Profile LFR-63

SPRUT

RUSSIA

GENERAL INFORMATION

NAME OF THE FACILITY	Liquid metal test facility "SPRUT" designed for studying thermal - hydraulic processes in steam generators and heat-exchanging equipment
ACRONYM	SPRUT
COOLANT(S) OF THE FACILITY	Sodium, lead, lead-bismuth, 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", State Corporation "Rosatom", Russian Federation
OPERATOR	State Corporation "Rosatom"
CONTACT PERSON (name, address, institute, function, telephone, email):	Mikheyev Alexandr Sergeevich Bondarenko Sq. 1, Obninsk, Kaluga Region, 249033, Russia Head of Laboratory, phone: (48439) 9-8934, mikheyev@ippe.ru

STATUS OF THE FACILITY	In operation
Start of operation (date):	1969. In 2011-2012 the facility process engineering design, electrical power supply system and instrumentation and control system were partially upgraded

MAIN RESEARCH FIELD(S)

- ☐ Zero power facility for V&V and licensing purposes
- ☐ Design Basis Accidents (DBA) and Design Extended Conditions (DEC)
- X Thermal-hydraulics
- ☐ Coolant chemistry
- ☐ Materials
- ☐ Systems and components
- ☐ Instrumentation & ISI&R

TECHNICAL DESCRIPTION

Description of the facility

The test facility SPRUT consists of four circulation loops: primary loop – lead; secondary loop – sodium; tertiary loop – lead-bismuth, fourth loop – high pressure water. They are designed for the experiments with thermal-hydraulic models of steam generators and other equipment of reactor facilities with the cores cooled by liquid metal. Liquid metal coolant circulation is implemented using electromagnetic and centrifugal pumps. The coolant temperature in the loops is up to 550°C. Heat removal from steam generator models (water steam condensation and condensate cooling) is implemented in condensers and coolers. The installed capacity of test facility is about 2 MW.

Primary loop:

The primary loop includes the following process units (according to the flow diagram): a centrifugal pump CP-1; a thermal-hydraulic model of steam generator consisting of modules 1 and 2; a buffer tank; a dump tank, a lead heating loop consisting of sections 1 and 2; motor-driven and manual bellow valves; electromagnetic flow meters; oxygen thermodynamic activity sensors.

The loop pipelines are made of austenitic stainless steel of the following diameters: main lines − ∅57×3.5; auxiliary lines – ∅32×3.5.

The volume of metal in the dump tank is ~700 litres.

Secondary loop

The secondary loop includes the following process units: an electromagnetic pump EMP; a thermal-hydraulic model of steam generator; a buffer tank; a dump tank; a sampling/distillation device; an air-cooled cold trap for oxides; an oxide plugging meter; an air heat exchanger of oxide indicator; motor-driven and manual valves; electromagnetic flow meters.

The loop pipelines are made of austenitic stainless steel. The pipeline diameter is ∅32×3.5.

The dump tank metal volume is 200 litres.

Tertiary loop

The tertiary loop includes the following process units: an electromagnetic pump EMP; a coolant heater; a steam generator model; two buffer tanks; a dump tank; a measuring tank; a separator; bellow valves; electromagnetic flow meters; ; oxygen thermodynamic activity sensors.

The loop pipelines are made of austenitic stainless steel. The diameters on the main pipelines are ∅76×4; ∅57×4.

The dump tank volume is 400 litres.

Pumps for liquid metal

The electromagnetic pumps EMP are designed for liquid metal circulation in the test facility loops. EMP pump characteristics for sodium are as follows: coolant flow rate - 10 m^3/h; pressure - 0.6 MPa; maximum sodium temperature - 500^0C. EMP pump characteristics for lead-bismuth alloy: coolant flow rate - 5 m^3/h; pressure - 1.0 MPa; maximum coolant temperature - 450^0C.

Characteristics of centrifugal pump CP for lead: coolant flow rate -15 m^3/h; pressure - 2 MPa; maximum permissible coolant temperature - 450^0C.

Coolant heaters (general information on design)

Direct electrical heating devices are used as coolant heaters. The primary advantage of direct electrical heating devices is their high thermal efficiency, because heat is released directly in the liquid metal. An electric heater contains busbars, current leads and a heating section, where coolant is moving. The electric current is supplied to the section from the power transformer. The direct electric-thermal conversion occurs within the heating section.

Condensers

Water loop condensers are designed for condensing superheated water steam generated in the steam generator model. They represent shell-and-tube heat exchangers. Heat is removed by service water.

