Profile LFR-67

6B

RUSSIA

GENERAL INFORMATION

NAME OF THE FACILITY	Liquid metal test facility "6B" designed for studying thermal hydraulic processes in cores and heat-exchanging equipment (liquid metal test facility "6B").
ACRONYM	Liquid metal test facility "6B".
COOLANT(S) OF THE FACILITY	Sodium, sodium-potassium.
LOCATION (address):	Federal State Unitary Enterprise "State Scientific Centre of the Russian Federation – Institute for Physics and Power Engineering named after A.I. Leypunsky", State Corporation "Rosatom", Russian Federation.
OPERATOR	State Corporation "Rosatom".
CONTACT PERSON (name, address, institute, function, telephone, email):	Privezentsev V.V. Bondarenko Sq. 1, Obninsk, Kaluga Region, 249033, Russia Head of Laboratory, Candidate of Technical Sciences, phone: (48439) 9-56-57, privezentsev@ippe.ru.

STATUS OF THE FACILITY	In operation.
Start of operation (date):	1970. In 2011 the facility electrical power supply system and instrumentation and control system were upgraded.

MAIN RESEARCH FIELD(S)

- ☐ Zero power facility for V&V and licensing purposes
- × Design Basis Accidents (DBA) and Design Extended Conditions (DEC)
- × Thermal-hydraulics
- ☐ Coolant chemistry
- ☐ Materials
- ☐ Systems and components
- × Scientific research instruments

TECHNICAL DESCRIPTION

Description of the facility

The main research fields of Liquid metal test facility "6B"are experimental thermal hydraulic studies (hydrodynamics and heat transfer) to justify temperature conditions of operation for cores and equipment components (elements) in fast reactors with different types of liquid metal coolant (sodium, HLMC) for nominal, off-nominal and emergency conditions and verification codes; calibration and testing of liquid metal level sensors in tanks and magnetic flow meters in circulation loops.

The “6B” facility consists of three loops: primary loop with sodium-potassium, secondary with sodium and tertiary with sodium-potassium (an auxiliary one). The primary and secondary loops are the main ones. They are meant for experimental studies based on thermal models of cores and other equipment of fast reactors with liquid metal coolants. The tertiary (auxiliary) loop is designed to cool primary and secondary cold traps. Liquid metal coolant circulation is provided by electromagnetic pumps with the capacity up to 150 m^3/h and outlet pressure of 0.6 MPa. The coolant temperature in the loops runs to 450°C. The volume of the main loops is 1 m^3 each. Heat generated in the fuel subassembly models is removed in “metal-water” coolers with a separating cavity. The facility installed capacity is 1.2 MW.

“6B” Primary loop

The primary loop includes the following process units (see the process flow chart): electromagnetic pump EMP-1; working section No.1 (thermal model of the system core); working section No.2 (thermal model of the reactor core); working section No.3 (hydraulic model); heat-exchanger model; metal-water coolers No.1, 2, 3, 4; calibration (measuring) tank; expansion tank; dump tank; oxide indicator; sampling/distillation device; oxide indicator air heat exchanger; oxide trap (low-temperature); oxide trap (high-temperature); filter in the drain line to the dump tank; sylphon valves made of acid-resistant steel with electric drives; magnetic flow meters.

The primary metal can circulate along the following lines: pump bypass; pump, working section No.1; pump, working section No.2, 3; pump, heat-exchanger model; pump, working section No.1, coolers; pump, working section No.2, coolers; pump, low-temperature cold trap, expansion tank; pump, high-temperature cold trap, expansion tank; pump, oxide indicator, surge (expansion) tank; pump, working section No.1, calibration tank, expansion tank (during calibration of a magnetic flow meter located at the inlet of working section No.1); pump, working section No.2, calibration tank, expansion tank (the line is used during calibration of a magnetic flow meter located at the inlet of working section No.2); pump, working section No.3, calibration tank (the line is used during calibration of a magnetic flow meter located at the inlet of working sections No.2, 3); pump, sampling/distillation device, drain line of the expansion tank.

It is technologically unreasonable to have other options of primary metal circulation.

The loop lines are made of the stainless steel and have the following diameters: the main lines − ∅114×5.5 mm; bypass lines – ∅83×3 mm и ∅76×3 мм; auxiliary lines – ∅45×2.5 mm and ∅32×2.5 mm. The volume of metal in the loop is 1000 liters.

