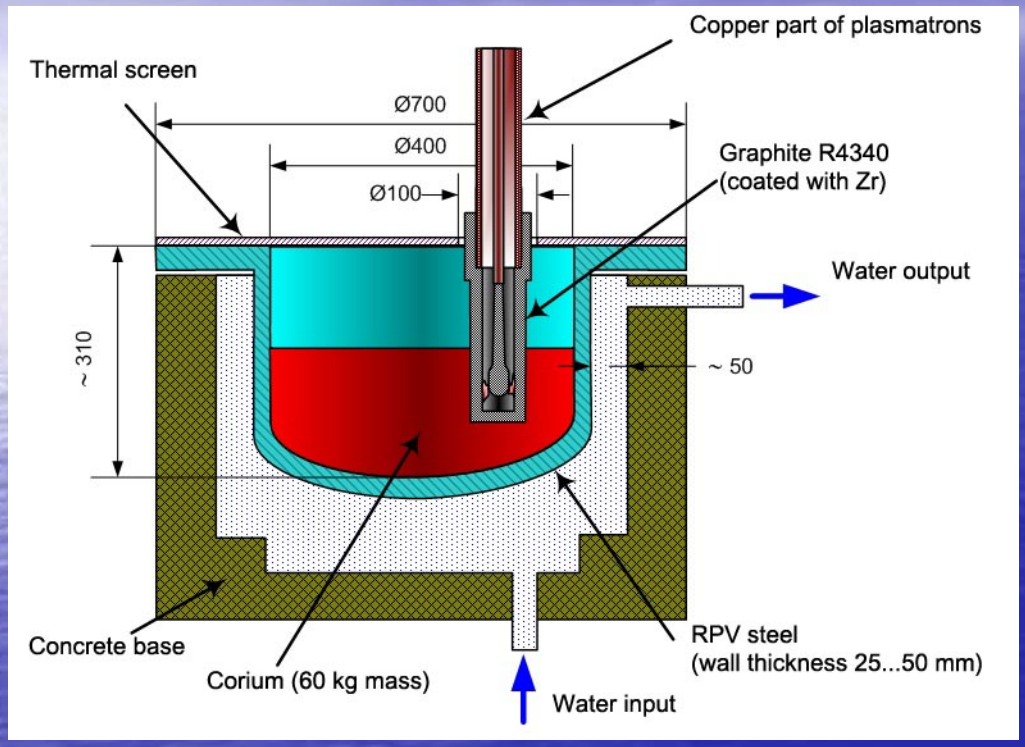
Possible scenario of INVECOR tests and test conditions

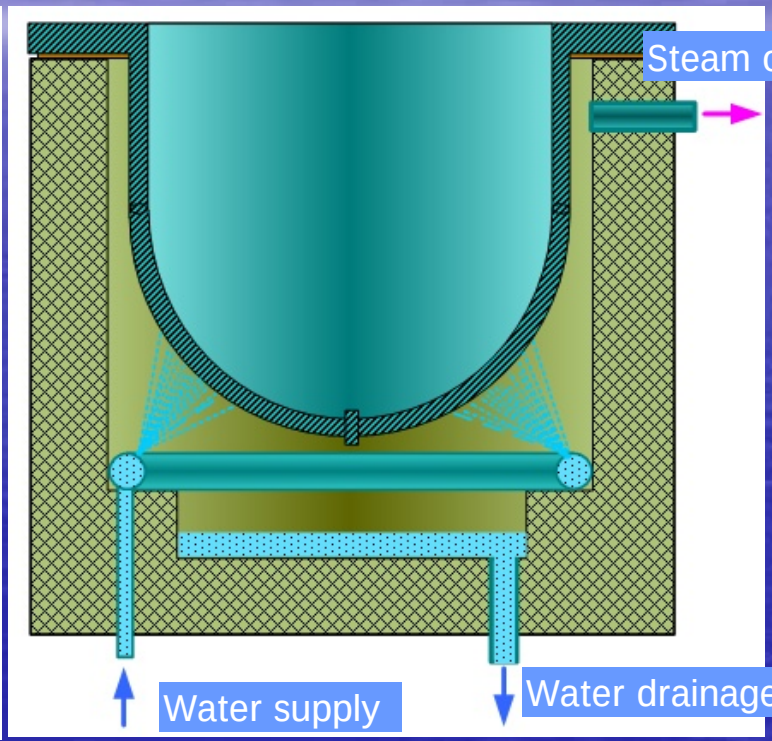
CEG-SAM 10th meeting
5-8 September 2006
Kurchatov,
Kazakhstan

