FSUE SRI SIA “LUCH”
IBRAE RAS
FSUE EDO “GIDROPRESS”

I S T C

Study of fuel assemblies under severe accident top quenching conditions in the PARAMETER-SF test series

(PARAMETER-SF3 and –SF4 experiments, ISTC project proposal)

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CEG – SAM, 11th Meeting
Dresden, 7 -9 March 2007

Objective:

The studying of behaviour of simulators fuel assembly VVER-1000 completed with standard constructional materials under severe accident conditions at the top flooding

Implementation:

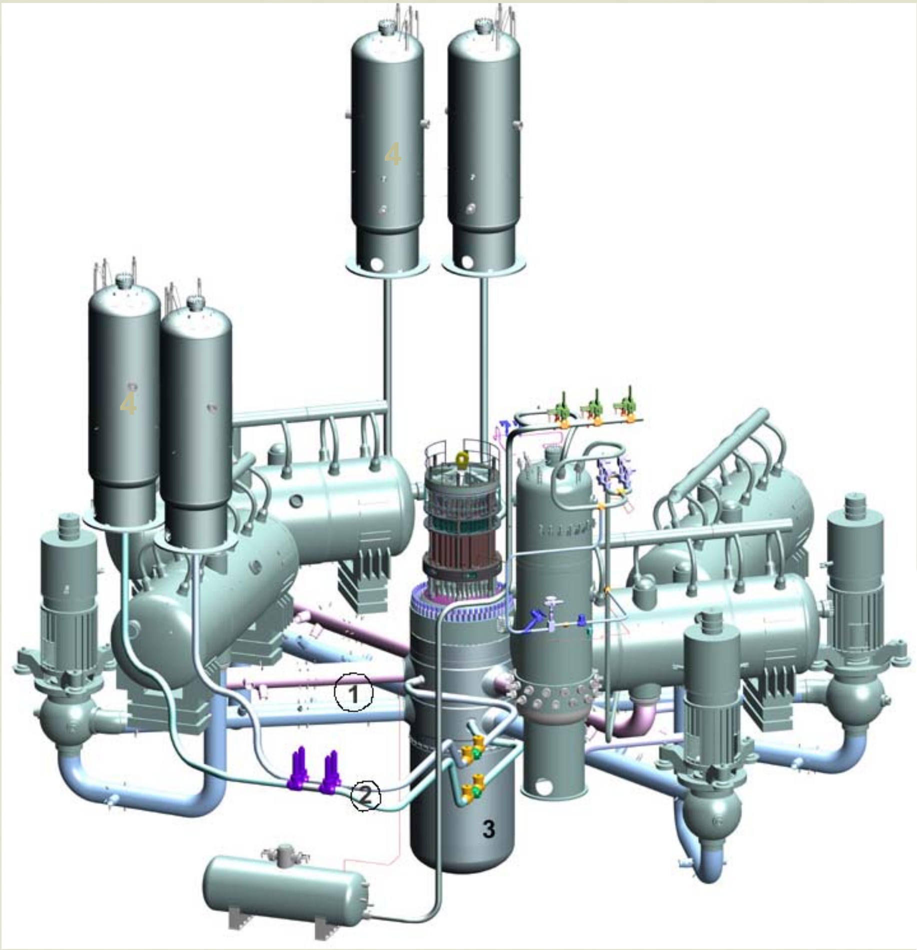
FSUE SRI SIA "LUCH"– rig experiments and post test analysis

IBRAE RAS – pre and post test analyses

FSUE EDO "GIDROPRESS" – justification of an experimental scenario, pre and post test analyses

