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CONTRACT B7-5350/99/6141/MAR/C2

EVALUATION OF MANAGEMENT ROUTES FOR THE PALDISKI SARCOPHAGI

FIRST INTERMEDIATE REPORT

TASK 1 - DATA COLLECTION

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A. *SUMMARY (AND/OR MAIN CONCLUSIONS) :*

Contract Number :	B7-5350/99/6141/MAR/C2
Title :	Evaluation of management routes for the Paldiski sarcophagi
Contractor :	TECHNICATOME – BNFL Engineering Ltd
Subcontractors :	AS ALARA Ltd – LI VNIPIET Institute – NUKEM Nuklear GmBH
Objectives and scope of this project	Task 1 - Data Collection and analysis Task 2 - Drawing up of potential dismantling scenarios Task 3 - Evaluation of dismantling options
Progress of work to date	Completion of Task 1
Period covered	June 1999 to December 1999
Objectives and scope of Task 1	Task 1 - Data Collection and analysis : – General characteristics of the main building and sarcophagi. – General characteristics of the two reactors primary systems enclosed in the sarcophagi. – Description of the works carried out while preparing the two reactor compartments for prolonged storage. – Estimates of the radionuclide inventory after 10, 50, 100 years. – Present conditions of waste treatment and conditioning equipment in the Paldiski site.

During withdrawal of Russian troops from Estonia, two stand ship's nuclear power plants of the former USSR Navy Training centre in town of Paldiski were laid up at the site where they were installed for a time period of 50 years.
In the period of performance of work on putting the stands in prolonged storage, nuclear fuel was discharged from the reactors and transported to Russia, adjacent compartments were dismantled, sealing of Nuclear Power Units equipment and bodies of reactor compartments was carried out, sarcophagi made of reinforced concrete were erected around the reactor compartments. As a result, for each reactor compartment a system was created providing three safety barriers: durably sealed reactor and the 1st loop, hermetic body of the reactor compartment and protective reinforced concrete sarcophagus of the reactor compartment to ensure protection of the reactor compartment against the effect of atmospheric precipitation for the whole period of storage.
Placement of concrete into the structures of the reactor compartment ensures prevention of unauthorised access to the components of the steam producing plants.
Additional fastening of the reactor compartment bodies to foundations of the building allows retaining of integrity of the reactor compartments under action of a probable earthquake of a maximum magnitude 7 (by MSK-64 scale).

The present report is the first intermediate report of a study aimed to identify feasible rational routes of dismantling and complete removal of radioactive components from these both Nuclear Powered Units. The main purpose of task 1 of this project is to collect the maximum available information about the two nuclear reactors, the two sarcophagi, the works carried out when the two reactors were shut down, and when erecting the two sarcophagi, the existing and foreseen waste conditioning equipment available on the Paldiski site that could be used to carry out dismantling work.

This report describes training Nuclear Powered Units, main equipment that is part of them, reactor compartments in which they are mounted, a concise characteristics of training stands' operating conditions, measures preceding the reactor units lay-up putting them for a long-term storage, and the design of shielding sarcophagi into which the reactor compartments were packed up to minimise ecological consequences in the course of their storage. The descriptions are illustrated with general drawings of buildings, sarcophagi and reactor compartments, and general drawings of major structural components.

Presently the sarcophagi itself are in quite stable state, with no visible cracks or other major defects. In regard to results of compression strength measurements of samples taken from the walls of sarcophagi #2, the walls are made of high quality and strong concrete. But the sarcophagi around reactor units were constructed without humidity control, any alarm or monitoring systems etc. Moreover, the absence of ventilation inside the sarcophagi has been accelerated corrosion processes. The latter fact points out the need for installing any humidity control equipment in both sarcophagi.

A certain amount of radioactive waste was stored in both reactor compartments. According to the lists of wastes included in the files given to Estonian authorities when transferring the ownership of the site, most of the wastes stored are miscellaneous low level radioactive wastes with surface contamination. But some radioactive sources were also put into concrete poured into the reactor compartment #1 (stand 346A). These sources were used for calibrating radiological measurement equipment. They are located inside containers placed into the reactor compartment #1 before grouting. No radioactive source was stored in reactor compartment #2.

The radiation conditions around the reactor compartments that are given in this report were obtained in the course of the comprehensive inspection of the training centre carried out in 1994. The radiation conditions inside the reactor compartments were obtained from measurements accomplished while preparing them for prolonged storage.

The predictions of activity in the reactor compartments are provided for the years 1999, 2050 and 2100. Concerning reactor compartment #1, the predictions of activity and radionuclide composition have been calculated for each main piece of equipment. Highly activated components are the removable part of the reactor with the compensating grid and control rods, reactor vessel with jacket and screen and IWS tank (Iron and Water Shielding tank). All other structures located outside the reactor and IWS tank are characterised by significantly lower induced activity. Concerning reactor compartment #2, only global predictions of activity for the NPU as a whole have been calculated. for According to the analysis carried out, the accumulated activity of long-term radionuclides in NPU materials are summarised in the table below :

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NPU	Date	1999	2049	2099	Key radionuclides
	Delay time (year)	10	50	100	
Stand 346 A	Total activity (TBq)	362 TBq	69 TBq	47 TBq	^{55}Fe, ^{60}Co, ^{63}Ni, ^{59}Ni
Stand 346 B	Total activity (TBq)	144 TBq	13.3 TBq	9.6 TBq	^{55}Fe, ^{60}Co, ^{63}Ni, ^{152}Eu, ^{154}Eu

We analysed this data owing to our know-how in the field of nuclear propulsion reactors, and we compared the information provided by the VNIPIET Institute to the data we have about the land based prototypes reactors that TECHNICATOME operates in Cadarache.

An interim waste storage is in operation since 1997 in the main technological building of the Paldiski site. No time limitation has been decided for the use of the interim storage, but the containers will have to be transferred sooner or later to a final disposal site. Another project is to be launched to define the criterion in order to choose a suitable site and to decide what type of repository would be constructed.

In order to reduce the cost of waste management, we will assume that the future final repository in Estonia for the decommissioning waste will be available before starting dismantling works. This final repository will be assumed to be of the same type as l'Aube in France, made for low and medium level short-lived radioactive waste.

At the moment, AS ALARA does not dispose of equipment fitting to the requirements the dismantling of the sarcophagi and reactor compartments. All the pieces of equipment that could be necessary to carry out such dismantling works have to be taken into account in the cost calculations.

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B. ATTRIBUTES :

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- ☐ *dispatch note*
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- ☐ *standard distribution*
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Rev	Rédaction	Vérification	Approbation
A	L. ANTONEL	B. ROBIN – J. MILLER	L. ANTONEL

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Note : The plans and drawings included in appendices were reduced in order to be printed on paper of standard format. All the digital files are provided within the intermediate report file, available on the atached CD-ROM. When drawings were implemented with AUTOCAD, the AUTOCAD files are also available on the attached CD-ROM.

List of References

<1> Evaluation of management routes for the Paldiski sarcophagi – First AS ALARA Report

<2> Evaluation of management routes for the Paldiski sarcophagi – First VNIPIET Report

<3> Evaluation of management routes for the Paldiski sarcophagi – First progress meeting minutes (TA-144666)

List of abbreviations

ACP	Auxiliary Coolant Pump
AF	Activity Filter
CACP	Cooler of Auxiliary Coolant Pump
CDB	Central Design Bureau
CMCP	Cooler of Main Coolant Pump
CPS	reactor Control Protection System
IWP	Iron-Water Protection
LWSB	Liquid Waste Storage Building
LWTF	Liquid Waste Treatment Facility
MCP	Main Coolant Pump
MTB	Main Technological Building
MWP	Metal-Water Protection
NPP	Nuclear Power Plant
NPU	Nuclear Powered Unit
NS/M	Nuclear Submarine
NSSS	Nuclear Steam Supply System
PIERG	Paldiski International Expert Group
SG	Steam Generator
SPP	Steam Producing Plant
RC	Reactor Compartment

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1 GENERAL

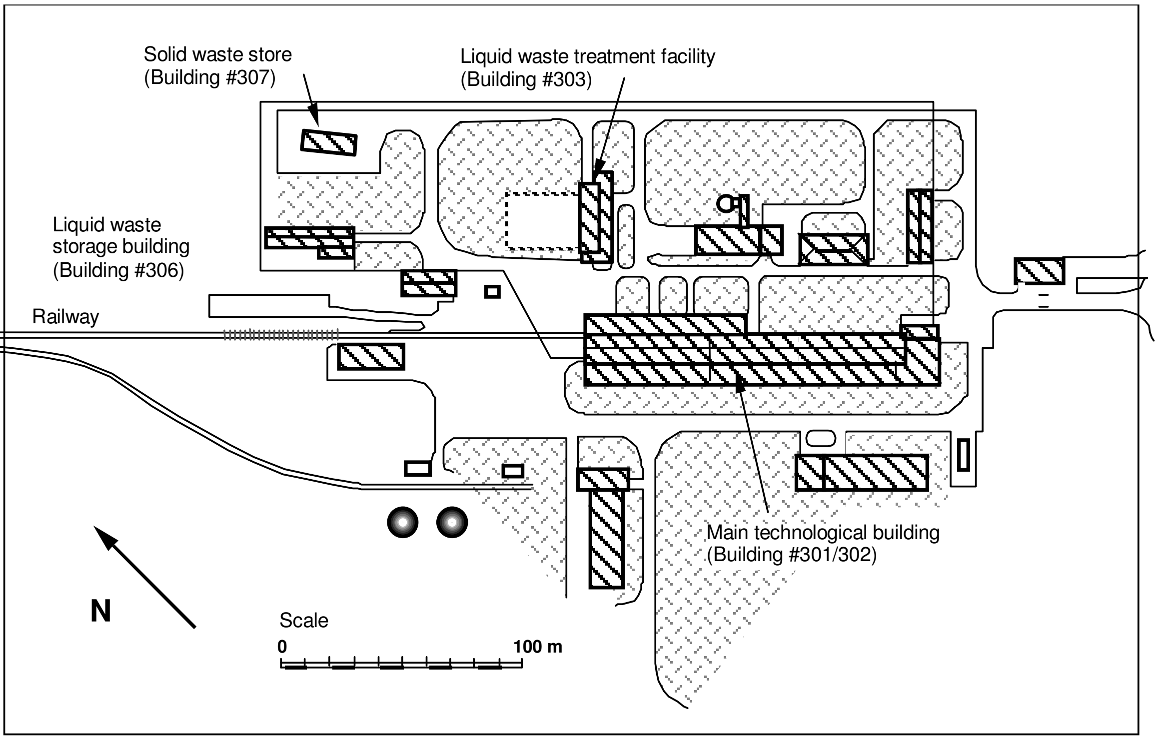
1.1 BACKGROUND

The necessity to develop the submarine fleet in Russia required constructing a special training base for a preliminary training of submarine crews made most realistic in conditions. To this purpose two prototypes of nuclear power units (NPU), close analogous of NPU installed at nuclear submarines (NS/M) were constructed and commissioned in the sixties on the Navy training centre's base located on the Pakri peninsula in the town of Paldiski (Estonia).

According to an agreement between Government of the Russian Federation and Government of Estonian Republic of July 30, 1994, for transfer of this training facility of Navy Training Centre located in Pakri Peninsula (town of Paldiski), with laid-up nuclear reactors and nuclear waste storage facilities to the ownership of Estonian Republic. Nuclear was discharged from the reactors and transported to Russia while the reactors themselves have been prepared for prolonged storage.

A number of uncertainties remain concerning the way the Russians carried out this enclosure process and consequently in predicting dismantling operations.

The other site buildings consist mainly of a liquid waste treatment plant, a decontamination plant, liquid and waste stores, a radiochemical laboratory, each of them being in poor shape. Important work is being done through PIERG (Paldiski International Expert Group) members to clean up the site and to commence building new waste conditioning and storage facilities.



Paldiski site plan

1.2 PRESENTATION OF THE PROJECT

The main purpose of this contract is to identify feasible rational routes of dismantling and complete removal of radioactive components from two nuclear power units of the former RF Navy Training Centre on the Pakri peninsula in Estonia.

This study will be made up of three different tasks:

- Task 1 : Data collection analysis
- Task 2 : Drawing up of potential Dismantling scenarios
- Task 3 : Evaluation of Dismantling options

This report is the first intermediate report of the study: it presents the results of the first task of the project.

1.3 INVOLVED PARTIES

The two companies TECHNICATOME and BNFL Engineering Ltd have joined to perform this study, with the main aim to define the best dismantling route for the Paldiski sarcophagi, regarding cost and radiological impact on the environment, in accordance with IAEA safety recommendations and Estonian radioactive waste management regulations. TECHNICATOME has been the leader of the contract with Laurent ANTONEL as project manager. The deputy project manager has been Nikolay SHULIAK from BNFL Engineering Ltd.

Three subcontractors have been involved in this study :

- The Russian design institute VNIPIET, which designed the complex of buildings and premises in which the power stands were located and, later on, the general concept of NPU decommissioning and sarcophagi design,
- The Estonian Waste Management Agency AS ALARA, which is responsible for the site,
- NUKEM Nuklear GmBh, to benefit from Ted GROCHOWSKI's great experience of the Paldiski site (Mr. GROCHOWSKI stationed for two years in Estonia as the Resident Technical Adviser to the Estonian government, on the transfer of the Paldiski site from Russian to Estonian government control).

Several Russian design and development organisations were involved in designing the training power stands including :

- the engineering bureau CDB ME «Rubin», which was involved in preparation of stands 346A and 346B for prolonged storage,
- the research and development institute RDIPE, which designed the 346A unit,
- the engineering machine-building bureau OKBM, which designed the 346B unit.

All these organisations were involved in the first task of this project as VNIPIET's subcontractors.

1.4 TASK 1 : DATA COLLECTION

The main purpose of task 1 of this project is to collect the maximum available information about :

- The two nuclear reactors,
- The two sarcophagi,
- The work carried out when the two reactors were shut down, and when erecting the two sarcophagi,
- The existing and foreseen waste conditioning equipment available on the Paldiski site that could be used to carry out dismantling work.

The present report describes training nuclear power units, main equipment which is part of them, reactor compartments in which they are mounted, a concise characteristics of training stands' operating conditions and measures preceding the reactor units lay-up putting them for a long-term storage, the design of shielding sarcophagi into which the reactor compartments were packed up to minimise ecological consequences in the course of their storage, and an assessment of activity accumulated in NPU equipment are given The predictions of activity in the reactor compartments are provided for the years 1999, 2050 and 2100. The descriptions are illustrated with general drawings of major structural components.

We analysed this data owing to our know-how in the field of nuclear propulsion reactors, and we compared the information provided by the VNIPIET Institute to the data we have about the land based prototypes reactors that TECHNICATOME operates in Cadarache, especially about the PAT Nuclear Powered Unit. This reactor is the first French land based prototype of nuclear power units installed in French nuclear submarines. PAT Nuclear Powered Unit was constructed and commissioned in the early sixties in Cadarache, in the south of France.

This PWR type reactor was in operation from 1964 to 1992, and generated 2160000 MWh. Its thermal capacity was close analogous to the Paldiski NPU's thermal capacity. TECHNICATOME began the dismantling process in 1993, and the level 1 of the three decommissioning levels defined by IAEA was reached in the end of 1994.

- Spent nuclear fuel was discharged from the reactor. Control rods were discharged in the same time as fuel assemblies, and the reactor internals were left inside the vessel.
- Circuits were drained and dried.
- Confinement barriers are maintained
- Ventilation systems, Radiological measurements equipment, monitoring and alarm systems are maintained.
- Inspections of the radiation condition are carried out every month into the reactor compartment.

2 OVERVIEW OF THE PROBLEMATIC RELATED TO NUCLEAR POWERED UNITS (CONSTRUCTION AND OPERATION, SHUTDOWN AND LAYING-UP).

2.1 CONSTRUCTION

A main technological block (buildings 301/302) was designed and constructed to accommodate and maintain the training NPU as well as a complex of auxiliary buildings and premises intended to provide a long-term and safe operation of training power stands.

The main technological block consists of 2 parts : building 301 and 302 constructed in different time but combined together.

Power unit #1 (stand 346A) being an analogy of 1st generation NS/M NPU was mounted in building 301. The NPU was located in a metal housing which corresponds in the geometry and dimensions to that of NS/M. Unit #1 consisted of a reactor compartment (RC) and 3 support compartments abutting with the reactor compartment at both ends. Total length of the stand was 50 m. The unit was commissioned in 1968 and operated till January 1989. Spent nuclear fuel was discharged from the reactor in 1994 and transported to Russia. After decommissioning the test rig 346A and unloading spent fuel from the reactor, the three support compartments were dismantled. RC has been prepared for long-term storage, provided with physical protection and transferred to Estonia.

Later on, in the early eighties building 302 was added to building 301 in which the other prototype NPU (unit #2, stand 346B), analogous to 2nd generation NS/M NPU, was mounted. Unit #2 consisted of a reactor compartment and four support compartments abutting with the reactor compartment at both ends. Total length of the stand - 50 m. Unit #2 operated from 1983 till December 1989. Spent nuclear fuel was discharged from the reactor in 1994 and transported to Russia. The four support compartments were dismantled.

Two electric bridge cranes (of 50 tons capacity each) were mounted in the stands hall of the main technological block to serve the power stands.

2.2 SELECTION OF AN OPTION TO MANAGE NPUS AFTER THEIR SHUTDOWN

A decision was made by the Russian government to decommission the above training stands after the recognition of Estonia independence in 1991 and the withdrawal of Russian troops from the Estonian territory. LI «VNIPIET» together with organisations involved in the creation of the stands have developed a concept of NPU decommissioning in 1993. Three possible options were considered and a technical and economic comparison was carried out.

Option 1 - construct an interim radioactive waste storage facility on the training centre site conforming to present-day safety regulations where reactor compartments and other conditioned radioactive wastes have to be placed for storage during 100 years. The compartments have to be dismantled after the storage period has elapsed. It is reasonable to recycle non-radioactive scrap and radioactive metal must be ultimately disposed of like other radioactive wastes. After all the radioactive wastes have been disposed of, the site territory can be transferred for an unlimited use.

