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

I S T C

Experimental results of complex starting-up and adjustment actions on preparation of the PARAMETER-SF2 Experiment

(Status of Project # 3194)

Presented by W. Nalivaev

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The Structure of Project

1. Financial support – I S T C

2. The basic participants:
   FSUE SRI SIA “LUCH”
   IBRAE RAS
   FSUE EDO “GIDROPRESS”

3. Another participants:
   A.A. Bochvar FSUE VNIINM,
   A. I. Leipunsky SSC RF-IPPE,
   RSC “Kurchatov Institute”

4. Foreign collaborators: FZK, GRS, EdF, IRSN

Main Tasks of the PARAMETER-SF2 Experiment

Study of the conditions of cooling of the test bundle under combined top and bottom flooding;

Experimental trial of the system and method of the combined top and bottom flooding;

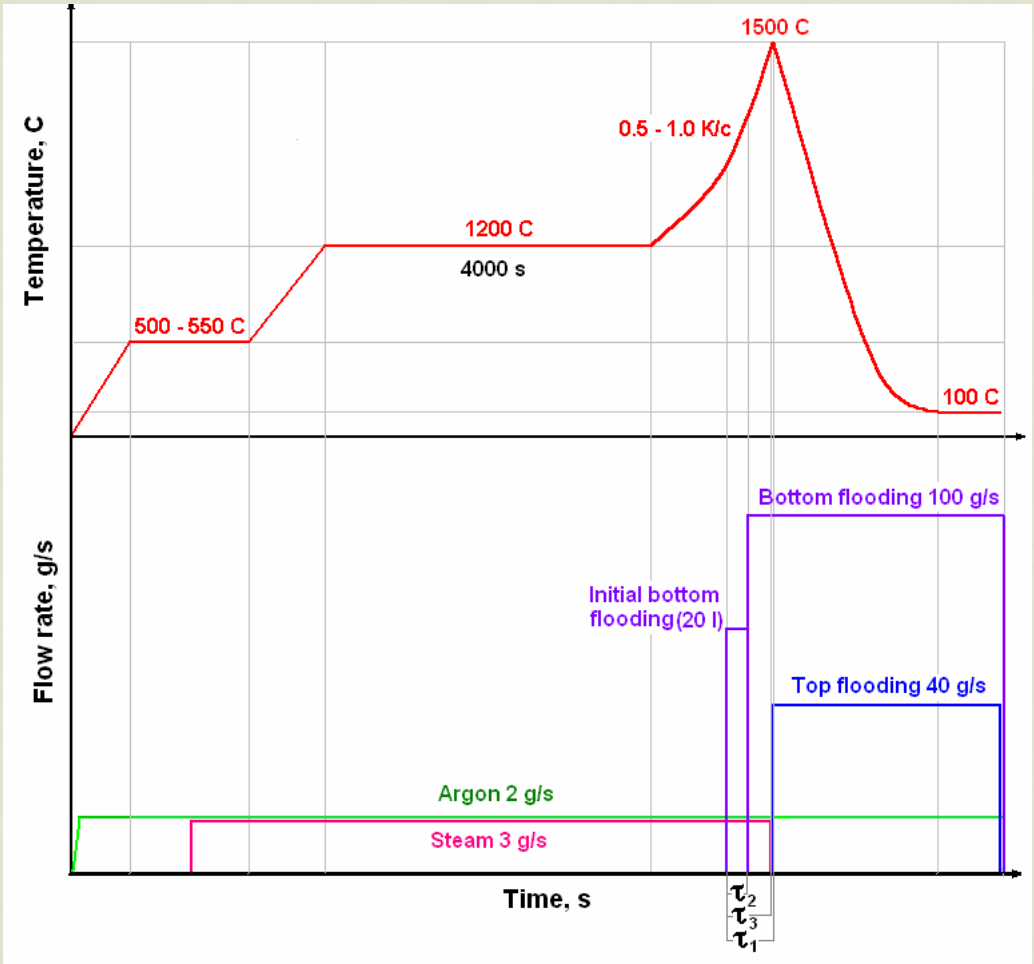
Adjustment of the method for steam-water balance control under top and bottom flooding.

The PARAMETER-SF2 experiment

Main parameters of experiment

Coolant	Steam/ argon
Flow rate of coolant, g/s	3/2
Temperature of coolant, C	~500
Heating rate of cladding, K/s	0.3
Temperature of cladding at the pre-oxidation phase, C	1200
Duration of the pre-oxidation phase, s	4000
Maximal temperature of cladding, C	1500
Quenching phase	Top and bottom flooding
Flow rate of flooding, g/s: - top - bottom	~ 40 ~ 40

Sequence diagram of experiment



Some results of the PARAMETER-SF1 Experiment

The cooling of the 19-fuel element assembly from the temperature of ~ 2270 K by top flooding with the flow rate of 2 g/s per fuel element:

1. Cooling of the upper elements of the assembly (Z=1250 - 1500 mm) in 3-5 seconds down to the temperature of ~ 400 K and to ~ 330 K in ~ 150 seconds.

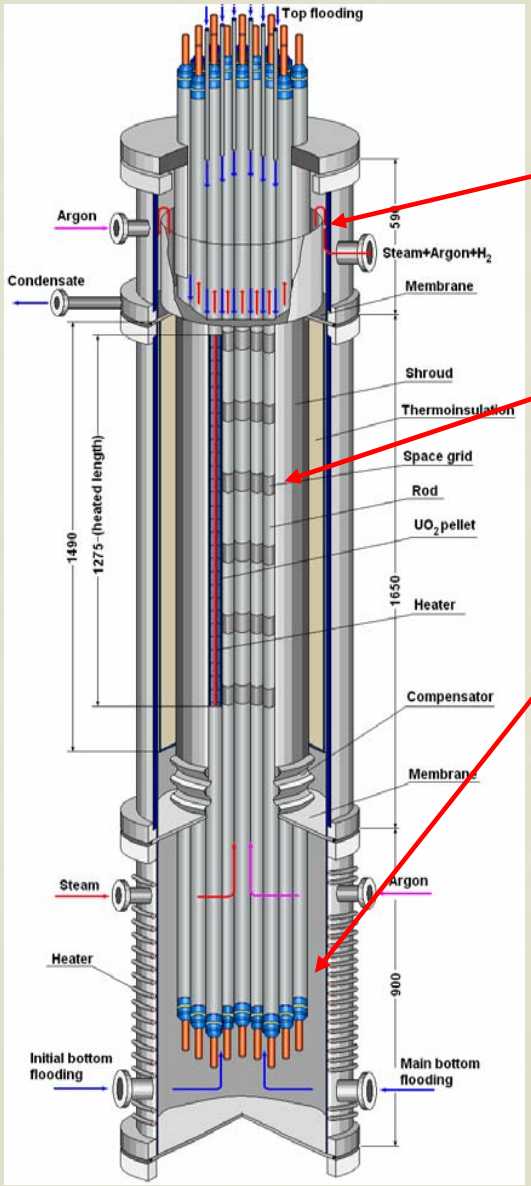
2. Cooling of the lower part of the assembly (Z=0 - 600 mm) in 400-600 s (to the temperature of ~ 370 K) by the cooling front propagation upward with the rate of ~ 10 degrees/s.

