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Collection of meeting reports, quarterly reports and annual reports from the ISTC project HOT ASTRA

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Advanced High-Temperature Reactors for Cogeneration of Heat and Electricity R&D
EC Scientific Officer: Dr. Panagiotis Manolatos

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Summary

This report contributes to task 2.4.3. The objective of this task was collaborate with ISTC project #685.2 (?HOT ASTRA?) to ensure that project results concerning HTGR core physics at elevated temperatures are transferred to EU FP project partners, through the (established) western collaborators (AREVA and NRG). ISTC project #685.2 "Self-protection of reactors", nicknamed "HOT ASTRA", at the Kurchatov Institute (Moscow) aimed at obtaining experimental data on the criticality of pebble-bed HTR configurations at elevated temperatures. One of the expected results was the graphite temperature coefficient of reactivity at high temperatures. This is key information would improve the validity and reliability of nuclear analyses, in the high temperature region. This report presents a collection of updates from the project and meeting reports, gathered during the duration of the ARCHER project. It also includes a travel report from a visit held in December 2012.

Approval

Date	By
11/02/2015	Michael BUCK
12/02/2015	Norbert KOHTZ
12/02/2015	Steven KNOL

Distribution list

Name	Organisation	Comments
P. Manolatos	EC DG RTD	Through the EC participant portal
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Table of contents

Summary - Document content

This document contains a collection of reports that were made available from the Kurchatov institute to the ARCHER project. Many reports were produced during the project, the reports collected in this deliverable describe the initial outline of the project in the Detailed Work plan of the project, followed by a collection of update reports, describing the progress within the project. The final results are reported in a separate report, also submitted as a separate deliverable within ARCHER (D24.32).

Table 1 shows the documents included in this report, with a short description of its content.

Table 1 : Overview of included documents

	Title	Pages	content
1	Detailed Work plan	17	Describes the initial project plan and scope
2	Annual Project Technical Report - on the work performed from December 1, 2007 to November 30, 2008	19	Describing the project progress during the first year of the project
3	Minutes of the Meeting with the Collaborators under ISTC Project 0685.2 “Hot ASTRA”	2	Protocol for meeting March 2008
4	Quarterly Technical Report on performance of works in the period from June 1, 2009 to August 31, 2009 - Quarter # 7	9	Quarterly report
5	Hot ASTRA Meeting report December 2012	9	Report of meeting in Moscow, December 2012
6	Letter from A. Balanin	1	Letter describing to the international partners that delays occurred, and an extension was requested.

1. Detailed Work plan

ANNEX I

Work Plan

I. Summary Project Information

1. Project Title

Nuclear Safety and Inherent Self-protection Investigations for Modular High Temperature Gas-cooled Reactors (HTGR-M)/Experimental Demonstration in the ASTRA Facility of the Inherent Safety Characteristics of HTR's

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3. Participating Institutions

3.1. Leading Institution

Short reference: RRC Kurchatov Institute	
Full name: Federal State Institution Russian Research Center Kurchatov Institute	
Street address: Kurchatov sq. 1	
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ZIP: 123182	**Country:** Russia
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3.2. Other Participating Institutions

Participant Institution 1

Short reference: OKBM	
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4. Foreign Collaborators/Partners

4.1. Collaborators

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4.2. Partners

None.

5. Project Duration

24 months

6. Project Location and Equipment

Institution	Location, Facilities and Equipment
Leading Institution	Russian Research Center "Kurchatov Institute" (RRC KI), Bld. 116 (Rooms 4, 22, and ASTRA facility), Bld. 135 (Rooms 305, 306, etc.) and Experimental Design Bureau of Machine-Building (OKBM), Bld. 33, Rooms 702, 703, 818, 816. Description of main equipment existing at RRC KI: • ASTRA critical facility for investigation of neutron-physical characteristics of high temperature gas-cooled reactors (HTGR) at room temperature. • Critical assemblies simulated HTGRs being investigated at the ASTRA facility represent graphite structure of the side, bottom and top reflectors with the cavity in the central part that is filled with fuel elements forming a core. • Computers and office equipment. • Design and drawing equipment. • Machine shop equipment for fabrication of devices, units and parts developed under the Project. The ASTRA facility is completed with necessary experimental procedures, experimental equipment, staffed with skilled personnel, and provided with safety and control systems required for neutronic investigations.

	Modernized at RRC KI: To perform the proposed modernization of the ASTRA facility and conduct investigations at the facility, new equipment, devices, units and parts shall be designed, fabricated and purchased that would allow operating assemblies at high temperatures as applied to modular HTGRs: • The ASTRA facility assembly will be heated with special electric heater. • It is suggested that the critical assembly of the modernized ASTRA facility be placed in a metal vessel with thermal insulation. • The cooling system will be located on the periphery inside the vessel. The annular type of core simulating the Generation IV reactor will be created at the modernized ASTRA facility. Most of the above mentioned components of equipment and devices to be enhanced are custom developed and will be fabricated at pilot production facilities of OKBM and RRC KI. In addition, there shall be purchased modern equipment for dose monitoring during operations, computer equipment with software for processing of measurement results, instruments for neutronics experiments, etc.
Participant Institution 1	Experimental Design Bureau of Machine-Building Building 33, rooms 702, 703, 818, 816 Existing at OKBM: • Design and drawing equipment, including computer-aided design systems. • Computers and office equipment. • Machine shop and pilot production equipment for fabrication of devices, units and parts developed under the Project. Complex of facilities for experiments on ball dynamics of HTGR pebble-beds, including studies on pebble-bed porosity with sumulated seismicity.

II. Specific information

1. Introduction and Overview

Modular gas-cooled high temperature reactors with a core of graphite fuel elements being developed in a number of countries (USA, Germany, Japan, Russia, China etc.) have an improved safety and are promising for the next generation of nuclear power plants.

Graphite moderator, fuel particles with multilayer coating dispersed in graphite fuel element matrix, inert coolant (helium) used in them allow high temperature of coolant combined with high reliability and safety of the reactor.

HTGR advantages are based on the following characteristics of this kind of reactors:

- high temperature of coolant at the reactor outlet, low heat rejection to the environment, low intake of cooling water that provides high thermal efficiency, cost effectiveness, and using of direct cycle for the GT-HTGR;

- chemically inert single-phase helium coolant, high heat capacity of the graphite core, high endurance of fuel elements based on fuel particles with multilayer coating, negative temperature coefficient of reactivity;

- low specific activity of the loop and low release of radioactivity to the environment.

All this ensures improved inherent safety of this reactor type.

The large side surface of the modular HTGR combined with its small size makes possible passive removal of reactor residual heat even in the case of full loss of coolant circulation in the primary loop, including loss of coolant.

The modular high temperature gas-cooled reactors are most prepared ones for the new strategy of nuclear power development throughout the world, especially for many small and developing countries in the Middle East, Africa, Latin America, etc.

CFP-based HTGRs using two types of fuel elements are being developed in the world. HTGRs with prismatic fuel elements are being cooperatively developed by Russia, USA, France and Japan, and pebble-bed HTGRs are under development in South Africa, Russia and China.

Since the core melting scenario is excluded for the modular HTGRs (HTGR-M), the safety criterion for them is the maximum temperature at which fission products are effectively retained inside CFP, which is 1600°C. This safety criterion is ensured for the HTGR-M, along with fuel elements operability, even on occurrence of most severe hypothetical accidents with positive reactivity insertion, reduced heat removal from the core, leakage of the primary loop combined with additional equipment failures.

Concepts and designs of different power level HTGR reactors with spherical fuel elements intended for various purposes have been developed in Russia over many years, along with R&D in this area.

The HTGR designs developed in Russia use fuel based on uranium dioxide of different enrichment with uranium-235, namely 21% for VGR-50 and 8% for VG-400 and VGM. However, uranium-235 concentration in the cores of these reactors is approximately the same and corresponds to loading of about 0.5 g of uranium-235 into each spherical fuel element of these reactors, with the diameter of the fuel particle kernel being 500 μm.

Critical facilities were built in Russia for the HTGR neutronics investigations.

A lot of critical assemblies differing in configuration, size and composition of the core were investigated at the ASTRA facility at room temperature. These experimental investigations at room temperature allowed a lot of peculiarities of HTGR-M physics to be studied, and computation methods and codes to be verified.

However peculiarities of the annular core HTGR-M physics and temperature effects that play a large role in ensuring nuclear safety and inherent self-protection have been never studied in the experiments.

Therefore, it is important to use capabilities of the ASTRA critical facility for experiments on the HTGR-M neutronics with heating up to high temperatures under the ISTC Project # 0685.2.

The use of the annular core and internal graphite reflector in the reactor results in peculiarities of temperature reactivity effect and control rod worth. All this generates a need for experimental neutronic investigations of critical assemblies simulating Generation IV reactors with the annular core at the ASTRA facility with heating.

It should be noted that neutronic characteristics of the HTGR-M, including the temperature effect, are essentially determined by the ratio of graphite nuclei to the nuclei of fissile material in the core. The optimum ratio of graphite nuclei to the nuclei of fissile material in the core is the same for the most of HTGR-M reactors being considered in the world, and is about C = 6000-8000. The spherical fuel elements used at the ASTRA facility have the value of this ratio approaching the above number (C = 7000-8000).

Main Project activities:

I Activities on substantiation of experiments at the ASTRA facility with heating up to high temperatures

- Development and improvement of computational models (neutron-physical, thermophysical, dynamic) for study of HTGR-M nuclear safety and inherent self-protection.
- Development and substantiation of a detailed list of neutronic experiments with heating of critical assembly simulating the HTGR-M at the ASTRA facility up to high temperatures.
- Development and substantiation of general programs of experiments and working programs for specific experiments at the ASTRA facility with heating of critical assembly up to high temperatures.

II Modernization of the ASTRA facility for experiments with heating up to high temperatures

- Development of design and technical documentation for the modernized ASTRA critical facility allowing neutronic experiments with heating of critical assembly up to high temeperatures.
- Purchase of materials, equipment, components, and fabrication of nonstandard equipment for the modernized ASTRA critical facility. Erection, adjustment and commissioning of the modernized ASTRA critical facility.

III Performance of neutronics (criticality) experiments at the heated ASTRA critical assembly. Totally about 20-25 critical configurations are planned similar to the PBMR related measurements.

- The first series includes experiments at room temperature (5-6 critical configurations);
- The second series includes experiments with heating of uranium fuelled critical assembly up to high temperatures. The experimental program provides measurement of temperature reactivity effect and its components, critical position of control rods versus core (or/and its parts and reflector) temperature, reactivity margin, etc. (totally about more than 20 critical configurations. For each critical configuration, detailed description will be prepared. The measurements will be accompanied with computations.
- Analysis of experimental results.
- Based on the results of experiments carried out at the ASTRA facility, verification of computational methods, codes and models designed to study nuclear safety and inherent self-protection of the HTGR-M will be performed.
- Issue of scientific and technical reports on this Project for the ISTC, publications, workshops, meetings, presentations, etc.

Scientific works implemented within the ISTC Project 0685.2:

1. Measurement of temperature effect and its components for annular core.
2. Determination of critical position of control rods at various levels of mean temperatures of various components of critical assembly (core, internal reflector, side reflector, outer surface of the outer reflector, etc.).
3. Determination of worth of control rods at various temperatures of the core and reflectors.
4. Determination of reactivity margins, compensated by control rods at various temperatures.
5. Development of computational models intended for studying of safety and inherent safety of HTGR-M type reactors: neutronic model, thermal model, and dynamic model.
6. Verification of computational methods and codes intended for computation of temperature effects and their components, computation of worth of control rods as function of temperature for HTGR of modular type and in case of need improvement of these methods and codes.

<u>Preliminary List of Experiments</u>

<u>Implementation of Neutronic Measurements During Loading of the ASTRA Critical Assembly at Room Temperature</u>

- Determination of critical states during increasing of height of pebble bed of the critical assembly in loading procedure.
- Measurements of worth of individual control rods and groups of control rods at various core heights during fuel loading of the critical assembly.
- Determination of reactivity margins during increasing of the core height.

The preliminary number of critical configurations differ in core height is 4…5. The following experiments performed for each configuration of the critical assembly: determination of critical state, measurement of worth of control rods and groups of control rods, determination of calibration curves for specified control rods, estimation of reactivity margin (taking into account the fact that some of the control rods are used for compensation of reactivity margin during increasing of core height). Spatial relative neutron distribution will be measured at room temperature.

<u>Implementation of Neutronic Measurements During Heating of the ASTRA Critical Assembly</u>

- Determination of temperature effect and its components.
- Determination of critical position of control rods at various levels of mean temperatures of various components of critical assembly (core, internal reflector, side reflector, outer surface of the outer reflector, etc.).

- Determination of worth of control rods at various temperatures of the core and reflectors.
- Determination of reactivity margin, compensated by control rods at various temperatures.

The number of critical states for which the mentioned above experiments are performed is defined by specified temperature step and will be determined in the experimental program. Now, the number of states is estimated as about 20. The figures of the ASTRA critical facility are given below.

