LIVE-CERAM experiment: Objectives and status of preparation

A. Miassoedov, X. Gaus-Liu, J. Foit, T. Cron, T. Wenz, S. Schmidt-Stiefel

Karlsruhe Institute of Technology, Germany

Institute for Nuclear and Energy Technologies

Outline

- Objectives of LIVE-CERAM experiment
- Difficulties in creating a 8 cm crust layer
- Meeting of CEA and KIT and proposal of methods
- Performance of three pre-tests (VV1, VV2 and VV3) for the formation of a refractory layer
- Summary of the pre-tests
- Ongoing activities

Background and Objectives of LIVE-CERAM experiment

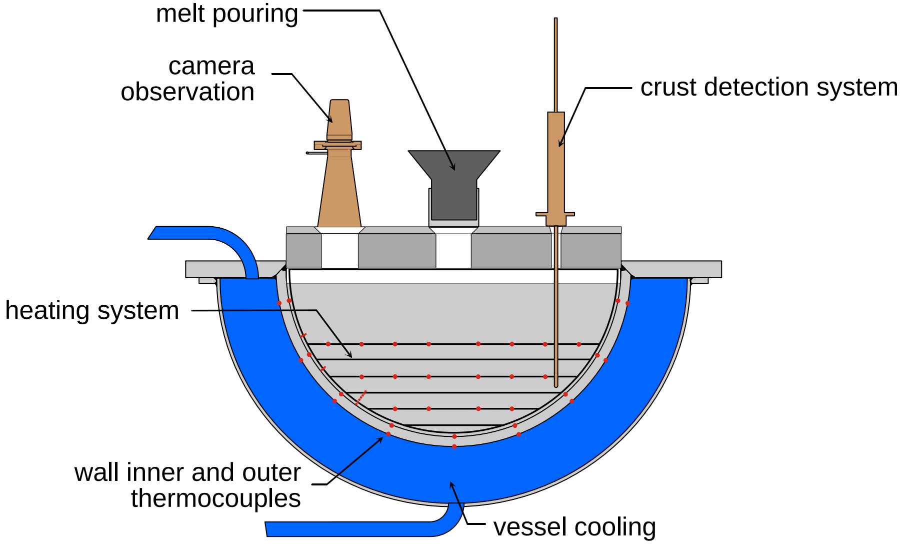
- Background:
  - Design of refractory liners for core catchers and for protection of concrete walls (applications for LWRs and for LMFBRs).
  - Development of model calculations for corium – refractory material interaction
  - Few data on corium-refractory material interaction
  - No detailed transient data available for the corium-refractory material interaction for 2D geometry

- The objective is to simulate ablation process of a high-melting temperature refractory material by low-melting temperature corium
  - KNO_3 as refractory material (melting temperature ~334°C) and a KNO_3+$NaNO_3$ melt at, initially, the eutectic composition (melting temperature ~220°C) as corium
  - Provide data for transient corium-refractory material interaction
    - Evolution of boundary temperature during ablation transient
    - Evolution of melt pool temperature during ablation transient

Expected Behaviour

- The initial pure KNO_3 layer acts as thermal barrier. The melt will heat up. The KNO_3 material can be dissolved by the melt below the melting temperature of pure KNO_3.
- In the end state, the residual thickness of KNO_3 will be compatible with conduction heat transfer and the final power dissipation. The melt will be enriched in KNO_3.
- The interface temperature between the melt and the residual KNO_3 liner should, in the final steady state, reach the liquidus temperature of the actual, final, melt composition.

