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Modernisation and enhancement of NMAC at the Mayak RT-1 Plant

Reference Base document

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Abstract

The RT-1 plant of the PA Mayak complex of the Russian Federation is the operating nuclear reprocessing facility for civil spent fuel of VVER-440 and BN-600 nuclear reactors, submarines, ice breakers and research reactors.
Within the RF the RT-1 reprocessing facility represents the future reprocessing facility for all the nuclear fuel from power reactors and power research reactors: as a consequence this site is of high importance concerning nuclear safeguards.
Several Nuclear Material Accountancy and Control (NMAC) system devices and techniques of RT-1 were installed many years ago and need modernization.
Furthermore the new RF SSAC imposes restructuring the accountancy and measurement approaches and the implementation of the new system requires intensive personnel training, both in the use of instruments and in the application of NMAC procedures.
The European Commission (EC) decided to develop an approach for the modernization and enhancement of systems at the RT-1 plant, with the main scope of improving the NMAC at the facility.
The results of former projects to enhance accountancy methods and measurements by the DoE and DTI will be taken into account.
The main objectives of the project are the implementation of the new system and the modernization of existing ones, coupled with intensive training in NMAC methodological activities for the staff. The project, when approved, will be carried out under the EC-TACIS program, by the Joint Research Centre, together with PA Mayak and the Institute for Physics and Power Engineering (IPPE), Obninsk.
Several other subcontractors will be called for various kind of technical support within the RF and the EU.

The project consists of five main activity lines:

- An initial design study of the facilities to identify the main areas/locations for improving NMAC
- Modernization and Implementation of Solution Monitoring Systems inclusive of application software for data acquisition and elaboration
- Modernization and Implementation of other NMAC systems identified in the design study such as hybrid K-edge, NDA equipment and techniques, computerized accountancy system
- Elements of near-real time accountancy (NRTA) for RT-1 plant will be studied, designed and implemented, allowing information gathering with its immediate analysis
- Training will form an integral and fundamental part for the successful implementation and utilization of the instruments and for the application of the software and NMAC reporting

This paper presents a summary of the project description and of the planned activities which will be carried out under the project in a tight collaboration between the EU and the RF.

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TACIS Budget 2002-2003

REFERENCE BASE DOCUMENT (RBD)

Summary

It is proposed to carry out a project, with TACIS funds, with the main scope of improving the Nuclear Material Accountancy and Control (NMAC) at the RT-1 facility of PA Mayak.
The PA Mayak plant is the operating nuclear reprocessing facility (RT-1) for spent civilian fuel of VVER-440 and BN-600 nuclear reactors, submarines, icebreakers and research reactors. All kinds of waste, liquid and solid, are stored on site. The various forms of liquid waste are first conditioned in the vitrification facilities before going to disposal.
Within the RF the RT-1 reprocessing facility of PA Mayak represents the future reprocessing facility for all nuclear fuel from the power reactor and the power research reactors: as a consequence this site is of high importance concerning nuclear safeguards.
The installations are not very modern. The RT-1 plant was created from the basis of the radiochemical plant used for production of weapon grade plutonium dioxide and started in 1977 the reprocessing of spent assemblies on a larger scale.
The main part of the NMAC system devices and techniques were installed many years before and need modernisation. The implementation of new NMAC elements requests intensive personnel training both on use of the instruments and in the application of NMAC procedures.
The main objective of the Project is the improvement of the RT-1 NMAC system, through the implementation of new or the modernisation of existing systems coupled with intensive training and methodological activities.
The project will consist of an **initial design study** of the facilities to identify the main areas/locations for improving NMAC (taking into account the existing Mayak-BNFL study); then, following the results of the study, **modernisation and implementation of Solution Monitoring Systems and of other Nuclear Material Accountancy Systems** identified in the design study such as solution mass/volume devices, K-edge, gamma-absorption meters and neutron control detectors. **Training** will form an integral and fundamental part for the successful implementation and utilisation of the instruments and application of the software.

The project will be subdivided into five main sub-projects, namely:

Sub-project 1	Design Study and Detailed Requirements
Sub-project 2	Activities at RMTC
Sub-project 3	Activities at PA Mayak
Sub-project 4	Equipment to be tendered
Sub-project 5	Management

The project will be completed within four years and will require the sum of 3.0 MEUROs.

A. Introduction

The Mayak Complex in Ozersk is situated close to Chelyabinsk, a city near the Northwestern Ural Mountains, as shown in Fig. 1. PA Mayak is one of the most important nuclear sites of the Russian Federation. Almost all kinds of nuclear activities, with the exception of uranium enrichment and fuel assembly fabrication are covered by the nuclear facilities, including:

nuclear reactors decommissioning,
spent fuel reprocessing (RT-1 Plant),
chemical-metallurgical processing of uranium and plutonium,
production of radioactive sources also for medicine purposes,
waste conditioning,
analytical laboratories.

Fig. 1: Geographical situation of Mayak Production Association in Ozersk, Soviet Era Chelyabinsk-65 [1]

In the RF, spent civilian fuel of VVER-440 and BN-600 nuclear reactors, submarines, icebreakers and research reactors are reprocessed by the RT-1 Plant in Mayak. On the site are also 5 graphite-moderated military reactors, all inactive and awaiting decommissioning. Various forms of waste can be conditioned by the vitrification facilities and stored for longer term at disposal sites.

The Mayak RT-1 Plant is the main Russian plant for current and future reprocessing of nuclear fuel from the Nuclear Power Reactors and Power Research Reactors of the RF.

The radiochemical plant RT-1 reprocesses at the moment, beside the special cores of Russian reactors, mainly the spent fuel assemblies (SFA) from the Russian VVER-440 power reactors and from the Ukrainian VVER-440 Rovenskaya and from the Slovenian VVER-440 Bogunitsa.

Spent fuel from the Finnish VVER-440s Lovisa and Voima, from the Bulgarian VVER-440 Kozlodui, from the Hungarian VVER-440 Paksh, from the Czech VVER-440 Pzez and from the German VVER-440 Greifswald were also formerly reprocessed at PA Mayak. The situation now is that income from abroad over the last few years has almost ceased. These activities could be restarted in the future once a decision on reprocessing of long term stored spent assemblies is made. A recent decree of President Putin and Russian Duma has allowed RF to reprocess fuel coming from abroad.

The RT-1 plant has many facilities for spent fuel reprocessing, however only one line, which handles and treats the spent fuel from VVER-440 (initial uranium enrichment from 3 to 4.4

%) and BN-600 (initial uranium enrichment from 15 to 26 %) will be included in the study. The final products are uranium nitrate with uranium enrichment of between 2.2%-2.6% for RBMK fuel, plutonium dioxide powder from BN-600 spent fuel and plutonium dioxide powder from VVER-440 spent fuel. The capacity of these facilities is for the VVER SFA up to 400 tons/yr whilst for the BN SFA up to 20 tons/yr. The current throughput fell to 160 tons/yr for VVER SFA and to 15tons/yr for the BN SFA due to economical reasons (financial shortcoming of the power reactors) and for ecological reasons (restriction to a maximum of 250 tons/yr by the Chelyabinsk administrative office). A batch in one dissolver can take up to 8 VVER-440 SFA or 2 BN SFA.

It is planned that PA Mayak will play a central role also in verifying, storing and later on, processing Pu from weapons. Once the special storage for storing metal pieces is built, PA Mayak will reprocess the Pu coming from the dismantling of nuclear weapons. It is evident that PA Mayak currently is and will ever increasingly in the near future become a strategic complex for nuclear material handling and hence safeguards.

