**Profile SFR-70**

**V-200**

**RUSSIA**

## GENERAL INFORMATION

| | |
|---|---|
| NAME OF THE FACILITY | Three loop water facility "V-200" with an integrated model of the fast reactor designed to study thermal hydraulic processes in primary elements under various operation conditions |
| ACRONYM | "V-200" water facility |
| COOLANT(S) OF THE FACILITY | Water |
| LOCATION (address): | Federal State Unitary Enterprise "State Scientific Centre of the Russian Federation - Institute for Physics and Power Engineering named after A.I. Leypunsky", Russian Federation |
| OPERATOR | State Corporation "Rosatom" |
| CONTACT PERSON (name, address, institute, function, telephone, email): | Opanasenko A.N.<br>Bondarenko Sq. 1, Obninsk, Kaluga Region, 249033, Russia<br>Leading scientific researcher, Ph. D.<br>phone: +7 484-39 9-89-30, oan@ippe.ru |

| | |
|---|---|
| **STATUS OF THE FACILITY** | In operation |
| Start of operation (date): | 2000. In 2011 the process layout, facility power supply and instrumentation and control systems 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
- ☐ Instrumentation & ISI&R

## TECHNICAL DESCRIPTION

### Description of the "V-200" water facility

The thermohydraulical water test facility "V-200" with integrated model of fast reactor is purposed for investigations on models of thermal hydraulic characteristics in reactors vessel

(BN-800, BN-1200, MBIR, BREST) in normal, transitive and accidental regimes of fast reactor including decay heat removal, processes of stratification flow and data getting for verification of computer codes.

Three loops “V-200” water facility with an integrated model in the primary circuit of the fast reactor makes it possible to roughly simulate (according to the principal similarity criteria) thermal hydraulics of the primary circuit of fast reactors cooled by different liquid metals (Na, Pb, Pb/Bi).

**The primary circuit**

The primary circuit of the integrated reactor model consists of two parallel loops, each of them contains two intermediate heat exchanger models (IHX), an autonomous heat exchanger (or emergency heat exchanger-EHX) and dummy main circulation pumps (MCP-1).