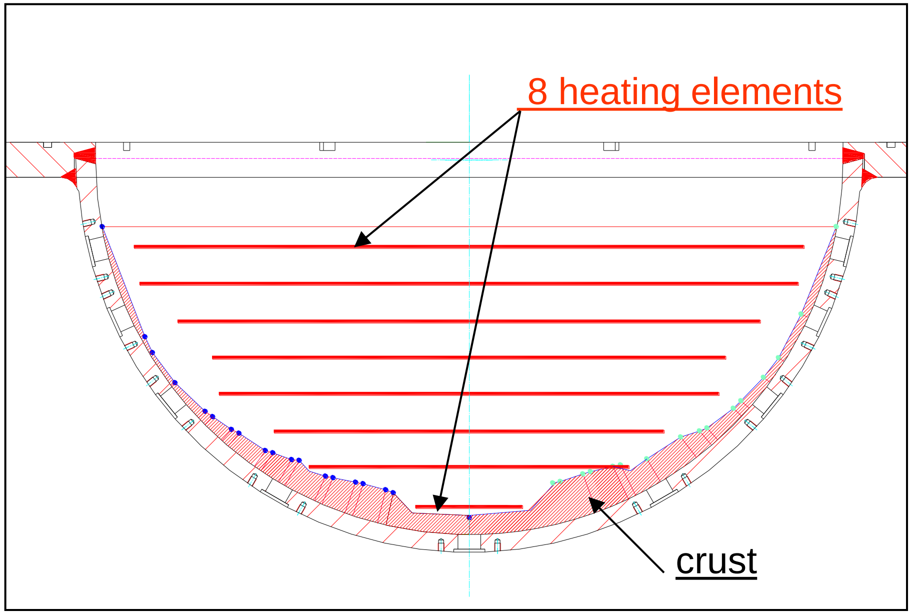
LIVE 3D facility



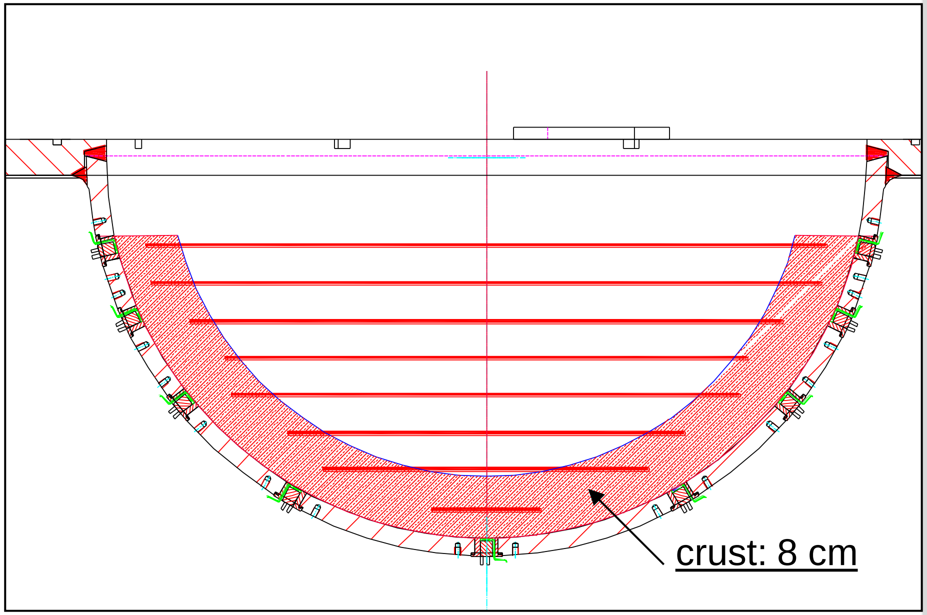
- 3D 1:5 scaled RPV of a typical German PWR
- Surrounded by a cooling vessel to cool the test vessel by water or air
- Volumetric heating system
- Central and non-central melt pouring
- Measurements and Instrumentation
  - Melt temperature: 60 thermocouples and crust detection lance
  - Heat flux: 17 pairs wall temperature.
  - Crust growth: thermal couples trees in the melt near the wall
  - Video cameras and infrared camera
  - Melt mass and crust mass: weighting cells
  - Melt sampling

Difficulties to generate refractory layer

A 8 cm KNO_3 crust layer should be generated at the vessel wall.

