Profile SFR-61

AR-1

RUSSIA

GENERAL INFORMATION

NAME OF THE FACILITY	High-temperature liquid-metal test facility designed for investigation of Accident Regimes of fast neutron reactors (AR-1 facility).
ACRONYM	AR-1
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):	1976. 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 and beyond-design-basis accidents
- × Thermal hydraulics
- ☐ Coolant technology
- ☐ Materials
- ☐ Systems and components
- ☐ Scientific research instruments

TECHNICAL DESCRIPTION

Description of the facility

The main research fields of "AR-1" facility are experimental thermal hydraulic studies to justify temperature conditions of reactor cores and equipment components (elements) of fast reactors and accelerator-driven systems with liquid metal coolant (sodium, HLMC) to justify their safety, in particular, in accident situations with sodium boiling and verification codes.

"AR-1" facility consists of three loops: the primary and secondary loops are sodium-potassium, the tertiary one is sodium. The primary and tertiary loops are the main ones. They are designed for the experimental work on core thermal models and other equipment of nuclear reactors with liquid coolant. The secondary loop (satellite) is used to decrease the coolant temperature in the primary and tertiary loops.

"AR-1" Primary loop

The primary loop of the facility includes the following components: electromagnetic pump NAV 1/5-NK (4); heater No.1 (pos. 3); cold trap (5); sampling/distillation device (6); calibration section (2); expansion tank (13); vapour trap (7); working section No.1 (thermal model of the reactor core) (1); magnetic flow meters (8).

Secondary loop

The secondary loop of the facility consists of the following components: electromagnetic pump (NAV-15/25.7) (9); "metal – water" cooler (10); "metal – air" cooler (11); cold trap (12); expansion tank (13); dump tank with sodium-potassium (Na-K) (14); magnetic flow meters (8).

Tertiary loop

The tertiary loop of the facility includes the following process units: electromagnetic pump ENIV-3TV (15); cold trap (16); oxide indicator (17); sampling/distillation device (18); recuperator (19); heater No.2 (20); working section No.1 (21); dump tank with sodium (22); expansion tank (23); filter (24); magnetic flow meters (8).

Electromagnetic pumps are designed for coolant circulation in the facility loops

The electromagnetic pump (ENIV-3TV; NAV1/5-NK; NAV-15/25.7) operational principle is based on the interaction of the alternating magnetic field of the stator with the induced magnetic field of liquid metal.

Heaters No.1 and No.2

The heaters of the primary and tertiary loops are designed to heat coolant to a higher temperature at the inlet of the working section. The coolant in the heaters is heated up due to Joule heat which is generated in the pipe when electric current passes through it.

Coolers

The coolers are intended for heat removal released in the working sections of facility AR-1. There are two types of coolers installed at "AR-1" facility: "metal – water" (10) and "metal – air" (11). The "metal – water" cooler is designed to decrease the coolant temperature at low temperatures – to 500°C. Air coolers "metal – air" are meant for heat removal released in the working sections. There are two air coolers installed at the tertiary loop.

Cold traps

The oxide cold traps are used to remove oxygen from liquid metal coolant. The trap operational principle is based on oxide deposition throughout the trap filled with stainless steel chips and cooled by water or metal. The traps with water cooling are mounted at the primary and secondary loops.

Coolant is supplied to the cold trap at a temperature of 300-400°C. At such temperatures impurities are dissolved. Getting into a settling section the coolant temperature decreases to 200°C. At such temperatures the impurities will deposit on cooled surfaces (on the wall of the cooling jacket).

Oxide plugging meter

The plugging meter is a device designed for immediate remote determination of impurities content in coolant. Its operating principle is based on the capability of impurities precipitating from a solution to plug cross sections. At the moment of flow rate decrease to a certain value, the plugging temperature is recorded; it approximately accords with the saturation temperature. The impurity concentration is determined based on the saturation temperature. The plugging meter is usually used to determine the level of oxygen content in Na and Na-K alloy.