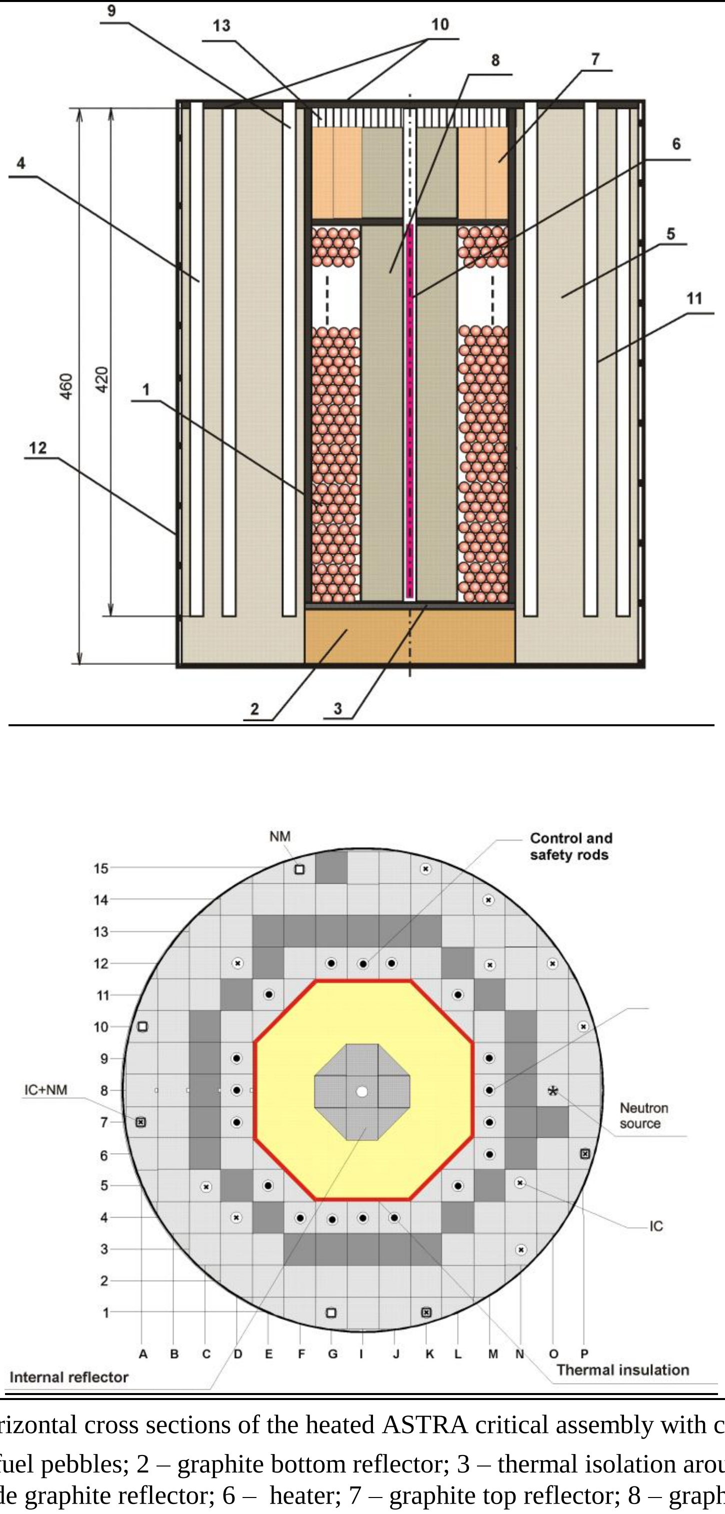

Fig. 1 – The vertical and horizontal cross sections of the heated ASTRA critical assembly with central heater as an example.

1 – the core filled with fuel pebbles; 2 – graphite bottom reflector; 3 – thermal isolation around the core; 4 – channels in side reflector; 5 – side graphite reflector; 6 – heater; 7 – graphite top reflector; 8 – graphite internal reflector; 9 – channels in the side reflector with control rods; 10 – thermal isolation; 11 – neutron source and its channel in the side reflector; 12 – vessel; 13 – thermal insulation, dimensions are given in cm.

About 30 thermocouples will be used to obtain “dense” spatial distribution of the temperature.
The expected precision of temperature measurement is 4.5 C.
The expected precision of temperature coefficient determination is about 10% (relative).

The precision of measurement of worth of manual rod is 1% (relative) as its worth is 0.13 β_{eff} and the precision of measurement of worth of control rod is 0.5% (relative) as its worth is 2.7β_{eff} .

2. Expected Results and Their Application

In executing this Project there will be obtained results of studying of safety and inherent self-protection of modular HTGRs both at normal operation and in emergency situations. Namely, the following will be produced:

Computational models for studying the HTGR-M safety and inherent self-protection will be developed:

- neutron-physical model;
- thermophysical model;
- dynamic model.

Design documentation for modernization of the ASTRA facility will be developed, the modernization will be implemented.

Programs of experiments will be developed, and experimental investigations will be performed at the ASTRA facility. The following will be done at the ASTRA critical facility, RRC KI:

- temperature reactivity effect will be obtained with the critical assembly heated from 20°C to 600°C;
- components of the temperature reactivity effect of this assembly in the same temperature range will be singled out (temperature effect of the core, reflectors, etc.);
- the worth of absorber rods versus temperature will be determined for the same temperature range;
- computational and experimental investigation of inherent self-protection of these reactors with reactivity perturbations will be performed;
- computational methods and codes for determination of temperature effects and their constituents and of control rods worth versus temperature for modular HTGRs will be verified.

Thus execution of this Project will allow the modular HTGR safety and inherent self-protection to be substantiated at minimum cost using the modernized ASTRA critical facility, skilled personnel and research experience available.

At the Preliminary Study Stage of the ISTC Project # 0685.2, the feasibility and advisability of the ASTRA facility modernization for HTGR-M neutronic experiments with heating up to high temperatures (600°C) were demonstrated, and the list of activities under the ISCT Project # 0685.2 "Nuclear Safety and Inherent Self-protection Investigations for Modular High Temperature Gas-cooled Reactors (HTGR-M)" and its funding in full volume for the main stage of the Project were substantiated.

Within ISTC Project # 0685.2, there will be performed substantial volume of critical experiments at the ASTRA facility with heating of the annular core, which will ensure representativeness of results obtained for the GT-MHR reactor.

2.1. Sustainability Implementation Plan

2.1.1. Results to be promoted

Eexperimental data obtained at the modified ASTRA critical facility for validation of HTGR-M safety and inherent self-protection, including temperature effects of the reactor reactivity and of the worth of control rods as a function of temperature intended for validation of codes used in nuclear reactor designing. The IRPhE Handbook benchmark experiment description standards will be used as much as possible to ensure preparation of well-defined benchmark evaluation.

2.1.2. Uniqueness of results

Experiments with heating of an annular core were not performed earlier.
Experiments with heating at the ASTRA facility will be sufficiently representative for all types of HTGR-M reactors.

The ASTRA critical facility will be modernized in the course of the work under the ISTC Project # 0685.2 to enable HTGR-M neutronics experiments with heating up to high temperatures (600°C) for the core loaded with low enriched uranium, and further with plutonium fuel as plutonium fuel elements are fabricated. These high quality experiments can be best performed in critical assemblies of the ASTRA facility and will produce unique information on nuclear safety and inherent self-protection of modular high temperature gas-cooled reactors loaded with low enriched uranium, and further with plutonium fuel as plutonium fuel elements.It is difficult to perform such experiments at power reactors because of the uncertainties in parameters and strong reactor power feedbacks.

Substantial volume of critical experiments with uranium fuel will be performed at the ASTRA facility for the annular core under the ISTC Project # 0685.2, which will ensure representativeness of results.

2.1.3. Demand for results

As demonstrated, new reactors can efficiently use both plutonium and uranium fuel. The Generation IV reactor fuelled with low enriched uranium offers much promise, in terms of its technical and economic aspects, for the international power market, especially in developing countries.
In this connection the investigation of nuclear safety and inherent self-protection of modular high-temperature gas cooled reactors with low enriched uranium loaded in the reactor core is a very important stage of solving this problem for the Generation IV reactors.

2.1.4. Expected income

Implementation of this project will allow obtaining experimental data for validation of computer codes used to substantiate nuclear safety and inherent self-protection of modular HTGR at minimum costs using the modified ASTRA critical facility, and the available qualified personnel and experience in research of this kind as a basis.

2.1.5. IPR situation

Confidentiality under nonproliferation agreement. The European partners of this project (AREVA, CEA Saclay, FZ Juelich and NRG) will be provided with the measured data originating from the experiments to be performed. They are allowed to pass on these data to other European organizations.

2.1.6. Additional developments

No other activities would still be required.

2.1.7. Plan of implementation

Further cooperation.

2.1.8. Additional licenses or permits

Final material including detailed description of the critical assembly along with the experimental results, are under the export control but export license is not required.

2.1.9. Business network

Issue of scientific and technical reports on this Project for the ISTC, publications, workshops, meetings, presentations, etc.

3. Meeting ISTC Goals and Objectives

The work under the ISTC Project # 0685.2 will be for the most part performed by Russian specialists formerly engaged in military activities (OKBM, RRC KI). Thus this project will provide alternative employment of scientists and engineers engaged in weapons development and fabrication.

4. Scope of Activities

Activities on substantiation of experiments at the ASTRA facility with heating up to high temperatures

- Development and improvement of computational models (neutron-physical, thermophysical, dynamic) for study of HTGR-M nuclear safety and inherent self-protection.
- Development and substantiation of a detailed list of neutronic experiments with heating of critical assemblies simulating the HTGR-M at the ASTRA facility up to high temperatures.
- Development and substantiation of general programs of experiments and working programs for specific experiments at the ASTRA facility with heating of critical assemblies up to high temperatures.

Modernization of the ASTRA facility for experiments with heating up to high temperatures

- Development of design and technical documentation for the modernized ASTRA critical facility allowing neutronics experiments with heating of critical assembly up to high temperatures.
- Purchase of materials, equipment, components, and fabrication of nonstandard equipment for the modernized ASTRA critical facility. Erection, adjustment and commissioning of the modernized ASTRA critical facility.

Performance of experiments at the modernized ASTRA facility with heating of critical assembly

- Performance of neutronic (criticality) experiments at the existing ASTRA facility (at 20°) and at the modernized one (over the range 20…600°), and analysis of experimental results.
- Based on results of experiments performed at the ASTRA facility, verification of computational methods, codes and models designed to study nuclear safety and inherent self-protection of the HTGR-M.

- Issue of scientific and technical reports on this Project for the ISTC, publications, workshops, meetings, presentations, etc.

The first priority is to be given to the upgrading of the ASTRA facility, the execution of critical experiments at elevated temperatures, and reporting the experimental data.

Task 1

Task description and main milestones	Participating Institutions
Development and improvement of computational models for studying of criticality safety and inherent self-protection of HTGR-M reactors (neutron-physical model, thermophysical model, dynamic model).	1- RRC KI 2- OKBM

Description of deliverables	
1	Annotation reports, I, II, III and IV q. of the first year, II q. of the second year
2	Final report

Task 2

Task description and main milestones	Participating Institutions
Development of the list of neutronics experiments at the room temperature and with heating of ASTRA critical assembly up to high temperatures.	1- RRC KI

Description of deliverables	
1	Annotation reports, I, II, III and IV q. of the first year

Task 3

Task description and main milestones	Participating Institutions
Development of general programs of experiments at the ASTRA facility.	1- RRC KI

Description of deliverables	
1	Annotation reports, II, III and IV q. of the first year.

Task 4

Task description and main milestones	Participating Institutions
Development of working programs of experiments at the ASTRA facility at the room temperature and with heating up to high temperature.	1- RRC KI

Description of deliverables	
1	Annotation reports, II, III and IV q. of the first year.

Task 5

Task description and main milestones	Participating Institutions
Development of technical documentation intended to perform modernization of the ASTRA critical facility insuring implementation of experiments with heating up to high temperature.	1- RRC KI 2- OKBM

Description of deliverables	
1	Annotation reports, II and IV q. of the first year.

Task 6

Task description and main milestones		Participating Institutions
Purchase of materials, equipment, components, fabrication of nonstandard equipment for the modernized ASTRA facility.		1- RRC KI 2- OKBM
Description of deliverables		
1	Annotation reports, IV q. of the first year, I, II q. of the second year.	

Task 7

Task description and main milestones		Participating Institutions
Commissioning of the modernized ASTRA facility. Acquisition of the required certificates.		1- RRC KI 2- OKBM
Description of deliverables		
1	Annotation reports, I, II q. of the second year.	

Task 8

Task description and main milestones		Participating Institutions
Performance of criticality experiments at the ASTRA facility in the temperature range 20…600 °C.)		1- RRC KI 2- OKBM
Description of deliverables		
1	Annotation reports, III q. of the second year.	
2	Final report	

Task 9

Task description and main milestones		Participating Institutions
Analysis of experimental results obtained at the ASTRA facility.		1- RRC KI 2- OKBM
Description of deliverables		
1	Annotation reports, III q. of the second year.	
2	Final report	

Task 10

Task description and main milestones		Participating Institutions
Verification of computational methods and codes on the basis of the experimental results obtained at the ASTRA facility..		1- RRC KI 2- OKBM
Description of deliverables		
1	Annotation reports, III q. of the second year.	
2	Final report	

Task 11

Task description and main milestones	Participating Institutions
Analysis of the obtained results and issue of the final report on the entire Project.	1- RRC KI 2- OKBM

Description of deliverables	
1	Final report

5. Role of Foreign Collaborators/Partners

CEA (France) s the leading scientific organization in France on development of prospect nuclear gas cooled reactors. Development of high temperature gas cooled reactor and creation of its prototype within 25 years is the strategy direction of nuclear activity in France.

Framatome ANP - World leader in the design and construction of nuclear power plants, and the supply of fuel, maintenance and modernization services.

NRG- focuses on researches in the fields of new generation nuclear systems. It has a huge experience in nuclear experimental activity.

The Institute for Safety Research and Reactor Technology works on basic research and development tasks concerning the safety of nuclear energy technology and of nuclear waste management. Methods, data and experimental results are supplied for further development of the safety in these areas.

