines from the Kitaevsky high voltage substation 35/10 kW.

Water supply of the reactor’s site is provided by the water intake to the reactor’s building by means of two water pipes of ∅100 mm, to the water tower of ∅80 mm and to the cooling tower of ∅50 mm.

Sewerage system consists of 2 pipelines of ∅100 to the common network of ∅150 mm.

Engineering shop. Three types of tools are foreseen for the execution of decommissioning works: 1) elementary, which don’t need the elaboration of design drawings; 2) such, which were already used at the reactor; 3) special tools, which will need the elaboration. The elementary tools will be made at the place of work execution in accordance with the technological chart and especial designing is not necessary for them (for example, step ladder etc). Tools for the reactor technologies are available and their utilization is described in the technological charts. Special tools will be necessary for the cutting and fragmentation of the reactor’s components. All such tools after manufacturing will be tested at the special table simulator for the selection of the most optimal regimes of their application.

Load lifting mechanisms:

- ***Bridge crane, electrical, hood, double speed.*** The bridge crane is located in the reactor hall. The crane is used for the installation works in the reactor hall: assembling/disassembling of the reactor vessel, the reactor covers (big and small), the transfer of heavy large scale units of the radiation protection at the horizontal channels, the transportation of casks with the high active radioactive sources and spent fuel elements. Technical characteristics of bridge crane: loading capacity–10 t; lifting height–16 m; passage–19.5 m;

- ***Bridge single girder crane, electrical, support***. The crane is used for the lifting of heavy large scale equipment, which is a subject of bringing in and removal to/from the reactor hall as well as the operation on the fuel reloading and fuel cask transportation, when it is directed outside the reactor site. Technical characteristics of crane: loading capacity–15 t, lifting height–12 m, passage–9.0 m;

- ***Electrical chain hoist*** is used for the lifting (lowering) of the equipment from the primary circuit pump house to the reactor hall. Technical characteristics: loading capacity–1 t, lifting height–6 m;

- ***Electrical rail trolley*** is designed for the transportation of heavy equipment from the reactor hall to the premise No.102, namely, from the accessible space of the bridge crane in the reactor hall to the accessible space of the bridge crane in the premise No.102 as well as from the accessible space of the bridge crane in the premise No.102 to the accessible space of the truck crane outside the reactor building.

10. Quality assurance

Quality assurance system is the component of management system, which is directed on the achievement of relevant results in the field of quality and allowing to facilitate the planning, resource distribution and increasing the work efficiency as a whole. The measures on the quality assurance at the decommissioning of reactor will be carried out in accordance with “Programme of quality assurance at the operation of the WWR-M reactor” (**QAP**) which is developed in accordance with the requirements of DSTU ISO 2000–2004 and “Requirements for the quality assurance programme at all lifecycle stages of nuclear installation”, DSTU ISO 2000–2004.

The QAP for decommissioning includes all general requirements and the specific requirements for associated activities and it will be permanently updated during the decommissioning in order to control the changes in the reactor for each phase of decommissioning process.

QAP includes at least the following documented elements: control changes, radiological safety and environmental monitoring, inspections and surveillance, services, information management, audits, management review, performance indicators, events report.

In brief, the functioning of quality assurance system is carried out in the following manner:

- The processes needed for the quality assurance system are indicated;
- The sequence and relation of processes are determined;
- The availability of resources and information, which are necessary for the execution and control of processes, are provided;
- The control, measurements and analysis of processes to be performed;
- The actions, which are necessary for the achievement of planned results and process improvement, are executed.

For all processes having an impact on safety, the necessary working documents were developed, namely, the operational instructions, the programmes, the technological cards, the operational schemes, the measurement methods etc, which are related to the operation, technical maintenance, measurements etc. Temporary procedures for activities which have a restricted applicability will be issued. Temporary procedures for such activities will be issued, analyzed, reviewed and approved in the same way as the permanent procedures.

The data resulting from the decommissioning activities are recorded, analyzed and used for improving the decommissioning activities. For emergency and unusual situation, DDR department issues specific operational procedures. This provides the necessary measures for ensuring respect from the public, personnel and environmental health and safety legal requirements.

The personnel for decommissioning activities must be selected on the basis of competence and specific experience, trained, and authorized, if required. The staff actions are regulated by the job descriptions and technological instructions in accordance with “The list of acting norms and rules on nuclear and radiation safety”. Training and maintenance of skill level of the staff is carried out in accordance with “Guide on examination order of the knowledge, rules, norms and standards on the nuclear and radiation safety of the senior and engineering/technical staff at the object of nuclear power”.

11. Safety provision

Safety provision at the reactor decommissioning is the most important element in the whole technological chain. Each planned action at the execution of decommissioning works will be considered from the point of view of influence on the following safety components: nuclear, radiation, fire, industrial etc. The staff, population and environment should be protected from the decommissioning dangers at all stages of decommissioning. Safety at the decommissioning is provided in accordance with the requirements of acting normative documents, norms, rules and standards. Radiation, fire and industrial safety as well as the safety of environment at the decommissioning are provided by following: the designed systems which remain in operation by regular manner; the organizational and technical measures; the quality assurance system.

Analysis and safety assessment should start after approval of the decommissioning programme and continued during the development of the decommissioning design with the gradual increasing of the safety details and substantiation [17].

Nuclear safety. SNF is the subject of removal outside the reactor site at the termination of operation stage after exposure time of 3 years in the cooling pond. The operations for the SNF extraction, storage and loading will be the same as at the reactor operation. Following decommissioning works will be carried out in accordance with the decommissioning license, which doesn't foresee the SNF management and, therefore, the nuclear safety provision isn't considered in this document.

Radiation safety. Purposeful destruction of protective barriers will take place at the decommissioning and, therefore, the release of radioactive substances in the solid, liquid and gaseous state or in the form of aerosols will be potentially possible. For the radiation safety provision at the decommissioning the separate programme of radiation protection will be developed; this programme guarantees that the radiation protection is optimal and irradiation doses doesn't exceed the established limits [18, 19]. The statistical information concerning the staff external exposure in dependence on the duration and number of works is shown in Table 3. As one can see in Table 3, the annual averaged individual dose doesn't exceed 2.41 *mSv* (in 1999), which is significantly lower established limit. Dynamics of individual doses are depending on the character and duration of radiation hazardous works and can be used as an explanation of the collective dose variation during considered period. Thus, the main radiation hazardous works when the staff has the largest dose load are following:

- Repair, assembling and dismantling of technological equipment, especially in the pump house of primary circuit;
- Works on the reactor cover plate, especially at the core reloading;
- Replacement of cleaning resins;
- Coolant sampling and analysis;
- Collection, conditioning, transportation and storage of radioactive waste;
- All kinds of works with the spent nuclear fuel in the cooling pond.

In accordance with the results of individual dosimetry control during last decade, the cases of individual dose exceeding doesn't registered during the whole time of reactor operation. The main criterion of the radiation protection effectiveness is the absence of the individual dose exceeding. Moreover, the additional criteria are the maximal and averaged exposure doses; the decreasing of collective dose; the decreasing of individual exposure doses; the decreasing of radioactive aerosol releases; the decreasing of violations.

TABLE 3. COLLECTIVE AND INDIVIDUAL DOSES OF THE REACTOR STAFF

Year	Quantity of staff [a)] (*persons*)	Number of works	Duration of works, (hours)		Dose	
			total	average	Collective (*man x mSv*)	Averaged individual (*mSv/year*)
1998	54/22	269	322,8	1,2	68,7	3,12
1999	58/32	219	635,1	2,9	140,2	4,38
2000	70/41	247	790,4	3,2	160,5	3,91
2001	73/49	262	995,6	3,8	168,9	3,45
2002	73/28	298	476,8	1,6	108,9	3,89
2003	74/31	237	616,2	2,6	125,0	4,03
2004	74/34	211	738,5	3,5	152,7	4,49
2005	74/29	219	613,2	2,8	132,7	4,58
2006	73/37	263	867,9	3,3	161,7	4,37
2007	67/35	184	220,8	1,2	89,6	2,56
2008	69/33	150	255,0	1,7	107,9	3,27
2009	75/47	176	488,3	2,8	104,4	2,22
2010	79/43	170	358,4	2,1	112,9	2,63

[a)] list of members of staff / used for the radiation works

Setup of the radiation protection system at the reactor decommissioning will be a logical continuation of the currently existing system [20, 21]. This system will be rearranged and adopted for the needs resulting from the nature and content of decommissioning works. It will be necessary to implement specific surveillance and monitoring programmes, including the appropriate standards and separate measuring procedures. At the same time, the established approach for the staff exposure will be retained, namely:

– The staff and population exposures cannot exceed the established dose limits;

– The levels of individual exposure and number of persons subjected to exposure should be so low as much as it can be achieved with an allowance for economical and social factors.

The design limit for Category A worker dose is 20 mSv/y although it is permissible for individual workers to receive up to 50 mSv in a year subject to an overall (50 year) lifetime limit of 1000 mSv. The design intent of the decommissioning operations is that the annual individual dose will not exceed 20 mSv and will be as far below 20 mSv as is reasonably achievable (ALARA). There are limits on maximum dose rates in areas according to occupancy. The dose rate limits allow a safety factor of 2 and would result in annual exposures of 10 mSv for group A workers (this corresponds to the daily dose limit of 70 μSv).

The additional administrative and engineering measures will be implemented for the safety provision for the staff, population and environment at the decommissioning:

- Works will be carried out in the conditions established by the rules of radiation hygiene, namely, the availability of radiation control, protective barriers, sanitary sluices etc. will be provided;

- Working premises and areas will be divided on separate zones;

- Restriction of staff exposure by means of use of the remote equipment, optimization of dismantling and cutting procedures etc;

- Secondary radwaste minimization;

- Local ventilation and dust suppression will be used together with the available one;

- Additional individual protection tools will be necessary as well as the mobile protective shield and temporary barriers;

- Radiological mapping of working areas should be arranged;

- Radiation monitoring aimed on the detection of areas with an increased dose rate;

- Permanent measurements of contamination;

- Perfection of the external monitoring system;

- Account and control of radioactive waste before the removal outside the reactor site;

Physical protection system. The existing physical protection system can provide protection during the decommissioning period. Physical protection at the decommissioning will be arranged on the base of planned state of the reactor site for the provision of protection against of unauthorized access. The physical protection system was commissioned in 1998; this system includes the elements providing the multi-level system for the intruder detection and access control to the secured areas. System includes three protection levels, namely:

– First: double fence around the reactor building and system for intruder detection between fences — TV cameras, infrared and vibration sensors, alarming for the opening/closing of gates;

– Second: system for detection of intruder and access control into reactor building and hotcells (metal doors with opening sensors and magnet and mechanical locks);

– Third: premises of fresh and spent nuclear fuel, reactor hall.

Thus, the physical protection of the reactor site will be provided by the set of technical and organizational measures directed on the maintenance of efficiency of physical protection, which was created during the reactor operation. Operation of the physical protection system is foreseen during whole decommissioning period till the full completion of all works and measures predicted by the Decommissioning Programme.

Fire safety at the decommissioning works will be provided by means of organizational, technical and other measures directed on the fire prevention, decreasing of negative ecological after effects, creation of conditions for the fast call of fire brigades and successful fire extinguishing. The existing fire detection and alarm system is capable to provide the required protection during the decommissioning period.

Existing fire safety system includes the system of automatic fire alarm and extinguishing tools, such as the fire hydrants, fire extinguishers and sand boxes.

The dismantling of separate elements of existing fire safety system will occur during the decommissioning works and, therefore, some new additional elements will be necessary. The quantity and inventory of main kinds of fire engineering is established by the requirements of the State standards, building norms and separate normative documents.

Industrial safety. Gradual decrease of hazard from the reactor and radiation risks with the parallel increase of industrial risks available at the places of building and dismantling works is the typical feature of the decommissioning process. Variety of technological tools with the high level of mechanization during the decommissioning works requires a reliable safety measures for the personnel. Therefore, the estimations of these industrial risks and determination of adequate measures for their elimination or mitigation are especially important for the decommissioning.

Creation of the normal and safe working environment for the personnel is regulated by the acting legislation; the rules and measures on industrial safety, labor protection and creation of the sanitary/hygienic working conditions are established.

Besides the common safety measures, the special safety and protection measures are established for each installation or equipment, which should be presented in the instructions on assembling, operation and maintenance.

The significant part of works at the reactor decommissioning will be considered as the works with an increased level of risks, such works are following:

- The electro and torch cutting;
- The works with electrical mechanisms;
- The works with utilization of the hand electrical and pneumatic instruments;
- The works with highly inflammable substances;
- The works in closed areas;
- The works at the height.

For all decommissioning works the safety criteria should be established for the system and equipment in correspondence with the requirements of acting safety norms, rules and standards, industrial hygiene and sanitary.

Emergency response. Emergency response system of INR (ERS) is the interconnected complex of technical tools and resources, the organizational, technical and radiation/hygienical measures, which are implementing by the institute's administration and staff with the goal of emergency response, i.e. the prevention or mitigation of radiation impact on the staff, population and environment in the case of accident at the WWR-M reactor.