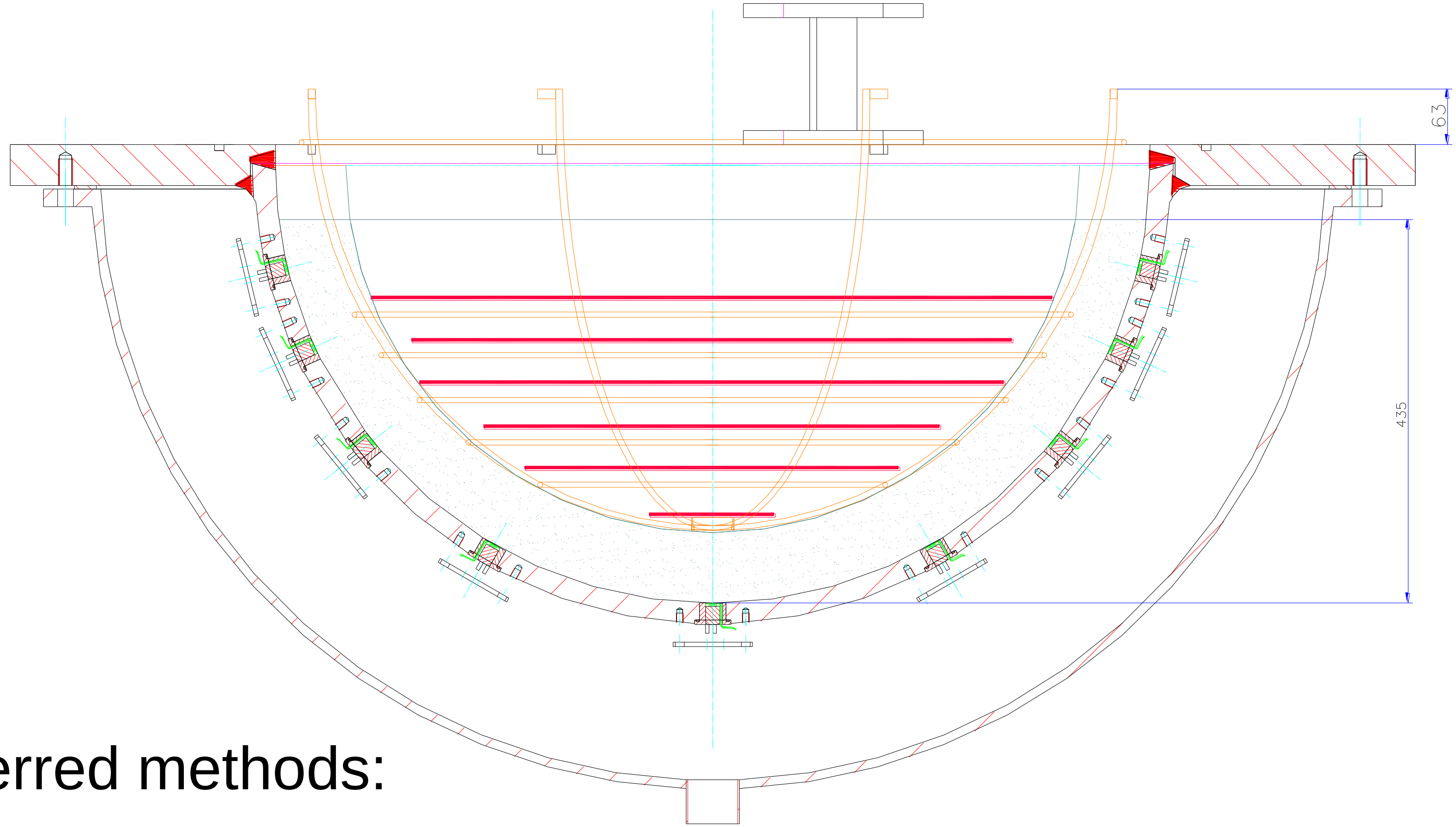


crust profile in a volumetrically heated pool: thin and non-uniformly



desired crust profile in