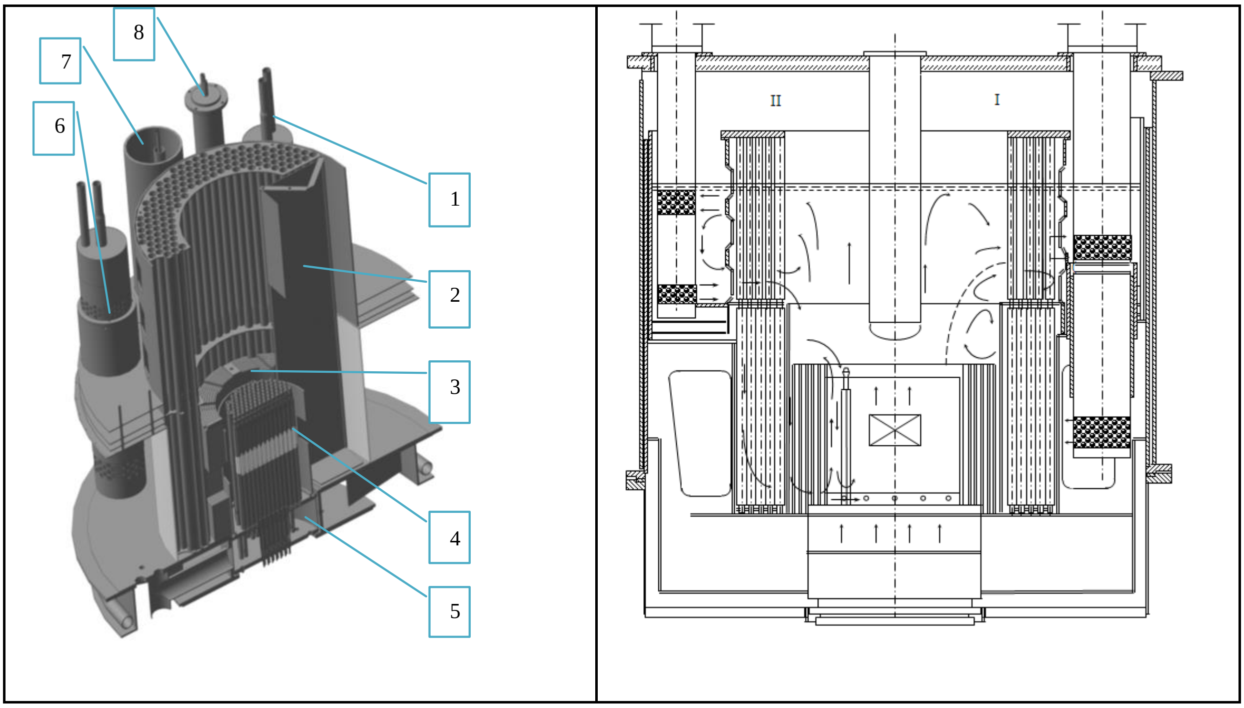



*FIG. 1. Primary elements of “V-200” water facility (left): 1,6-intermediate heat exchangers (IHX); 2- elevator partition; 3-in-vessel shield components; 4 -core (dummy FSA); 5- pressure chamber; 7 – dummy main circulation pump; 8-emergency heat exchanger (EHX) and*
*Coolant flow diagram in the integrated model of “V-200” water facility (right): I – nominal conditions, II – natural circulation conditions (NC)*

Through the high pressure pipeline of the pump (Pump-1) the distillate enters the external pressure header. Then, through two pipelines, the coolant flows to the dummy MCP-1 sections and, when the dummy pump valve is closed, through the high pressure pipeline it goes to the pressure chamber of the reactor model from which the coolant is distributed into the dummy subassemblies. The part of the distillate from the pressure chamber simulating leaks through bottom nozzle seals of fuel subassemblies (FSA) of a full-scale reactor goes into the space above the upper plate of the pressure chamber to the dummy subassemblies which have no electric heaters. Passing through the dummy subassemblies the coolant enters the cavity of the upper chamber common to both loops. From the upper chamber through the in-vessel shielding and windows in the profiling shell, the distillate is supplied to IHX models. Through the IHX drain windows the cooled coolant enters the lower drain chamber and then suction nozzles of dummy MCP-1 connected to the outer part of Pump-1. The part of the distillate from the external pressure header is supplied to the distributing header of the section simulating the vessel cooling. The inlet pipeline section of vessel cooling by the pipeline with an inspection window and shutoff valves (Valve-2) is connected to the pressure chamber. From the external pressure header the part of the coolant is supplied through separate pipelines to cool the pump supports and dummy in-vessel ionization chambers.

**The secondary circuit**

The secondary circuit is also a closed circulation system with Pump-2 filled with distillate and designed for heat removal from IHX and EHX models. Pump-2 helps to supply the distillate of the secondary circuit to IHX and EHX distribution headers. After that the coolant with the preset parameters goes to the inlet nozzles of four IHX and two EHX models, passes through their tube system and goes to the heat exchangers of the water thermophysical facility where it is cooled by water of the building cold-water supply. In the course of emergency cooling down simulation the dummy MCP-1 valves are opened and the coolant flow rate with calculated parameters (temperature, flow rate) is generated within the EHX intermediate circuit.