Emergency response system of INR is a part of the object level of the territorial subsystem of the unified state system for the civil protection of population and territorial domains, which is created in Kiev with the goal of the prevention and elimination of emergency after effects induced by the man caused, natural and military reasons within the relevant area [22].

Main ERS task are following:

– Maintaining the necessary level of emergency preparedness in the case of accident at the reactor WWR-M;
– Response on accidents and emergency situations, including the implementation of meaures for the protection of staff, population and environment.

Main ERS elements are:

(1) Institute's normative/legal basis;

(2) Emergency plan;

(3) Institute's emergency organizational structure;

(4) Tools of emergency response;

(5) System of personnel training and exercising;

(6) System of interaction with the external organizations.

12. Use of personnel

Preservation and use of the personnel's practical experience is one of the priority targets during the decommissioning planning and implementation. Application of this experience will allow reducing a risk of possible accidents as well as the problems with the recruitment and training of new staff and significantly facilitating the work execution. The initial decommissioning tasks are the same as the operational ones, for example, the SNR reloading, decontamination etc. The reactor staff has a deep knowledge of the reactor and relevant systems. Therefore, the main part of works will be performed by the reactor staff. Besides the regular reactor staff at the moment of reactor final shutdown, it is necessary to attract other workers as the consultants, which work formerly at the reactor maintenance. For the specific works, which are not typical for the reactor operation, it is worthwhile to attract the institute's specialists or specialists from another enterprises dealing with the nuclear power.

The acting legislation declares that the State promotes the provision of each nuclear installation during the whole lifecycle by sufficient quantity of well qualified personnel having a necessary level of education and training with the aim of maintenance at the needed level of safety of such installation. The integrated planning and provision of educational programmes should compensate the decrease of skilled staff. Staff training and retraining for the execution of decommissioning works should provide the knowledge of operation of the main systems and mechanisms as well as the safe manner of work execution. Training with the simulators, mock-ups and models will be conducted with the aim of safety and efficiency increasing. At the staff training for the decommissioning works, it will be provided the requirements to the operator concerning the implementation of relevant measures for the preparation of responsible persons in accordance with the requirements of operational license.

The staff training should provide the following:

- Fulfillment of safety requirements;
- Execution of decontamination and dismantling works;
- SNF and RAW management;
- Operation and maintenance of the auxiliary systems (ventilation, power and water supply, load lifting mechanisms etc.);
- Work management and coordination;
- Operation of the quality assurance system;
- Emergency preparedness.

At the works for reactor decommissioning it will utilise the staff, which knows in detail the technology of works, safety instructions and operational instructions for special tools and mechanisms. As a whole it is foreseen the use of about 70 specialists of institute for the reactor decommissioning. Quantitative and professional content of the working groups will be determined by the executed work.

13. Social protection of the reactor staff

Final shutdown of reactor will lead to the decreasing scope of works and, respectively, to the partial release of staff. In accordance with the preliminary estimations one can expect that at the termination of operation stage due to significant volume of works connected with the preparation of next decommissioning stages the sharp staff decreasing will be absent. However, at the transition to further decommissioning stages, the workforce needs will be sequentially and significantly reduced.

With the objective of provision the social protection and socioeconomical development of town, it is necessary to elaborate "Programme of social protection of the WWR-M reactor's staff", which should determine the measures on creation of new jobs and financial resources (volumes and sources) for implementation of these measures.

Programme of measures directed on mitigation of negative consequences of the reactor shutdown and decommissioning will include the following directions:

- Utilization of available workforce; training and retraining of staff;
- Creation of new jobs for the employment of staff released due to the reactor decommissioning;
- Provision of social protection of the reactor's staff.

14. Environmental external monitoring

The systematic radiation control of the rector's impact on environment is carried out continuously during the reactor operation. Main task of radiation monitoring is the overall control of gamma, beta and alpha radioactivity as well as the content of basic radionuclides of reactor's origin (first of all, ^{3}H, ^{90}Sr and $^{134,137}Cs$) in the environmental objects around the reactor's affected zone. The investigations are performed in 6 stationary points within the reactor site area (300 m) and 12 stationary points within the supervised area (3000 m), which were selected accounting the wind-rose. The subjects of interest are the following: the near surface air; the atmospheric precipitates and settling dust; the water from the main collectors; the water from the open reservoirs (including the water flow of river Dnepr — above and below the rector's location); the water from melted snow; the birch sap; the soil and vegetation. The measurements of the short lived and long lived alpha and beta aerosol content in the near surface air were performed too together with the measurements of gamma radiation dose rates in the control points. Currently, there are following types of control: the air radioactive contamination; the water radioactive contamination; the soil radioactive contamination.

As the whole, the results of radiation monitoring give an evidence that the reliable increase of radionuclide content within the controlled parameters in comparison with the Kiev's typical ones was not founded during the whole time of investigations and this confirm the safety of reactor. The reactor radiation impact on the environmental objects is very small and it is difficult to distinguish on the natural background and man caused contaminations caused by the Chernobyl accident and global fallout [23].

The existing system of environmental radiation monitoring will remain in operation during the reactor decommissioning and it will be adapted for the tasks connected with the decommissioning works.

The Environmental Monitoring Programme for the decommissioning period will follow the same targets as the targets during the operation period and will consider the followings:

- Modification of the „source" term and consequently, the corresponding modification of the critical radionuclides, of the critical exposure pathways and the critical groups;
- Modification of the activities for the release of the radionuclides to the environment.

Function of the targets, the environmental monitoring programme includes: a) routine monitoring programme; b) emergency monitoring programme;

The typical objectives (targets) of the environment routine monitoring are:

- Verification of the radioactive emission monitoring programme results and associated models in order to check the protections supplied by the employed models;

- Supply of required data for the assessment of current or potential doses to the critical group members, resulted from the decommissioning activity;

- Detection of any unexpected modification of the radioactivity concentrations and the evaluation of the long term trends of the radioactivity levels in the environment as a result of the radionuclide releases to the environment;

- Supply of information to the public.

Environmental Radioactivity Monitoring Programme for emergency cases will be so designed that it can provide the fulfillment of the following specific objectives:

- Supply, in due time, of the accurate data on the level and degree of dangers resulted from a nuclear emergency event and mainly on the environmental radiation and contamination levels;

- Satisfaction, by its results, of the requirements for the personnel involved in decision making regarding the protection and repair actions;

- Supply of required information for the protection of personnel involved in interventions;

- Supply of information on the degree of the existing hazard for population.

15. Public relations on the decommissioning problems

Public hearings and discussions will be organized in the district, where the reactor decommissioning is occurring. For these purposes, the following measures will be implemented:

– Publication of design solutions in the mass media, such as newspapers, radio, television;

– Information sheets and bulletins;

– Public opinion poll;

– Public hearings;

– Official meetings of the representatives of customer and EIA developer with the community (delegates, local authority etc.);

– Informal meetings with the small group of local residents;

– Workshops;

– Advisory committees.

As the result of the EIA discussions and revision of design materials, all interested parties will create the understanding of possibility and practicability of the WWR-M reactor decommissioning at this site on the base of ecological after effects at the presented and fixed conditions.

Before a final approval, it is necessary to show the possibility of the emergency plan implementation. The site should be free from any adverse conditions, which are putting obstacles in the way of resident evacuation or in the input and output of external services dealing with the accident elimination. Realization of emergency plan should be demonstrated on the base of main characteristics of the natural peculiarities and infrastructure conditions in this district. Under infrastructure it is considered the transport and communication networks, industrial activity and all other factors influencing on the fast and free moving of people and transport in the region of reactor site. For the evidence of the emergency plan feasibility, it is necessary to collect the regional information, such as the information about readiness, the system of collection and distribution of milk and other agricultural production, the data on specific population groups, the industrial constructions and the environmental conditions (weather range etc).

16. Collaboration with other CRP members

Project of this type is a convenient platform for information exchange since it covers a wide range of expertise and knowledge. This information has helped in the adequate planning and implementation of decommissioning. Discussions were with all CRP participants and as the result some new idea evolved. The task oriented information was obtained from Niels Strufe concerning the different decommissioning problems at the Riso National Laboratory. The aspects of decommissioning planning for the multi-unit NPPs were discussed with Vladimir Michal and Ferenc Takats. A set of decommissioning documents on the WWR-M reactor was transferred to Pham Van Lam for consideration and further use.

17. Conclusions

Although the present technical condition of the WWR-M reactor allows its safe operation, nevertheless, in accordance with the national legislation the decommissioning planning must be performed at the operation stage as early as possible. It is the function of the project management to plan and prepare the decommissioning tasks on the technical, administrative and legal levels properly and well in advance. Recently, the Decommissioning Programme was approved by the regulatory body. It is concluded that the WWR-M reactor can be safely dismantled at any time using an existing technologies.

The decommissioning goal is the release of the buildings for unrestricted release and an immediate dismantling was chosen to be optimum decommissioning strategy. The approved initial decommissioning plan creates a requisite for further decommissioning planning and it is utmost importance to continuously upgrade the decommissioning planning system.

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THE PRELIMINARY DECOMMISSIONING PLAN OF THE DALAT NUCLEAR RESEARCH REACTOR

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Abstract

Recently, after 25 years of operation, a preliminary decommissioning plan for the Dalat Nuclear Research Reactor (DNRR) has been produced but as yet it has not been implemented due to the continued operations of the reactor. However, from the early phases of facility design and construction and during operation, the aspects that facilitate decommissioning process have been considered. This paper outlines the DNRR general description, the organization that manages the facility, the decommissioning strategy and associated project management, and the expected decommissioning activities. The paper also considers associated cost and funding, safety and environmental issues and waste management aspects amongst other considerations associated with decommissioning a nuclear research reactor.

1. Introduction

During the design and construction phases of DNRR, the aspects to facilitate the decommissioning process and reduce occupational exposures such as selection of material to reduce activation products, use of modular for easy dismantling, designing to avoid contamination or to allow easy decontamination have been utilized. Next to the reactor pool in the same concrete shield structure, there is spent fuel storage tank. It was the old bulk shielding experimental tank, kept from the former TRIGA reactor. For the present reactor, this tank is coated with stainless steel and filled with demineralized water. The capacity of the spent fuel storage tank is 300 fuel assemblies. The 2.5 metric ton lead flask and the crane with 3.6 ton capacity in the reactor building are provided to transfer spent fuel assemblies from the reactor pool to the spent fuel storage tank. The liquid waste treatment station is designed for treatment of about $5m^3$/day of liquid radioactive wastes using methods of coagulation, precipitation, mechanical filtration, and ion exchange. The disposal facility in Bldg. No.5, designed for disposal of low level solid radioactive waste, contains 8 pits of 94 m^3 volume each for storing the metal drums of radioactive wastes. These pits hydrologically isolate with the entrails.

During operations, consideration is given also to minimizing the extent of contamination of structures and surfaces, segregation of different categories of wastes, avoidance and prompt cleanup of spillages and leaks, and selection of material for specimen irradiation and experiment.

The purpose of the initial decommissioning plan of the Dalat Nuclear Research Reactor (DNRR) is to provide general information on the reactor as well as the radiological status at present time and the administrative and technical measures applied to implement decommissioning activities after the reactor is permanently shutdown.

This decommissioning plan will give sufficient information on location, main parameters and technological systems of the DNRR, the experimental equipment as well as radiological status at present in the facility. A proposed decommissioning strategy for the DNRR and rationale for chosen strategy are stated clearly in the decommissioning plan. The method of project management approach, organization and responsibilities for the project management, decommissioning activities, surveillance and maintenance for Equipment and systems used in decommissioning stage, and cost estimate and funding mechanisms for decommissioning project are also presented in the plan. Besides, the plan will contain waste management programme; programme for radiation protection, nuclear critical safety, and industrial safety; quality assurance programme; and physical security and safeguards programme. The contents of the plan are based on IAEA Safety Report Series No.45 [1] and IAEA Safety Guide G-2.1 [2].

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In addition, this decommissioning plan will also provide detailed information on safety assessment and environmental assessment during decommissioning of the DNRR; an emergency planning at the Nuclear Research Institute in accordance with decommissioning stage; and final characterization survey after finishing the contamination and dismantling of the reactor.

The authorization owner:

Name: Nuclear Research Institute

Address: 1 Nguyen Tu Luc Street, Đa Lat City, Lam Dong, Vietnam

Constitutive act: Governmental Decision No. 64-CP/26.4.1976

The DNRR is owned by NRI, which is a state organization and a branch of Vietnam Atomic Energy Institute (VAEI) under governmental administration of the Ministry of Science and Technology. Beside the operation and utilisation of the reactor, the Institute also carries out other activities in nuclear applications for peaceful purposes in the country. The authorized activities of the NRI include:

(1) To ensure the safe operation and effective utilization of the DNRR;

(2) To conduct scientific research, and develop applications of nuclear technique and atomic energy in different fields of national economy;

(3) To prepare material and technical potentials and manpower training for the development of the Institute and nuclear sector in Vietnam;

(4) To ensure the safety for the operation of the Institute. To provide technical support to State management on radiation protection and nuclear safety. To study on radioactive waste treatment techniques and emergency response in handling radiation and nuclear incidents. To perform radioactive environmental monitoring in national network, calibrate radiation dosimeters and nuclear facilities as assigned by State agencies;

(5) To implement technology transfer and technical services in the field of atomic energy and related fields in conformity to law;

(6) To implement joint ventures with domestic and foreign agencies in the fields related to Institute’s functions according to law;

(7) To manage the Institute’s organizations and personnel in accordance with current regulations of the State.