Main objectives of INVECOR project

- To obtain the molten corium in Electric Melting Furnace (EMF) and discharge it into the RPV model (not less than 60 kg of molten corium)
- To measure the transient phenomena describing initial interaction of molten corium with RPV
- To provide the energy release in the corium pool (not less than 90 kW during 2 hours)
- To provide temperature in corium/steel interface corresponding presence of physical and chemical processes (not less than 1300°C)
- To measure the temperature fields and RPV wall deformation
- To research the solidified corium composition (special attention to a zone of corium/steel interaction)

Basic configuration of INVECOR test





For a continuous water flooding into clearance between RPV model and concrete base

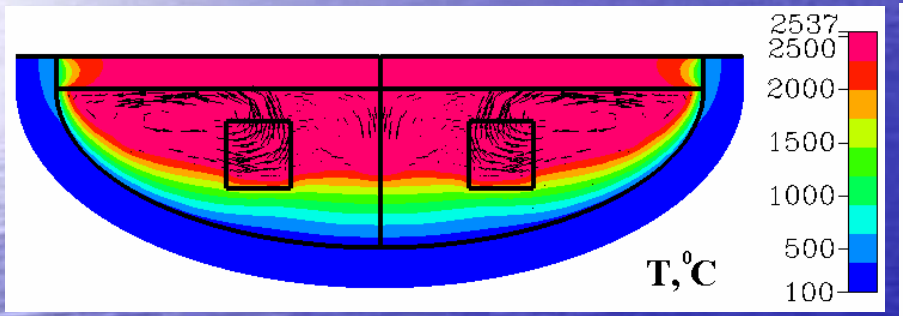
For water spray on RPV model outer surface

Conclusions of NITI calculation

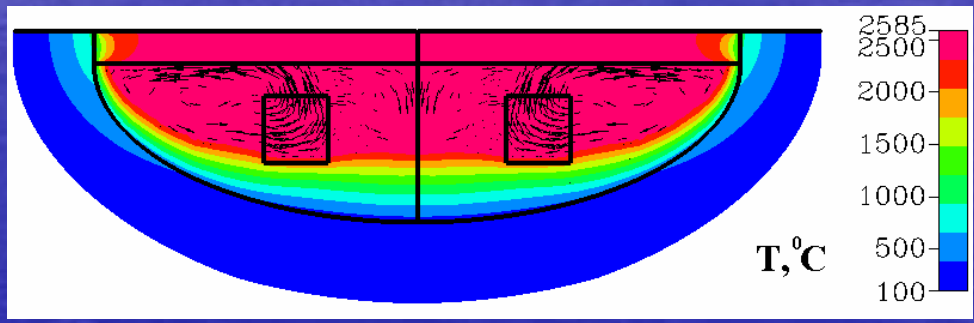
- DYMELT code enables to calculate the molten core behavior on the bottom of RPV model
- Preliminary calculations have confirmed the possibility of molten pool formation, if the total power of electrodes is close to 90 kW, but the volume fraction of a liquid phase in the pool is below 50 %
- Ways to increase the volume of liquid phase and temperature:
  - to raise electrode power
  - to reduce distance between the screen and melt surface
  - to increase the vessel wall thickness