**Acceptance of radioactive material**

No

**Scheme/diagram**

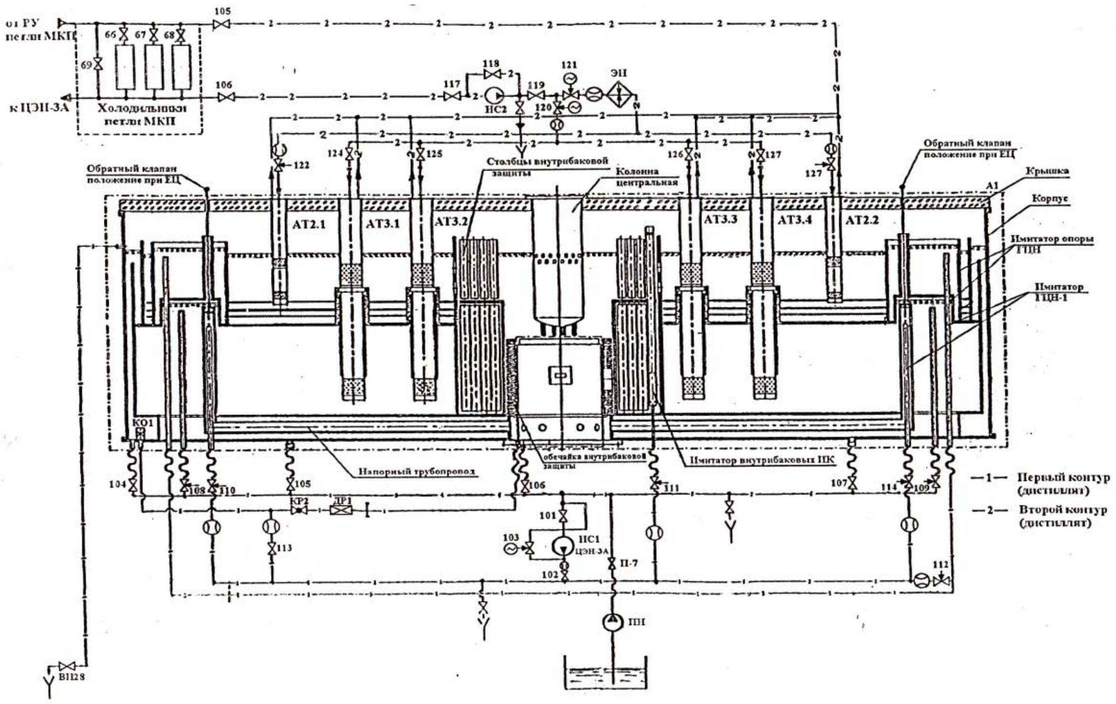



*FIG. 2. Basic diagram of the integrated model at "V-200" water facility.*

Legend to the diagram (clockwise): loop cooler, check valve (NC position), columns of in-vessel shielding, central column, check valve (NC position), lid, vessel, MCP dummy support, dummy MCP-1, -1- primary circuit (distillate), -2- secondary circuit (distillate), dummy in-vessel ionization chamber, in-vessel shielding shell, high pressure pipeline

### 3D drawing/photo

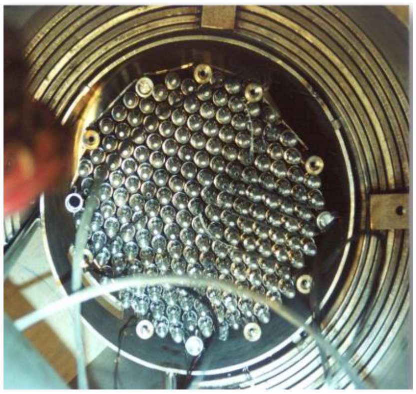
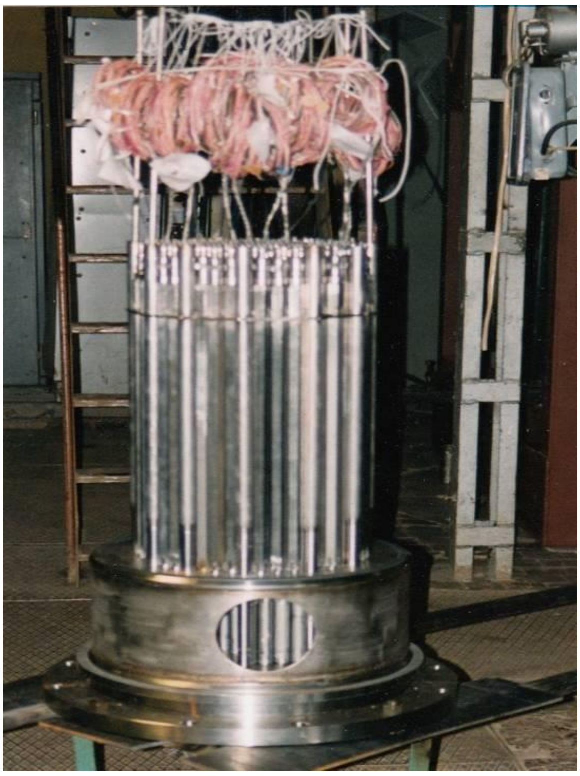