1. NEED FOR MODERNIZATION

The installations are not very modern. The RT-1 plant evolved from the radiochemical plant utilised for production of weapon grade plutonium dioxide and started in 1977 spent assembly reprocessing. The main part of the NMAC system devices and techniques were installed many years before and need modernisation, with the exception of plutonium dioxide storage where the modern system was created under the Minatom-DOE cooperation.

New instruments and techniques, and computerised systems have to be implemented to assure the quality of NMAC requested by new Russian regulations at different stages of spent fuel reprocessing and production of plutonium dioxide and uranium final products. The situation at the reprocessing plant RT-1 is worse than in other Russian radiochemical plants in Zeleznogorsk and Seversk, where many efforts have been made, supported by US DOE and ISTC, to improve the NMAC systems[1].

However under the US/FSU program [2] the US DOE aimed to improve also at PA Mayak nuclear material protection, control and accounting with computerisation of material accounting techniques for bulk materials, including liquid solutions at the dissolver, intermediate product and waste areas. Tank volume measurement systems have been provided by BNL [3] for volume monitoring on 3 inventory tanks and installation was completed in 1997. Improvements in the chemical analytical laboratory have been successfully carried out by SNL, with the recent delivery of a new mass spectrometer (see below). Further upgrading of the laboratory’s equipment has recently been reconsidered.

In addition BNFL started in the nineties a cooperation with PA Mayak, financed by the British Department of Trade and Industry UK DTI, to enhance and modernise the NMAC system. However due to lack of resources, the proposals forwarded by the study, with the procurement of all the equipment needed, could not be executed. Only with financial help from the US a new mass spectrometer was provided in 2001. In the mean time, the Russian State System for NMAC evolved as well, so that the Mayak-BNFL study, or so-called yellow report [5], needs some revision in order to meet and satisfy the new requirements.

[1] At the site of GChC (Zeleznogorsk) the construction of a new RT-2 plant started but had to be stopped because of economical reasons, the VVER-1000 spent assemblies storage was built and is operated now. Spent assemblies from Russian and Ukrainian NPPs are accumulated in this storage, which is loaded close to 40%.

2. SAFEGUARDS REGULATIONS

In the early nineties the Russian Federation decided to join the NPT. In safeguards agreements pursuant to the NPT, Russia was required to establish and maintain a State System of Accounting and Control of Nuclear Material (SSAC) within its territory, jurisdiction or control. The SSAC falls under the responsibility of Minatom and integrates several important components, including the state system of accountancy, nuclear export and import control and physical protection. The system was established in accordance with the "Law on Use of Atomic Energy" and defines the responsibilities of Russia under the Safeguards Agreement between the IAEA and Russia under the NPT. According to the NMC&A Basic Rules (OPUK), which was issued by RF GAN decree (2001) [4] the Physical Inventories must be made periodically (for Category I – monthly, for Category IV – annually). The acceptance criteria for the Inventory Difference (ID) of the different categories of materials are specified in Table 1.

Material	The SS NMAC Regulation of the RF
Category I: PuO_2 powder+ Pu compounds With $c_{Pu}>25g/l$	$\|ID\| = 2s_{ID}$ *(corresponding to a confidence level of 95%)* $\|ID\| = 3$ *kg Pu* $\|ID\| =$ *2% of through-output (corresponding for 1 ton Pu/yr to about 1.5kgPu/month)*
Category IV: LEU compounds	$\|ID\| = 2s_{ID}$ *(corresponding to a confidence level of 95%)* $\|ID\| = 70$ *kg U-235* $\|ID\| =$ *2% of through-output (corresponding for 160 ton SFA/yr to about 5kgU-235/month)*

Table 1: Statistical criteria for Inventory Difference in the RF.

3. SPECIFIC RECOMMENDATIONS

a. Specific objective

The purpose of the project is an upgrade and improvement of NMAC, with e.g. the reduction of the measurement errors for the uranyl nitrate samples (with VVER-440 and BN-600 regenerated uranium) and for the other end products: PuO_2 powders. Solution monitoring is also envisaged, and some measurements for process control may be used for Near Real Time Accountancy.
A sensitivity analysis of the inventory differences on the number of measurement points and the accuracy of the measurements will be used for the priority ranking of the proposed

instruments needed to enhance NMAC (see Subproject 1, Design Study and Detailed Requirements). **(deliverable # 1(*)).**

b. Variety of Input Material

Special attention should be given to the instrumentation and measurement procedures proposed for NMAC, which are to be dedicated for both highly enriched and low enriched fuels reprocessed at this plant. The content of Nuclear Material in the fuel is also very different. The radioactivity of both initial products (spent fuel) and final products (PuO_2 and $UO_2(NO_3)_2$ is a very serious factor, which increases the difficulty of implementing modern NMAC.

c. Need for training

The implementation of new NMAC elements requests intensive personnel training both on the use of the instruments and in the application of NMAC procedures. Special training courses, especially concerning the operation of new equipment such as a hybrid K-edge, have to be organised. The above mentioned obstacles and plant technological processes have to be taken into account in the elaboration of the courses.
(deliverables # 15, 16, 17).

(*) Deliverables are defined in this document as "macro-outcome" of the project. Reference is made to Annex 5 to this document. In future documents (e.g. the AIDCO/JRC Administrative Arrangement) the definition of deliverables may be different, with much higher degree of detail.

B. Description of RT-1 Plant's Reprocessing Flow

The TACIS project is oriented to enhance and improve NMAC in the VVER-440 and BN-600 lines of the RT1 radiochemical plant of the Mayak complex, which reprocesses spent fuel from mainly Russian NPPs as described above

There are many processing facilities in RT-1, as is schematically shown in Fig. 2. A detailed flow chart of the reprocessing lines at Mayak RT-1 Plant included in the project is given in Fig. 4 of Appendix I. First the assemblies are cut[2], chopped, and dissolved. The main spent fuel solution is transferred to the input accountancy tanks (IAT) then filtered and reprocessed to separate fission products, from uranium and plutonium and finally to obtain the final separate products of uranium and plutonium solutions. The creation of a reprocessing line in RT-1 plant for VVER-1000 spent assemblies is under discussion. However, the project will only include the work on modernizing NMAC system in the process of reprocessing VVER-440 and BN-600 reactors spent fuel. The site-specific processing with its procedures for mixing U solution from reprocessing of VVER-440 and BN-600 spent fuel type and its procedures for fabricating low enrichment paste of Uranyl nitrate and PuO_2 powders from VVER-440 and BN-600 spent fuel will be described in the study phase of the project.