Justification of test scenario

VVER-1000 3D view



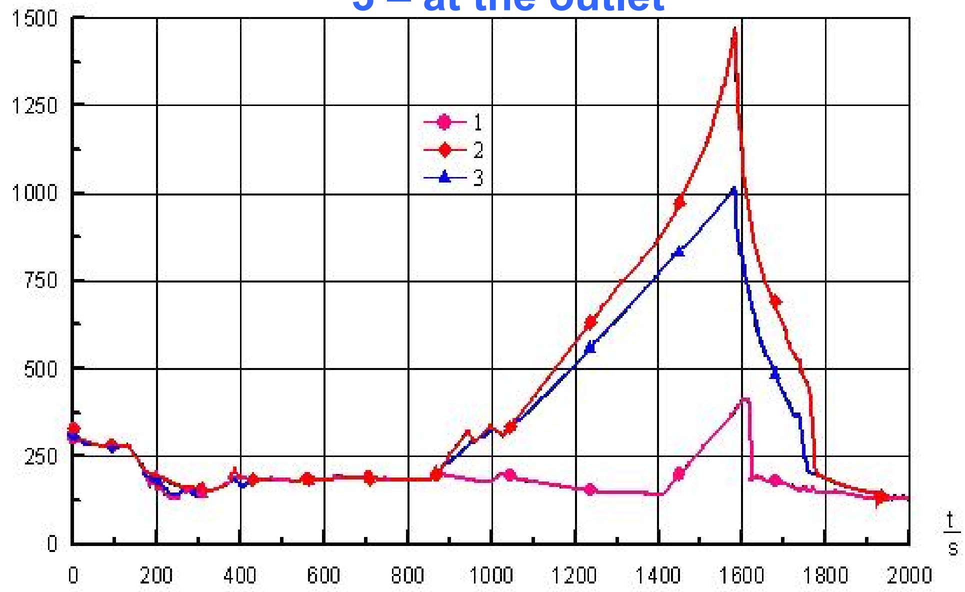
1 - главный циркуляционный трубопровод (холодная и горячая нитки одной петли);
2 - трубопроводы система аварийного охлаждения активной зоны;
3 – реактор; 4 – ёмкости САОЗ.

Simulated SA scenario of VVER-1000

- Large break of cold leg of Main Circulation Loop with fault of ECCS (ED 200);
- Recovery of 1 channel of ECCS at late accident stage in a range from 1600 up to 1800 C;
- Water injection from top and bottom of core with total rate 200 Kg/s

Clad temperature

1 – at the inlet; 2 – in the middle;
3 – at the outlet



Main outcomes of LBLOCA (ED 200) analysis

Design of WWER-1000 ECCS allows to provide simultaneous top/bottom flooding of overheated core

Pre flooding stage:

- **Clad heat up rate – 1…2 K/s**
- **Steam flow rate – 0.2 g/s per rod**

Flooding stage:

- **Water injection – > 2 g/s per rod from top**

At a simultaneous flooding of a core from top and bottom the top part of a core long time is exposed only to cooling by water from top at intensive movement of steam from bottom

