NNC experimental facilities for out-of-pile test conduction

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National Nuclear Center of the Republic of Kazakhstan

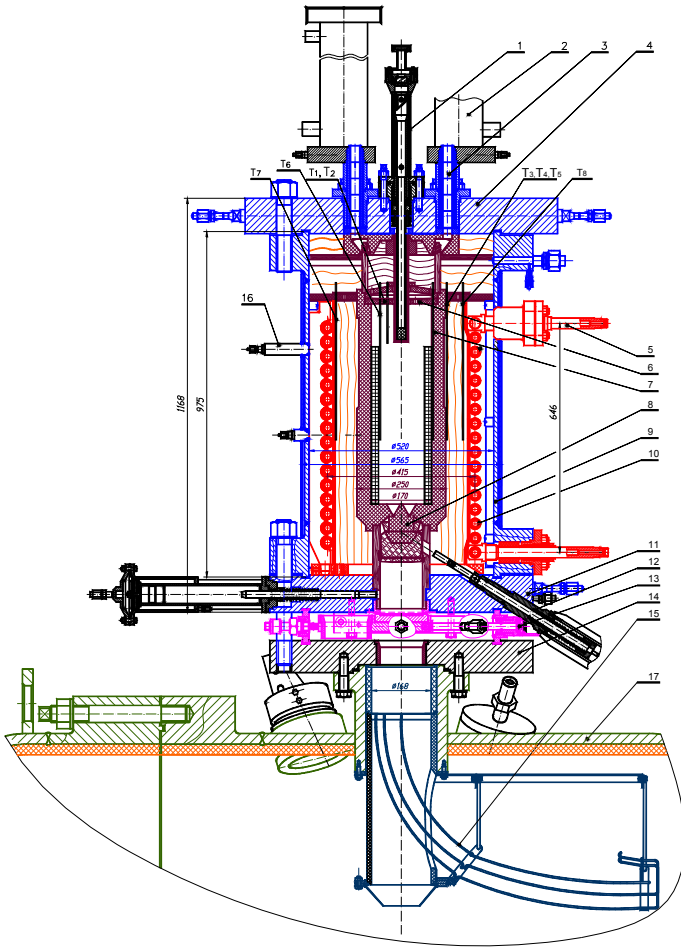
Principal Directions of NNC RK Activity

- Radioecology of those Kazakhstan regions where nuclear tests were conducted and where atomic industry plants and nuclear facilities are located
- Nuclear power engineering and its safety
- Nuclear physics and radiation materials structure testing in the field of nuclear power
- Application of nuclear-physical methods and scientific technologies in national economy of the Republic of Kazakhstan
- Study of nuclear testing impact on the earth's crust and nuclear test monitoring
- Nuclear Infrastructure Monitoring

Experiments on LWR safety validation in NNC RK

- **Experiments on fuel – coolant interaction (FCI)**
- **Experiments on molten core – concrete interaction (MCCI) with decay heat modeling in debris**
- **Experiments on research of corium interaction with reactor pressure vessel steel (LHI)**
- **Experiments on research of corium interaction with reactor pressure vessel steel with decay heat modeling in debris (IVR-AM)**

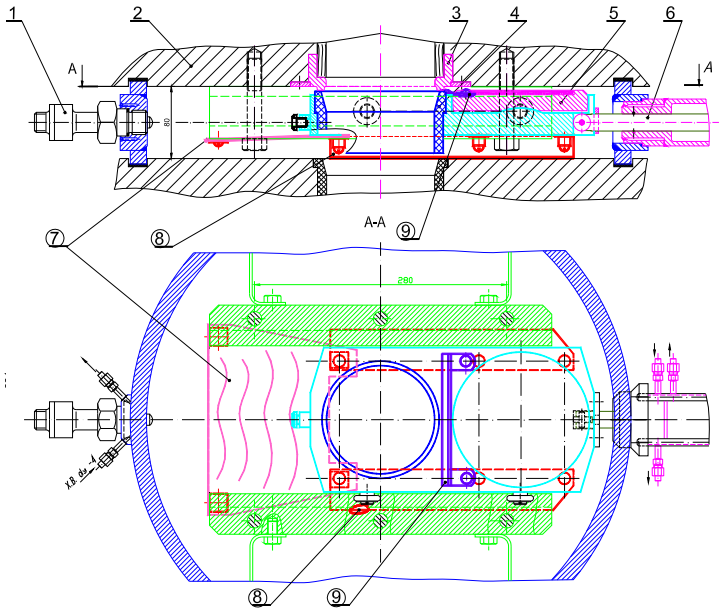
Electric melt furnace of LAVA-B facility



EMF OF LAVA-B FACILITY

MAJOR EMF PARAMETERS

Mass of molten burden with uranium dioxide, kg	up to 60
Melt temperature, K	3300
Technique for melting	Induction
Duration of warming and melting the burden, min	up to 60
Maximum active power supplied to EMF crucible, kW	up to 165

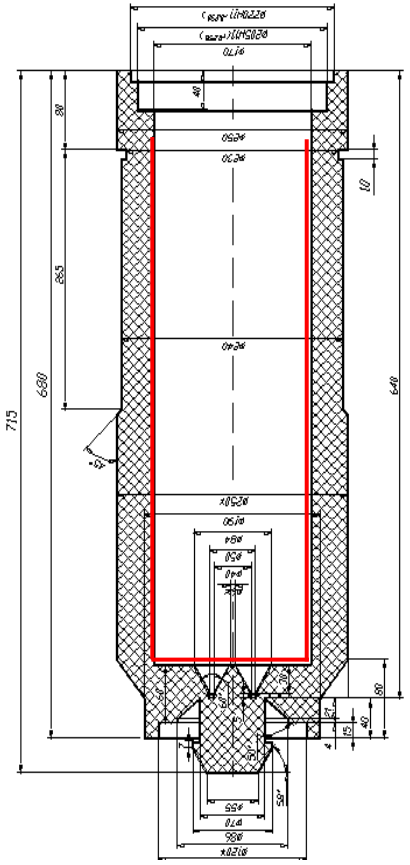


1 - position indicator; 2 - EMF bottom; 3 - shatter saddle;
4 - drain bush; 5 - shatter valve; 6 - rod of the pneumocylinder;
7 - collapsing armored protective board (graphitic fabric 2 layers + wire mesh); 8 - protective slat; 9 – knife (outlined position is marked new designed detail)

SHUTTER FOR EMF (“LAVA-B” FACILITY)

The parts of high temperature Electric melt furnace

INFRARED TEMPERATURE SENSOR



THE DRAWING OF EMF CRUCIBLE

ASSEMBLED CASSETTE

STAGE OF EMF ASSEMBLY AND PROCEDURES ON INSTALLATION OF SENSOR STRUCTURAL ELEMENTS IN THE EMF CRUCIBLE.