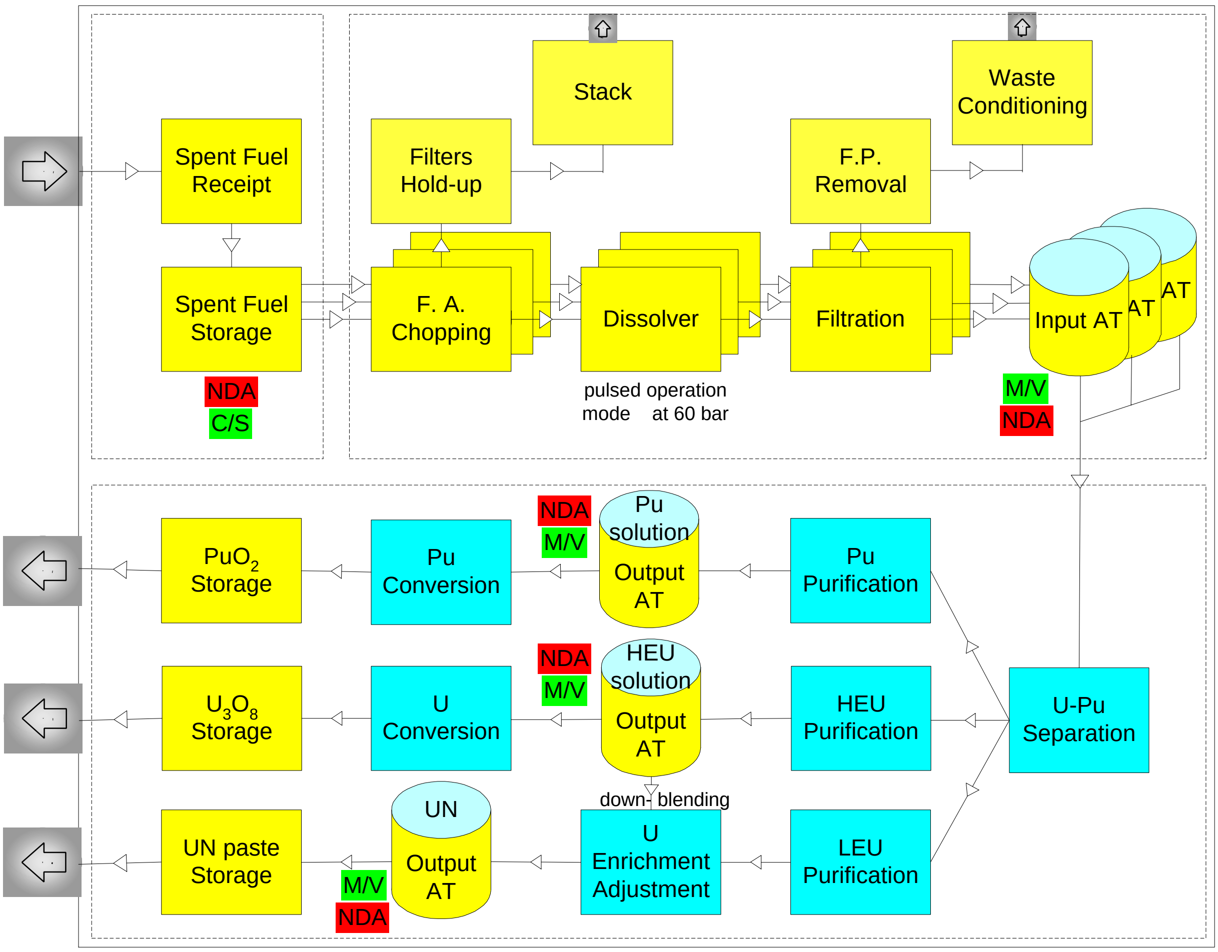


Fig. 2: Sketch of the reprocessing flow

[2] VVER-440 spent fuel assemblies are at the input, before the cutting of the ending parts, measured by registration of self neutron emission.

1. General Description of Technological Process

The facility under consideration follows a modified PUREX process with additional separation of Np, which differs from the process followed in European reprocessing plants.
The structure of the facilities in question comprises 10 technological areas:
- storage for nuclear material received: spent fuel assemblies of VVER-440 and BN-600 reactors;
- preparation of spent fuel assemblies for chopping: cutting off the tail end parts and preparing batches for dissolution.
- assembly identification (neutron emission measurement from spent fuel assemblies before chopping)
- operations line for assembly chopping and dissolving;
- chemical processing line for extracting fission products solution, separation and refining nitrate solution of uranium and plutonium;
- oxalate precipitation and conversion to plutonium dioxide powder;
- evaporation of nitrate low enriched uranium solution (2.4-2.6%);
- storage for plutonium dioxide product;
- storage for uranyl nitrate paste product;
- vitrification and storage for high and medium level waste;

2. General structure of the facility

For the description of the flow at the reprocessing lines in the Mayak RT-1 plant the reader is also referred to Fig. 4 in Appendix I.

a. Spent fuel storage pond

Spent fuel assemblies (SFA) of VVER-440 and BN-600 reactors arrive at the facility in transportation casks by rail. The SFA as arranged by canisters, are unloaded from casks and transferred by fuel handling equipment to the pond storage area. Material accountancy measures at this stage of the technological cycle are based on item counting and identification of transport/storage canister ID, as well as identification of specific positions within the canister. Assembly identification is not a routine operation as individual serial numbers of assemblies are not always easily readable.
The SFA SFAs VVER-440 and BN-600 are shipped from the storage pond to the examination cell (about 40m upwards), in a transport cask canister. The verification measurements of neutron emission from spent fuel at this stage would be useful as an initial control of received items. The collection of SFAs for the reprocessing batch is made following the task of operation.
Lighting installations with video cameras for underwater operation for control of SFA and canisters number and IDs are recommended for improvement of items control in storage pond.

b. Head-end operations area

In this Area the operations of: chopping, dissolving, leaching, filtering, are carried out. In the preparation cell the SFAs are prepared for chopping by unloading them from the transport canisters into a device, where neutron emission measurements are performed (for VVER-440 assemblies only). The neutron emission from VVER-440 SFA is measured by two detectors located in parallel close to the SFA to verify the declared fuel burn-up and the mass of burned U235 as well. This is done mainly for nuclear criticality safety reasons.
First the tail end parts of the SFAs are cut, then the SFAs are fed into the shear feed magazine and chopped. The segments of fuel rods fall into the dissolver tank filled with nitric acid, where fuel material is leached from the cladding pieces (hulls).
The dissolved product is transferred to the process feed preparation stage; the preparation involves filtering of the solution. Volumetric measurements, as well as sampling for material content and isotopics, by analytical methods and by mass-spectrometry, are carried out for NMAC purposes before solution filtration.

Purge air and dissolve off-gas is collected by a gas treatment system and filtered for particles/aerosols of the fuel; the latter is returned to the dissolving stage. The nitrogen oxides are absorbed to recover nitric acid, the off-gas is filtered, purified and blown up to the main ventilation stack.
Insoluble residues (hulls) are blown out of the dissolving tank by a burst of pressure (up to 60 bar overpressure) and dumped into the feed line, to be transferred to an interim storage before going to the long term storage. The process stages of filtering, dissolving and transfer ramp for hulls storage are equipped with instrumentation to monitor the fissile material, by gamma and neutron emission detection for process control, for criticality control and NMAC purposes. See the lines 15 and 15' in Fig. 4 of the Appendix I.

c. Chemical processing area

In this area the following operations are carried out:

- clarification
- HLW conditioning ("16")
- U/Pu separation
- purification
- PuO_2 Conversion
- LEU (2.6%) uranyl nitrate paste production and storage
- Np separation and solution and storage

After clarification and conditioning of the feed, the solution of fission products is separated from the U/Pu solution by means of solvent extraction. High level waste raffinate from the first extraction cycle is collected in tanks for cooling and storing before being subjected to a vitrification process (solidification in a glass matrix) and final shipment to a repository.
For uranium and plutonium separation the solution of uranium and plutonium is conditioned by a special chemical process to change the plutonium valence to +3. After separation, auxiliary extraction purification is carried out for both uranium and plutonium solution. As the uranium and plutonium solution undergoes the solvent extraction process, it is purified from residual fission products. The purified uranyl nitrate is then corrected for prescribed enrichment level by means of adding high enrichment solution of U from BN-600 reprocessing cycle, then the solution undergoes stages of evaporation/condensation and it is

loaded into cans for storing and shipment. All these stages of the process include the most accurate measurements of fissile material mass, enrichment of uranium and content of impurities both for process and NMAC purposes. The Next Section C.3 gives a detailed description of the measurement systems and associated accuracy).

The purified plutonium nitrate solution is then transferred for an oxalate precipitation and decontamination step, filtration of the oxalate pulp and finally heat treatment to convert the pulp into plutonium dioxide powder. The VVER PuO_2 powder is loaded into containers and transferred to the storage area, BN PuO_2 powder is shipped to MOX fuel production facility.