The common goals determined fruitful cooperation with the Collaborators and their participation in the Project is unexpendable. In particular, the Collaborators will take active part in preparation of the experiments and comparative analysis of experimental and calculational results. Their experience will be used in the designing procedure,, and choice of construction materials, developing of experimental methods and treatment of experimental results.

Cooperation with the collaborators will be realized in the following forms:

- Exchange of scientific and technical information;
- Joint development of plans within the Project,
- Discussion of experimental programs and obtained results,
- Joint use of obtained results.

The following conditions will be applied to the cooperation with the Collaborators:

- All information obtained within this Project will be preferentially provided to the Collaborators,
- The Collaborators will give their comments and proposals on the results obtained within this Project.

These comments and proposals should be discussed with the manager of the Project and may be used in correction of working plan. In this case the ISTC Secretariat should be properly informed and this will help in best realization of the tasks described in the working plan.

Cooperation with the collaborators will be realized in the following ways (not within the project budget):

- Visiting of agreed working places to survey realization of the project,
- Reviewing of all delivered documentation,
- Providing of recommendations on correction of project implementation aimed to attainment of best results in implementation of the project,
- Review of final report with the goal best presentation of results obtained within this project,
- If necessary, providing of technical and scientific support.

6. Technical Approach and Methodology

Development and improvement of mathematical merthods, algorithms and computer codes.

Calculation of neutron-physical, thermophysical, dynamic characteristics for the ASTRA critical facility.

Development of design requirements, detailed designs, purchase of materials, equipment, components and fabrication of nonstandard equipment. Standard materials shall be used where possible.

Thermocouples, resistance thermometers, thermal converters, color pyrometers, etc. will be used to measure temperature fields.

It is planned to automate the experiments, mostly through the use of software running on modern PCs.

The experiments will be performed using a variety of experimental techniques available, primary detectors, electronic equipment and PCs.

Analysis of experimental results, their initial and in-depth processing will be done with the help of computers using mathematical apparatus and codes available.

Computational methods and codes will be verified using modern PCs.

7. Technical Schedule

	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8	Person*days
Task 1 Development and improvement of computational models for studying of criticality safety and inherent self-protection of HTGR-M reactors(neutron-physical model, thermophysical model, dynamic model).	Annotation report	Annotation report	Annotation report	Annotation report		Annotation report		Final report	
Subtask 1 Development of neutronic model.	124	124	104	124	160	160			796
Subtask 2 Development of thermophysical model	114	114	104	114	150	150			746
Subtask 3 Development of dynamic model	115	115	105	114	150	150			749
Person*days	353	353	313	352	460	460			2291
Task 2 Development of the list of neutronics experiments at the room temperature and with heating of ASTRA critical assembly up to high temperatures.	Annotation report	Annotation report							
Subtask 1 Development of the list of experiments at the critical assembly of the ASTRA facility at the room temperature and on heating up to high temperatures.	290	210							500
Person*days	290	210							500
Task 3 Development of general programs of experiments at the ASTRA facility.	Annotation report	Annotation report	Annotation report						
Subtask 1 Program of investigation of temperature reactivity effect on heating in the range of 20…600 °C	110	110	90						310
Subtask 2 General program of separation of components of temperature reactivity effect.	110	110	90						310
Subtask 3 Program of determination of function of control rod worth versus temperature.	110	110	90						310

Subtask 4 Program of performance of calculation and experimental investigation of inherent safety of such type reactors against reactivity disturbance.	110	110	90						310
Person*days	440	440	360						1240
Task 4 Development of working programs of experiments at the ASTRA facility at the room temperature and with heating up to high temperature.			Annotation report	Annotation report	Annotation report	Annotation report			
Subtask 1. Working Program for investigation of the reactivity temperature effect with heating the assembly in the range of 20…600°Ñ			70	90	146	150			456
Subtask 2 Working Program for separation of constituents of the assembly reactivity temperature effect.			70	90	146	150			456
Subtask 3 Working Program for determination of variation of the worth of control rods with temperature.			70	90	147	150			457
Person*days			210	270	439	450			1369
Task 5 Development of technical documentation intended to perform modernization of the ASTRA critical facility insuring implementation of experiments with heating up to high temperature.		Annotation report		Annotation report					
Subtask 1 Development of Specifications for modification of the ASTRA critical facility.	156	146	116						418
Subtask 2 Development of technical documentation on the critical assembly.	115	80	70	80					345
Subtask 3 Development of technical documentation on electric power supply of the ASTRA critical facility.		80	70	80					230
Subtask 4 Development of technical documentation on data acquisition system		80	70	80					230
Subtask 5 Development of technical documentation on upgrading of the control rod system.	115	80	70	80					345

Subtask 6 Development of technical documentation on cooling systems.			70	80					150
Subtask 7 Issue of technical documentation on the ASTRA critical facility as a whole.			120	137					257
Person*days	386	466	586	537					1975
Task 6 Purchase of materials, equipment, components, fabrication of nonstandard equipment for the modernized ASTRA facility.				Annotation report	Annotation report	Annotation report			
Subtask 1 Identification of needs.				140					140
Subtask 2 Selection of suppliers. Placement of orders.				140	260				400
Subtask 3 Receipt of equipment and materials for CPS, I&C, power systems.						150			150
Person*days				280	260	150			690
Task 7 Commissioning of the modernized ASTRA facility. Acquisition of the required certificates.					Annotation report	Annotation report	Annotation report		
Subtask 1 Approval of the facility documentation by Russian Rostechnadzor.					221				221
Subtask 2 Installation of equipment of the “hot” ASTRA facility.						152	151		303
Subtask 3 Presentation of the facility to an acceptance commission. Obtaining of a sanitary certificate.						100	100		200
Subtask 4 Presentation of the facility to the internal MINRS commission. Obtaining of a certificate for the critical facility.						100	100		200
Person*days					221	352	351		924
Task 8 Performance of criticality experiments at the ASTRA facility in the temperature range 20…600 °C.)							Annotation report	Annotation report	
Subtask 1 Loading of the core.							188	181	369

Subtask 2 Experiments on determination of control rod worth.							188	181	369
Subtask 3 Experiments on determination of the reactivity effect at temperatures up to 600 °Ñ								181	181
Person*days							376	543	919
Task 9 Analysis of experimental results obtained at the ASTRA facility.							Annotation report	Annotation report	
Subtask 1 Analysis of results of experimental and computational studies.							170	180	350
Subtask 2 Analysis of nuclear safety and inherent self-protection.							150	150	300
Person*days							320	330	650
Task 10 Verification of computational methods and codes on the basis of the experimental results obtained at the ASTRA facility..							Annotation report	Annotation report	
Subtask 1 Verification of the neutronics model.							110	110	220
Subtask 2 Verification of the thermophysical model.							110	110	220
Subtask 3 Verification of the dynamic model.							110	110	220
Person*days							330	330	660
Task 11 Analysis of the obtained results and issue of the final report on the entire Project.								Final Report	
Subtask 1 Generalization and analysis of stages 6...9							230	221	451
Person*days							230	221	451
TOTAL	1469	1469	1469	1439	1380	1412	1607	1424	11669

2. Annual Project Technical Report - on the work performed from December 1, 2007 to November 30, 2008

ISTC Project # 0685.2

Nuclear Safety and Inherent Self-protection Investigations for Modular High Temperature Gas-cooled Reactors (HTGR-M). Experimental Demonstration in the ASTRA Facility of Inherent Safety Characteristics of HTRs

Annual Project Technical Report

on the work performed from December 1, 2007 to November 30, 2008

FSI RRC "Kurchatov Institute"
1 Kurchatov square, Moscow 123182 Russia

Project Manager	**Balanin, Andrey Leonidovich**	____________________
Director of INR, RRC KI	**Semchenkov, Yury Mikhailovich**	____________________

December 2008

This work is supported financially by the European Community and performed under the contract to the International Science and Technology Center (ISTC), Moscow

Title of the Project:	Nuclear Safety and Inherent Self-protection Investigations for Modular High Temperature Gas-cooled Reactors (HTGR-M). Experimental Demonstration in the ASTRA Facility of Inherent Safety Characteristics of HTRs.
Contracting Institute:	Federal State Institution Russian Research Center “Kurchatov Institute”
Participating Institutes:	Experimental Design Bureau of Machine Building
Commencement Date:	01 December 2007
Duration:	24 months
Project Manager:	Balanin, Andrey Leonidovich
phone number:	(499) 196 91 42
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1. Brief description of the work plan: objective, expected results, technical approach

The main objective of the project is to obtain experimental data on the temperature reactivity effect and its constituents for verification of methods, codes and developed computational models intended for investigation of nuclear safety of high-temperature gas cooled reactors under development within the framework of the Generation IV Program.

Main areas of activities under the project:

I. Work on substantiation of experiments at the ASTRA facility with heating up to high temperatures (600°C):

- Development and improvement of computational models (neutronic, thermophysical, dynamic) for investigation of the HTGR-M nuclear safety and inherent self-protection.
- Development and substantiation of a detailed list of neutronic experiments with heating of critical assemblies simulating the HTGR-M at the ASTRA facility.
- Development and substantiation of general programs of experiments and working programs of particular experiments with heating of critical assemblies.

II. Upgrading of the ASTRA facility for experiments with heating up to high temperatures:

- Development of technical documentation for the facility upgrades intended to provide for performance of neutronic experiments with heating of critical assemblies.
- Purchase of materials, equipment and components, and fabrication of special equipment for upgrading the facility. Assembly, adjustment and commissioning of the upgraded ASTRA facility.

III. Performance of experiments at the upgraded ASTRA facility with heating of critical assemblies:

- Performance of experiments at room temperature.
- Performance of neutronic experiments with heating up to high temperatures in a critical assembly with uranium fuel, including measurement of the temperature reactivity effect and its constituents, measurement of the worth of control rods as a function of temperature. Preparation of detailed descriptions of critical configurations. Calculations in support of the experiments.
- Analysis of experimental results.
- Verification of computation techniques, codes and developed computational models for investigation of nuclear safety of uranium-fuelled HTGR-M based on results of experiments at the ASTRA facility.
- Issue of scientific and technical reports on this project for ISTC, issue of publications, holding workshops, working meetings, making presentations, etc.

Main results expected from performance of this project:

- Determination of the temperature reactivity effect and its individual constituents when heating the critical assembly between 20°C and 600°C.
- Determination of a critical position of absorber control rods at different values of mean temperature in various critical assembly zones (core, side and internal reflectors, etc.).
- Determination of the worth of control rods in the above-mentioned temperature range.
- Determination of the reactivity margin compensated for by the system of absorber rods at different temperature levels.
- Analysis of experimental data with estimation of uncertainties associated with the obtained measurement results.
- Verification of computation techniques and codes used for determination of temperature reactivity effects and their constituents, and the worth of control rods as a function of temperature for modular HTGR.
- Development of computational models for investigation of nuclear safety and inherent self-protection (neutronic, thermophysical and dynamic models).

2. Technical progress during the year of reference

During the first year the work under the ISTC Project # 0685.2 “Hot ASTRA” was performed in accordance with the planned tasks and technical schedule, and in general consisted in planning and substantiation of neutronic experiments with heating the critical assembly and preparations for upgrading the ASTRA facility related to development of technical documentation.

A concept of upgrading the ASTRA facility for experiments with heating (see publication listed in Attachment 2) was proposed and substantiated in the course of the work under Project # 0685.2. Basic points of the concept include:

– the use one steel heater in the central part of the core;
– no modifications to the graphite stack of the side reflector in the existing critical assembly;
– the use of the existing ventilation system with possible connection of air ducts of the critical assembly cooling system, equipment, CPS, etc. to the former;
– establishment of nitrogen atmosphere for graphite components heated to temperatures above 350°C;
– mounting of thermal insulation between the core and side reflector, between the core and top/bottom reflectors, and on the top of the critical assembly;
– means are provided for implementation of the second stage of experiments at the “hot ASTRA” under follow-up ISTC projects with attainment of higher temperatures and larger list of experiments.

At this concept development stage, schematics of the upgraded ASTRA facility critical assembly for experiments at room temperature and with heating up to high temperatures were developed as shown in Figs. 1 and 2 of Attachment 1 (see publication listed in Attachment 2).

According to Task 1 of the work plan, neutronic, thermophysical and dynamic computational models for investigation of HTGR-M nuclear safety and inherent self-protection have been developed and are being improved.

Input data for the neutronic model of the ASTRA facility critical assembly were developed taking into account refined data on physical properties of graphite and characteristics of fabricated spherical elements used for neutronic experiments at the ASTRA critical facility (see publication listed in Attachment 2).

Uncertainties in heat conductivity characteristics of materials chosen for thermal insulation were taken into account when developing models for thermal calculations.

Preliminary thermal and neutronic calculations of the heated ASTRA facility critical assembly were performed using the developed computational models (see publication listed in Attachment 2).

Figures 3 and 4 in Attachment 1 show the transverse and longitudinal sections of the heated assembly model. Dimensions of the cylindrical model are given in Table 1.

Table 1. Dimensions of the computational model corresponding to schematics shown in Figs. 3 and 4

Radial dimensions, cm	
Heater: inner radius/outer radius	1.2/1.7
Channel in the IR and SR1: channel radius	5.70575
Internal reflector IR: outer radius	37.318
Core: inner radius/outer radius	37.318/85.024
Thermal insulation: inner radius/outer radius	85.024/90.314
Side reflector SR1: inner radius/outer radius	90.314/117.16
Side reflector SR2: inner radius/outer radius	117.16/140.34
Side reflector SR3: inner radius/outer radius	140.34/190.00
Axial dimensions, cm	
Height of the bottom reflector BR	50,0
Thickness of the bottom thermal insulation (on the BR)	5.0
Core height	300.0
Thickness of the top thermal insulation	5.0
Thickness of the top reflector	100.0
Heater height (within the core)	300.0
Busbar height (within the TR and fireclay)	105.0

Temperature effects of reactivity of the assembly and its components were analyzed through neutronic calculations using the effective cylindrical model.