Secondary loop

The secondary loop includes the following process units: electromagnetic pump EMP-2; working section No.1 (thermal model of the system core); working section No.2 (thermal model of the reactor core); cooler; calibration (measuring) tank; expansion tank; dump tank; cooler start-up water heat-up tank; sampling/distillation device; oxide indicator; oxide indicator air heat exchanger: oxide trap (high-temperature); valves with electric drives (with freezable seals in the main and bypass lines; sylphon valves in the auxiliary lines); magnetic flow meters.

The loop pipelines are made of stainless steel of the following diameters: main lines of ∅114×5.5 mm; bypass lines of ∅83×3 mm and ∅76×3 mm; auxiliary lines of ∅45×2.5 mm and ∅32×2.5 mm. The volume of metal in the loop is 1000 liters.

The secondary metal can circulate along the following lines: pump bypass; pump, working section No.1; pump, working section No.1, cooler; pump, working section No.2, cooler; pump, oxide trap, drain line of the expansion tank; pump, oxide indicator, expansion tank; pump, sampling/distillation device; pump, measuring tank, expansion tank (during calibration of a magnetic flow meter located in the pump – mixer line); pump, measuring tank, expansion tank (during calibration of a magnetic flow meter located in the pump – working sections line).

It is technologically unreasonable to have other options of secondary metal circulation.

Tertiary loop

The tertiary loop includes the following process units: electromagnetic pump EMP-3; two metal-water coolers; expansion tank; oxide trap; sylphon valves; magnetic flow meters.

The loop pipelines are made of stainless steel with the diameters of ∅45×2.5 mm; ∅32×2.5 mm; ∅18×1.5 mm. The loop is filled with metal from the primary dump tank. The loop volume is ~50 liters.

The tertiary metal can circulate along the following lines: pump bypass; pump, tertiary oxide trap; pump, primary oxide trap, tertiary cooler; pump, secondary oxide trap, tertiary cooler.

Electromagnetic pumps

Electromagnetic pumps (EMP-1, EMP-2 and EMP-3) are meant to circulate liquid metal along the facility loops. Specifications of the EMP-1 and EMP-2 pumps: coolant flow rate (sodium-potassium and sodium, respectively) is 150 m^3/h; head is 6 kg/cm^2; power consumption is 170 kW; maximum coolant temperature is 500°C. Specifications of the EMP-3 pump: coolant flow rate (sodium-potassium) is 10 m^3/h; head is 10 kg/cm^2; electric power consumption is 14 kW; maximum allowable coolant temperature is 300°C.

Working section heaters (general information about the design)

Primary and secondary working section heaters are a system of connected in parallel elements of the liquid metal cooled reactor core models. They are made of nichrome wire or band of a certain cross-section and are located inside the elements. The heaters are made in the form of coils insulated from walls of the elements along the entire length under heating. They provide energy release which is continuous or profiled according to a certain law along the core height and radius.

Coolers

The primary and secondary coolers are designed to remove heat generated in the “6B” facility working sections. The tertiary cooler is meant to remove heat from the primary and tertiary traps.

The design characteristics of primary and secondary coolers are as follows: service water flow rate is $6 \cdot 10^{-3}$ m^3/s, water pressure is 6 kg/cm^2, inlet water temperature is 20°C, outlet water temperature is 30°C, water flow velocity is 0.36 m/s. The liquid metal coolant flow rate is $0\text{-}27.8 \cdot 10^{-3}$ m^3/s, pressure is 10 kg/cm^2, velocity covers the range of 0-1.15 m/s, inlet temperature runs to 300°C, outlet temperature is 290°C. The maximum allowable sodium temperature in the secondary cooler is 500°C.

The design characteristics of tertiary coolers are as follows: cooling water flow rate in each cooler is 3 m^3/h; coolant pressure is 10 kg/cm^2.

Oxide traps

Oxide traps are designed to clean the liquid metal coolant from oxygen. The principle of the trap operation is based on precipitation of oxides inside the trap volume filled with stainless steel chips and cooled with water (low-temperature trap) or sodium-potassium alloy (high-temperature trap). Water-cooled traps are installed in the primary and tertiary loops.