Option 2 - lay up RCs on site for a period of 50 years. The residual gamma-activity of equipment items mainly caused by ^{60}Co, ^{54}Mn, ^{55}Fe and other radionuclides that will decrease more than 1000 times within that storage period. The remaining long-lived radionuclides like ^{59}Ni, ^{63}Ni, ^{94}Nb and others show soft beta-radiation, which does not create a harmful radioactive background near equipment items of the primary circuit and poses no substantial obstacles for their dismantling. This option allows to dismantle adjacent non-active compartments and to remove non-radioactive equipment from RC, to lay up reactor compartments and to construct around them additional safety barriers ensuring a reliable isolation of the compartments from the environment for the entire storage period. The RCs do not need servicing and power supply in the process of storage. Only a periodic radiation monitoring is required within the area of their location and a control over the integrity of external shielding barriers. The RCs have to be dismantled after the storage period has elapsed. Non-radioactive metal will be recycled and radioactive wastes have to be conditioned and disposed of. The site territory after clearing it from all the radioactive wastes can be transferred for an unlimited use for a new purpose.

Option 3 - a complete dismantling of reactor units and other premises of the radiation-hazardous complex without a preliminary conditioning. A complete dismantling of the reactor compartments and other contaminated structures is foreseen with a subsequent removal of arisen and accumulated wastes after containerising, in a storage facility constructed in advance. The site has to be transferred for further use after the waste removal from the territory and the control of non-contamination.

A detailed analysis of the proposed options has shown that each of them possesses advantages and disadvantages.

Option 1 features a relatively low dose burden, the lack of necessity to remove radioactive wastes off the site for disposal, small volumes of radioactive wastes and low environmental impact. But the implementation of this option requires constructing an interim radioactive waste storage facility meeting present-day safety regulations on the site, which is a rather expensive affair. The site will be occupied for a long time and, besides, it will be necessary to come back to the problem of the complete dismantling of the reactor compartments after the storage period has elapsed.

An analysis showed that time required to construct that interim storage facility, to condition and place all the accumulated wastes and to conduct other associated works will make up 6-8 years.

Option 2 is much similar to option 1 in dose consumption, minimal environmental impact, minimal radioactive wastes etc. But time of monitored storage of the compartments is reduced to 50 years. Building the multibarrier RC shielding allows to construct a small-sized store instead of an interim radioactive waste storage. This small-sized store can be constructed in the main technological block areas to be cleared, at the place of dismantled reactor compartments for instance. This option can be implemented within a minimal period of about two years.

A main disadvantage of this option is a necessity to return to the complete dismantling of the reactor compartments after their storage period has elapsed and only after the dismantling of the reactor compartments and removal of all radioactive wastes the site can be cleared for an unlimited use.

Option 3 - the complete RC dismantling without a preliminary conditioning is most difficult from the engineering point of view. This is due to a high residual activity of the main NPU equipment items. For example, the reactor vessel and the steel/water-shielding tank can create an exposure dose rate right up to the equipment items from some unities to tens of sieverts per hour. The application of expensive remotely controlled automated devices is required under these conditions for cutting high-active NPU equipment items into fragments which then are to be placed into shielding containers for a safe shipment and storage. Moreover, the availability of vacant volumes is required in the preliminary constructed radioactive waste storage facility to dispose of intermediate-level and high-level NPU components and other radioactive wastes accumulated earlier.

This option provides a minimal environmental impact in the course of RC dismantling, radioactive waste shipment and disposal. The calculated implementation period for this option is 6-7 years.

To the positive considerations refers the fact that over the mentioned period the site can be completely cleared from radioactive wastes and all the radiation restrictions can be removed after monitoring.

Following up the review of the proposed options together with Estonian side it was recognised that option 2 is most feasible in terms of implementation period and costs. This decision was thoroughly analysed and approved by the international PIERG experts group.

The nuclear fuel unloading from the reactors, fuel packaging into casks and shipment to Russia for reprocessing were paramount and extremely critical phases in laying-up the reactor compartments, which were successfully implemented and completed in October 1994.

Simultaneously a laying-up design was developed based on the selected option. The following organisations were involved in the design activity: LI «VNIPIET», as well as CDB ME «Rubin», RDIPE and OKBM.

It was supposed according to this design to completely dismantle adjacent reactor compartments, which accommodated support radiation safe equipment, instrumentation systems, and a power stand control panel. After that RC lay-up works had to be carried out.

The lay-up design had to satisfy the following requirements:

- no advert environmental impact during the entire storage period,
- no permanent service, minimal power consumption at a minimal monitoring,
- resistance to the changes of weather, ground water level and other natural occurrences,
- resistance to attempts of non-authorised access inside the compartments and to other external impacts,
- maximal feasible use of safety barriers incorporated in the power stands design.

2.3 LAYING-UP OF REACTOR COMPARTMENTS

The reactor compartments with NPU enclosed in them were placed in long-term storage in the following condition: RCs were separated from the adjacent ones which are dismantled, fuel from the reactors was unloaded, the reactors and primary circuit systems were made airtight, drained and stayed under atmospheric pressure. Undrainable bodies of the coolant in amount of ~ 1 and 2 m^3 remained in the primary circuit equipment (the purification systems, reactor, steam generators) in RC #1 and #2 respectively (see section 4 and section 5). Calculations show that multicyclic freezing of water remaining would not lead to the depressurisation of these systems.

Sorbents from the coolant purification filters were discharged. Some non-radioactive equipment items located above the biological shielding were dismantled. An additional reinforcement of reactor compartments' support units was carried out so that a maximal calculated earthquake of grade 7 (MSK-64 scale) would not lead to the disturbance of the RC stability.

The grout was poured inside RCs on the most critical places of equipment items and rooms (reactor lid, manhole to the steam-generator's enclosure, upper portion of the steel-water shielding tank etc.) to increase radiation shielding properties of the reactor compartments whose efficiency decreased due to complete draining of the biological shielding tank (unit #2) and steel-water shielding tanks of both RCs as well as to provide an additional physical protection of equipment items in the course of the long-term storage. The body of poured concrete makes up 31 and 41 m^3 for RC #1 and RC #2 respectively (see section 4 and section 5).

Fire fighting, lightning , control and warning systems were not maintained.

The monitoring of the atmosphere quality and radiation situation inside the sarcophagi as well as ventilation of the space could be realised through tube penetrations embedded in the sarcophagi walls.

No maintenance and power supply are required for the laid-up RCs during the entire storage period. No visiting of RCs in the course of storage is foreseen. Only entering into the inner sarcophagus's space to examine outside surfaces of the compartments and to make control measurements is possible.

Radiation safety in the course of the long-term storage is provided with a system of measures including three safety barriers: the airtight reactor vessel and airtight primary circuit systems (the first barrier), the airtight reactor compartment partitions (the second barrier), the concrete sarcophagi round the reactor units (the third barrier).

Drawings attached in appendix 1 show the general view of the main technological block and sarcophagi (plan and section views), and reactor compartments.

3 DESCRIPTION OF BUILDINGS AND SARCOPHAGI

This part of the report presents a description of the civil-engineering aspects of the premises.

3.1 A CONCISE CHARACTERISTICS OF THE TRAINING STANDS AREA

The training stands site is located on the northern shore of the Pakri peninsula in a forest area 1.2 km off the Gulf shore and 3 km off the town of Paldiski. The main technological block, which accommodates the stands, has a northeast orientation by its longitudinal axis. Highways and railways are advanced to the site.

The climate is transitional from west European to east-European continental. Totally it is a humid climatic zone. Winter is not severe, and summer is cool. Precipitation quantity is up to 560 mm/year. The thickness of snow covering is up to 17 cm/year. Average annual temperature is +5.3 °C. Average annual relative humidity is 86 %.

The site relief is flat with a 1 % inclination to the Gulf. According to engineering and geological surveys the rocks with bearing capacity of 5-7 kg/cm^2 occur at a depth of 1.0 m on which building foundations rest.

Underground waters in chemical composition not corrosive to concrete occurs at a depth of 0.8 m from the natural surface, they have seasonal level variations.

Note : Sarcophagi drawings attached in appendix 1 demonstrate that the "base" of the reactor compartments is below grade.

Some moderate earthquakes were recorded in 1670, 1827, 1881 and 1976 with their intensity reaching from 3 to 6 on the MSK-64 scale. Epicentre concentration within the western and northern parts of Estonia shows relatively intense tectonic activity in these areas during the last centuries.

3.2 DESCRIPTION OF BUILDING 301/302

3.2.1 Architectural and civil aspects

The Main Technological Building (MTB) is the largest of the facilities of Paldiski site; its dimensions are about 208 m long, 40 m wide and 23 m high (see MTB plan in appendix 1). The main block of the technological area consists of two buildings 301 and 302 constructed in different times and incorporated as a unit.

Actually, The MTB consists of a major volume where the training stands are located and two annexes on the longitudinal sides of the building one of which accommodates technological rooms (for the auxiliary equipment, control boards etc.), and the other accomodates amenity rooms, class rooms, offices etc... (See photos no 1 to 4 in appendix 5).

The construction volume of the building is 108950 m^3, including an underground part - 2500 m^3. The construction area is 7290 m^2, and the total area is 14010 m^2.

- Building 301 - Technological block of phase 1 (see Building 301 drawings in appendix 1).
  Designed in 1963, completed in 1967.
  Dimensions:
  - length - 132.5 m,
  - width - 40.2 m,
  - height - 22 m.

  The training facility, coded as 346A, was installed in room no 141 with dimensions 54 m by 14,5 m and 11 m high. This room has several openings in its ceiling for installation and maintenance of equipment, which were normally covered by removable reinforced concrete slabs. The other rooms in the main hall were housing auxiliary systems and facilities. The stand was commissioned in 1968. The power unit of the stand operated till 1989.

– Building 302 - Technological block of phase 2 (see Building 302 drawing in appendix 1).
  Designed in 1974, completed in 1982.
  Dimensions :
  - length - 75 m,
  - width - 40.2 m,
  - height - 22 m.

  The block accommodates training stand 346 B (power unit #2). The main hall of the building #302 (room no 114) has dimensions 75 m by 18 m and a height of 21,4 m. It is connected with the room no 327 of building #301 at the level of 11,4 m and forming together with a common hall of the MTB with total volume of about 49 680 m^3. Along the western wall of the hall at the height of 11,4 m there is a platform, which leads to the room no 327 of building #301 and also to the top of the sarcophagus of Unit 2. In the north-west corner of the main hall are access stairs to the platform.

The frame of the main building consists of concrete columns and prefabricated concrete roof beams at a distance of 6 m. Additionally, the frame is stiffened by lateral bracing of structural steel (See photo no 5 and 6 in appendix 5). Outer walls between the columns are assembled of prefabricated concrete slabs 6 by 1.2 m, while the walls between the main hall and annexes are made bricks. Concrete roof elements, 6 m long and 1,2 m wide, span over the roof beams and on top of these elements an insulation of light weight concrete covered by a layer of bituminous felt is placed.

The main hall has glass windows in steel frames in the eastern wall of building #301 and in the western wall of building #302. Two overhead bridge cranes have been installed the common hall. Each of them has two lifting devices with capacity of 50 and 10 tons.

Along the western side of the common hall there is a two-and three-storied annex, which was housing offices, classrooms, workshops, warehouses and other auxiliary facilities. A three-storied annex at the southern end of building #301, housing changing rooms and radiological control facilities was used as main entrance to the MTB. Along the eastern wall of the building #302 was constructed annex for emergency cooling water tanks. The walls of southern and western annex are constructed of brick masonry where the bricks are made of silicate concrete, while the eastern annex is built of concrete slabs.

The foundation plate (1.2 m thick) for bodies of the stands is steel-concrete cast - in place reinforced with welded forming and reinforcing system.

Material of the foundation plate is concrete of grade M150 (class B12.5). Reinforcing bars are round of class AI and AIII of die-rolled section.

Material of walls and floor slabs is concrete of grade M200 (class B15) of volumetric weight γ = 2.4 t/m^3. Support walls and the reactor compartment plate of unit #1 (building 301) along axes 8 to 10 between axes G-L are made from extra heavy concrete of grade 150 and volumetric weight γ = 3.3 t/m^3 and super heavy concrete (γ = 4.2 t/m^3).

The roofing of the main hall is made of precast steel-concrete ribbed plates on steel-concrete beams. Walls are made of expanded-clay lightweight concrete 240 mm thick and partly of lime-and-sand bricks of grade M75 with the use of M50 - grade mortar.

The main technological block (building 301/302) is designed for :

- wind pressure (region III) of 38 kgf/m^2,
- weight of snow covering (region II) of 70 kgf/m^2,
- seismicity (design - basis earthquake) - grade 6 on MSK 64 scale, (maximum calculated earthquake) grade 7 on MSK 64 scale,
- structure class - II,
- reliability factor - γ_N - 0.95,
- fire-resistance grade - II,
- fire-hazard category - D.

Service equipment of the technological block :

- water supply,
- special sewerage,
- heating,
- ventilation,
- hot water supply,
- electric power supply,
- lifts and hoists,
- cranes (bridge, manual, electric),
- electric telphers.

3.2.2 Radiological data

The following data were obtained in the course of the comprehensive inspection of the training centre of February 3, 1994 and December 16, 1994, registered # 0206/37-132.

That inspection of the radiation condition showed that practically all the rooms of building 301 have no contamination exceeding 0.25 μSv/h, except for some rooms which have radiological concern because of contamination or elevated radiation level. A short description of these rooms is given in the table below.

Room no	Description	Contamination level [Bq/cm^2]	Remarks
131	Standby space	4-3000	The room under spent fuel pool for reactor unit #1. The pool was damaged during refuelling of Unit 1 in early 80's.
139	Sampling room	3-5	Glove box for sampling from 1. and 2. circuit
142	Pipe corridor		Not accessible, provisionally estimated dose rate 5-10 μSv/h
144	Buffer tank	5-15	For receiving waste water from room no 145 prior pumping to special sewage system C2
145	Decontamination basin	15-80	
146	Corridor	5-10	
153	Pump station	15-35	
154	Buffer tank		For receiving water from system C2
155	Buffer tank	2-5	For receiving water from the primary circuit
232	Storage room for containers	15-20	
233	Spent fuel pool for reactor unit #1		Not accessible, but expectedly highly contaminated. The pool was covered with concrete prior to the site take over
234	Pipe shaft		Not accessible
238	Assembling and decontamination of equipment	50-250	

In some rooms, the gamma-radiation dose rate exceeds 0.25 μSv/h: the inside volume of the empty cooling pond - 1.5 up to 20.0, the circuit water collection tank room - 50, rooms under the cooling pond: 2 up to 4 μSv/h, the sample reception room and the room for washing and assembly equipment items: 1.5 μSv/h.

3.3 PREPARATION OF REACTOR COMPARTMENTS FOR LAYING-UP

A complete dismantling of auxiliary compartments adjacent to the reactor compartment was made after fuel removal from reactor stands 346A and 346B.

Non-radioactive equipment items were unloaded from the reactor compartments, RC support structures were additionally reinforced in view of a maximal earthquake (grade 7 on MSK 64 scale). Additional bulkheads were installed at the compartment ends and all the holes in compartment bodies and bulkheads were sealed up.

Steel-concrete shelters (sarcophagi) are constructed in 1995 around reactor compartments of stands 346A and 346B for laying-up and long-term storage :

- sarcophagus #1 in building 301,
- sarcophagus #2 in building 302.

3.4 DESCRIPTION OF SARCOPHAGI STRUCTURES FOR REACTOR COMPARTMENTS

Sarcophagus #1 in building 301 :

- Major dimensions.
  - Internal sizes :
    - length - 16.1 m,
    - width - 10.5 m,
    - height - 12.2 m.

  - External sizes :
    - length - 16.9 m,
    - width - 11.1 m,
    - height - 12.4 m.

- The sarcophagus around the reactor compartment was constructed by erecting dividing walls, made of reinforced concrete, up to the ceiling in rooms no 141. The sarcophagi is partly using existing walls of the MTB (walls between rooms 142/139, 142/141 and 141/234) as well as foundation of the reactor compartment.

- The existing longitudinal walls and the cast- in place steel-concrete floor slab at elevation of 11.40 are partly used in sarcophagus construction.

- The longitudinal walls along axes «L» and «E» from elevation - 1.00 to elevation +6.00 are 300 mm thick and 400 mm thick over elevation +6.00 (see sarcophagus #1 drawing in appendix 1).

- The transverse walls near axes «8» and «10» are 400 mm thick all over the (see sarcophagus #2 drawing in appendix 1).

- There are three doors from the sarcophagi to neighbouring rooms, two on the ground level to room no 142 and one on the level of +6,00m to room no 234 (See photos 8 and 9 in appendix 5). All these steel doors are closed and welded to their frames, also the hinges of the doors are spoiled by welding. The foundation of the reactor compartment has two heavy steel doors to rooms no 140 and 140B, under reactor vessel and main circulating pump, respectively (See photos 10 and 11). Both of these doors are closed and sealed the same way as described above, additionally in front of the door to room no 140 is pile of hardened concrete mortar about 30 cm high. The roof of the sarcophagi has a trap-door for inspections and monitoring condition of inside of sarcophagi and the outer surface of submarine hull.

Sarcophagus #2 in building 302 :

- Major dimensions.
  - Internal sizes :
    - length - 12.7 m,
    - width - 11.5 m,
    - height - 14.1 m.

  - Dimensions :
    - length - 13.5 m,
    - width - 12.3 m,
    - height - 14.32 m.

- The longitudinal and transverse walls are 400 mm thick.

- The sarcophagus of Unit #2 is a freestanding structure.

- The roof has a trap-door for inspections and monitoring condition of submarine hull, which is the only access into the upper part sarcophagi. Inside the sarcophagus there are stairs and three platforms adjacent to the both ends of reactor compartment. In addition of the access route in the roof there is a heavy steel door in the eastern wall of foundation for the hull enabling inspection of room under the reactor compartment (See photo 12).

Joggles and nests 50 mm deep are cut out wallswide along the abutment length to connect new structures of sarcophagi #1 and #2 in the existing steel-concrete walls, floor slabs of building 301 and 302 in places where cast-in place steel-concrete sarcophagus walls abut with them.

Holes for reinforcement anchoring (welding) to the existing reinforcement (for sarcophagus #1, stand 346A, building 301) are cut out in floor slabs at elevations +6.00 and +11.40 in places where new walls abut with them.

Hacking is made on surfaces of the existing steel-concrete structures in places of abutment of newly constructed structures of sarcophagi #1 and #2 to connect new structures with existing ones.

Shielding walls of the reactor compartments (stands 346A and 346B) are used as support structures to attach new longitudinal and transverse walls of sarcophagi #1 and #2.

Walls of sarcophagi #1 and 2 for the reactor compartments are made of cast-in place steel-concrete of class B25 (grade M300) with density $\gamma = 2.4$ t/m^3 (GOST 25192-82).

The reinforcement of new walls (sarcophagi #1 and 2) is made by vertical and horizontal reinforcing fabric factory-made according to GOST 23279-85/ Working reinforcing fabric bars arc of class AI and AIII (GOST 5781-82). Diameter ∅25AIII, ∅12AIII, ∅8AI. Rolled products of steel C245 and C345 grades (GOST 27772-88), angle pieces 50x5, flange beams 60SH1.