C. NMC&A System at the RT-1 Plant

1. INTRODUCTION

The existing NMC&A system in the plant has an administrative structure, which is not in accordance with the NM categories prescribed by federal NMC&A rules. Each division of the plant has to make a physical inventory each month and balance NM account. The NM account is balanced in all divisions of the plant quarterly. No evaluation of inventory difference (ID) is made both for divisions and plant.

The base information for NM accounting is the results of measurements of NM content and mass in reprocessed and final products (spent assemblies, spent fuel solution, uranium and plutonium solutions, liquid wastes, plutonium dioxide powder and uranyl nitrate paste). Many equipment units and sub-facilities for solution reprocessing may not be cleaned before the physical inventory for technological and operational reasons. This is the reason for using different NDA techniques and instruments for measurement of NM content and mass in the equipment (level meters, deep NDA instruments, NDA of hold-up and accumulations). Accuracy of measurement techniques was limited by technology requests – not by NMC&A ones. The reader is referred to the measurement points in Fig. 4 for this evaluation. The measurement accuracy for the final product and the main part of solution transactions between divisions is good for NMC&A goals but many techniques and instruments have to be improved to reach criteria prescribed for ID by federal rules. Special manuals exist for each division on how to measure and calculate the NM mass in equipment, tanks, sub-facilities (so called PT manuals).

Data processing is based on simple calculations and hard copies of documents, very few computerised techniques are used for this. Very preliminary analyses are done for IDs and error evaluation. The implementation of NMC&A basic rules requests the essential reconstruction of plant NMC&A system, definition of MBAs and re-establishing of KMPs, modernisation of measurement techniques and instruments, implementation of new ones, creation of NMC&A computerised system. The determination of new plant MBA/KMP structure, development of detail specifications for modernised and new measurement techniques and instruments, computerised system is the task for sub-project 1. **(deliverable #1)**.

2. NEAR REAL TIME ACCOUNTANCY

In order to carry out nuclear material accountancy it is necessary to measure and account for all nuclear materials handled by the plant, to perform these measurements accurately and in a timely manner and most importantly to perform these measurements with a minimum of cost and interference for the operator. It is clear that in order to introduce a whole series of instruments in various Material Balance Areas (MBAs) for NMAC then some detail thought needs to be dedicated to the architectural structure of the computerised data acquisition and evaluation and analysis as well as final NMAC reporting.

Considering the complexity of a plant with the type of material flow and unit operations performed, an appropriate accountancy plan needs to be developed. The plan needs to integrate the information obtained from various sources (instrumentation, records etc.,) and aim for reliable and automatic accountancy techniques utilising today’s technology. Information gathering in so called near-real time with immediate analysis will allow near real time accountancy (NRTA) to be achieved.

NRTA in RT_1 will be studied and described in the Sub-project 1:Design Study and Detailed Requirements **(deliverable #1)**.
BNFL, through DTI funding, carried on a study together with Mayak on the needs for implementation of a NRTA system at the RT-1 plant, which was documented by the yellow report [5] as mentioned in section A.1. This project will take that study into consideration and ways for exploiting and using BNFL experience will be explored.
The essential modernisation of hard and software of existing NMC&A computerised plant system is requested **(deliverable # 10).**
Main goal of this system must be the "on-line" NM accountancy reprocessed in under project facilities.

In order to attain NRTA the following basic elements are required:
- improvement of bulk measurement methods
- computerisation of data acquisition both from the plant and the analytical laboratory
- computerisation of record keeping and reporting, data evaluation and verification, measurement sequences
- estimation of in process inventory hold-up in order to have up-to-date and frequent material balances

For NRTA to be successful it is necessary therefore to have a computerised system with a well defined architecture for data acquisition and interpretation. Modernising the instrumentation in the various process areas of the plant needs to take into account the acquisition of data from these instruments and the handling and evaluation of the data. This needs to be well defined in sub-project 1 so that NRTA can be achieved.

3. MEASUREMENTS, DIFFICULTIES, WEAKNESSES, ETC.

The above mentioned unit operations lead to problems with measurements and control of Nuclear Material (NM) in various forms (solid, liquids, pulp and bulk form), which are processed in the plant. Practically all operations with NM products including the movement of NM are made remotely; all equipment is protected by biological shields and can be reached only after careful decontamination during planned maintenance. For the NMAC the radioactive characteristics of the processed substances, which are belonging to category IV, require to make for practically all NM, with exception of oxalic precipitation and conversion of $PuO_{2,}$ one inventory every year.

a. Input

The problems with NMAC start at the input – there is no possibility to verify the spent assemblies' numbers during receipt of the transport cask. The operators can check only the cask and cask canister IDs plus the quantity and arrangement of SFAs. Material accountancy measures at this stage of the technological cycle are based on counting SFAs, identification of transportation cask and canister IDs, as well as identification of specific positions within the canister. Assembly identification is not a routine operation as individual serial numbers of assemblies are not always easily readable.
The following improvements/enhancements are recommended:
To implement lighting installations with video cameras for underwater operation for control of SFA and canisters number and IDs for improvement of items control in storage pond.

b. In-Process

Some equipment, sub-facilities can not be cleaned before any PIT and the content of NM has to be measured/evaluated by Destructive and Non-destructive Analyses (DA/NDA) and by solution Mass and Volume Measurement (M/V) techniques and devices. This problem is concerned with:

- spent fuel hold-ups in filters of spent fuel and solutions reprocessing facilities,
- presence of organic and water phases in extraction/re-extraction facilities at different stages of the solutions reprocessing,
- hold-ups in filters of plutonium dioxide conversion lines.

The current situation of the NMAC measurements and procedures (is mainly non-online) in RT-1 is briefly described underneath:

b.1. Mass/volume: M/V

For M/V technique: 20 tanks at key measurement points are equipped with level probes, 10 of them are inventory tanks. 8 out of the 10 inventory tanks do not have a pressurised transfer system. Because of this pressurised transfer system Russian level probes are installed, which measure the variation in level by means of an inductance, transformed to a high frequency signal. Therefore the probes are in the RF called high frequency inductive probes. The original type of this probe, URES, was developed at St. Petersburg in the seventies and used at Mayak because of its high performance. In the eighties the electronics have been upgraded, yielding the UVV type. Additionally a multichannel analyzer with 16 channels was included, leading to the UVM type probe with an accuracy <1%. In total 150 inductive probes are installed over the plant, with a ratio of 1UVM/5UVV.

Upgrade of M/V technique: Under cooperation with BNL bubbling probes are installed on the tanks without pressurised transfer system in the Pu subdivision, as requested by the Mayak-BNFL study.

A first dip tube system with 5 probes was installed on 2 tanks in parallel and successfully tested. This tank volume measurement system TVM-01 used a Scanivalve to register the 2x5 pressures with a rate of 1sample per 5s and allowed to determine the volume with an accuracy of 0.2% and a high reliability (no failure during two years of operation).

A second system TVM-02 was installed on 2 annular input tanks in series and is still in the test phase. A third system TVM-03 was provided close to the extractor but did not operate either. Bad experience with the unreliable Scanivalve leads to the request of Mayak to install digital pressure modules of higher quality. Problems remain with no spare parts or maintenance/calibration checks and the data acquisition system.