Figure 5 in Attachment 1 shows an example of results of such calculations with the MCU Monte Carlo code.

From Fig. 5 in Attachment 1 it follows that the maximum negative reactivity effect in absolute magnitude occurs when the core material temperature increases. The temperature reactivity effect is almost a linear function of the mean temperature of the core moderator. When the graphite moderator and fuel in the core are heated from 300 K to 900 K, the temperature reactivity effect is -7.8%, while the fuel temperature effect (Doppler effect) in the same temperature range is -0.8%. Hence the temperature effect of the core graphite moderator being heated from 300 to 900 K is -7.0%.

The temperature effect of reactivity of the side reflector material is positive and increases with saturation as the temperature increases (Fig. 5 in Attachment 1). The value of the temperature effect at the temperature increase from 300 K to 900 K is + 2.3 %.

The temperature effect of reactivity of the internal reflector material is positive and increases with saturation as the temperature increases (Fig. 5 in Attachment 1). The value of the temperature effect at the temperature increase from 300 K to 900 K is + 0.3 %.

Results of the neutronic calculations show that for the critical assembly under consideration the total temperature reactivity effect is negative and depends on the temperature distribution pattern. The worth of control rods at heating the assembly increases significantly in absolute magnitude.

From results of thermophysical calculations (Figs. 6, 7 in Attachment 1) it follows that radial distribution of temperatures at heating the critical assembly is non-uniform both over the core and over the internal and side reflectors.

So it has been demonstrated that when planning and doing experiments in the ASTRA facility critical assembly particular attention should be given to measurement of temperature fields, critical parameters of the assembly and worth of control rods. To obtain detailed spatial temperature distributions along the assembly radius and axis, a necessary number of thermocouples will be installed.

According to Tasks 2 and 3, a detailed list of neutronic experiments and general programs of experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperatures in the range from 20 to 600°C have been developed and substantiated (see publications listed in Attachment 2). These documents encompass:

- investigation of the reactor temperature reactivity effect at heating the assembly;
- identification of the assembly temperature effect constituents;
- determination of the temperature dependence of absorber rod worth;
- performance of computational analyses and experimental investigations of inherent self-protection of HTGR-M type reactors with respect to reactivity perturbations.

The list and general program of experiments in the assembly at room temperature include:

1. Physical start-up of the upgraded critical assembly at room temperature with gradual increase of the core height and determination of the first criticality with the core not completely filled with fuel balls;
2. Gradual increase of the core height, installation of the top reflector and attainment of the final core configuration.

The following measurements are to be performed in the assembly at room temperature:

- Measurement of the assembly geometrical parameters;
- Measurement of the worth of absorber rods;
- Measurement of reactivity calibration curves of absorber rods;
- Determination of assembly critical parameters and reactivity margin;
- Measurement of assembly kinetic parameters;
- Measurement of spatial distribution of fission reaction rates;
- Measurement of temperatures of assembly components.

The program of experiments with heating the assembly between 20 and 600°C includes:

– Selection of the critical assembly heating mode;
– Measurement of temperatures of assembly components;
– Measurement of the worth of absorber rods;
– Measurement of reactivity calibration curves of absorber rods;
– Determination of assembly critical parameters and reactivity margin.

According to Task 4, development of working programs of experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperatures has been started and continues.

According to Task 5, technical documentation for upgrading the ASTRA facility to provide for experiments in the facility critical assembly with heating up to high temperatures has been developed. Design Specifications have been developed for such systems as a heater and its control system; critical assembly cooling system; critical assembly gas supply system, information and measuring system. Technical requirements for the critical assembly thermal insulation have been developed. Technical documentation for the critical assembly, a heater and its control system, gas supply system, cooling system, thermal insulation required for upgrading the ASTRA facility has been developed. The work under this task is at the stage of agreement, approval and issue of a set of documents for the ASTRA critical facility as a whole.

According to Task 6, material, equipment and components requirements are being defined on the basis of the developed technical documentation, and analysis of potential suppliers and manufacturers is being performed accordingly.

3. Current technical status

In general the work under the project is performed in accordance with the technical schedule. Task 5 where both Kurchatov Institute and OKBM are involved and which is the most labor intensive task in the period of reference is currently at the stage of agreement and approval of the technical documentation by the management.

In view of the actual project budget (as the project proposal was submitted to the ISTC more than ten years ago) and the current economic situation in Russia, there was worked out a stage-by-stage approach to completion of works planned under ISTC Project # 0685.2. In these circumstances it is decided to successively accomplish the specified project objectives. In particular, it is planned to issue a supplement to the ASTRA facility detail design which will allow heating the critical assembly in the temperature range from 20 to 600°C. And further purchases and installation of new equipment will be performed according to priorities (for example, no gas supply or cooling systems will be required for heating up to 300°C).

4. Cooperation with foreign collaborators

A meeting with foreign collaborators was held at RRC “Kurchatov Institute” on March 4-6, 2008. The purpose of the meeting was to familiarize the collaborators with the preliminary program of experiments to be performed in the ASTRA critical assembly within the framework of ISTC Project # 0685.2. The following issues were discussed at the meeting:

- General collaborators’ view of performance of experiments, their purpose and objectives.
- NRG activities and potentialities of providing support to experiments at the ASTRA critical facility.
- Main areas of Kurchatov Institute activities and experience in development of reactor systems.
- Russian experience in development of high-temperature gas cooled reactors.
- Experience in performing experiments at the ASTRA critical facility.
- Substantiation of the program of experiments at the ASTRA critical facility.
- Overview of experiments planned to be performed according to the program of experiments at the ASTRA critical facility.
- Tour of the ASTRA critical facility.
- Temperatures attainable at heating.
- NRG capabilities to deliver thermocouples in the framework of the present project.
- Discussion and adjustment of the program of experiments.

The meeting was attended by the following collaborator representatives:

Jim KUIJPER - NRG (Netherlands);

Frederic DAMIAN - CEA (France);

Christos TRAKAS - AREVA (France).

The next meeting with foreign collaborators was tentatively scheduled for the end of January 2009.

The second meeting with collaborators was held at RRC “Kurchatov Institute” on 27-28 January 2009. The purpose of the meeting was to familiarize collaborators with general programs of experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperatures as planned in the project.

The Minutes of the meeting are presented in Attachment 3.

Attachment 1. Illustrations attached to the main text

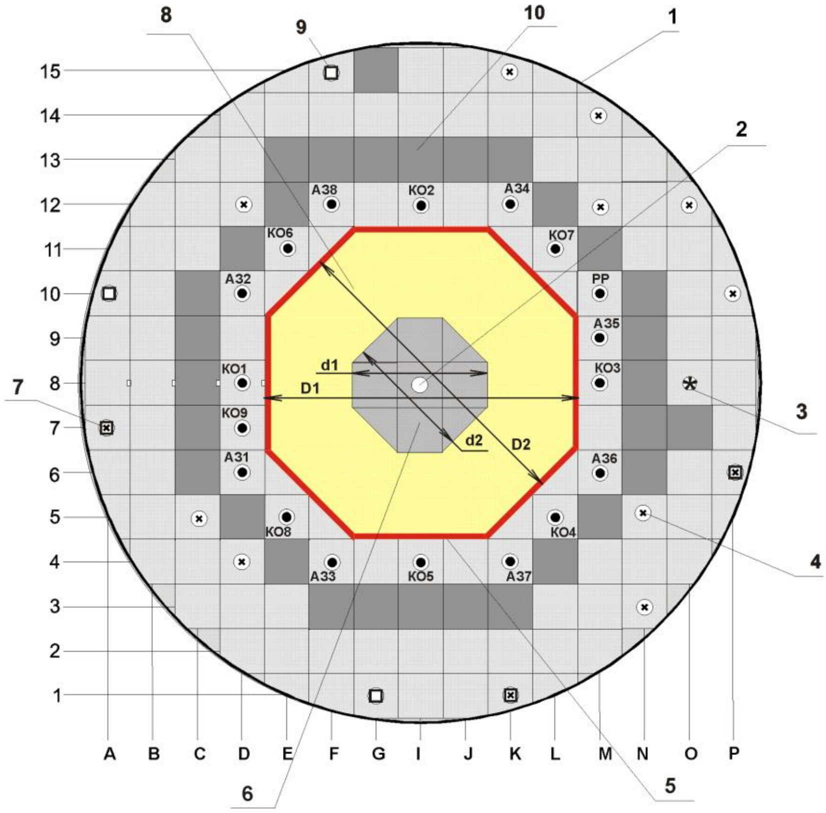

Fig. 1. Preliminary schematic of the heated critical assembly cross section at the concept development stage

1 – vessel; 2 – heater; 3 – neutron source channel; 4 – ionization chamber channels; 5 – thermal insulation; 6 – internal reflector; 7 – ionization chamber and neutron counter channels; 8 – pebble bed; 9 – neutron counter channel; 10 – side reflector.

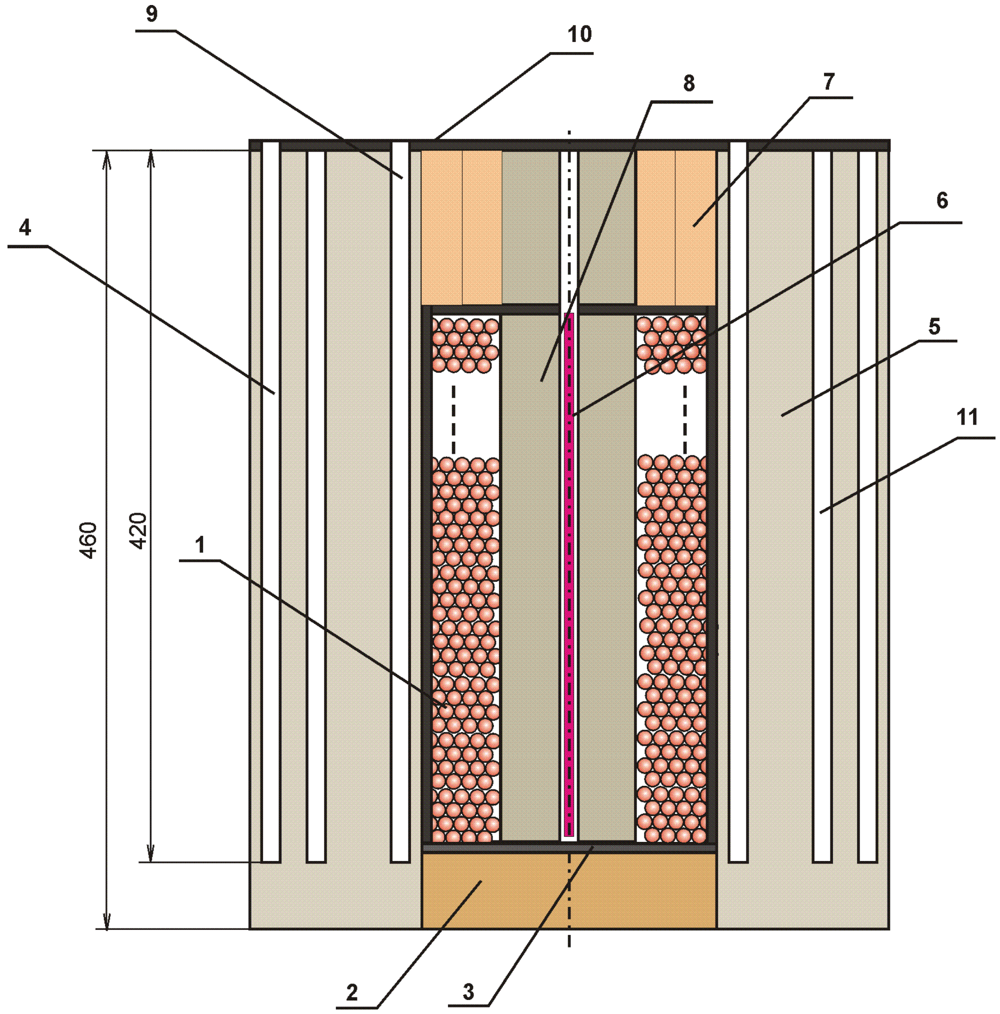

Fig. 2. Preliminary schematic of the heated critical assembly longitudinal section at the concept development stage

1 – pebble bed; 2 – bottom reflector; 3 – thermal insulation; 4 – channels for ionization chambers; 5 – graphite stack of the side reflector; 6 – heater; 7 – top reflector; 8 – internal reflector; 9 – channels for absorber rods; 10 – thermal insulation; 11 – neutron source channel.

