ANNEX I

Work Plan

I. Summary Project Information

1. Project Title

Construction of the Subcritical Assembly with Combined Neutron Spectra Driven by Proton Accelerator at Proton's Energy 660 MeV for Experiments on Long Lived Fission Products and Minor Actinides transmutation

(Phase I: Design, Design Documentation and Safety Substantiation). **EXTENSION**

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3. Participating Institutions

3.1. Leading Institution

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3.2. Other Participating Institutions

Participant Institution 1

Short reference: NIKIET	
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Participant Institution 2

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4. Foreign Collaborators/Partners

4.1. Collaborators

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4.2. Partners–none

5. Project Duration

48 months

6. Project Location and Equipment

Institution	Location, Facilities and Equipment
Leading Institution	JINR, 141980, Dubna, Russia. 660 MeV Phasotron, building #1, rooms 35, 38; FLNP building 42, rooms 58, 65
Participant Institution 1	NIKIET, 101000 Moscow, St. Krasnoselskaya 2/8, Russia, room 301
Participant Institution 2	Mayak, 456780, Ozersk, Russia. PAKET pilot plant, building #1, room 117
Participant Institution 3	GSPI, 107078, Moscow, Novoryazanskaya 8a, Russia, building #1, room 519
Participant Institution 4	VNIINM, 123060, Moscow, P.B. 369, St. Rogova 5A, Russia, building B, rooms 348, 346; building I-3, room 231; building A, rooms 61, 62, 63.

II. Specific Information

1. Introduction and Overview

Creation of large subcritical accelerator driven systems ADS for nuclear waste incineration should precede experimental checks of the theoretical predictions and estimation of technological features of such systems. Tasks requiring the solution are:

- Substantiation of safety of operation of such systems;
- Calculation of the ADS power gain;
- Choice of fuel, target type and reflectors;
- Design of an active core;
- Development of methods of reliable monitoring of keff;
- Measurement of the ADS power gain;
- Measurement of the contribution of high-energy (E >10 MeV) part of a neutron spectrum, especially important for creation of reliable radiation protection.

To resolve these tasks an ADS with thermal power of about 25 kW is sufficient.

In JINR the experimental and theoretical works on usage of the proton accelerators in nuclear technology are conducted from middle of the 50-s' years. The yields of neutrons and their spectra in lead and uranium targets of various types, neutron cross sections for a number of isotopes, important for an estimation of efficiency of various modes of transmutation are measured, the mathematical models with appropriate databases and software for calculation of electronuclear systems properties are created. JINR has the license for operation the research nuclear reactors with active cores with metal plutonium and plutonium oxide. These reactors are maintained reliable and safely within more than 35 years. JINR has also the long-term experience of operation of proton accelerators. All mentioned above is a good basis for creation and subsequent use in Dubna of the experimental ADS with MOX fuel. The JINR international status allows joining the financial contributions of the JINR member countries. The creation in JINR of the subcritical assembly with MOX fuel based on standard fast neutron reactor BN-600 fuel elements, will give unique experimental basis for solving the complex tasks connected to a problem of safe operation and maintenance of subcritical fast assemblies driven by proton accelerator for nuclear waste transmutation.

Given project will be the natural step on the way from experimental subcritical assemblies of zero power, driven by external neutron source (MASURCA, BFS, YALINA) to proton beam driven semi industrial installations (MYRRHA, XT-ADS) which are now in the design in Europe.

2. Expected Results and Their Application

During implementation of the present project the complex of the design and construction works will be fulfilled according to normative documentation of Russian Federation and in volume providing in future creation of experimental installation SAD at JINR, and also the time profile and financial expenditures on its creation will be defined. In particular works on the active core (AC), proton beam line and fuel element (FE) technical projects will be fulfilled, the technology of manufacture of fuel pellets made of MOX fuel will be designed, the technology of manufacture and assembling of the FE will be prepared and tested, production will be prepared and test batch of the fuel pellets will be manufactured. Within general engineering project the part of the project, necessary for licensing will be released, including substantiation of the safety operation (SSO).

