GTS Phase VI

# HotBENT
## High Temperature Bentonite Project Ideas

**Studying the effects of high temperatures on clay buffers/nearfield**

**Florian Kober** (Nagra, on behalf of interested parties)

**IGD-TP Exchange Forum, Cordobá;**
**25/26 October 2016**

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# HotBENT Motivation to study THMC behavior under high T

- Thermal limit is an important design and cost-optimisation parameter:
  - repository footprint
  - storage time at the surface
- A higher thermal limit is especially beneficial for the:
  - disposal of dual-purpose canisters
  - disposal in host rocks with high background temperature (steep geothermal gradients)
- Bentonite exposed to much higher temperature → a proof of robustness is needed from a safety point of view → optimal and shared allocation of resources should be pursued
- Bentonite behaviour is a common thread → In order to do so a substantial database and experience still needs to be gathered which is likely to be an international multi-annual exercise
- Previous or running higher temperature experiments have been only up to < 150°C (LOT, ABM → 130 $^{0}$C, PEBS/HE-E → 140 $^{0}$C, TBT ~ 150 $^{0}$C)

# HotBENT What to expect in the buffer for T > 150 °C

- Due to the high temperature it is expected that the following physico-chemical effects will occur:

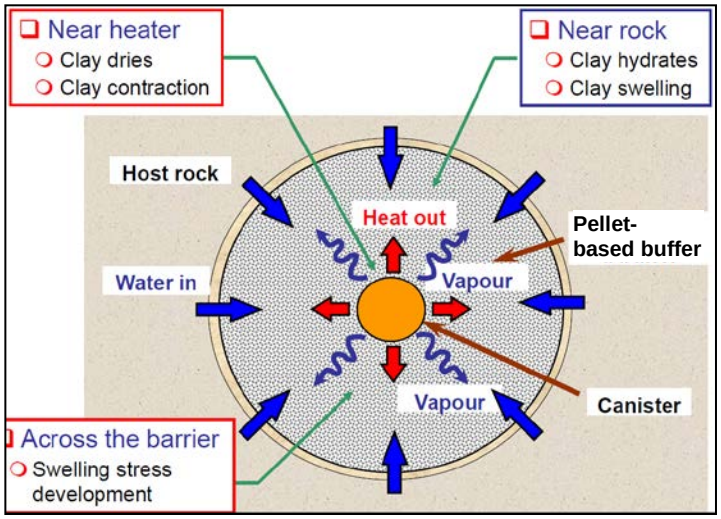
Laboratory scale

- cementation possibly affecting mechanical properties
- illitization (under certain conditions, e.g. high potassium concentrations) affecting mechanical properties (reduced swelling, increased hydraulic conductivity and diffusivity)

- Due to the strong thermal gradients:

Large scale (Mock-up/URL)

- complex moisture transport process, including convection of vapor
- delayed saturation
- heterogeneous, time-dependent density distribution (differential swelling)




- Numerical models developed, or being under development, can be used to simulate the thermal period of a repository, but database for T > 150 ˚C limited (laboratory) or non-existent (large scale)

# HotBENT - Kickoff Meeting – gathering and formulating the interests

- HotBENT Kickoff Meeting (Baden, CH, Feb 12th, 2016):
  **"HotBENT - Studying the effects of high temperatures on clay buffers / nearfield - Brainstorming"**

**Interested / participating organizations**

NUMO 原子力発電環境整備機構

BERKELEY LAB U.S. DEPARTMENT OF ENERGY

SÚRAO

Radioactive Waste Management

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GRS

SKB

**And various interested universities: EPFL, UdC, KIT, CTU, ..**

# HotBENT Aims (from first meeting)

- Increase data base on buffer / host-rock performance under high T (up to 200°C and demonstration at **realistic scales/conditions → upscaling**) vs process understanding
- Broad interest in: what are the **T- limits** (max) to assure safety function of buffer (and host rock) …
- Need of repository **optimisation** with respect to design, space and costs …
- Compare different materials, concepts/designs, boundary conditions (e.g. types of bentonite and canister materials, water chemistries, temperatures, …)
- Evaluation of microbial activities / corrosion (e.g. buffer/canister)
- Integrating of modelling (e.g. THMC) and lab activities (and also mock-up experiments)
- Availability of data and samples must be possible not only after 20 years, preferred are ~5 years … → develop and implement suitable monitoring/sampling strategies