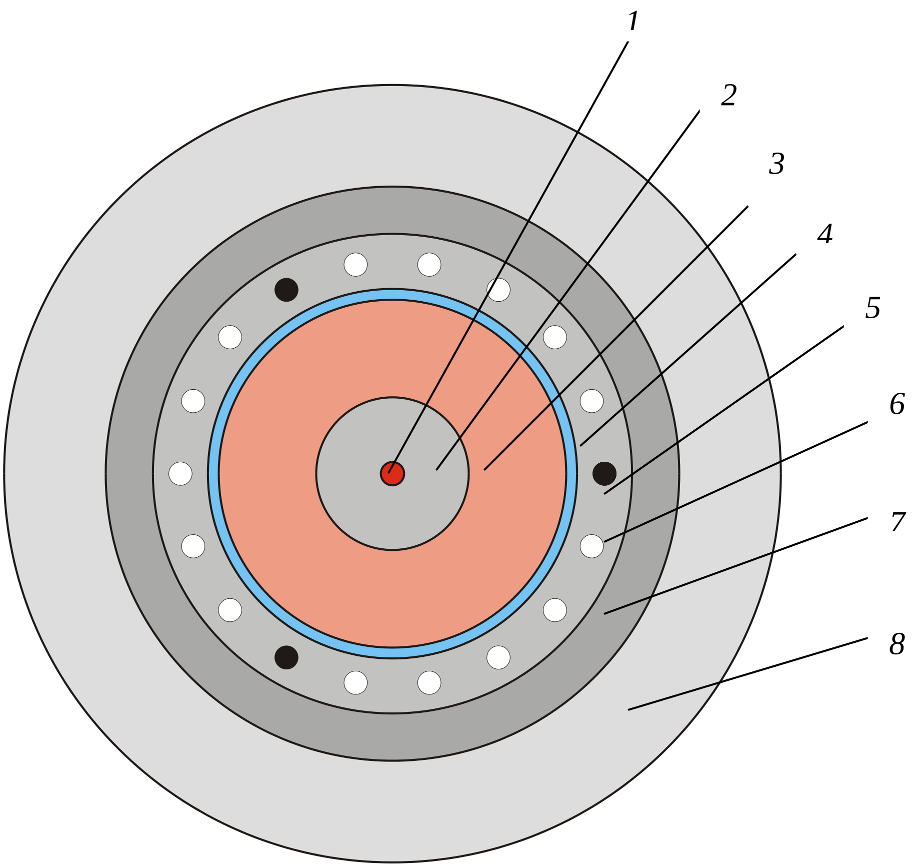

Fig. 3. Cross section of the heated assembly computational model

1 – electric heater; 2 – internal reflector (IR); 3 – pebble bed; 4 – thermal insulation; 5 – side reflector (SR1); 6 – control rod channels; 7 – side reflector (SR2); 8 – side reflector (SR3).

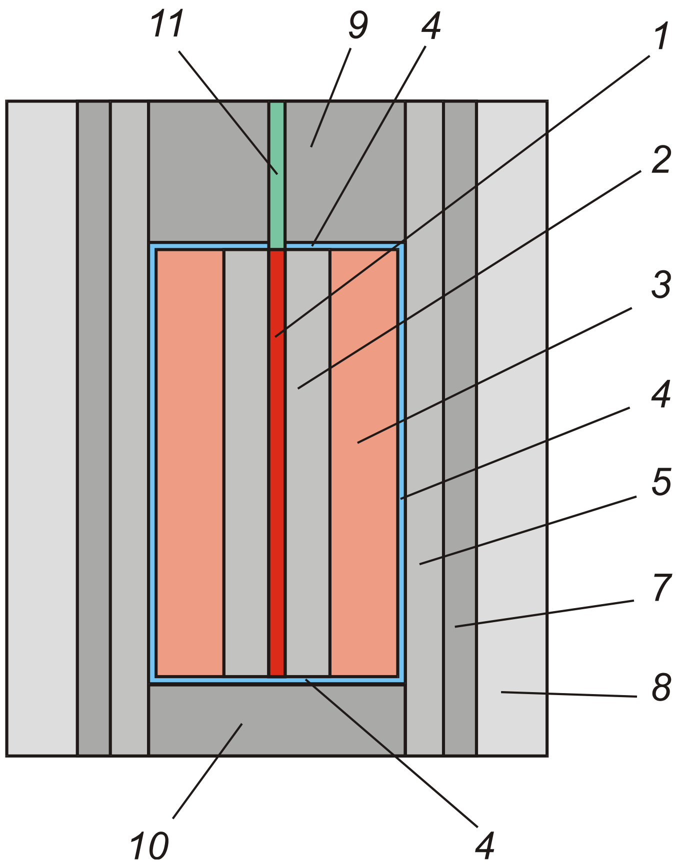

Fig. 4. Longitudinal section of the heated assembly computational model

1 – 8 – same as in Fig. 2; 9 – top reflector (TR);

10 – bottom reflector (BR); 11 – current leads

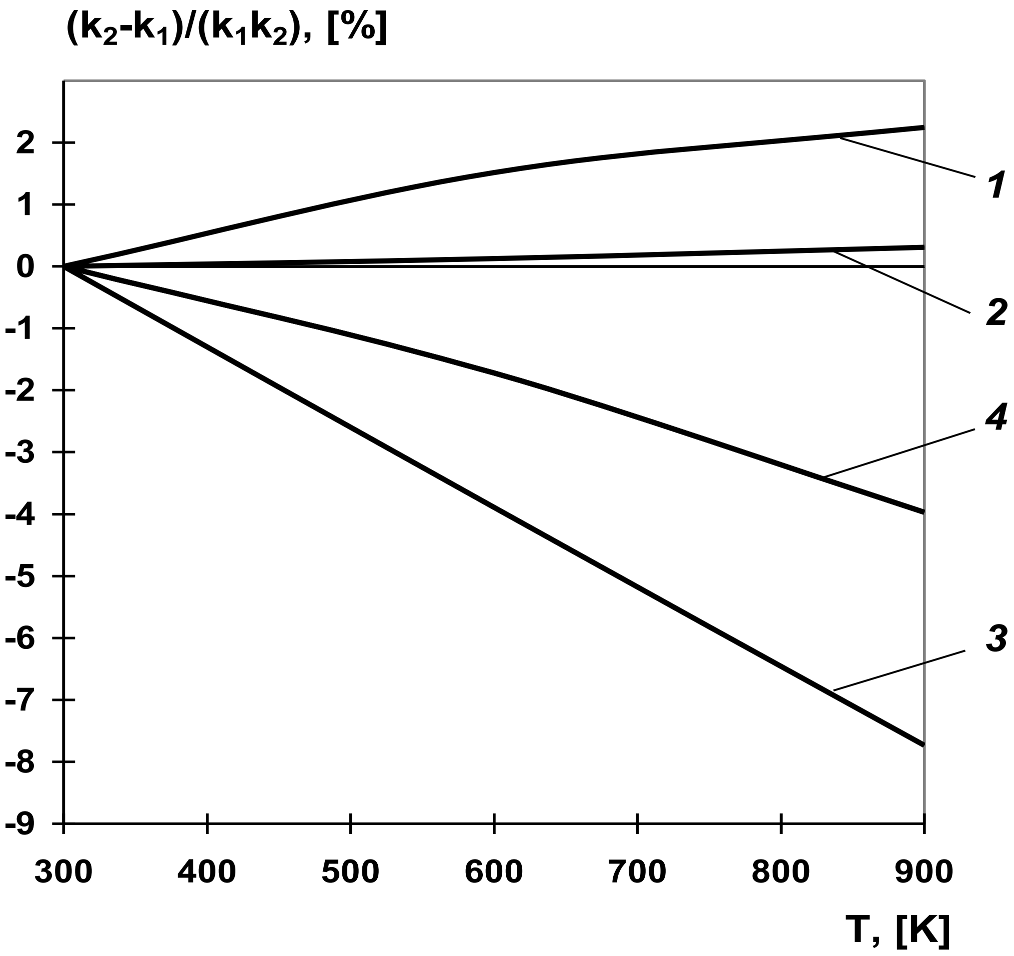

Fig. 5. Temperature reactivity effect at heating the critical assembly

1 – heating of the side reflector only; 2 – heating of the internal reflector only; 3 – heating of the core (graphite and UO_2) only, the temperature effect at heating UO_2 from 300 K to 900 K (Doppler effect) is negative and is –0.8 % of reactivity; 4 – uniform heating of all assembly components.

k_1- the value of k_{eff} at room temperature (T_0 = 300 K) , k_2 – the value of k_{eff} at temperature T K.

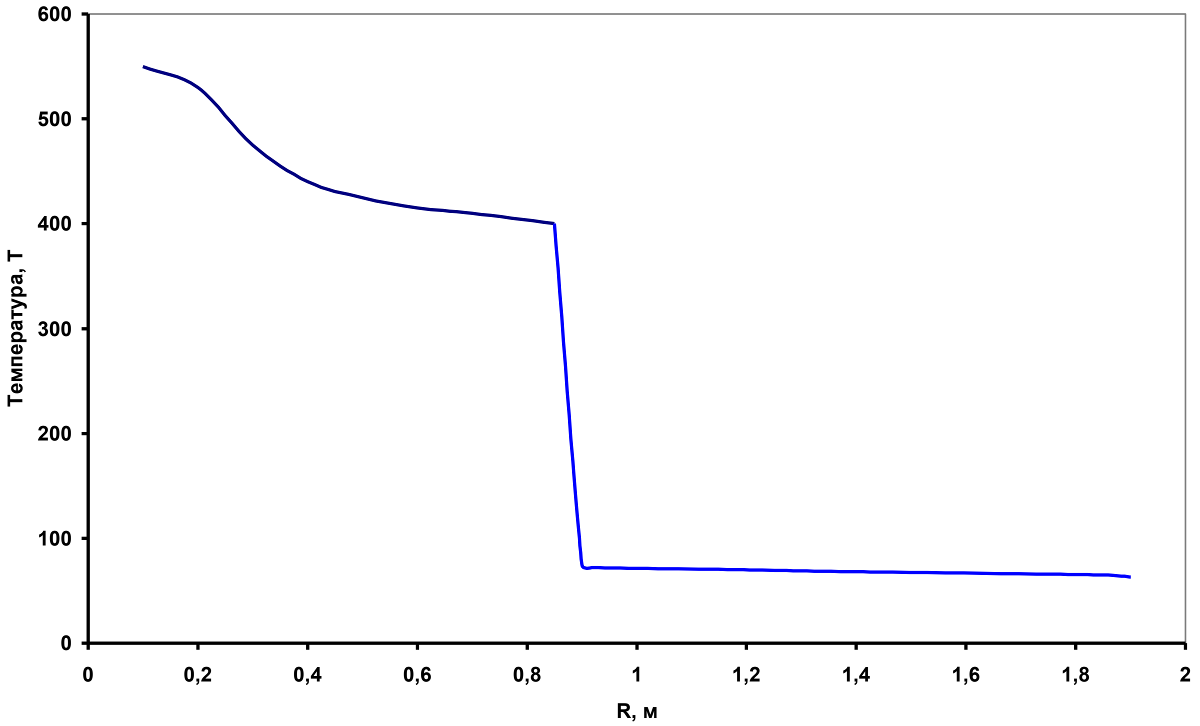

Fig. 6. Distribution of temperature T (°C) along the critical assembly radius (in the central section)

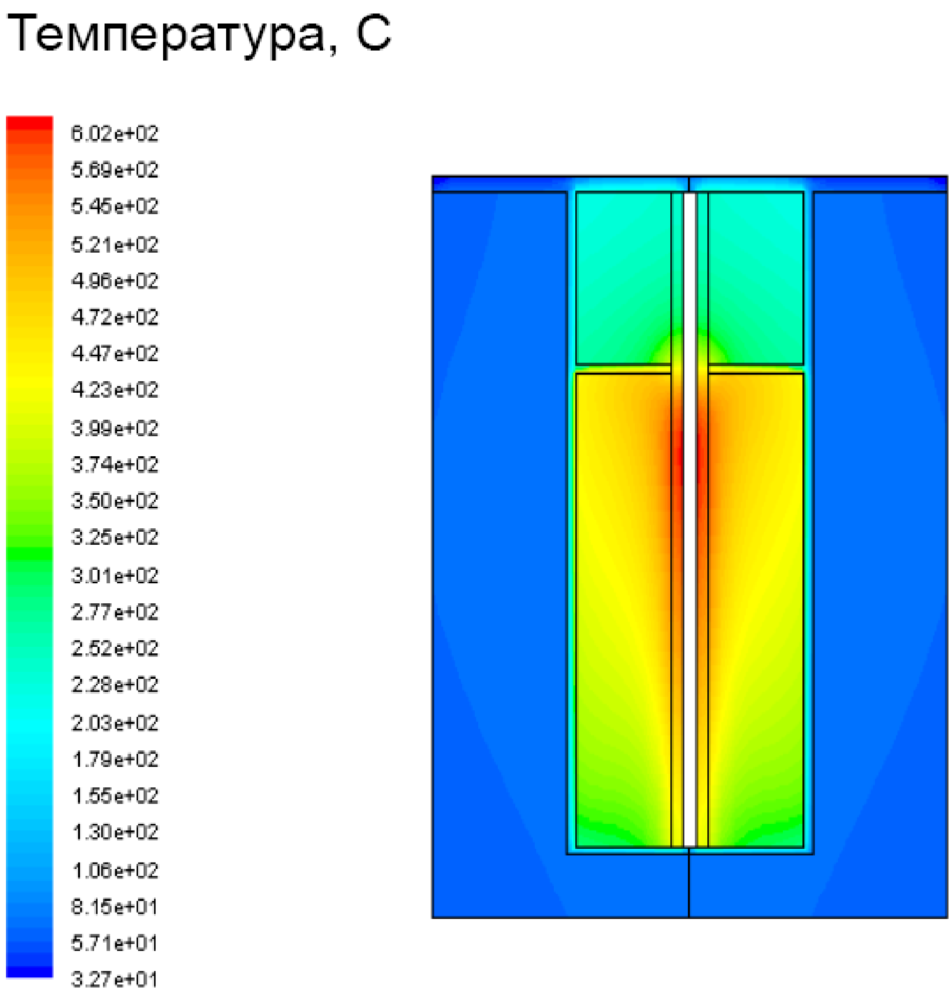

Fig. 7. Spatial distribution of temperature T (°C) over the critical assembly

Attachment 2: Abstracts of papers and reports published during the year of reference.