It will allow at presence of sufficient financing creating experimental installation (SAD) on the basis of the proton accelerator with energy 660 MeV with replaceable target and subcritical blanket with mixed-oxide (MOX) uranium-plutonium fuel.

In the present project the following tasks will be fulfilled:

- On the basis of computer codes developed in JINR and other centers, modeling of the process of interaction of protons with a heavy target and ADS parameters will be carried out to optimize the installation design.
- Optimization of the spallation target design, estimation of the effects of charged particle interactions with the fuel in vicinity of a spallation target will be realized.
- Experimental ADS installation based on subcritical assembly with keff ≈ 0.95 and JINR proton Phasotron with thermal power –about 25 kW will be designed (design and calculation documentation developed).
- The following computer codes will be used in SAD-project: MCNP/MCNPX, CEM and eventually some others, depending on collaboration within SAD project.

At the following stage – stage of creation and maintenance of the installation the following tasks will be solved.

- Documentation of equipment for the plants-manufacturers will be designed.
- The complex of civil work will be fulfilled.
- Equipment will be manufactured and mounted on site.
- The starting-up and adjustment works will be carried out and putting of the installation into operation will be realized.
- Main characteristics (neutron yield, spectral and angular distributions) of the heavy neutron producing targets made of Pb, Pb-Bi, W will be measured. It’s characteristics dependencies on proton energy, dimensions and shape of the proton beam will be studied. Those data, if appropriate will be used for validation of the computer codes.
- The measuring techniques for neutronic and kinetic characteristics of subcritical assembly will be prepared and the first test measurements are conducted. The equipment and techniques for realization of experiments on measurement of minor actinides and fission products transmutation reaction rates in subcritical assembly will be prepared.

3. Meeting ISTC Goals and Objectives

The implementation of the SAD project will give the scientist and experts bound with the weapon from organizations participating in the project the possibility for applying their abilities on peace activity. The task, which will be solved in the project, lies within of one of the most priority directions of scientific and technical development of a modern society – problem of the spent nuclear fuel and radioactive waste management.

The implementation of the project directly is coupled to support of fundamental and applied researches and development of technologies in the peace purposes, especially in the field of protection of an environment, energy production and nuclear safety.

The JINR participation in the project as leading organization will allow effectively carry out an integration of scientists from the JINR member-countries (countries of former USSR, Czech, Poland, Romania, Bulgaria, other JINR member-countries) in solving the fundamental and applied tasks connected to realization of the project.

4. Scope of Activities

Within the first stage of ISTC project #2267 all tasks determined by the working plan have been executed, namely – the technical design of SAD installation is developed, the safety analysis report is prepared, the technology of fuel pellets fabrication is prepared and the experimental batch of fuel pellets is manufactured. During the project extension it is supposed to start the tasks connected to a technological part of the project, which lay on a critical path of the network diagram of the project. It will enable to keep rates of realization of the project during preparation of a technological part of the project.

At a stage of the project realization it is planned to carry out the following tasks:

Task 1 Documents preparation for the physical startup and putting into operation

Task description and main milestones		Participating Institutions
1.1	Development of the design quality control program;	1- JINR, Dubna, Russia
1.2	Technical project update;	2- NIKIET, Moscow, Russia
1.3	Safety assessment;	3- GSPI, Moscow, Russia
1.4	Development of the physical startup program;	
1.5	Development of the nuclear safety instruction on FE and FA;	
1.6	Permission on FE and FA storage;	
1.7	Documents preparation for the operational license;	
1.8	Final report preparation.	
Description of deliverables		
1	Technical report	

Task 2 Licensing

Task description and main milestones		Participating Institutions
2.1	License on allocation and creation of the facility;	1- JINR, Dubna, Russia
2.2	Operational license;	2- NIKIET, Moscow, Russia
2.3	Final report preparation.	3- GSPI, Moscow, Russia
Description of deliverables		
1	Technical report	