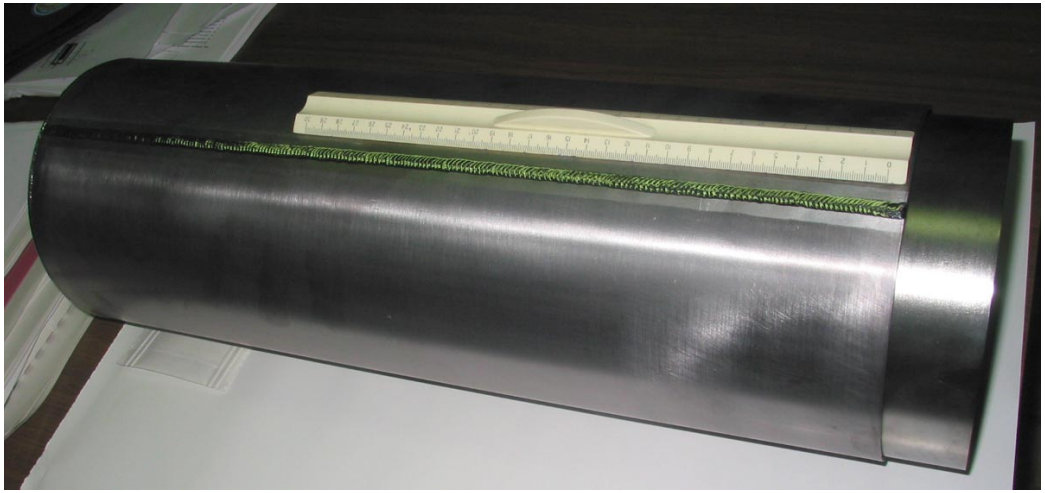
SENSOR MOUNTING ON THE EMF LID

THE VEIWS OF EMF CRUCIBLE

INSERTS FOR EMF CRUCIBLES

Tungsten insert

Tantalum insert



Tantalum insert

EMF crucibles

Equipment for small-scale experiments

High frequency induction heating VCG-135 stand

VCG-135 working chamber

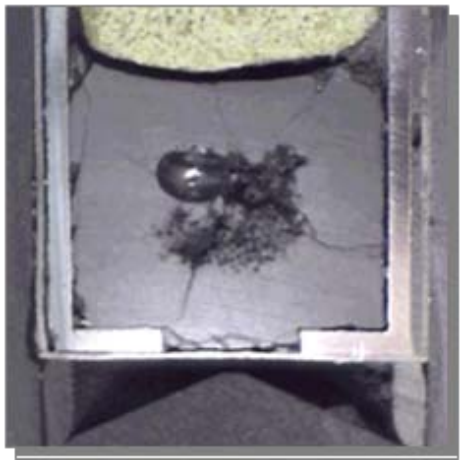
Maximum heating temperature 3000 deg.C (at 0.5 MPa)

Small-scale experiments on Electric melting furnace material testing

NbC+TaC coating
on graphite crucible

Tungsten insert + TaC coating
on graphite crucible

Combined insert W+Ta



Modeling of melt discharging hole in
the crucible bottom

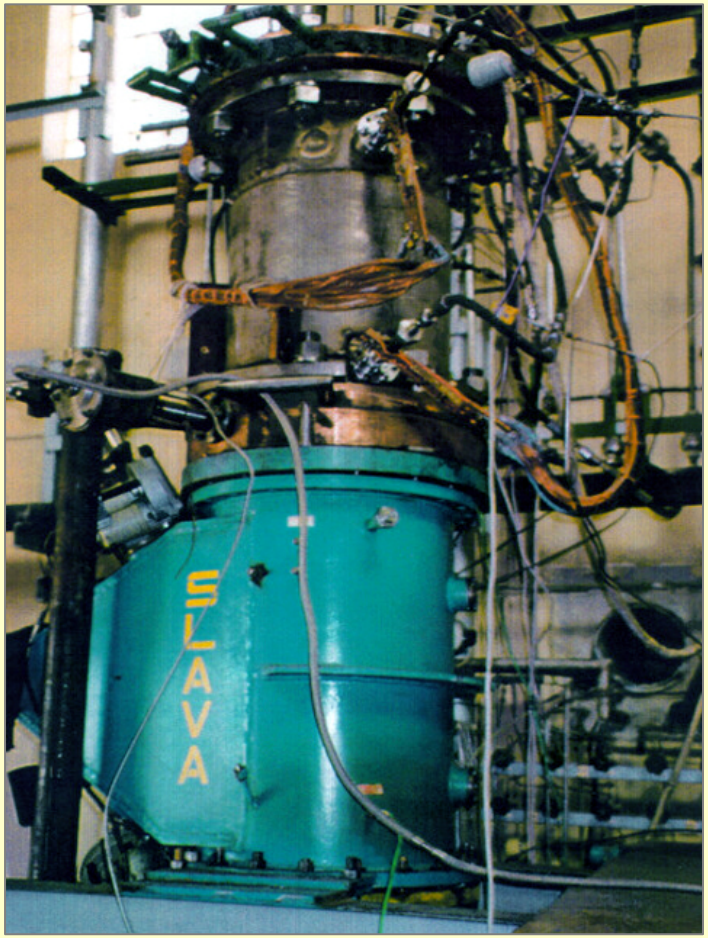
Metallic zirconium coating usage

Heightened content of metallic
zirconium in the initial burden

Graphite crucible coated
with metallic zirconium

Graphite crucible coated
with TaC

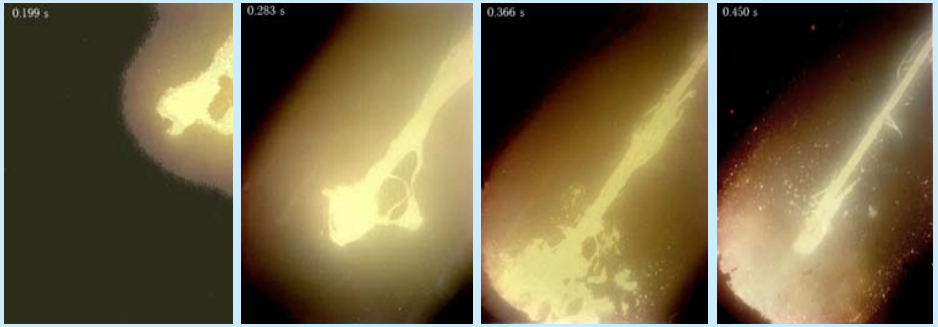
Methodical tests for studying of corium jet dropping flow mode