1. A.L. Balanin, A.A. Bobrov, V.P. Garin, E.S. Glushkov, V.N. Grebennik, N.G. Kodochigov, G.V. Kompaniets, E.V. Marova, V.A. Nevinitsa, D.N. Poliakov, A.A. Sedov, Yu.P. Sukharev, P.A. Fomichenko, S.F. Shepelev, E.I. Chuniaev — The concept of upgrading the ASTRA critical facility for experimental investigation of HTGR physical characteristics at heating — “Topical Issues of Nuclear Reactor Physics – Efficiency, Safety, Nonproliferation. VOLGA-2008”, Proceedings of the XV Workshop on Reactor Physics Issues, Moscow, 2-6 September 2008, pages 159-161.

Extensive experimental investigations were performed at room temperature in assemblies simulating physics peculiarities of various types HTGR reactors at the ASTRA critical facility, Kurchatov Institute. A concept of upgrading the ASTRA facility for experimental investigation of neutronic characteristics at heating the critical assembly simulating a modular annular-core high-temperature reactor was developed.

The paper presents basic points of the concept of upgrading the ASTRA facility for experiments with heating the critical assembly that are reflected in the supplement to the detail design of upgrading to be issued according to Task 5 of the technical schedule.

2. A.E. Glushkov, E.S. Glushkov, M.I. Gurevich et al. Physical model of the heated ASTRA facility critical assembly. Internal report, RRC “Kurchatov Institute”, 2008.

The report describes the physical model developed in accordance with Task 1 of the technical schedule and used for neutronic calculations, including determination of temperature reactivity effects, control rod worth and critical parameters of the heated critical assembly of the upgraded ASTEA facility.

3. N.N. Ponomarev-Stepnoy, E.S. Glushkov, G.V. Kompaniets, V.I. Nosov et al. — Physical characteristics of reactor-grade graphite – *Issues of Nuclear Science and Engineering*, Issue 2, Nuclear Reactor Physics Series, 2008, pages 57-82.

The work consolidates data on physical properties of graphite used in ASTRA, RBMK and GROG facilities at Kurchatov Institute. Graphite density and microscopic thermal neutron absorption cross section were determined with due regard for impurities on the basis of statistical analysis of manufacturer’s data and results of measurements of sizes and weights of graphite blocks and thermal neutron diffusion length in graphite stacks, and associated uncertainties were estimated. These data were obtained for correct specification of initial characteristics of the ASTRA facility graphite when developing computational models according to Task 1 of the technical schedule.

4. N.N. Ponomarev-Stepnoy, E.S. Glushkov, G.V. Kompaniets, V.I. Nosov et al. — Statistical processing of characteristics of HTGR spherical fuel, graphite and absorber elements for the ASTRA facility — *Issues of Nuclear Science and Engineering*, Issue 2, Nuclear Reactor Physics Series, 2008, pages 82-93.

Information available on characteristics of fabricated spherical elements used in neutronic experiments at the ASTRA critical facility was processed with mathematical statistics procedures. The algorithm and code were developed for statistical processing of data on HTGR fuel spheres, graphite spheres and absorber spheres. Statistical analysis was performed, and processing results were summarized. These data were obtained for correct specification of characteristics of spherical elements used in the ASTRA facility when developing computational models according to Task 1 of the technical schedule.

5. V.P. Garin, A.E. Glushkov, E.S. Glushkov et al. The list of experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperatures. Internal report, RRC "Kurchatov Institute". 2008.

The report presents the List of experiments in the critical assembly of the upgraded ASTRA facility at room temperature and with heating up to high temperatures developed according to Task 2 of the technical schedule.

6. V.P. Garin, A.E. Glushkov, E.S. Glushkov et al. Development of general programs of experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperatures. Internal report, RRC "Kurchatov Institute". 2008.

The report presents the General program of experiments in the critical assembly of the upgraded ASTRA facility at room temperature and with heating up to high temperatures developed according to Tasks 2 and 3 of the technical schedule.

Attachment 3. Minutes of the meeting with collaborators on 27-28 January 2009

Minutes of the meeting with collaborators under ISTC Project # 0685.2

"Nuclear Safety and Inherent Self-protection Investigations for Modular High Temperature Gas-cooled Reactors (HTGR-M). Experimental Demonstration in the ASTRA Facility of Inherent Safety Characteristics of HTRs"

27-28 January 2009. RRC "Kurchatov Institute", Moscow

The meeting was held under the agreement between RRC "Kurchatov Institute" and ISTC of 19.11.2007.

Meeting attendees from the Russian party:

RRC "Kurchatov Institute":
A.L. Balanin, A.A. Bobrov, V.N. Baryshnikov, V.P. Garin, E.S. Glushkov, A.E. Glushkov, V.N. Grebennik, S.B. Danelia, G.V. Kompaniets, M.E. Mironenko-Marenkova, V.A. Nevinitsa, V.I. Nosov, A.A. Sedov, D.N. Poliakov, N.N. Ponomarev-Stepnoi, P.A. Fomichenko

ISTC:
A.A. Bychkova, L.V. Tocheny

Attendee from collaborators:
Jim KUIJPER - NRG (Netherlands)

Purpose of the meeting:
Review of the project work progress. Familiarization of collaborators with general programs of experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperatures that are planned under ISTC Project # 0685.2.

The meeting language was English with consecutive interpretation into Russian.

The following issues were discussed during the meeting on **27.01.09**:

1. Presentation by the collaborator: NRG activity areas. EUROATOM projects FP 5,6,7 relating to high-temperature gas cooled reactors. HTR reactor core physics calculations. Application of results expected from experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperature that are planned under ISTC Project # 685.2 in European projects. Jim KUIJPER.
2. Review of work progress under ISTC Project # 0685.2. Presentation of tasks completed in the first year of the project according to the work schedule. General overview of the concept of upgrading the ASTRA facility critical assembly, including newly developed systems such as heater, thermal insulation, side reflector air cooling system, critical assembly gas supply system. A.L. Balanin.
3. Thermal insulation of the ASTRA facility critical assembly: purpose and design, operating conditions, requirements, materials (including demonstration of samples,

results of chemical analysis of the samples), insulation assembly concept. S.B. Daneliya.

4. Concept of the ASTRA facility information and measuring system: purpose, structure (breakdown into functional subsystems), layout of the system components, monitoring of physical characteristics and equipment of the critical assembly, control of subsystem parameters, hardware and software levels. Problems associated with deployment of the information system. A.A. Bobrov.
5. Thermohydraulic computation model, temperature monitoring points. Thermohydraulic calculations of the critical assembly heating with estimation of uncertainties. Comparison of results of preliminary thermohydraulic calculations performed for different values of thermal insulation conductivity and porosity. Dynamic mode of heating the critical assembly. A.A. Sedov.

The following issues were discussed during the meeting on **28.01.09**:

1. General philosophy of conducting experiments in the ASTRA facility and assessment of measurement accuracy. Estimation of uncertainties in measurement of the Keff, control rod worth, core sizes, spatial distribution of fission reaction rates. V.I. Nosov.
2. Basic neutronic model of the critical assembly: description, model parameters, objectives of experiments, neutronic calculations with the basic model. E.S. Glushkov.
3. Preliminary neutronic calculations with the full-scale model of the ASTRA facility critical assembly. Sensitivity analysis. Calculations by different computer codes. Reactivity effects. V.A. Nevinitsa.
4. Development of general programs of experiments in the ASTRA facility critical assembly at room temperature and with heating up to high temperatures. Description of the critical assembly loading and start-up procedures. V.P. Garin.
5. In view of the actual project budget (as the project proposal was submitted to the ISTC more than ten years ago) and the current economic situation in Russia, there was worked out a stage-by-stage approach to completion of works planned under ISTC Project # 0685.2. In these circumstances it was decided to successively accomplish the specified project objectives. In particular, it is planned to issue a supplement to the ASTRA facility detail design which will allow heating the critical assembly in the temperature range from 20 to 600°C. And further purchases and installation of new equipment will be performed according to priorities (for example, no gas supply or cooling systems will be required for heating up to 300°C). A.L. Balanin.

Visit results:

It was confirmed that the project work was being performed in accordance with approved plans and agreement signed between the RRC “Kurchatov Institute” and ISTC.

The collaborator has on the whole approved the general programs of experiments.

The stage-by-stage approach to completion of the project works has been also approved by the collaborator.

It was proposed to hold the next meeting with collaborators at one of research institutions in France which are represented by collaborators who did not attend this meeting.

3. Minutes of the Meeting with the Collaborators under ISTC Project 0685.2 “Hot ASTRA”

Minutes
of the Meeting with the Collaborators under ISTC Project 0685.2 “Hot ASTRA”

March 4-6, 2008, FSI RRC “Kurchatov Institute”, Moscow

Participants of the project:
Russian side:

RRC Kurchatov Institute:
A.L. Balanin, A.A. Bobrov, V.P. Garin, V.V. Grebennik, S.B. Daneliya, A.A. Zimin, G.V. Kompaniets, N.E. Kukharkin, V.G. Motenko, M.E. Mironenko-Marenkova, V.A. Nevinitsa, V.I. Nosov, D.N. Polyakov, A.S. Ponomarev, E.N. Samarin, A.A. Sedov, O.N. Smirnov, P.A. Fomichenko, E.I. Tchunyaev.

OKBM
N.G. Abrosimov, S.F. Shepelev.

Collaborators:
Jim KUIJPER – NRG,
Frederic DAMIAN – CEA,
Christos TRAKAS – AREVA.

ISTC:
A.A. Bychkova

Objective: Preliminary discussion on the experimental program, visit to the ASTRA facility.

The following issues were discussed on March 4:

Brief information concerning structure and main activities of the Kurchatov Institute, N.E. Kukharkin;

“Hot ASTRA” kick-off meeting: Introducing the Nuclear Research & Consultancy Group, Jim Kuijper;

CEA Interest to the Hot Experiments at the ASTRA Facility, Frederic Damian;

Developments of HTGR in Russia, V.N. Grebennik;

Experience of room temperature critical experiments at the ASTRA facility on simulating various types of HTGR, D.N. Polyakov;

Determination of reactivity temperature effect and its components, V.A. Nevinitsa;

Preliminary results of thermal computation of critical assembly heating; A.A. Sedov;

Concept of hot experiments at the ASTRA facility, D.N. Polyakov.

The following issues were discussed on March 5:

Visit to the ASTRA facility, E.I. Tchunyaev;

Preliminary program of hot experiments, D.N. Polyakov;

Discussion of the preliminary experimental program;

Answers concerning modification of the ASTRA facility, OKBM representatives.

Conclusion:

Collaborators approved the preliminary experimental program and modification of the critical facility in general.

It was recommended to consider possible ways of additional funding of the experiments and provision of equipment and software.

The next meeting will be held on the latter half of the year.

D. Polyakov, Project Manager
J. KUIJPER, NRG,
F. DAMIAN, CEA,
C. TRAKAS, AREVA.

4. Quarterly Technical Report on performance of works in the period from June 1, 2009 to August 31, 2009 - Quarter # 7

ISTC Project # 0685.2

Nuclear Safety and Inherent Self-protection Investigations
for Modular High Temperature Gas-cooled Reactors
(HTGR-M)/Experimental Demonstration in the ASTRA Facility
of Inherent Safety Characteristics of HTGRs

Quarterly Technical Report

on performance of works in the period from June 1, 2009
to August 31, 2009
Quarter # 7

FSI RRC "Kurchatov Institute"
1 Acad. Kurchatov sq., Moscow 123182 Russia

Project Manager Balanin, Andrey Leonidovich

19.10.09
Signature / Date

1. Brief description of work progress under the Project

1.1. Status of works under the Project

Task Subtask	Starting (Quarter)	Finishing (Quarter)	Status / Comments
Task 1 Subtask 1.1	Quarter 1	Quarter 6	In progress
Task 1 Subtask 1.2	Quarter 1	Quarter 6	In progress
Task 1 Subtask 1.3	Quarter 1	Quarter 6	In progress
Task 2	Quarter 1	Quarter 2	Completed
Task 3	Quarter 1	Quarter 3	Completed
Task 4 Subtask 4.1	Quarter 3	Quarter 6	In progress
Task 4 Subtask 4.2	Quarter 3	Quarter 6	In progress
Task 4 Subtask 4.3	Quarter 3	Quarter 6	In progress
Task 4 Subtask 4.4	Quarter 3	Quarter 6	In progress
Task 5 Subtask 5.1	Quarter 1	Quarter 3	Completed
Task 5 Subtask 5.2	Quarter 1	Quarter 4	Completed
Task 5 Subtask 5.3	Quarter 2	Quarter 4	Completed
Task 5 Subtask 5.4	Quarter 2	Quarter 4	Completed
Task 5 Subtask 5.5	Quarter 1	Quarter 4	Completed
Task 5 Subtask 5.6	Quarter 3	Quarter 4	Completed
Task 5 Subtask 5.7	Quarter 3	Quarter 4	In progress
Task 6 Subtask 6.1	Quarter 4	Quarter 4	Completed
Task 6 Subtask 6.2	Quarter 4	Quarter 5	In progress
Task 7 Subtask 7.1	Quarter 5	Quarter 5	In progress
Task 7 Subtask 7.2	Quarter 6	Quarter 7	In progress

1.2. Tasks according to the Working plan

Task 1. Development and improvement of computational models for studying criticality safety and inherent self-protection of HTGR-M.