Task 3 Subcritical assembly (SA), optional protection and first loop equipment

Task description and main milestones		Participating Institutions
3.1	SA working design;	1- NIKIET, Moscow, Russia
3.2	Tender on manufacturing;	2- JINR, Dubna, Russia
3.3	Manufacturing of the equipment;	3- GSPI, Moscow, Russia
3.4	Procurement;	
3.5	Equipment assembling;	
3.6	Balancing and commissioning;	
3.7	Acceptance evaluation, licensing, certification;	
3.8	Final report preparation.	
Description of deliverables		
1	Technical report	

Task 4 Facility building

Task description and main milestones		Participating Institutions
4.1	Working design (building drawings);	1- GSPI, Moscow, Russia
4.2	Working design (equipment assembling);	2- JINR, Dubna, Russia

4.3 Tender on building construction; 4.4 Geophysical investigation of the soil to be excavated; 4.5 Excavation, existing constructions dismantling; 4.6 Geological engineering and geodesic survey; 4.7 Foundation building; 4.8 Building construction; 4.9 Working design of the special crane; 4.10 Manufacturing of the special crane; 4.11 Special crane assembling and putting into operation; 4.12 Equipment assembling in concrete bulk; 4.13 Finishing of the construction works; 4.14 Diking restoring; 4.15 Rough finishing; 4.16 Fine finishing; 4.17 Land improvement; 4.18 Final report preparation.	

Description of deliverables	
1	Technical report

Task 5 FA production line

Task description and main milestones	**Participating Institutions**
5.1 Calculation of the critical masses; 5.2 Requirement specifications on equipment; 5.3 Technical project; 5.4 Equipment manufacturing; 5.5 Construction and assembling work; 5.6 Design work on containers; 5.7 Containers manufacturing; 5.8 FE and FA imitators manufacturing; 5.9 Design of the production line; 5.10 Construction and assembling work; 5.11 Putting into operation; 5.12 FA technology developing; 5.13 Final report preparation.	1- JINR, Dubna, Russia 2- VNIINM, Moscow, Russia 3- NIKIET, Moscow, Russia

Description of deliverables	
1	Technical report

Task 6 Fuel

Task description and main milestones	**Participating Institutions**
6.1 Pellets fabrication; 6.2 FE working design; 6.3 Component parts manufacturing;	1- JINR, Dubna, Russia 2- VNIINM, Moscow, Russia 3- IA Mayak, Ozersk, Russia

6.4	Cladding tube manufacturing;	
6.5	Cladding tube delivery to Mayak;	
6.6	FE production;	
6.7	FE acceptance and certification;	
6.8	Design and manufacturing of FE transport containers;	
6.9	FE delivery to JINR;	
6.10	FA components manufacturing;	
6.11	FA production;	
6.12	Core assembling;	
6.13	Final report preparation.	

Description of deliverables	
1	Technical report

Task 7 Beam line

Task description and main milestones		Participating Institutions
7.1	Beamline working design;	1- JINR, Dubna, Russia
7.2	Vertical deflecting magnets manufacturing;	2- GSPI, Moscow, Russia
7.3	Magnetic elements manufacturing;	
7.4	Magnetic elements delivery to JINR;	
7.5	Vertical magnets assembling;	
7.6	Beam line equipment assembling;	
7.7	Beam line balancing and commissioning;	
7.8	Beam line test facility	
7.9	Final report preparation.	