The organization charts of VAEI and NRI are shown in Figures 1 and 2 respectively.

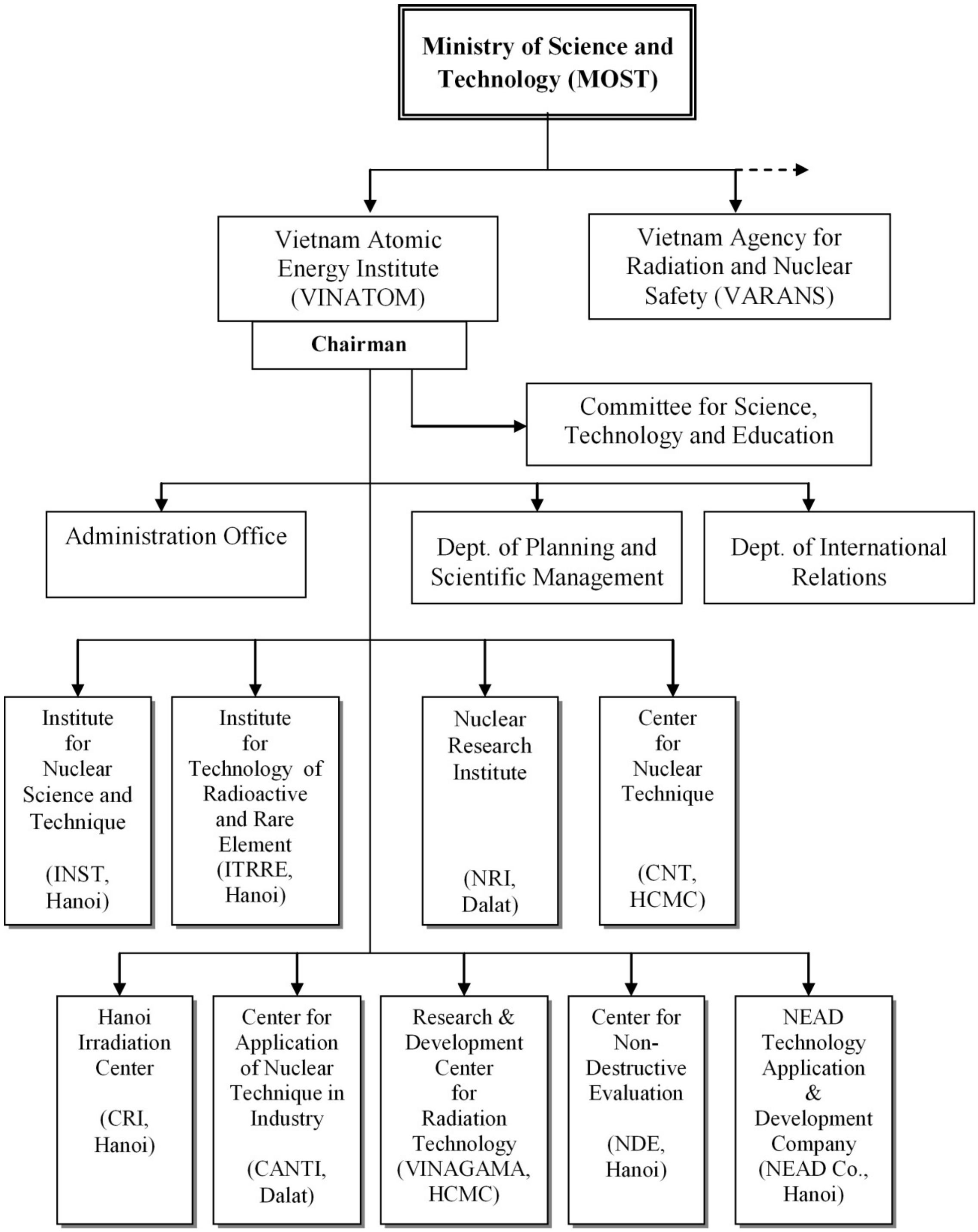

FIG. 1. Organizational chart of the Vietnam Atomic Energy Institute (VINATOM).

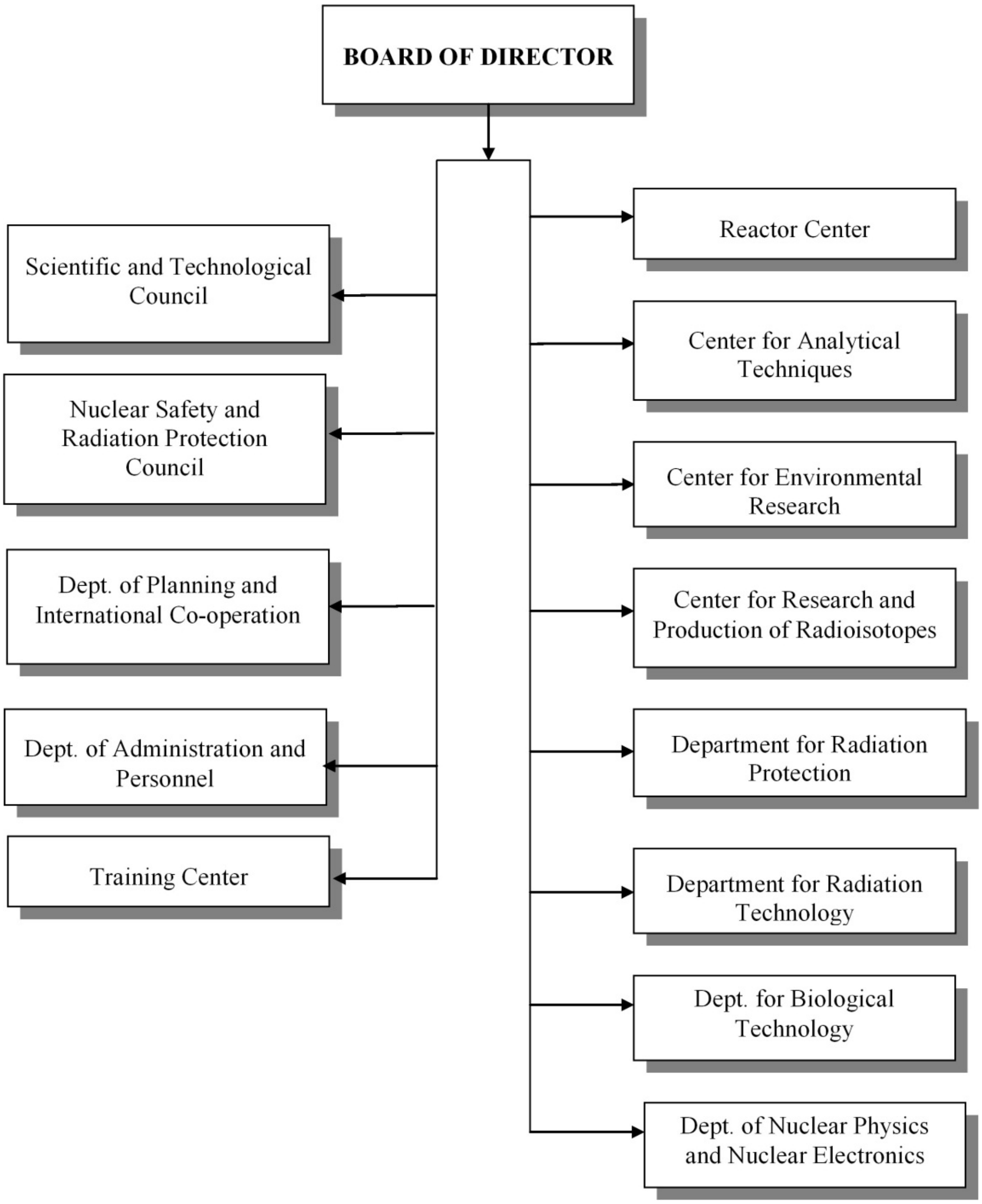

FIG. 2. Organizational chart of the Nuclear Research Institute (NRI).

2. General description of the Dalat Nuclear Research Reactor

The Dalat Nuclear Research Reactor (DNRR) is located within the city of Đa Lat in Lam-Dong Province, South of the Central Plateau of Vietnam. Layout of facility is shown in Figure 3. The Đa Lat city is at about 300 km far of East-East North from Ho-Chi-Minh city, at about 180 km of West South from Nha-Trang city and at about 100 km bird flight west from the coastal town of Phan-Rang.

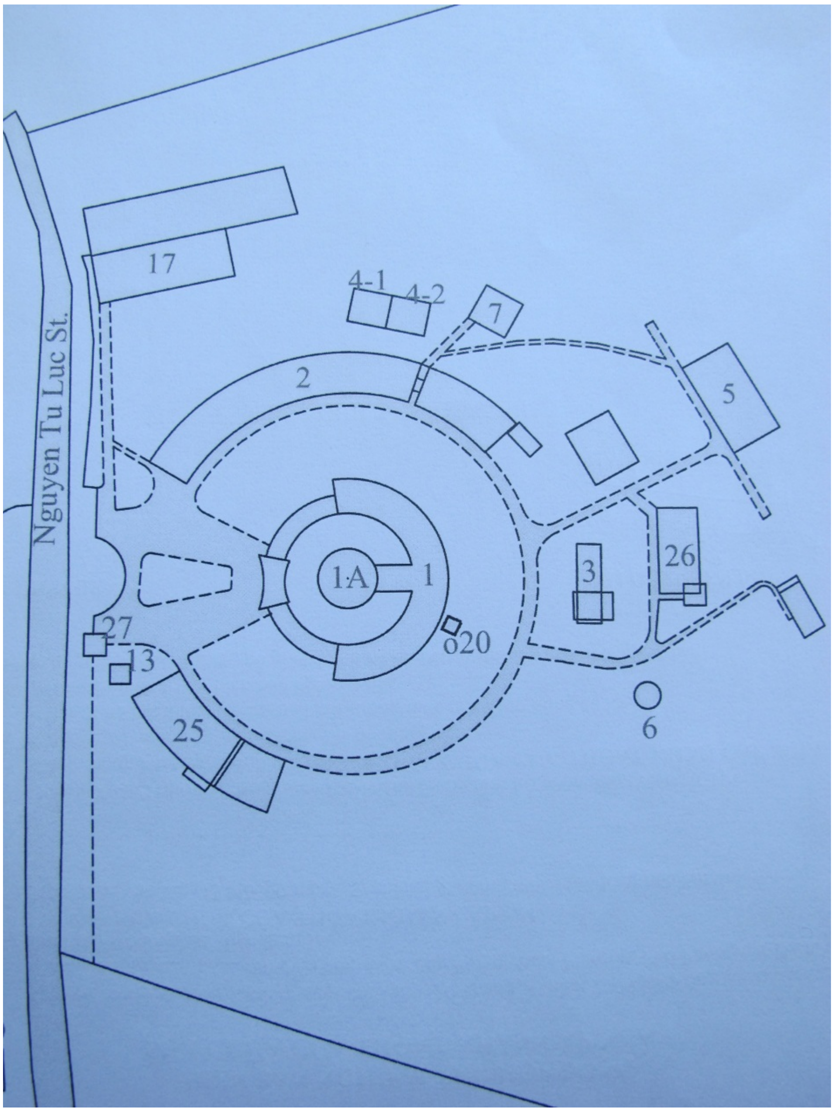

FIG. 3. Layout of facility.

The reactor facility is situated on a hilltop at an altitude of 1506.35 m compared to sea level, about 2.5 km North-North East of the city centre and at a distance of 500 m northeast of the nearest Xuan Huong Lake. The reactor located near the middle ground of the DNRI, bounded by a fence with the area of 137,000 m^2. Buildings and structures of the facility and of the Institute as well, are oriented on circular orbits around the reactor hall. The buildings and main structures of DNRR are listed in Table 1.

TABLE 1. BUILDINGS AND STRUCTURES OF THE DNRR

Building and structure	Number
Reactor building	1A
Building for research laboratories	1
Building for technical services and research laboratories	2
Transformer station and diesel generators	3
Water reservoirs, 250 m^3 each	4-1, 4-2
Building for radioactive waste disposal	5
Water tower	6
Cooling tower	7
Building for telephone exchange and communication	13
Mechanical workshop	17
Air stack	20
Administration building	25
^{60}Co irradiator building	26
Security post	27

The 500-kW pool typed, light water cooled and moderated, Dalat Nuclear Research Reactor (DNRR) was reconstructed and upgraded from the USA made 250-kW TRIGA reactor. The upgraded reactor reached the first criticality on 1 November 1983. And then, since March 1984, the reactor has been officially put into operation for the purposes of radioisotope production, neutron activation analysis, fundamental and applied research, and manpower training.