Realization of the top flooding at SA

1. VVER - 1000

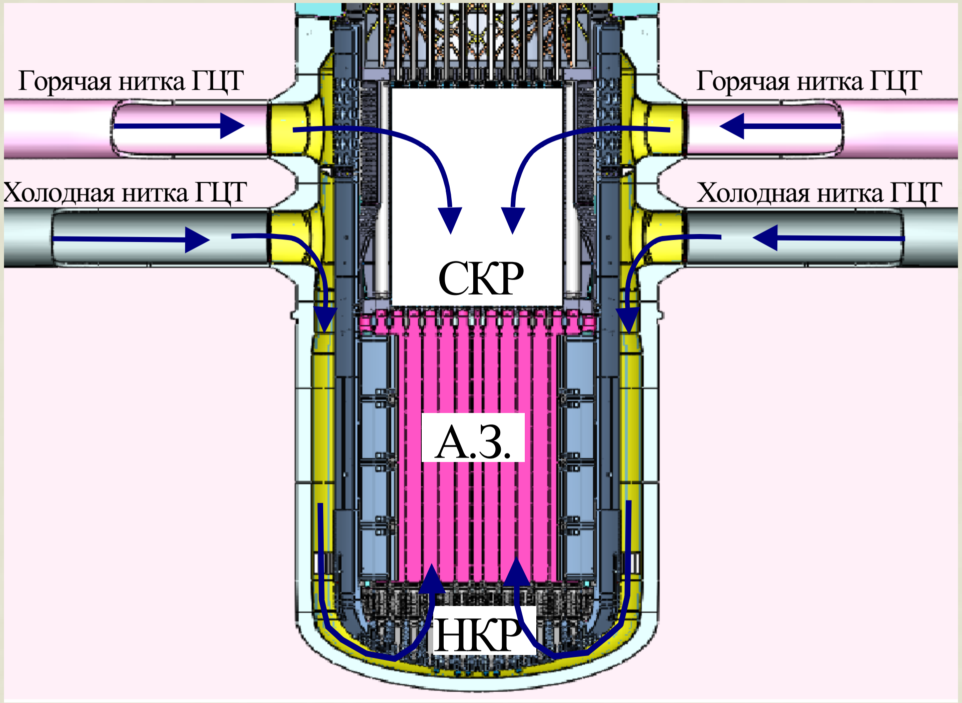


Схема залива активной зоны (А.З.) двумя насосами низкого давления:

-верхнего, через сборную камеру реактора (СКР);

-нижнего, через напорную камеру реактора (НКР).

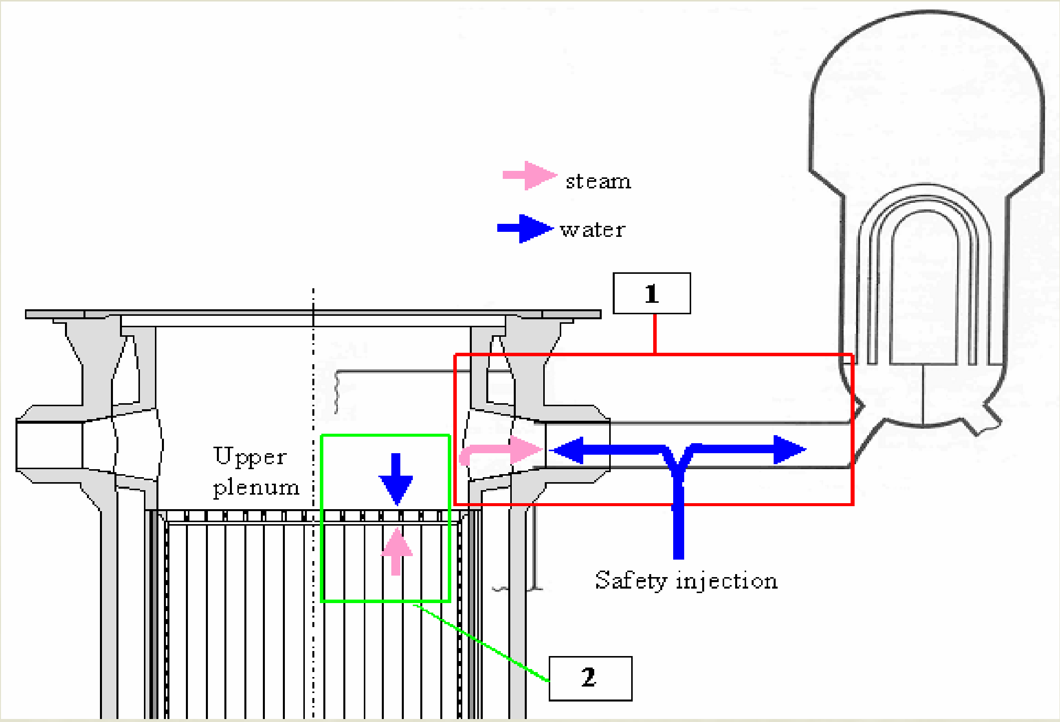
Cooling of a core it is determined by two processes:

1. Increase in a water level in the bottom chamber (at a top flooding and directly in the chamber at a bottom flooding).

2. Water inflow in the top chamber, distribution on section of a core and passage through a core from it cooling, filling of the bottom chamber with rise of a level of the coolant.