Coolers

Water loop coolers are designed for cooling the condensate down to the preassigned temperature before supply to the circulation pump. Cooling is performed with the use of service water.

Air coolers for oxide indicators represent a system of two parallel tubes (longitudinally plate-finned) enclosed in a split duct. The coolant flows inside the tubes and cooling occurs from outside of the tubes by the air flow from the ventilator installed in the facility hall.

Oxide trap

A cold oxide trap is designed for purification of the sodium coolant from oxygen and hydrogen. The principle of the trap operation is based on crystallization of oxides in the trap volume filled with stainless steel chips. The trap is air-cooled.

Sampling/distillation device

A sampling/distillation device is designed for sodium (100 g in weight) sampling from the circulation loop, its subsequent distillation in vacuum and determination of oxygen content in the remaining 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 in sodium is determined by the saturation temperature.

The study of heat transfer and temperature fields using the models of steam generators and heat transfer equipment is performed by measuring the temperature of coolant and heat-transfer surface with the use of microthermocouples.

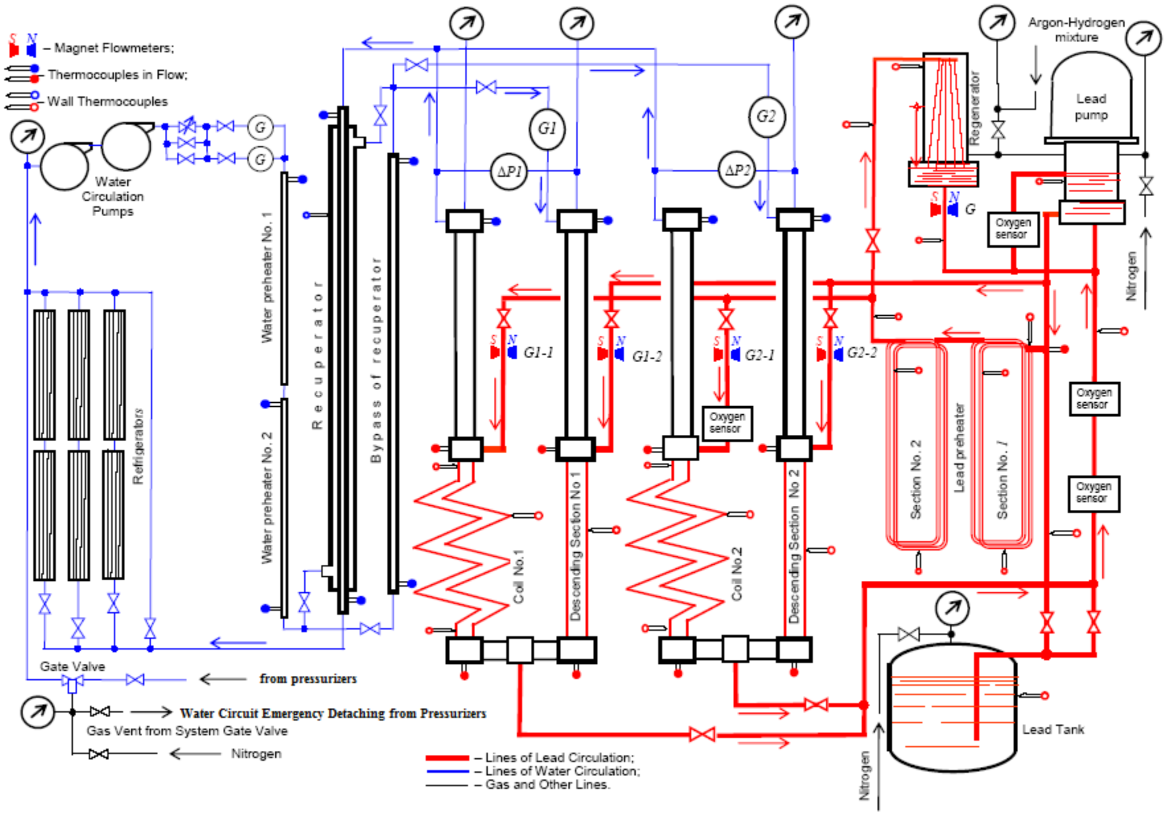
The miniature thermocouples are located in the coolant flow, as well as mounted on the surface of heat transfer tubes, thus ensuring the measurement of circumferential temperature distributions and that along the tubes.

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.