Results of corium pool calculation

Total power 90 kW
Lower thermal screen position
RPV caliber 400 mm

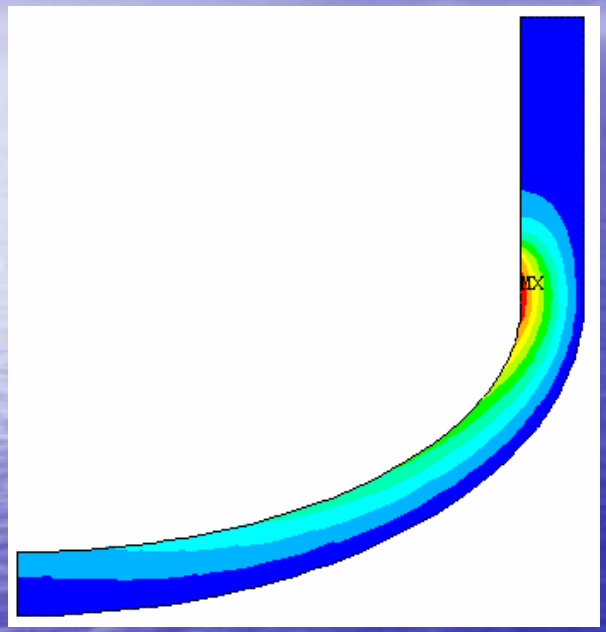


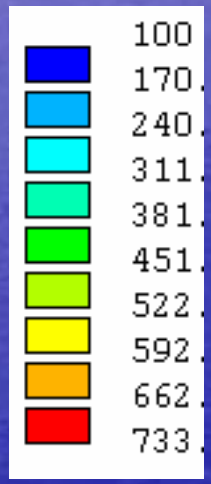
RPV wall thickness 25 mm



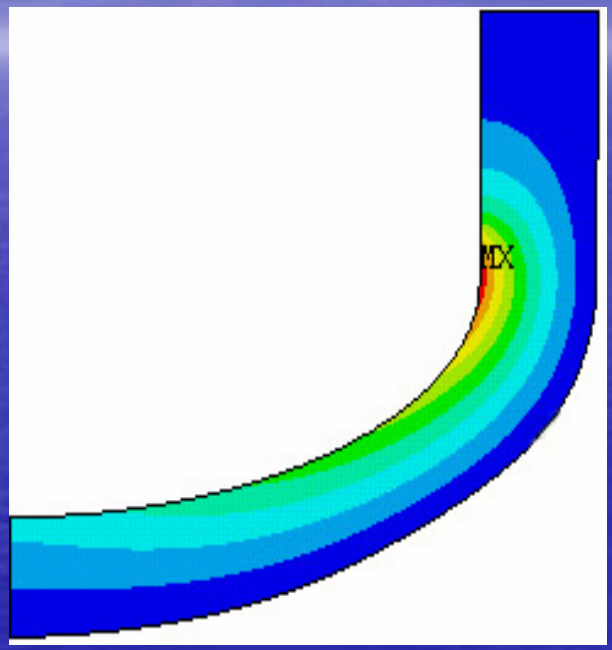
RPV wall thickness 50 mm

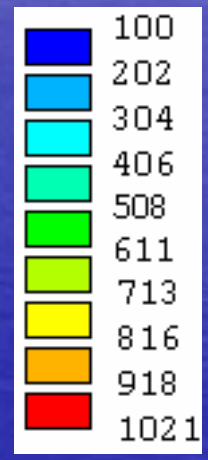
RPV temperature





Wall thickness 25 mm





Wall thickness 50 mm

Objective of 1st calibration test

- To specify the loaded mixture heating mode (EMF)
- To prove the possibility of corium melt obtaining without impurities (carbon and carbides)
- To specify the parameters of device for decay heat modeling in real test section (short-timed switch-on)
- To estimate the geometry of corium pool
- To measure the temperature field in the RPV model wall at short timed plasmatrons working
- To specify the pre-calculation results
- To itemize the scenario of 2nd calibration test
- Post-test research of solidified corium and RPV wall

Note. 1st calibration test can be performed using existing RPV model (with the hemispherical bottom, made of stainless steel)

Objective of 2nd calibration test

- To specify the parameters of device for decay heat modeling in real test section (long-timed switch-on)
- To estimate the reliability of plasmatrons
- To estimate the reliability of Zr-coating
- To measure the temperature and deformation of RPV wall
- Post-test research of solidified corium and RPV wall