Water delivery from ECCS simultaneously from top and bottom allows to avoid a situation, when all submitted water is carried away in a leak. Water delivery from top allows to organize cooling earlier, than at water delivery from bottom.

2. PWR



There are two possibilities for top quenching occurrence:

1. In case of severe accident, the steam in steam generator tubes can condensate and water thus produced can return to the core via the hot leg.

2. When the injection point of safety injection system is located on the hot leg, one can expect that a part of the injected water rate can directly go to the core through the nozzle of the hot leg.

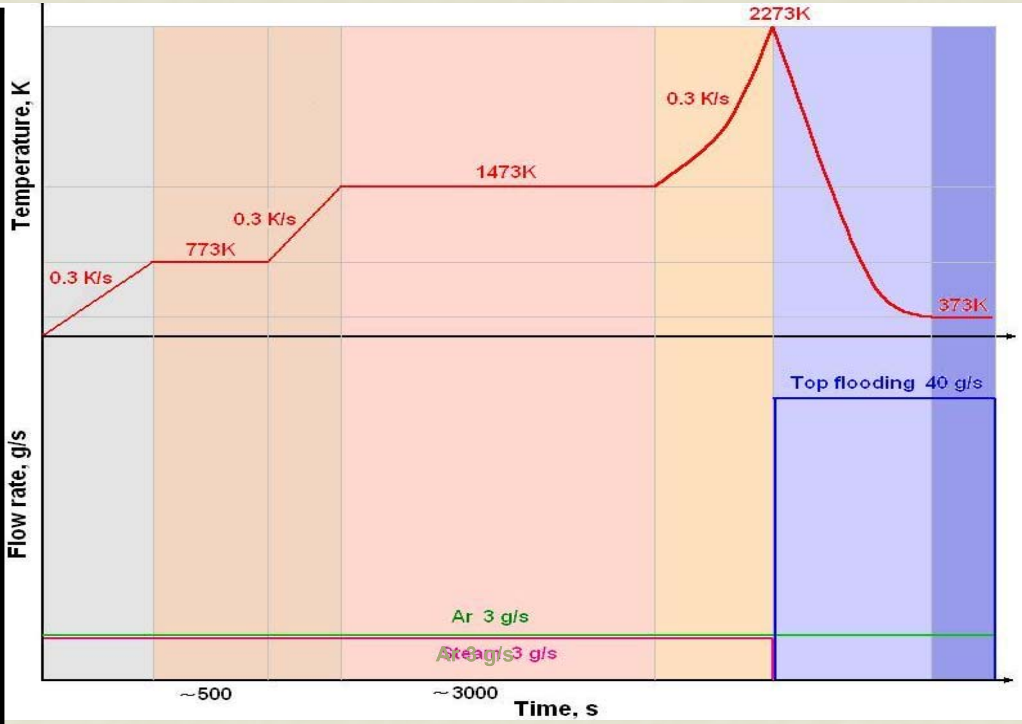
(International Conference Nuclear Energy for New Europe 2006 Portorož, Slovenia, September 18-21, 2006)

The PARAMETER SF-1 Experiment

Main parameters of experiment

Coolant	Steam/ argon
Flow rate of coolant, g/s	3/2
Temperature of coolant, K	~773
Heating rate of cladding, K/s	0.3
Temperature of cladding at the pre-oxidation phase, K	1473
Duration of the pre-oxidation phase, s	3000
Maximal temperature of cladding, K	2273
Quenching phase	Top flooding
Flow rate of top flooding, g/s	~ 40

Sequence diagram of experiment



Some conclusions by results of the analysis of PARAMETER SF-1 experiment

1. Difficult character of movement of cooling front of test bundle at a top flooding is caused by infringement of geometry of test bundle and blocking of through passage section of bundle by the formed zones of fusion.