SLAVA Facility

Jet of melted stainless steel (T=2100°C)

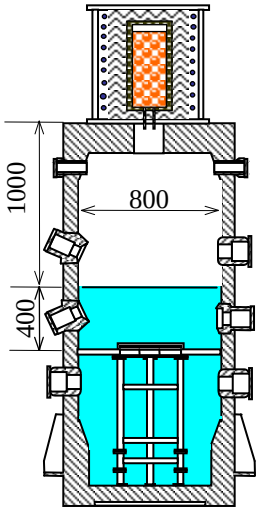
Corium jet (T=3000°C)

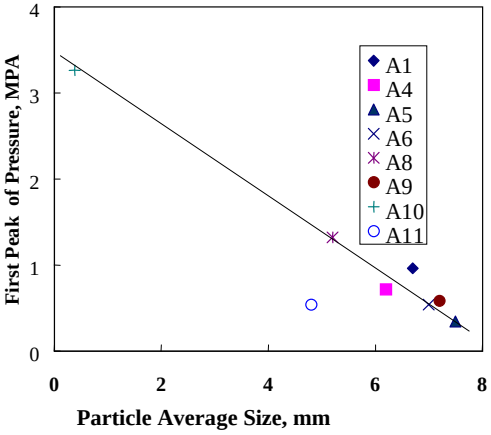


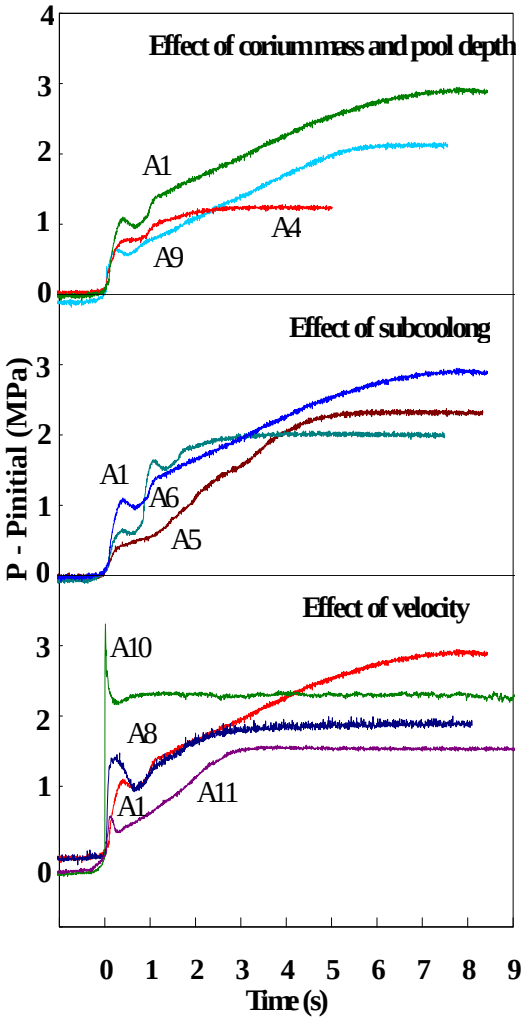
Corium mass – 60 kg
Corium content – UO_2/ Zr/ ZrO_2 /SS

Results of the fuel-coolant (water) interaction tests (FCI tests)

LAVA Facility



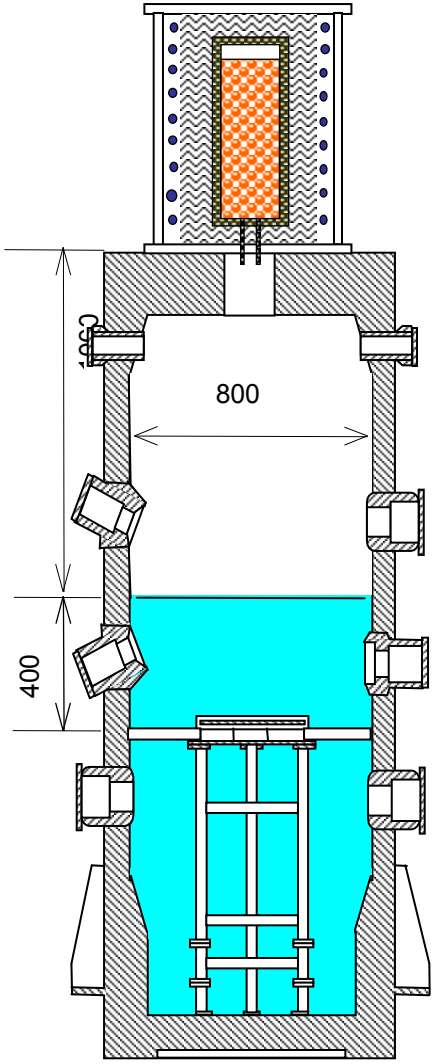




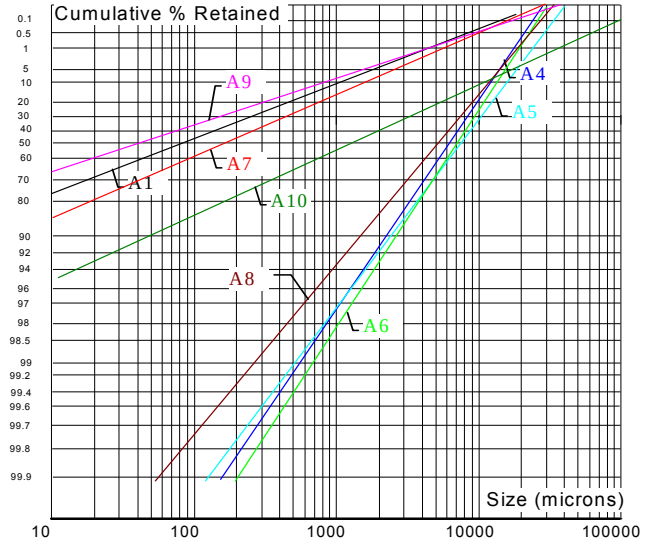
Results of fuel-coolant (water) interaction tests (FCI tests)