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;

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.

Modernization of technological systems of the PARAMETER facility

1. Test section

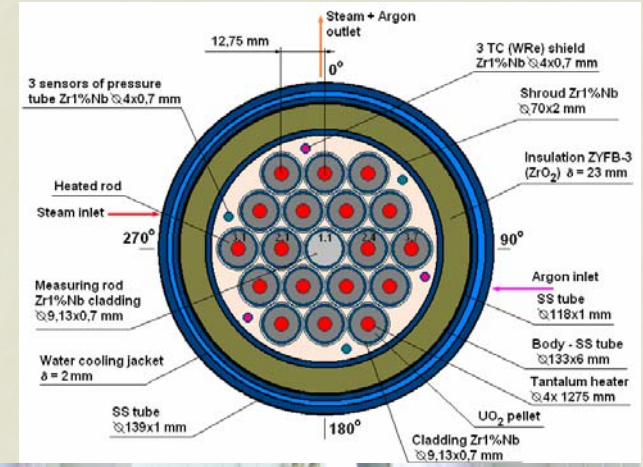


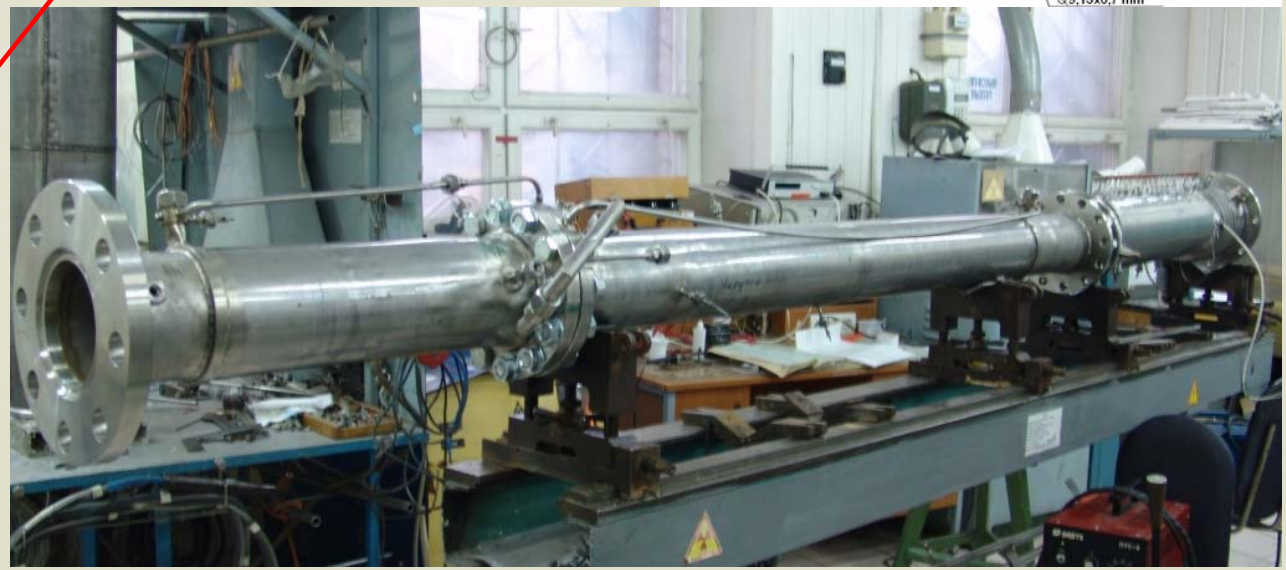
The improved test section comprises three parts