*FIG. 3. General view of the integrated model of the fast reactor at "V-200" water facility (left) and top view of the dummy core and shielding shell (right)*



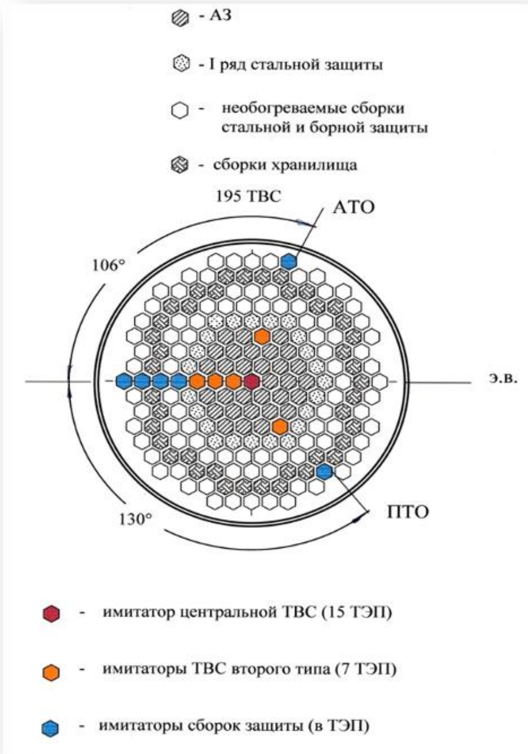



*FIG. 4.* Pressure chamber with dummy subassemblies (left) and dummy core arrangement: core (right), 1 row of steel shielding, unheated subassemblies of steel and boron shielding, storage

**Parameters table**

<table>
<tr><td>Coolant inventory</td><td>Water (the facility consists of three loops)</td></tr>
<tr><td>Power</td><td>150 kW</td></tr>
<tr><td colspan="2">Test sections</td></tr>
<tr><td rowspan="6">TS #1</td><td><u>Characteristic dimensions</u><br>Transverse dimensions (diameter) – 1800 mm<br>Model height - 1700 mm<br><u>Dimensions and weights</u><br>Model weight (without water) – about 4000 kg<br>Water weight – 3600 kg</td></tr>
<tr><td><u>Static/dynamic experiment</u><br>Static and dynamic experiments</td></tr>
<tr><td><u>Temperature range in the test section</u><br>20-95 °C</td></tr>
<tr><td><u>Operating pressure and design pressure</u><br>atmospheric</td></tr>
<tr><td><u>Flow range (mass, velocity, etc.)</u><br>25 000 kg/h</td></tr>
<tr><td>Coolant chemistry measurement and control<br>(active or not, measured parameters)</td><td>Oxide entrainment filters are used for the purpose of Na and Na-K loop purification. In the course of facility operation the consumed electric power, coolant flow rate, pressure and temperature are controlled, impurity content in coolant is determined using sampling/distillation devices and oxide indicators</td></tr>
<tr><td>Instrumentation</td><td>Heat sensing devices of various designs (designer and manufacturer – FSUE "SSC RF - IPPE");<br>Thermocouple probes designed to measure temperature in a mixing chamber (designer and manufacturer – FSUE "SSC RF - IPPE");<br>Sensors for measuring pressure difference «Metran-150 SD»;<br>Flow rate measurements at coolant flow paths in the primary and secondary circuits of the experimental model are carried out by vortex and coriolis flow meters «Metran»;<br>Correlation measurement sensor of local velocities in the coolant flow (designer and manufacturer – FSUE "SSC RF - IPPE");<br>Current measurements using calibrated shunts of 0.5 class, voltage measurements using dividers (accuracy class - 0.1%)</td></tr>
</table>