Fragmented debris after FCI

Melt discharging
in the test section

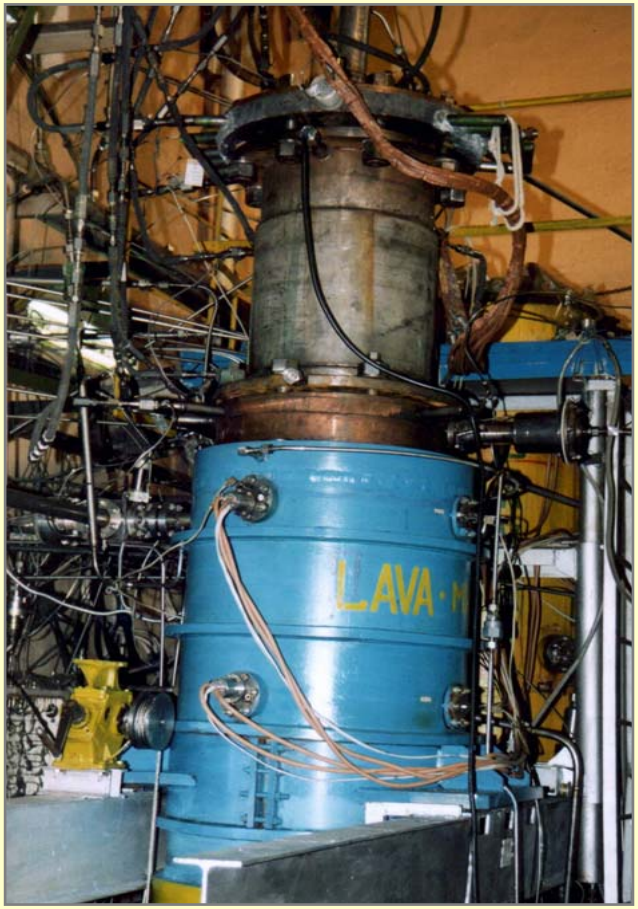


Fragmented debris after FCI



Results of debris particles size
distribution after FCI tests

Results of molten core concrete interaction tests (MCCI tests)



LAVA-M Facility

Corium mass - 60 kg.