Subtask 1.1. Development of a neutronic model.

Development and improvement of the basic neutronic model are almost completed.

Adjustments to the neutronic model shall be done with regard to the thermal insulation of the critical assembly core. Since thermal insulation suppliers do not produce blocks of necessary sizes any more, the insulation design had to be revised. No final decision has been made in respect to the thermal insulation material and design.

- **Individual participants**

Name	Category	Days
Boyarinov Victor Fedorovich	1	15
Fomichenko Petr Anatolievich	1	10
Abrosimov Nikolai Gennadyevich	1	10
Kodochigov Nikolai Grigoryevich	1	10
Osipov Sergey Leonidovich	1	15
Sukharev Yuriy Petrovich	1	10
Shepelev Sergey Fedorovich	1	10

Subtask 1.2.: Development of a thermophysical model.

Development and improvement of the basic thermophysical model are almost completed.

Adjustments to the thermophysical model shall be done with regard to the thermal insulation of the critical assembly core. Since thermal insulation suppliers do not produce blocks of necessary sizes any more, the insulation design had to be revised. No final decision has been made in respect to the thermal insulation material and design.

- **Individual participants**

Name	Category	Days
Sedov Aleksey Aleksandrovich	1	10
Afanasyev Vladimir Nikolayevich	1	20
Baluyev Dmitriy Evgenyevich	1	10
Nikanorov Oleg Leonidovich	1	10
Osipov Sergey Leonidovich	1	10
Kuznetsov Lev Evgenievich	1	20
Kodochigov Nikolai Grigoryevich	1	5
Kaidalov Viktor Borisovich	1	9
Vasyayev Aleksey Viktorovich	1	10
Shepelev Sergey Fedorovich	1	15
Anishev Evgeniy Yuryevich	2	10
Chuvilin Maksim Aleksandrovich	2	7
Shohonov Vladimir Petrovich	2	13

Subtask 1.3.: Development of a dynamic model.

Development and improvement of the basic dynamic model are almost completed.

Adjustments to the thermophysical model shall be done with regard to the thermal insulation of the critical assembly core. Since thermal insulation suppliers do not produce blocks of necessary sizes any more, the insulation design had to be revised. No final decision has been made in respect to the thermal insulation material and design.

- **Individual participants**

Name	Category	Days
Sedov Aleksey Aleksandrovich	1	6
Petrushenko Raisa Pavlovna	1	10
Fomichenko Petr Anatolievich	1	7
Frolov Aleksey Anatolyevich	2	12
Kurganova Vera Pavlovna	2	20
Sukharev Yuriy Petrovich	1	10

Task 4: Development of working programs of experiments at the ASTRA facility critical assembly at room temperature and with heating up to high temperatures.

Subtask 4.1.: Working program of investigation of the reactor temperature reactivity effect at heating the critical assembly in the range from 20 to 600 °C.

The work on development of the working program of investigation of the temperature reactivity effect at heating the ASTRA facility assembly in the range of 20-600 °C was continued.

It was decided that the critical assembly would be heated in a dynamic mode without attainment of the steady state, with measurement of necessary neutronic characteristics in quasi-stationary thermal states. The critical assembly design and material composition are being finalized.

- **Individual participants**

Name	Category	Days
Glushkov Aleksey Evgenyevich	1	14
Glushkov Evgeni Serafimovich	1	10
Gurevich Mikhail Isaevich	1	4
Kompaniets Geogiy Vasilievich	1	10
Smirnov Oleg Nikolaevich	1	12
Mironenko-Marenkova Mariya Evgenievna	2	3
Nevinitsa Vladimir Anatolievich	2	4

Subtask 4.2.: Working program of separation of components of the assembly temperature reactivity effect.

The work on development of the working program of separation of components of the ASTRA assembly temperature reactivity effect was continued.

According to the general program developed in Task 3 (Subtask 3.2), the procedure of neutronic experiments on separation of temperature reactivity effect components for the core, internal reflector and side reflector at heating the critical assembly is described. The critical assembly design and material composition are being finalized.

- **Individual participants**

Name	Category	Days
Glushkov Evgeni Serafimovich	1	10
Kompaniets Geogiy Vasilievich	1	10
Krotov Vladislav Andreevich	2	20
Privalova Ludmila Aleksandrovna	2	5
Shatrova Lidiya Petrovna	2	16
Ivanova Tatiana Sergeyevna	4	4

Subtask 4.3.: Working program of determination of control rod worth versus temperature.

The work on development of the working program of determination of control rod worth versus temperature was continued.

According to the developed conceptual program (Subtask 3.3), the procedure of measuring the rod worth by the rod drop method at room temperature and at heating the ASTRA critical assembly is described. The critical assembly design and material composition are being finalized.

- **Individual participants**

Name	Category	Days
Nosov Vitaliy Ivanovich	1	14
Gurevich Mikhail Isaevich	1	10
Kleymenov Vladimir Aleksandrovich	1	10
Kukharkin Nikolay Evgenyevich	1	8
Nevinitsa Vladimir Anatolievich	2	8
Subbotin Aleksey Stanislavovich	2	12

Task 5: Development of technical documentation for modification of the ASTRA critical facility ensuring performance of experiments in the ASTRA facility critical assembly with heating up to high temperatures.

Subtask 5.7.: Issue of technical documentation for the ASTRA critical facility as a whole.

The work on issue of modifications and supplements to technical documentation for the ASTRA critical facility is at the stage of review and approval by the management.

- **Individual participants**

Name	Category	Days
Baryshnikov Vladimir Nikolayevich	1	7
Grebennik Vadim Nikolaevich	1	12
Daneliya Sergey Borisovich	1	10
Novikov Lev Ivanovich	1	16
Samarin Evgeni Nikolaevich	1	12
Balanin Andrey Leonidovich	2	25
Abrosimov Nikolai Gennadyevich	1	13
Vasyayev Aleksey Viktorovich	1	12
Vilensky Oleg Yuryevich	1	12
Kaidalov Viktor Borisovich	1	11
Pobedonostsev Aleksey Borisovich	1	10
Silaev Vladimir Mikhailovich	1	20
Chumanin Viktor Andreevich	1	10
Scherbakov Pavel Ivanovich	1	10
Dokushkin Yuriy Evgenyevich	2	20
Karasev Sergey Vyacheslavovich	2	10

Task 6: Purchase of materials, equipment and components, and fabrication of special equipment for upgrading the ASTRA facility.

Subtask 6.2.: Selection of suppliers. Placement of orders and purchase requisitions.

Analysis and selection of potential suppliers of materials, equipment and components and manufacturers of special equipment was completed on the basis of Subtask 6.1 (Determination of requirements) and the ASTRA facility modification design being developed.

Orders for fabrication of equipment and purchase of necessary components and materials are being placed.

- **Individual participants**

Name	Category	Days
Daneliya Sergey Borisovich	1	10
Ryazanov Dmitriy Sergeyevich	2	20

Task 7. Commissioning of the modified ASTRA facility with execution of necessary operational documentation.

Subtask 7.1. Approval of the facility documentation by the RF GAN, obtaining necessary permits.

A set of facility documentation (a supplement to the detail design and an explanatory note, a safety analysis report) is being prepared. The supplement to the facility detail design is at the review and approval stage.

- **Individual participants**

Name	Category	Days
Baryshnikov Vladimir Nikolayevich	1	10
Zaichkina Irina Ivanovna	1	10
Kapitonova Alla Viktorovna	1	5
Motenko Vladimir Georgievich	1	20
Nechaev Yuriy Aphanasyevich	1	5
Ponomarev-Stepnoi Nikolay Nikolayevich	1	8
Balanin Andrey Leonidovich	2	25

Subtask 7.2. . Installation of the heated ASTRA facility equipment.

Spherical fuel elements were removed from the critical assembly core. So the critical assembly is prepared for forming a new configuration and installation of equipment. Lengths are being measured for laying cables, gas supply pipes, etc.

- **Individual participants**

Name	Category	Days
Bobrov Anatoly Alexandrovich	1	16
Zimin Alexander Alexeevich	1	16
Kleymenov Vladimir Aleksandrovich	1	14
Lobkovskiy Boris Semenovich	1	10
Moroz Nikolai Petrovich	1	20
Tchunyaev Evgeni Ivanovich	1	22

2. Краткая информация по индивидуальным участникам

	Number of persons	Total Days	Total Grants (US $)
Category I	43	664	18164
Category II	16	257	5979
Category III	-	-	
Category IV	1	4	72
Total:	60	925	24215

3. Preparation of Reports and Publications

There were no publications.

4. Important Travel and Meetings

4.1. Internal Travel and Meetings

A project meeting was held at RRC “Kurchatov Institute” on July 2 and 3, 2009.
Issues discussed at the meeting:
1. Progress of work under the project.
2. Design solutions for:
- heater;
- cooling system;
- gas supply system;
- gas atmosphere and temperature control system.
3. Dynamic mode of heating the critical assembly.
4. Status of documentation to be approved by the RF GAN.
5. Possible locations for the gas supply and cooling systems equipment at the ASTRA facility.

4.2. Travel and Meetings outside CIS

1. Prague, Czech Republic on July 21-27, 2009.

Delegation:
A. L. Balanin, P. A. Fomichenko.

Participation in the European Commission International Conference “EURATOM research and training on reactor systems” – FISA-2009 and attached topical workshops.

There was made a poster presentation in English entitled “Nuclear Safety and Inherent Self-protection Investigations for Modular High Temperature Gas-cooled Reactors. Experimental Demonstration in the ASTRA Critical Facility of the Inherent Safety Characteristics of HTRs”

2. Amsterdam, Petten, the Netherlands on July 20-22, 2009.

Delegation:
A. L. Balanin, P. A. Fomichenko.

Participation in the working meeting on Generation IV VHTR Computational Methods Validation & Benchmarking (provisional) Project Management

5. Cooperation with Foreign Collaborators

1. At the FISA-2009 Conference in Prague, Czech Republic on July 21-17, 2009.

At a special ISTC Workshop, the progress of work under Project # 0685.2, current tasks and issues relating to possible extension of the project were discussed with collaborator representatives Mr. von Lensa (FZJ, Germany) and Dr. van Heek (NRG, the Netherlands).

2.At the working meeting on Generation IV VHTR Computational Methods Validation & Benchmarking (provisional) Project Management in Amsterdam and Petten, the Netherlands on July 20-22, 2009.

The progress of work under Project # #0685.2, intermediate results, the approach to follow-up works, and prospects were presented at the meeting.

6. Procurement

There was no procurement.

7. Questions, Proposals

(Including plans for next quarter if significant changes were included in the Working Plan).

5. Hot ASTRA Meeting report December 2012

note

Restricted

to	:	N. Kohtz	TüV Rheinland; ARCHER SP2 leader
		J. Bader	IKE; ARCHER WP2.4 leader
		S. de Groot	NRG; ARCHER Coordinator
		S.T. Jayaraju	NRG; project manager
From	:	J.C. Kuijper	NRG; representative of Western collaborators
Copy	:	E.S.M. Bot	NRG; team manager
		A.L. Balanin	Kurchatov Institute; project manager
		C. Trakas	AREVA; Western collaborator
		Y. Malakhov	ISTC; project officer
Date	:	22 January 2013	
reference	:	22902/13.118136 I&D/JCK/RK	
subject	:	Status ISTC project #685.2 “Self-protection of reactors” - Report ASTRA meeting, Moscow, 11 and 12 December 2012	

1 Introduction

The main objective of ISTC project #685.2 “Self-protection of reactors”, is to upgrade the pebble-bed HTR-type ASTRA critical facility at the Kurchatov Institute in Moscow to the possibility of performing critical experiments at elevated temperatures. It is planned to install an electrical heater in the centre of the facility. The experiments in the upgraded facility are expected to provide valuable data on temperature reactivity feedback coefficients and efficiency of control rods in a pebble-bed HTR configuration at high temperatures. This information will be made available to the formal Western collaborators, and consecutively to the ARCHER consortium.

Since the start of the project, 1 December 2007, NRG has been involved as formal Western collaborator, initially together with AREVA, FZ Jülich and CEA. As far as NRG is concerned, these liaison activities were originally embedded in the EU FP6 project PUMA (“Plutonium and Minor Actinide Management in Thermal High-Temperature Gas-Cooled Reactors”). After the finalisation of this project end of 2009, these liaison activities (NRG and AREVA only) have been transferred to the EU FP7 ARCHER project, as part of SP2, Task 2.4.3.

The previous ASTRA meeting in Moscow was held 27 and 28 January 2009. Since then the project has suffered from considerable delays. To a large extent these were connected to the lack of funds to purchase the heating equipment, due to inflation in the rather large time span between moment of the cost estimation/proposal submission (1990-s) and the actual start of the project, December 2008. In order to reduce the costs, the project management at the Kurchatov Institute decided to build the necessary equipment themselves. However, it turned out to be another problem to purchase the required small amounts of necessary special types of steel. The delay was communicated in an update of the project plan, which initially shifted the date of completion to the 2nd quarter of 2013. The problems with the steel seem to have been solved now (see meeting report in next sections). Another problem is that, with the Russian Federation pulling out of ISTC by 2015 (at least as a recipient), ISTC is putting pressure on current projects to be terminated as soon as possible. For the ASTRA upgrade project, which already had several extensions without extra funding, this would mean termination by the end of 2012. Fortunately it was possible to convince the ISTC management to grant an extension (without extra funding) until 31 May 2013. However, due to additional problems the latest updated planning foresees the finalisation of the project by the 3rd quarter of 2014 (see next sections).