The dismantling and decontamination for the DNRR will be conducted in the buildings having structures and devices that are enabled activation or radioactive contamination. Buildings, structures and equipments are expected to conduct decontamination and dismantling activities include:

- Reactor hall (including reactor shield structure, reactor components structure and primary pump loop equipment);
- Some rooms with radioactive contamination in Bldg No. 1 (Exhaust ventilation V-1, 7-1 pneumatics channels equipment, radioisotope production labs and laboratories of Center for analytical techniques);
- Some rooms with radioactive contamination in Bldg No. 2;
- Systems and equipment of the DNRR can be radioactive contamination including: primary cooling loop, primary purification system, secondary cooling loop, ventilation system V1, ventilation system V2, spent fuel storage purification system, pneumatics systems 7-1 and 13-2, hot cells for radioisotope production, collecting and transferring of liquid waste system and station for radioactive liquid wastes treatment in basement of Bldg No. 2.

The main purpose of decontamination activities and dismantling of the DNRR after the end of operations of the reactor is that it will free up the reactor building and laboratories in the Bldg No. 1 and No. 2 from the supervision of legal rules and re-use these sites without any restrictions.

The present reactor has been reconstructed from the former TRIGA Mark II reactor. The TRIGA reactor, supplied by General Atomic (GA, San Diego, California, USA), was built in early 1960s, put into operation in 1963 and operated until 1968 at nominal power of 250 kW. In 1975, all fuel elements of the reactor were unloaded and shipped back to the USA.

During the 1976–1980 periods, a programme to reconstruct and upgrade the reactor, as well as to enlarge the reactor facility, was set up with the cooperation and assistance of the former Union of Soviet Socialist Republics (USSR). The new reactor was redesigned by the State Design Institute of the USSR State Committee for the Utilization of Atomic Energy. The reactor facility equipment was supplied by the Atomic Energy Import and Export Company (ATOMENERGOEXPORT, Moscow, USSR). A number of structures from the original TRIGA reactor, such as the aluminium tank with the surrounding concrete shield, the beam ports, the thermal column and the graphite reflector, have been retained. The first criticality of the reactor was achieved on 1 November 1983. The nominal power of 500 kW was attained in February 1984, and then, on 20 March 1984 the present DNRR was officially inaugurated and its activities restarted.

It should be noted that, from the beginning and up to now, all the stages, including sitting, design and construction, commissioning, operation, utilization and any modification of the reactor, have been authorized and funded by the competent organizations at the governmental level. However, in order to better meet the national and international requirements for safety and regulation of nuclear and radiation installations, DNRI has implemented a licensing process for DNRR and obtained the License No. 380/GP-BKHCN on 18 March 2004. After the end of this time limit, DNRR also has been re-licensed for a period of 5 years (License No. 1846/GP-BKHCN on 04 September 2009).

3. Decommissioning strategy

According to Nuclear Research Institute's project submitted for Vietnam Atomic Energy Institute and Ministry of Science and Technology, it is anticipated that Dalat Nuclear Reactor will be shut down in 2029 and then decommissioning process will commence. The purposes of decommissioning process of Dalat Nuclear Reactor after its operation are to release areas such as Reactor Building, technical rooms and laboratories in Building No.1 and No.2 from regulatory control and to re-use these areas without any restriction.

Three decommissioning strategies have been defined by IAEA namely: *immediate dismantling, deferred dismantling and entombment* [3].

The selection of a particular decommissioning strategy for DNR will define timeline and series of decommissioning activities. These strategies could be Immediate Dismantling and move all radioactive materials off reactor site (allow the unrestricted release) or on site Entombment option includes secure entombment and restricted access later on. In order to select an adequate decommissioning strategy, many factors will be considered such as: fund, health, safety, environmental effect, capability of resources, relationship with involvement organizations, etc. In some cases, the lack of a major resource could lead to elimination of some decommissioning strategies.

Immediate dismantling of the reactor site could allow re-use for other purposes and the decommissioning work could be accomplished by on site workforce who has good understanding of the facility. Although this selection requires a high initial expenditure, the total expenditure of this option may be lower than others'. A part of initial expenditure could be for the use of thicker radioactive shielding or remote operation tools to avoid high dose loading on staff because this strategy does not benefit from time allowed for radioactive decay.

In contrast to immediate dismantling, deferred dismantling has the benefits of significant reduction of radioactivity resulting in reduced exposure to personnel and the public and also in a decrease of waste volume. Deferred dismantling, however, will delay the reactor site and surrounding areas for re-use for a long period. In addition, equipment maintenance, security and monitoring control will be required until completion of decommissioning process; as a consequence this option needs annual expenditure for operation and management. In accordance with those reasons and international experience, the total expenditure for implementation of this selection will be approximate or higher than that of immediate dismantling. Moreover, the availability of personnel who have experience and good understanding of the reactor will reduce due to a long decommissioning period. As a result, the deferred dismantling option will face potential risk of the lack of trained staff.

On site storage will include removal of fuel assemblies from reactor core, draining water in reactor pool and the remaining radioactive materials entombed for long term storage using concrete to stabilize. This is the cheapest option for decommissioning not requiring much time and human resource. The final state of the reactor following this option, however, will be radioactive structures, results in requirement of long term monitoring. That will restrict the re-use of the site.

When selecting a preferred decommissioning strategy in a specific facility, a range of general and site specific factors needs to be considered, typically, in a multi-attribute analysis. These factors include cost, health and safety issues and environmental impact, availability of resources, stakeholder involvement, etc.

The factors that impact on the selection of a decommissioning strategy for DNR will include:

- National policies and regulatory framework;
- Financial resources / cost of implementing a strategy;
- Spent fuel and waste management system;
- Health, safety environmental impact;
- Knowledge management and human resources;
- Social impacts and stakeholder involvement;
- Suitable technologies and techniques.

In addition, when selecting the decommissioning strategy, the following features will be considered:

- The reactor location which is close to the city center and the increase of residents surrounding the reactor site will require the re-use of the site which counters the disadvantages in shipment of spent fuel, radioactive waste and contaminated equipment;
- Activated structures and components loaded in reactor core is insignificant due to the low neutron flux density;
- Majority of building constructions are not contaminated; only the surface levels in some reactor technical equipment rooms, radioisotope production chambers and labs of activation analysis;
- Radioactive waste management and disposition facility is available at DNRI and radioactive waste generated during decommissioning process is consider minimal;
- The operational personnel of Dalat Nuclear Reactor in NRI have good experience and understanding of the reactor;
- Another radioactive source, ^{60}Co, is in operation in DNRI.

On site entombment has the disadvantage in restricting the re-use of the site (or it will take a long time to release the site from restriction) so that this strategy selection will not meet the major goal to re-use the DNR site after completion of decommissioning. In addition, this selection does not meet the international experience which often requires releasing the site from restriction after decommissioning. For two other options (immediate dismantling and deferred dismantling), general tasks need to be done prior to decommissioning process:

- Reactor final shutdown and disconnection of control systems with the aim of prevention of the reactor repetitive startup;
- Spent fuel removal;
- Drainage of primary coolant;
- Decontamination;
- Completion of removal and treatment of operational radioactive waste.

The selection of deferred dismantling option for DNR is possible to get some advantages due to the natural decay of radioactive substances and, thereby, to decrease the dose loading on the staff, however it has the following disadvantages:

- Loss of the operational personnel experience after deferred dismantling;
- Necessity of maintenance of corresponding document management system for decommissioning purposes;
- Additional expenditures will be necessary for the maintenance during long term storage;
- Potential danger of radioactive release into environment is remaining due to the accident or destruction of protective barriers;
- The selection could not get the agreement from organizations who are involved in decommissioning.

In the case that immediate dismantling selection is applied for DNR decommissioning, the experience and understanding of operational personnel of nuclear facility status and history will be used effectively. This is very important for plan establishment and completion of DNR decommissioning.

Based on the comparison of presented arguments and combination with DNR particular features mentioned above, immediate dismantling option will be a reasonable selection for DNR decommissioning after its shutdown.

When selection of immediate dismantling option for DNR, these following required factors which affect reactor decommissioning should be considered and evaluated to implement sufficient actions:

At present, Regulatory framework for reactor decommissioning is provided in Nuclear Energy Legislation but detail criteria in order to release materials, structures and site to re-use for another nuclear or non-nuclear purposes are lacking. The lack of these criteria during period of decommissioning will lead to the delay in immediate dismantling due to the need of framework which defines all stages of reactor decommissioning. At this time, when government is strongly conducting programmes of nuclear energy applications with peaceful purposes especially the construction of Nuclear Power Plants in near future, current limitations of detail criteria for disposing radioactive materials and releasing the area will be soon remedied. In addition, it is anticipated that DNR will be in operation until 2029, so that time is enough to prepare and complete Regulatory Framework and criteria related to reactor decommissioning.

Because the strategy of immediate dismantling requires a large fund in such a short period, it can be easily affected by the potential of inadequate funds. DNR facility, however, belongs to government, the funds for operation, maintenance and for reactor decommissioning are also provided annually by Ministry of Science and Technology. The lack of fund for DNR decommissioning only occurs in the case there is no requirement in Regulatory Framework. However, in according to the Article 7 and Article 30 of section 3 in Vietnam Nuclear Energy Legislation, government will be responsible for supplying funds for DNR decommissioning and that ensures that the risk of potential lack of funding will not happen during the project of DNR decommissioning.

Ideally, spent fuel and waste management system, including final repositories for all types of waste, will be available at the time of decommissioning. The immediate dismantling could not be completed if there is no on site management system which deals with waste generated during decommissioning except the availability of waste repositories.

In order to safely manage radioactive waste generated in DNRI, a combining technical management system for low and intermediate — levels of waste was designed and installed by former USSR in the stage of reactor innovation (1982–1984). This system includes Liquid Waste Treatment Station and its control room, temporary waste storage and chemical — physical laboratories. After DNR's shutdown, this waste management system will still be in operation to support reactor decommissioning.

To store spent fuel assemblies, in the rector building a spent fuel pool which contains up to 300 assemblies can be used. This spent fuel pool has capability to store all the remaining assemblies loaded in DNR core. After reactor shutdown, assemblies loaded in core will be adequately cooled, and consequently they will be moved to spent fuel pool for temporary storage. Before dismantling of reactor structures, these assemblies will be shipped back to the Russian Federation or to another site (in DNRI area or national radioactive waste repositories) for long term storage.

The evaluation of Health, Safety and Environment Impacts includes the evaluation of the impact in terms of occupational and public exposure and safety hazards associated with the decommissioning actions as well as environmental impacts.

The selected immediate dismantling strategy is also subjected to review of the specific methodologies and techniques to minimize the exposure for personnel, the public and the environmental impact; to optimize protection of the workforce and the public. Moreover, the minimization of radioactive waste movement should be considered.

Knowledge of the status and history of the nuclear facility is essential for successful planning, decommissioning strategy selection and execution from both safety and technical points of view. Ideally the knowledge of the operational staff is utilized during decommissioning phase. On the view of getting advantages from the current knowledge and operational staff, immediate dismantling option is dominant. Moreover, in order to strengthen human resources for reactor decommissioning, the involvement of international organizations for planning and reactor decommissioning management should be considered.

During the planning stage of DNR decommissioning project the concerns, issues and views of the different stakeholders are taken into consideration. Environmental and social impacts play an essential role in the implementation of this project. Therefore, to be successful the DNR decommissioning project needs to be open, transparent and clear to all stakeholders. Most importantly to gain public acceptance might be through a procedure whereby the proposals, discussion, dialogue and decisions are brought forward in the public meetings. It is noticed that for the case requires the re-use of reactor area, the immediate dismantling option is the most reasonable strategy.

The availability and use of suitable technology are important parts of decommissioning planning and can influence the selection of a strategy. Site specific features may demand technology development and adaptation, but in many cases mature technology is commercially available.

In brief, the recommended selection for DNR decommissioning includes immediate dismantling together with the movement of radioactive waste generated during decommissioning process to store temporarily in Temporary Radioactive Waste Repository (building No.5) in DNRI. Reactor area will be released unrestricted after removing the reactor building, technical rooms and labs in building No.1 and building No.2 will become nuclear relic area or be used for R&D activities. It is anticipated that it will take 5 to 6 years from the DNR shutdown point to implement decommissioning process.

4. Project management

The main objectives of the decontamination and decommissioning of the DNRR are:

- Reduction of any potential risks of radiation on the public health and the effects of radiation on the environment;
- Removal and permanent isolation of contamination sources;
- Compliance with the national, international rules and regulations especially in the nuclear field, but also in other social and economic fields;
- Releasing the DNRR's area from licensing requirements and reusing it for other purposes.

The national, international laws, decrees and regulations are following the activities related to decontamination and decommissioning of DNRR should be observed:

- Vietnam's atomic energy law (No. 13/2008/L-CTN, 12 June 2008);
- Vietnam's environmental protection law (No. 52/2005/QH11, 12 Dec. 2005);
- Procedures of ionizing radiation protection (TCVN 4498:1988);
- Management of radioactive waste — classification of radioactive waste (TCVN 6868:2001);
- Regulations for activities on nuclear control (No. 45 / 2010/QD-TTg, 14 June 2010);
- Regulation for hazardous waste management (No. 155/1999/QD-CP, 16 July 1999);
- ALARA principle of IAEA.