the LIVE-CERAM: thick and uniformly

Solution: elevating the heating elements



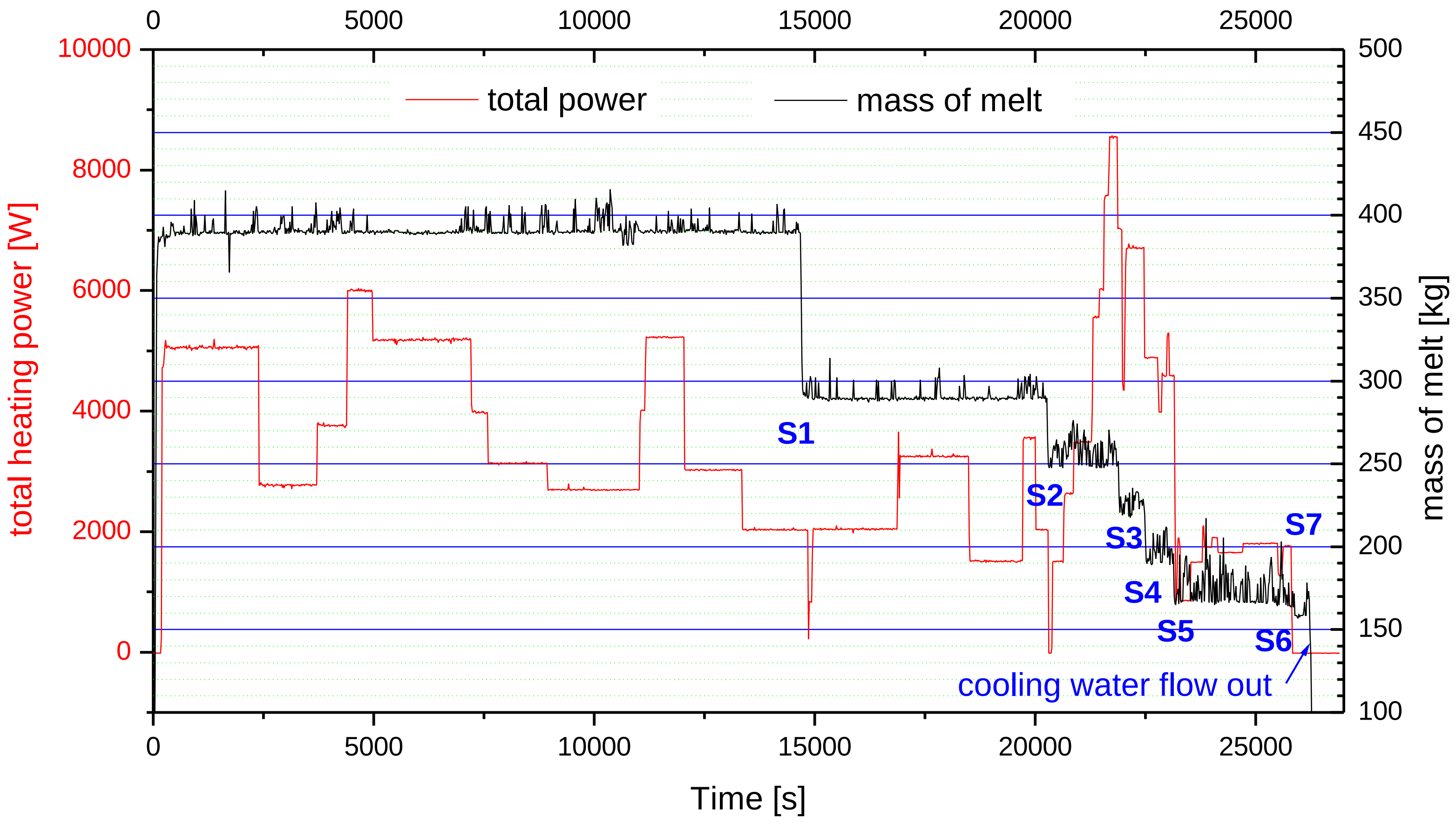
Preferred methods:

- multi-step melt extraction or
- one-step melt extraction and heterogeneous heating

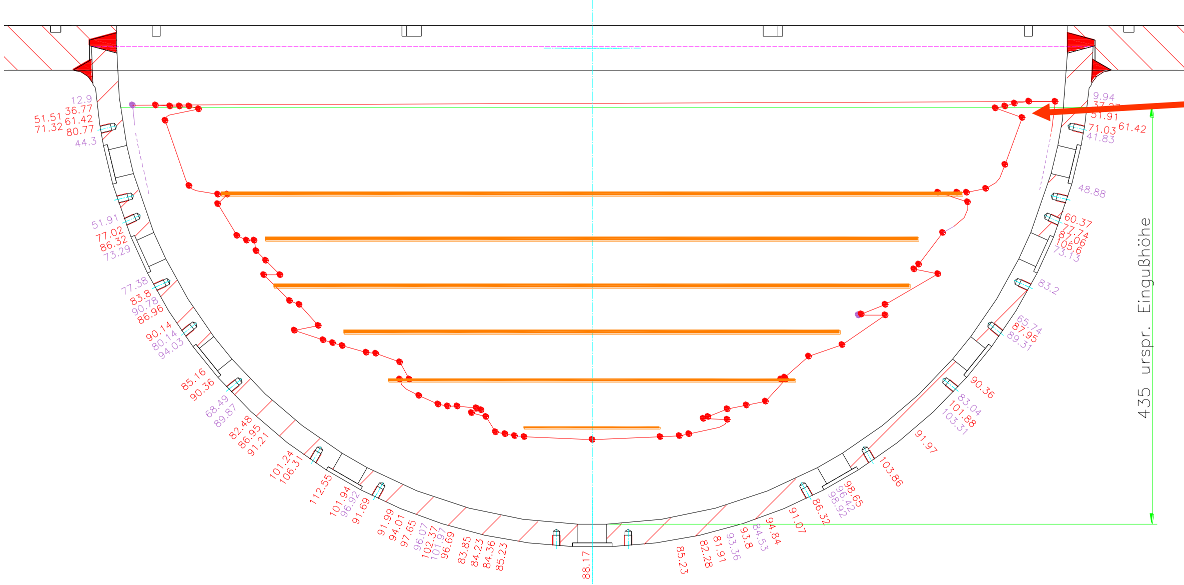
Other agreements at the CEA/KIT meeting

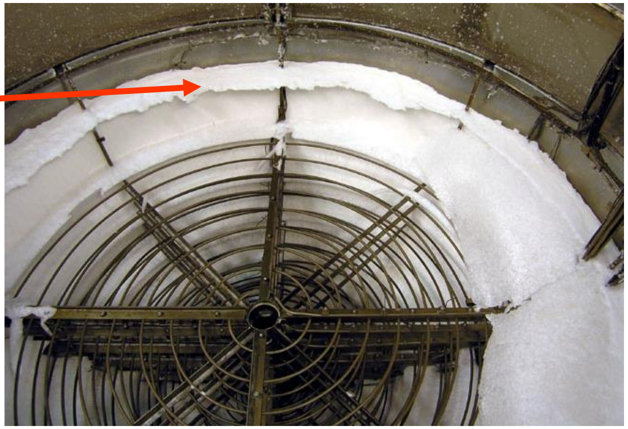
- Geometries: height of refractory line: 435mm, height of ablation pool 385mm
- Measurements:
  - Evolution of melt pool temperature: 36 thermocouples
  - Evolution of the interface temperature
    - Four thermocouple trees for crust temperature and interface temperature (new),
    - two positions for crust detection lance (new)
- Initial ablation conditions: pouring temperature 260°C, maximum melt temperature 330°C, heating power 7kW in the liquid pool, vessel wall externally cooled by water
- Steady-state criteria: steady melt temperature and crust temperature at polar angle 52° and 66°