Upper part

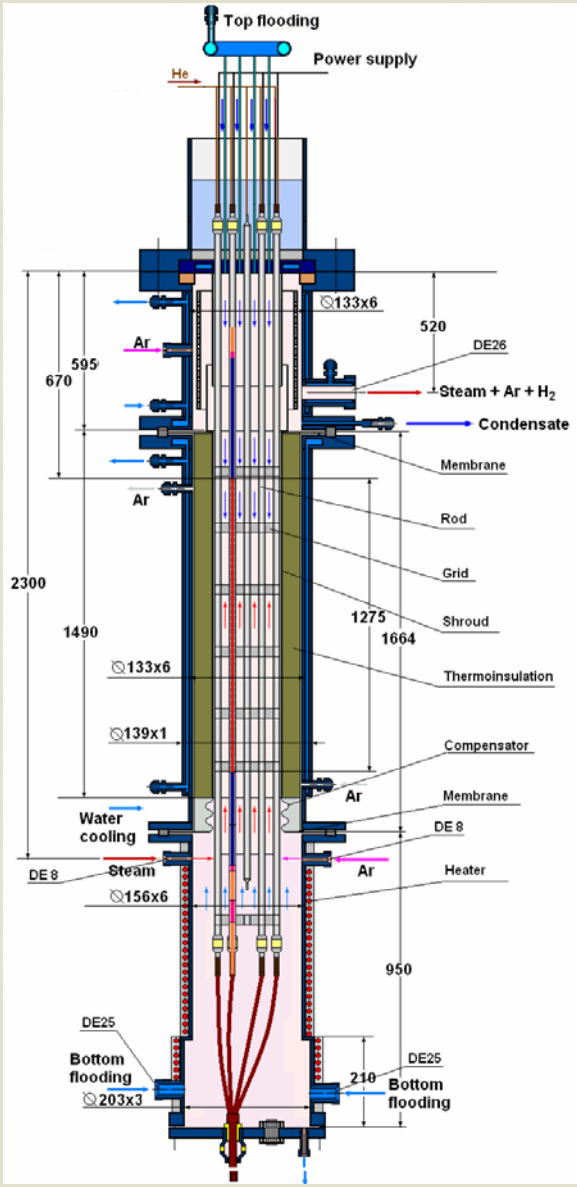
Middle part

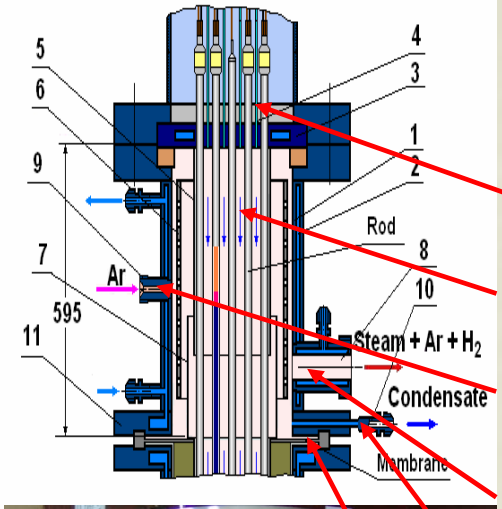
Bottom part





1.1. Upper part

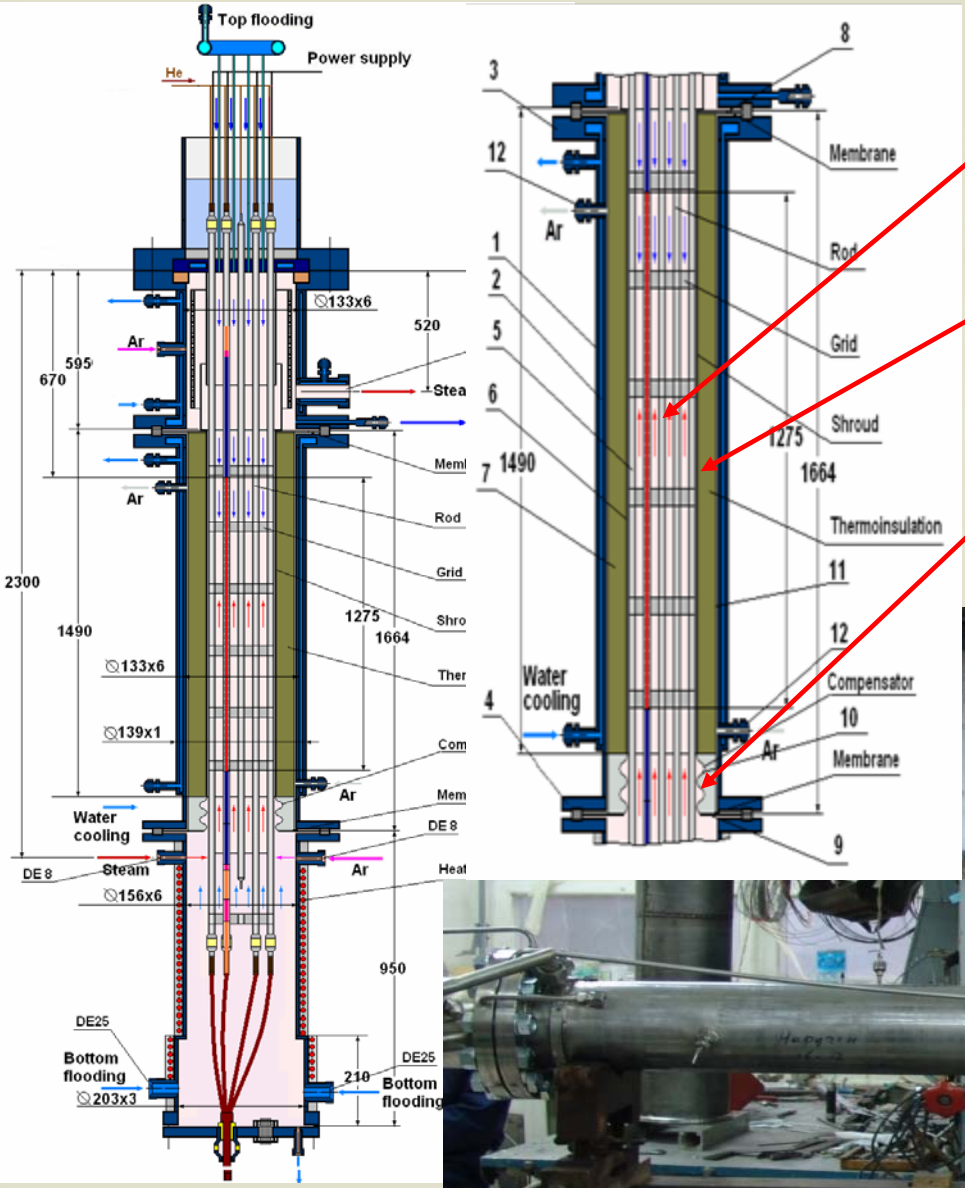




The upper water-cooled part provides:

- input rods and TC;
- top flooding;
- input of argon at quenching phase;
- output steam-gas mixture;
- gathering of a condensate and the control of volume of emission of water of the top flooding;
- tight division of the top and middle parts.