The instrument includes a special-purpose device with a small cross section, a heat exchanger to remove heat from coolant, a control valve to set a necessary flow rate (with the help of the instrument), a flow meter, and a thermocouple to determine the coolant temperature flowing through narrow gaps.

Recuperator

There is a recuperator installed in the working section to study sodium coolant boiling. It is designed for maintaining high temperature in the high-temperature section of the loop at low power consumption. In terms of design the recuperator is like a “metal – metal” heat exchanger.

Test working sections of the facility high-temperature area

The high-temperature area of the facility consists of two working sections No.1 shown in the facility technological scheme. The first section is designed to study Na-K coolant boiling, while the second one is meant for Na boiling studies. Both working sections are alike and structurally made as separate/unconnected models.

The working section for Na boiling studies consists of one module while the working section for studies on Na-K coolant boiling includes two modules. Each of the modules consists of a vessel which is represented by a 60×4 mm diameter tube, upper chamber, two-thirds of which is filled with coolant, and current lead chamber of fuel rods simulators located in the lower part of the module.

Measurement system

In the process of experiments the following parameters are measured:

- electric power of the fuel rods simulators;
- coolant flow rate and mass-flow rate perturbation in the loop model;
- coolant pressure at the inlet/outlet of the subassembly fuel rods simulators, pressure fluctuation, pressure in the cover gas;
- temperature of the fuel elements walls at several cross sections along the area of energy release and coolant temperature in various sections of the loop including the heating zone;
- recording of the steam phase along the height of the subassembly fuel rods simulators;
- acoustic emission.

Automated system for experimental data acquisition, processing and visualization

The acquisition, processing and visualization of experimental data are carried out with the help of two systems. First of all the measurement-software system based on the Compact RIO platform produced by American company “National Instruments” is used. This platform is equipped with several separate measuring racks controlled by an industrial computer with a dual core processor, 1.33 GHz. Each rack has 8 measuring units and is equipped with special-purpose devices (PLD and real-time processor) which make it possible to keep a record of sensor readings through time. Standard Gigabit Ethernet is used for connection among separate units; solid-state drives are used for data recording and storage via the USB interface with a data transfer rate up to 480 Mb/s.

In addition, a separate workstation is used with a National Instruments NI 6251 data acquisition module and an ADLINK DAQ measuring system. Visualization and partial data processing are carried out at two separate workstations using the NI Developer suite software package.

Acceptance of radioactive material

No.