In the next sections the present status of the project will be given, as presented at the recent ASTRA meeting, Kurchatov Institute, Moscow, 11 and 12 December 2012.

2 ASTRA progress meeting, 11 and 12 December 2012

2.1 Agenda (draft)

	11 December	
9.00	Transport to the RRC KI	
10.00	Visit to ASTRA critical facility	
12.00	Visit to pilot production	
13.00	Lunch	
15.00	Transport to the hotel	
	12 December	
9.00	Transport to the RRC KI	
10.00	Presentation of participants	
10.10	Discussion of agenda	
10.20	Opening address	P. Fomichenko
10.35	Communication of collaborator	J. Kuijper
10.50	Status of works on HTGR in the “Kurchatov institute”	P. Fomichenko
11.20	Review of project working status	A. Balanin
12.20	Lunch	
14.00	Information & measuring system	A. Bobrov

14.30	Reactivity analysis of dynamic heating regime of ASTRA critical assembly	V. Nevinitsa
15.00	Review of HTGR activities in Europe	J. Kuijper
15.30	Discussion	
17.00	Transport to the hotel	

2.2 Part 1 – 11 December 2012

2.2.1 Participants

Pavel Alekseev	Director of Institute of Advanced Energy Technologies
Alexander Kostin	Head of pilot production plant
Nicolai Moroz	Head of ASTRA facility
Sergey Danelia	Engineer
Alexander Propletin	Technician
Andrey Balanin	Project manager
Maria Mironenko	Interpreter
Jim Kuijper	Representative of Western collaborators

2.2.2 Visit to pilot production plant

Jim Kuijper and Andrey Balanin visited the “pilot production plant”, actually the workshop, where the heater system and other new components for the upgraded ASTSA facility will be made. Alexander Kostin, head of the pilot production plant, explained some of the equipment to be used for the production of the heater. There is no doubt that all the required components can be manufactured according to specifications, once the required material (mainly a special type of steel) becomes available.

2.2.3 Visit to ASTRA facility

The core of the ASTRA facility is empty at the moment. All fuel pebbles and the central reflector structure have been taken out in preparation for the modifications. Sergey Danelia explained the foreseen thermal insulation of the (pebble-bed) core. The core will be insulated in radial as well as axial direction.

The type of pebble stacking to be applied was briefly discussed. The choice is between regular and stochastic stacking. This is still to be decided. In any case the graphite at the bottom of the core cavity has to be made perfectly flat, in order to accommodate the placement of thermal insulation.

There still is a problem with the delivery of the required special steel. Initially the Elektrostal Company produced a certain amount of steel, which was a little bit more than paid by ISTC (due to production features).. An additional payment, according to the right specifications was needed, resulting in a delay of delivery. The extra payment is not a principal problem and just needs time. This problem is about to be solved by the project manager.

2.3 Part 2 – 12 December 2012

2.3.1 Participants

Evgeny Glushkov	Chief scientist (glushkov@adis.vver.kiae.ru)
Victor Boyarinov	Head of laboratory (boyarinov@dhtp.kiae.ru)
Anatoly Bobrov	Senior research scientist (aab@atomar.net.ru)
Vadim Grebennik	Senior research scientist (greben@dserver.dhtp.kiae.ru)
Gennadiy Trukhanov	Leading scientist (ecosail2009@yandex.ru)
Vladimir Nevinitsa	Head of department (neva@dhtp.kiae.ru)
Andrey Balanin	Project manager (alb@dhtp.kiae.ru)
Peter Fomichenko	Director of division (pf@dhtp.kiae.ru)
Maria Mironenko	Interpreter (m.mironenko@kra.kiae.ru)
Jim Kuijper	Representative of Western collaborators

2.3.2 Opening

- Opening address by Peter Fomichenko.
- Introduction of the participants.
- Slides will be made available

2.3.3 Brief overview of the work: HTGR physics at the Kurchatov Institute

Peter Fomichenko, Evgeniy Glushkhov and Victor Boyarinov gave a brief overview of the HTGR physics work at the Kurchatov Institute, which is mainly the GT-MHR development program (presentation available):

- Disposition of WG Pu (USA-RU agreement; PDMA)
- GT-MHR technology ➔H- production, LWR Pu utilization:
- Direct cycle gas turbine (Brayton cycle); in the USA: indirect cycle
- PuO_2 in ZrO_2 inert matrix kernel (400 micron) with oxygen getter

- Addition of SiC in buffer layer
- Conceptual design and preliminary design completed and reviewed by international experts, US/DOE and MINATOM
- GA involvement has decreased
- Overview of project and milestones
- Development plan ➔ Work scope descriptions
- Reactor physics/neutronics calculations
- 200 micron kernel rejected, as result of fuel performance calculations
- CRP-6 Golt code (fuel performance)
- Analysis of gas bypass by CFD codes. Conservative approach for design calculations
- Er-167 burnable poison to achieve negative temp. react. coeff. ➔optimize Pu-9/Pu-1 to Er-167 mass ratio
- Codes:
    - WIMS-D+JAR+HTGR
    - UNK
    - MCU
    - MCNP
- Regulator: Rostechnadzor ➔evaluates codes regularly➔certification➔"Passport of certification"

Facilities at NRC KI:

- ASTRA
- TsGS out-of-pile loop (He-technology)
- OSA facility (fission product release)
- HTS – Thermochemical facility for hydrogen production (not in use at the moment)

An irradiation test is being conducted in Dimitrovgrad.

Perspectives for extension of the project:

- NGNP
- GenIV International Forum
- IAEA CRPs

Bismark Tyobeka (IAEA) has recently visited the Kurchatov Institute in the frame of HTGR "uncertainty propagation" (a new CRP).

In the 2008 GT-MHR Action Plan it was stated that it was expected to have the first GT-MHR ready by 2020. This is now regarded as too optimistic. A 600 MWth GT-MHR may not be economical…

2.3.4 Address of Western collaborator

Jim Kuijper presented the point of view of the Western collaborator(s). Main points of concern are:

- ISTC project #685.2 will be terminated 31 May 2013
- Will the ASTRA upgrade be ready in time?
- Which experimental program can and will be carried out?
- Which data will be made available to the Western collaborators in which detail?
- Will the level of detail be sufficient for further experimental validation of HTR neutronics (design) computer codes?

The slides of the presentation are available.

2.3.5 Status of the project

Project manager Andrey Balanin presented the present status of the ASTRA upgrade project, and highlighted some problems in the execution.

There have been difficulties in manufacturing the heater. The original supplier lost the capability to manufacture the heater. OKBM proposed another manufacturer, which was, however, too expensive ($120000 instead of $50000). $120000 is nearly the total budget for all equipment and materials in the Project.

The decision was taken to have the heater produced by the appropriate division of the Kurchatov Institute. ISTC was prepared for an agreement on this. However, at some point the head of division refused. The Kurchatov Institute prepared the design/fabrication drawings, which were consecutively approved by the pilot production facility and the ceramics factory. The pilot production made several attempts to find a steel supplier. This gave a lot of problems (mostly of bureaucratic nature).

Production of the heater requires 21 kg of two types of rolled steel, which is much less than minimum quantity that the steel supplier is normally willing to provide. This problem is about to be solved by the project manager, through contacts with the Electrostal metallurgical works. Hopefully the required steel will be delivered before the end of 2012. The pilot production plant can then immediately start to manufacture the heater.

The heater will also contain ceramic parts. There has been reorganization at the factory where these ceramic parts were to be made, and the factory lost the capability to produce these parts. A request has been sent to other possible manufacturers. First replies are expected before the end of 2012. It may be possible to use an alternative material (like alumina ceramics). The Kurchatov Institute does not have the capacity to do this.

The next problem concerns the thermal insulation tiles (fire clay bricks) surrounding the reactor core. A new frame was designed to support the thermal insulation tiles in the core cavity. These thermal insulation tiles are fire clay bricks. In the design of the frame tile dimensions of 25x25 cm was assumed. Unfortunately the producer of these special-size tiles went bankrupt. Other producers can only make standard forms or standard bricks. These are too small, which would lead to too many bricks. Also the design work for the frame has to be repeated for a different size brick/tile.

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The final problem is connected to the operating license of the ASTRA facility. In 2011 the license expired (30-year operation life). In the original project plan this would not have been a problem, as the upgrade of the facility as well as the experiments at elevated temperatures would have been finalized before the expiration of the license. The board of directors of the Kurchatov Institute has decided to prolong the operating life of the ASTRA facility. Rostechnadzor has been informed. Changes to the SAR (Safety Analysis Report) are required to operate at higher temperatures. A detailed work plan has been drafted for obtaining a new license.

The new license is expected 4th quarter 2013. Because this will be after the formal expiration of the ISTC project #685.2, all possible efforts will be made to finalize the experiments. All necessary actions will be undertaken to purchase the equipment before the formal expiration of the project.

It was known from the beginning that the project funds would be insufficient. Additional funds may come from GT-MHR project, as the experimental data will also be used there. No decision on this has been taken yet. Western collaborators will be kept informed.

2.3.6 Information and measurement system

Anatoli Bobrov presented the planned data acquisition system (presentation available in Russian). Three categories of data will be collected and stored:

- Data directly taken during experiments
- Control of the critical assembly ➔current power, power change rate
- Process parameters

The information collection system can handle ~ 200 channels at the moment. Adding extra channels is not expected to be a problem.

The maximum (fission) power of the ASTRA facility is 100 W. A paper is available on the power measurement.

Channels for flux/power measurements:

- 4 current cannels
- 3 pulse channels (very low power); 0.2 % uncertainty STI-3 channel ➔ reference

The control of the partial composition of gas in the assembly room is not critical.

Temperature measurements will be conducted I the assembly, and as part of the heater control system.

The sampling rate depends on requirements and available storage. For reactivity measurements the highest possible sampling rate will be applied during fast experiments. Procedures have yet to be defined.

For some temperature measurements platinum resistance thermometers (PRT) will be used. For these devices a 4-wire set-up should be used: 2 wires for the stable current source, 2 wires for the voltage measurement. Unfortunately, the available PRTs are 3-

wire types. This will give a systematic shift in the reading. This has to be compensated for. A similar problem occurs with the thermocouples.

The required length of the cables for the thermocouples is determined by the design of thermal insulation. This design has not been completed yet (see previous section).

Altogether, the instrumentation part seems to be under control.

2.3.7 Reactivity analysis

Vladimir Nevinitsa presented the reactivity analyses of proposed heated experiments (presentation available). It takes a long time (> 10 days) to achieve a heated steady state. Using the steady state also has other disadvantages. Therefore it was decided to a use dynamic mode of operation.

The computational analysis was carried out by:

- WIMS-D , JAR (3D multi-group diffusion)
- 2D R-Z thermal hydraulics model

Coupled neutronics and thermal hydraulic calculations were performed to predict the temperature distribution. Only a very small change of reactivity (and k_{eff}) is expected within the time frame of 8 hours.

MCU models exist for ASTRA (previous, “room temperature” version; submitted to IRPhE). These are quite similar to MCNP model. A semi-automatical conversion should be possible.

Generally, It is important to have as much detailed information as possible, not only for the validation of present codes, but also for future, more detailed codes.

3 Conclusions

Despite numerous difficulties the experiments with an upgraded ASTRA facility seem to be heading to a successful completion, although with a considerable delay.

The experiments with the upgraded ASTRA facility will not have been finalized before the formal expiration of the ISTC project #685.2, June 2013

All necessary actions will be undertaken to purchase the equipment before the formal expiration of the ISTC project.

NRC KI will make all possible efforts to finalize the experiments (including the ASTRA license renewal/extension) on other funds, within the timeframe originally stated in the request for extension to ISTC, i.e. 2nd quarter of 2014. Experimental data are expected to be delivered to the Western collaborators in that time frame.

4 Most recent status information (21 January 2013)

The special steel for the heater has been purchased and delivered to the Kurchatov Institute. The search for an appropriate supplier of the ceramics parts is on-going.

J.C. Kuijper

NRG

6. Letter from A. Balanin

Dear Colleagues!

This is to inform you that analytical/theoretical studies and designing of systems and components of the facility to be modified have been basically completed under Project # 0685.2 “Hot ASTRA”. Comprehensive substantiating calculations were performed, and basic technical documentation was developed. However, the situation with carrying out practical work on preparation of the facility for experiments develops in a non-optimum way, which causes delays.

Firstly, the purchase of the heater and its control and power supply system was delayed, because the initially intended manufacturer of this equipment (namely, OKBM – an institute participating in the project) does not have the capability to fabricate it any longer due to reasons related to the production process, and a new manufacturer proposed by OKBM quoted a price much higher than provided for in the cost estimate. A search for an acceptable supplier also takes time. At the moment a tender for procurement of said equipment has been announced through the ISTC.

Secondly, the purchase of materials for thermal insulation of the ASTRA critical assembly core was delayed because, due to the economic crisis, suppliers suspended manufacturing of right size plates of the thermal insulation material included in the design for an indefinite period. A search for a new material takes a long time, since the material shall satisfy numerous technical, physicochemical and economic requirements.

Unfortunately, these circumstances that are beyond control of RRC KI made it impossible to complete the practical work specified in the project work schedule in a timely manner.

We believe that due to the difficulties described above the project performance period should be extended for at least 2 quarters without additional funding. Such a procedure is provided for in the ISTC project performance rules, and we believe its application is justified in this case. Note that in the current difficult economic conditions this step is aimed at fulfillment of the stated project objectives in the future as the difficulties are resolved. Therefore, we would appreciate if the collaborators support this decision.

Sincerely,

Andrey Balanin
Project Manager