A Project Management board should be established to manage the entire project activities. The activities of the project are divided into a number of areas based on functional activities such as administrative activity, the activities related to engineering and technology, activity related to safety surveillance. The following activities are required for a project to operate effectively:

- Project management;
- Safety management;
- Health physics and radiation control;
- Quality assurance;
- Waste management;
- Finance and accounting management;
- Personnel management;

- Contracts and procurement management;
- Planning and scheduling development;
- Operation and maintenance of equipment/systems of DNRR;
- Carrying out decontamination and decommissioning;
- Security of the site.

The main packages of activities within the DNRR's decontamination and decommissioning project are:

- The activities carried out before decontamination and decommissioning;
- The decontamination activities;
- The decommissioning activities;
- Waste disposal, transport and the final surveillance.

The activities of decontamination and decommissioning projects of DNRR consist of two levels: (1) the planning and (2) procedures to control the daily activities.

The development of detailed plans for decontamination, decommissioning, removing radioactive waste, chemical/hazardous and radioactive characteristics surveying after the decommissioning is necessary documents for bidding. These plans also provide a detailed activity's order for the project manager to understand the sequence and schedule of the activities that need monitoring and supporting.

The control of daily activities will be through a programme of activities approved by the Project Management Board. In addition, the controlling of the dose and radioactive materials, the detail activities and specific instructions will be specified and included with the request of the Project Manager for each type of activities. The technical problems will be specified in order to reduce radiation doses to workers as low as reasonable achievement (ALARA principle Atomic Energy Agency International).

The contractor must prepare and carry out the activities according to the requirements of the Project Management Board with the detailed analysis of planning tasks. These requirements will include the area or components affected by radiation, prerequisites (including support equipment, condition of facilities, environment, human resources and needed equipment) estimated time to complete the work and its dependence on the previous works. When there is a change compared with predetermined schedule it must be reported and written permission of the contractor obtained from the Project Manager.

During the decommissioning process of DNRR, the plan must be regularly reviewed and monitored to keep to the project schedule that has been set.

Funding for the decommissioning project of DNRR will be made and approved for each year and will be provided from government.

During decommissioning planning, the organization of DNRR's decommissioning project will be formally organized and appropriately staffed. Project governance will be defined prior to project initiation including definition of roles and responsibilities, division of authority, reporting structures, and lines of communication. In addition, project administrative procedures will be prepared and documented in a manner supporting staff training prior to project initiation. The following decommissioning project management and oversight organizations will be established in order to ensure that the decommissioning activities of the facility are completed safely and to the highest standard of quality and performance.

Head of project management is in charge of all activities on schedule as well as for safety of the decontamination and decommissioning project of DNRR within predefined plan. Head of project management should be the Director of the Nuclear Research Institute.

The Operation, Maintenance and Decommissioning Group shall continue to maintain the systems / equipment of DNRR until the end of the decommissioning; they shall ensure the carrying out of the activities of decontamination and dismantling of structures, systems / equipment of DNRR (or coordinate with other contractors); moving, radioactive waste management in facility and control of radiation characteristics after the end of decommissioning.

The head of Operation, Maintenance and Decommissioning Group should be the Director of DNRR's Centre, they are responsible for ensuring that all activities of decontamination and decommissioning are carried out safely and the control radiation and radioactive materials in accordance with current national safety standards and ensure ALARA principle of the Atomic Energy Agency International. The Head of Operation, Maintenance and Decommissioning Group is responsible for the implementation of quality assurance programmes and the effectiveness of the radiation and industrial safety programme. This person has the final authority to approve minor changes and procedures (not required for safety assessments) and to conduct the decontamination and decommissioning activities every day.

Radiation safety group is responsible for radiation monitoring and safety competence to perform daily tasks of decontamination, decommissioning and relocation of radioactive material in the area of DNRR. Radiation Safety Group may suspend the work related to radiation protection and industrial safety if the method or process is not done safely. This will also include the non-compliance with the principle of ALARA, which can lead to the release of radioactive material that is not in control of the environmental planning and / or compliance with current regulations.

The Quality Management Group is responsible for monitoring compliance with the implementation of the decontamination and decommissioning by a process already laid out. This group shall report to the Project Manager on all activities failing to comply with the procedures approved in advance. The Administrative Group is responsible for:

- The management of project plans;
- Organization;
- Funds, supplies and equipment;
- Security of DNRR's area.

Training Center is responsible for coordinating with the radiation safety team to open training courses for all persons involved in the DNRR's decontamination and decommissioning of the radiation safety; a respiratory protection and occupational safety. The training will include all training classes in accordance to the needs of the activities.

The Safety Committee is responsible for independent review and assessment of safety in decontamination and decommissioning activities and suggesting appropriate control measures. The Committee also reviews the process as well as work related removal of radioactive materials, radiation control, changes in the plan when carrying out decommissioning. In addition, The Safety Committee is also responsible for periodically checking the results for the control of nuclear safety, radiation safety and the environment. As a minimum, the Safety Committee should meet monthly based on the extent of the decontamination and decommissioning. The Safety Committee shall report to the Project

Manager the results of reviewing and evaluating by writing documents. The Safety Committee may request to stop the activities if they do not meet the conditions of safety.

During implementation of the DNRR's decontamination and decommissioning projects, some activities require the invite of a number of contractors involvement. The bidders must have completed paperwork to legally participate in the decommissioning of DNRR. The contractor will take full responsibility for the activity, quality of work as well as for safety (safety of radiation as well as safety in job) before the Project Management Board.

All employees of the contractors should have health inspection, must pass a training course on radiation safety by the project management and only the employees who have license of Project Management can participate in activities of DNRR's decommissioning.

5. Activities related to decontamination and dismantling

Decontamination and dismantling activities of the DNRR should be done safely in accordance with the ALARA principle, the radiation safety programme of the DNRR and the procedures that have been issued. The purpose of decontamination and dismantling activities is to free from the control of regulatory body for the reactor hall, the technology rooms and labs in region of the building No.1 and No. 2 in order to re-use unlimitedly these positions.

In the operation phase of the DNRR, some works need to be done in order to prepare for decontamination and dismantling phase after final shut down of the DNRR. Here are the concerned activities that should be conducted regularly.

- Classification, calculation and forecast of the quantity and volume of the radioactive waste generated during operation phase of the DNRR as well as during decontamination and dismantling activities;
- Collecting, processing and storing of the necessary information related to buildings, structures and technology systems of the DNRR for the decontamination and dismantling;
- Preparation related to removal of fuel assemblies from the core;
- Collection of the technical document and information for the preparation of decontamination and dismantling;
- Development of final plan for decontamination and dismantling;
- Preparation of plans/procedures for the works in the transition period and approval requirement.

In terms of legislation, the preparation for decontamination and dismantling plan should be carried out a few years before the final shut down of the reactor due so that procedures and processing time may be extended.

The operational phase should be ended before decontamination and dismantling phase of the DNRR. The transition phase from the final shut down of facility to the implementation of decontamination and dismantling plan includes some routine tasks and specific activities for this particular phase. The adjustment of both technical and organizational aspects of the DNRR should be conducted in order to get new objectives and requirements. The facility should conduct the important works related to the safe storage of radioactive materials (which is independent from the choice of decontamination and dismantling plan) as soon as when the reactor stops working to reduce the radiological and non-radiological hazards to personnel and the public.

During this period, the final decommissioning plan should be submitted to the authority. The plan should include detailed plans for activities during the transition phase, detailed plans for the decontamination and dismantling, and the plan describes the final activities to ensure that the radiological and non-radiological hazards are reduced and meet the requirements that have been issued by the authority.

The activities that can be expected in the final shut down period include:

- Handling and temporary store of nuclear fuel;
- The operation of technology systems should be ended except the systems for the routine activities such as ventilation system; radiation dose control system; water filter system of the spent fuel storage etc;
- Drainage of cooling system;
- Cleaning and decontamination of the technology system/device of the DNRR to store or permanent disposal;
- Measuring and surveying radiation doses in the technology rooms and the radioisotope producing rooms of the DNRR;
- Determining radioactivity of the contaminated or activated technology system of the DNRR as a basis for the decontamination and dismantling in the future;
- Removal of the experimental equipment placed at horizontal beams of the DNRR and dismantling of the external systems that are not related to safety and no longer used in the later dismantling phase;
- Maintenance and enhancement (if necessary) of the protective barriers to prevent the spread of contamination, increasing protection of concrete walls around the biological shielding;
- Arrange for temporary storage location to simplify the operation of the device (using the empty room);
- Classification, conditioning and removal/storage of radioactive waste generated in the operation phase;
- Designing, installation, operation and maintenance of additional equipment for the classification of radioactive and toxic substances (if necessary);
- Gathering resources and techniques for dismantling period;
- Updating of decontamination and dismantling records for permission to begin dismantling period;
- Development of the necessary designs and technical documents;
- Implementation of administrative and organize measures corresponding with the changed status of the DNRR.

The DNRR's final status after the completion of this stage can be characterized as follows:

- The radioactive materials are placed in protective barrier areas and temporary storage;
- Some of the equipment/technology systems of the DNRR are no longer used at this stage will be dismantled completely.

The timing of the transition period can be extended from 2 to 3 years depending on the preparation of technical and resources to perform the tasks mentioned above.

The goal should be achieved of the dismantling phase when the equipment is broken down and components and radioactive material is moved out of the area of the reactor. To achieve this goal the following actions should be taken:

- Decontamination of areas and equipment to facilitate the dismantling;
- Preparation of the temporary storage for the positions of the broken or removed components;
- Removal of the technological equipment at the top of the reactor and in the reactor tank;
- Dismantling of the beryllium reflector, rotary specimen rack, graphite reflector and grid plate;
- Dismantling of the shielding structure of thermal column and thermal column;
- Removal of the horizontal beams;
- Removal of the reactor tank;
- Dismantling of the primary cooling system;
- Dismantling of the secondary cooling system;
- Removing of the shielding concrete;
- Drainage and remove spent fuel storage;
- Dismantling hot cells in the isotope producing rooms in Building No.1;
- Removal of contaminated components due to serving for dismantling of equipment and other components;
- Dismantling of the cleaning auxiliary equipment and uncontaminated structures to provide for the entry;
- Moving the contamination from the reactor area, the technology rooms at the Building No. 1 and No. 2;
- Cleaning up surrounding area (if necessary);
- Investigation of radiation characteristics of radioactive materials for unrestricted use or reburial;
- Decontamination for re-use;
- Conditioning and transferring of radioactive waste generated by the decontamination and dismantling to the long term storage places;
- Surveying specific radioactive waste packages;
- Recovery the reactor position depends on the later using;
- Final surveys for specific radioactivity in the reactor building, equipment rooms and technology labs in the Building No.1 and No. 2;

- Implementation of the process aimed at ending the radiation control (compiled final safety analysis report) and termination of decontamination and dismantling permission;

- Implementing administrative measures corresponding with the changed state of DNRR location.

Final state of completed dismantlement phase is characterized by releasing of the DNRR position out of radiation control and reusing unlimitedly this position including transfer of reactor building and technology rooms or laboratories in Building No. 1 and No. 2 into the place for the nuclear exhibitions or for R&D. The proposed time for implementation of this phase will take about 2 to 3 years depending on the available resources, technology and obtained experience for the decontamination and dismantling.

6. Surveillance and maintenance

During decommissioning a part of the existing technology systems will be operational. The systems that must be operational until the end of the decommissioning activities will be the subject of a surveillance and maintenance programme. That programme will be reviewed and updated to comply with the corresponding phase and phase acting at that date. As the dismantling activities are developed and some systems, loops or devices are removed, the surveillance and maintenance programme will be revised for the remaining system.

The systems and equipment that must remain operational during the decontamination and dismantling of the Dalat research reactor can be classified as follows:

- The dosimetry system at building number 1 must be used to measure radiological gamma at 12 positions including: on the surface of reactor, on the spent fuel storage, the primary loop equipment (room 148), reactor control room (room 128), ventilation and air filtration room (room 127), as well as on the pipes of primary and secondary cooling loop;

- Process and instrumentation system: provides the ability to monitor water level, flow rate, and conductivity of water in the spent fuel storage;

- The ventilation system for the reactor hall and ventilation system for working room at the building number 1;

- The auxiliary systems such as purified water delivery system to supply the spent fuel storage tank, water supply systems, the crane in the reactor hall, telephone communication systems, etc.;

- Normal and emergency electric power supply system for the entire Dalat Nuclear Research Reactor;

- The physical security system such as: security camera systems and sensor monitoring in the reactor hall and in the building number 5;

- The fire prevention and extinction system for entire facility, including smoke detectors and fire equipment (fire pumps, hydrant, fire extinguishers etc.).

Besides, during decontamination and dismantling the DNRR, a number of devices and systems will be installed and this additional equipment needs to be inspected and periodically maintained.

Surveillance and maintenance period of the systems/technology equipment in accordance with RR and regulatory processes is to maintain the reliability and efficiency of all equipment/systems according to technical features and original design calculations. Therefore, Nuclear Research Institute (NRI) is responsible for ensuring funding and materials for making timely surveillance and maintenance.

Head of Operations, Maintenance and Dismantling is responsible for arranging the resource organizations to fully implement the planned inspection and maintenance. Results of the inspection and maintenance must be reported in writing to the Head. System/equipment has been tested and maintained only in operation after gaining Head of Operations, Maintenance and Dismantling review and approval.