Scheme/diagram

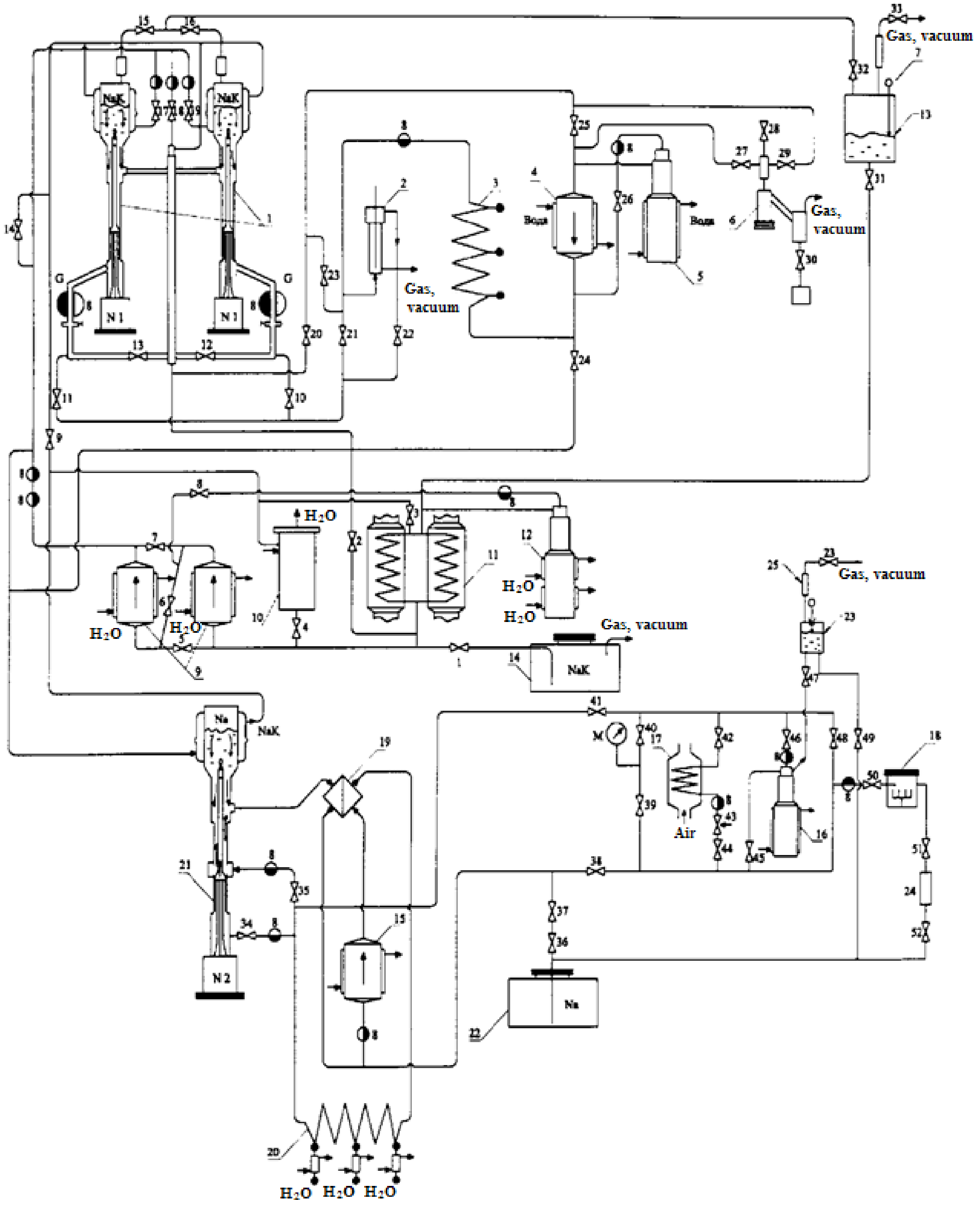

FIG. 1. Technological scheme of the liquid metal test facility "AR-1":

1 – experimental model No.1; 2 – section of magnetic flow meter calibration; 3 – primary heater No.1; 4 – primary electromagnetic pump NAV 1/5-NK; 5 – primary oxide cold trap; 6 – primary sampling/distillation device; 7 – expansion tank vapor traps; 8 – magnetic flow meters; 9 – secondary electromagnetic pumps 15/25,7 (2 pieces); 10 – "metal – water" cooler; 11 – air coolers (2 pieces); 12 – secondary oxide cold trap; 13 – primary expansion tank; 14 – dump tank with Na-K alloy; 15 – tertiary electromagnetic pump; 16 – tertiary cold trap; 17 – plugging meter cooler; 18 – tertiary sampling/distillation device; 19 – recuperator; 20 – tertiary heater No.2; 21 - secondary experimental model No.2; 22 – dump tank with Na; 23 –

tertiary expansion tank; 24 – sampling/distillation device dump tank; 25 – tertiary expansion tank vapor traps4 1-52 – valves

3D drawing/photo

FIG. 2. View of the AR-1 facility.

Parameters table

Coolant inventory	Sodium (Na), sodium-potassium eutectic alloy (Na-K); The facility has three loops: primary and secondary loops contain sodium-potassium alloy, the tertiary loop contains sodium coolant.
Power	750 kW.
Test sections (experimental model)	
TS #1	<u>*Characteristic dimensions*</u> Outer diameter 1500 mm, Overall height 14000 mm
	<u>*Static/dynamic experiment*</u> Stationary and dynamic experiments.
	<u>*Temperature range in the test section (Delta T)*</u> Sodium coolant – up to 950°C, Sodium-potassium eutectic alloy – up to 800°C