The following improvements are recommended:

- To deliver, install and test bubble probe systems in 9 measurement key points **(deliverable # 2).**
- To produce, install and test modified inductive level meters in 10 key measurement points **(deliverable # 3)**.

b.2. Non Destructive Analysis: NDA

- NDA techniques for U/Pu concentration measurements with Dip GAS-GAM type gamma-spectrometers have been installed at 40 key measurements points. In order to enhance their accuracy and reliability these gamma-spectrometers are to be upgraded **(deliverable # 4).**
- Neutron Control Detectors (NCD) for Pu concentration are requested in various locations for NMAC. Presently such NCD devices at 25 KMPs need to be computerised with auto diagnostics. NCDs are requested also for the NDA of hulls and hold-up (about 20 KMP) **(deliverable # 5).**
- Portable NaI gamma-spectrometers are requested for the verification measurements of uranium enrichment in paste items during PIT/PIV and before shipment **(deliverable # 6).**
- Development or improvement of gamma and neutron NDA techniques for NM content in solution, hulls, accumulation and hold-up are requested in various KMPs for NMAC. Characterisation and certification of these techniques is also requested **(deliverable # 12).**

b.3. Analytical Measurements

On the Mayak RT-1 plant site the chemical analytical laboratory is continuously operating.

The analytical laboratory on site treats all samples of all lines. NDA techniques as well as DA techniques are used, and reviewed by Sazhnov et al (2000) [6]. For the DA a dilution of the highly concentrated sample with factor 10^{-4} is made in the hot cell and transferred for the analysis to the glove box. Sophisticated techniques for sample preparation are available on site. An overview of all the equipment in use with indication of the instrument error is given in Table 2. The analytical laboratory is operating continuously with 4 shifts. The number of samples analysed is limited by the maximum capacity of the instrument, which leads to maximum 4 samples/day for the Coulometry and 3 samples/day for the mass spectrometry. Examination of the accuracy of the instruments as indicated in Table 2 lead to the following conclusions:

- The second and third instrument of Table 2 show a rather high error and indicate that the accuracy of the analytical analysis on the main input solution is not sufficient for the NMAC. Mayak agreed that the control on the input accountancy tank must be improved and the JRC proposed to purchase therefore a hybrid K-edge **(deliverable # 7).**
- Mayak intended to replace the gravimetry for solution samples DA by titration
- Mayak intended to replace in cooperation with SNL the spectrophotometry for samples of MBA 5 (liquid waste) by liquid chromatography.
- The gamma spectrometer for U-235 samples of reprocessing area is not very accurate (2.6%) but fast. In case the results are not sufficiently accurate, a back-up analysis can be performed with the mass spectrometer.
- SNL discusses with Mayak also to use more advanced equipment instead of the Coulometry.
- The alpha spectrometer for Pu content measurement in solutions is recommended **(deliverable # 8).**
- The implementation of isotope tags technique and instrumentation for isotopic dilution method improvement is recommended **(deliverable # 9).**

(No. MB flow)	Comp.	Analytical Instrument	Error (%)
2(main solution)	U	Gamma absorptiometry	0.9
2(main solution)	Pu	Spectrophotometry of Pu(III)	5
3	U	Titration (Davies-Gray method)	3
3	U-235	Gamma spectrometry	2.6
3’	U	Gravimetry (precipitation weighing)	0.3
3’	U-235	Mass spectrometry	0.1
4	U, Pu	NDA, neutron counting	50-100
5	U	Spectrophotometry of U complex with Arsenazo III	15-30
5	Pu	Spectrophotometry of Pu complex with Arsenazo III	15-30
6	Pu	Gamma absorptiometry	5
7	U	Gamma absorptiometry	0.9
8 (product)	Np	Controlled-potential coulometry (with isotopic spiking)	0.5
9 (product)	Pu	Controlled-potential coulometry (with isotopic spiking)	0.4
10 (product)	U	Gravimetry (precipitation weighing)	0.15
10 (product)	U-235	Mass spectrometry	0.2
11 (product)	Np	Controlled-potential coulometry (with isotopic spiking)	0.5

Table 2: Equipment of the analytical laboratory

c. Output

NMC&A procedures and measurements for BN and VVER PuO2 powders were essentially improved as results of co-operation with US DOE that provided HLNCCs and HRGSs.
NDA for the output storage within this project will be oriented at the NMC&A measurements of uranyl nitrate paste, which is shipped to the ULBA plant in the Republic of Kazakhstan for RBMK pellets production (see previous chapter: **(deliverable # 6)**
The main problem in this KMP (see 11, fig 1) is connected with measurement of net and gross weight of the containers with U paste. The delivering and installation of a crane scale for this measurement is also recommended. **(deliverable # 11)**.

D. Objectives and Main Lines of the Project

The main objective of the project is the improvement of the RT-1 NMAC system, through the implementation of new or the modernization of existing systems coupled with intensive training in NMAC methodological activities for the staff.

1. ACTIVITY LINES

The project consists of five main activity lines:

- **An initial design study** of the facilities to identify the main areas/locations for improving NMAC
- **Modernisation and Implementation of Solution Monitoring** Systems inclusive of application software for data acquisition and elaboration
- **Modernisation and Implementation of other NMAC systems** identified in the design study such as K-edge, NDA equipment and techniques, computerised accountancy system
- **Near-real time accountancy (NRTA)** for RT-1 plant will be studied, designed and implemented, allowing information gathering with immediate analysis
- **Training** will form an integral and fundamental part for the successful implementation and utilisation of the instruments and for the application of the software and NMAC reporting

According to the TACIS rules EC-AIDCO (EU) is to be indicated as the contractor and MINATOM (RF) as the Beneficiary

2. MAIN ACTORS AND THEIR ROLE

The main three actors are:

- JRC (IPSC and ITU)
- IPPE (RMTC)
- PA Mayak (RT1)

a. Role of JRC

The role of the JRC will be as principal contractor taking on a coordinating role between the other actors. In particular the JRC will provide its expertise in the areas of solution monitoring and DA/ NDA systems. This will include the overseeing for the correct installation of the instrumentation and the training of the operators in the JRC facilities, in the RMTC facilities and in field in the PA Mayak RT-1 plant. As principal contractor the JRC will also be responsible for the overall management of the project including tender specification and preparation for publication, technical evaluation and general overseeing.

b. Role of RMTC

The RMTC facility in Obninsk will be sub-contracted to provide the necessary interface support between the JRC and the PA Mayak operating plant. The RMTC facility itself will be utilised to set up mock experimental rigs to test the instrumentation proposed for installation in the PA Mayak facility. RMTC staff will be involved in development and improvement of NDA techniques **(deliverable # 12)**. Training of operators will also take place here in collaboration with the JRC staff.

c. Role of PA Mayak

The PA Mayak plant will be sub-contracted to support the installation on site and at RMTC as well as to place the local infrastructure to the Contractor's disposal. PA Mayak will perform the installation of instruments and all necessary supporting work required. Especially PA Mayak will provide all necessary data to successfully implement the present project.

3. SUB-CONTRACTORS

Several RF companies may be required to co-operate to the project (see list of deliverables) as local subcontractors: their involvement will be considered following TACIS rules.
At the moment it is suggested to look tentatively at Arzamas, Mayak PA and Chelyabinsk as local subcontractors for developing specifications and software for NRTA, and to some specific institutions, licensed by the RF Authorities, for certifying the new techniques and/or equipment **(deliverable # 12)**.

BNFL (UK) because of its expertise acquired during the BNFL-Mayak study period (1995-1999) will be required to co-operate to the project. The outcome of the BNFL-Mayak study was (besides others) a list of recommendations, but unfortunately no financial means could be achieved for implementation. The study of originally ecological justification was financed by the British Department for Trade and Industry. Mayak RT-1 experts provided the complete information on all subdivisions of the one VVER-440 and BN-600 reprocessing lines and this documentation is included in the final yellow report [5]. In the study BNFL concentrated on the purification line of Pu after the U/Pu separation and selected for this Pu subdivision at 17 KMPs out of the 25. BNFL demonstrated for this Pu subdivision.
The final study comprised also the set-up of a computerised network with the design of a software tool for processing all measured data. This design study was never implemented because of missing funding. The cooperation between BNFL and Mayak is still actively present. The Mayak-BNFL study needs to be updated with special regard to all safeguards issues, as specified in the new Russian SS NMAC, which is in force since March 2002
The diagram of Fig. 3 represents the TACIS structure of the different actors for the project.