Sampling/distillation device

Sampling/distillation devices are designed for sodium and sodium-potassium (100 g in weight) sampling from the circulation loop, its subsequent distillation in vacuum and determination of oxygen content in oxides.

Plugging meter

A plugging meter represents a device designed for on-line remote determination of impurity content in coolant. The principle of plugging meter operation is based on the ability of impurities precipitating from the solution to plug the flow area. At the moment of flow reduction down to a certain value the plugging temperature is recorded, which roughly corresponds to the saturation temperature. The impurity concentration is determined by the saturation temperature. The plugging meter normally is used for determination of the extent of oxygen impurity in sodium and sodium-potassium alloy.

Instrumentation

For the purpose of measuring, the use is made of advanced methodology for investigation of the velocity fields and temperature in the fuel subassembly models developed in the SSC RF – IPPE based on physical simulation of fuel elements and the local method of velocity in the channels using local-operating electromagnetic sensors and heat-emitting surface temperature measurement.

The study of heat transfer and temperature fields on the models of reactor core elements and heat exchange equipment is performed by measuring the temperature of coolant and heat-transfer surface using microthermocouples.

The miniature thermocouples are located in the coolant flow and also are mounted on the surface of fuel rods simulators, thus ensuring the measurement of circumferential temperature (patterns) distributions for various fuel element types (internal, lateral, angular) in the fuel subassemblies, running both in the nominal conditions and with part of fuel subassembly’s flow area blocked, deformation of fuel element lattice and fuel subassembly claddings, at power burst and other off-nominal and emergency conditions. In this case the fuel rods simulators with thermocouple sensors are made rotary and movable along the fuel subassembly height, which allows the local temperature of fuel rods simulators surface to be measured in any point of the fuel subassembly model.