Description of deliverables	
1	Technical report

Task 8 Physical security

Task description and main milestones		Participating Institutions
8.1	Vulnerability estimation;	1- JINR, Dubna, Russia
8.2	Conceptual specification development;	2- GSPI, Moscow, Russia
8.3	Tender participants selection;	
8.4	Tender, conclusion of a contract;	
8.5	Requirements specification;	
8.6	Technical project;	
8.7	Sketch project;	
8.8	Working design;	
8.9	Equipment manufacturing and delivery;	
8.10	Equipment assembling;	
8.11	Balancing and commissioning;	
8.12	Equipment training;	
8.13	Commissioning;	

8.14	Final report preparation.	

Description of deliverables	
1	Technical report

Task 9 Automatic control system

Task description and main milestones		**Participating Institutions**
9.1	Conceptual specification development;	1- JINR, Dubna, Russia
9.2	Tender participants selection;	2- GSPI, Moscow, Russia
9.3	Tender, conclusion of a contract;	
9.4	Design work;	
9.5	Equipment manufacturing and delivery;	
9.6	Equipment assembling;	
9.7	Balancing and commissioning;	
9.8	Commissioning;	
9.9	Final report preparation.	

Description of deliverables	
1	Technical report

Task 10 Development of the scientific experimental program, physical startup

Task description and main milestones		**Participating Institutions**
10.1	Requirement specifications on experimental channels (EC);	1- JINR, Dubna, Russia
10.2	EC technical project;	2- NIKIET, Moscow, Russia
10.3	EC working design;	
10.4	EC equipment manufacturing;	
10.5	EC equipment assembling, balancing and commissioning;	
10.6	EC equipment assembling, balancing and commissioning;	
10.7	Development of the experimental program;	
10.8	Physical startup;	
10.9	Commissioning;	
10.10	Final report preparation.	

Description of deliverables	
1	Technical report

5. Role of Foreign Collaborators/Partners

According to by-law ISTC documents foreign collaborators will have the following involvement in development of the project proposal and its realization:

- Information exchange during realization of the project
- Joint review of the technical reports
- Joint workshops and consultations
- Check of results with usage of independent methods
- Parallel research efforts
- Advice on the intellectual property rights in case of the share inventions

Foreign collaborators together with project manager and sub-managers (V. Shvetsov, I. Tretyakov, M. Vorontsov, I. Golovnin, B. Ryabov) and an ISTC-representative (project “curator”), will form a SAD Advisory Group. This group will be responsible for:

- All collaborative efforts between the SAD-project management and foreign collaborators;
- Approval of changes in the work plan;
- Dissemination of SAD reports and results;
- Integration of SAD-project into European activities in ADS-field;

SAD Advisory Group will meet at least once a year. Foreign collaborators in consultancy with ISTC will prepare a short document (white paper) specifying the duties and working platform of this Group.

SAD Advisory Group will prepare annually a short activity report to be sent to the ISTC office in Moscow and to the ISTC Contact Expert Group on Transmutation related projects.

6. Technical Approach and Methodology

The purpose of the project is realization of the designed subcritical assembly with plutonium MOX fuel driven by proton accelerator with energy 660 MeV according to the requirements of normative documents of Russian Federation. The various concepts of installations for minor actinides (MA) and long lived fission products (LLFP) incineration are now considered, with a neutron source based on nucleon-hadron cascade arising at interaction of a beam of protons with energy 0.5 – 2 GeV with the target. As targets in such installations it is supposed to use “heavy” materials: Pb, Pb-Bi, W.

In JINR the various concepts of demonstration electronuclear installation were studied which differed by a type of fuel used in subcritical blanket. Now preference is given back to creation the MOX blanket, as it is more preferable to use developed electronuclear systems, by virtue of the increased nuclear safety, for utilization of military and power Pu.

An opportunity of creation of subcritical assembly on the basis of experimental FE of BN-600 reactor, manufactured in Russia, with MOX fuel, is presented.

Configuration of the SAD installation

- The proton accelerator with energy 660 MeV.
- Beam transport line.
- Replaceable targets of various length and material (Pb, W, Pb-Bi).
- Subcritical multiplying blanket with FE of a BN-600 type with $k_{eff} \approx 0.95$.
- Reflector and radiation protection.
- Systems of cooling of a target and blanket.
- Blanket and target cooling systems.
- Protective and monitoring systems.
- Other systems and components necessary for safe maintenance of the installation.