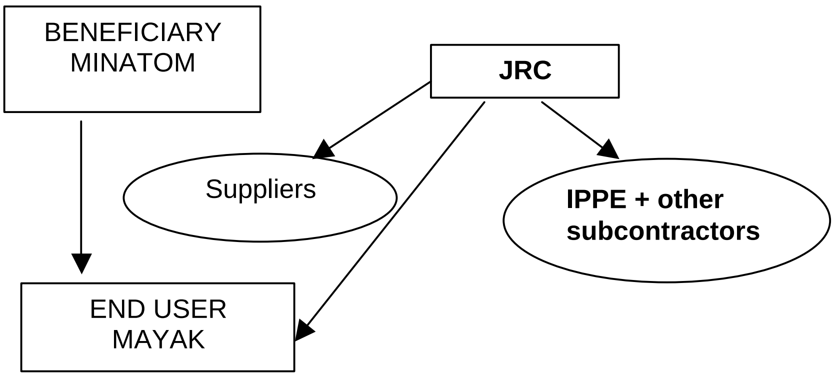


Fig. 3: Organisational Chart of the Partners Involved

E. Project Management

The project will be subdivided into five main sub-projects, namely:

Sub-project 1	Design Study and Detailed Requirements
Sub-project 2	Activities at RMTC
Sub-project 3	Activities at PA Mayak
Sub-project 4	Equipment to be tendered
Sub-project 5	Management

1. SUB-PROJECT 1: DESIGN STUDY AND DETAILED REQUIREMENTS

The scope of the study is to provide an overall detailed analysis of the PA Mayak complex activities, with particular focus devoted to the NMAC aspects. The scope of the work will be clearly presented. Both all involved facilities as well as all actors involved in the project will be described in separate sections.
The involvement of BNFL is recommended and the existing Mayak-BNFL feasibility studies are taken into account eventually after a revision, particularly with regard to the new NMAC State System regulations within the RF.
The expected result of the study will identify all the areas relevant to NMAC within the RT-1 plant of PA Mayak complex of the RF nuclear fuel cycle, describing the material flows of input/output to PA Mayak, the internal process operations and exchange between different MBAs, as well as the current types of accountancy systems and measurement capabilities and the computerised accountancy records applied in the plant at SFA BN-600 and VVER-440 reprocessing. The study will identify and detail the needs and requirements in the above mentioned areas.
The study will be subdivided in the following "chapters":

a. *Introduction*

This chapter will describe the RF civil cycle, the present and future role of Mayak and RT-1 in the RF cycle, the need for improving the NMAC system in RT-1. I will also present the scope of the work and the sections of the facilities, which will be involved.

b. *Spent fuel Input*

This chapter will give details of the systems employed for the receiving, assaying and conditioning of the spent fuel prior to its input in the reprocessing facilities. This section will describe the fuel cutting systems and the filtering aspects. It is expected that one of the aspects to be considered in the project will be the study and the modernization of the control systems of the hold-up in different points of the plant, in particular at the input level.

c. *Radiochemical installations*

A description of the solution filtration, separation and purification installations and their role will be provided.

d. *MBAs and Key-measurement points:: NMAC system architecture*

This chapter is subdivided in to two subchapters: the first describes the existing NMAC system, the second describes the new proposed system:

d.1 Existing NMAC system

This sub-chapter first describes with a complete overall picture the existing system of NMAC currently in forces at the RT-1 plant. The subsystems and equipment will be identified in the flowchart of the reprocessing facility. Subsequent details will specify the RT-1 subsystems, the path to form the Inventory Difference with the measurement uncertainties and the error propagation scheme.

d.2 Proposed NMAC system

Then the requirements for modernisation of the system will be discussed, the new error propagation model proposed and finally the NMAC system requirements (modelling, software of subsystems, hardware and computerisation) will be detailed. The impact of the new proposed NMAC instrumentation will be evaluated with the redefinition of the KMPs/MBAs and of the entire NMAC architecture. The study will describe the NMAC measures taken in MBAs and KMPs. It will indicate measurement uncertainties, their propagation to the ID. Also the architecture for a computerised NMAC will be proposed. The study will as well propose a sensitivity test to allow decision making on new equipment and procedures. This chapter will also forward recommendations for NRTA. The study will be considering the previous BNFL/Mayak study.

e. *Solution Monitoring complex*

One of the main tasks of the project will be the study and the modernisation of the existing solution monitoring system.
The PA Mayak's solution monitoring system applies a different measurement technique to the one commonly used under similar conditions in the EU main plants: the Russian systems are based on high-frequency inductive probes (instead of the bubbling technique in EU plants).
The Russian high-frequency inductive probe consists of a coaxial steel tube, of which the inner tube is insulated with Teflon and the outer tube has holes to allow the solution to fill the gap between the two tubes. The level variation of the electrically conducting solution, which is surrounding the probe, is principally measured by the inductance variation. The total length of the probes can be up to 11 m and the immersed length of the probe varies between 1500mm and 8000mm. Depending on this active length a measuring frequency between 2MHz and 10 MHz is applied. These high-frequency energy pulses are transmitted down the coaxial cable. When the pulse reaches the surface of the solution, the pulse is reflected back to the head of the probe, because the solution creates a short circuit. The probe measures the time it takes for the signal to travel down the cable and to reflect back and converts this time into a waveform or distance reading. This is the operation principle of the so-called

Time Domain Reflectometry (TDR). According to the American Instrument Society[3] the probes could be called TDR probes. The concentration of the solution seemed not to influence the level measurement. For calibration and protection of the electronic head of the probe a plastic valve is foreseen just underneath the electronic head, which can be manually closed.

A comparison of the Russian high-frequency inductive probe, a Western TDR-probe and the dip-tube system should be carried out, especially regarding their accuracy and their sensitivity to concentration and temperature variations.

In order to achieve the goal of performing level measurements with a precision of 0.2%, the Russian type of level probes and the American TVM system may be upgraded, or replaced.

Numerous tank systems at PA Mayak (almost 60%) are operated under pressure. The transfer of liquids is performed by pressurising the tanks to force solution through the pipe-lines connecting the different tanks. Those tanks present some technical difficulties in the application of the bubbling technique. The design of a passive system, protecting the dip tube of becoming filled with the radioactive solution under the operation of the pressurised transfer system could be studied, in order to extend to applicability of the accurate dip tube system.

A large number (at least 40) of Neutron Control Detectors (NCD) need to be computerised with autodiagnostics.

The existing 40 Dip GAS-GAM type gamma-spectrometers are to be upgraded. This enhances significantly the reliability of the gamma-spectrometers and so the precision of the gamma-spectrometer measurements.

f. *Types of tanks and calibration procedures.*

Design studies should be carried out, in order to define the solution monitoring systems to implement or how to improve the existing one. Calibration procedures and methodology of tank calibrations on mock-up tanks (TAME, MiniTAME at Ispra and TAMSKA at IPPE) are required. Comparison of the performances of bubbling (dip-tubes) system with respect to capacitance system and to the inductive system is also required. The mock-up tanks should be of the same shape and if possible dimension (height) as in the PA Mayak plant together with a mock–up of the pressure transfer mechanism. Security system interlocking would have to be introduced during the transfer phase.

g. *Sampling schemes and analytical measurement system*

This chapter will deal with the study of the sampling and analytical flows in and “around” the RT1 facility in Mayak. In particular, the sampling point, the vial transfer system and the central analytical laboratory will be described in order to ascertain the requirements of analytical equipment of type:

- Hybrid K-edge for U/Pu concentration measurements. The Hybrid K-edge is to be completely integrated in the hotcell with the transfer tube for the sample vials and with a sample changer. Vial design and HKED integration should be described at this

[3] Example of tutorial in reference [7]

stage. Procurement and installation of the Hybrid K-edge will be provided utilising the expertise of ITU.