Every welded joint is made according to GOST 5264-80 and GOST 14098-91. Manual welding is made with electrodes of E42 type according to GOST 9466-75 and GOST 9467-75. The structures are constructed with in compliance with SNIP 3.03.01-87 and SNIP III-4-80.

The protection of building structure of sarcophagi #1 and #2 against moisture and corrosion is made according to SNIP 2.03.11-85 and SNIP 3.04.03-85 :

- by applying paint coatings on inside and outside surfaces of the structures,
- by using concrete of normalised penetrability.

The roofing above sarcophagi #1 and #2 is made of precast reinforced concrete slabs of II-03-02 and PK-01-III, 119 series, over which an inclined cement covering is placed with damp proofing by means of RKP-350B- grade ruberoid (GOST 10923-82) in four layers with a 25 mm thick protective coating of a cement and sand mortar (M100 grade).

The cast-in place steel-concrete structures of sarcophagi #1 and #2 - walls and ceilings - are painted (2 times) with enamel 59-1-90 and silicate paint OS-12-03, namely :

- the roofing and walls (on the outside) by enamel 59-1-90 (specification 301-100-323-90) 2 times on primer GF-021 (GOST 25129-82),

- the ceilings and walls (on the inside) by silicate paint OS-122-03 two times according to specification 84-725-78E and PCH-40-81 on the primer by the same paint deluted in proportion 1 : 2.

The consumption of concrete for sarcophagus #1was150 m^3, and for sarcophagus #2: 263 m^3.

In regard to results of compression strength measurements (43 Mpa or so) of samples taken from the walls of sarcophagi #2, the walls are made of high quality and strong concrete

Total consumption of reinforcement for sarcophagi #1 and #2 :
- class AIII reinforcement - 26.71 t,
- class AI reinforcement - 1.37 t,
- rolled products - 5.75 t (angle pieces - 50 kg, flange beams - 3.5 t, steel plates 4,8,12 mm thick - 2.2 t).

Consumption of paint, primer and ruberoid for sarcophagi #1 and #2 :
- enamel 59-1-90 - 822 kg,
- primer PF-170 - 190 kg,
- hard putty PF-002 - 235 kg,
- silicate paint 05-12-03 - 715 kg,
- ruberoid RKP-350B - 1750 m^2.

The building structures of sarcophagi # 1 and 2 are designed for :

- seismic impacts according to SNIP II-7-81 and PNAEG-5-006-87, design - basis earthquake - grade 6, maximal calculated earthquake - grade 7 (MSK scale),
- temperature impacts of the inside and outside air typical for that locality according to SNIP 2.01.01.82, 2.01.07.85,
- sarcophagi #1 and #2 are firesafe, structures material is non-combustible, the fire-safety is settled by the fire-fighting system of the main technological block (buildings 301/302),
- ventilation of the reactor compartments is settled by means of temporary air ducts connected to the pipe penetrations embedded in the walls and roofings of sarcophagis #1 and #2,
- the protection against inundation due to a high underground water level: the outer walls and the bottom of foundation slabs are coated with 2-3 layers of cold asphalt mastic 10 mm thick. The Underground structure of building 301/302 is made of hydraulic concrete W6. A contour drainage is provided in deepened parts allowing decreasing the ground water level down to the bottom of deepened parts of buildings 301 and 302.

In August-September, 1995 the construction of sarcophagi #1 and #2 was completed and they were accepted for operation by the international commission and the project was handed over to representatives of Estonia.

3.5 PRESENT STATUS OF MAIN BUILDING, SARCOPHAGI AND REACTOR COMPARTMENTS

3.5.1 <u>Current and/or future use of the MTB</u>

- **Building #301**
  - Annex buildings :
    The western and entrance annexes are not on use and any use of these parts of the building is not foreseen in the future. All rooms of these annexes are abandoned and containing lots of different type trash e.g. demolished apparatus and equipment, metal scrap, broken furniture, paper, rug, etc. Only exception is the room no. 118, former main electrical power switchboard for the building #301, which is still partly in use. The other areas of the annex buildings are powered off, water supply system is disconnected, and the original heating and ventilation systems are not operational and partly dismantled. In order to reduce risk of fire there it is intended to clean up all rooms in annexes by removing all ignitable materials from the area.

  - Main hall of building #301 :
    Presently all rooms in the main building of #301 below the level 11,4 m are powered off, most of technological systems like cooling water supply system, heating and ventilation systems were partly dismantled prior to construction of the sarcophagi and are not functioning. The upper part of the main hall in building #301, room no 327 on the level 11,4 m with dimensions 114 m by 18 m and 10 m high, is currently used for temporary storage of empty containers. Before taking into use this area was

radiologically surveyed and decontaminated and the PVC floor cover removed. The room has one electrical breaker box to power up an overhead bridge crane with original lifting capacity of 10/50 tons. This crane, currently having no valid license, needs renovation and re-licensing.
The eastern wall of this room is furnished with glass windows in steel frames, which are in poor shape and tending to brake during strong winds.

– **Building #302**

- The western annex :
  As the annex is not on use and any use of this part of the building is not foreseen in the future, the area is powered off, water supply system is disconnected, the original heating and ventilation systems are not functional.

- The eastern annex (building #302A) :
  The eastern annex of building #302 was completely reconstructed recently. The size of the building was reduced by demolition of upper floors (Photo 13). Nowadays the building #302A is a single-storied construction housing the following facilities:
  * offices of AS ALARA staff (150 m^2)
  * mechanical workshop and warehouses (220 m^2)
  * changing rooms (60 m^2)
  * active laundry (50 m^2)
  * radiometrical laboratory (40 m^2);
  * Waste Treatment Area (360 m^2).

  The building is electrically heated and arranged with two independent ventilation systems : one for uncontrolled area and the other for controlled area. The latter is equipped with HEPA filters.

- The main hall of the building #302
  In connection with constructing by ALARA Ltd an interim storage in the main hall of building # 302, this part of the building was renovated as following:
  * the main hall was cleaned up from unnecessary equipment, cables, pipes etc.;
  * electrical installation was replaced;
  * an overhead crane was renovated and equipped with radio controlled device for remote handling of waste containers;
  * the roof was repaired and the outer wall surfaces of the building #302 were covered by steel lining in order to make the building weather tight.

3.5.2 General condition of reactor compartments and sarcophagi

- **Ventilation, humidity control**

  Only very simple unrefined ventilation of reactor compartments was designed and constructed. It enables very limited air exchange by natural convection through two pipes with about 10 cm diameter at the bottom of sarcophagi wall and trapdoor in the ceiling. Moreover, the pipes in the wall of sarcophagi #2 are plugged by concrete. Due to lack of temperature and humidity control of both, the main hall and sarcophagi, the submarine hulls are at the mercy of seasonal changes of temperature and humidity. This is causing "sweating" of metal surfaces during warming up of submarine hulls after winter season. The presence of condensed water inside both sarcophagi has significantly accelerated corrosion processes. This fact strongly points out the need for installing any humidity control equipment in both sarcophagi.

  The both sarcophagi contain lots of construction rubbish like reinforcement bars, cables dismantled pipes, wood, concrete, etc (See Appendix 5 photos 10, 11, 13). These wastes are not radioactive wastes. High humidity and lack of ventilation have caused disintegration of organic material and growing mould inside of sarcophagi. AS ALARA has planned to clean up these areas next year.

- **Fire extinguishing system.**

  Original system is out of service and partly demolished. During the renovation of main hall of building #302 in connection with establishing the interim storage the fire alarm and extinguishing systems were installed there.

- **Radiological measurements equipment, leak detection systems, monitoring and alarm systems**

  These equipment and systems are completely absent at the moment in sarcophagi

- **Drainage systems**

  According to "passport documents" the drainage of primary system should be plugged. However, under the reactor compartment of Unit 2 the drainage pipe, connected to the special sewage system, is clearly visible. It is still unclear, if any drainage exists in the sarcophagi #1, as the access doors to the space under that reactor compartment are sealed.

- **Cracks and corrosion**

  As stated earlier, the absence of humidity control has accelerated the corrosion processes of reactor units. No cracks have been observed neither in the walls of enclosed RC sections . Presently the sarcophagi itself are in quite stable state, with no visible cracks or other major defects.

A certain amount of radioactive waste was stored in the reactor compartments. In the initial version of the decommissioning project, it was not planned to store radioactive waste into reactor compartments. But it was necessary to do that, because Russian teams had a very short time to deal with these radioactive wastes, and there was no free storage area within the site.

These radioactive wastes were stored in the reactor compartments in 1995, and lists of wastes were issued in September 1995. These lists were included in the files given to Estonian authorities when transferring the ownership of the site (See Appendix 4).

3.5.3 Radioactive wastes stored in Reactor Compartment 1 (stand 346 A) :

Most of the radioactive wastes stored in reactor compartment #1 are miscellaneous low level wastes (rags, metallic wastes, tools …), with surface contamination. These wastes are located principally on the third floor of the reactor compartment. The total weight of waste for Unit #1 compartment is something up to 14 tons (see Appendix 4).

But some radioactive sources were also put into concrete poured into the compartment. These sources were used for calibrating radiological measurement equipment :
- Neutron sources : Pu238-Be, Cf252.
- γ-radiation sources : Co60
- β-radiation sources : Cl Sr90, Sr90 + Ittrium 90, Cl Na22, Tallium 204, Cs 137.
- α-radiation sources : Pu 239.

Most of these sources are small sources. Plutonium and Cesium sources are very small sources (from a few kBq to a few MBq). Their activity is given in waste lists above mentioned (See appendix 4). The total activity of the radioactive sources that were on site and had or might have been placed into RC #1 was to 4.4 TBq or so in 1995 (main radionuclide : Co60), and can be estimated to two thousand times lower after fifty years, and to a few MBq in 2100.

This work was carried out in a very short time, and the only pieces of information we have about it are the lists above mentioned. It is not possible to indicate the exact location of these radioactive sources. It is not sure that we can rely on the lists to determine the exact number of sources, but according to these lists, around one hundred radioactive sources might be located in Unit #1 compartment, in five or so containers. Some complementary information could be obtained asking questions to the people who were directly involved in these works.

All these sources are located inside containers. For neutrons sources and some γ-radiation sources, the container is a special paraffin and/or lead container, but for β-radiation and α-radiation sources, the container is a simple plastic container or wooden case. Most of them were placed into the U-shaped room (first floor – room where the main equipment of first loop is located), and on the roof of this room (second floor – motors and pumps), before these spaces were grouted with concrete. Some sources could also have been placed in concrete poured onto the reactor vessel lid.

3.5.4 Wastes stored in Reactor compartment 2 (stand 346 B) :

Most of the wastes stored in reactor compartment #2 are miscellaneous low level wastes (rags, metallic wastes, tools …) with surface contamination. The total weight of waste for Unit #2 compartment is something up to 2.5 tons (see Appendix 4).

Radioactive lead with very low level of activity was stored in reactor compartment #2. Ten ionising chambers PKI (length 4 m) are stored in reactor compartment #2. These pieces of equipment were used to measure neutron flux within the reactor core. Only the low part of this chamber is active. They were placed in the reactor room before grouting.

According to the information provided by Mr. SIMANOVSKI at the occasion of the first progress meeting that took place in Paris, no radioactive source was stored in reactor compartment #2.

4 DESCRIPTION OF REACTOR COMPARTMENT OF STAND 346A WITH REGARD TO MEASURES TAKEN TO PUT IT IN PROLONGED STORAGE

This part of the report describes reactor compartments of stand 346A with regard to measures taken to prepare it for prolonged storage, using the materials developed by CDB MT "Rubin" during preparation of stand 346A for prolonged storage and those developed during the period of putting reactor compartment in prolonged storage.

Power unit #1 (stand 346A) being an analogy of 1st generation NS/M NPU was mounted in building 301. The NPU was located in a metal housing which corresponds in the geometry and dimensions to that of NS/M. Unit #1 consisted of a reactor compartment (RC) and 3 support compartments abutting with the reactor compartment at both ends. Total length of the stand was 50 m.

Stand 346A included a reactor plant with type PWR/VM-A reactor of 70 MW thermal capacity which was in operation according to its direct purpose from April 10, 1968, to January 29,1989. Fuel reloading and the replacement of a set of steam-generators for a new updated design were carried out in 1978-81, which allowed to substantially simplifying their maintenance. No other large - scale repair and maintenance works were carried out (Refueling was carried out in 1980). Total operation time of the reactor at powers of 20% to 40% of the rating was 20821 hours (13781 hours with the first fuel load, and 7040 hours with the second load). Spent nuclear fuel was discharged from the reactor in August-October 1994 and transported to Russia.

4.1 DESIGN FEATURES AND MASS/DIMENSIONAL CHARACTERISTICS OF REACTOR COMPARTMENT

This section sets forth basic characteristics of the reactor compartment before starting the work on preparing it for prolonged storage.

4.1.1 Design features of the reactor compartment

The general view of the reactor compartment is shown in Fig. 1 hereafter.

The cylinder-shaped body of the reactor compartment is confined on its ends by transverse bulkheads.

The reactor compartment, by means of two foundation supports, is mounted on tangential supports of the foundation of the building, which, by their embedded studs, restrict movement of the reactor compartment body in the horizontal plane.

Outside, the reactor compartment is provided with biological protection in the form of vertical concrete walls up to 3000 mm thick which exceed in terms of the height the level of biological protection of the steam producing plant inside the reactor compartment.

Underneath, the reactor compartment is provided with biological protection in the form of two 1700 mm thick concrete blocks located in the areas of fore and aft bulkheads of the reactor compartment.

Fig. 1. General view of the Reactor Compartment #1

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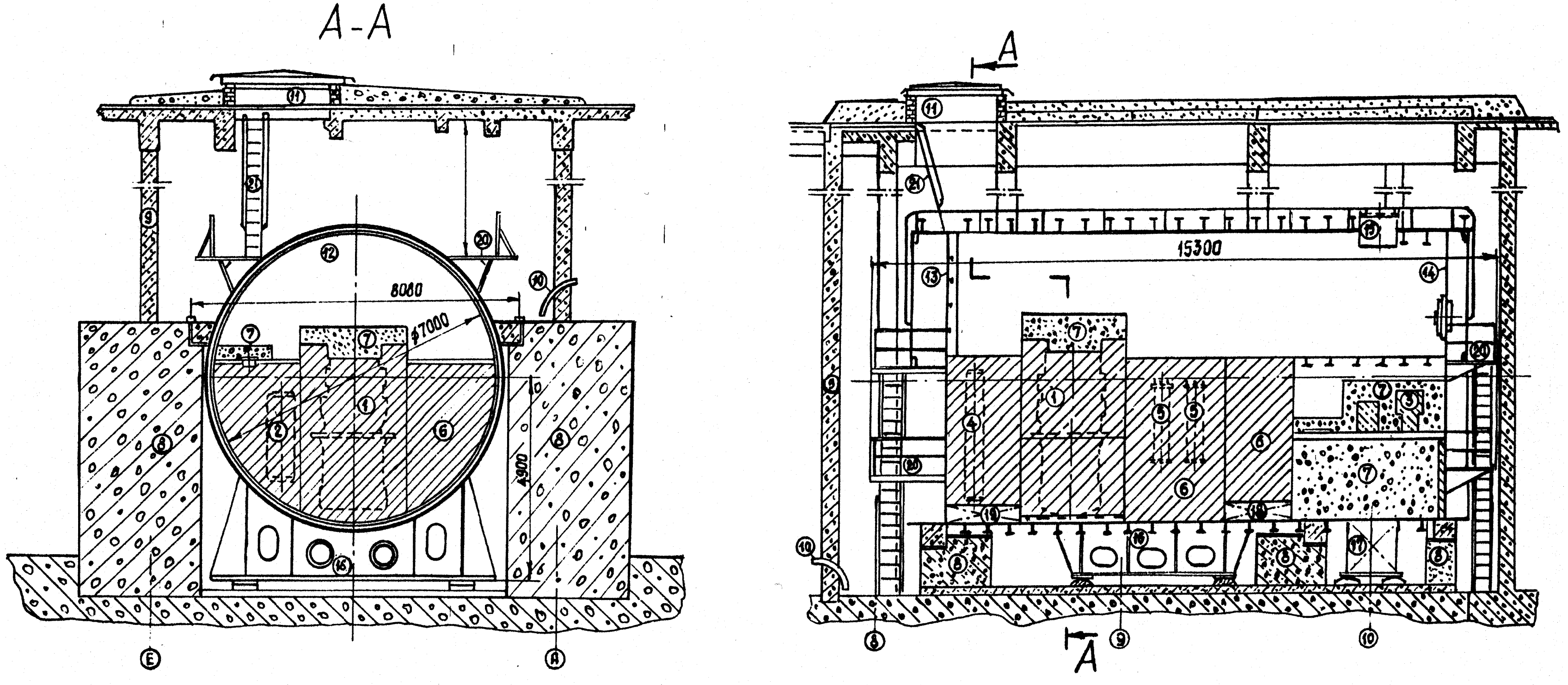


Fig.1 Reactor compartment № 1. Cross and longitudinal sections.

1 - reactor; 2 - steam-generator; 3 - 1 circuit pump; 4 - pressurizer; 5 - coolant purification filter; 5 - non-attended rooms; 7 - new-placed concrete in RC; 8 - concrete shielding wall; 9 - vault wall; 10 - penetrations in the vault for control measurements; 11 - manhole into the enclosure; 12 - RC vessel; 13,14 - cross partitions; 15 - manhole to RC; 16 - metal supports; 17,18,19 - tanks; 20 - passover landing; 21 - trap.