The section of Operations, Maintenance and Dismantling department; Administration services and Radiation Protection and Industry department are responsible for the required surveillance and maintenance of the system/devices due to their respective section. All personnel who perform surveillance and maintenance procedures are required to master and understand the structure and principles of operation of the system/equipment surveillance and maintenance.

All verifications and revisions results for systems/equipment are recorded in operational books surveillance and maintenance for systems/devices respectively and also recorded in the same form quality assurance programme (QA).

Periodically, surveillance and maintenance plans must be reviewed and possibly revised and supplemented to suit the actual conditions taking into account factors such as operational experience, aging or upon amendment design of technological systems of RR.

Head of Operations, Maintenance and Dismantling is responsible for submitting annual surveillance and maintenance plan to the Director for approval. Head of Operations, Maintenance and Dismantling is also responsible for periodical training of personnel who perform surveillance and maintenance activities.

7. Preliminary decommissioning cost estimates and availability of funds

The preliminary cost estimates for decommissioning project of the Dalat Nuclear Research Reactor are based primarily on IAEA-TECDOC-1476 [4], on study of the decommissioning costs of the University of Illinois' Advanced Teaching Research Isotope General Atomic (TRIGA) Mark II nuclear research reactor, "Bottom up" technique and "Work Breakdown Structure – WBS" method. The approach of this technique has been developed jointly by work of the EC, the IAEA and the OECD/NEA. In the study process to cost estimates for the decommissioning project of the Dalat Nuclear Research Reactor, the analysis materials of decommissioning costs for the nuclear facilities of the other nation are used for reference. Furthermore, the decommissioning cost estimates result of the Dalat Nuclear Research Reactor are also compared with the decommissioning cost estimates of the nuclear research reactors that have similar characterizations to the Dalat Nuclear Research Reactor.

Table 2 presents the preliminary cost estimate results for decommissioning project of the Dalat Nuclear Research Reactor assuming that the choice decommissioning strategy is the immediate decommissioning. In the process of major project activities analysis, the cost estimate for storage and shipping of the spent fuel isn't considered yet, because of the spent fuels are possible for long term storage at the Nuclear Research Institute or the shipping to the Russian Federation.

TABLE 2. COST ESTIMATES RESULT FOR DECOMMISSIONING PROJECT OF THE DALAT NUCLEAR RESEARCH REACTOR

No.	Major Project Activities	Estimated Cost in 2011		Percent rate (%)
		USD (thousands)	VNĐ (millions)	
1	Pre-decommissioning actions	72.6	1 496	2.6
2	Facility shutdown activities	219.7	4 529	7.9
3	Procurement of general equipment and material	94.6	1 951	3.4
4	Dismantling activities	502.0	10 351	18.1
5	Waste processing, storage and disposal	926.2	19 096	33.5
6	Site security, surveillance and maintenance	101.1	2 085	3.7
7	Site restoration, cleanup and landscaping	54.5	1 124	2.0
8	Project management, engineering and site support	44.6	920	1.6
9	Other costs	752.9	15 523	27.2
	Total Estimated Decommissioning cost	**2 768.2**	**57 075**	**100.0**

The cost estimates presented in this report are only preliminary cost estimates. The cost estimates for decommissioning project of the Dalat Nuclear Research Reactor shall be continued to be update and will be in more detail in the final decommissioning plan of Dalat Nuclear Research Reactor.

The Nuclear Research Institute belongs to the national research institute, so the government will provide financial assurance during the life cycle of facility, including the operation costs of the reactor and decommissioning costs of the Dalat Nuclear Research Reactor when it is in permanent shutdown. This is in accordance with article 7 and article 40, Vietnam atomic energy law. Consequently, the funds for decommissioning activities of the Dalat Nuclear Research Reactor will be obtained when necessary.

8. Safety assessment for decontamination and dismantling activities of the Dalat Nuclear Research Reactor

Decommissioning of a nuclear facility refers to administrative and technical actions taken to allow removal of some or all of the regulatory controls from a nuclear facility. These actions involve decontamination, dismantling and removal of radioactive materials, waste, components and structures. At all phases of decommissioning, workers, the public and the environment should be properly protected from hazards resulting from the decommissioning process. Radiological and non-radiological hazards and appropriate protective measures should be identified in a safety assessment to ensure the safety of workers and the public and protection of the environment during decommissioning activities.

In the process of decontamination and dismantling the structures of the reactor, the involved works as well as radiation exposure of workers must be controlled within the limitation of nuclear safety, radiation protection and occupational safety regulatory. Individual radiation doses must follow the ALARA principle with the main purpose is to avoid unnecessary radiation dose and reduce the dose to the lowest level reasonably as possible. According to the regulations that have been issued by the competent national authorities, the individual dose must be limited so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit.

The DNRR must be required to have the countermeasures in order to reduce or eliminate the effects of radiation on workers, the public and the environment in case of incidents or accidents.

In addition, the criteria of occupational safety, fire and explosion safety (unrelated to radiation) were specified in the legislation on occupational and fire safety. Therefore, these criteria will not be mentioned in this section.

Based on the guidance of the IAEA, the operational limits and conditions that apply during the operational phase of nuclear facilities are identified and reviewed for their applicability to the decommissioning phase. Some of the operational limits and conditions relevant to operation of the facility if they continue to be applied may become unnecessary barriers in the process of decommissioning. The operational limits and conditions that applied during the operation phase of the DNRR include: (1) the safety limits, (2) the threshold settings of safety system, (3) the limiting conditions for safe operation, and (4) the surveillance and administrative requirements. Except some of the requirements for surveillance and administrative requirements have been provided in the operational regulations of the DNRR, the remaining of the operational limits and conditions applied during the operation phase of the DNRR are no longer appropriate or not applicable for the decontamination and dismantling stage. Therefore, after final shutdown of the DNRR, the operational limits and conditions need to be reviewed and revised to suit the new stage. For the management of radioactive waste at the DNRR, the limits and safety criteria will be applied based on the radiation safety standards and radioactive waste management of Vietnam and the guidance of the IAEA.

Some hazards will arise in the decommissioning activities of nuclear facilities [5]. In addition to the risks the loss of workplace safety can occur (such as dangers while working with heavy equipment, someone or something falling down from elevation in the course of operations, the injury risks for employees from sharp metal objects and debris from the cutting work pieces, the ability to significantly increase amount of dust, toxic gases etc.), some other hazards can be foreseeing during decontamination and dismantling activities. These hazards include the dangers of radiation exposure from the activated materials in time of dismantling, surveying, moving and packaging components or equipment. Similarly, the radiation dose uptake risk of radionuclides from the contaminated surface or air pollution need to be solved by safety protects measures. The main activity in the process of decommissioning of the DNRR is a gradual removal of hazards by the decontamination methods and the gradual dismantling of structural components of the DNRR, these tasks should be conducted in the safe boundaries that have been approved by authorities. All situations that may cause dangers in the normal operations and accidents should be considered and evaluated fully as possible. Workers, the public and the environment should be protected by the method of eliminating or reducing the radiological and non-radiological hazards that may arise during decommissioning process.

Radiological hazards:

For the DNRR, the accident of fuel cladding failure and release of fission products from the fuel into the environment is possible. The possibilities leading to fuel cladding failure might be the corrosion or due to inadvertent dropping of a fuel assembly during its handling from the core or spent fuel storage (mechanical damage). According to the calculated results for the case of mechanical damage of fuel, leading to fission products in fuel assembly releasing a small amount, therefore the radiation dose for working staffs (at a period of time in the reactor hall) and the public does not exceed the dose limit.

To assess the radiation exposure to workers and the public in the maximum hypothetical accident (MHA) of the DNRR, an irradiated fuel assembly at the maximum neutron flux position in the core with the burnup of 30% is assuming completely damaged of cladding after 100 hours operation at full power of the reactor. The dose calculation in this case shows that the total effective dose for the public is lower than the dose limit for each year (1 mSv/year). During the transition period of the DNRR (see section 5.1.2 in this plan), this MHA can also be applied on the assumption that a heavy object falls into the area containing the fuel assembly and causes damage for fuel cladding, however, the radiological consequences in this case will be lower than in the case that has already been mentioned.

Non-radiological hazards:

- Broken or collapsed building structures: This event can occur when heavy objects fall or collapsed structure of the roof cause damage to fuels or other structures in the reactor hall and cause body irradiation exposure, injury to personnel actions in the working areas etc. This cause is difficult to occur.

- Some postulated accidents including security incidents or unusual events such as facility flooding, earthquake, plane crash etc. are very rare so that they should not be considered in this report.

Preventive and mitigating measures consist of preventive and mitigating measures for the risk of radiation exposure from activated materials or structures of the reactor; preventive and mitigating measures for the risk of ingestion and inhalation of radionuclides released in the process of dismantling and decontamination of structural components of the reactor; preventive and mitigating measures to prevent and mitigate hazards are expected to be generated during fuel handling operations; preventive and mitigating measures for non-radiological hazards.

Based on the experiences of other countries, we could find that the decontamination and dismantlement of nuclear facilities will be performed safely if the decontamination and dismantling plan is prepared and implemented appropriately. The assessment and analysis of radiological and non-radiological hazards as well as preventive measures to prevent or minimize their effects is one important part for safe decontamination and dismantling of a nuclear facility.

In the framework of this preliminary safety analysis report, the radiological and non-radiological hazards as well as preventive measures during the implementation of decommissioning activities of the DNRR have been mentioned. Although the biggest accident is quite difficult to occur during decontamination and dismantling activities, but if it occurs, the public radiation dose will still be lower than the dose limit. To cope effectively with the hazards and accidents that may occur during the decontamination and dismantling stage of the DNRR, the emergency response plan for nuclear events, radioactive or common emergencies has been developed and issued during the operational phase of the DNRR and needs to be updated and amended to suit the decommissioning phase.

9. Environmental assessment during decommissioning of the DNRR

The environmental surveying and measuring during operational process of the Dalat Nuclear Research Reactor (DNRR), we recognized that ambient environment of the DNRR is not radioactively contaminated and the radioactivity is not higher than natural background level. During the decommissioning process of the DNRR, all the works have to be optimized and carried out under very strict surveillance in order to minimize the radiation exposure to the workers and members of the public. The environmental assessment must investigate and establish very detailed procedure before the beginning of the decommissioning process of the DNRR. During the commissioning this procedure will have to investigate, assess and update so that this procedure is fully worked out.

Disassembling the termination of activities is a nuclear facility operations and technical administration to permanently remove part or all of the control of the management body and safety of the facility. These activities include decontamination, dismantling and moving of radioactive material, radioactive waste, the composition and structure of radioactive contamination.

The purpose of the decontamination and decommissioning of the DNRR after the operation is to free from supervison of the sector regulator for the reactor and the surrounding areas to use the position without any restriction.

All the works of the decommissioning will be carried out under the regulation of safety of radioactive protection.

During the DNRR's decommissioning process, all the works must optimize and control very strictly to minimize the effects of radioactivity for the workers and surrounding environment. All the works of DNRR's decommissioning have to obey the ALARA principle of the IAEA.

The radioactive nucleuses cause the contamination for the surrounding environment during DNRR's decommissioning are: ^{51}Cr, ^{59}Fe, ^{58}Co, ^{54}Mn, ^{60}Co, ^{131}I etc. These materials are mainly in solid state, very small particles in the air or water to cause the contamination for the ambient environment.

The purposes of environmental protection programme are:

- To meet the requirements of regulator;
- To assess the need for sampling or routine monitoring;
- To provide the data necessary to assess the dose radiation exposure for the groups most irradiative from decontamination and decommissioning reactors;
- To measure the release of radioactive materials to environment by sampling and to detect the concentration of unexpectedly radioactive nucleuses;
- To determine the long term development of environmental radioactivity due the releasing of radioactive nucleuses to environment;
- To ensure that the public at surrounding environment were not irradiated by a noble gas if its concentration will exceed the limit;
- To provide timely accurate data of radioactivity and hazard of nuclear accident mainly for environmental radioactivity and contamination; to provide information for workers to take preventative action; and to provide information of hazard existing in the public.

The environmental protection programme for the DNRR's decontamination and decommissioning will include the frequent controls of an environment in normal state as well as in an accident.

The environmental control programme will include radioactivity effluent monitoring occurring during the decontamination and decommissioning of DNRR. The purpose of this programme will:

(1) To determine the reasons of the leak of chemical materials;

(2) To determine influential scope for environment;

(3) The methods are carried out for minimizing the effect to environment;

(4) The supplementary methods are carried out for preventing and minimizing the effect to environment.

The effluent monitoring programme of the environmental contamination during DNRR's decommissioning is consisted the frequently monitoring the contamination through two ways following:

- Through liquid effluent;
- Through air effluent.

The effluent monitoring frequently surrounding environmental contamination is mainly effluent monitoring through two ways. The results of effluent monitoring will establish the radioactive condition at the time and recording of these conditions enables us to estimate the trend of radioactivity over time. This effluent monitoring programme is established before the beginning of decommissioning process. The results of sampling or monitoring at the constructed and operational period of DNRR will be data base for comparison for the whole decommissioning process and after decommissioning.