- COMPUCEA-type for U concentration and enrichment measurements. Depending on the results of the design study, ITU (JRC) will also provide and install a COMPUCEA for Urarium solution concentration and enrichment measurements.
- Here special attention should be given to the training needs.

h. ***Output Products***

The output products of the facility will be described (PuO_2, RBMK $UO_2(NO_3)_2$) together with the existing measurements in place and the need for further NDA requirements, such as neutron / gamma monitoring, and verification of RBMK $UO_2(NO_3)_2$ paste by portable gamma spectrometer.

i Waste Conditioning and Assay

A description of the waste treatment facilities, including the type, quantity of waste produced and the existing assay methods and suggestions for future needs, concerning Containment/Surveillance will be included.

j. NRTA

This chapter, based on the outcome of Chapter 4, will describe the architecture and the practical aspects (hardware, software, modelling) of the NRTA system which will be implemented at RT-1. The chapter should indicate what information (data) is required from the plant to determine an in-process inventory, which vessels will have direct measurements, which vessels will have mathematcial models and which will have nominals with associated mesurement uncertainties. Functional and detailed specifications for NRTA will be described.

k. Training Needs

The training of the operators will be an important and fundamental step in NMAC. Training in:

- mass/volume methodology
- neutron and gamma NDA of NM content in items and hold-up
- weighing scales calibration
- DA/NDA instrumentation set-up and maintenance
- Special training on the operation of a Hybrid K-edge
- data acquisition and storage
- data elaboration analysis
- error propagation modelling, inventory difference
- physical inventory taking and verification at Radiochemical Plant
- NMC&A software engineering

l. Conclusions and Drafting of Detailed Specifications of the Project

This chapter will be fundamental towards the subsequent specifications of the project. It will identify the instruments required, the activities and testing to be carried out and the role of each player in detail.

2. SUB-PROJECT 2: ACTIVITIES AT RMTC

Scope of the sub-project
The activities to be carried out in the RMTC facility will cover the following areas:

1 Complete training and calibration M/V facilities (TAMSKA)
2 Prepare mock-up tanks (including the use of solutions simulated real ones) as utilised in RT1 plant in Mayak to study solution monitoring and process operations, such as transfers, sampling, mixing
3 Mass/volume methodology training of operators in tank calibration
4 Level measurements comparison of techniques: high-frequency inductive technique versus time domain reflectometry technique and versus dip tube technique. This comparison study should comprise bubbling probes as well as different TDR probes (western type), as well as the different inductive probes (Russian type URES, UVV and UVM). The three types of probes should be provided to both research sites, IPPE (Obninsk) and IPSC (Ispra) (?)
5 Evaluation of the influence of the sampling line on the data
6 Training in :
  - K-edge instrumentation
  - mass/volume methodology
  - neutron and gamma NDA of NM content in items and hold-up
  - weighing scales calibration
  - DA/NDA instrumentation set-up and maintenance
  - Special training on the operation of a Hybrid K-edge
  - data analysis interpretation
  - data acquisition and storage
  - data elaboration analysis
  - error propagation modelling, inventory difference
  - physical inventory taking and verification at Radiochemical Plant
  - NMC&A software engineering

3. SUB-PROJECT 3: ACTIVITIES AT PA MAYAK, RT-1 PLANT

Scope of the sub-project:
The RT1 plant in Mayak site is where the instrumentation will be installed to enhance their NMAC systems. Therefore it is envisaged that a large part of the work will be concerned with preparation of certain areas of the plant and indeed modifications to the facility itself to accommodate certain equipment. The general work will involve the following, predominantly carried out by RT-1 plant staff operators:

1 Preparation of identified tanks for installation of stainless steel bubbling probes

2 Procurement and installation of probes and connection of air flow meters together with associated compressed air supply, pressure controllers reductors etc.,
3 Connection of the probe lines to the solution monitoring instrumentation located in a suitable area; preparation of instrumentation area;
4 Modernisation of the other Russian high-frequency inductive level probes of URES and UVM type
5 Calibration of the tanks, provided adequate training has been completed at Ispra and RMTC.
6 Installation of hardware data acquisition systems for archiving of data for analysis
7 Installation of hybrid K-edge densitometer and sample changer in hotcell with integrated sample line.
8 Identification of locations(s) (e.g. IAT) and provision for sample taking and delivery to K-edge.
9 Installation of COMPUCEA in glove box
10 Hardware architecture for computerisation of sub-facilities – data acquisition. Modernisation of computerised accountancy system
11 measurement uncertainties for all in-process inventory contributors as input for NRTA
12 Improvement, production, installation and testing of solution NDA instruments: neutron control detectors and gamma-absorption meters
13 Improvement, production, installation and testing of Waste NDA equipment: neutron control detectors
14 Development and certification of measurements techniques reproducibility for all the implemented measurement systems.
15 Training in the above instrumentation and maintenance; identification of training locations/laboratories

4. Sub-project 4: Equipment to be tendered

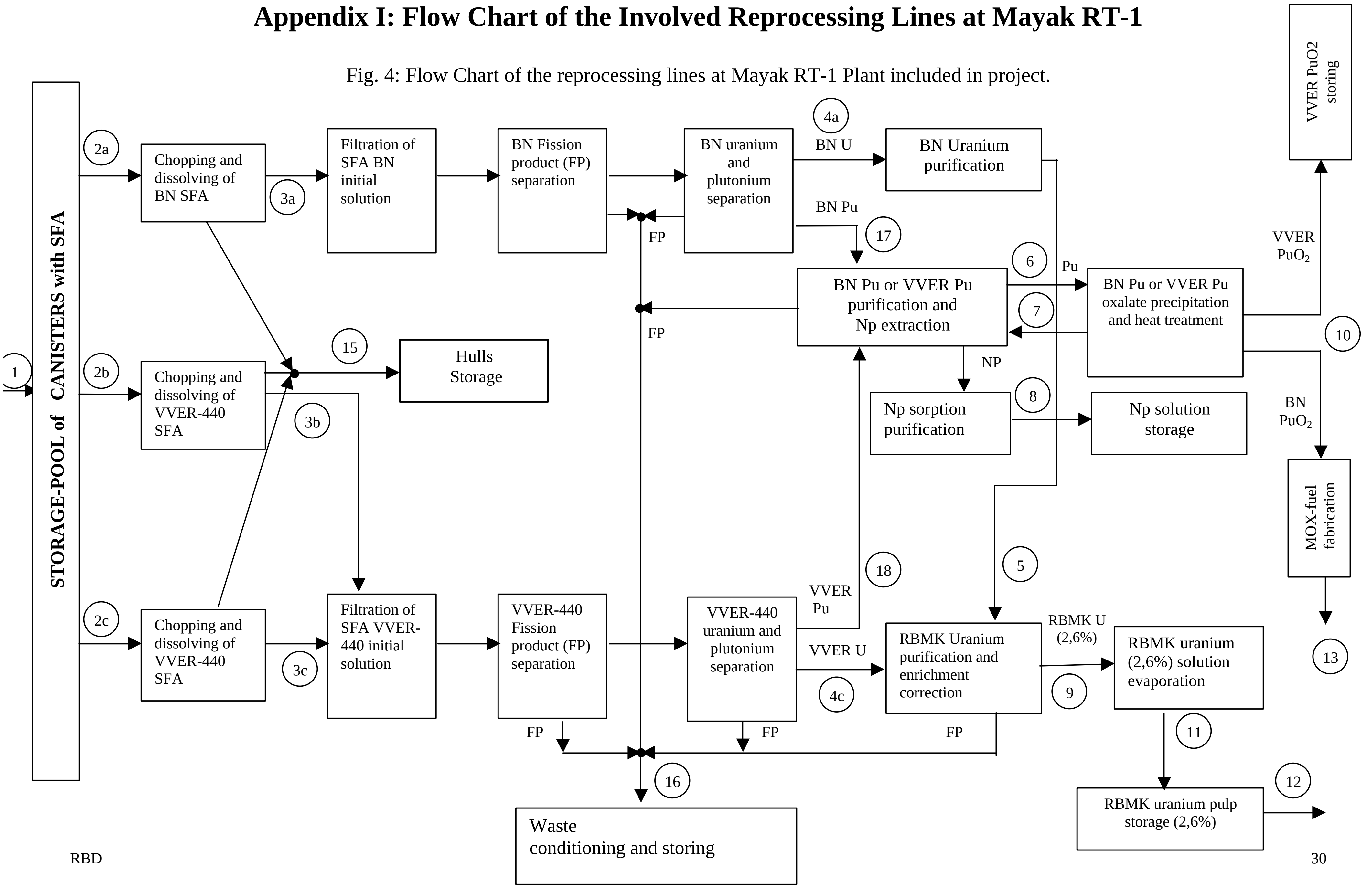
The requirement and need of the equipment will be established and the technical specifications prepared for the tender publication.