Acceptance of radioactive material

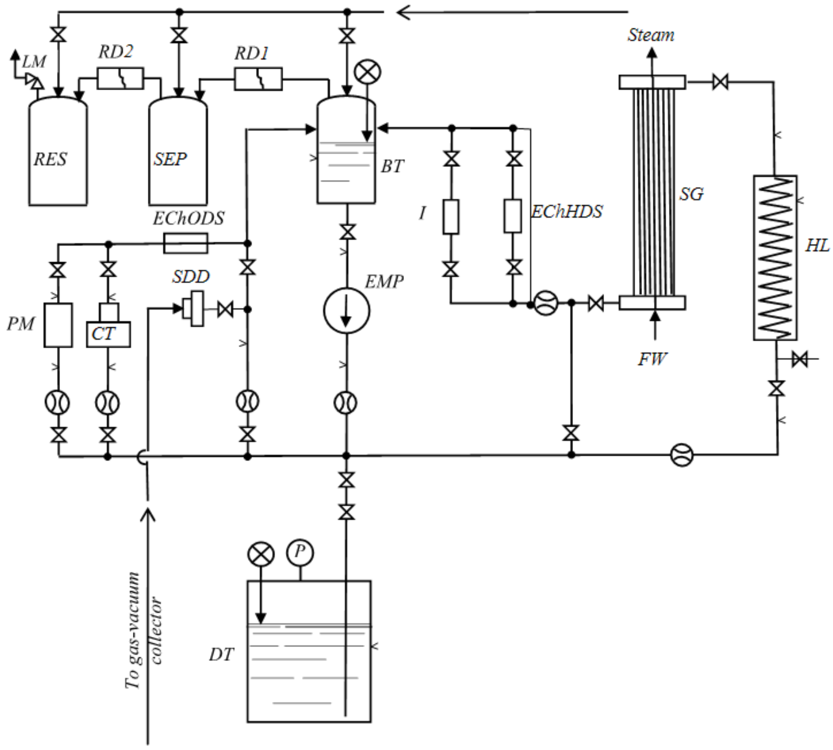
No

Scheme/diagram



⋈– Valve; – pressure gauge

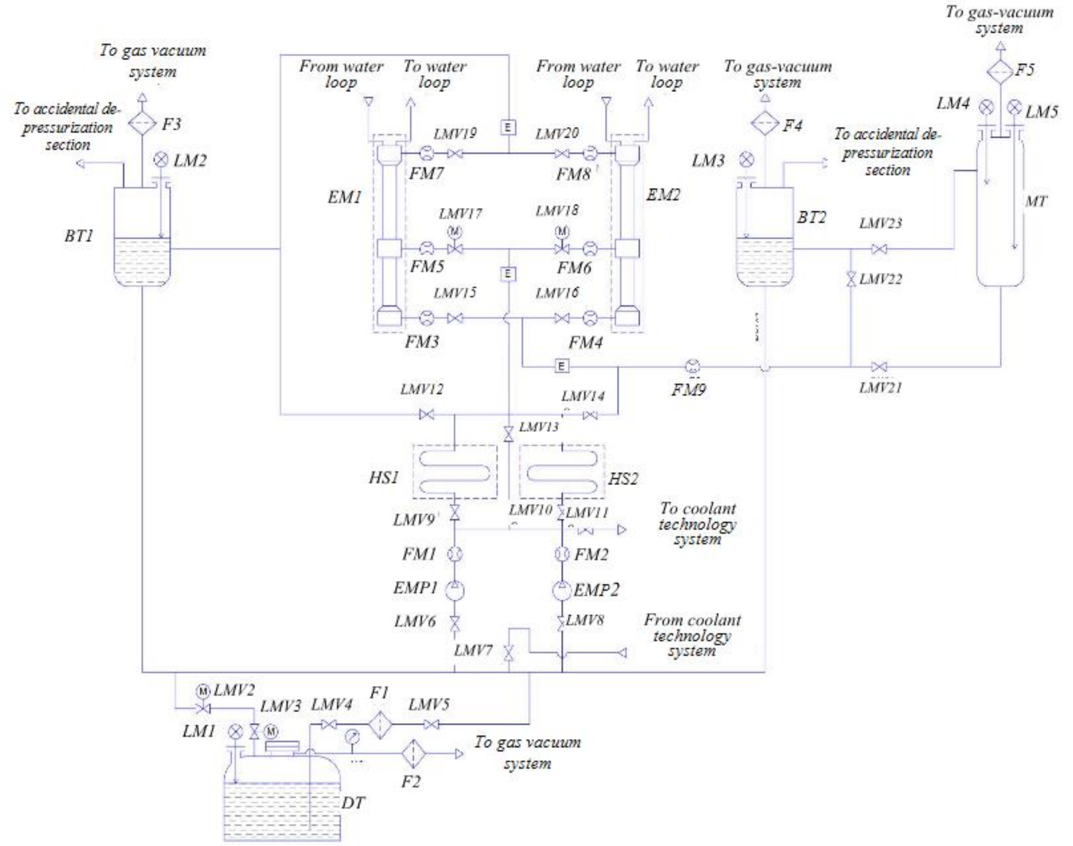
FIG. 1. Lead loop flow diagram of the SPRUT facility



