3.15. I.I. Afrikantov EXPERIMENTAL MACHINERY DESIGN BUREAU

603074, Nizhni Novgorod,
Burnakovsky proyezd, 15
Telephone: (831) 275-26-40
Fax: (831) 241-87-72
http://www.okbm.nnov.ru
E-mail:okbm@okbm.nnov.ru

The history of the I.I. Afrikantov Experimental Machinery Design Bureau (OKBM Afrikantov) dates back to December 27, 1945, when following a governmental decree Experimental Special Machinery Design Bureau was set up on the basis of Gorkiy Artillery Works No. 92 to support the activities of the Soviet "Atomic Project".

Starting in the late 1940s, the Bureau was actively involved in creation of the first production reactors and in the 1950s embarked on development of reactors for the Navy and the civil fleet.

Panorama of the OKBM Afrikantov site

I.I. Afrikantov

On January 1, 1964, the Bureau became an independent organization within the framework of the State Committee of the USSR for the Use of Atomic Energy.

In 1967, it came to be openly referred to as the Experimental Machinery Design Bureau and in 1998 added to its title the name of Igor Afrikantov – Chief Designer (since 1961) and Director (from 1964 to 1969).

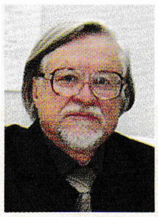
OKBM Afrikantov is one of the leading design organizations of Rosatom and a major diversified research and production center in the sphere of nuclear engineering with its own manufacturing and experimental capabilities.

The company's well-developed infrastructure supports a full engineering and manufacturing cycle: from design to manufacture and testing, to complete delivery of products to customers, to servicing support throughout the full operating period of highly reliable reactor facilities.

The experimental capabilities of OKBM are concentrated in its Research and Testing Complex (RTC).

D.L. ZVEREV
Director – General Designer of OKBM Afrikantov

A.M. BAKHMETIEV
Dr. Sc. (Tech.), Professor
Deputy Director for Science – RTC Manager



S.G. ANTIPIN
Head of the Laboratory of Critical Systems (Assemblies) and Thermal Physics

This complex built to deal with integrated and diverse objectives is engaged in research and development activities to provide special equipment for the nuclear power industry and to carry out experiments and tests in a wide spectrum including:

– studies of neutronic processes in the reactor core;

– studies of thermal processes in fuel assemblies, reactor facility, safety circuits;

– tests of the whole range of reactor facility components, fuel handling equipment, whole-plant systems;

– studies of structural strength and material properties;

– studies of tribotechnical characteristics, corrosion properties and resistance of materials to extreme impacts.

The Research and Testing Complex includes the Laboratory of Critical Systems (Assemblies) and Thermal Physics with two critical rigs for "cold" tests (ST-659) and "hot" tests (ST-1125).

The critical facilities of the laboratory are intended for testing first-of-the-kind and series-produced reactor cores of ships, submarines and

Nuclear research facilities of OKBM

NRF type	NRF name	Thermal power, kW	First criticality, year	Status	Operation period, years*
CF	ST-659	0.10	1963	In operation	49
CF	ST-1125	0.60	1975	In operation	37

**As of 2012*

NCGP, supporting development of advanced reactor cores and producing experimental data to be used in verification of computer codes for analysis of reactor cores developed by OKBM Afrikantov.

The technical competence of the testing center, which is part of the RTC, is confirmed by its accreditation in the framework of the GOST R Certification System and the System for certification of components, products and technologies for nuclear facilities, radiation sources and storage facilities.

CRITICAL FACILITY FOR "COLD" TESTS OF REACTOR CORES, ST-659

The ST-659 critical facility for "cold" tests (a neutronic model of water-cooled and water-moderated reactors) was put into operation in 1963 (with first criticality reached on June 15, 1963). The ST-659 rig was designed for studying the neutronic characteristics of reactor cores (and their components) of water-cooled and water-moderated nuclear reactors at atmospheric pressure and ambient temperature.

The "cold" ST-659 facility serves for studies of modeled and operational cores of propulsion reactors.