4.1.2 Mass/dimensional characteristics of the reactor compartment

Before carrying out the laying-up works, the reactor compartment of training stand 346A had the following mass/dimensional characteristics :

Clear diameter of the body, m	7.0
Length of reactor compartment body, m	12.35
Width of rector compartment body (max.), m	8.1
Height of reactor compartment body (max.), m	8.5
Thickness of reactor compartment body sheathing, mm	27.0
Thickness of reactor compartment bulkheads sheathing, mm	10.0
Mass of reactor compartment body, t	855.0

4.1.3 Spaces of the reactor compartment

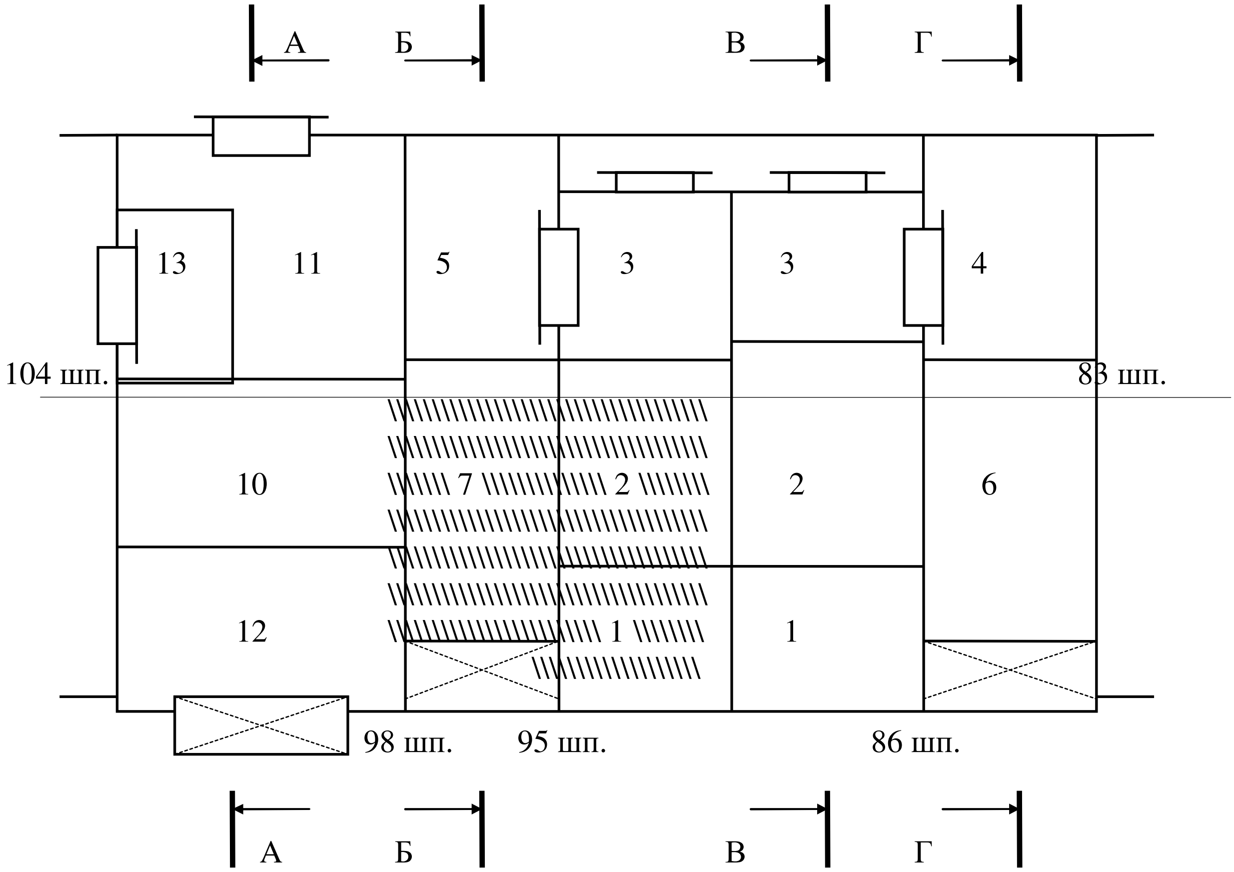
The reactor compartment is divided by intermediate transverse and longitudinal bulkheads into a number of spaces (see Fig. 2 and Fig. 3 hereafter) :

- equipment space (durably sealed) located between frames 86 and 95 and consisting of rooms of I(1), II(2) and III(3) tiers,
- two reactor protection control system spaces, fore (4) and aft (5), located outside the III-tier room of the equipment space,
- two pressurizers spaces, fore (6) and aft (7), located under the reactor protection control system spaces,
- two steam generator spaces on the starboard side (8) and the port side (9) located on the right and left of the equipment room, respectively,
- pump space consisting of rooms in tier II (10) and tier III (11),
- U-shaped space (12) located in the lower part of tier II of the pump space.

At the entrance to the reactor compartment, a sluice lobby (13) is provided.

Note : The numbers in parentheses correspond to the numbers of reactor compartment spaces shown in Figs. 2 and 3.

Fig. 2. Layout of spaces of reactor compartment of stand 346A. Longitudinal section along diametrical plane



1. Equipment space, tier I (fore and aft)
2. Equipment space, tier II (fore and aft)
3. Equipment space, tier III (fore and aft)
4. Reactor protection control system space, fore
5. Reactor protection control system space, aft
6. Pressurizer space, fore
7. Pressurizer space, aft
8. Steam generator space, starboard side (see Fig. 3)
9. Steam generator space, port side (see Fig. 3)
10. Pump space, tier II
11. Pump space, tier III
12. U-shaped space
13. Sluice lobby

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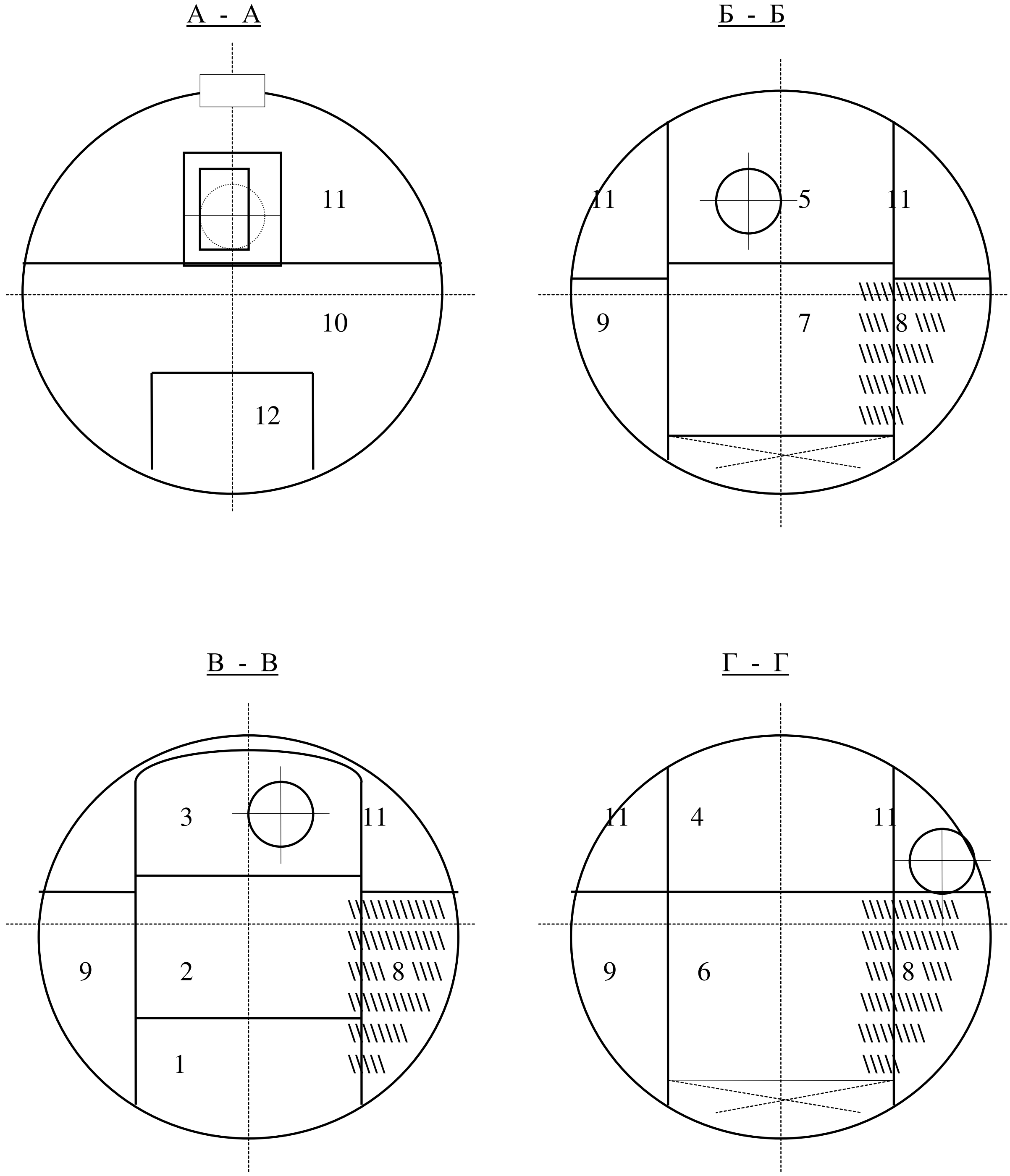
Fig. 3. Layout of spaces of reactor compartment of stand 346A. Cross-sections



4.1.4 Equipment layout in the reactor compartment

The fore equipment space accommodates bow reactor enclosure with VM-A reactor, placed in the iron-water protection tank. The two activity filters of the primary circuit, installed in concrete shielding, are located in the stern reactor enclosure.

Tier III of the equipment space houses equipment and pipelines of the cooling system, ventilation and air-conditioning equipment, electric equipment for control of reactor compartment mechanisms. Electric reactor control equipment is mounted in the fore protection control system space.

Pressurizers for compensation of coolant volume in the 1st loop are located in the fore pressurizer space.

The port side steam generator space accommodates steam generators with associated pipelines, valves and standard biological protection. Serpentine concrete blocks are placed in the starboard side steam generator space.

In tier III of the pump room, on the starboard side, equipment and pipelines of the 1st loop make-up and high-pressure gas make-up system and various electric devices are located; on the port side, the evacuation compressor, electric current converter and other electric equipment are mounted.

The upper and middle parts of tier II of the pump room accommodate equipment and pipelines of the 3rd and 4th loops systems, steam collectors and the main steam pipeline, a current converter, equipment and pipelines of the ventilation and air conditioning systems.

In the lower part (tier I) of the pump room, in the U-shaped space, pumps of the 1st loop with coolers and the heat exchanger of the 3rd and 4th loops with associated pipelines and valves are located.

The rooms in tiers I and II of the aft equipment space are filled with concrete. The aft pressurizers space accomodates no equipment : it is filled with concrete blocks.

The design of biological protection of the reactor with its pipeline systems and pressurizers and with steam generator chambers inside the reactor compartments assure radiation level lowering in compliance with regulative documents.

4.2 MOUNTING WORKS CARRIED OUT DURING PREPARATION OF THE REACTOR COMPARTMENT FOR LAYING-UP

In this section, a list of mounting works carried out during preparation of the reactor compartment for laying-up is given.

4.2.1 Mounting works carried out inside the reactor compartment

– Welding of the reactor cover to the body (with the pressure ring of the reactor cover removed),

- fixation of the reactor cover pressure ring in the standard position,
- mounting of plugs on the reactor cover supports,
- installation of sheath sheets of metal formwork for placement of concrete,
- laying of concrete on the reactor cover in the tier III room of the equipment space.

4.2.2 Mounting works carried out outside the reactor compartment

- Mounting of additional platforms on bulkheads,
- mounting of additional gangways and guards on the platforms,
- additional fastening of the reactor compartment body to the foundation.

4.3 WORKS ON THE REACTOR COMPARTMENT BODY

This section lists the works carried out on the reactor compartment body during preparation of the reactor compartment for laying-up.

4.3.1 Mounting of protective sheets of metal formwork for concrete placement

For placement of concrete that will provide “physical” protection of steam producing plants remaining for prolonged storage within the reactor compartment stand, protective sheets of metal formwork have been mounted :

- on the roof of the U-shaped space,
- on the deck of tier III of the pump space on the port side, near the hatch,
- on the deck of tier III of the fore equipment space.

4.3.2 Mounting of additional platforms outside the reactor compartment

To provide for carrying out dismantling/mounting works outside the reactor compartment, additional platforms on frame 83 and frame 104 bulkheads were mounted (see section 4.1.3 Fig. 2 and section 4.1.1 Fig. 1 : general view of RC #1).

4.3.3 Mounting of additional gangways and guards

To facilitate movements and to ensure safety of the personnel working outside the reactor compartment, additional gangways and guard railings have been mounted on the outside platforms (see section 4.1.1 Fig.1 : general view of the RC #1).

4.3.4 Fastening of the reactor compartment body to the foundation of the building

To provide safe storage of the reactor compartment during 50 years under conditions of possible exposure to seismic activity, the body of the reactor compartment has been additionally fastened to the foundation of the building. For this purpose, steel sheets were embedded in the spacing between the protective sheets of the “movable” biological protection mounted on the main body of the reactor compartment and the protective sheets of the immovable biological protection mounted on the foundation of the building, with subsequent welding them together over the edges.

4.4 LAYING-UP OF THE REACTOR COMPARTMENT

After preparation of the reactor compartment of the stand for laying-up (all dismantling, mounting, body works being completed), laying-up works were carried out.
Laying-up works include :

1 Mounting works carried out for putting the reactor compartment in prolonged storage.
2 Testing the reactor compartment for tightness.
3 Drying of air inside the reactor compartment.
4 Construction of a protective shelter (sarcophagus) for the reactor compartment.

4.4.1 Mounting works carried out for putting the reactor compartment in prolonged storage

Mounting works carried out during putting the reactor compartment in prolonged storage included :

1. Works for prevention of physical access to the components of the steam producing plants.

2. Sealing of the reactor compartment.

In order to meet the requirement for prevention of physical access to the equipment of the steam producing plants, placement of concrete around some items and body structures of the reactor compartment was carried out (see section 4.1.1 Fig.1 : general view of the RC #1).

On the preparation stage, 4.7 m^3 of concrete were laid onto the reactor cover in the fore equipment space.

During laying-up stage, concrete was placed :

- into the U-shaped space (to prevent access to the main equipment of the 1st loop located in this space): 17.65 m^3,
- on the roof of the U-shaped space (to prevent access to the steam producing plant equipment and the pumps of the 1st loop): 7.5 m^3,
- on the hatch located above the port side steam generator space (to prevent access to the steam generators, valves and pipelines of the 1st loop): 0.9 m^3.

The total volume of concrete placed in the reactor compartment is 30.75 m^3.

The weight of the concrete is 67.65 t (density being 2.2 t/m^3).

To ensure tightness of the reactor compartment of the stand during the whole period of storage and to provide the second safety barrier, plugging of holes and cut-outs on the main body of the reactor compartment and its end bulkheads has been carried out.

Plugging was made by mounting of plugs on weld-in reinforcement and on standard and temporary cutouts in the body and end bulkheads of the reactor compartment.

4.4.2 Sealing works performed inside the reactor compartment

A removable sheet was mounted on the deck of tier III of the pump space.

4.4.3 Sealing works performed outside the reactor compartment

- Plugs were mounted on weld-in reinforcement of the bulkhead at frame 83 and sealing pieces were provided under the door and under cable boxes,
- Plugs were mounted on weld-in reinforcement of the bulkhead at frame 104 and sealing pieces were provided under the door and under cable boxes,
- A removable sheet was mounted on the body of the reactor compartment,
- A cover for the maintenance hatch was mounted on the body of the reactor compartment.

Plugging of the weld-in reinforcement was made in the form of barrels up to 120 mm in diameter was provided by mounting inside the sleeves round steel inserts (rods) of a diameter equal to that of inside diameter of sleeves, with subsequent welding around the ends.

Plugging of the weld-in reinforcement was made in the form of weld-in sleeves of 120 mm or more in diameter was provided by mounting plugs made of 10 mm thick steel sheet welded on the outside of the sheath of the main body and end bulkheads of the reactor compartment.

Plugging of cable boxes on the end bulkheads of the reactor compartment was provided by cutting out cable boxes from bulkhead webs and inserting sealing pieces of 10 mm thick sheet in cutout places.

Plugging of round doors in the end bulkheads of the reactor compartment was provided by mounting inside the door coming a piece of 10 mm thick sheet, 800 mm in diameter.
For making sheet plugs, the sheet material taken from dismantled body structures was used.
Removable sheets were mounted in their places and welded around the perimeter.
The cover of the maintenance hatch was mounted in its place without rubber seals. The cover was pressed by bolts and welded to the hatch coming around the perimeter.

4.4.4 Tightness testing of the reactor compartment

Tightness testing of the reactor compartment was performed by blowing air into it under 0.05 MPa pressure and keeping it during one hour. No pressure drop was detected.

Note : For conduction of testing, weld-in sleeves of nominal diameter 250 of the ventilation system located on the reactor compartment body and weld-in sleeves of nominal diameter 125 of the air conditioning system located on the frame 104 bulkheads were utilised.
Monitoring of pressure variation in the reactor compartment during testing was carried out by means of a control pressure gauge mounted on one of the weld-in sleeves.
After tightness testing, the outside surfaces of the body and the bulkheads of the reactor compartment, platforms, gangways and guard railings were painted.

4.4.5 Drying of air inside the reactor compartment

According to the information supplied by the VNIPIET Institute, after applying paint coating to outside surfaces of the reactor compartment, air inside the reactor compartment was dried to remove residual moisture, air parameters were controlled at the outlet of the reactor compartment. In achieving a relative humidity in the reactor compartment of 40% at a temperature of +5°C, the drying operation was completed. Desiccant was placed inside the compartments to keep humidity at this specified level.

However, this information has to be taken very carefully, and should be checked by examining the specific procedures. We have requested these documents, and some complementary information about the nature of the desiccant used, and when the purported drying occurred. Actually, Mr. GROCHOWSKI didn't witness these works, and according to his personal observation, these works, if they were challenged, were carried out immediately after placement of concrete with no correlation to the concrete drying. If the curing of the concrete was not taken into account then the current moisture level will be significant due to the drying and setting up of the concrete.

4.4.6 Construction of a protective sarcophagus for the reactor compartment.

As the third safety barrier, a protective sarcophagus was constructed of reinforced concrete around the stand reactor compartment. The characteristics of this protective shelter are given in section 3.4.