Basic data

SAD project basic features are determined with “Phasotron” JINR proton accelerator characteristics and usage as a basic FE serially released in Russia MOX FE of a BN-600 reactor. Low proton current (maximum value is 3.2 μA) and correspondingly power released in heavy target determines total thermal power of the installation because 0.95 limits effective multiplication factor[1] of the installation. Thus, installation described in the project, is the prototype for the future subcritical reactors of an industrial scale, which projects now are actively considered in many countries with developed nuclear technology, for example project of installation XT-ADS in EC 6 FP IP EUROTRANS with power of a proton beam from a LINAC with about 2-5 MW and total thermal power –50-100 MW[2].

[1] Effective multiplication factor – ratio of the effective average number of neutrons appearing in the reactor in a unit of time to the effective average number of neutrons disappearing in a unit of time (the absorption by the nuclei, leakage from the reactor).

[2] Annex I IP EUROTRANS, FI6W-CT-2004-516520

The basic data of the project, parameters of the accelerator and MOX fuel characteristic are listed in the following tables:

SAD installation basic data

Thermal power	15 ÷ 20 kWt
Protons energy	660 MeV
Beam power	0.75 ÷ 1 kWt
Proton beam / target orientation	Vertical
Fuel elements orientation	Vertical
Criticality coefficient	$k_{eff} \approx 0.95$
Fuel - see table below for details on composition	MOX, $UO_2 + PuO_2$
Cladding tubes maximum temperature	400° C
Spallation target	Replaceable: Pb, Pb-Bi, W
Reflector	Pb
Coolant	Air

JINR Phasotron beam parameters

Intensity of the extracted proton beam:	3.2 μA ($1.997 \cdot 10^{13}$ protons/s)
Beam emittance:	$\Sigma_x = \pi(5.1 \pm 2.3) cm \cdot mrad$ $\Sigma_y = \pi(3.4 \pm 1.4) cm \cdot mrad$
Time structure	
Fast extraction	
Frequency	250 Hz
FWHM	20 μs
Number of protons in pulse	$0.8 \cdot 10^{11}$
Slow extraction	
Frequency	250 Hz
Pulse width	3500 μs
Beam microstructure	
Micropulse FWHM	10 ns
Micropulse period	70 ns

Basic features of the SAD core fuel

Parameter	Value
Fuel composition	($UO_2 + PuO_2$)
Plutonium dioxide content in fuel composition, %(mass)	Up to 30*
^{239}Pu content in Pu %(mass), not less than (with accuracy not worse than 10^{-4} for basic isotopes)	95
Fuel density, g/cm^3	From 10,0 to 10,7
Fuel pellet diameter, mm	5,95*

*– parameters become defined more accurately during FE design

The installation will be equipped with experimental channels, which will allow to dispose in different parts of installation detectors and isotopic samples and to extract them after an irradiation.

Key solutions on arranging and allocation of installation

The main part of the SAD installation is multiplying subcritical blanket. GSPI team together with DLNP and FLNP staff considered different modifications of subcritical blanket allocation:

- Allocation between outer walls of the Phasotron main building and complex YASNAPP outhouse;
- Allocation near outer wall of the main Phasotron building near communication gallery;
- Allocation at the ground floor of the Phasotron main building.

The most extensively were worked out variants with blanket allocation outside accelerator building. Cardinal differences of the blanket allocation inside accelerator building are the next:

- Absence of the external radiation shielding (accelerator building walls will act as radioprotection);
- Necessity to arrange inside accelerator hall another separate secured room with heavy concrete body for blanket accommodation.

For normal operation of the installation SAD the following locations should be arranged:

- Control room – 36 m^2;
- Switchgear room – 36 m^2;
- Blanket cooling system room – 36 m^2;
- Incoming vent chamber – 54 m^2;
- Exhaust vent chamber – 36 m^2;
- Sanitary inspection room for 20 person – 80 $м^2$;
- Corridors, stairs. Total area – 130 $м^2$.