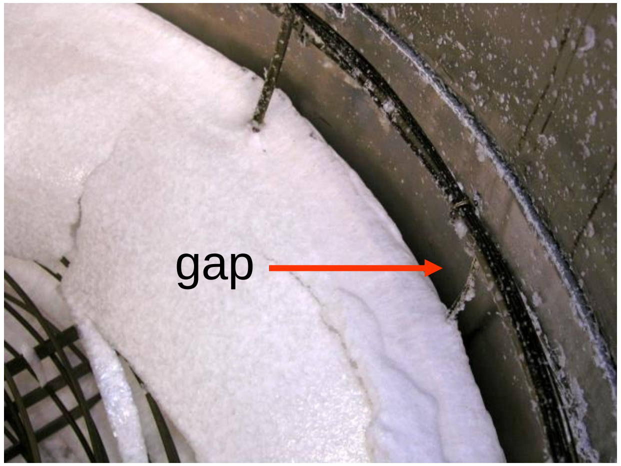
Pre-test 1 (VV1) : Multi-Step Melt Extraction

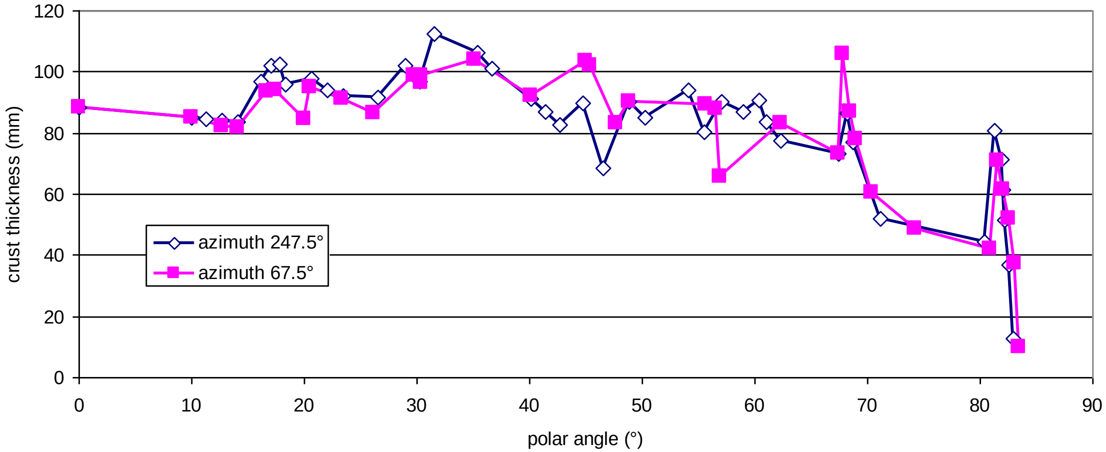


Pre-test 1 (VV1) : Multi-Step Melt Extraction

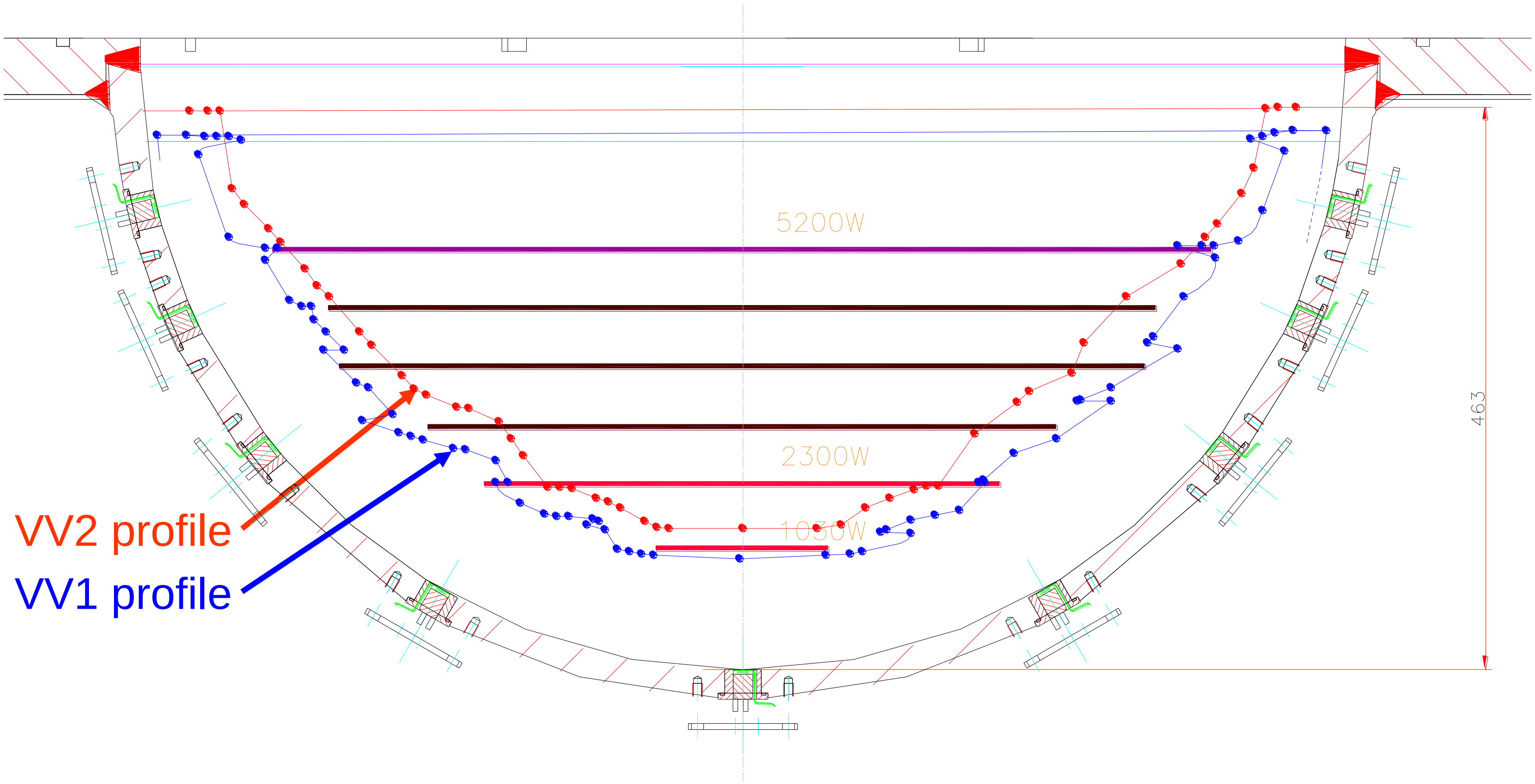








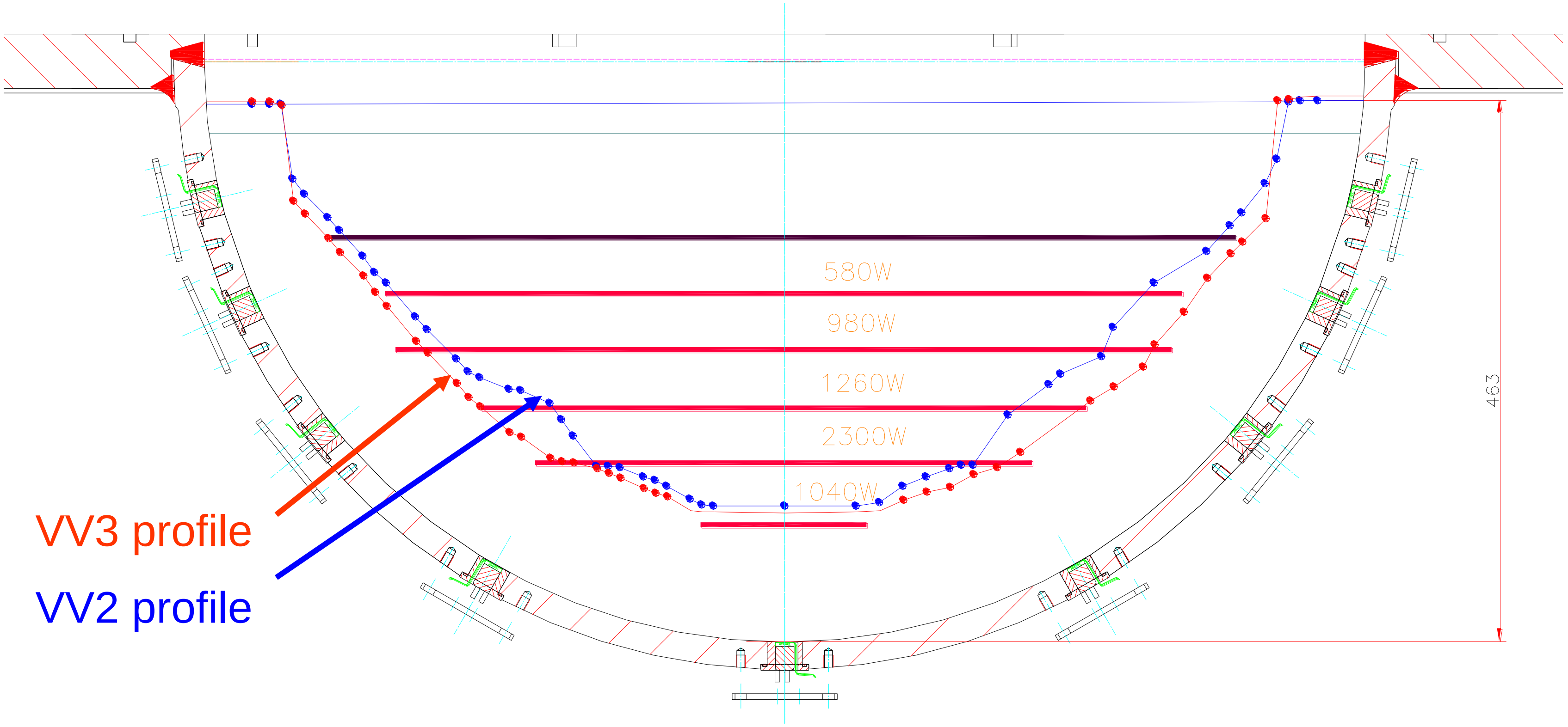
Pretest 2 (VV2) : Smoothing the Crust of VV1 and Filling the Gap



Total heating power: 3300W at lower pool

Crust thickness: 6.5cm at top, maximum 14cm

Pretest 3 (VV3) : Heterogeneous Heating



Total heating power: 6200W, heterogeneous heating

Crust thickness: 6cm at top, 10cm at middle part and 11cm at bottom

Summary of the Pre-tests

- The method of pre-test 3 (VV3) gives the best result.
- A gap is formed between crust and wall due to crust shrinkage →
  - The gap has a width about 1cm.
  - Most of the wall inner temperature thermocouples were destroyed during crust shrinkage.
  - The heat flux determination based on wall inner temperature will be not exact.
  - During ablation test, hot melt might penetrate through the crust to the gap and fill in the gap, so that the local heat transfer condition afterwards will be changed.
  - By filling the gap before the ablation test can decrease the width of the gap, but not completely get rid of it.
  - The plug temperatures at the wall can be used instead of the wall inner temperatures for the heat flux determination.

Ongoing Activities

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- Instrumentation of 4 crust-temperature thermocouple trees, totally 63 pieces,
- looking for the possibility of the second position for the melt/crust boundary temperature measurement with crust detection lance,
- Waiting for the reply from CEA about
  - Confirmation of the method to create the refractory layer;
  - Confirmation of the instrumentations;
  - Opinion about the gap filling before the ablation test;
  - Confirmation of the participation of the test and the date of the test performance. The suitable date for KIT is November 28- December 09, 2011.

Thanks for your attention