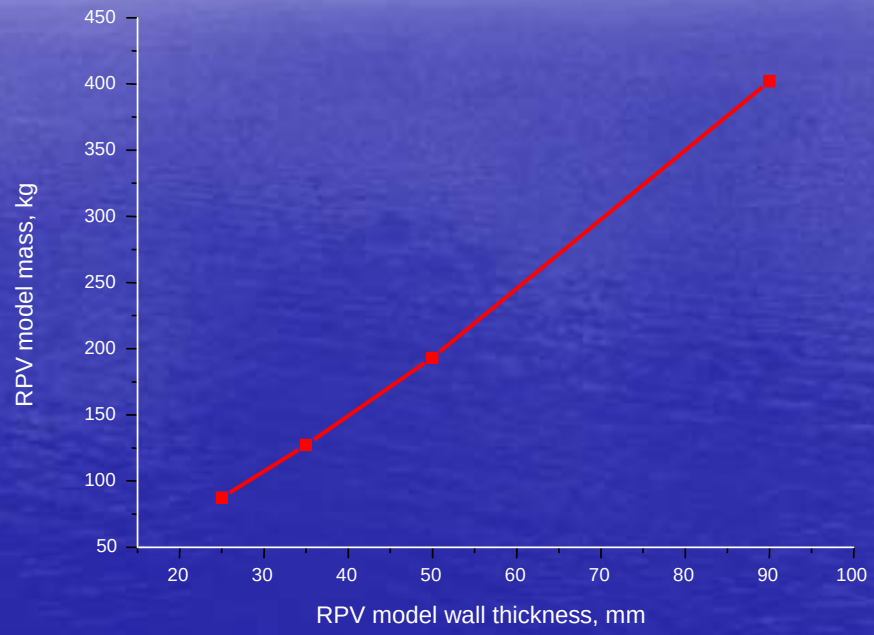
(Special attention of a corium area near to electrodes)

- To specify the scenario of 1st integral test

Note. 2nd calibration test can be performed using existing RPV model (with the hemispherical bottom, made of stainless steel)

Limiting parameters of LAVA-B facility

- Maximum corium melt mass - 60 kg
- Maximum total power of 5 plasmatrons - 90 kW
- Maximum corium pool depth (at caliber RPV model 40 cm) – 10 cm
- Maximum time of plasmatrons operation – 2 hours



RPV model mass depending on wall thickness

Basic criteria for a RPV model choice

- Caliber of RPV model
  - To obtain the deepest corium pool
  - To place 5 electrodes for power input

(our recommendation: 400 mm inner diameter)

- Wall thickness
  - To provide temperature of corium/steel interface up to 1300°C
  - To ensure the absence of wall melting through within 1,5...2 hours

(our recommendation: 25...30 mm wall thickness)

Summary of Progress Meeting of INVECOR Project

(St.-Petersburg, 16th June 2006)

It was therefore agreed:

1) The prior calculations to be done for the pre-tests (NITI, FZR, NNC).
2) Dimensions of the slice geometry vessel to be fixed, suppliers of a Russian (as first priority) alternatively European (as second priority) vessel steel to be identified and estimates for its construction to be obtained.
3) Progress to be reported and actions and schedule updated at the 10th CEG-SAM meeting in September (Kurchatov City) (All).

Initial data for corium pool calculation

- Corium
  - C-30;
  - C-50;
  - C-70
- Corium mass - 60 kg
- Energy reserved in the corium up to slump in RPV model ~60 MJ
- Corium temperature during the slump into RPV model~ 2800 deg. C
- Height of corium melt slump - 1.7 m
- Hole' diameter for corium slumping (in the crucible bottom) - 50 mm
- Duration of corium slumping - 3...5 seconds

Initial data for corium pool calculation
(continued)

- Total power of plasmatrons - 90 kW
- Number of plasmatrons - 5
- Initial temperature of plasmatrons nozzles $\geq$ 2000 deg.C
- Initial temperature of RPV model inner surface $\geq$1200 deg.C
- Operation time of plasmatrons - not less than 2 hours
- Inner diameter of RPV model - 40 cm
- RPV model wall thickness
  - 25 mm
  - 35 mm
  - 50 mm