EMP – electromagnetic pump; BT – buffer tank; DT – dump tank; HL – heating loop; SG – steam generator; PM – plugging meter; CT – cold trap; SDD – sampling/distillation device; REC – receiver; SEP – separator; RD1, RD2 – rupture diaphragms; I – automatic hydrogen indicator; EChHDS – electrochemical hydrogen detector in sodium; EChODS – electrochemical oxygen detector in sodium; FW – feed water; S – steam; LM – level meter; – electromagnetic flow meter; – valve; (P) – pressure detector; ⊗ – safety valve; > – thermocouples.

Sodium loop flow diagram

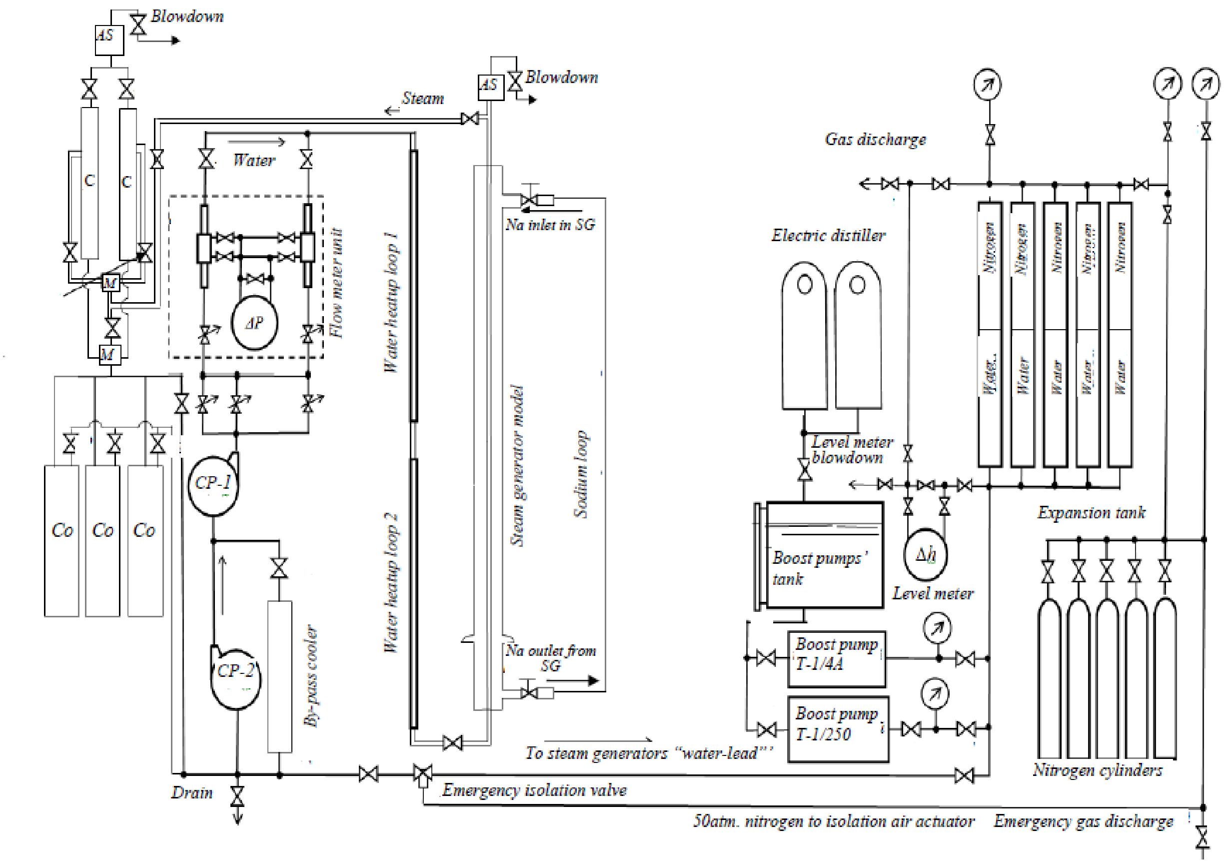
FIG. 2. Sodium loop flow diagram of the SPRUT facility