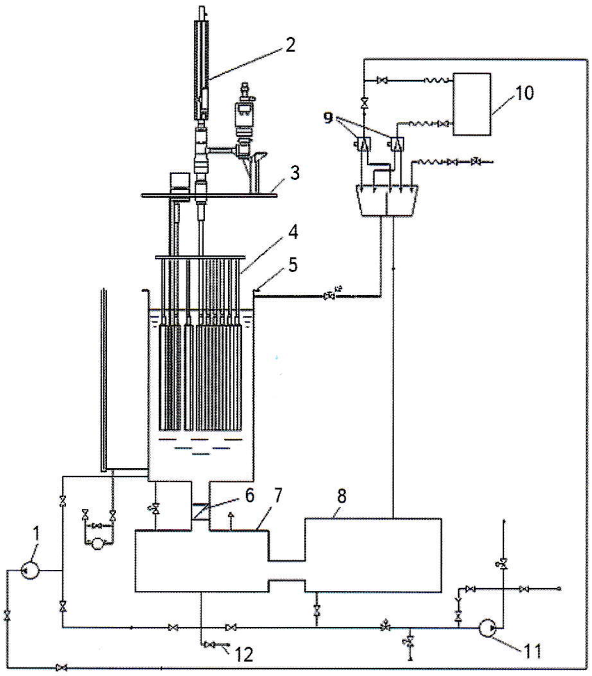
Nuclear material loading patterns are drawn up as core-specific maps.

The ST-659 fuel elements appear as metal-clad rods containing uranium fuel and filling. The loading in terms of isotope ^{235}U is a variable quantity.

The fuel assemblies are bundles of fuel rods, burnable absorber rods and displacers arranged in accordance with the core map. The bundles are enclosed in round or hexahedral shrouds. The end-pieces of a shroud serve for spacing of fuel assemblies in a removable unit.

Overall view of the ST-659 facility

An emergency protection (EP) member is an array of five articulated absorbing elements, with an absorber enclosed in a cylindrical metal case. EP members are found in "dry" CPS sleeves which, in turn, reside in CPS fuel assemblies. Use is made of no less than 4 EP members.



Schematic hydraulic circuit of the ST-659 facility:
1 – electric pump; 2 – CPS member control mechanism; 3 – CPS support; 4 – critical assembly; 5 – main tank; 6 – emergency drainage valve; 7, 8 – emergency drainage tanks; 9 – distributor (devices for breaking the precision makeup jet and the coarse makeup jet); 10 – solution preparation tank; 11 – drainage pump; 12 – sampling point

Shim members comprised of absorber rods are grouped on one cross-arm which is moved in a vertical plane by a special control mechanism. The absorber rods travel in between assemblies or inside them. The number of the rods and the form of the cross-arm depend on the core type.

The moderator system comprises subsystems for:

– intake and accumulation of distilled water inside the facility;

– moderator supply to the main tank of the facility (makeup);

– makeup control and safety assurance;

– monitoring of the moderator level in the main tank;

– emergency emptying of the main moderator tank;

– preparation of solutions (moderator "poisoning");

– spent moderator drainage.

For their operation the above subsystems rely on the following components:

– main tank to accommodate the critical assembly;

– emergency drainage tank where moderator is stored (the tanks communicating via an emergency drainage valve 250 mm in diameter);

– solution preparation tank, which serves also for precision makeup (with the speed of level rise in the main tank set at 0.1 mm/s) and communicates with the main tank via a device for the precision makeup jet breaking.

Main performance of the ST-659 facility

Thermal power N	Up to 100 W
Maximum neutron flux at N=100 W:	
thermal	$2.0\cdot10^{7}$ $cm^{-2}\cdot s^{-1}$
fast	$3.0\cdot10^{7}$ $cm^{-2}\cdot s^{-1}$
Moderator	Distilled water
Coolant	Absent
Forced cooling	Not required
Reflector	Iron and water
Number of fuel assemblies in the core	Variable*
Number of emergency protection members	No less than 4*
Number of shim members	Up to 5*
CPS member materials	Absorber materials based on B, Eu, and Dy compounds
Type of CPS member drive	Electromechanical

* *Depends on the core type*

Control and protection system

The CPS of the ST-659 facility incorporates:

– physical parameters monitoring system;

– emergency control signal generation system;

– emergency protection features;

– shim and urgent reactivity reduction features (regulators);

– systems for control of emergency protection devices, regulators and shim devices.

The emergency protection – information and control – signals are generated:

– if the preset power level is exceeded – in any one of the eight channels;

– if the power doubling time is reduced (to below the preset value) – in one out of two channels;

ST-659 control room

– if the preset gamma background level is exceeded – in one out of two channels;

– if the preset moderator level in the main tank is exceeded – in one out of two channels;

– if power is lost to any physical monitoring detector;

– if any physical monitoring instrument becomes unavailable or is switched off;

– if the gamma background monitoring channel proves unavailable.

Warning signals are generated:

– if voltage is lost to the shim control circuit;

– if physical monitoring instruments show a malfunction;

– if the monitored parameters reach the warning setpoints;

– if the door to the facility compartment is opened.