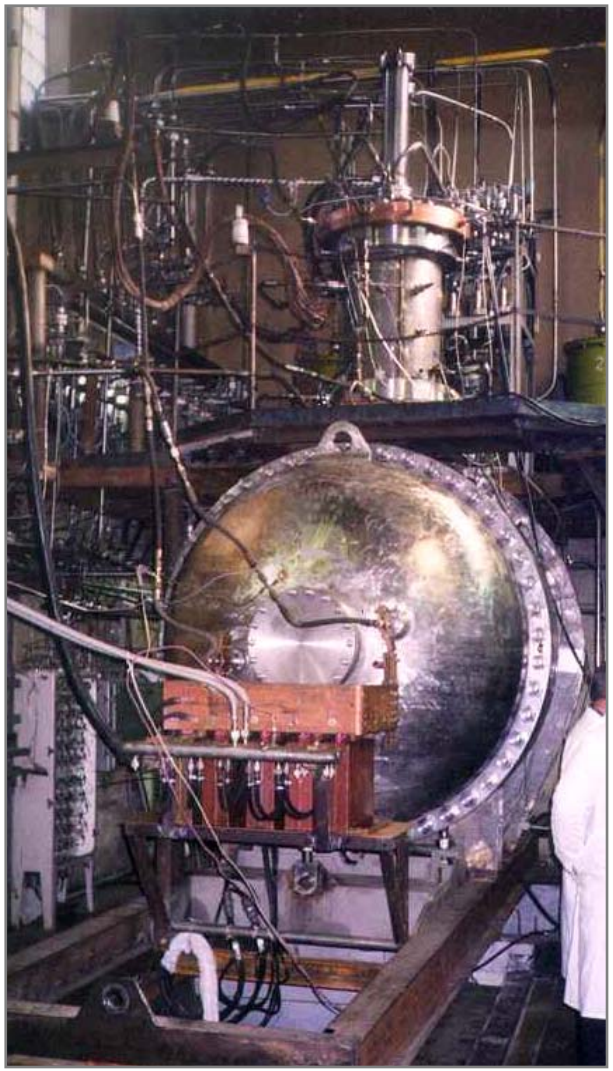
Corium content - $UO_2/Zr/ZrO_2/SS$

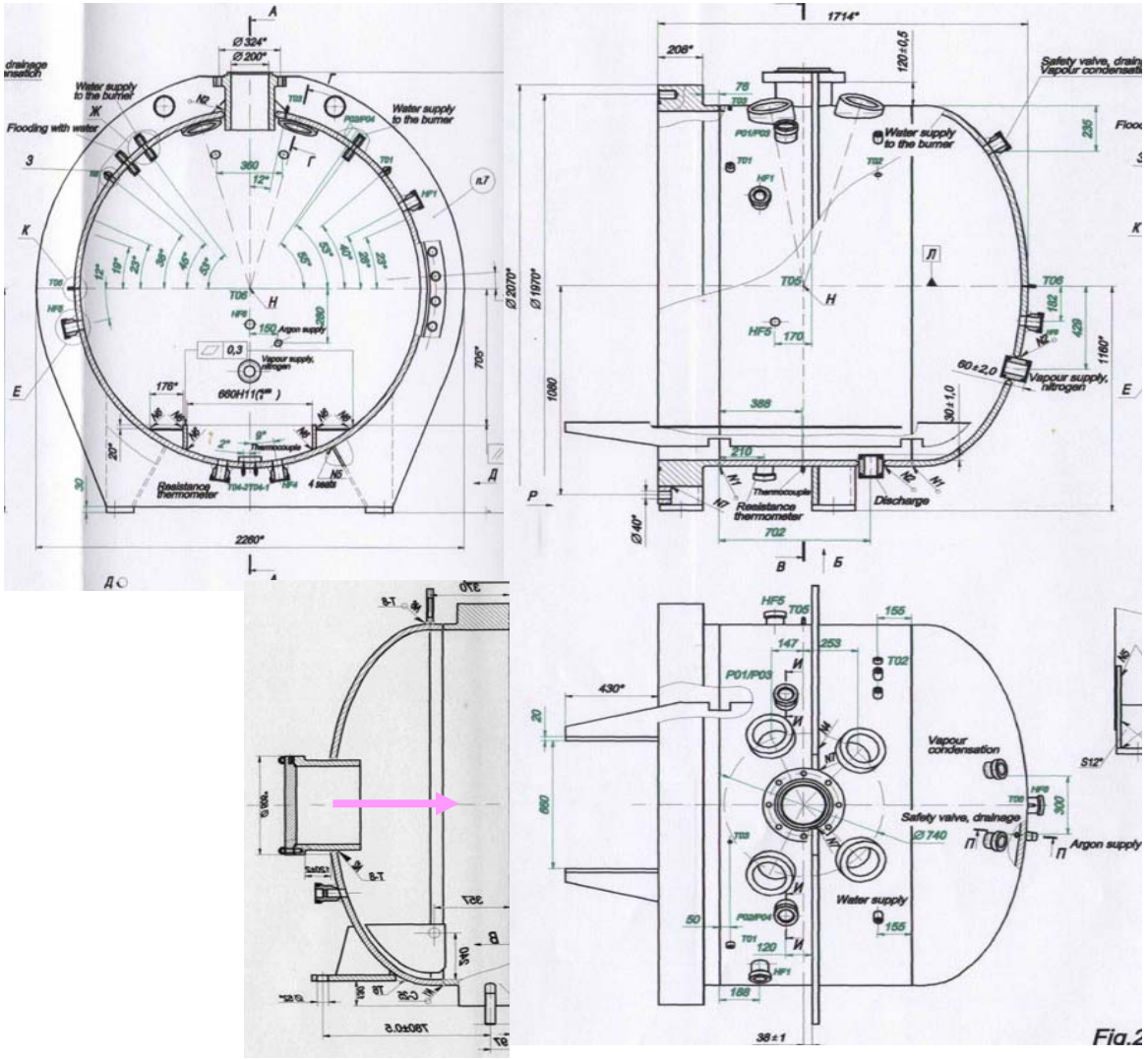
Corium temperature - 3000°C

Simulation of residual heat release in fuel was made by inducting heating of corium discharged into trap

Solidified melt in concrete trap

Description of the LAVA-B facility





Description of the LAVA-B facility

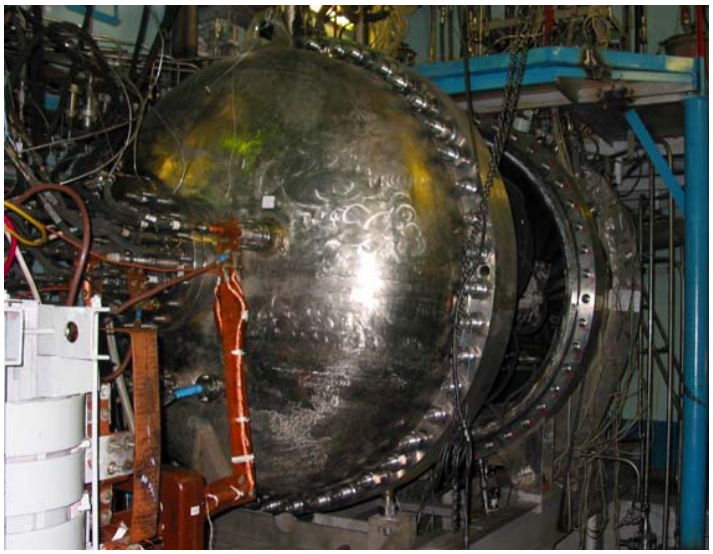
BASIC TECHNICAL CHARACTERISTICS OF LAVA-B FACILITY MELT RECEIVER (MR)

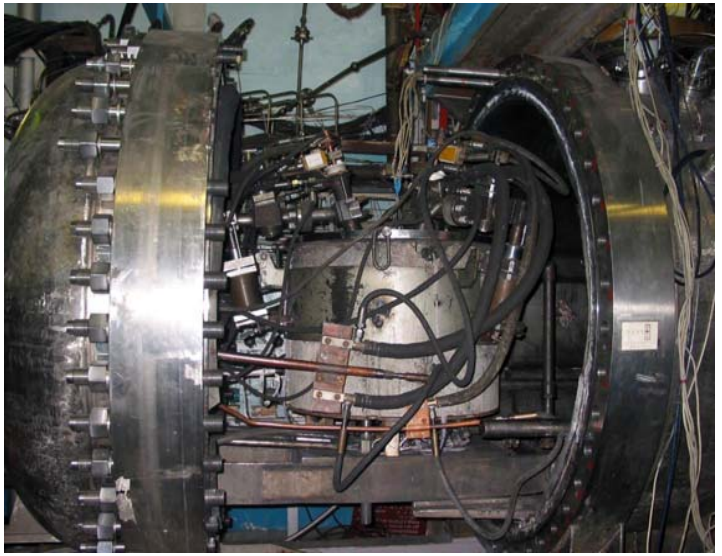
Vessel inner diameter, mm	1800
Maximum length of inner cavity, mm	2510
Vessel wall thickness, mm	Not less than 30
Vessel mass (without thermal insulation), kg	~8300
Removable lid mass (without a cart), kg	~2500
Operating pressure, MPa:	
– under stationary mode	4.0
– under pulsed mode	up to 6.0
Accessible temperature in MR cavity, °C	up to 600
Upper flange diameter, mm	200
Structural access door, mm	400
Quantity of viewing windows	4
Thickness of internal heat-insulation, mm	30
Thermal conductivity of thermal insulation, W/m*K	0.5