Initial data for corium pool calculation
(continued)

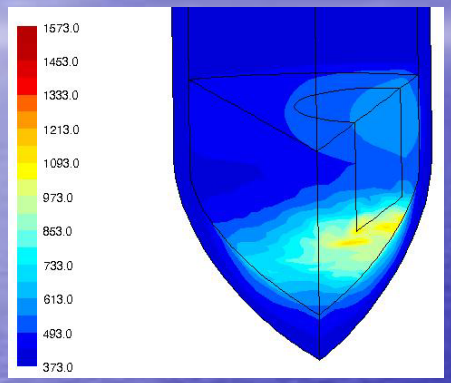
- RPV model steel - 15kH2MFA
  (or European steel for RPV)
- Outer diameter of plasmatrons nozzles - 90 mm
- Temperature of RPV model outer surface –
  100; 200 deg.C
- Distance from a corium surface
  up to the thermal screen - 12...15 cm

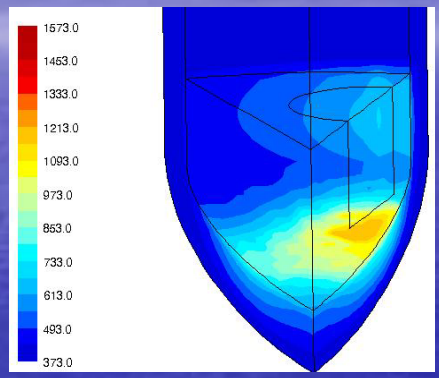
The special attention should be given initial transient process from corium melt falling in RPV model up to an establishment of steady state process (because the final of transient process will be initial condition of steady state process).