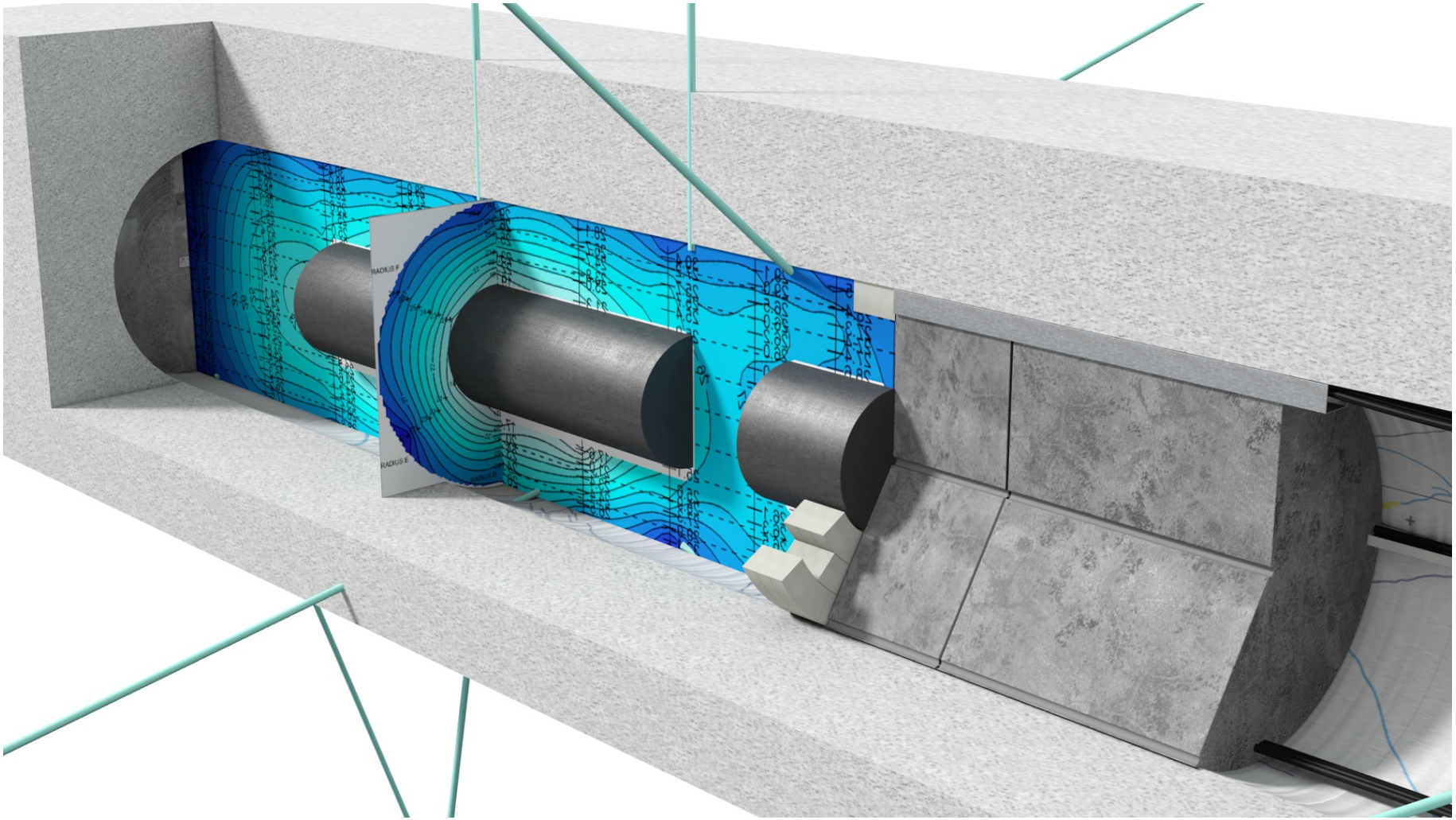
# HotBENT - Potential location - GTS, FEBEX-gallery

- At Grimsel Test Site (GTS)
  - Old/former FEBEX-DP tunnel (70 m long, geologically and hydrologically well characterized gallery, multiple boreholes,…)
  - Availability of GBM and bentonite blocks MX80
  - Auger machine