EM1 – single-tube SG model; EM2 – seven-tube SG model; BT1, BT2 – buffer tanks; DT – dump tank; EMP1, EMP2 – electromagnetic pumps; HS1, HS2 – heating sections; MT – measuring tank; LMV2…LMV23 – liquid metal valves; F1,F2 – filters; FM1…FM9 – electromagnetic flow meters; LM1…LM5 – level meters

Hydraulic circuit diagram of the lead-bismuth loop

FIG. 3. Hydraulic circuit diagram of the Lead-Bismuth loop of the SPRUT facility



CP-1, CP-2 – circulation pump; C – condenser; Co– cooler; M – mixer; AS – air separator; – fast-acting isolation valve ; – isolating slide valve; – flow meter orifice; – bellow; – fine adjustment valve; – air-operated isolation valve

FIG. 4. Flow diagram of high pressure water loop of the SPRUT facility

3D drawing/photo

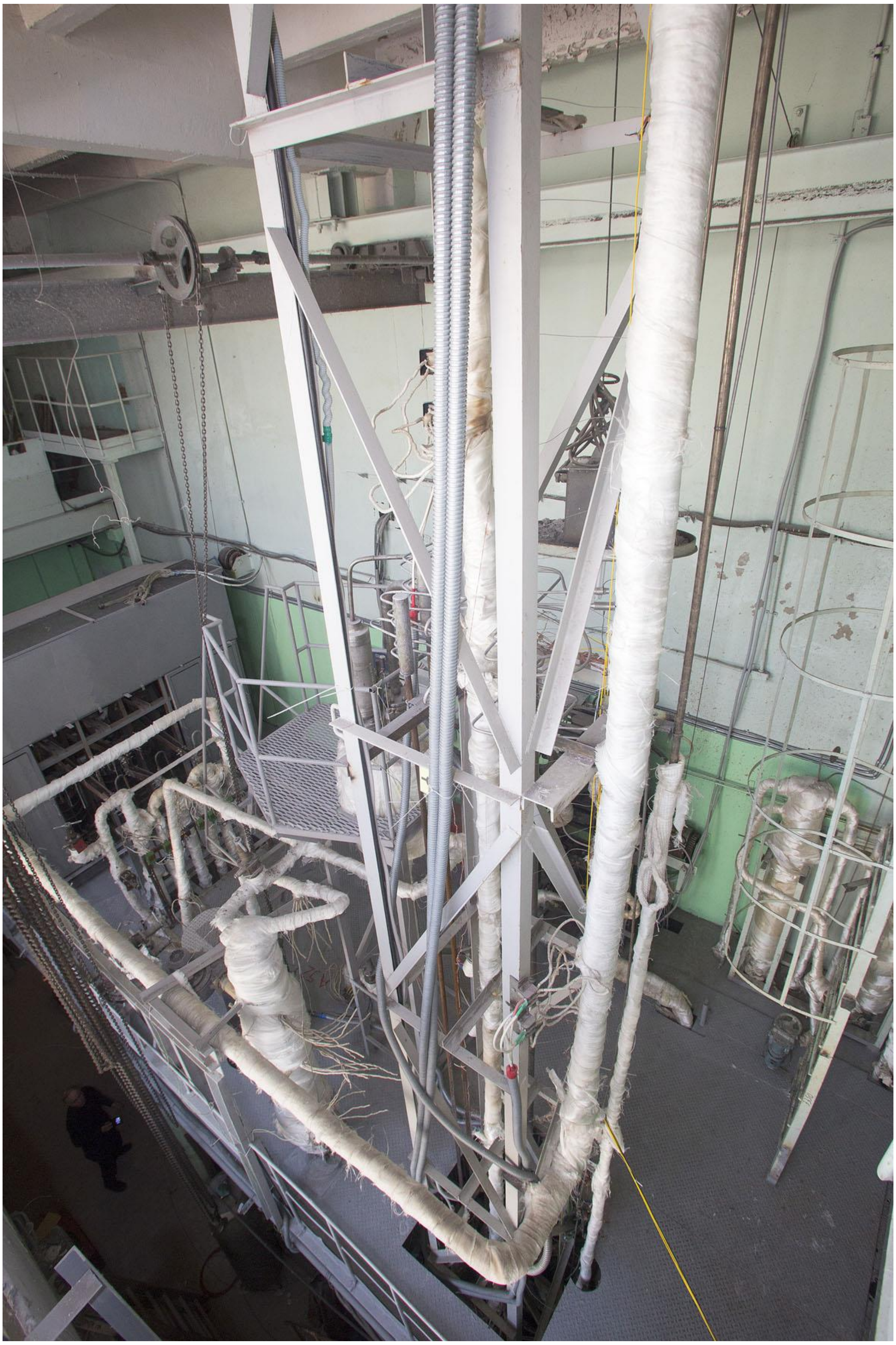


FIG. 5. The overall view of the Multipurpose Liquid Metal Test Facility "SPRUT" for the research into thermal- hydraulic characteristics of steam generators.

Parameters table

Coolant inventory	Na, Pb, Pb-Bi, H_2O(4 circulation loops included in the test facility)
Power	2000 kW
Test sections	
TS #1	*Characteristic dimensions* Outer diameter 1600 mm Overall height 12000 mm
	Static/dynamic experiment Static and dynamic experiments
	Temperature range in the test section (Delta T) 20-550°C
	Operating pressure and design pressure Liquid metal - 0.6 MPa, water – 20 MPa
	Flow range (mass, velocity, etc.) Sodium - 10 m^3/h, lead - 15 m^3/h, lead-bismuth - 10 m^3/h, water - 8 m^3/h
Coolant chemistry measurement and control (active or not, measured parameters)	For purification of sodium loop of the facility the use is made of cold oxide filter-trap. Removal of impurities for the lead and lead-bismuth loops is performed using hydrogen regeneration. In the course of facility operation the flow rate, pressure, coolant temperature, the content of impurities in coolants are monitored.
Instrumentation	• Thermal sensors of various design (developed and produced at SSC RF - IPPE); • Sensors to measure pressure in the loops using "SAPFIR (Sapphire)" – type modified sensors (produced at "MANOMETR" plant), "METRAN" (produced at the Chelyabinsk plant); • Differential pressure sensors ("SAPFIR" and "METRAN"- type); • Contact level meters (developed and produced at SSC RF - IPPE); • Electromagnetic flow meters.

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

The research was carried out into thermal-hydraulic characteristics of various models of steam-generating channels both sodium and lead-bismuth alloy - heated within a wide range of operating parameters' variation: pressure, flow rates and initial temperatures of coolants corresponding to the nominal and partial operating modes of steam generators.