1.2. Middle part

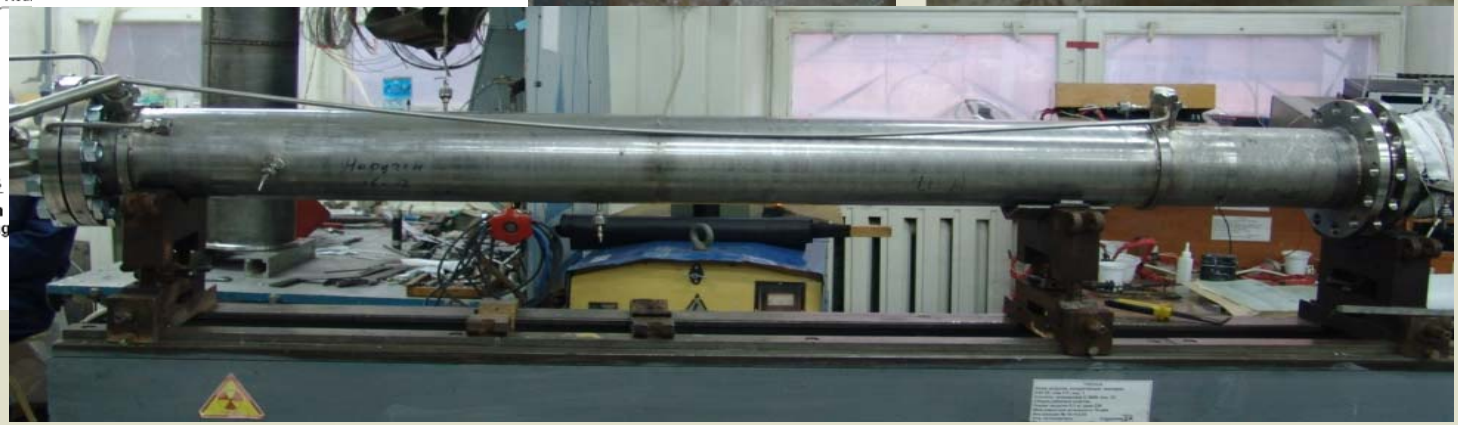


The middle water-cooled part provides:

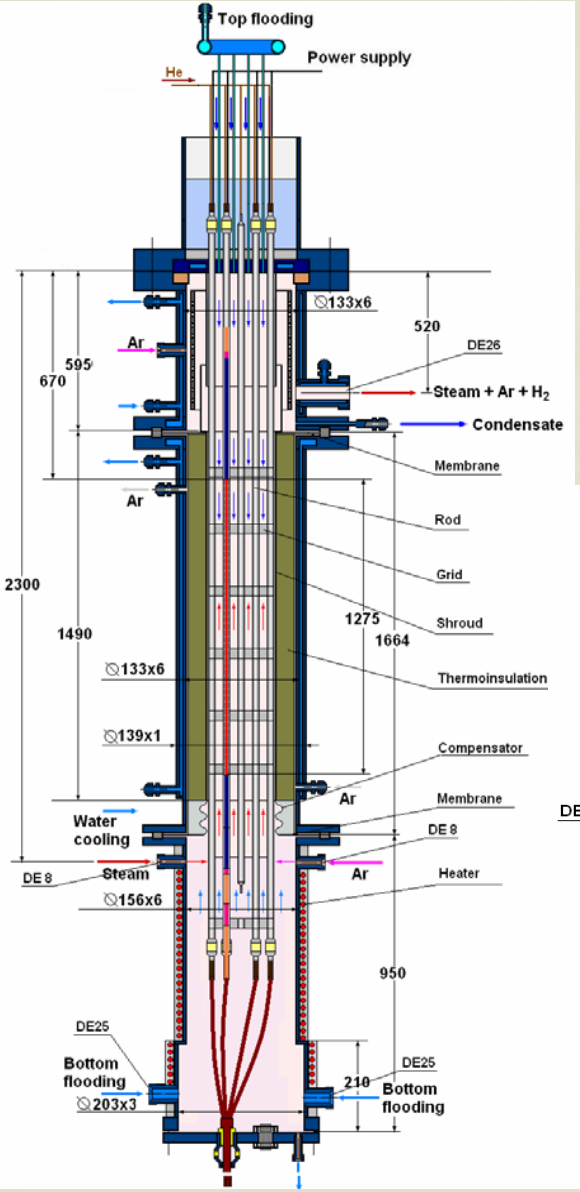
- **pass steam-gas mixture only through the bundle;**

- **tightness thermoinsulation and the control of pressure of argon inside of the free space of the thermoinsulation;**

- **compensation of temperature axial displacements of the shroud .**



1.3. Bottom part

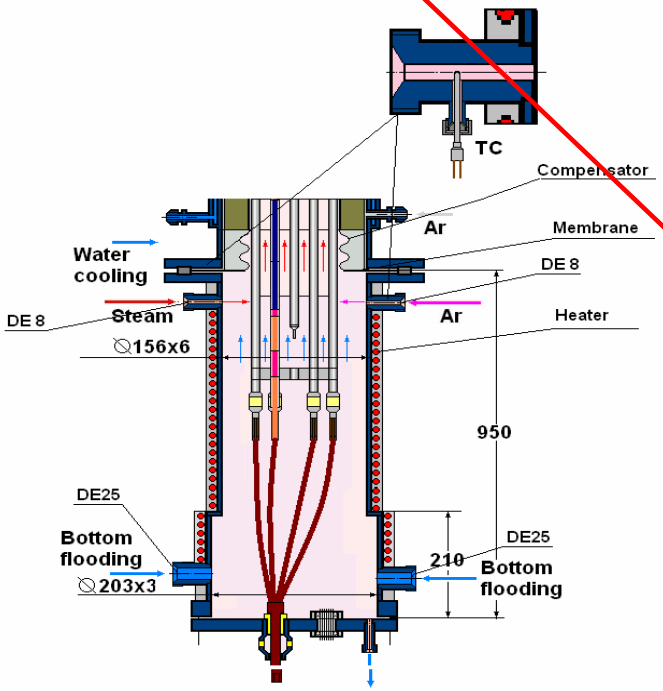


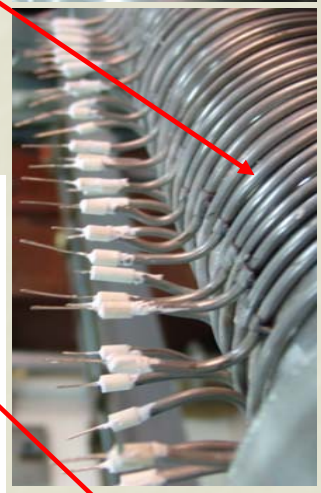
The bottom heated part provides:

- separate input steam and argon;

- heating up to temperature of steam saturation (T ~ 400-410 K at p ~ 0,30-0,35 МПа);

- bottom flooding.