The facility is protected, among other things, by an emergency moderator drainage mechanism which opens the associated valve in response to a signal from the control room.

An emergency signal will cause automatic release of emergency protection rods, release (lowering) of regulators, lowering of shim rods, and actuation of reactivity insertion interlocks in any way provided for this purpose.

The time taken by emergency protection rods to enter the core from the top end switch to the extreme bottom position, is < 1 s.

Californium neutron sources are used for reliable monitoring at the minimum power levels.

Experimental capabilities

The ST-659 facility can provide the following experimental data concerning a reactor core:

– critical mass values for different spacing of fuel assemblies;

– critical level and differential efficiency of moderator;

– critical positions and differential efficiency of shim rods, core reactivity margin for different positions of shim rods;

– power density distribution in the core (including such distribution inside individual fuel assemblies and along individual fuel elements), in the reflector region and in water cavities, which is determined by measuring the residual gamma radiation from fission products and by using radioactivity indicators;

– spectral characteristics of neutron fields (provided by activation of detectors with various neutron filters);

– efficiency of boric acid in the core moderator;

– efficiency of emergency protection and shim rods.

The facility allows:

– optimizing the fuel and burnable absorber content in the core for nuclear safety assurance and improvement of power density distribution;

– investigating the nuclear safety implications of failures to control the CPS members;

– optimizing the composition and configuration of the shim members.

Besides, the facility makes possible site-specific experimental studies for:

– checking the adequacy of hardware for monitoring the core condition during reactor loading, reloading and erection operations;

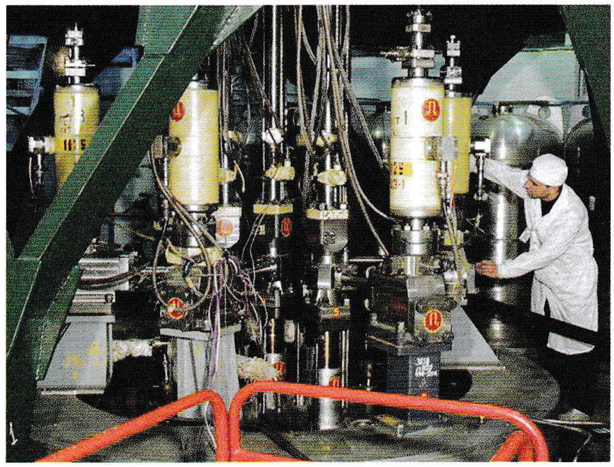
– optimizing core loading (reloading) procedures;

– determining the worth of experimental absorbers for future development.

CRITICAL FACILITY FOR "HOT" TESTS OF REACTOR CORES, ST-1125

The ST-1125 critical facility was put into operation in 1975 and was brought to first criticality on November 17, 1975. This critical facility was designed for studying the neutronic characteristics of various water-water reactor cores (and their parts) in a cold condition and during heating to the working temperature by an external source.

The facility combines pressurized components and support systems intended to maintain the specified thermal parameters of moderator-coolant (water or aqueous solution of boric acid), of water in component cooling circuits, as well as to monitor and measure the neutronic parameters during studies and tests of modeled and operational reactor cores.

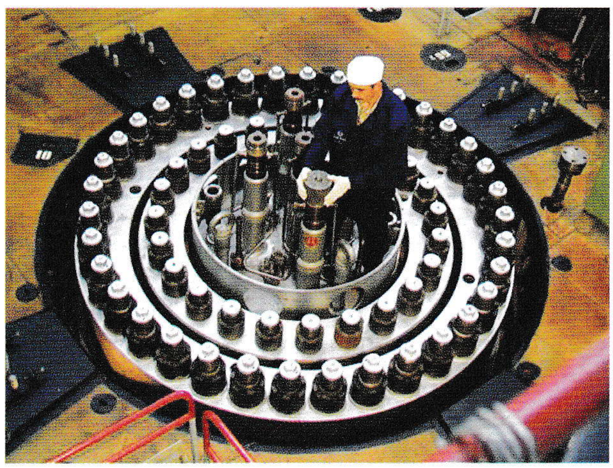


Installation of mechanisms for control of shim members at ST-1125

Main performance of the ST-1125 facility

Thermal power N	Up to 600 W
Maximum neutron flux at N=100 W:	
thermal	$1.2 \cdot 10^{8}$ $cm^{-2} \cdot s^{-1}$
fast	$2.5 \cdot 10^{8}$ $cm^{-2} \cdot s^{-1}$
Moderator	Distilled water
Coolant	Absent
Forced cooling	Not required
Coolant velocity in the core	< 0.1 m/s
Reflector	Iron and water
Reflector positions	Cylindrical side screen(s) enclosing the core, top and bottom reflectors
Number of fuel assemblies in the core	Variable*
Number of emergency protection members	No less than 9*
Number of shim members	Up to 7*
CPS rod materials	Absorber materials based on B, Eu, Dy
Type of CPS member drive	Electromechanical

* *Depends on the type of the core*



Preparation of the ST-1125 vessel for hydraulic tests of the main joint unit

The ST-1125 fuel elements are metal-clad rods with uranium fuel and filling inside. The ^{235}U content is variable.