5. Sub-project 5: Management Activities

The management activities of the project will be performed by the JRC Ispra. This will be a coordinating role through the different sub-projects and will also include the preparation for the tender of the equipment.

Appendix I: Flow Chart of the Involved Reprocessing Lines at Mayak RT-1

Fig. 4: Flow Chart of the reprocessing lines at Mayak RT-1 Plant included in project.



Designations in Fig. 4:

1 – SFA unloading into storage-pool
2 – SFA preparation to chopping and dissolving
3 – Solution transferring to the process stage for U/Pu separation and purification
4 – U solution for purification
6 – Pu solution transferring for oxalate precipitation.
7 – Oxalate mother liquor
8 – Np solution transferring into Np storage
9 – Uranium solution to evaporation
10 – VVER PuO2 powder transferring into storage, BN PuO2 powder transferring for MOX-fuel fabrication
11 – RBMK UN transferring into the storage
12 – RBMK UN transferring to ULBA fuel fabrication plant
13 – MOX-fuel transferring for fuel assemblies fabrication
15 – Hulls after leaching process
16 – Fission product solution.

Note: The numbers in the Figure doe not correspond to real KMP numbers. The Figure gives an overview of all process lines in RT-1 and serves as basis for the NMAC system modelling and ID calculation.

Appendix II: List of deliverables

Table 3: Deliverables, as discussed in Obninsk (07.07.02) and agreed upon for the TOR in Ispra (23.01.02)

Deliv #	Definition	Explanation
1	Design study and detailed requirements	Overall detailed analysis of the PA Mayak complex activities, with particular focus devoted to the NMAC aspects.
2a	Procurement of bubble probe systems (9 items)	M/V measurement at accountancy tanks (non-pressure operated)
2b	Installation and testing of bubble probe systems (9 items/4 buildings)	non-pressure operated
3	Modernization, installation and testing of modified inductive level meters in 10 key measurement points (under pressure operated)	M/V measurement at accountancy tanks/under pressure operated
4	Gamma-absorptiometers upgrading, installation and testing (40 units, GAS-GAM type)	U and Pu concentration NDA dip measurements in tanks
5	Neutron Control Detectors (NCD) upgrading (50 units)	U and Pu concentration NDA dip measurements in tanks and NDA of hulls, accumulation and hold-up
6	Procurement of 2 Portable NaI gamma-spectrometers	Verification of U enrichment of uranil nitrate paste
7a	Procurement and installation of hybrid K-edge densitometer	Pu and U/Pu concentration measurements in solution samples
7b	Procurement and installation of Compucea	U element and isotopics
8	Procurement of alpha spectrometer	Pu content measurement in solutions samples

10	Procurement of computer hardware and network cabling for computerised solution monitoring	Modernisation of existing NMC&A computerised plant system
11	Procurement of electronic crane scale (up to 5 t)	Measurements of Uranil nitrate paste mass
12	Developing and certifying measurements techniques	Accuracy/reproducibility for all the implemented measurement systems has to be certified with RF GOST
13a	Architecture design for computerised NMAC	from the study (deliverable 1), develope models, error propagation, project specs, software specs etc
13b	Modelling, specifications etc for NRTA	Use Mayak/BNFL previous study for developing models, error propagation, project functional specs, software functional specs etc, for NRTA.
13c	Software for NRTA	write detailed specs for NRTA software; write software
15	Training for RT-1 plant staff	Development and conducting courses for RT-1 plant staff at Mayak and the Russian Training Centers
16	Development and conducting of courses for RT-1 plant staff at JRC	Development and conducting 2 courses for RT-1 plant staff at JRC-Ispra and/or ITU (M/V, instrumentation, COMPUCEA, etc.)
17	RMTC training and calibration M/V calibration facilities, designing and fabrication of mock-up tanks	Development and conducting 4 courses for RT-1 plant staff at RMTC and Mayak
18	Installation of a subwater system of illumination and camera ..	

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List of Abbrevations

BN-600	600 MWe fast reactor, Na cooled
BNL	Brookhaven National Laboratory
BNFL	British Nuclear Fuels
COMPUCEA	Combined product-Uranium Concentration and Enrichment Assay (UN)
C/S	Containment/ Surveillance
DA	Destructive Assay
IAT	Input Accountancy Tank
ID	Inventory Difference
IPSC	Institute for the Protection and Security of the Citizen
IPPE	Institute for Physics and Power Engineering
ITU	Institute for Transuranium elements
HEU	High Enriched Uranium
HLNCC	Passive Neutron Coincidence Counter
HKED	Hybrid K-edge densitometer (for U/Pu concentration in liquid samples)
HLLW	High level liquid waste
HPLC	High performance liquid chromatography
HRGS	High Resolution Gamma Spectrometer
JRC	Joint Research Centre
KMP	Key Measurement Point
LEU	Low Enriched Uranium
MBA	Material Balance Area
MOX	Mixed Oxide Fuel
M/V	Mass/ Volume
NCD	Neutron Control Detector
NDA	Non-Destructive Analysis
NM	Nuclear Material
NMA&C	Nuclear Material Accountancy and Control
NRTA	Near Real Time (Material) Accountancy
NPP	Nuclear Power Plant
NPT	Non Proliferation Treaty
OAT	Output Accountancy Tank
PA Mayak	Production Association Mayak
PIT/PIV	Physical Inventory Taking/Verification
RBMK	(Russian) High Power Channel Reactor (C moderated, H_2O cooled)
RMTC	Russian Methodological Training Centre
SFA	Spent Fuel Assembly
SNL	Sandia National Laboratories
SSAC	(Russian) State System for Accountancy and Control
TVM	Tank Volume Measurement System
UK/ DTI	British Department of Trade and Industry
US/ DOE	US Department of Energy
UVV/UVM	High frequency inductive level probe (single/multichannel analyzer)
VVER-440	(Russian) Pressurized Water Reactor (of ±440 MWe for 230/213 type)