LIST OF MEASURING MEANS LOCATED IN THE MR OF «LAVA-B» FACILITY

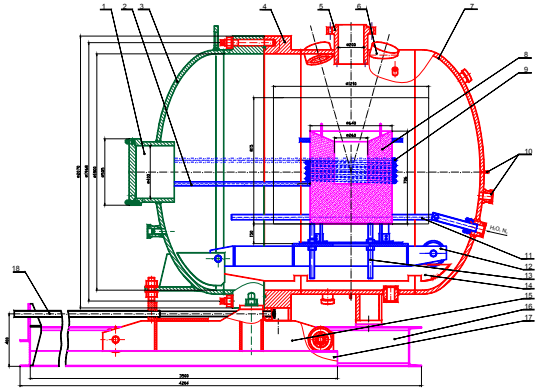
P01	Pressure sensor	0.1–5.0 MPa
P02	Pressure sensor	0.1–5.0 MPa
P03	Impulse pressure sensor	0.1–5.0 MPa
P04	Impulse pressure sensor	0.1–10.0 Mpa
T01	Thermocouple (CA type)*	273–1000 K
T02	Thermocouple (CA type)*	273–1000 K
T03	Thermocouple (CA type)	273–1000 K
T04-1	Thermocouple (CA type)	273–1000 K
T04-2	Thermocouple (CA type)	273–500 K
T04-3	Resistance thermometer	373–500 K
T05	Thermocouple (CA type)	273–1000 K
T06	Thermocouple (CA type)	273–1000 K
HF1	Heat flow sensor	up to 5 κW/m2
HF4	Heat flow sensor	up to 5 κW/m2
HF5	Heat flow sensor	up to 5 κW/m2
HF6	Heat flow sensor	up to 1 κW/m2
DP01	Differential pressure sensor	0.004 MPa
Pyro.	Pyrometer	~3300 K
V01.	High speed video camera	up to 100 frame/sec

*)thermocouple with a shielding screen



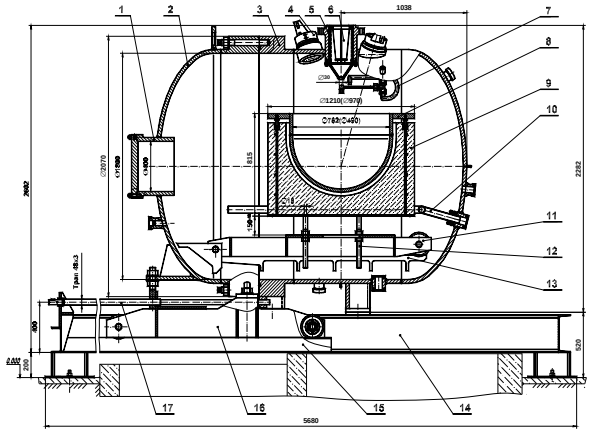


Views of the “LAVA-B” facility melt receiver with experimental sections



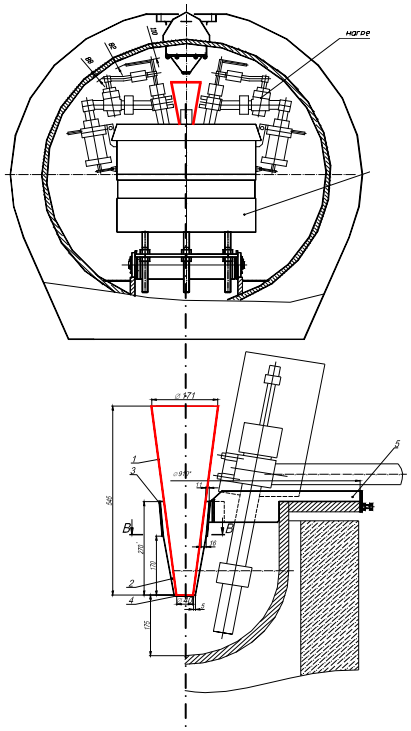
1-Structural access door; 2-Current lead of the inductor; 3-Removable cover; 4-Pressure vessel; 5- Upper flange; 6-Viewing window; 7-Bottom welded; 8-Concrete trap; 9-Inductor; 10-Construction branch pipe; 11-Vapor-gas input; 12-Trap trolley;13-Support screw; 14-Rail; 15-Cover trolley; 16-Skid; 17- Rail for cover trolley; 18-Lead screw.

MELT RECEIVER WITH CONCRETE TRAP USED AT MCCI TESTS PERFORMING



1- Technological hatch; 2- Removable lid; 3- Power vessel 4- Viewing window;5- Mouth flange; 6- Plug catcher; 7- Device for water filling; 8- Lower head model;9- Concrete rack; 10- Steam supply manifold; 11- Trap trolley; 12- Support screw; 13- Trail; 14- Support frame;15- Trail of lid trolley; 16- Lid trolley; 17- Lead screw.

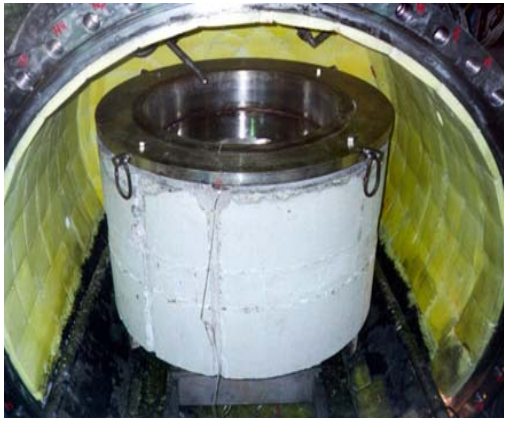
MELT RECEIVER WITH LOWER HEAD MODEL AT LHI TESTS PERFORMING



MELT RECEIVER WITH LOWER HEAD MODEL AND MELT HEATER USED AT IVR-AM TESTS PERFORMING

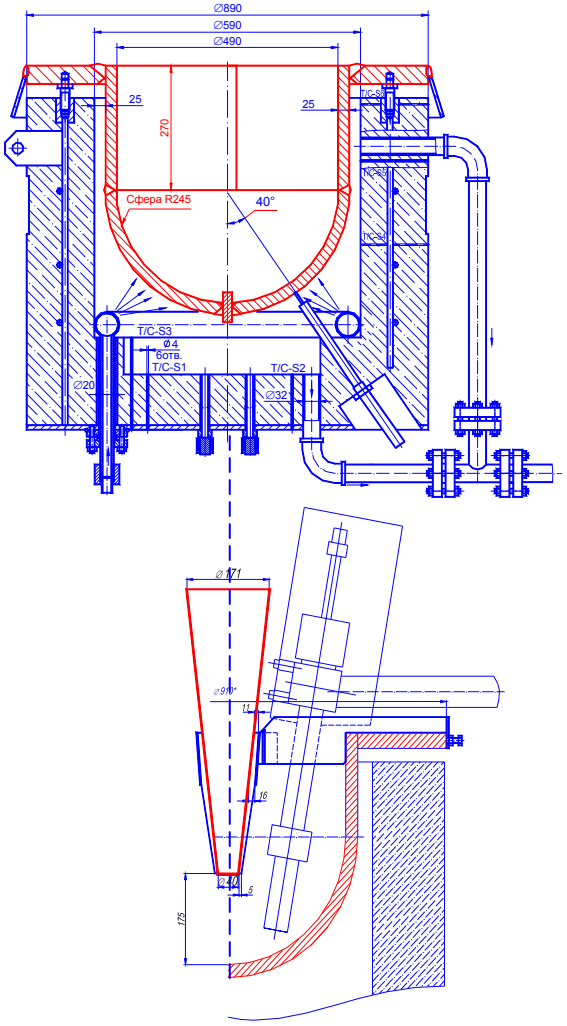
Experimental section - the lower head model used at IVR-AM tests performing