For allocation of the indicated rooms the outhouse to the main accelerator building should be created. Total area of that outhouse should be about 400 m^2. It could be designed as two-storied annex with dimensions in plan 15 x 9 m2, at the same time some rooms of the Phasotron building should partially used.

Technical and economic estimations of different variants of the installation allocation lead to the conclusion about final SAD allocation between Phasotron building and YASNAPP annex. Accepted variant envisages vertical allocation of the multiplying blanket.

Subcritical assembly

The installation is designed starting from usage of the Phasotron existing at JINR as a proton source, that decreases significantly total of the accelerator – blanket complex. The installation is designed with orientation on MOX fuel such as at BN-600. SAD should be experimental prototype installation of an electronuclear type demonstrating and investigating "burning out" of actinides and long-lived fission products operating on specially designed program of experimental researches.

The installation will be created on the territory of Russia and should satisfy to regulations, operating in Russian Federation, and requirements of safety. The program of experimental research is developed for this installation now, therefore total resource is not installed, but it is supposed not to be less than 10 years.

SAD subcritical blanket is placed within biological shielding, which is made of heavy concrete and placed in radial and top directions from active core (AC). In a downward direction shielding could be made of the ordinary concrete. There are borings within shielding bulk intended for allocation of the vertical and horizontal experimental channels, proton guide, cooling systems pipes and neutron power control channels. Upper part of the biological shielding is made demountable to provide access to the blanket and target during charge/discharge operations. In radial direction the biological shielding represents empty cylinder enveloped with stainless still sheets. To the outer part of the cylinder the beryllium insert with two vertical channels 30 mm in diameter joins. Channels are made of aluminum alloy and equipped with steel plugs.

Inside the cylinder of biological shielding at the supports embedded into concrete the stand representing stainless steel cylindrical shell with two flanges is installed. Into that stand the lead plates forming lower faceplate reflector are installed. In the reflector two horizontal experimental channels 80 mm in diameter made of stainless steel are disposed. These channels are located 650 mm lower than AC center, one of them crosses the central axis of the installation and the other one is located tangentially at 375 mm distance from the first. Both channels are equipped with stepped protective plugs. On the upper flange of the support the AC stainless steel case is placed. Case is intended for allocation of the replaceable targets, fuel blanket and also for creating cooling air flows. Replaceable targets are made identical but of different materials (Pb, Pb-Bi eutectic, W). Target represents cylindrical core with spiral groove on generatrix and outlying segments. Core is installed into the inner shell where path for cooling air is organized. Pipes make air supply and removal in upper and lower parts of the outer shell. Outlying segments create closed structure, which mates with the first row of fuel assemblies (FA) by outer surface and with inner shell by inner surface. In the upper part of the shell the thin-walled pipe leading proton beam to the target core.

AC consists of 129 FA, which are installed into support grating on triangular grid. Support grating is perforated with holes for FA installing and cooling air supply. It is fixed inside AC case and forms with the case floor the cavity for distribution air-cooling FA and outlying segments of the target.

FA represents set of 19 FE with MOX fuel, positioned between each other with the FA end pieces. FE are situated in a triangle lattice. FE cladding is made of stainless steel. Outer diameter of the fuel pellet is equal to 5.95 mm, inner one – to 1.7 mm. Average $(U+Pu)O_2$ fuel density is 10.2 g/cm^3. Bearing element of the FA is the central tube, welded with end pieces. Lower end piece has shank for FA positioning in support grid, upper end piece has spacers and head for locking on the charge/discharge tools.

The cooling of AC and targets is carried out by the air coolant medium with the help of two independent systems. The cooling of a target realized with open loop. The AC and outlying target segments are cooled with the closed loop.

Beam transport line

JINR Phasotron has the branchy system of 10 beam channels of used in various experiments.