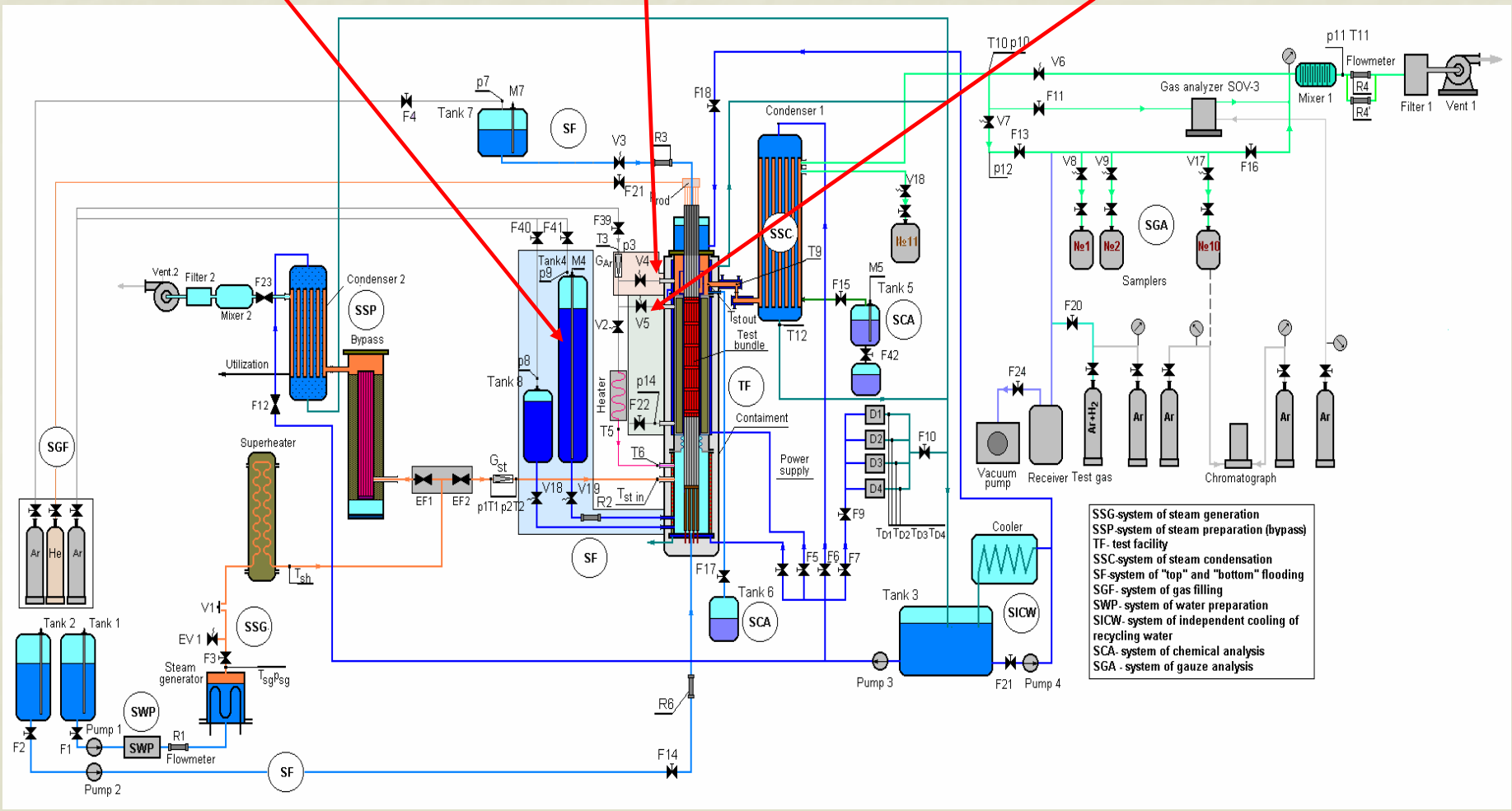
2. PARAMETER Facility

Additional technological systems:

System of the Bottom flooding

System of switching of input of argon

System of filling with argon of a free space of the thermoinsulation and the control pressure of argon

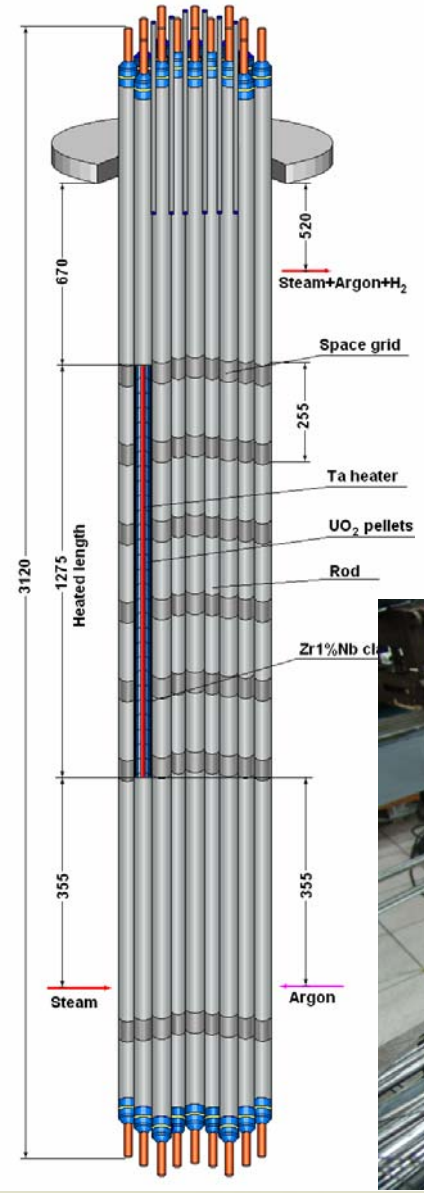


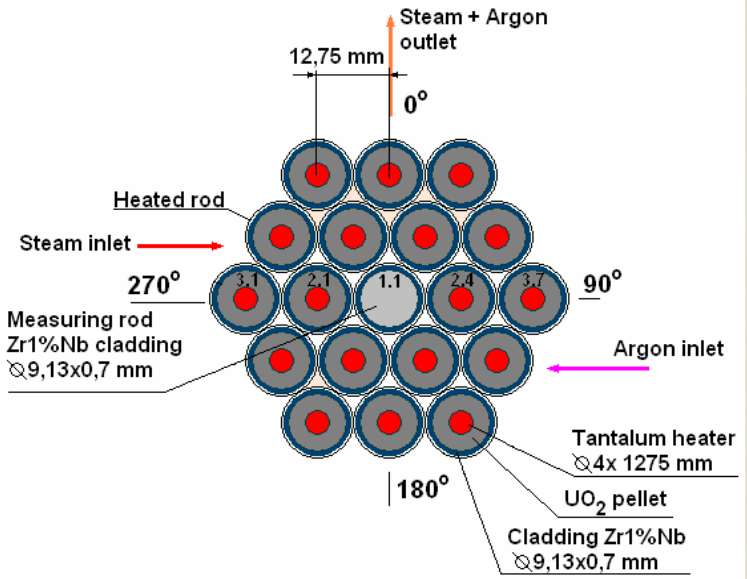
Test Bundle

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





Comparison of geometrical parameters of the PARAMETER-SF2 bundle with QUENCH-06 bundle