THE LOWER HEAD MODEL LOCATED IN MR



THE TEST SECTION ASSEMBLED WITH LOWER HEAD MODEL AND ELECTRICAL MELT HEATER

TECHNOLOGICAL BASE WITH WATER COOLING SYSTEMS SUPPLY



Results of molten core concrete interaction tests (MCCI tests)

MAJOR INDUCTOR HEATER PARAMETERS

Inductor coils quantity	- 6
Height between current leads, mm	- 180
Average diameter of coil turns, mm	- 450
Coil material – copper tube	- 30×5
Working current frequency, Hz	~ 2400
Inductor current value, A	~ 3580
Inductor voltage, V	~ 830
Coil current density, A/mm²	~ 28
Active inductor power, kWt	~ 130
Duration of continuous inductor work, hour	~ 2
Flow rate of water to cool the inductor, kg/ s	- 0,3

CONCRETE TRAP AND INDUCTION HEATER LOCATED IN MR AND PREPARED FOR CALIBRATION TESTS

RESULTS OF MCCI TESTS AT DIFFERENT GEOMETRY AND STRUCTURE OF CONCRETE TRAP

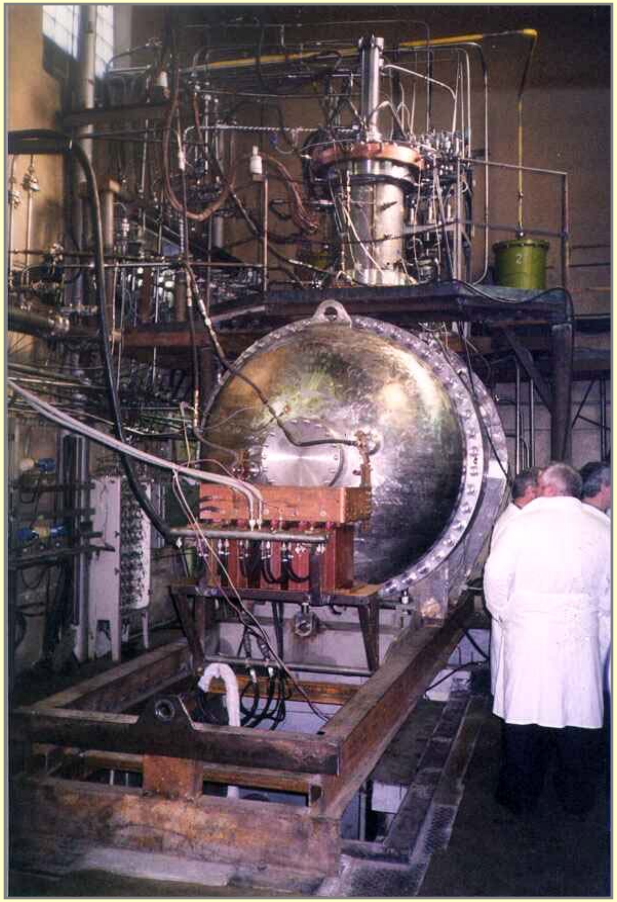
TRAP DIAMETER TO DEBRIS HEIGHT RATIO IS ~1,6:1

TRAP DIAMETER TO DEBRIS HEIGHT RATIO IS ~1:1

1-D INTERACTION (SIDEWALL MADE FROM MGO)

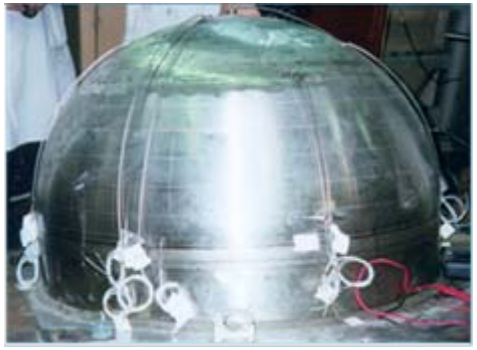
TRAP LINING WITH MORTAR (WITHOUT PEBBLES)

The views of lower head model cut after LHI tests performing using LAVA-B facility

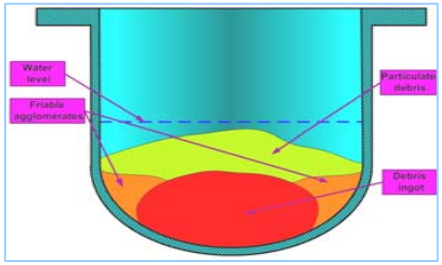


LAVA-B Facility

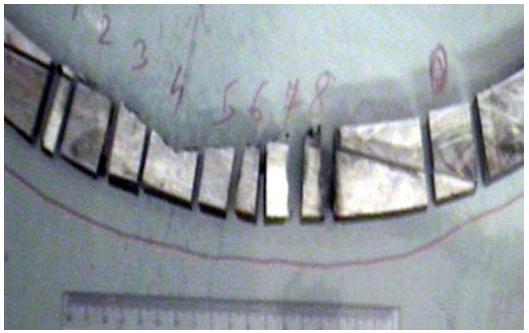
LOWER HEAD MODEL AFTER TEST



SOLIDIFIED INGOT DEBRIS IN LOWER HEAD MODEL



CUTTING OF THE LOWER HEAD



Electrical heater for simulating of decay heat in debris at IVR-AM tests performing