4.5 TECHNICAL CONDITION OF THE REACTOR COMPARTMENT PUT IN PROLONGED STORAGE.

The reactor compartment put in prolonged storage has the following mass/dimensional characteristics (after carrying out the laying-up works):

Diameter of reactor compartment body (across frames), m	7.54
Length of reactor compartment body (max.), m	15.30
Width of reactor compartment body (max.), m	8.08
Height of reactor compartment (max.), m	8.80
Sheath thickness of reactor compartment body, mm	27.00
Sheath thickness of end bulkheads, mm	10.0
Weight of reactor compartment, t	922.65
Including :	
– body, bulkheads and other body structures, t	318.00
– equipment and pipelines of steam producing plants under biological protection, t	92.00
– biological protection (made up of concrete slabs piled up), t	445.00
– weight of concrete placed in reactor compartment, t	67.65

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On completion of works for putting the reactor compartment in prolonged storage, its equipment and systems are in the following condition :

1 Fuel assemblies have been taken out from the reactor.
2 Actuating mechanisms and control/measuring instrumentation of the reactor protection control system are dismantled.
3 The reactor is closed with the standard cover welded to the reactor body.
4 All holes in the reactor cover are plugged with welded plugs.
5 The reactor has been emptied and has an atmospheric pressure inside.
6 All the systems of the compartment, pipelines, tanks, vats and the hold have been emptied as prescribed by standards.
  The equipment, pipelines and tanks contain "dead" remaining water stock in the 1st, 2nd, 3rd and 4th loops amounting to about 1370 litres. The circuits were emptied by adding low pressure nitrogen to push the water. The circuits were not rinsed out after emptying. Remaining water in the circuits was not treated to prevent corrosion.
  In case of water freezing in the pipelines of the 1st loop during storage, the reactor compartment body tightness is ensured for the whole storage time.
7 High pressure gas and air have been removed from cylinders and systems of the reactor compartment.
8 All sorbents have been removed from filters of the 1st and the 2nd loops.
9 All pipelines connected with the system of the 1st loop and the draining/drying system are plugged with welded plugs.
10 A part of equipment of structures located above biological protection have been dismantled and removed from the reactor compartment.
11 The equipment and pipelines of the steam producing plant located under standard and additional biological protection are fastened as prescribed by regulations in the reactor compartment.
12 The own water discharge, fire extinguishing, ventilation, lighting, control and signalling means of the reactor compartment are absent.
13 Durability of the reactor compartment body prepared for prolonged storage is designed for maximum design earthquake of magnitude 7 by MSK-64 scale.
14 The reactor compartment of the stand put in prolonged storage does not require any maintenance, control or power supply during the whole period of storage.

Before sealing the reactor compartment, only the fourth circuit, which is made up of carbon steel, presented corrosion marks.

4.6 RADIATION ENVIRONMENT AROUND THE REACTOR COMPARTMENT

The radiation examination of outside surfaces of RC #1 has shown the following :

1 No β-contamination has been found on outside surfaces of the reactor compartment.
2 Averaged exposure rate of γ-radiation over the outside surface of the reactor compartment body is characterised by the following data (in μSv /h) :

on the upper part of the reactor compartment	0.12 - 0.2
on the lower part of the reactor compartment immediately under the reactor	1900 - 5500
on the lower part of the reactor compartment within the range of 1 m away from reactor	up to 37
on outside surfaces of compartment bulkheads	0.12 -0.16

The natural radiation γ-background in the area where the reactor compartment is located is 0.12 - 0.16 μSv /h.

4.7 RADIATION ENVIRONMENT INSIDE THE REACTOR COMPARTMENT

According to the results of the radiological inspection carried out in 1994, the gamma-dose rate in accessible RC #1 rooms was 0.12 μSv/h, in the reactor room : 1.1 μSv/h, on the manhole lid of the steam generator compartment : 8 μSv/h, on the reactor lid : 1.9 μSv/h (4.7 m^3 of concrete were poured onto the reactor cover in the fore equipment space. After that the average exposure rate of γ-radiation onto the reactor cover was 1.9 μSv/h).

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The third floor houses equipment for ventilation and air conditioning systems, and electric equipment for control of reactor mechanism. There's no contamination. The average exposure rate of γ-radiation is around the natural radiation background (0.15 μSv/h).

The second floor encloses motors of primary circuit pumps, and pumps and heat exchangers of the third and fourth loops systems. There's no primary circuit equipment in this area. The average exposure rate of γ-radiation is 2 up to 110 μSv/h. The βγ-contamination is 1 Bq/cm^2 due to maintenance.

The primary circuit equipment is located on first floor. The primary circuit room was grouted with concrete. Before that, the average exposure rate of γ-radiation was 110 up to 280 μSv/h.

Note : We can compare these values to the gamma-dose rate measured in the reactor compartment of TECHNICATOME PAT reactor. According to the results of the radiological inspection carried out in October 1999 (seven years after shutdown), the averaged gamma-dose rate in PAT reactor room was 70 up to 110 μSv/h (all the main primary circuit equipment are located in this room). These values are quite similar to the values measured in Stand 346 A NPU. But the gamma-dose rate measured in contact to the main primary circuit equipment are significantly higher. The gamma-dose rate measured in contact to the PAT reactor main primary circuit equipment in October 1999 are (in μSv/h).

Immediately in contact with	*steam generators*	*230 μSv/h*
Immediately in contact with	*primary coolant pumps*	*80 μSv/h*
Immediately in contact with	*pressurizer*	*90 μSv/h*

Most radioactive of all the NPU equipment items are the reactor and the tank of steel/water shielding whose exposure dose rate (in contact) reaches tens of Sv/h.

There's nearly no contamination in the secondary circuit (secondary circuit water contamination: only 4 Bq/kg). The steam generators were replaced in 1980, in order to test new equipment (steam generators made of titanium alloy). According to the information supplied by the VNIPIET Institute , the reason of the steam generators replacement wasn't a leakage from the primary part to the secondary part of the steam generators, that would have resulted in diffusing contamination into the secondary circuits. After drainage of all the circuits about 1000 litres are held in the secondary circuit (in steam generators chambers).

The volume of water remaining in the primary circuit of unit #1 is around 360 litres. The primary circuit water activity was 2.2 MBq/kg after shutdown (1989). The main radionuclides were Cesium 137, Cobalt 60, Strontium 90, and tritium.

The third and fourth circuits are coolant circuits for auxiliary equipment. These circuits contain no contamination. About 6 litres are held in the fourth circuit.

5 DESCRIPTION OF REACTOR COMPARTMENT OF STAND 346B WITH REGARD TO MEASURES TAKEN TO PUT IT IN PROLONGED STORAGE

This part of the report describes reactor compartments of stand 346B with regard to measures taken to prepare it for prolonged storage, using the materials developed by CDB MT "Rubin" during preparation of stand 346B for prolonged storage and those developed during the period of putting reactor compartment in prolonged storage.

In the early eighties building 302 was added to building 301 in which the other prototype NPU (unit #2, stand 346B), analogous to 2^{nd} generation NS/M NPU, was mounted. Unit #2 consisted of a reactor compartment and four support compartments abutting with the reactor compartment at both ends. Total length of the stand - 50 m.

Stand 346B included a reactor plant with type PWR/BM-4 reactor of 90 MW thermal capacity (LWR type), which was in operation from February 10, 1983, to December 1989 at a reduced (30 %) capacity. No recharging of the fuel core was carried out. Total operation time of the reactor at power was 5333 hours. No emergency situations at the equipment items and systems were observed within the period of NPU operation. No fuel reloading and large - scale repair and maintenance works were carried out.

Spent nuclear fuel was discharged from the reactor in 1994 and transported to Russia.

5.1 DESIGN FEATURES AND MASS/DIMENSIONAL CHARACTERISTICS OF REACTOR COMPARTMENT

This section sets basic characteristics of the reactor compartment before starting the work on preparing it for prolonged storage.

5.1.1 Design features of the reactor compartment

The general view of the reactor compartment is shown in Fig. 4 hereafter.

The cylinder-shaped body of the reactor compartment is confined on its ends by transverse bulkheads.
The reactor compartment, by means of four foundation supports of its body, is mounted on tangential supports of the foundation of the building, which, by their embedded studs, restrict movement of the reactor compartment body in the horizontal plane.
Outside, the reactor compartment is provided with biological protection in the form of vertical concrete walls up to 1400 mm thick which exceed in terms of the height the level of biological protection of the steam producing plant inside the reactor compartment.
Outside the reactor compartment, in its lower part, in the area of the equipment room, a biological protection tank is installed framed on its ends by concrete walls.

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Fig. 4. General view of the Reactor Compartment #2

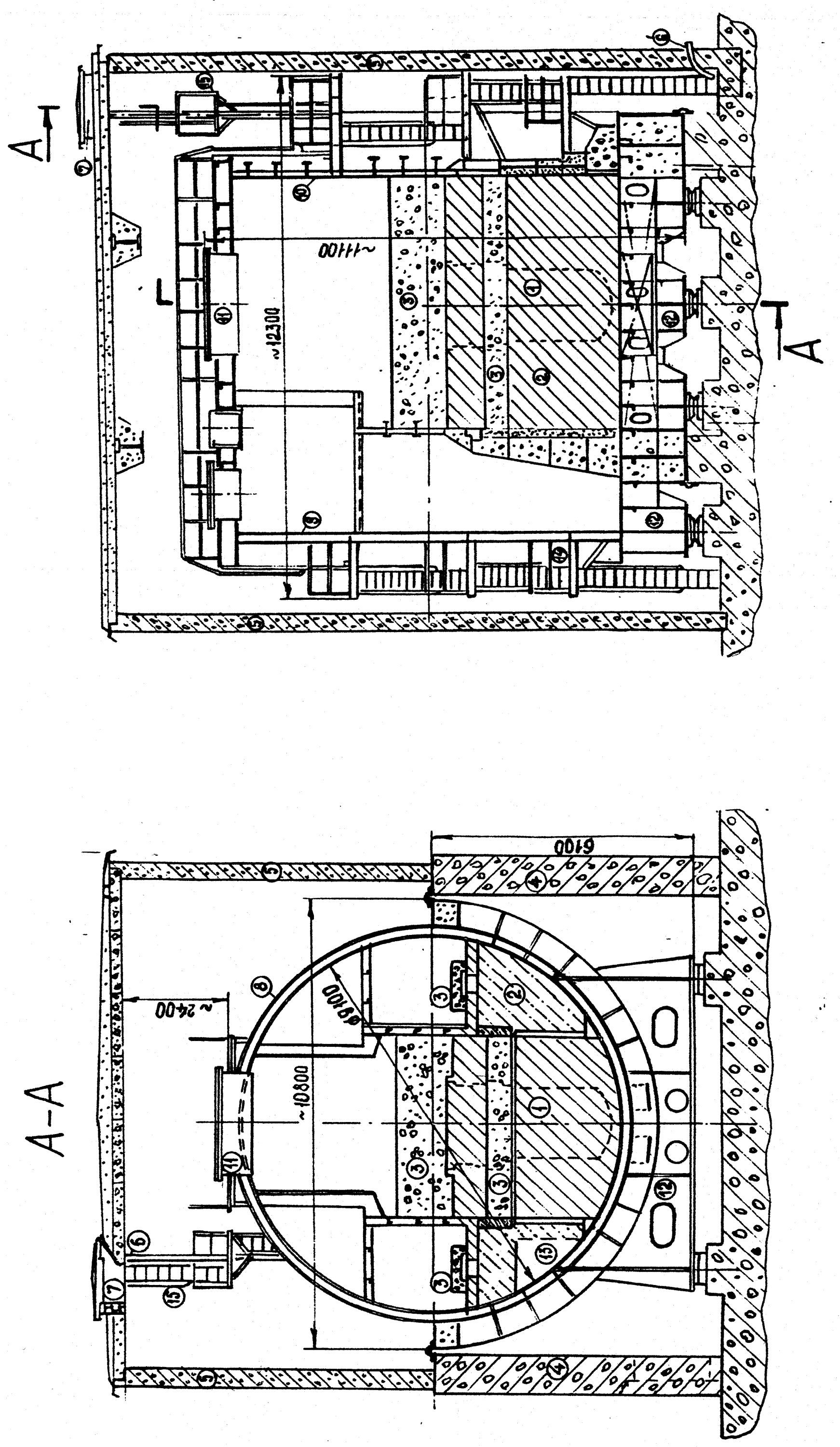


Fig.2 Reactor compartment № 2. Cross and longitudinal sections.

1 - reactor; 2 - non-attended rooms; 3 - new-placed concrete in RC; 4 - concrete shielding wall; 5 - vault wall; 6 - penetrations in the vault for control measurements; 7 - manhole into the enclasure; 8 - RC-vessel; 9,10 - cross partitions; 11 - manhole to RC; 12 - metal supports; 13 - tank; 14,15 - possover landing.

5.1.2 Mass/dimensional characteristics of the reactor compartment

Before carrying out the laying-up works, the reactor compartment of training stand 346B had the following mass/dimensional characteristics :

Clear diameter of the reactor compartment body, m	9.1
Length of reactor compartment body, m	8.4
Width of rector compartment body (max.), m	10.7
Height of reactor compartment body (max.), m	10.9
Thickness of reactor compartment body sheathing, mm	20.0
Thickness of reactor compartment bulkheads sheathing, mm	12.0
Mass of compartment body, t	950.0

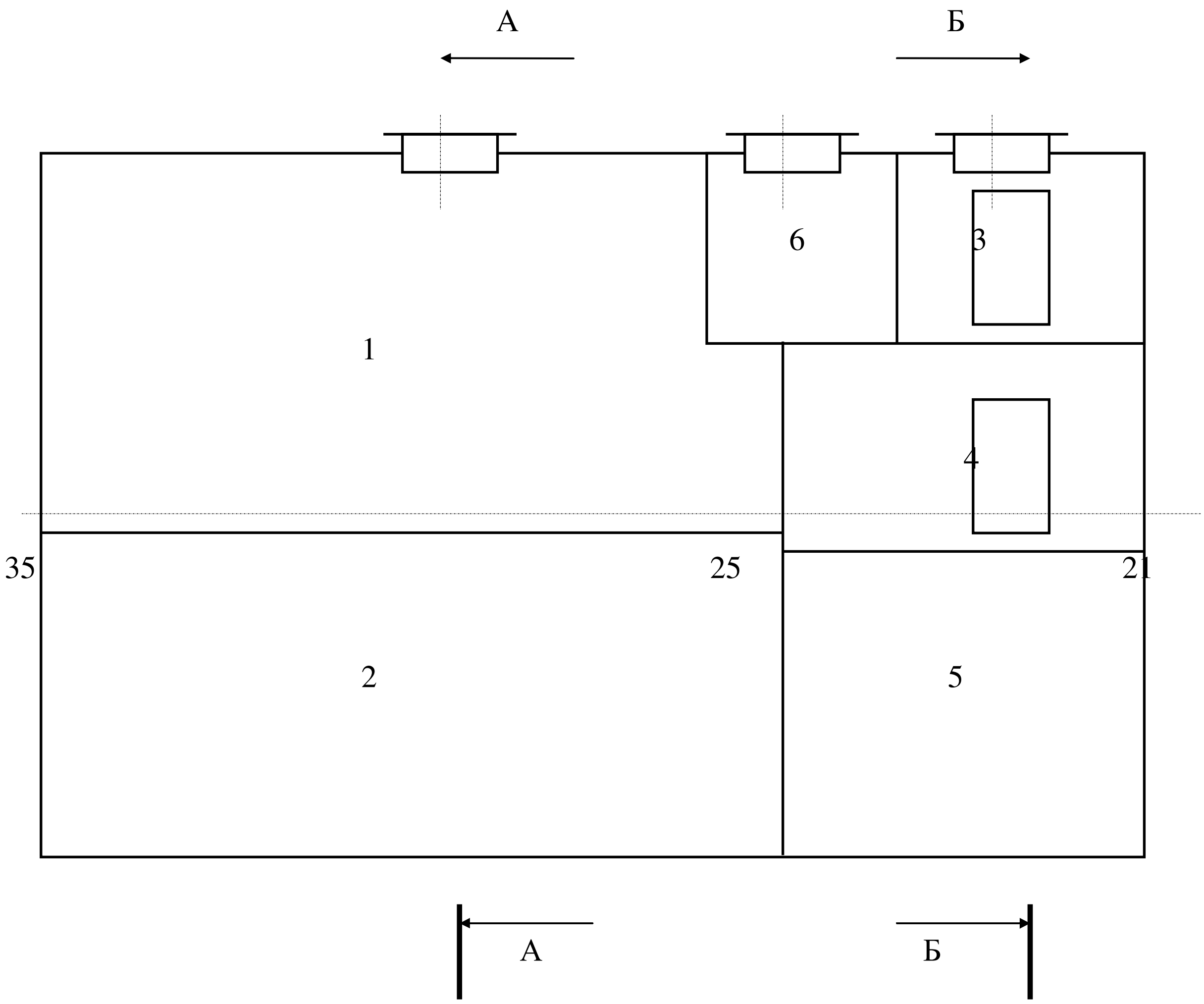
5.1.3 Spaces of the reactor compartment

The reactor compartment is structurally divided by bulkheads into a number of spaces (see Fig. 5, 6 and 7 hereafter) :

- equipment space (durably sealed) located between aft (frame 35) and intermediate (frame 25) bulkheads and consisting of upper (1) and lower (2) rooms,
- pump spaces on the starboard side and port side (4) are located on the sides of the equipment room along the reactor compartment from the fore bulkhead to the aft bulkhead and connected in the fore part of the compartment by a passageway formed by the fore bulkhead (frame 21) and intermediate bulkhead (frame 25) (end pump space),
- passageways of the starboard and port sides (3) are located above pump spaces and separated from them by a gas-tight deck. They are connected to each other in the fore part of the reactor compartment (end passageway). The starboard side passageway is a communicating alleyway,
- the hold (5) is located in the fore part of the reactor compartment under the end pump space between frame 21 and frame 25 bulkheads.

At the entrance to upper space of the equipment room from the starboard side passageway, a sluice lobby (6) is provided.