As stated above, the administrative control of DNRR's decommissioning is in order to minimize the contamination to the surrounding environment for both liquid and air effluents. Storage of solid radioactive waste packages will be maintained at minimum to prevent the potential inadvertent release of radioactivity to the environment. The action levels of radioactive contamination for water and air will be established at administrative control of about 10% of the issued standards. The action level for soil will established 185 Bq/kg above natural radioactivity for radioactive nuclei. The action levels for environmental gamma radioactivity will be established at 0.25 mSv/quarter or 0.01 mSv/h for all individuals in the unrestrictive areas (above the action levels are referenced from document "Decommissioning and Decontamination Plan for the Alan J. Blotcky Reactor Facility, USA, 2004").

Administrative controls will require immediate notification to the radiation safety officer and safety radiation protection group for any samples or radiation exposure levels that exceed action levels**.**

As stated above, during the DNRR's decontamination and decommissioning will ensure that radioactivity is not leaked out to the surrounding environment of the DNRR. The air effluent discharge from the first building of DNRR (main area are located the contaminated materials) to surrounding environment will go through HEPA filter before discharge from chimney. The liquid effluent discharge from the DNRR to surrounding environment must go through the station of radioactive waste processing at the second building of the DNRR. By the way, during decommissioning we frequently measure and control at fixed positions the monitoring for radioactive leaks from DNRR's area to surrounding environment.

Administrative controls will be established to ensure that environmental samples being collected are representative of the material sampled for the surrounding environment of DNRR. Replicated samples will be taken periodically for the comparing and assessing during decommissioning.

10. Radiation protection, nuclear critical safety and industrial safety

In the decommissioning process, radioactive isotopes (fission products) may release into the air as fallout. It causes the contamination at the working place which causes the internal exposure by inhalation amount of radioactive into human body. In addition, the fallout could cause the surface contamination also exposure to the workers who work in these areas.

Air samples shall be collected where it is expected that the concentrations of airborne radioactivity are likely to exceed the criteria. All air monitoring equipment will be checked daily prior to the start of work. Continuous Air monitors (CAMs) or fixed position air samplers will be prestaged in areas where dismantlement/demolition work will occur and there is a potential for airborne radioactivity to occur in general areas. Mobile continuous air samplers will be utilized at sites of any work that has the potential for releasing airborne contaminates, such as cutting, grinding, opening of systems, demolishing structures. Administrative controls will be used to limit personnel access to or time spent in an airborne area.

Routine operations are planned activities (generally repetitive and occur with various frequencies). For such operations, potential sources of airborne contamination shall be identified for respiratory protection. For non-routine operations (activities that are either non-repetitive or else occur so infrequently) when adequate limitation of exposures by engineering controls is impractical, the use of respirators to avoid excessive exposure to airborne contamination is appropriate.

The determination of the amount of radioactive isotopes entering the body will assess internal dose by some specialized software or based on dose conversion coefficients can also evaluate the dose.

Values of the radioactive concentrations in air of dismantling areas and the nature of task will define the plans to monitor internal dose in daily, weekly or monthly periods. The internal dose of every worker will be stored in dose record.

When the worker who is involved in decommissioning process is determined to have received doses that excess specified level (including the total of both internal and external dose), he will have a medical and be considered for applying medical measures to quickly recover and he can be moved to another task after that.

As recommended by the national authorities, the total effective dose (calculated for both internal and external exposure) will not excess the dose limits as listed in Table 3.

TABLE 3. THE DOSE LIMITS FOR RADIATION WORKERS AND THE PUBLIC
(*Not including the doses received from medical and natural exposure*)

	Dose limits	
Classification of exposures	**Radiation workers**	**The public**
Whole body	20 mSv/year averaged over 5 years	1mSv/year
Eyes	150 mSv/year	15 mSv/year
Skin	500 mSv/year	50 mSv/year
Limbs	500 mSv/year	-

During the decommissioning process, the involved workers could be subjected to external exposures.

During the process of reactor decommissioning, the risk of radioisotopes contamination from the removal products (reactor tank, reactor core etc.) to the reactor building floor, control room, machinery, equipment and instruments used for decommissioning is very high.

Depending on the terrain conditions of the contamination area and radionuclides that cause the contamination, the contamination materials or conditions of current facilities; using methods of monitoring surface contamination levels match with the actual requirements.

Minimization of the potential for spread of contamination will be accomplished by instituting work practices.

During operation of Dalat research reactor, DNRI was equipped with a radiation control system in reactor building as well as in related labs. This system consists of fixed and / or mobile equipment. These equipment will continue to be used during the decommissioning of the reactor.

Periodically, Department of Radiation and Industry Protection will conduct the inspection, repair and calibration of equipment and tools based on the procedures approved by the Director of DNRI.

It is anticipated that Dalat research reactor will be shut down in 2029. All of fuel assemblies in the core will be temporarily stored to spent fuel pool located next to reactor pool. The distance between cells in spent fuel pool has been calculated (proven in practice) to ensure that fuel assemblies stored in it will not reach criticality. Prior to the dismantling of structural components inside reactor pool and the shielding structure of the reactor, fuel assemblies will be moved to building No. 5 for temporary storage (may be stored in wet condition similar to that in the spent fuel pool) or will be returned to the Russian Federation.

The Manager of Department of Radiation and Industrial Protection is responsible for ensuring that the decommissioning process of Dalat research reactor meets the occupational health and safety requirements applicable to project personnel and the general public.

All participants in the process of decommissioning and supervisors must be instructed, trained and retrained.

Every 3 months, the Safety Council of DNRI will audit and assess radiation safety programme. The audit of radiation safety for workers involved in decommissioning process should be carried out once a week at least. Profiles of audit and assessment should include name of the auditing personnel, date and area of audit. Any error detected will be corrected.

The records such as radiation safety instructions, radiation safety procedures and other relevant records (including records of radiation characteristics survey, training and the assessment reports of Safety Council) will be maintained to implement radiation Safety plan of DNRI. Profiles of the radiation safety programme are kept following an established procedure. Profile of internal audits will be kept within certain period of time after license. Other documents such as diaries of equipment condition monitoring, equipment repair, etc. will be maintained as necessary.

11. Quality management programme

Project Management Board belonging to DNRI will be responsible for drafting, establishment and development of a specific Quality Management Programme for DNR decommissioning project after DNR shutdown. This programme will include documentation, guidelines of International Atomic Energy Agency (IAEA), the regulations and safety criteria of Nuclear Regulator (VARANS), Ministry of Science and Technology, Ministry of Natural Resources and Environment, Nuclear Regulatory and other related Laws in Vietnam.

During decommissioning process, the Quality Management Programme will be updated consistently in order to control all of changes related to plan, schedule, designs, methodology, movement, nuclear facility installation, waste release, applied criteria, etc. for every stage of DNR decommissioning.

DNRI will be responsible for building a Project Management Board and a Organization Chart to achieve the DNR decommissioning project in accordance to objectives, contains, management method, requirements of specific Quality Management Programme and general quality management programme of DNRI (this programme will be generally developed and applied for all active fields of DNRI).

Project Management Board will be the major organization responsible for planning and implement actions of D&D project. In addition, other departments and centers belonging to DNRI are responsible for supporting this project.

Employment of subcontractors is considered if needed. Before contract signed, subcontractors which have adequate capability and experience will be evaluated, appraised and selected by Project Management Board. During period of contract, the Project Management Board will monitor and verify to ensure every clause in contract and goals of quality management programme are fulfilled.

Quality management programme for actions of DNR decommissioning project is established in order to regulate decommissioning actions; processes in accordance to a general principle has to be planned, scheduled, safety assessed, approved, monitored and checked, reported and quality assessed.

Quality Management Programme established specifically for DNR decommissioning project is integrated in to the general Quality Management Programme of DNRI. Quality Management Programme of DNRI will meet requirements, standards of Vietnam Quality Management.

Project manager (Manager of Project Board) is responsible for creating and conducting the tasks of Quality Management Programme for decommissioning project.

Documents of Quality Management Programme for DNR decommissioning project are appraised by experts and experienced departments appointed by DNRI Director. Finally, documents will be approved by DNRI Director.

12. Emergency response plan

An emergency plan includes radiation emergency plan and conventional emergency plan. Radiation emergency plans are developed as a part of the overall emergency response system. One of the most important features of these plans is that they are integrated among the different bodies involved, ensuring clear lines of responsibility and authority.

An emergency response plan of the existing decommissioning activities of the RR will be used as a basis for planning emergency during the decontamination and dismantling of DNRR.

The Steering Committee emergency response at DNRI in the event of a nuclear incident, the conventional incident radiation is presented in Figure 4. In case of nuclear or radiological emergencies, the authority and responsibility for mitigating the consequences of accident at the scene and for taking decisions to apply intervention measures within the facility site are fully given to an ad hoc committee, which is headed by the DNRI Director or his designee.

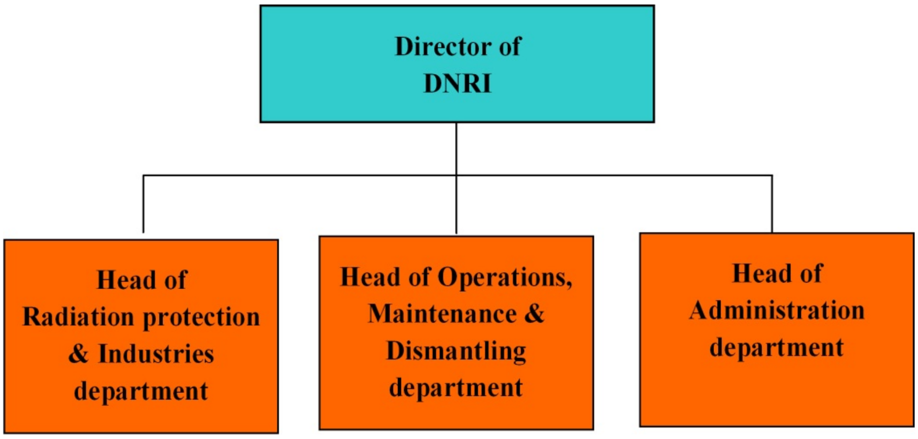

FIG. 4. Steering committees.

The DNRI Director is responsible for ensuring that the clear mechanisms for the coordination of the emergency response between the DNRI and local and national governments will be developed. These coordination mechanisms include organizations responsible for emergency services and for response to conventional emergencies. The mechanisms are documented and made available to all relevant parties.

The management of emergency situations is presented in Figure 5. Soon after the emergency situation has been identified, assessed and classified, the first actions must be promptly taken to cope with unfavorable evolution of the event. In case of emergency in the reactor, it is the responsibility of the decontamination and dismantling group for achieving safe control under direct command of head of Head of Operations, Maintenance and Decontamination (who acts as the on-scene controller).

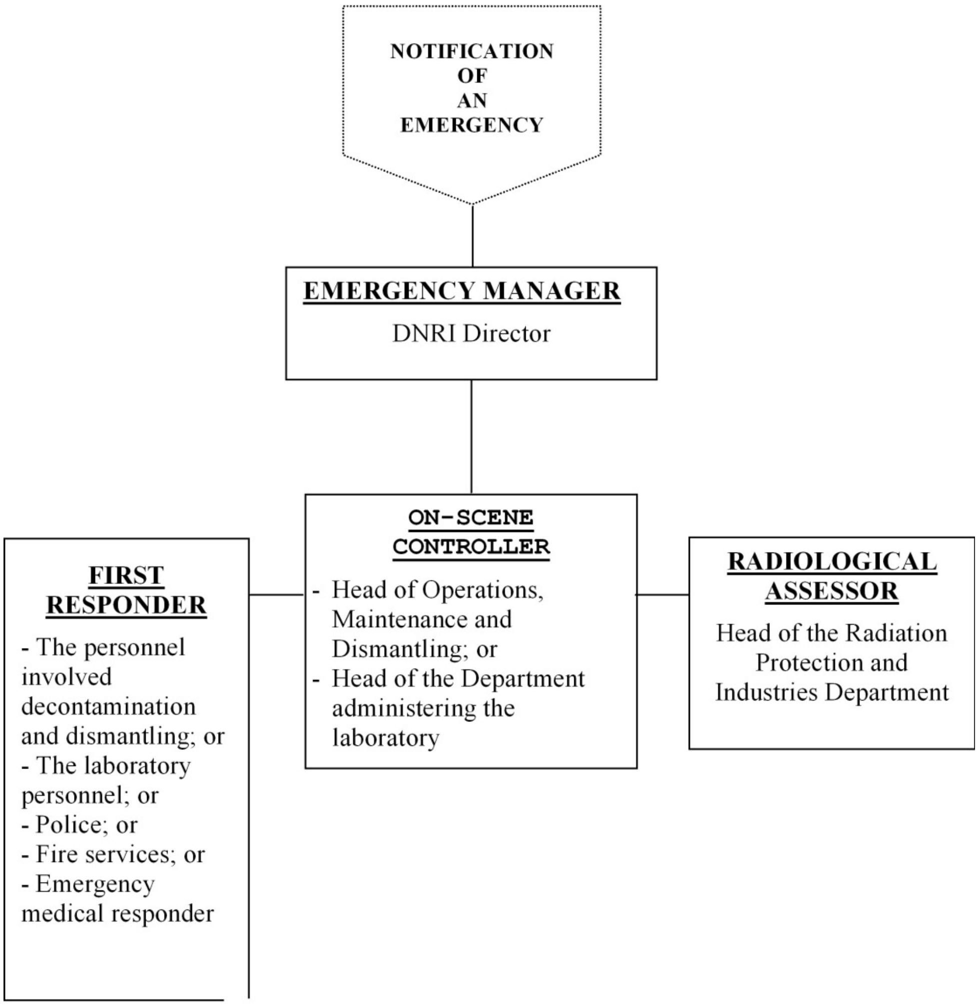

FIG. 5. Emergency response management.