On DLNP Phasotron experience of development, creations and maintenance of proton beam channels is already accumulated. Beam lengths are as high as 50 meters – to YASNAPP-2 and "Wide-aperture pi- meson lens" installations (channels XII and IX) with beam transition down to the level of the first floor of the Phasotron building with efficiency up to 94 %.

The existing radiation protection allows completely absorb output proton beam with intensity up to 2.0 μA in accelerator hall or in beam-stops at channels XII and IX.

In the beam transportation system usage of the following main magnetic elements is supposed: a deflecting magnet such as an OM-1, doublet of quadrupole lenses such as ML-3, and also their different modifications. The beam transfer from horizontal in a vertical plane is planed to realize with usage of two bending magnets made on the basis of ARES installation coils. ARES installation was dismantled on summer 2002.

Magnets OM-1 and doublets ML-3 are exploited in proton beam channels for a long time. The modifications to their design have been made several times and for designed installation their last variant is selected.

To provide reliable beam transportation on existing "T" – route and new route to the SAD installation without mechanical motion of the magnetic elements one suppose using of modified C- shape magnet, which design now is in progress. Such magnet will have identical with OM-1 magnet drive winding, but modified yoke for saving the value of a magnetic field in its gap.

Besides other modification of the OM-1 magnet are studied which can increase deflection angle owing to reallocation of a magnetic field in a gap by decreasing width of a magnetic track its simultaneous elongation, and also decreasing influence of edge fields.

Both in the basic OM-1 magnet, and in its modified variants, the form of the pole shoe will be profiled on side edges of a pole gap for the extension of area of a homogeneous magnetic field in a transverse direction or decreasing pole width for increasing magnetic field in a gap.

In some schemes of transport channels it will be possible to use profiled pole extensions, providing a strong focusing in systems with high number of the sequentially located deflecting magnets with interleaving signs of magnetic field gradient.

Proton beam is transported inside vacuum pipe. Inside lenses it is completed from pipes with an outer diameter of 100 or 120 mm, and in magnets the box-type chambers with steel covers and sidewalls from stainless steel are applied. The assembling of vacuum system is fulfilled with application of centering sealing and quick disconnect clamps. The compensation of inaccuracies of assembly is yielded by sylphons. The modular structure of beam transport system allows creation of different channels depending on choice of SAD place location, its layout and direction beam input.

Strong deflecting magnets on the basis of ARES installation windings now are not designed. The calculations of several variants with usage 2D and 3D computer models are carried out only. These calculations allowed to select final variant of beam transfer into vertical plane turning it on 120 degrees with two magnets, each providing 60 degrees deflecting angle and has radius of curvature of a magnetic track of 3 meters (required field in a gap – 1.45 T). The calculations have shown, that at usage of the trapezoidal form of a pole the efficiency of a magnet is boosted approximately on 15 % in comparison with rectangular. The calculations were carried out on the basis of two two-dimensional models (program SUPERFISH) and three-dimensional model (program RADIA). The magnetization curves of a magnet for two values of a pole gap – 6 and 8 cm were calculated.

To obtain most homogeneous magnetic field distribution in a gap the geometry of a pole was adjusted (end edges 10 x 45° and pole extensions 1.5 x 20 mm were added).

As a result of calculations the following conclusions are obtained:

- The most optimal configuration is represented by the structure consisting of two 60° magnets with radius of curvature of a magnetic track 3 meters;
- Working field in each magnet (1,45 T) can be provided at a pole gap 6 – 8 cm with a reserve on an exciting current, as a minimum, 100 % - 22 %, accordingly;

- Usage of two strong deflecting magnets, at growth of an overall dimensions and weight of entire installation, makes it more cost-effective.

Experimental program

Research program for SAD installation now is forming in collaboration between scientific teams and design organizations. Experimentalist's requirements are reviewed by designers and receive evaluation from point of view of reliability. Dimensions and positions of the experimental channels, which are necessary for scientific experiments, are determining, requirements on locations are establishing, necessary equipment is listing.