Fig. 5. Layout of spaces of reactor compartment of stand 346B. Longitudinal section along diametrical plane



1. Upper room of the equipment space
2. Lower room of the equipment space
3. Passageways: port side, starboard side, end
4. Pump spaces: port side, starboard side, end
5. Hold
6. Sluice lobby

Fig. 6. Layout of spaces of reactor compartment of stand 346B. Cross-sections A - A, B – B

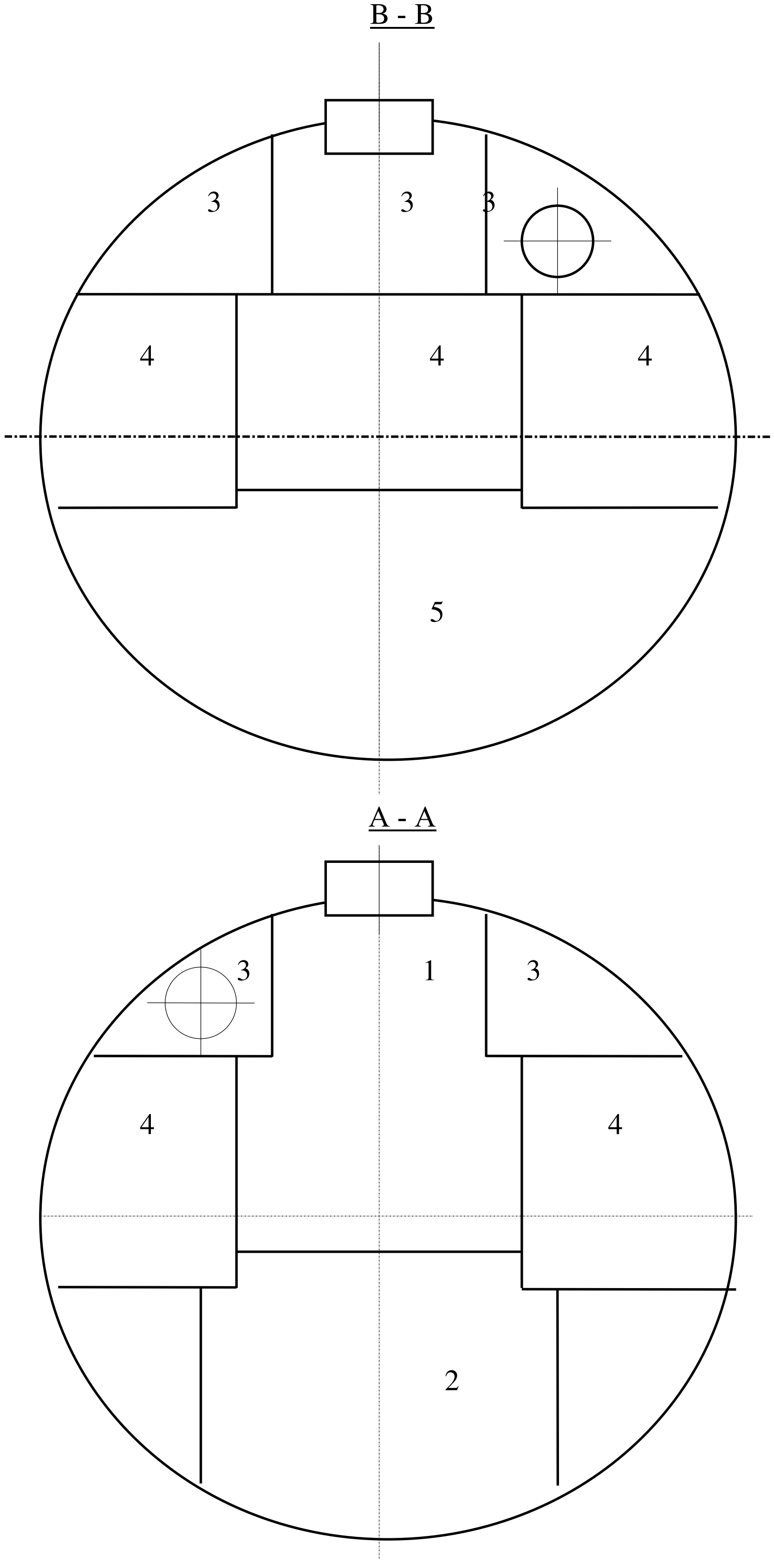
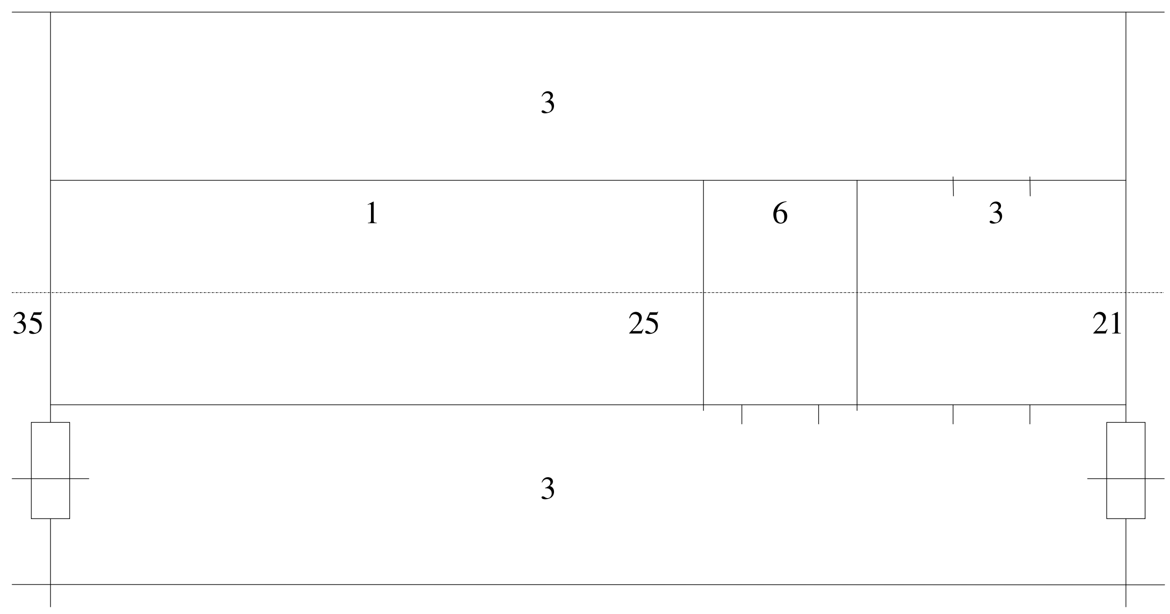
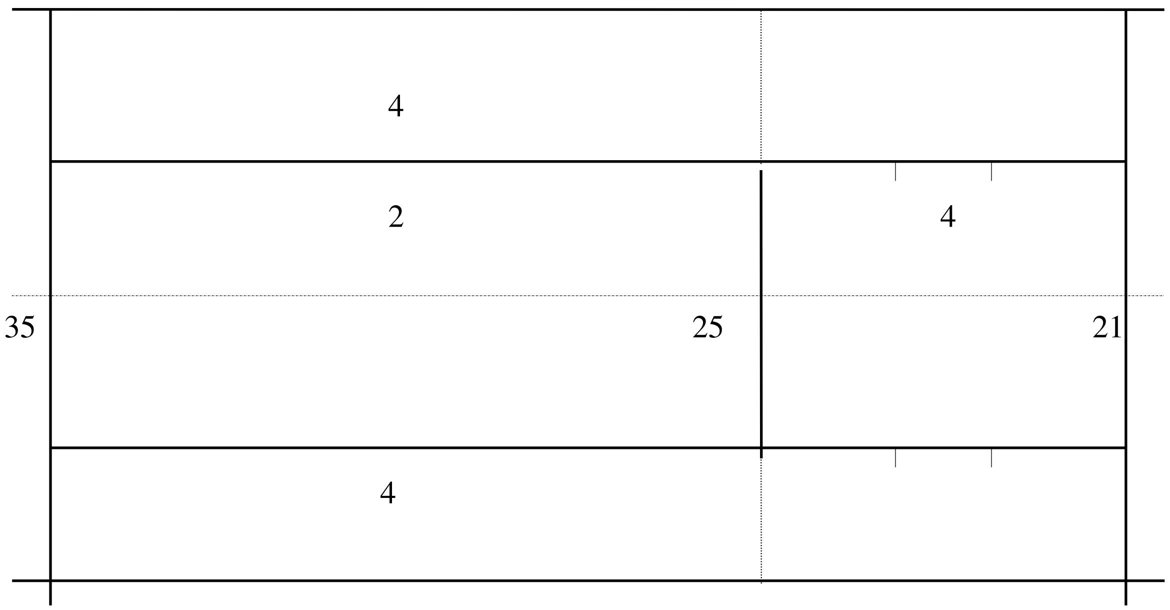


Fig. 7. Layout of spaces of reactor compartment of stand 346B. Plans of tiers II and III

1 - Plan of tier III



2 - Plan of tier II



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5.1.4 Equipment layout in the reactor compartment

The lower space of the equipment space accommodates the metal-water protection tank with equipment of the 1st loop (reactor, steam generator, etc.) and biological protection installed above the tank cover.

The upper room of the equipment space accommodates equipment and pipelines with their valves of the high-pressure gas system, the 3rd loop system and the ventilation and air conditioning systems. The uninhabited place under the biological protection contains pipelines of the 1st loop, steam pipelines and draining systems.

The pump spaces accommodate equipment and pipelines of the 2nd, 3rd and 4th loops, ventilation and air conditioning systems.

The passageways accommodate start/control electric equipment, converters, instruments of the automation system and equipment of ventilation and air conditioning systems.

The hold contains the drain tank of the 1st loop and the reserve heat exchanger of the 3rd loop with pipelines of the 3rd and 4th loop systems.

5.2 MOUNTING WORKS CARRIED OUT DURING PREPARATION OF THE REACTOR COMPARTMENT FOR LAYING-UP

In this subsection, a list of mounting works carried out during preparation of the reactor compartment for laying-up is given.

5.2.1 Mounting works carried out inside the reactor compartment

- sealing of the reactor cover,
- installation of sheath sheets of metal formwork,
- filling of the space above the metal-water protection tank cover to the protection blocks with concrete mixture.

After filling the space above the metal-water protection tank cover with concrete, drying of the biological protection tank, the metal-water protection tank and steam generators along the 2nd loop was carried out and their draining pipelines were plugged.

5.2.2 Mounting works carried out outside the reactor compartment

- mounting of additional platforms on bulkheads,
- mounting of additional gangways and guard railings on the platforms,
- additional fastening of the reactor compartment body to the foundation of the building.

5.3 WORKS ON THE REACTOR COMPARTMENT BODY

This subsection lists the works carried out on the reactor compartment body during preparation of the reactor body for laying-up.

5.3.1 Mounting of sheath sheets of metal formwork for concrete placement

For placement of concrete, which will provide "physical" protection of the system and equipment of the steam producing plants remaining for prolonged storage within the reactor compartment stand, sheath sheets of metal formwork have been mounted :

- on the deck of the upper room of the equipment space,
- above the roof of the metal-water protection tank,
- on the hatches of decks of the port side and starboard side pump spaces.

5.3.2 Mounting of additional platforms outside the reactor compartment

To provide for carrying out dismantling works outside the reactor compartment, additional platforms on bulkheads at frames 21 and 35 were mounted (see section 5.1.3 Fig. 5 and section 5.1.1 Fig.4 : general view of RC #2).
For making platforms, the structures of dismantled outside platforms were used.

5.3.3 Mounting of additional gangways and guards

To facilitate movements and to ensure safety of the personnel working outside the reactor compartment, additional gangways and guard railings were mounted on the outside platforms (see section 5.1.1 Fig. 4: general view of RC #2).

5.3.4 Fastening of the reactor compartment body to the foundation of the building

To provide safe storage of the reactor compartment during 50 years under conditions of possible exposure to seismic activity, the body of the reactor compartment has been additionally fastened to the foundation of the building. For this purpose, steel sheets were embedded in the spacing between the protective sheets of the "movable" biological protection mounted on the main body of the reactor compartment and the protective sheets of the immovable biological protection mounted on the foundation of the building, with subsequent welding of the sheets together over their edges.

5.4 LAYING-UP OF THE REACTOR COMPARTMENT

On completion of works for preparation of the reactor compartment of the stand for laying-up (all dismantling, mounting, body works being completed), laying-up works were carried out.
Laying-up works include :

- mounting works carried out for putting the reactor compartment in prolonged storage.
- testing the reactor compartment for tightness.

– drying of air inside the reactor compartment.
– construction of a protective shelter for the reactor compartment.

5.4.1 Mounting works carried out for laying-up the reactor compartment

Mounting works carried out during putting the reactor compartment in prolonged storage included :

– works for prevention of physical access to the components of the steam producing plants.
– sealing of the reactor compartment.

5.4.1.1 Works for prevention of physical access to the components of the steam producing plants

In order to meet the requirement for prevention of physical access to the equipment of the steam producing plants, placement of concrete on some items and body structures of the reactor compartment was carried out.

On the stage of preparation for laying-up, about 9.0 m^3 of concrete was laid onto the roof of the metal-water protection tank (1 m thick layer of concrete is laid in the reactor cubicle; the remaining space in the reactor cubicle is up to 2 m high - see section 5.1.1 Fig. 4 : general view of RC #2).

During laying-up stage, concrete was placed :

– on the deck of the upper room of the equipment space (to prevent access to the equipment of the steam producing plants including the reactor cover, the cooling pumps and the 1st loop pumps): about 31.0 m^3.
– on the hatches of the decks of port side and starboard side pump spaces (to prevent access to the equipment of steam producing plants and to uninhabited volumes of the equipment space): about 1.2 m^3 (for both hatches).

The total volume of concrete placed in the reactor compartment is about 41.2 m^3.
The weight of the concrete is 90.7 t (density being 2.2 t/ m^3).

5.4.1.2 Sealing of the reactor compartment

To ensure tightness of the reactor compartment of the stand during the whole period of storage and to provide the second safety barrier, plugging of holes and cut-outs on the main body of the reactor compartment and its end bulkheads has been carried out.

Plugging was made by mounting of plugs on weld-in reinforcement and on standard and temporary cutouts in the body and end bulkheads of the reactor compartment.

Sealing works performed inside the reactor compartment :

– removable sheets were mounted on temporary cutouts made in the body structures of the reactor compartment.

Sealing works performed outside the reactor compartment :

- Plugs were mounted on weld-in reinforcement of the bulkhead at frame 21 and sealing pieces were provided under the door and under cable boxes,
- Plugs were mounted on weld-in reinforcement of the bulkhead at frame 35 and sealing pieces were provided under the door and under cable boxes,
- Plugs were installed on the weld-in reinforcement of the reactor compartment body,
- Covers were mounted on the maintenance hatches the body of the reactor compartment.

Plugging of the weld-in reinforcement made in the form of barrels up to 120 mm in diameter was provided by mounting inside the sleeves round steel inserts (rods) of a diameter equal to that of inside diameter of sleeves, with subsequent welding around the ends.

Plugging of the weld-in reinforcement made in the form of weld-in sleeves of 120 mm or more in diameter was provided by mounting plugs made of 10 mm thick sheet which were welded on the outside of the sheath of the main body and end bulkheads of the reactor compartment.

Plugging of cable boxes on the end bulkheads of the reactor compartment was provided by cutting out cable boxes bodies from bulkhead webs and inserting sealing pieces made of 10-12 mm thick sheet in cutout places.

Plugging of round doors on the end bulkheads of the reactor compartment was provided by mounting inside the door coming a sealing piece of 12 mm thick sheet, 800 mm in diameter.
For making sheet plugs, the sheet material taken from dismantled body structures was used.
Removable sheets were mounted in their places and welded around the perimeter.

The covers of the maintenance hatch were mounted in their standard places without rubber seals. The covers were pressed by bolts and welded to the hatch comings around the perimeter.

5.4.2 Tightness testing of the reactor compartment

Tightness testing of the reactor compartment was performed by blowing air into it under 0.05 MPa pressure and keeping it during one hour. No pressure drop was detected.

Note : For conduction of testing, non-plugged weld-in sleeves of nominal diameter 350 of the ventilation system located on the reactor compartment body and weld-in sleeves of nominal diameter 80 of the air conditioning system located on the bulkhead at frame 35 were utilised.

Monitoring of pressure variation in the reactor compartment during testing was carried out by means of a control pressure gauge mounted on one of weld-in sleeves.

On completion of testing for tightness, the outside surfaces of the body and the bulkheads of the reactor compartment, platforms, gangways and guard railings were painted.

5.4.3 Drying of air inside the reactor compartment

According to the information supplied by the VNIPIET Institute, after applying paint coating to outside surfaces of the reactor compartment, air inside the reactor compartment was dried to remove residual moisture, air parameters were controlled at the outlet of the reactor compartment. In achieving a relative humidity in the reactor compartment of 40% at a temperature of +5°C, the drying operation was completed. Desiccant was placed inside the compartments to keep humidity at this specified level.

As for RC #1, this information has to be taken very carefully, and should be checked by examining the specific procedures. We have requested these documents, and some complementary information about the nature of the desiccant used, and when the purported drying occured. Actually, Mr. GROCHOWSKI didn't witness these works, and according to his personal observation, these works, if they were challenged, were carried out immediately after placement of concrete with no correlation to the concrete drying. If the curing of the concrete was not taken into account then the current moisture level will be significant due to the drying and setting up of the concrete.

5.4.4 Construction of a protective sarcophagus for the reactor compartment

As the third safety barrier, a protective sarcophagus was constructed of reinforced concrete around the stand reactor compartment. The characteristics of this protective shelter are given in section 3.4.

5.5 TECHNICAL CONDITION OF THE REACTOR COMPARTMENT PUT IN PROLONGED STORAGE

The reactor compartment put in prolonged storage has the following mass/dimensional characteristics (after carrying out laying-up works):

Diameter of reactor compartment body (across frames), m	9.45
Length of reactor compartment body (max.), m	12.3
Width of reactor compartment body (max.), m	10.8
Height of reactor compartment (max.), m	11.1
Sheath thickness of reactor compartment body, mm	20.0
Sheath thickness of end bulkheads, mm	12.0
Weight of reactor compartment, t	1040.7
including:	
– body, bulkheads and other body structures, t	322.0
– equipment and pipelines of steam producing plants under biological protection, t	168.0
– biological protection (made up of concrete slabs piled up), t	460.0
– weight of concrete placed in reactor compartment, t	90.7

On completion of works for putting the reactor compartment in prolonged storage, its equipment and systems are in the following condition :

1 Fuel assemblies have been removed from the reactor.
2 Actuating mechanisms and instrumentation of the protection control system are dismantled. The reactor is closed with the standard cover welded to the reactor body. The internal block with control assemblies is located within the reactor (control rods are made of Europium).
3 All holes in the reactor cover are plugged with welded plugs. The plugs were designed to carry out primary circuit leakage tests. So they are resistant to primary circuit pressure.
4 The reactor has been emptied and has an atmospheric pressure inside.
5 All the systems of the compartment, pipelines, tanks, vats and the hold have been emptied as prescribed by standards.
The equipment, pipelines and tanks contain “dead” remaining water stock in the 1st, 2nd, 3rd and 4th loops amounting to about 2285 litres. The circuits were emptied by adding low pressure nitrogen to push the water. The circuits were not rinsed out after emptying. Remaining water in the circuits was not treated to prevent corrosion.
In case of water freezing in the pipelines of the 1st loop during storage, the tightness of the reactor compartment body is ensured for the whole storage time.
6 High pressure gas and air have been removed from cylinders and systems of the reactor compartment.
7 All sorbents have been removed from filters of the 1st and the 2nd loops.
8 All pipelines connected with the system of the 1st loop and the draining/drying system are plugged with welded plugs.
9 A part of equipment and structures located above the biological protection have been dismantled and removed from the reactor compartment.
10 The equipment and pipelines of the steam producing plant located under standard and additional biological protection are fastened as prescribed by regulations in the reactor compartment.
11 The own draining, fire extinguishing, ventilation, lighting, control and signalling systems of the reactor compartment are absent.
12 Durability of the reactor compartment body prepared for prolonged storage is designed to withstand maximum design earthquake of magnitude 7 by MSK-64 scale.
13 The reactor compartment of the stand put in prolonged storage does not require any maintenance, control or power supply during the whole period of storage.