2. Process of degradation of constructional elements of bundle happened in experiment and absence of zones of destruction (debris) pellets are caused by presence of a skeleton of heaters of rods.

3. The received results have shown on necessity of carrying out of the additional researches, allowing to estimate character of cooling of assembly at a top flooding before its degradation and in conditions of formation of zones of destruction pellets (debris).

Proposal project # 3690 ISTC

Carrying out of two experiments of series SF in conditions of a top flooding:

Experiment SF3

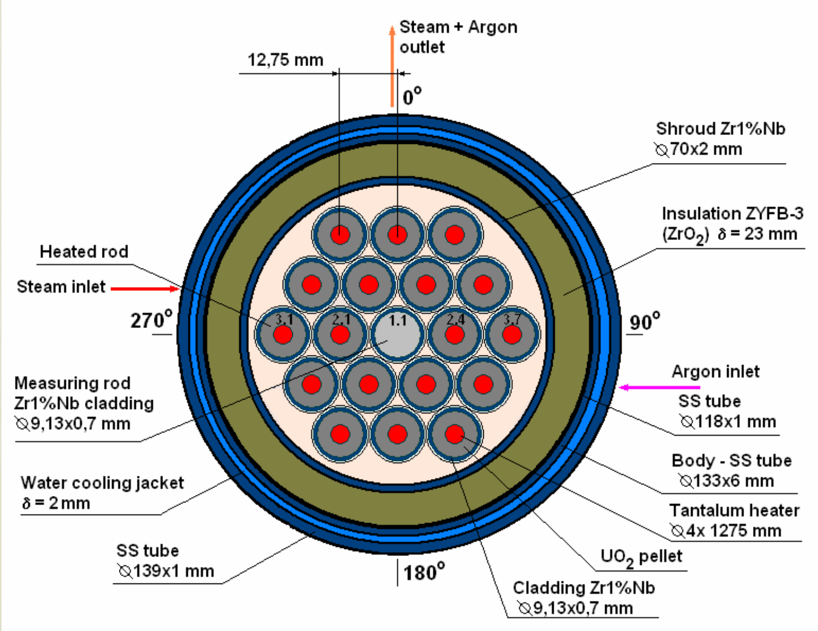
Research of features of cooling and change of structure materials of the bundle VVER-1000 at temperature ~1870 K in conditions of the top flooding

Object of tests:

19-rods test bundle VVER-1000 with 18 heated rods

The main requirements of experiment:

The maximal temperature of bundle before top flooding – **1870 K**
The water rate of top flooding - **40 g/s.**



Experiment SF4

Research of moving of materials of the bundle VVER-1000

which have been heated up to temperature ~ 2070 K, as a result of partial destruction of rods and formation debris.

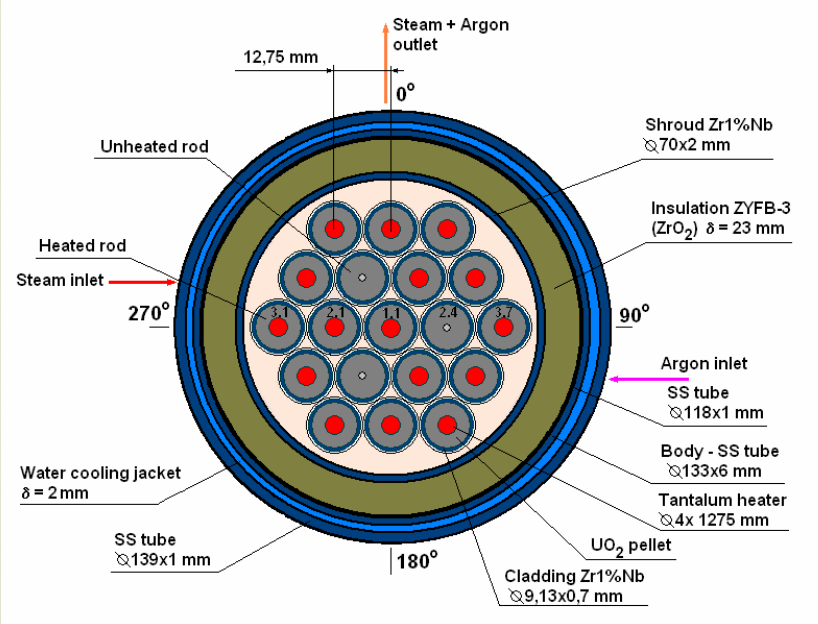
Studying of influence of change of structure of assembly on cooling at the top flooding