The fuel assemblies are designed as bundles of spaced fuel elements, burnable absorber rods and displacers arranged in accordance with the core map. The bundles are enclosed in round or hexagonal shrouds. The end parts of the shrouds serve for spacing fuel assemblies in a removable unit.

The emergency protection members appear as an array of five articulated absorber elements (with the absorber contained in a cylindrical metal case). The EP members travel in "dry" CPS sleeves located inside the CPS fuel assemblies. The members are arranged in no less than four groups.

The shim members comprised of absorber rods are grouped on one cross-arm which is moved by a special control mechanism in a vertical plane. The absorber rods travel in between fuel assemblies or inside them.

The STT-1125 configuration includes:

– vessel for accommodation of the critical assembly;

– high-pressure circuit;

– support systems of the high-pressure circuit;

– boric poisoning system – beyond design-basis accident management equipment;

– vessel lid-mounted system of supports for mechanisms controlling shim members;

– critical assembly consisting of a removable core support structure and a set of fuel assemblies;

– control and protection system.

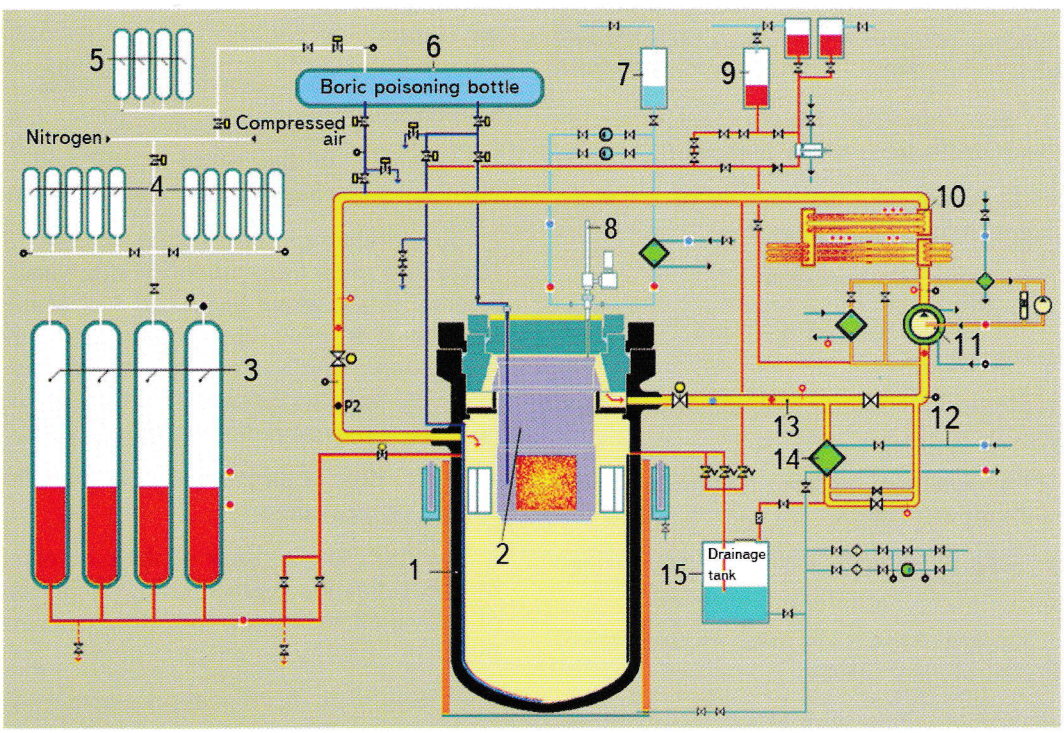

ST-1125 control room

For its operation in the EP or shim modes the CPS relies on the following types of control mechanisms:

– mechanisms with step motors performing both the shim and EP functions;

– mechanisms with induction motors performing the shim functions;

– mechanisms for control of EP members, including the raising and release mechanisms and servomechanisms.