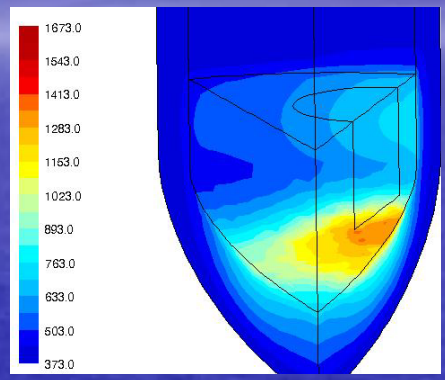
Results of NNC calculation

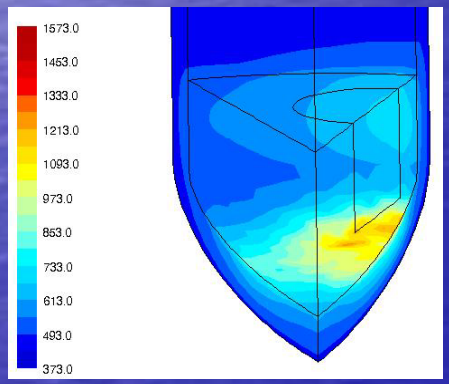
100 deg. C

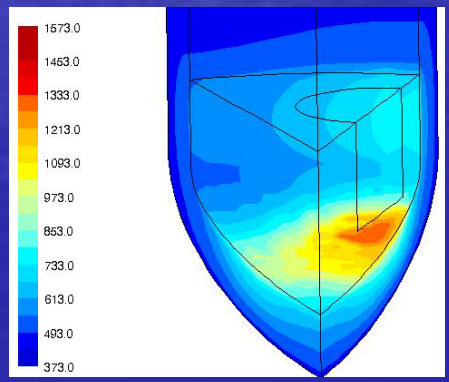
200 deg. C

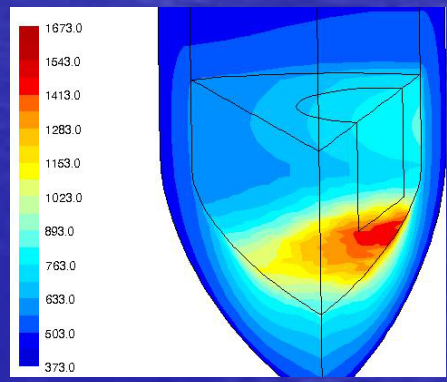












25 mm

35 mm

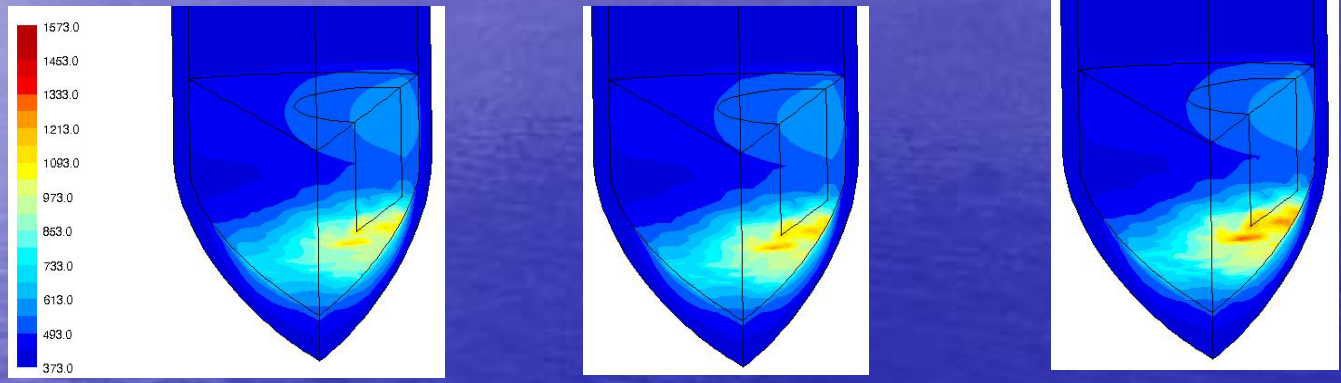
50 mm

Results of NNC calculation

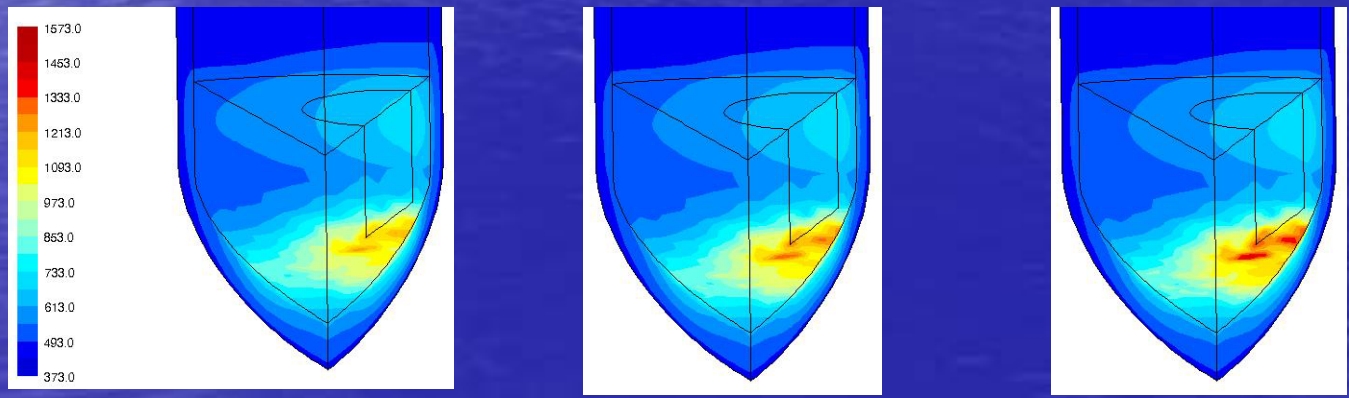
(thickness of wall is 25 mm)