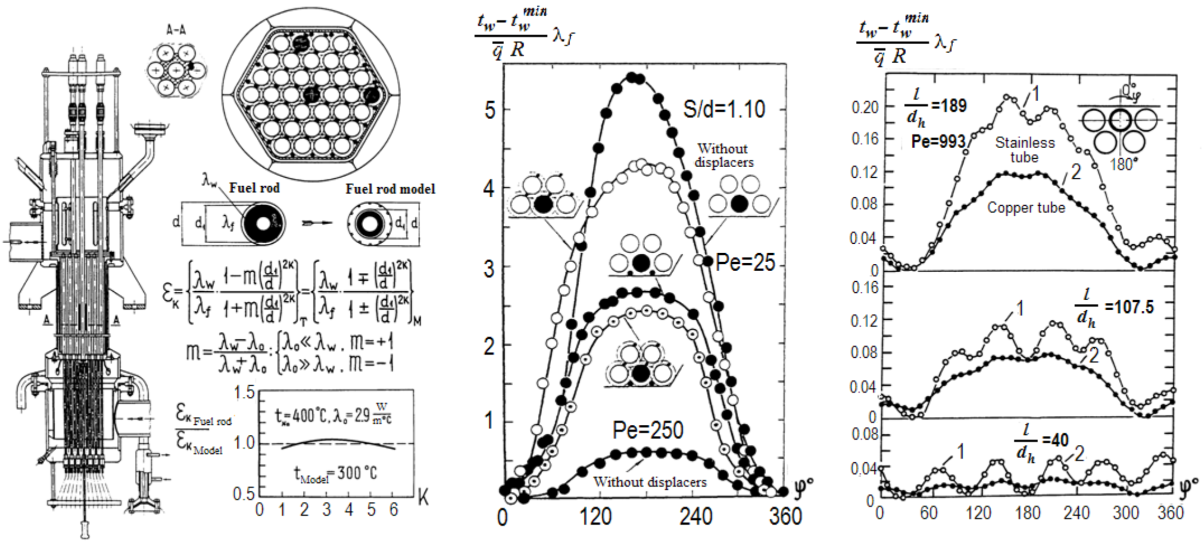


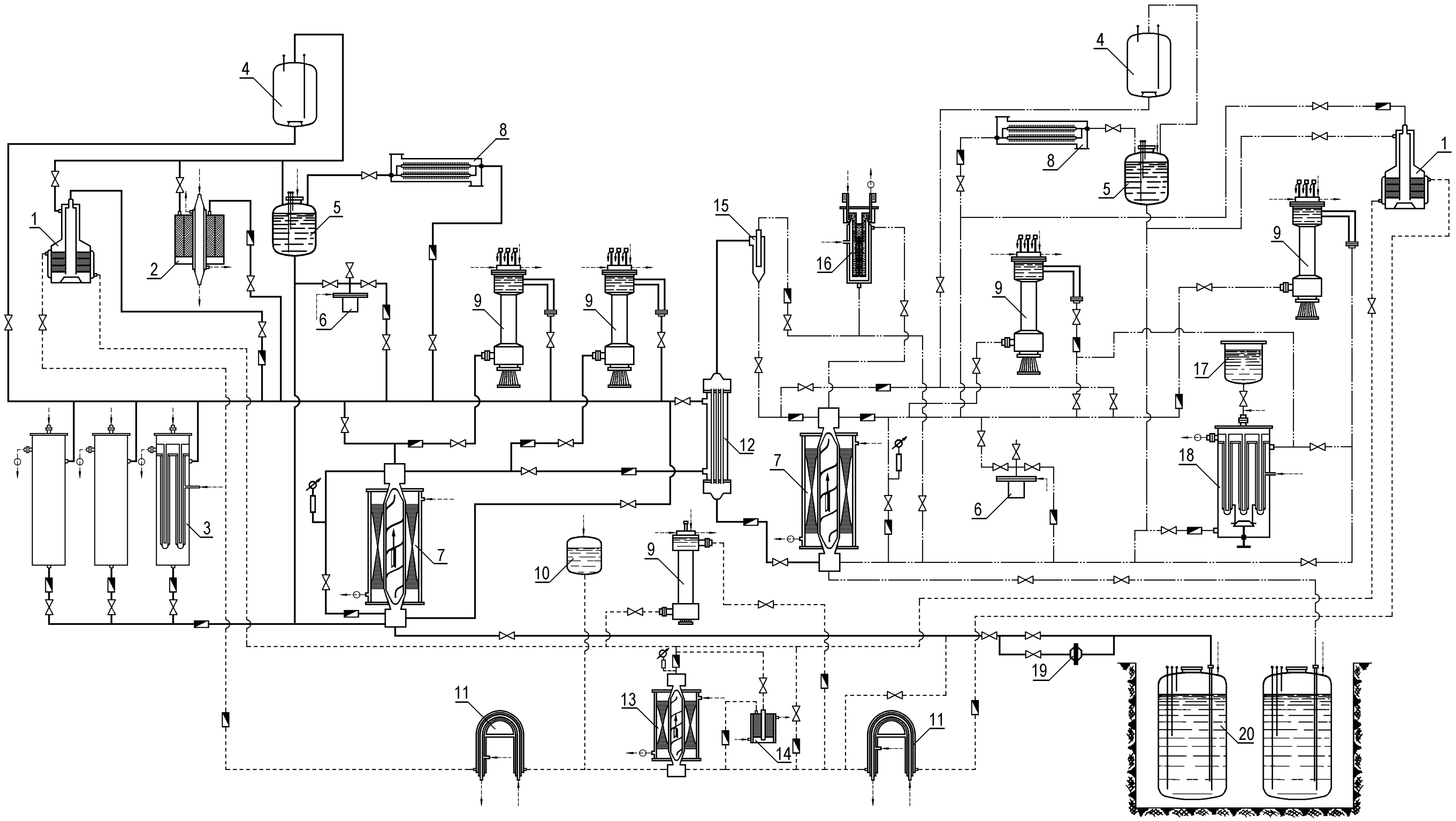
FIG. 1. Automated Thermophysical Research Management System (ATRMS)

The sensor readings are recorded with the use of the Automated Thermophysical Research Management System (ATRMS) with the subsequent on-line analysis of the acquired data (Fig. 1).

Acceptance of radioactive material

No.