The research done included an analysis of temperature fields, investigation of heat transfer in various steam-generating areas (nucleate and developed boiling, critical heat flux, film boiling and steam superheating).

Both bare tubes and finned tubes with variable spiral tube pitch, the height of fins, and their quantity were used as a heat transfer surface. The fins were both solid and cut

As applied to the BN-600 and BN-800 NPP steam generators the research was done into single-tube vertical models with once-through circulation of coolant, for the BN-350

NPP the operations were performed on the steam-generating channels with Field tubes and at the inclined steam generator model of Czech design "Nadezhnost".

As applied to the lead-bismuth alloy heated steam generators the experiments were made on vertical single-tube and seven-tube assemblies, an annular channel with different methods of heating (internal, external and double-sided) applied as a steam-generating channel.

The resulting experimental data were a constituent of the Bank of the Industry Center of Thermophysical Data, in the Technical Guides; the results were published in the form of articles in the scientific journals and were presented as presentations at various conferences domestically and abroad.

The results of the research were transferred to design and development organizations (OKBM, OKB Hydropress etc.) in justification of fast neutron reactor facility designs BN-350, BN-600, transportable NPS (nuclear power systems).

Recommendations were obtained on the operation of the Field tube steam generator (BN-350), which subsequently were used at the Mangyshlakenergozavod.

The research in justification of the new trend in the development of direct contact heat exchanging apparatuses heated by lead-bismuth jets and including such phenomena as temperature regime, heat transfer on the liquid heating surface (nucleate boiling regime, film boiling regime), heat transfer to the superheated steam, entrainment of alloy with the superheated steam etc.

PLANNED EXPERIMENTS (including time schedule)

The following experimental studies are scheduled for the period of 2014-2016:

– heat transfer, temperature regime and hydrodynamic stability of 18-tube model of fast neutron lead cooled RF steam generator;

– thermal-hydraulic characteristics of a single-tube model of sodium cooled RF (reactor facility).

TRAINING ACTIVITIES

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

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