Object of tests:

19-rods test bundle VVER-1000 with
3 unheated rods

The main requirements of experiment:

The maximal temperature of bundle before top flooding – **2070 K**
The water rate of top flooding - **40 g/s.**



The prospective scenario of experiments

Stage	Stage substance	Main parameters			
		Bundle temperature, K	Medium	Heating/ cooling rate	Time, s
1	Electric heating of the fuel bundle within argon	770	argon with flow rate of 3(2)* g/s	0.16	0-3000
2	Electric heating of the fuel bundle within the steam and argon flow	770	steam and argon with flow rate of 3/3(2) g/s	0	3000-5000
3	Heating of the fuel bundle (phase I)	770-1470	steam and argon with flow rate of 3/3(2) g/s	~0.3 K/s	5000- 8500
4	Pre-oxidation of the fuel bundle	~ 1470	steam and argon with flow rate of 3/3(2) g/s	0	8500-11500
5	Heating of the fuel bundle (phase II)	1470-1870(2070)**	steam and argon with flow rate of 3/3(2) g/s	0,1-0,3 K/s	Define experimentally as deign temperature will be reached
6	Flooding of the fuel bundle from the top (~5 s after Tmax reached)	up to saturation	water with flow rate of 40 g per bundle	100 – 10 K/s	~300

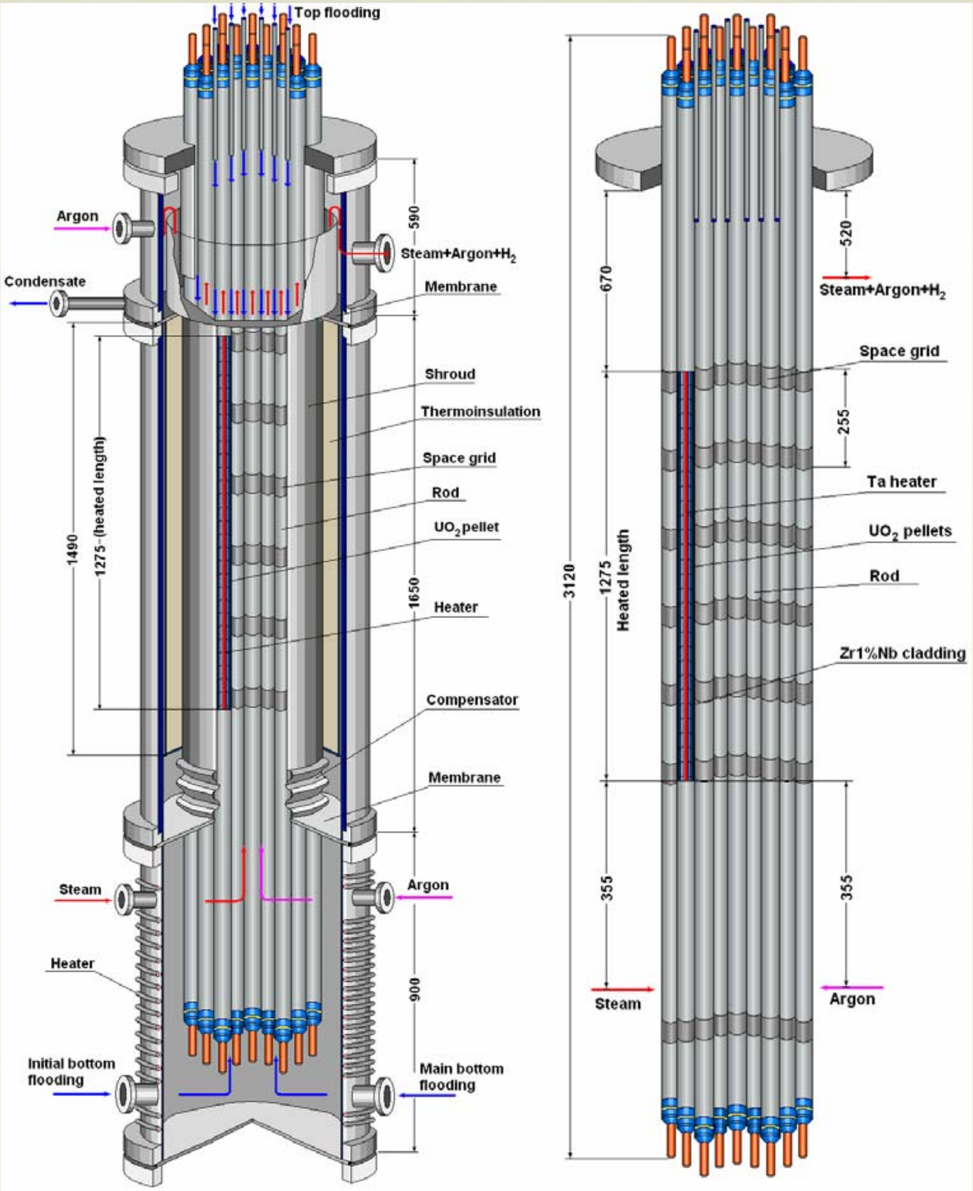
*) flow rate of argon of second test; **) Bundle temperature of second test.