	Operating pressure and design pressure 0.6 MPa
	Flow range (mass, velocity, etc.) 1st loop – 25 m^3/h, 2nd loop – 10 m^3/h, 3rd loop –5.2 m^3/h
Coolant chemistry measurement and control (active or not, measured parameters)	Oxide filter traps are used for cleaning the sodium and sodium-potassium loops of the facility. In the process of facility operation the following parameters are controlled: power consumption, flow rate, pressure, coolant temperature. Impurity content in coolants is determined using sampling/distillation devices and oxide indicators.
Instrumentation	– Thermal sensors of various design (developed and produced at the SSC RF – IPPE); – Sensors to measure pressure in the loops using the modified sensors of “SAPFIR” type (produced at “MANOMETR” plant), “METRAN-2 (produced at Chelyabinsk plant); – Differential-pressure sensor (SAPFIR and METRAN types); – Contact level meter (developed and produced at the SSC RF – IPPE); – Magnetic flow meters (developed and produced at the SSC RF – IPPE); – potentiometric sensors (developed and produced at the SSC RF – IPPE); – acoustic detector (developed and produced at the SSC RF – IPPE).

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

High temperature liquid metal facility “AR-1” located in SSC RF – IPPE is one of the main facilities of the “Rosatom” State Corporation used for high temperature experimental research in safety assessment of sodium-cooled fast reactors, as well as thermohydraulic parameters of accelerator-driven systems with heavy liquid metal coolers. In 1990s-2000s the “AR-1” facility was used to carry out a substantial set of thermohydraulic studies:

- Experimental research of the structure and parameters of two-phase flow during liquid metal boiling progression inside a fuel subassembly model (bubble, slug flow, annular-dispersed flow, critical heat flux). Studies of fuel rods simulators steady-state cooling boundaries during liquid metal boiling inside the subassembly fuel rods simulators of a fast reactor core under decay heat removal conditions.
- Experimental research of hydrodynamics and heat exchange parameters, as well as hydrodynamic stability of circulation during the start and progression of liquid metal boiling in a parallel fuel subassemblies system inside a natural coolant circulation loop.
- Studies of liquid metal dynamic boiling at an instant change of parameters (power, flow rate, pressure) aimed at developing analytical methods and verification of calculation codes.
- Analysis of liquid metal coolant boiling diagnostics in rods bundles.
- Studies of sodium boiling modes in a seven-element subassembly fuel rods simulators at moderate heat flows.
- Experimental research of dynamic characteristics of heat exchange and temperature fields on the surface of the target and inside the channel of the target model of an accelerator-driven system using eutectic sodium-potassium alloy simulating heat transfer conditions for lead-bismuth coolant.

- Experimental research of hydrodynamics, heat exchange and thermal cycling of finned heat transfer tubes on the sodium – air heat exchanger model of the decay heat removal system of the BN-800 reactor facility.

Experimental studies of start and progression of liquid metal boiling inside a subassembly fuel rods simulators in a natural circulation loop have been carried out at the request of Japanese specialists. Experimental research of thermohydraulic characteristics of the accelerator-driven system target model were conducted under contract with Los Alamos National Laboratory (USA).

PLANNED EXPERIMENTS (including time schedule)

The “AR-1” facility is planned to be used for experimental research of liquid metal two-phase flow at moderate heat flows. This stage of experiments is aimed to study the feasibility of the stabilized mode of liquid metal two-phase flow in absence of critical heat flux as applied to fuel subassembly geometry. The second stage involves studies of critical heat flux conditions in the power release region in stationary modes, as well as development of methods of sodium boiling early registration using aggregate data recorded by available hardware.

The final stage of studies will be devoted to dynamic modes of sodium coolant two-phase flow. These experiments are meant to obtain data for verification of the boiling model used in the COREMELT code and to justify self-protection of the sodium-cooled fast reactor core. The main goal of studies on this stage is to simulate different emergency modes, such as unprotected loss of flow (ULOF) accidents, and to analyze the impact of fuel subassembly geometry on accident development and two-phase flow modes.

TRAINING ACTIVITIES

Training activities for researchers at liquid metal thermohydraulic facilities must be coordinated with the “Rosatom” State Corporation.

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