C-30 C-50 C-70

100 deg.C



200 deg.C



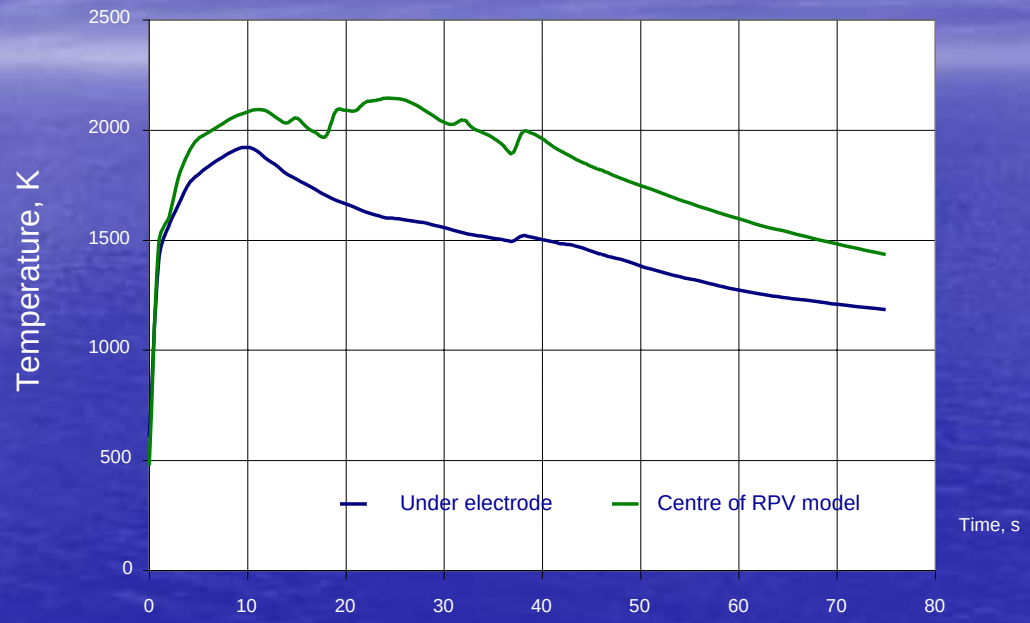
Results of NNC calculation

Corium C-30

Wall thickness 25 mm

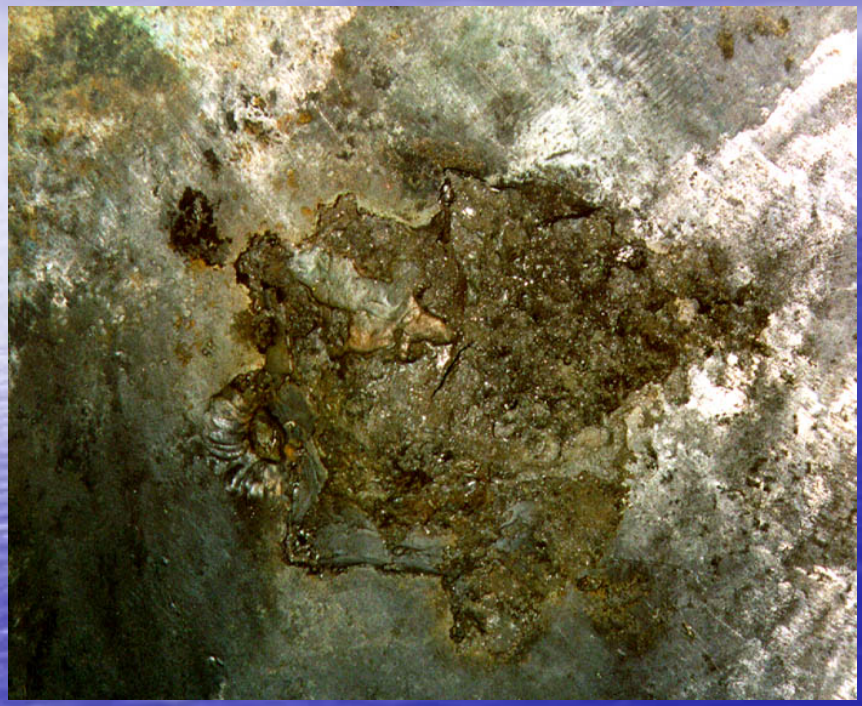
In 5 minutes the temperature of electrodes is stabilized at a level 2500 K