Test Bundle

The main technical characteristics

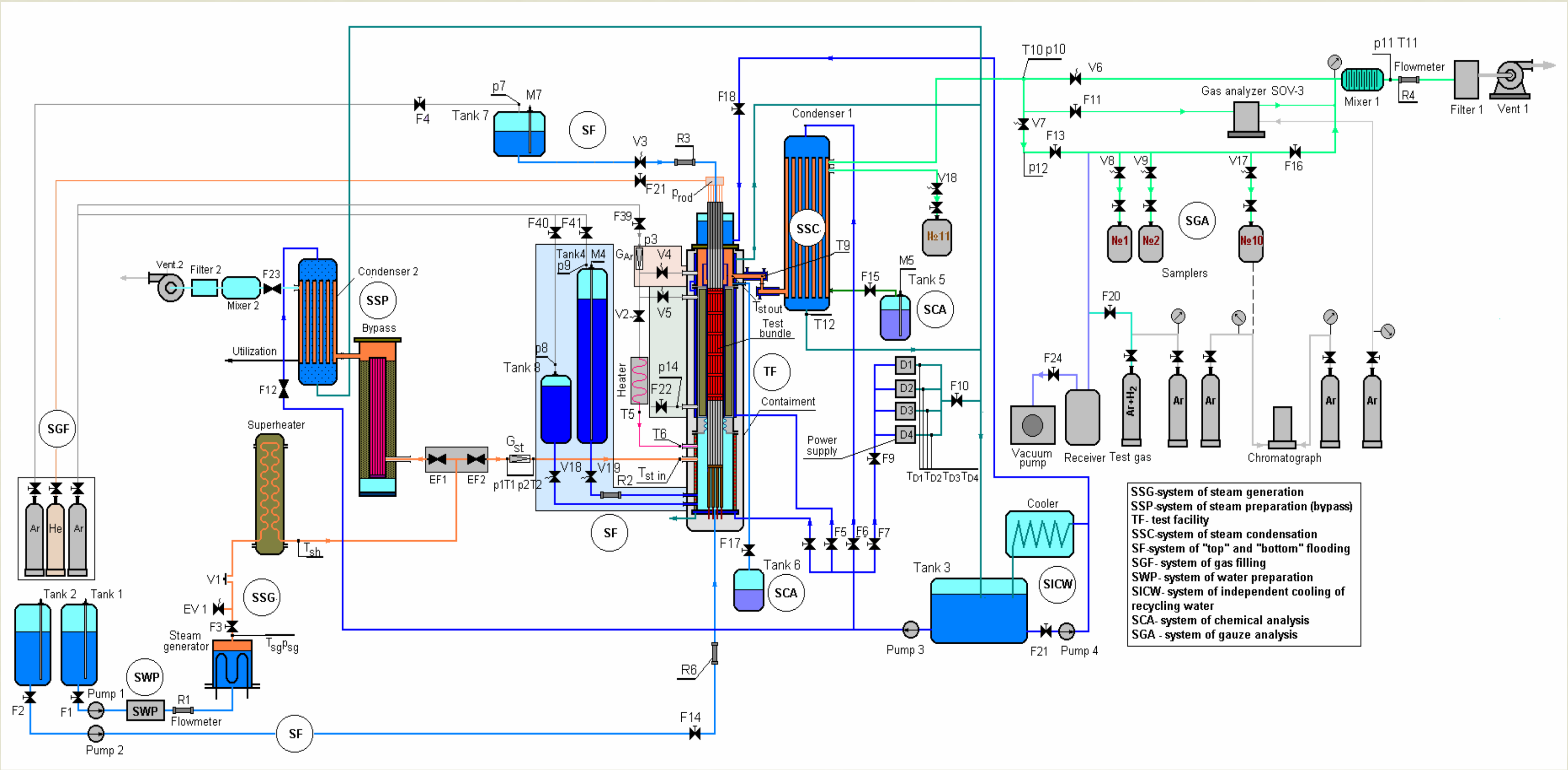
Type	VVER-1000
Number of rods	19
- heated	18
- unheated	1
Rods	
- cladding, mm	∅ 9,13/7,73 (Zr1%Nb)
- pellets	UO_2
- heater	∅ 4/1275 (Ta)
Grid type	triangle
- grid pitch, mm	12.75
Spacing grid	Zr1%Nb
- height, mm	20
- spacing, mm	255
Shroud	Zr1%Nb
- thickness, mm	2
- diameter/height, mm	70/1490
Thermoinsulation	ZrO_2 ZYFB-3
- thickness, mm	23
- diameter/height, mm	116/1490

General view



PARAMETER Facility

Functional diagram



Main technological systems

- System of separate input of argon;
- The monitoring system of balance of steam and water;
- System of top flooding;
- The monitoring system of hydrogen

Expected results of works under the Project

- Reception and ordering of the information on behaviour of model of fuel assembly VVER-1000 in severe accident conditions at the top flooding;

- Expansion of a database for verification SA codes (RELAP/SCADAPSKIM, MELCOR, РАТЕГ-СВЕЧА, ATHLET, ICARE-CATHARE, etc.);

- Research of opportunities of a top flooding of fuel assembly, heated up to ~1870 K and ~2070 K;

- Use of the received data for increase safety of the projected and working atomic power stations with VVER and PWR.

The basic stages of the project

Tasks	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5	Quarter 6	Quarter 7	Quarter 8
Task 1	**Post-test material analysis of the test bundle VVER-1000** **PARAMETER SF-2 Experiment**							
Task 2	**Research of features of cooling and change of structure materials of the bundle VVER-1000 at temperature ~1870 K in conditions of the top flooding** **PARAMETER-SF3 Experiment**							
Task 3					**Research of moving of materials of the bundle VVER-1000 which have been heated up to temperature ~ 2070 K, as a result of partial destruction of rods and formations дебриса.** **Studying of influence of change of structure of assembly on cooling at the top flooding** **PARAMETER-SF4 Experiment**			

Budget cost of the project

Full budget cost of the project ($ USA)	600000
Payments to individual participants	335120
The equipment	100320
Materials	65560
Other direct costs	18000
Business trips	45000
Overhead charge	36000
Duration of the project (month)	24