1) Coolant channel area relationship SF2/Q06 ≈ 0,686

2) Metallic surface relationship SF2 / Q06 ≈ 1,03

3) Heated metallic surface relationship SF2 / Q06 ≈ 0,95

4) Bundle material mass relationship SF2 / Q06 ≈ 0,96

Test instrumentation

Z, mm	Rods																				
	1.1	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10	3.11	3.12	Tsh	Tth	Tst
1475		TChA				TChA										PS						
1400				TChA																		
1300								TChA				TChA		TChA						TWRe	TChA	
1285	TWRe		TWRe																			TWRe
1250				TWRe		PtRh	TChA		TWRe		PtRh		PS					TChA				
1100	TWRe	TWRe			TChA					TChA							TWRe		TWRe	TWRe	TChA	
1030	TWRe						TWRe															TWRe
900													TWRe		TWRe			PS		TWRe	TChA	
800																						
775	TWRe				TWRe																	TWRe
700			TChA													TChA				TWRe	TChA	
600														TChA								
500				TChA														TChA				
400								TChA								TChA						
300						TChA							TChA									
200		TChA										TChA		PS								
100			TChA														TChA					
50				TChA																		
0							TChA															
-50									TChA													
-150						TChA			PS													
-300					TChA																	
-450	TChA																					
-550	TChA																					
-600	TChA																					

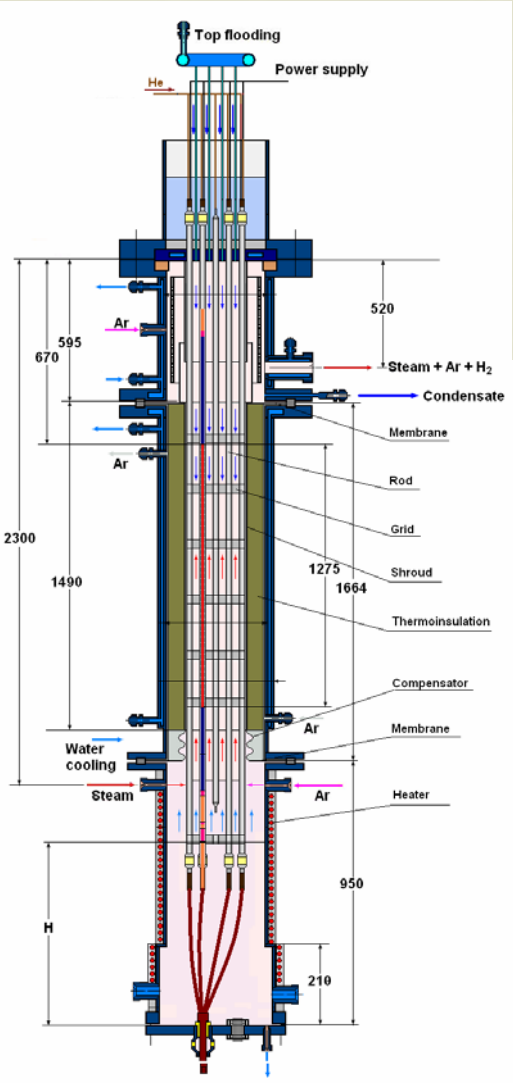
TC ChAl - 31, TC WRe – 14, TC PtRh – 2
Tsh – 4, Tth – 4, Tst – 3, PS (pressure sensor) - 5

Experimental results of complex starting-up and adjustment actions

The main starting-up and adjustment actions

1. Definition of parameters of system of the top flooding;
2. Definition of parameters of system of the bottom flooding;
3. Working off of system of steam generation and definition of hydraulic characteristics of a steam-gas path;
4. Working off of the control of balance of water;
5. Control Test at T_{bnl} ~ 770 - 870 K.

1. Working off of systems of steam generation



Main parameters:

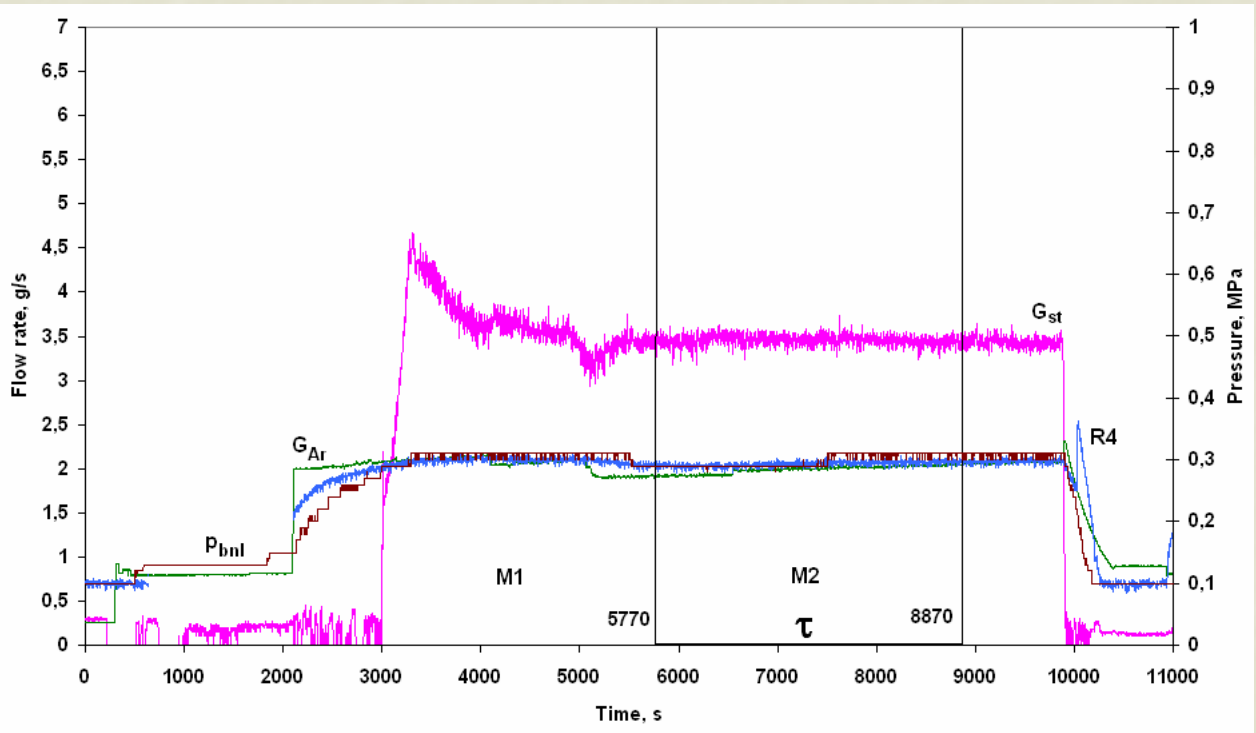
Bottom water level (H) – 0 mm,

The average temperature of bottom part wall- ~ 420 K,

Flow rate water cooling - 300 g/s, Gst - ~ 3 g/s, Garg - ~ 2 g/s

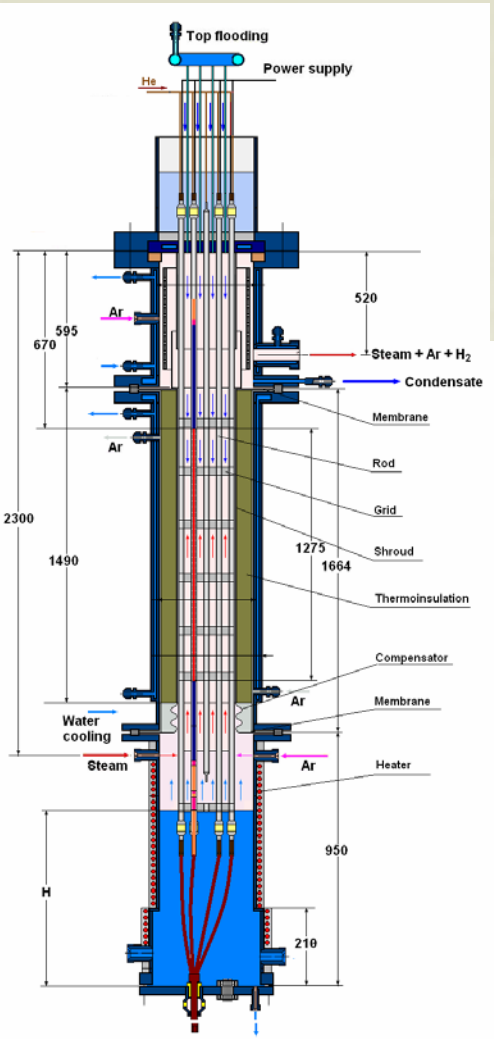
Tst in - ~ 770±50 K, Targ in - ~ 670±50 K, T bnl – ~ 770 K, Pbnl - ~ 0,3 MPa,

τ – ~ 3000 s



Inlet steam flow rate – 3,45 g/s M1 = 4647 g, M2 = 10800 g,
$G_{st} \bullet \tau$ = 3,45•3100 = 10695 g

2. Working off of the control of balance of water



Main parameters:

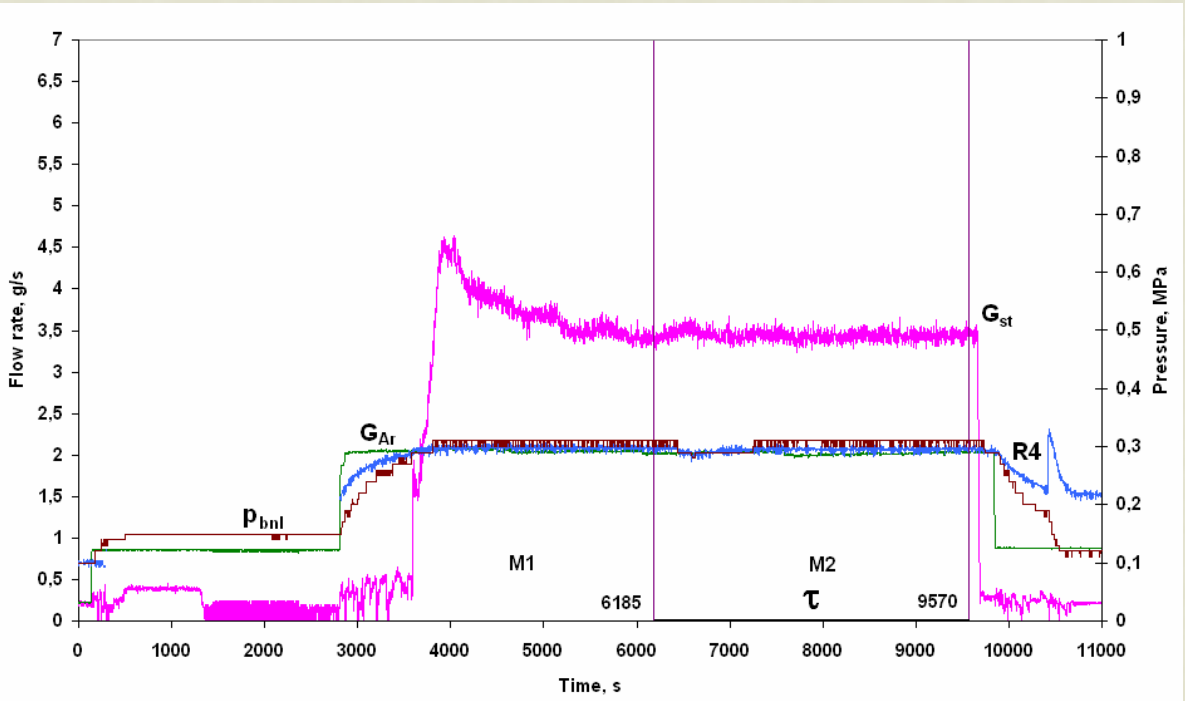
Bottom water level (H) – 550 mm,

The average temperature of bottom water- ~ 410 K,

Flow rate water cooling - 300 g/s, Gst - ~ 3 g/s, Garg - ~ 2 g/s

Tst in - ~ 770±50 K, Targ in - ~ 670±50 K, T bnl – ~ 770 K, Pbnl - ~ 0,3 MPa,

τ – ~ 3000 s

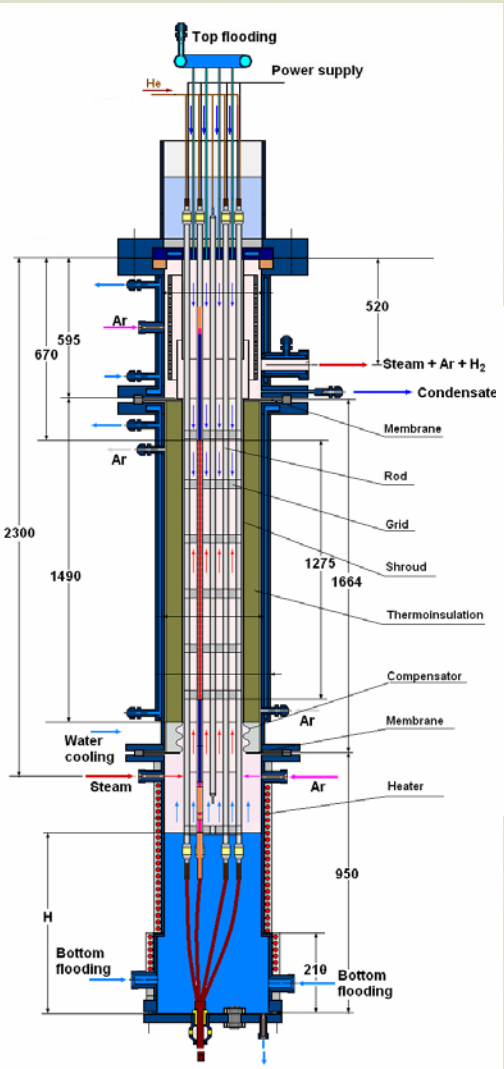


Inlet steam flow rate – 3,44 g/s,

M1 = 9142 g, M2(τ=3385 s) = 13575 g, M5* = 1002 g (при сбросе давления), loss of water in the bottom of test section – 3142 g

$G_{st\ bnl}$ = M2/τ ≈ 4,01 g/s, ΔG_{st} ≈ (3142-1002)/3385 = 0,61 g/s

3. Definition of parameters of systems of top and bottom flooding

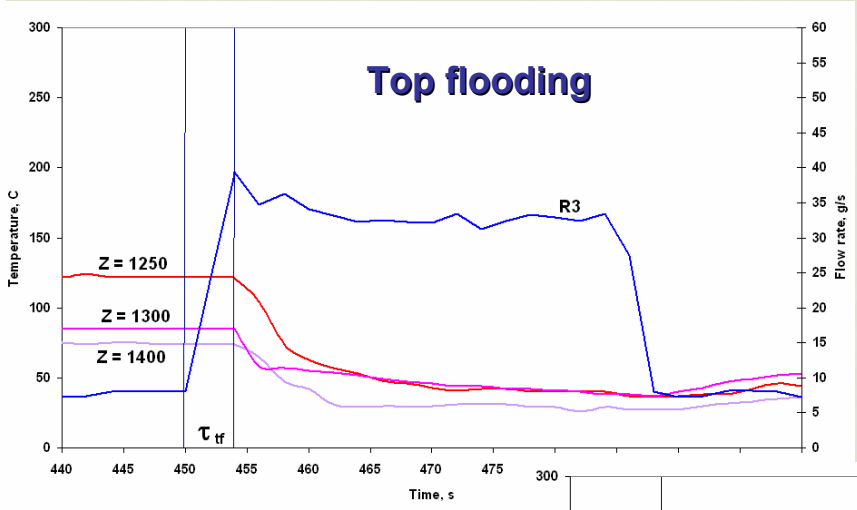


Main parameters:

Bottom water level (H) – 550 mm,

The average temperature of bottom water- ~ 410 K,

Flow rate water cooling - 300 g/s, Garg - ~ 2 g/s, T bnl – ~ 370 K, Pbnl - ~ 0,3 MPa, τ – ~ 3000 s, Gtf - ~ 40 g/s, Gbf - ~ 100 g/s



Time of moving of water up to a level Z = 1250

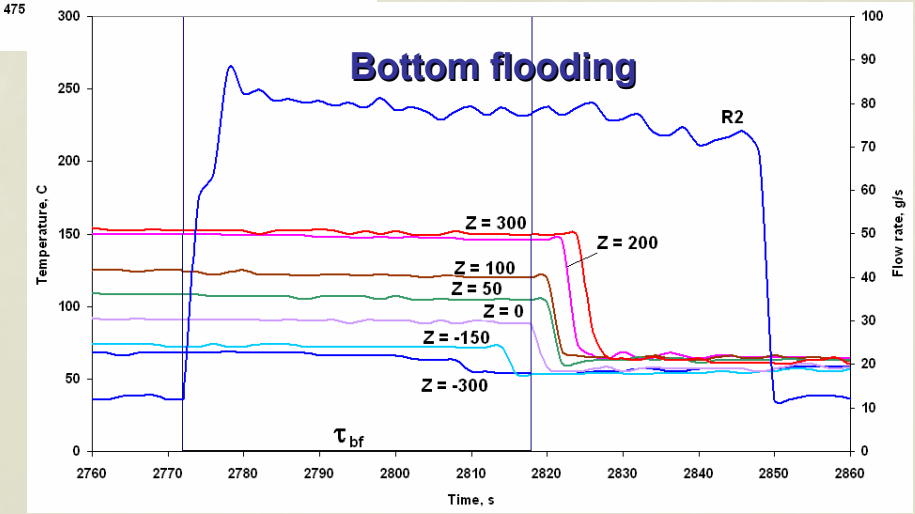
$\tau_{tf} \approx 4$ s

Gtf - ~ 35 g/s

Time of moving of water up to a level Z = 0

$\tau_{bf} \approx 46$ s

Gbf - ~ 80 g/s



Conclusion

All systems of the PARAMETER facility are prepared for carrying out of test PARAMETER-SF2 planned in March, 2007