5.6 RADIATION ENVIRONMENT AROUND THE REACTOR COMPARTMENT

The radiation examination of outside surfaces of RC #2 have shown the following:

1 No β-contamination has been found on outside surfaces of the reactor compartment.
2 Averaged exposure rate values of γ-radiation over the outside surface of the reactor compartment body are characterised by the following data (in μSv /h) :

on the upper part of the reactor compartment	0.12 - 0.16
on the lower part of the reactor compartment immediately under the reactor	2.5
on the lower part of the reactor compartment within the range of 1 m away from reactor	0.12 – 0.9

on outside surfaces of compartment bulkheads 0.12 - 0.16

The natural radiation γ-background in the area where the reactor compartment is located is 0.12-0.16 μSv /h.

5.7 RADIATION ENVIRONMENT INSIDE THE REACTOR COMPARTMENT

In accessible rooms of RC #2 an exposure dose rate varied from background values of 0.14 to 2.5 μSv/h. At the same time this value reached 0.23 μSv/h on the reactor lid. Values of 0.3-0.9 μSv/h were registered on the second floor near the circulation pumps' motors.

Most radioactive of all the NPU equipment items are the reactor and the tank of steel/water shielding whose exposure dose rate reaches tens of Sv/h.

The volume of water remaining in the primary circuit is around 600 litres. The primary circuit water activity was 1 MBq/kg after shutdown (1989). The main radionuclides were Cesium 137, Cobalt 60, Strontium 90.

There's no contamination in the secondary circuit. The steam generators were never replaced; no leakage from the primary part to the secondary part of the steam generators.

The third and fourth circuits are coolant circuits for auxiliary equipment. These circuit contains no contamination.

6 DESCRIPTION OF THE NUCLEAR POWER FACILITY 346A

This part of the report considers equipment left for long-term storage in RC in the test rig building 301.

6.1 DESCRIPTION OF COMPONENTS AND SYSTEMS PLACED IN SARCOPHAGUS OF UNIT 1

According to the design, RC houses equipment on only left board with the reactor located at the bow, see Figs. 2, 3 and 4 in appendix 2.

6.1.1 Primary circuit components

The process flow diagram of the VM-A reactor primary circuit was provided by VNIPIET during the first progress meeting. This diagram is attached in Appendix 2 Fig. 1. All the primary circuit components are shown on this diagram, and the diameter and thickness of primary circuit pipeline is indicated.

After compartment dismantling was completed and RC was prepared for long-term storage, the following components were left in the compartment :

Reactor
VM-A reactor (see Appendix 2 Fig. 5) was in operation for 20821 h and generated 472177 MWh during two core lives. Spent fuel was unloaded in August 1994. During unloading the Automatic Control and Emergency Protection sleeves with absorber rods were shortened and left in the reactor as well as shortened dry out sleeve was left.

Inside the reactor is fastened removable part (screen assembly) with compensating grid made of stainless steel 1Cr18Ni9Ti. The reactor vessel is made of doped carbon steel 48TS and lined inside with thin-wall jacket made of stainless steel 1Cr18Ni9Ti. These reactor internals are most activated among the primary circuit components. Moreover, the control rods are located within the reactor. The material of the control rods is not given in the third report, and the corresponding radionuclides seem not to be given in the radionuclides inventory. Some more would be given by the VNIPIET Institute later.

After unloading of spent fuel the reactor cover was welded to the vessel, plugs were inserted in sleeve penetrations and welded around. The reactor is thus sealed and its inside space has no contact with the environment. Besides, the reactor above the cover and shielding plate of the enclosure are grout with concrete to ensure physical protection.
The reactor together with the primary circuit is drained.
Reactor weight is 30000 kg.

Steam generator
Steam generator PG-14t (see Appendix 2 Fig. 6) was installed in RC during middle-level repair of NSSS in 1978-81. PG-14t was in operation under various modes for 7107 h.

PG-14t consists of 8 cylindrical chambers connected in pairs from primary and secondary sides in 4 sections. Space between the chambers is filled with boron carbide.

Casing of the cylindrical chamber of 786 mm in diameter and 18 mm thick is made of carbon steel 20K. Height of the chamber casing without protuberant nozzles is 2300 mm.

Heated primary coolant is supplied to the chambers from top through nozzle ∅65 and moves further inside the chamber via coiled tubes 18x2.5 made of titanium alloy.

The secondary coolant flows from bottom to top and is removed as steam through steam nozzle ∅75 at top head of the chamber. Steam from 4 sections is directed via pipes to a steam collector of 400 mm in diameter placed on the 2nd floor of pump enclosure on left board. Primary and secondary coolants are supplied to collectors and from there to SG sections and backwards along the pipelines made of stainless steel 1Cr18Ni9Ti. The pipe from steam collector to the turbine compartment is made of carbon steel.

Weight of steam generator and attached pipelines is 21600 kg.
Near the bow partition-wall of RC in the floor of dead-end corridor there is a hatch to SG enclosure. During preparation of RC for long-term storage the hatch was welded and covered with concrete.

MCP-146, see Appendix 2 Fig.7
Main coolant pump of the primary circuit MCP-146 is intended for arranging primary coolant circulation. MCP is a vertical pump where electric motor and flow path are placed in a single unit. The lower part of flow path is located beneath lead shielding of 2^{nd} floor of pump enclosure. The upper stator part of the pump casing is placed on 2^{nd} floor of pump enclosure and is accessible for in-service maintenance. The stator part of the pump is isolated from the primary circuit by means of nichrome jacket.

All parts of the electric pump in contact with the primary coolant are made in stainless steel 1Cr18Ni9Ti.
Pump weight is 4600 kg.

ACP-147P, see Appendix 2 Fig.8
Auxiliary centrifugal electric pump ACP-147P is similar in terms of design and location in pump enclosure to MCP. The major difference is lower capacity and small size of ACP. This pump is installed in the primary circuit in parallel to MCP-146.
Pump weight is 1800 kg.

Pressurizer, see Appendix 2 Figs. 9, 10
Pressurizer is designed for compensating of primary coolant volume extension when heated.
Pressurizer consists of 6 steel cylinders holding 340 litres each. One of the cylinders has a level indicator.
Top part of the indicator is protected by a lead plug that protrudes from the floor of bow CPS enclosure. Pressurizer cylinders are placed beneath the floor of CPS enclosure. Free space among the cylinders is filled with carborite bricks. Lead shielding is arranged on the floor of enclosure.
Cylinder material is 20CrMo steel. Inside there is a thin jacket made of stainless steel 1Cr18Ni9Ti.
Gas and water pipelines attached to the cylinders are made of stainless steel 1Cr18Ni9Ti.
Weight of one cylinder is 1185 kg.

Activity filter, see Appendix 2 Fig. 11
Activity filter (AF) is meant for cleanup of primary coolant from salts, including radionuclides.
Two AFs are installed in concrete biological shielding located in metal structures of bow tank of IWS.
AF is made of stainless steel 1Cr18Ni9Ti.
AF weight is 565 kg.

Cooler MCP-601, see Appendix 2 Fig.12
CMCP-601 is designed for cooling the primary coolant supplied to AF.
Cooler is of coiled type. Primary coolant flows inside coiled tubes, cooling water of the fourth circuit moves outside tubes and inside the cooler casing. Cooler is installed on the 1^{st} floor of pump enclosure.

Cooler casing is made of stainless steel 1Cr18Ni9Ti, coiled tubes are made of cupronickel MNZhMTs 30-1-1.
Weight of CMCP-601 is 300 kg.

Coolers of MCP and ACP, see Appendix 2 Figs. 13 and 14
Coolers CMCP-146M and CACP-147M are designed as U-type units. They are similar and differ only in size, they are used for cooling of primary coolant supplied for pump rotor bearing cooling. Coolers are placed near the pumps on the 1st floor of pump enclosure.
Casings and tubes of primary coolant are made of cupronickel MNZh 5-1.
Weight of CMCP-146 M is 114 kg, weight of CACP-147M is 52 kg.

Primary circuit pipelines
Primary circuit pipelines can be subdivided in the following groups depending on their location :
- pipes attached to the reactor (supplied together with the reactor) are placed within the bow reactor enclosure, attaching pipes 108x11 are made of stainless steel 1Cr18Ni9Ti,
- SG enclosure on left board accommodates collectors of "hot" (from the reactor to SG) and "cold" (from MCP to the reactor) coolant with appropriate valves, collectors are made of tubes 140x15, collectors and valves are made of stainless steel 1Cr18Ni9Ti ,
- in the corridors between outside walls of IWS tank on left and right boards and walls of SG enclosures there are pipelines (lyriform) 140x15 supplying "cold" coolant from MCP, pipes are made of stainless steel 1Cr18Ni9Ti,
- on the 1st floor of pump enclosure there are pipelines supplying and removing coolant (to/from MCP - pipes 180x17, 140x15 and to/from ACP-108x11), pipes are made of stainless steel 1Cr18Ni9Ti,
- also on the 1st floor of the pump enclosure there are smaller pipes 28x4, 15x2.5, these pipes are made of stainless steel 1Cr18Ni9Ti.

After drainage the primary circuit holds about 360 litres of water, including :
- 70 litres in the reactor,
- 100 litres in Pressurizer,
- 100 litres in SG,
- 80 litres in pipelines,
- 13 litres in AF with attached pipes.

The primary coolant was borated water.

6.1.2 Auxiliary equipment in RC

Pump 2P-2, see Appendix 2 Fig.15
Pump 2P-2 is used for drainage of active and non-active RC water to special tanks placed outside the sarcophagus. Pump is located on the 2nd floor of the pump enclosure, near the hatch opening in the hold.
Pump weight is 525 kg.

Pump TsN-21, see Appendix 2 Fig. 16
Circulation electric pump TsN-21 is intended for circulation of water in the third circuit. Two pumps TsN-21 (the second pump is standby) are placed on the 2nd floor of the pump enclosure near to the bow partition-wall.
Pump casing is made of stainless steel 1Cr18Ni9Ti.
Pump weight is 292 kg.

<u>Pump TsN-23, see Appendix 2 Fig. 17</u>

Circulation electric pump TsN-23 is intended for circulation of fresh water in the fourth circuit. Two pumps TsN-23 (of which the second pump is standby) are placed on the 2^{nd} floor of the pump enclosure near to the stern partition-wall of RC.
Pump casing is made of stainless steel 1Cr18Ni9Ti.
Pump weight is 280 kg.

<u>Heat exchanger VP2-1-0, see Appendix 2 Fig. 18</u>

Heat exchanger VP2-1-0 is intended for cooling the third circuit water using water of the fourth circuit. Two heat exchangers are installed on the 1^{st} floor of the pump enclosure near its bow partition-wall.
Heat exchanger casing is made of stainless steel 1Cr18Ni9Ti.
Weight of heat exchanger is 450 kg.

<u>Current converter PR50-2, see Appendix 2 Fig.19</u>

Current converter is designed for converting direct current into alternative current to supply MCP-146. PR50-2 is located on the left board 2^{nd} floor of the pump enclosure between MCP and RC strong vessel.
Weight of PR50-2 is 9035 kg.

<u>IWS tank</u>

IWS tank is a metal structure with a caisson intended for housing two reactors. The space intended to the bow reactor houses V-MA reactor, and the space intended for the stern reactor is filled with concrete. The purpose of IWS tank is to provide biological shielding from neutron (mainly) when the reactor is in operation.
Prior to preparation for long-term storage the third circuit water was drained from IWS tank. After drainage of this tank only 70 litres remain in the third circuit.
IWS tank is made of stainless steel 1Cr18Ni9Ti.

After drainage of all the circuits about 1000 litres remain in the secondary circuit (in SG). And about 6 litres are held in the fourth circuit.

6.2 RESIDUAL ACTIVITY OF COMPONENTS PLACED IN SARCOPHAGUS OF UNIT 1 AND ITS RADIONUCLIDE COMPOSITION

According to the analysis carried out the accumulated activity of long-term radionuclides in NPU materials (stand 346A) in five years after the reactor shutdown without involving nuclear fuel was ~ $1 \cdot 10^{15}$ Bq. The radionuclide composition at the end of 1994 was the following: ^{60}Co - 31 %, ^{55}Fe - 58 %, ^{59}Ni - 1.2 %, ^{63}Ni - 10.3 %.

This analysis show that about 99 % of radioactivity is accumulated in the reactor vessel, the remaining radioactivity is stored in materials affected by an intensive neutron exposure and on surfaces of equipment items and pipeworks surrounded by primary circuit coolant where activated products of structural materials corrosion are accumulated.

Radiation levels in RC after unloading the spent fuel and drainage of all the circuits are defined by two sources of radiation: induced activity of structural materials with shielding and radioactive corrosion products distributed along the primary circuit flow path and components. The major induced activity is concentrated in the reactor internals, reactor vessel and nearest metal structures (primarily in IWS tank and screens). Radioactive corrosion products spreaded over the surfaces of the primary circuit make up about 0.1% of total activity generated during the reactor operation.

The calculations performed to determine the build-up activity in NSSS components include the following stages :

- determination of neutron fields in structural materials of equipment and shielding,
- calculation of induced activity for the materials of the main structures,
- calculation of corrosion products build-up in primary circuit components.

The calculations were performed as for the actual operating conditions of NSSS at the test rig 346A. Distribution of neutron flux was obtained by ANISN and DOT-111 codes. The energy spectrum of neutrons was divided into 12 groups.

The actual operating conditions and calculated neutron fields served as a basis for the analysis of induced activity of materials by SAM code, The code employs nuclear data library for 233 activation reactions of 37 chemical elements-targets in the activating neutron energy range from 14.7 MeV to thermal energy.

Activation of corrosion products was calculated by means of RAPK-6 code.
The main radionuclides defining the activity of RC materials in 10 years after the reactor shutdown are summarised in Table 1 along with their brief characteristics.

Table 1

Radio nuclide	Half-life	Type of radiation	Radiation energy, MeV
Fe-55	2.6 years	γ , β	0.0059 (γ) 0.0051 (β)
Co-60	5.27years	γ , β	1.2 (γ) 1.3 (β)
Ni-59	80000 years	γ , β	0.007 (γ) 0.0065 (β)
Ni-63	100 years	β	0.017
Mo-93	3500 years	γ , β	0.018 (γ) 0.016 (β)
Tc-99	210000 years	β	0.101
Er-152	13.2	γ, β	1.408 (γ) 0.2 (β)
Er-154	8.5	γ, β	1.27-1.6 (γ) 1.855 (β)

Notes:
1. γ - gamma-radiation, characteristic radiation.
   β - beta-radiation, auger electrons.
2. The table shows the main lines of nuclide radiation energy spectra.
3. Energy of beta-radiation is given only for nuclides emitting photons of characteristic radiation.

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Highly activated components after spent fuel unloading include the removable part of the reactor with the compensating grid, reactor vessel with jacket and screen, IWS tank (caisson for the reactor, a set of sheets, basement).

The results of activity calculations (measured in Bq) for the given structures predicted for 1999, 2050 and 2100 are presented in Table 2.

Table 2

Year	Radio nuclide	Removable part with compensating grid and rods (Bq)	Reactor vessel with jacket and screen (Bq)	IWS tank (Bq)	NSSS as a whole (Bq)
1999 2050 2100	Fe-55	$1.17\ 10^{14}$ $2\ 10^{8}$ 304	$5.5\ 10^{12}$ $9.4\ 10^{6}$ 14	$1.3\ 10^{12}$ $2.2\ 10^{6}$ 3.4	$1.24\ 10^{14}$ $2.6\ 10^{8}$ 321.4
1999 2050 2100	Co-60	$1.36\ 10^{14}$ $1.87\ 10^{11}$ $2.6\ 10^{8}$	$3.9\ 10^{12}$ $5.43\ 10^{9}$ $7.54\ 10^{6}$	$1.53\ 10^{12}$ $2.12\ 10^{9}$ $2.95\ 10^{6}$	$1.41\ 10^{14}$ $1.94\ 10^{11}$ $2.7\ 10^{8}$
1999 2050 2100	Ni-59	$1.15\ 10^{12}$ $1.15\ 10^{12}$ $1.15\ 10^{12}$	$2.71\ 10^{10}$ $2.71\ 10^{10}$ $2.71\ 10^{10}$	$1.37\ 10^{10}$ $1.37\ 10^{10}$ $1.37\ 10^{10}$	$1.19\ 10^{12}$ $1.19\ 10^{12}$ $1.19\ 10^{12}$
1999 2050 2100	Ni-63	$9.25\ 10^{13}$ $6.55\ 10^{13}$ $4.44\ 10^{13}$	$1.76\ 10^{12}$ $1.25\ 10^{12}$ $8.45\ 10^{11}$	$1.1\ 10^{12}$ $7.81\ 10^{11}$ $5.3\ 10^{11}$	$9.51\ 10^{13}$ $6.73\ 10^{13}$ $4.59\ 10^{13}$
1999 2050 2100	Mo-93	--- --- ---	$5.85\ 10^{8}$ $5.77\ 10^{8}$ $5.70\ 10^{8}$	--- --- ---	$5.85\ 10^{8}$ $5.77\ 10^{8}$ $5.70\ 10^{8}$
1999 2050 2100	Tc-99	--- --- ---	$1.61\ 10^{8}$ $1.61\ 10^{8}$ $1.61\ 10^{8}$	--- --- ---	$1.61\ 10^{8}$ $1.61\ 10^{8}$ $1.61\ 10^{8}$
1999 2050 2100	**SUM**	**$3.47\ 10^{14}$ $6.67\ 10^{13}$ $4.55\ 10^{13}$**	**$1.12\ 10^{13}$ $1.28\ 10^{12}$ $8.66\ 10^{11}$**	**$3.96\ 10^{12}$ $7.96\ 10^{11}$ $5.48\ 10^{11}$**	**$3.62\ 10^{14}$ $6.88\ 10^{13}$ $4.70\ 10^{13}$**

We can compare these predictions to the calculations performed by TECHNICATOME for the PAT reactor. The comparison of calculated values of induced activity in 10 years after the reactors shutdown for the highly activated components (removable part of the reactor with the compensating grid and sleeves with rods, reactor vessel with jacket and screen, and IWS) for PAT reactor and V-MA reactor is given in table 3 hereafter.

This table shows that the calculated values induced activity for these two reactors are globally consistent. the calculated values of induced activity in 10 years after the reactor shutdown are quite similar for the reactor vessel with jacket and screen.

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For the reactor internals, the calculated values for V-MA reactor are ten times higher than the calculated values for PAT reactor. The reason of this difference is certainly the presence of control rods within V-MA reactor (control rods were discharged from PAT reactor).