In case an emergency occurs, the health physicists under direction of the Head of the Radiation Protection Department (the radiological assessor) will quickly carry out the measurements and determine the degree and kind of radioactive contamination at each location in order to report to the on-scene controller. Off-site monitoring may be needed to confirm there is no off-site problem. The Health Physics group will provide the on-site personnel and emergency workers with adequate protective equipment and with detailed manuals or instructions of use.

The group will precisely specify the time duration and the measures that the personnel must take in emergency intervention and recovery in order not to be exposed to the radiation over the dose limits. The contaminated locations must be localized and bared with warning signs, and the effective measures to prevent contamination from spreading should be implemented. After the emergency recovery, the facility personnel are permitted to return to their workplace only if the radiation dose, the surface contamination and the air contamination are back to the normal levels.

For the purpose of the emergency medical response, the DNRI's medical staff and trained personnel on every reactor operating shift will provide any first aid for injured persons when required. The research and rescue for injured persons will be performed as soon as possible. The treatment of serious or life threatening injures will take priority over other actions. In the case of the injures that are non-radiological, e.g. thermal burns or injures associated with the conventional aspects of an accident, the conventional first aid to save life, reduce pain and aid recovery will be needed. For persons with signs of high radiation exposure and other injures and/or burns, they will be transported urgently to a specialized hospital after appropriate medical care. For externally contaminated persons, they will be confined in a comfortable area to prevent the spread of contamination and there they will be decontaminated as soon as practicable. Because patients may not express symptoms of radiation exposure early on, there will be a need to sort and follow up potentially exposed individuals according to their assessed doses. In the case of serious injury, medical personnel from the Lam-Dong Provincial Hospital will be available.

For a nuclear or radiological emergency that may occur at the DNRI, the DNRI Director (the emergency manager) or the Head of Administration Services will inform the media and the public of an emergency. It is essential that the information given to the media should be in time and its contents should be carefully and responsibly processed. The communication with the media and the public will be maintained in uninterruptible level until the emergency has been ceased.

When the accident is overcome, recovery operations must be conducted in order to return the facility to the safe situation and to recover the accident consequences. The emergency situation will be considered terminated only when the safe situation of the facility is fully re-established. The chairperson of the ad hoc committee is responsible to declare the emergency termination.

13. Physical security and safeguard

Physical security and safeguard for the controlled zone as well as for entire area of Nuclear Research Institute area is very important, especially during procedures of decommissioning and radiation cleaning of reactor. The purpose of physical security and safeguard is protect nuclear materials from loss and sabotage. Up to now, the physical security and safeguard process is implemented, updated and completed, including both of equipment and management.

The administrative organization of Dalat Nuclear Research Institute, which directly carries out the physical security and safeguard task (including fully rights and obligations of each personnel), has responsibilities as:

- Control all facilities taking into/out of the controlled zone of Dalat Nuclear Reactor;
- Control personnel who entry/exit from the controlled zone of the DNRR as well as any his/her operation inside the controlled zones;
- Prepare plans to response with any event related to the physical security and safeguard task;
- Manage and check the spent fuel and radiation materials or facilities during decommissioning process; preserving them before they will be returned to the Russian Federation.

The Lead of Operation, Maintaining and Decommissioning Division has responsibilities to ensuring that the physical security and safeguard procedure have been implemented and reached to all of its achieved targets. All the staff also has responsibilities to implement this procedure following his/her assigned works. Therefore, all of staff should be trained before decommissioning of reactor to master any foreseeable events which can be occurred during the decommissioning for reactor, and preparing the tight security methods to prevent the stealing of radiation materials or facilities dismantled.

A physical security programme shall be established before decommissioning of reactor by the authorized staff. Following the Decommissioning Programme, the spent fuels withdraw from the reactor core will be stored in the spent fuel storage for two years, and then they will be returned to the Russian Federation. In that time, a communication, security controlled system shall be installed and updated to improve potential of control for the radiation sources and facilities, especially for the spent fuels. This system shall be operating reliably and continuous.

The security controlled system for reactor building was installed and now it is updating and completing. In this system, observing cameras are installed to control all of doors and passage ways in the reactor building. Sensors are installed to control the radiation sources and facilities such as the spent fuel storage lid, fuel containers. The alarm system is installed to control any unpermitted moving into/out of reactor building by personnel or non-personnel.

Presently, almost all of radiation materials and facilities in the reactor building are updated in the management document following the IAEA rules.

Before decommissioning of reactor, the authorized staff shall review the entire radiation list of facilities, materials and sources which are present in the controlled zone, and establishing special records for each of these facilities or radiation sources. Any moving or handling of them shall be updated in the records.

Any operation of personnel in the reactor building, especially for handling with spent fuel assemblies must be agreed by the leader of physical security and safeguard organization. These operations shall be observed by other personnel, who are assigned by the leader of physical security and safeguard. Any abnormal event occurring during the operation shall be immediately report to the authorized person.

14. Proposed final status survey plan

The core of Dalat Nuclear Research Reactor (DNRI) and support components will be removed prior to site release. Consequently, the Final Status Survey (FSS) will include only the exposed soils, floors and walls of reactor building and the rooms used for radioactive material.

The FSS will focus mainly on the areas of Building No.1 (Figure 6), the location of ^{60}Co source, Building No. 5 and the pathways used for the transportation of radioactive material during the D&D.

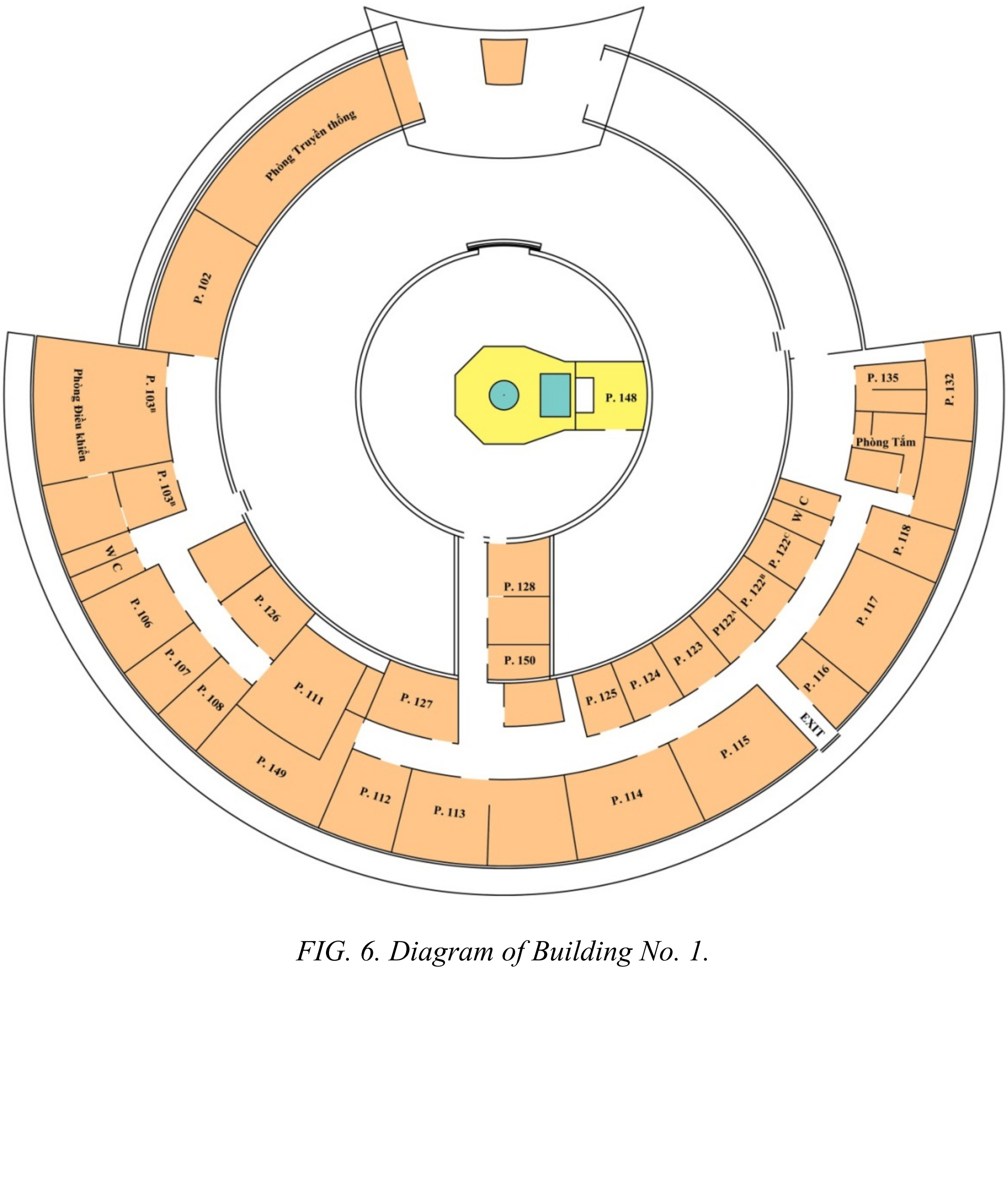

FIG. 6. *Diagram of Building No. 1.*

This FSS will be performed in accordance with an FFS Plan by trained technicians experienced in performing FSS. The technicians will follow written procedures regarding surveys and sampling, sample collection and handling, chain of custody, and recordkeeping. The FSS Plan will define sampling locations, required analysis, and survey types. Any additional release criteria set forth by authorities will be contained within the FSS Plan which will direct surveys or sampling efforts required to demonstrate compliance with such criteria.

The FSS may include surface gamma surveys using sodium iodide (Nal) gamma scintillation detectors. Surface and subsurface soil samples will be collected using either a random start grid pattern or randomly generated locations as appropriate commensurate to the classification of the survey area. Soil samples will be analyzed for contaminants of concern using standard analytical methods including liquid scintillation counting for hard to detect beta emitting radionuclides (i.e., ^{14}C and tritium) and gamma spectroscopy for gamma emitting radionuclides.

The object of the FSS is to demonstrate that the radiological conditions of the DNR site satisfy the decommissioning criteria of the authorities provided in the D&D objective section. In general, the authorities could obtain these criteria from the *Safety Reports Series No. 44 – Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance* [6].

In some guidelines such as Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) used in USA, the object is to provide a 95% confidence level for the false negative (Type I error) in demonstrating that the site meets the criteria. Typically, the false positive (Type II error) will also be defined as a 95% confidence level, but may be modified to apply to a specific situation. Therefore, the Type I decision error will be 5 percent. The decision error rates are used in determining the required number of samples necessary in each survey unit as well as the required minimum number of data points used for the final nonparametric statistical test performed to evaluate contaminant concentrations in the survey units against release criteria. Data Quality Objectives (DQOs) will be fully described in the FSS Plan and will include limits on the sensitivities of survey and analytical methods.

The establishment of these DQOs will incorporate standard regulatory and industry measures applicable to the FSS and will be reviewed and approved by the Reactor Committee.

Survey methods are applied differently depending on the data requirements of a survey area. For example, removable activity measurements provide little, if any, benefit when attempting to assess the radiological conditions in an excavation. Conversely, assessing a building surface via volumetric sampling would provide the necessary data, but at great costs of time and money.

Data evaluation is performed on FSS results for individual survey units to determine the weather the survey unit meets release criterion. Appropriate tests such as the Sign test and Wilcoxon Rank Sum (WRS) test will be used for the statistical evaluation of survey data.

If the contaminant is not in the background or constitutes a small fraction of the Derived Concentration Guideline Level (DCGL), the Sign test will be used. If background is a significant fraction of the DCGL the Wilcoxon Rank Sum (WRS) test will be used. It is anticipated that the sign test will be the only statistical test applied to the collected data because of the small fraction of the DCGL that background radionuclides will contribute.

The Final Status Survey Report will be prepared to document and present the findings of the FSS, including all FSS data and data analysis. The report will summarize the decommissioning activities conducted at the DNRR in support of license termination. This report will be provided to the regulatory to support the request for the releasing of the site.

15. Conclusions

The preliminary decommissioning plan of the DNRR has been constructed. It consists of Facility description; Decommissioning strategy; Project management; Activities related to decontamination and dismantling; Surveillance and maintenance; Radioactive waste management; Preliminary decommissioning cost estimates and availability of funds; Safety assessment for decontamination and dismantling activities; Environmental assessment during decommissioning of DNRR; Radiation protection, nuclear criticality safety and industrial safety; Quality management programme; Emergency response plan; Physical security and safeguards; Proposed final status survey plan. The DNRR is in operation state. It is important to continuously upgrade the decommissioning plan of the DNRR.

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