Scheme/diagram



———— – primary pipeline; ——··——··—— – secondary pipeline; - - - - - – tertiary pipeline;
⋈ – valve; ▰ – magnetic flow meter; ⌀ – pressure gauge; –⊖–▪– – flow switch

1 – hot trap; 2 – cold trap; 3 – cooler; 4 – measuring tank; 5 –expansion tank; 6 – sampler; 7 – electromagnetic pump; 8 – air cooler; 9 – working section; 10 –expansion tank; 11 – cooler; 12 – recuperator; 13 – electromagnetic pump; 14 – cold trap; 15 – mixer; 16 – graphite heater; 17 – water heat-up tank; 18 – cooler; 19 – filter; 20 – dump tank

FIG. 1. Technological scheme of the liquid metal test facility "6B":

3D drawing/photo

FIG. 2. The overall view of the liquid metal test facility “6B”

Parameters table

Coolant inventory	Na, Na-K (a three-loop test facility: one loop – sodium, two loops – sodium-potassium).
Power	1200 kW.
Test sections (experimental model)	
	<u>*Characteristic dimensions*</u> Outer diameter 1500 mm, Overall height 12000 mm/
	<u>*Static/dynamic experiment*</u> Steady-state and dynamic experiments.
TS #1	<u>*Temperature range in the test section*</u> up to 450°C
	<u>*Operating pressure and design pressure*</u> 0.6 MPa
	<u>*Flow range (mass, velocity, etc.)*</u> 150 m^3/h.
Coolant chemistry measurement and control (active or not, measured parameters)	Oxide filter traps are used for purification of sodium and sodium-potassium loops of the test facility. In the course of test facility operation the flow rate, pressure, coolant temperature are monitored, the content of impurities in coolants is determined with the use of sampling/distillation devices and oxide indicators.
Instrumentation	– Developed and produced at the SSC RF – IPPE).

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

The thermohydraulic liquid metal test facility "6B" in SSC RF – IPPE is one of the principal test facilities in the State Atomic Energy Corporation "Rosatom", ensuring the performance of experimental research in justification of the parameters and safety of both sodium cooled and heavy liquid metal cooled fast reactors. For the period of more than 40 years of liquid metal test facility "6B" operation numerous studies were carried out there in justification of thermohydraulics of the reactor cores and equipment units of BN type reactors (BOR-60, BN-350, BN-600, BN-800 etc.) and the BREST reactor for their different operating modes:

- local measurements of velocity and temperature fields on the reactor fuel subassembly models with the aim to study the effect of structural components (spacing, displacers, as well as deformation, flow area blockage, heat exchange between the adjacent fuel subassemblies) on heat transfer, interchannel mixing, temperature conditions of fuel elements in fast reactor fuel subassemblies;
- experimental research of velocity and temperature fields in fast reactor intermediate heat exchangers with a transverse inlet and outlet with a view to optimize the parameters and improve their efficiency;
- experimental research of coolant mixing efficiency in mixing chambers; studies of the efficiency of temperature conditions diagnostics in the core mixing chamber using a thermocouple grid, studies of temperature fluctuations in the coolant flow and structural elements including those in the mixing chambers;
- studies of heat transfer and temperature distribution under the spacer grids of BREST-OD-300 reactor fuel rods simulators in the square-lattice fuel subassembly models;
- experimental research of hydraulic resistance and heat transfer of the air heat exchanger model of BN-800 reactor in the decay heat removal condition;
- studies of the feasibility of modeling with the use of water in the processes of mixed and natural convection in the sodium-cooled fast reactor vessel (primary circuit) as applied to transients and emergency conditions including fast reactor decay heat removal.

Research was done into the characteristics and tests were performed of various types of level meters for the Beloyarskaya NPP Unit 3 (BN-600 reactor facility) upon request of the «Siemens» company (Germany). The flow meters for the Chinese research reactor CEFR and the pressure sensors for the experimental sodium test facility in the scientific research center KAERI (Republic of Korea) were calibrated.

PLANNED EXPERIMENTS (including time schedule)

The following experimental research is scheduled for the period of 2014-2016:

- Research into heat transfer and temperature conditions of fuel rods simulators in a sodium-potassium cooled fuel subassembly model of fast neutron reactor in a broad triangular lattice with the fuel rods simulators spaced by fins and grids;
- Research into characteristics of passive safety system devices by the temperature in the sodium model of fast reactor channel etc.

TRAINING ACTIVITIES

The activity in training the specialists – experimenters at the liquid metal test facilities has to be approved by the State Atomic Energy Corporation "Rosatom".

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