The situation is the same with the calculated values for the IWS. This difference is probably due a different design, but the induced activity of this equipment is not preponderant.

Table 3

	Activity (Bq)		
Component	Radionuclide	PAT (10 years)	346 A (10 years)
Reactor vessel with jacket and screen	Fe 55 Co 60 Ni 63 Ni 59 Total	$7.38\ 10^{12}$ $6.85\ 10^{12}$ $1.85\ 10^{12}$ $5.01\ 10^{10}$ $1.67\ 10^{13}$	$5.51\ 10^{12}$ $3.92\ 10^{12}$ $1.76\ 10^{12}$ $2.70\ 10^{10}$ $1.12\ 10^{13}$
Removable part with compensating grid and sleeves (with control rods for 346A NPU, and without control rods for PAT NPU)	Fe 55 Co 60 Ni 63 Ni 59 Total	$1.96\ 10^{13}$ $1.82\ 10^{13}$ $4.93\ 10^{12}$ $1.33\ 10^{11}$ $4.44\ 10^{13}$	$1.17\ 10^{14}$ $1.36\ 10^{14}$ $9.25\ 10^{13}$ $1.15\ 10^{12}$ $3.47\ 10^{14}$
IWS	Fe 55 Co 60 Ni 63 Ni 59 Total	$1.43\ 10^{11}$ $1.33\ 10^{11}$ $3.60\ 10^{10}$ $9.72\ 10^{8}$ $3.24\ 10^{11}$	$1.31\ 10^{12}$ $1.54\ 10^{12}$ $1.10\ 10^{12}$ $1.37\ 10^{10}$ $3.96\ 10^{12}$
TOTAL		**$6.14\ 10^{13}$**	**$3.62\ 10^{14}$**

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All other structures located outside the reactor and IWS tank both inside and outside the reactor enclosure are characterised by significantly lower induced activity. The calculated values of induced activity for these structures and biological shielding materials in 10 years, in 2050 and 2100 after the reactor shutdown are given in Tables 4 and 5.

Table 4

No.	Structures (materials)	Year	Activity (Bq)	Specific activity (Bq/kg)	Type of radionuclide composition
1	SG chambre (Nos. 3,4)	1999 2050 2100	2 10^6 21.2 10^3 14.8 10^3		(2)
2	SG chambre (Nos.2,5)	1999 2050 2100	6.2 10^3 67.7 47		(2)
3	SG chambre (Nos.1,6)	1999 2050 2100	20 0.2 0.1		(2)
4	SG chambre (Nos. 7,8)	1999 2050 2100	0.1 0 0		(2)
5	AF in the primary circuit (without sorbents)	1999 2050 2100	70.7 10^3 14 10^3 10 10^3		(1)
6	Pressurizer	1999 2050 2100	1.4 10^3 14.5 10		(2)
7	Walls of SG enclosure opposite to the reactor	1999 2050 2100		17.8 0.2 0.13	(2)
8	Floors of the corridors and CPS enclosures	1999 2050 2100		2.23 0.02 0.01	(2)
9	Strong vessel of RC below the reactor, along RC axis	1999 2050 2100		126 10^3 10.5 10^3 7.4 10^3	(3)
10	Strong vessel of RC below IWS tank without the reactor	1999 2050 2100		2 10^3 166 117	(3)

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No.	Structures (materials)	Year	Activity (Bq)	Specific activity (Bq/kg)	Type of radionuclide composition
11	Primary circuit pipelines in reactor enclosure	1999 2050 2100		$707 \; 10^3$ $141 \; 10^3$ $100 \; 10^3$	(1)
12	Pipelines of the primary and third circuits in CPS enclosure (beneath shielding)	1999 2050 2100		212 42 30	(1)
13	Pipelines of the primary and secondary circuits in SG enclosure (left board)	1999 2050 2100		283 56 40	(1)
14	Concrete	1999 2050 2100		$68 \; 10^3$ $3.5 \; 10^3$ 259	(4)

Notes :

1. Radionuclide composition of activity (type of radionuclide composition) and, respectively, structural material are shown in Table 5.
2. SG chambers are given numbers counting from bow partition-wall.

Table 5

Correlation of activity of radionuclides generated outside the reactor and IWS tank as well as in corrosion products in 10 years after the reactor shutdown, in 2050 and 2100 (presented in percentage).

Year	Radionuclide	Material (type of radionuclide composition)				
		Steel 1Cr18Ni9Ti (1)	Steel 3, Steel 20K (2)	Steel AK-25 (3)	Concrete (4)	Corrosion products (5)
1999	Fe-55	33.5 %	85.1 %	64.8 %	24.8 %	31.1 %
2050		2.85 10^{-4} %	1.27 10^{-2} %	1.32 10^{-3} %	8.3 10^{-4} %	2.48 10^{-4} %
2100		6.13 10^{-10} %	2.91 10^{-8} %	2.83 10^{-9} %	1.7 10^{-8} %	5.33 10^{-10} %
1999	Co-60	38.5 %	13.4 %	23.5 %	3.6 %	39 %
2050		0.27 %	1.7 %	0.39 %	9.7 10^{-2} %	0.25 %
2100		5.22 10^{-4} %	3.4 10^{-3} %	7.6 10^{-4} %	1.84 10^{-3} %	4.94 10^{-4} %
1999	Ni-59	0.31 %	0.017 %	0.14 %	----	0.33 %
2050		1.57 %	1.61 %	1.7 %	----	1.56 %
2100		2.22 %	2.3 %	2.39 %	----	2.21 %
1999	Ni-63	27.7 %	1.47 %	11.5 %	----	29.5 %
2050		98 %	96.7 %	98 %	----	98 %
2100		97.8 %	97.7 %	97.6 %	----	97.8 %
1999	Mo-93			9.2 10^{-4} %		
2050				1.1 10^{-2} %		
2100				1.52 10^{-2} %		
1999	Tc-99			2.26 10^{-4} %		
2050				2.71 10^{-3} %		
2100				3.83 10^{-3} %		
					68.2 %	
1999	Er-152				98.7 %	
2050					99.6 %	
2100						
					3.47 %	
1999	Er-154				1.33 %	
2050					0.36 %	
2100						

The analysis of activity calculations allows concluding that in the year 2050 activity of the materials outside the reactor shall be defined mainly by radionuclides having no hard gamma-radiation. Thus, radioactivity of nuclides will not present a serious obstacle to RC components dismantling.

7 DESCRIPTION OF THE NUCLEAR POWER FACILITY 346B

Attention is focused on the primary circuit equipment, where basically all radioactive products are concentrated, which remained inside the plant after its defueling.

The Explanatory Note reflects results of the first phase of activity as per the Technical Specification document, thus giving a general idea about the primary circuit equipment mix and arrangement, its weight and size characteristics, as well as about amount of radioactivity which would contain in the plant's equipment on different dates of its long-term delay after decommissioning.

This Explanatory section is designed on the basis of the documents available in OKBM.

The reactor plant has been operated for six years in strict conformity with the operating documentation, without deviations from the normal operating conditions.

7.1 REACTOR PLANT PRINCIPAL FLOW DIAGRAM

Appendix 3 Fig. 1 shows principal flow chart of the double-circuit light water nuclear reactor plant BM-4 used in the 346B facility. All the primary circuit components are shown on this diagram. The diameter and thickness of primary circuit pipeline is not indicated on this diagram, but this reactor is very compact, with extremely short pipelines. However, the size and the length should be indicated later by The VNIPIET Institute.

The plant includes the following key systems :

- primary circuit system,
- feed water & steam system.

The primary circuit system includes :

- main circulation circuit,
- pressurisation system,
- coolant purification and shutdown cooling system.

The main circulation circuit incorporates the reactor, 5 steam generators and 5 primary coolant-circulating pumps. It consists of five parallel loops connected to the reactor.

The reactor is of LWR-type system, where high purity water is used as primary coolant and moderator for neutrons. The pressurisation system consists of three gas-filled pressurizers and connecting lines to the reactor.

The primary coolant purification/shutdown cooling system incorporates the following equipment :

- ion-exchange filter,
- primary coolant filter cooler supplied for purification and residual heat removal,
- shutdown cooling pump,
- piping with valves.

The feed water & steam system intakes thermal energy from the primary coolant in the steam generators and transports it to the consumer.

Double shut-off valves are provided in feed water and steam lines to isolate individual steam generators.

7.2 PRIMARY CIRCUIT EQUIPMENT AND PIPING LAYOUT

Appendix 3 Fig. 2 shows schematic diagram of the reactor plant's primary system equipment layout.

The primary system's equipment and piping are located inside a leak-tight cubicle, which in turn is divided into an upper "serviceable" cubicle, and lower "unserviceable" one. The cubicles are separated from each other by a leak-tight plating of the biological shielding.

Key equipment items of the reactor plant are assembled in a single unit located in the "unserviceable" cubicle. The unit is installed on the container foundation. The shielding tank serves as a basis for the unit.

The reactor, steam generators, pressurizers, filter cooler and the filter itself are located in caissons of the shielding tank. The indicated equipment items are fixed on the shielding tank roof. The reactor and steam generators are attached by bolt joints, the rest equipment - by welds.

The biological shielding, which forms the leak-tight plating and separates radioactive equipment from the upper «serviceable» cubicle, is located above the shielding tank. The biological shielding consists of individual blocks connected to each other by welds.

The upper head of the reactor, primary coolant pumps and primary system's valve drives are located above the biological shielding level.

The main primary system's piping and valve gates are located in the space between the biological shielding and the shielding tank.

After the plant decommissioning, the primary circuit's equipment and piping are nearly empty. Remaining volume of primary coolant within the equipment does not exceed 600 litres, steam generators, steam and feed water pipelines are empty.

The biological shielding is installed beyond the unit in adjacent cubicles, thus encompassing the unit over its entire perimeter. The support systems, servicing the reactor plant, steam and feed water valves are also located in these cubicles.

Weight and size data for the key equipment items are given in Section 7.3.
More detailed information on overall size of the equipment is given Appendix 3 Figures 3 to 11.
Data on basic structural materials of the reactor plant equipment are summarised in Section 7.4.
Data on accumulated radioactivity of the reactor plant of 346B facility are given in Section 7.5.

7.3 MASS AND SIZE CHARACTERISTICS OF KEY EGUIPMENT

Table 1 summarises data on mass and size of key equipment of the reactor plant.

Table 1

Equipment	Nos.	Mass of 1 piece, kg	Overall dimensions, mm
Reactor	1	50400	2550x2550x4660
Steam generator – primary coolant pump block	5	14200	1440x1550x4485
Pressuriser	3	2000	795x795x2826
Primary coolant filter	1	1980	800x800x2075
Primary coolant filter cooler	1	2780	800x800x2130
Shielding tank	1	66180	2565x4860x6140
Shutdown cooling pump	1	750	545x566x1135
Primary system valves	8	91	200x250x1710
Steam shut-off valve	10	up to 357	280x872x1480
Feed water valve	10	40	180x180x630
Biological shielding blocks (removable)	30	up to 1270	475x1450x1850

7.4 DATA ON BASIC STRUCTURAL MATERIALS

Table 2 summarises data on structural materials of key equipment and piping of the reactor plant

Table 2

Equipment	Material	Additional data
Reactor	Heat-resistant steel	Weld cladding on internal surface - from stainless steel
Steam generator shell	Carbon steel	
Primary coolant pump shell	Stainless steel	
Pressurizer	Heat-resistant steel	Weld cladding on internal surface - from stainless steel
Primary coolant filter	Stainless steel	
Primary coolant filter cooler	Heat-resistant steel	Weld cladding on internal surface - from stainless steel
Shielding tank body and caissons	High strength alloyed steel	Reactor caisson - stainless steel
Shutdown cooling pump	Stainless steel	
Primary circuit valves	Stainless steel	

Ending table 2

Equipment	Material	Additional data
Steam shut-off valve	Stainless steel	
Feed water valves	Stainless steel	
Biological shielding blocks (removable)	Concrete, lead, heat insulation. Lined by carbon steel	Top liner - stainless steel
Primary system piping	Stainless steel	

7.5 RADIOACTIVITY OF THE REACTOR PLANT EQUIPMENT

Radioactivity accumulated in the reactor plant during its operating life consists of induced activity of equipment and metalwork, radioactive deposits on surfaces of the primary circuit and radioactive water contained in non-empty cavities of the primary circuit.

Induced radioactivity, accumulated in the reactor and adjoined metalwork of the shielding tank, practically defines the entire radioactivity of the plant.

Total amount of radioactivity in the reactor plant depending on a delay time after the last shutdown of the reactor (December 26, 1989) and key radionuclides are given in Table 3.

Some more details will be given about the radionuclides inventory: the activity will be detailed for each main component of the reactor, with ratio of each different radionuclide, as it has been done for the first unit.

Table 3

Date	December 1999	December 2049	December 2099	Key nuclides
Delay time (year)	10	50	100	
Total activity (Bq)	144 TBq	13,3 TBq	9,6 TBq	^{55}Fe, ^{60}Co, ^{63}Ni, ^{152}Eu, ^{154}Eu

8 PRESENT CONDITION OF WASTE TREATMENT AND CONDITIONING OF THE PALDISKI SITE

8.1 WASTE TREATMENT POLICY

After the site take-over ALARA Ltd. started to reconstruct site facilities for the needs of future decommissioning projects, which included establishment of on site interim storage for conditioned radioactive waste as well as facility for waste treatment conditioning. The decision was made to construct an interim storage in the building #302, north of the sarcophagi #2 with reactor 346B, and a waste treatment and conditioning facilities in the eastern annex of building #302.

This interim waste storage is in operation since 1997. It was designed for 720 standard size (1,2 by 1,2 by 1,2 m) waste containers, consists of two cells, each for 360 containers in 8 layers, 5 by 9 containers (See appendix 5 Photos 14 and 15).
For lifting the waste containers one of the existing overhead cranes was renovated and equipped with radio controlled device for remote handling of waste containers. This crane have been licensed recently for 10/30 tons lifting capacity.

Currently 79 filled waste containers were stored into the interim storage (about 11%.of its total capacity). The interim storage is temporarily used also as a storage place for sealed sources, until the proper scheme for their conditioning will be worked out. Moreover, it may be used to store the wastes resulting from the solidification of the sludge and liquid wastes from the LWSB (liquid waste storage building). In that case, 150 m3 more wastes would be stored in the interim storage.

The maximal weight of a full container is 10 tons (due to the annex building crane capacity). External surface contamination is below 4 Bq/cm2. External surface dose rate is limited by transport regulations : 0.1 mSv/h (at 1 m distance).

Besides of standard size waste containers there are specific waste packages for some type of highly radioactive or large components for instance control rods and steam generators which were retrieved from the former Solid Waste Storage, building #307. Control rods which were packaged into four specially designed containers are stored in cells associated to unused/clean spent fuel pool area, originally intent for storage of heat exchangers of Unit 2. Eight steam generators are temporarily stored in the cell designed for storage of reactor vessel of Unit 2. Both of these cells are constructed of heavy concrete and lined with stainless steel layer.

Currently the area between the sarcophagi #2 and building #301 is used for temporary storage of containers with metallic scrap and other unconditioned low level waste, which will be removed as soon as the waste treatment area in #302A will be equipped with necessary facility.

AS ALARA has to receive wastes from other sources (Tammiku for instance), but the volume is quite small compared with the volume of wastes to be produced in Paldiski.

No time limitation has been decided for the use of the interim storage, but the containers will have to be transferred sooner or later to a final disposal site.

Another project is to be launched to define the criterion in order to choose a suitable site and to decide what type of repository would be constructed.

Six possible locations have been identified. These possible locations were chosen because of suitable geological layers. They are all located along Estonia northern cost. Paldiski is one of these alternatives, but for geological reasons, Pakri peninsula might not be the best place to set up a final disposal site.

Anyway, the repository must be available before starting sarcophagi and reactor compartments dismantling operations. In the other case, the cost of waste management would be much more higher, because we would have firstly to store the waste packages in the interim storage, and then to transfer it later to the repository.

So we will assume that the future final repository in Estonia for the decommissioning waste will be available before starting dismantling works.
This final repository will be assumed to be of the same type as l'Aube in France, made for low and medium level short-lived radioactive waste. In the cost calculation, the cost of waste packages transport from Paldiski to the site that is the most likely to be chosen as disposal site will be included.

8.2 EXISTING AND FORESEEN WASTE TREATMENT AND CONDITIONING EQUIPMENT IN THE PALDISKI SITE

At the moment the waste treatment area is not equipped yet. There is intention to install in this area equipment for size reduction (cutting, compaction, etc.), decontamination (high-pressure water jet cabin, electropolishing), a cementation plant, final waste package characterisation equipment etc.

The cementation plant is to be used to solidify the sludge and liquid wastes from the LWSB. This cementation plant will be later transferred to the main technological building, in annex building 302 A (not far from sarcophagi #2). This equipment is designed to treat small amounts of liquid wastes. It could be used to treat a few hundred litres of liquid wastes from reactor compartments: primary remaining water for instance. But if higher quantities of liquid wastes are produced (resulting from decontamination processes, or from the use of water jet cutting systems or Electro-erosion cutting systems), the necessary equipment to treat liquid wastes must be defined as part of the project.

AS ALARA is trying to obtain a budget in order to buy next year a small decontamination facility (total volume of the decontamination tank : 1.5 m^3). This decontamination facility would allow AS ALARA to decontaminate small metallic items (small pipes, small components of equipment). But this equipment won't be of course adapted to reactor compartments dismantling works.

As a conclusion, all the pieces of equipment that could be necessary to carry out the dismantling of the sarcophagi and reactor compartments have to be taken into account in the cost calculations. There's no existing or foreseen equipment fitting to the requirements of such dismantling works.

The main overhead bridge crane is available in the main technological building. Its original lifting capacity is 10/50 tons. This crane, currently having no valid license, needs renovation and re-licensing. We can't be sure that this equipment will still be fit for use in 50 years or more.

9 APPENDIX 1 : DESCRIPTION OF MTB, SARCOPHAGI, RC #1 AND RC #2

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10 APPENDIX 2 : PROCESS FLOW DIAGRAM OF REACTOR #1 AND DRAWINGS OF MAIN COMPONENTS

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11 APPENDIX 3 : PROCESS FLOW DIAGRAM OF REACTOR #2 AND DRAWINGS OF MAIN COMPONENTS

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12 APPENDIX 4 : LIST OF SOLID RADIOACTIVE WASTE PLACED INTO REACTOR COMPARTMENT OF UNIT 1 (346A) AND UNIT 2 (346B)

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13 APPENDIX 5 : PHOTOS