**Automated system for measurements, acquisition, processing, and control of thermohydraulic parameters of "V-200" facility**

The automated system for measurements, acquisition, processing, and control of thermohydraulic parameters of the tank-type model on water facility "V-200" contains more than 400 sensors, and with consideration of specific features of the experiments conducted therewith, it is subdivided into four subsystems, as follows:

- subsystem of slow measurements (SSM) performs the scanning of all sensors for 1 sec.;
- subsystem of express measurements (SEM) contains 120 channels with a scanning frequency of 10 Hz;

- subsystem of correlation measurements (SCM) of local velocities;
- subsystem of monitoring the flow rates, temperature, heaters' power (SMFTHP).

Cable thermocouples KTMS (KhK) [KTMC (XK)] 2×0.03 according to standard specification TU16- 505.757-75 are used for temperature measurements. In order to reduce the thermal inertia to 0.1- 0.2 sec., the hot end is made with thinning to 0.5 mm. Individual calibration of all temperature transducers makes it possible to provide the level of error for normal statistical characteristics of ± 0.5°C in the temperature range of 0÷100°C. The compensation of cold junction temperature is performed by the resistance thermometer detectors with an accuracy of ± 0.1°C.

The measurement of currents for each group of heaters of the dummy subassemblies is carried out using the calibrated shunts of 0.5 class. The dividers (accuracy class of 0.1%) with voltage reduction to the required level are used for the voltage measurement.

The automated system for control of thermohydraulic studies and the instrumentation control system ensure the monitoring and measurements of the model parameters (temperatures, velocities, pressure levels, flow rates, power, etc.), acquisition and express processing of information from measurements, displaying the selected parameters (including the graphic information), communicating the information for its further processing; it forms the electrically driven commands on execution units, including the emergency protection subsystems.

### Methodology and conditions for modelling fast reactor thermohydraulics on facility "V-200"

The "V-200" facility basic circuit includes all principle elements of the fast reactor made in a specified scale. The approximated method of modelling the thermohydraulic processes in the fast reactor tank at the "V-200" facility is provided by the following:

- similar geometry of the model and reactor;
- modeling the coolant flow diagram through the primary circuit under standard and transient operation modes;
- modeling the operation with varying the dummy subassembly power according to the specified law, under transient conditions, with varying water temperature and its flow rate in the secondary and intermediate circuits (coasting of the main circulation pumps of the real facility primary and secondary circuits);
- simulation of the required transverse section of energy generation profile;
- modeling the hydraulic characteristics in the core and radial shielding models;
- ensuring the needed throttling of the flow in the dummy subassemblies in accordance with the law of heat release variation over the core radius;
- modeling the hydraulics and temperature conditions in the IHX and EHX from the primary circuit side, close to full-scale ones;
- equal determining criteria of similarity for the forced and natural circulation conditions as follows: Froude ($Fr$), Euler ($Eu$), Homochronicity ($Ho$), Balance of heat ($N$), Richardson ($Ri$), Peclet ($Pe$).

## COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

"V-200" thermohydraulical water test facility was constructed at FSUE "SSC RF - IPPE" in 2000, initially it was used for justification of thermohydraulic characteristics of the emergency cooling system of the research fast reactor project CEFR, which was developed in Russia and subsequently was constructed in China. After modernization in 2011, it became one of the facilities of the “Rosatom” State Corporation to provide implementation of a set of experimental studies for justification of design solutions for passive systems of emergency cooling and investigation of features of the stratification phenomena inside the reactor vessel and safety of advanced fast reactors with both sodium, and heavy liquid metal coolants (BN-1200, MBIR, BREST). A large scope of studies has been completed using the “V-200” facility on measurements of non-steady state fields of temperature and velocity in the primary circuit elements for reactor BN-1200 in various operation conditions: forced circulation, transient modes, under conditions of emergency cooling down. The studies have shown a stable temperature stratification of coolant in the peripheral zone of the upper chamber, in the cold chamber and the pressure chamber, in the elevator partition, the system for cooling the reactor vessel in various operation modes. At the borderlines (interfaces) of the stratified and recirculation formations, large temperature gradients and pulsations have been registered.

The experimental data obtained are used for the verification of thermohydraulic computer codes. The features of thermal hydraulics of stratified flows of coolant have been studied. Feasibility of modelling the processes of mixed and natural convection in fast neutron reactor vessels (primary circuit) with liquid metal coolants using water has been shown, as applicable to transient and emergency conditions, including the emergency cooling down of fast reactors by natural convection.

**PLANNED EXPERIMENTS (including time schedule)**

In 2014-2016 it is planned to continue the work on measurements of non-steady state local temperatures and velocities and their statistical characteristics in the fast reactor primary circuit elements. Different conditions will be studied, including partial outages of the primary and secondary circuit equipment, for the justification of design approaches in passive systems of emergency cooling down of advanced fast reactors.

**TRAINING ACTIVITIES**

Experimental model V-200 will be used for training purposes, to model the typical conditions of fast reactor operation and education of personnel for scientific research and engineering works.

**REFERENCES (*specification of availability and language*)**


1. OPANASENKO A.N., SOROKIN A.P., ZARYUGIN D.G., RACHKOV M.V. Stratification of coolant in nuclear power facilities // Atomnaya Energia, 2011, vol. 111, issue 3, pp. 131-163. (Rus)
2. ZARYUGIN D.G., KALYAKIN S.G., OPANASENKO A.N., SOROKIN A.P. Studies on stratification of coolant and temperature pulsations in nuclear power facilities // Teploenergetika, 2013, No 3, pp. 12-21. (Rus)
3. ZARYUGIN D.G., KALYAKIN S.G., LESKIN S.T., OPANASENKO A.N., SOROKIN A.P. Computation and experimental studies of thermal hydraulic characteristics in a fast reactor vessel on the SARH integral model in different modes of facility operation // Yadernaya Energetika, 2013, No 2, pp. 96-104. (Rus)

4. OPANASENKO A.N., SOROKIN A.P., ZARYUGIN D.G., KOSAREV S.A., KOROVIN S.V., YAUROV S.V. Experimental studies of temperature fields and structure of the coolant flow in the upper chamber of the sodium cooled fast reactor under conditions of forced circulation // Book of abstracts, Scientific and Engineering Conference "Thermal Physics of Fast Neutron Reactors (Teplofizika-2013)", Obninsk: FSUE "SSC RF - IPPE", information division, 2013, pp. 46-49. (Rus)
5. LESKIN S.T., SLOBODCHUK V.I., SHELEGOV A.S., YAUROV S.V., SOROKIN A.P., OPANASENKO A.N., KALYAKIN S.G., ZARYUGIN D.G. Numerical modelling of the non-isothermal flow of coolant in the fast reactor vessel // Izvestia Vuzov. Yadernaya Energetika, 2013, No 4, pp. 78-85. (Rus)
6. ZARYUGIN D.G., POPLAVSKY V.M., RACHKOV V.I., SOROKIN A.P., SHVETSOV YU.E., ROGOZHKIN S.A., SHEPELEV S.F. Computation and experimental justification of the design system for emergency heat removal at reactor BN-1200 // Atomnaya Energia, 2014, issue 4, pp. 222-228. (Rus)