Basic hydraulic diagram of ST-1125:
1 – vessel for critical assembly accommodation; 2 – critical assembly; 3 – pressurizers; 4 – gas bottles; 5 – gas bottles of the boric poisoning system; 6 – bottle with boric acid solution; 7 – system for cooling lid-mounted supports; 8 – shim members; 9 – filling and makeup system; 10 – external electric heater; 11 – circulation pump; 12 – component cooling system; 13 – high-pressure circuit; 14 – cooldown cooler; 15 – drainage system

The facility has six control mechanisms with step motors and seven control mechanisms with induction motors.

The number of penetrations in the replaceable vessel lids allows mounting on them up to seven mechanisms for control of shim members and up to seventeen mechanisms for raising and releasing EP members (rods).

Emergency protection – information and control – signals are generated:

– if the specified power level is exceeded – in any one of the four independent pulse channels and four independent current channels;

– if the power doubling time is reduced (to below the specified value) – in any one of the four independent pulse channels and four independent current channels;

– if the specified gamma background level is exceeded – in one out of two channels;

– in the event of overpressure in the facility vessel and high-pressure circuit (> 18 MPa) – in one out of two independent channels;

– in the event of pressure drop in the facility vessel and high-pressure circuit (< 5 MPa) – in one out of two independent channels;

– if power is lost to any detector of the physical monitoring system;

– if any physical monitoring instrument becomes unavailable or is switched off;

– in the event of a malfunction of a gamma background monitoring channel.

Warning signals are generated:

– if voltage is lost to the control circuit of the shim members;

– if physical monitoring instruments are found faulty;

– if the monitored neutronic parameters reach the warning setpoints;

– if supply voltage is lost to the position indicators of shim control mechanisms;

– if supply voltage is lost to the end switches of shim control mechanisms;

– if coolant temperature at the facility vessel inlet exceeds the specified level;

– if doors to the facility compartment are opened.

An emergency signal will cause automatic release of emergency protection rods, release (lowering) of regulators, lowering of shim rods, and actuation of reactivity insertion interlocks in any way provided for this purpose.

The time taken by EP rods to enter the core from the top end switches to the extreme bottom positions, is < 1 s.

Experimental capabilities of the ST-1125 facility

The facility can provide the following core characteristics to be determined through experiments:

– critical positions and differential worth of the shim members at different core temperatures and absorber concentrations in moderator, which can be used in estimating the core reactivity margin at working temperature;

– boron coefficient of reactivity;

– temperature and pressure coefficients of reactivity which are involved in estimation of the temperature effect of reactivity;

– the worth of emergency protection members throughout the range of core temperature variations;

– criticality conditions at different core temperatures;

– variations in the worth of EP and shim members with changes in the core temperature;

– power density distribution in the core (including such distribution in individual fuel assemblies and along individual fuel elements) for the core state specific to the working temperature, which is obtained on the basis of measured residual gamma radiation of fission products and using radioactivity indicators;

– power density distribution near the reflector and the core cavities;

– spectral characteristics of the core obtained by the activation method using combinations of activation indicators with different neutron filters.

The facility is fit for experimental studies relating to nuclear safety of reactor cores and including:

– estimation of the core subcriticality in the case of one or several CPS members getting stuck in the topmost position (with allowance made for possible errors during core loading and reloading);

– estimation of the minimum temperature at which the core can be kept critical in the process of cooldown, with several CPS members stuck in the topmost position and the available members lowered to the extreme bottom position;

– identification of the optimal conditions for monitoring of the core state during reactor loading and reloading as well as during erection operations.

Main activities

The critical facilities were used in studies for validation of advanced core designs.

The series-produced core for the reactor facility of a nuclear icebreaker was tested at the ST-659 facility.

At present, the facilities are being prepared for the planned tests of the first-of-the-kind core of the KLT-40S reactor facility for a floating nuclear cogeneration plant.

The facilities have been in operation by the same enterprise for more than 30 years. With the specified service life of the facilities coming to the end, a package of life extension work was carried out in 2007–2009. The results of those activities made it possible to extend the operation of facilities for another 15 years. The required licenses were issued by the Federal Service for Environmental, Technological and Nuclear Supervision.

The expected near-term uses of these experimental capabilities include:

– tests of the first-of-the-kind and series-produced reactor cores for nuclear icebreakers;

– tests of the first-of-the-kind and series-produced reactor cores for the floating nuclear cogeneration plant being built;

– experimental studies of the modeled reactor cores and those to be produced in series for the versatile nuclear icebreaker under development;

– experiments for improving the cores of propulsion reactor facilities.

Contact person

SERGEY ANTIPIN
Head of the Laboratory for Critical Systems and Thermal Physics
Tel.: (831) 246-95-12
Fax: (831) 241-87-72
E-mail: okbm@okbm.nnov.ru