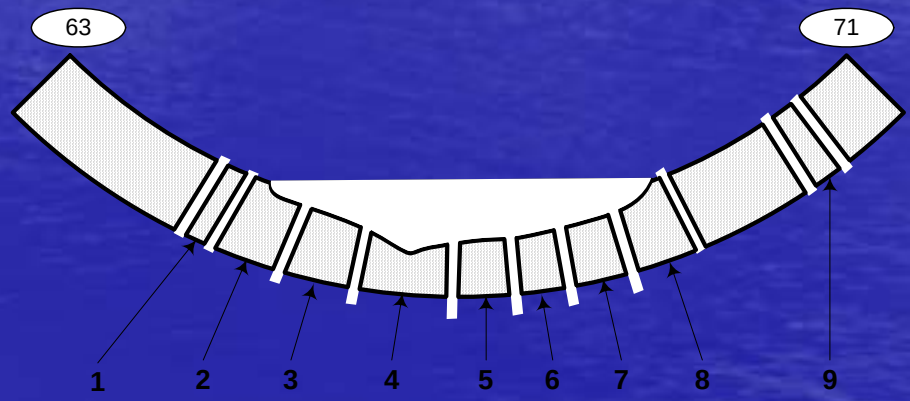
At initial contact of molten corium with RPV wall the partial steel fusion is possible (during 30...50 seconds)



Temperature transient of RPV model inner surface at the initial stage of experiment

Result of corium – stainless steel interaction
(in previous test)





- Molten corium mass about 50 kg
- Water volume in RPV model about 160 liters
- RPV wall thickness – 25 mm
- No power input in the test section

Result of corium – stainless steel interaction (in previous test)

- Corium mass about 50 kg
- Power input not more than 40 kW
- Test duration about 1,5 yours

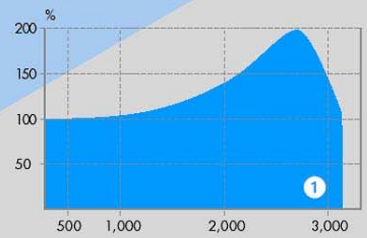
Some graphite properties

SGL Carbon Group data

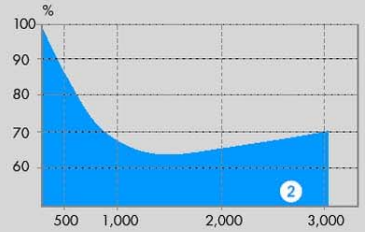
Temperature resistance

Graphite does not melt but sublimes at about 3,900 K. In air graphite is resistant to temperatures up to about 750 K.

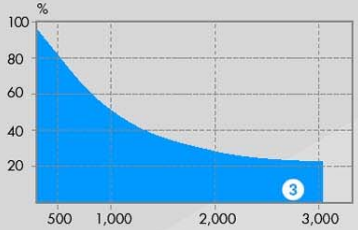
Mechanical strength



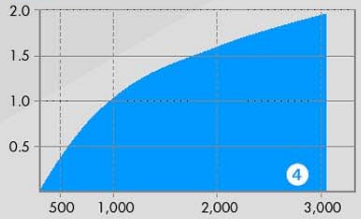
Electrical resistivity



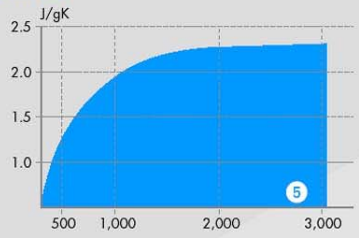
Thermal conductivity



Thermal expansion
Amount X to be added to α



Specific heat



Density

The theoretical density of monocrystalline graphite is 2.26 g/cm³. The density of artificial graphite is typically 1.5 up to 1.9 g/cm³ and 2.1 g/cm³ for solid pyrolytic graphite. The density of the highly pure graphite grades is defined as quotient between mass and volume including all pores.

Possible design of RPV model with thermal resistive gap