One of the most important tasks for subcritical assembly physics is the problem of reactivity measurements and monitoring at high subcriticality. Investigations in that direction are carrying out at zero power subcritical assemblies with fast (MASURCA) and thermal (YALINA) neutron spectra. This task resolution is extremely important step on the way to creation of the industrial scale ADS facilities, dedicated for radwaste transmutation, because reactivity fluctuations, proton beam parameters influence on reactivity characteristics of the subcritical blanket determine drastically the safety substantiation for such systems.

In SAD scientific program it is proposed to pay attention for experiments on measurements and monitoring of the k_{eff}. It is planned to measure k_{eff} average value by means of inverse multiplication, asymptotic period and other techniques. Time structure of the proton beam (see Table 5) gives wide possibilities in application of the so-called pulse technique of reactivity measurements, in which one measures neutron flux decreasing time constant. That time structure also gives possibility to measure the influence of blanket surrounding (concrete shielding) on its neutronic properties.

The program on measurements neutron spectral flux densities and power release at different parts of the installation, prompt neutrons lifetime, and effective fraction of the delayed neutrons is planned.

To measure spatial and energy characteristics of the neutron field inside subcritical assembly one suppose to place in the target and fuel part of the core specially selected experimental samples, which permit to measure threshold reactions rates. To investigate neutron field in fast energy region absolute reaction rates will be determined for ^{209}Bi, ^{115}In (or ^{197}Au), ^{59}Co, and ^{27}Al.

Besides that samples made of multi component alloy ^{55}Mn+^{63}Cu+^{197}Au+^{176}Lu will be used for measurements (n,γ) reaction rates in thermal and resonance energy region (up to 1 MeV).

It is planned to measure also following spectral indices using ^{235}U, ^{239}Pu, and ^{238}U:

- ^{235}U(n,f)/^{238}U(n,γ);
- ^{239}Pu(n,f)/^{235}U(n,f);
- ^{238}U(n,f)/^{235}U(n,f).

One of the experimental fields of investigation at SAD facility will be actinides and U, Pu isotopes fission rates measurement. This cycle of research will be conducted in collaboration with ITEPH. One suppose using isotopic layers, manufactured and certified during ISTC projects #17, #1145 and #2405 implementation. For FP registration the dielectric (glass) track detectors (SSNTD), insensitive for another radiation will be used. In each measurement one array containing studied isotope and track detector will be placed in corresponding location inside the blanket together with similar array consisting of track detector and monitor isotope (^{235}U or ^{239}Pu). Corresponding reaction cross-section ratios to fission cross-section of the monitor isotope one can consider as spectral index. Each glass will be developed manually, that permits to decrease significantly errors caused by false tracks.

It is planned to place inside the target samples made of the same material and also samples of other enriched isotopes in which spallation products yields due to irradiation with target/blanket proton/neutron field will be investigated. Using data on isotope yield cross sections obtained in ISTC projects #1372, #2002, proton spectra at sample locations will be unfolded. To measure secondary product yield cross section for the target material the helium gaseous loop passing through the target at different distances from the beam entrance point will be designed and created. Secondary products represented by the recoil nuclei entered in the channel inside a target are picked up by a stream of gas and transported to the gamma-detector analyzing isotope composition and absolute values of activities of spallation products. Extremely small time of transportation (1 – 5 seconds) permits one to measure precisely short-lived products and to restore initial isotope composition with much higher accuracy in comparison with other methods.

May be the most important scientific task for the SAD installation will be computer codes and nuclear data used for ADS modeling tests and adjustment. At present time some reaction rates calculated by different codes, differ in some times, completely excepting an opportunity of accurate calculation of physical characteristics and technology requirements for installations of industrial scale. At SAD design and manufacturing stages the basic task will be to describe with maximum precision isotope and element composition of SAD components its geometry. It will enable to expect in future that all experiments described above could be compared with results of calculations. Thus, all experimental works spent on installation, become benchmark tests of computer codes and nuclear databases used today.

7. Technical Schedule

Project technical schedule is located in separate file.