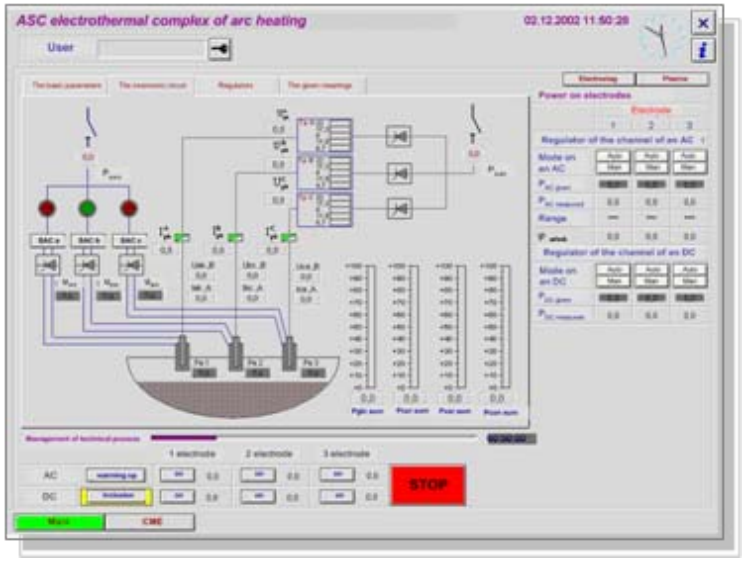
THE TEST SECTION ASSEMBLED WITH LOWER HEAD MODEL AND ELECTRICAL MELT HEATER

THE LOWER HEAD MODEL WITH ELECTRICAL MELT HEATER ARE LOCATED IN MR OF LAVA-B FACILITY

MAJOR MELT HEATER PARAMETERS

• Amount of the combined electrodes	3
• Capacity of the power supply of a direct current, kW	15×3
• Amount of sources of a direct current	3
• Voltage of the direct current source idling, V	170
• Range of the direct current change in an electrode circuit, A	5-315
• Regulation of the alternating current power supply voltage, V	8-41,6
• Maximum achievable voltage between electrodes, V	76,3
• The maximal value of an alternating current on an electrode, kA	8
• Time of processing, hour	2

COMBINED ELECTRODE



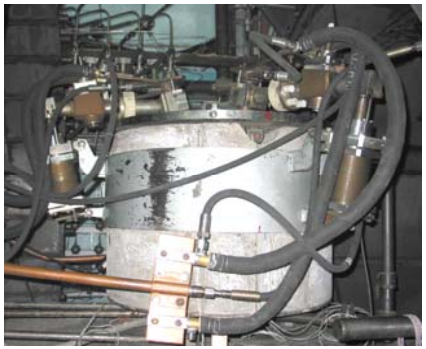
"BASIC PARAMETERS" WINDOW OF THE POWER CONTROL SYSTEM

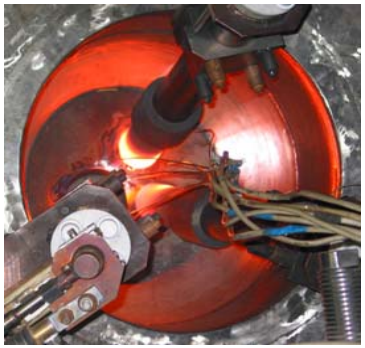
The preparation tests with electrical heater for simulating of decay heat in debris at IVR-AM tests performing

THE PREPARATION TESTS WITH ELECTRICAL MELT HEATER AT ALTERNATING CURRENT OPERATION




THE PREPARATION TEST WITH ELECTRICAL MELT HEATER AT DIRECT CURRENT OPERATION





Parameters and conditions of IVR-AM test conducting

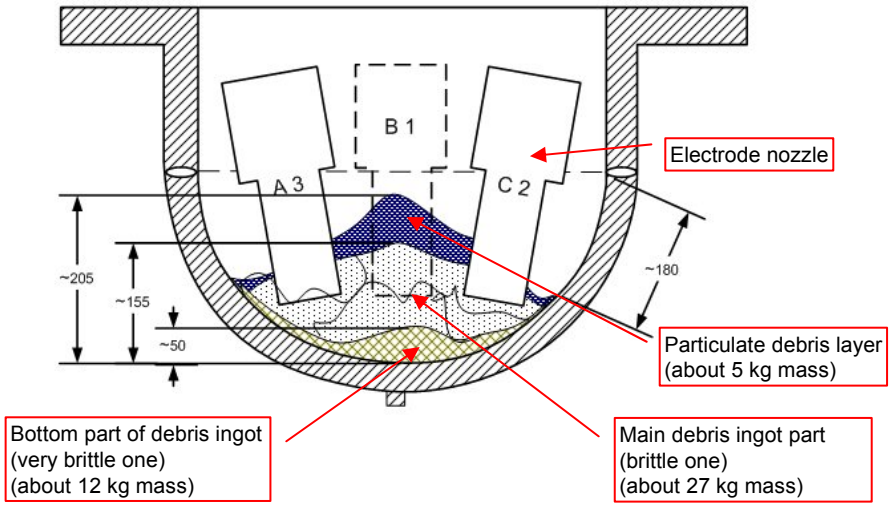
LOWER HEAD MODELS WITH MELT AFTER EXPERIMENT IVR-1

LHM INNER SURFACE AFTER DEBRIS REMOVAL

PARAMETERS AND CONDITIONS OF IVR-AM TEST CONDUCTING

Lower head model (LHM)	– 500 mm in diameter – 25 mm wall thickness
Loaded burden in electric melt furnace crucible	– PWR imitation ($78\%UO_2 + 17\%ZrO_2 + 5\%Zr$)
Discharged corium mass	– up to 50 kg
Decay heat power	
– electric arc in co-axial electrodes	– up to 36 kW
– direct heating using 3-phase alternating current	– up to 40 kW
Time of test	– 2 hours
Cooling	
– water-supply for cooling of LHM external surface	– 1500 liters
– water-supply for cooling of LHM inside surface	– 700 liters

APPROXIMATE SCHEME OF DEBRIS LOCATION IN LHM



Conclusion

- NNC possesses the electro thermal stand for the experimental research of the processes accompanying interaction of LWR core materials melt with the reactor pressure vessel material (LHI) and concrete (MCCI) with the maximal weight of discharged melt up to 60 kg.
- Uranium dioxide of natural enrichment comprises into corium composition, and also materials of fuel rod cladding and core constructive materials.
- Decay heat is modeled at research of the above-stated processes via the induction heating method (in MCCI experiments) via method of electric arc heating or via direct electric current through corium (in IVR-AM experiments).
- Properties of materials of the electrical melting furnace and corium at high temperature can be investigated during small-scale experiments at VCG-135stand.