# HotBENT - FEBEX gallery – well characterized boreholes



## Water content

Data from: Villar et al.(2016) FEBEX-DP: Onsite determinations report. NAB 16-012



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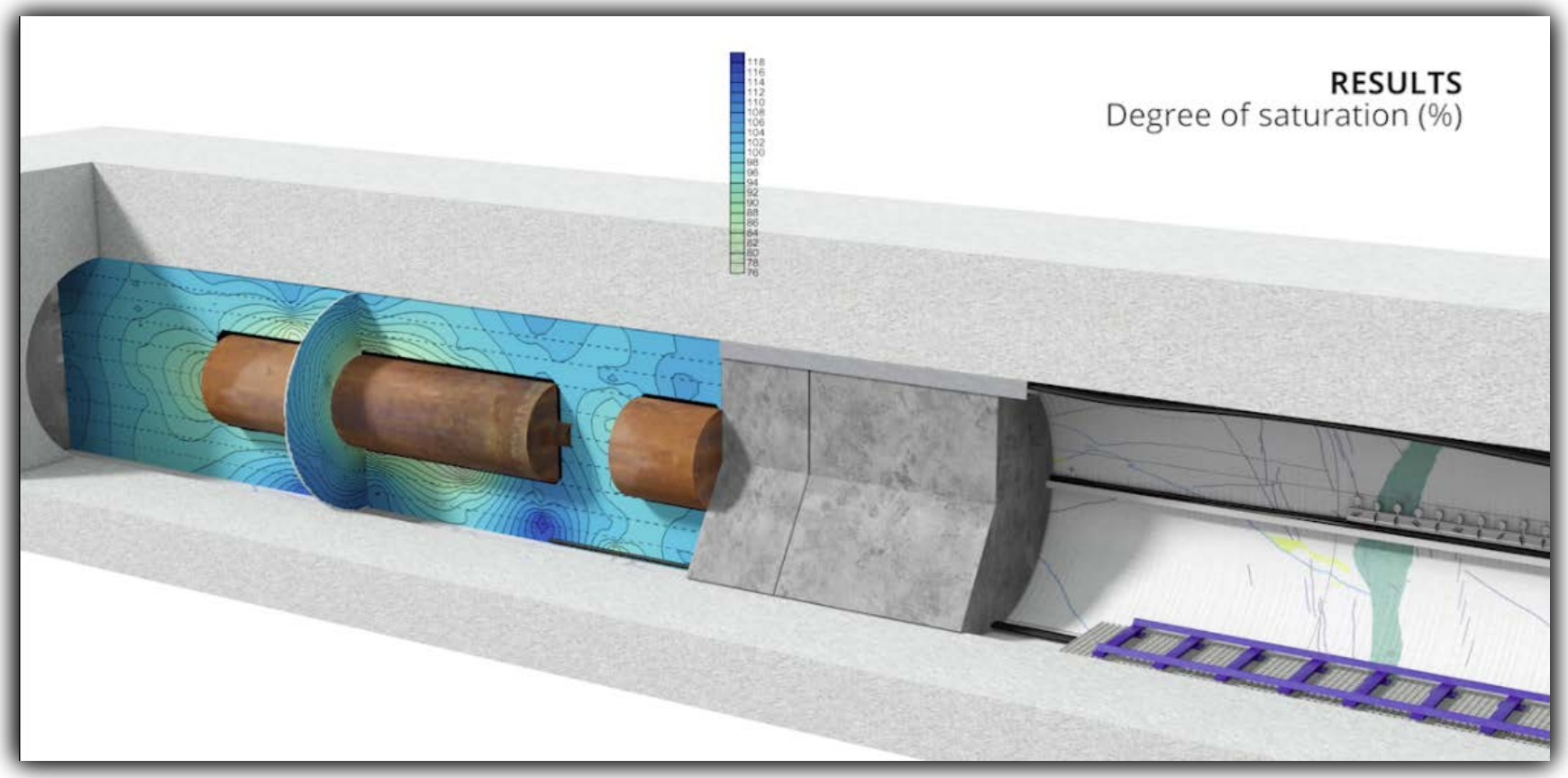
# HotBENT since ISCO 2015 (4) - FEBEX gallery – onsite analysis

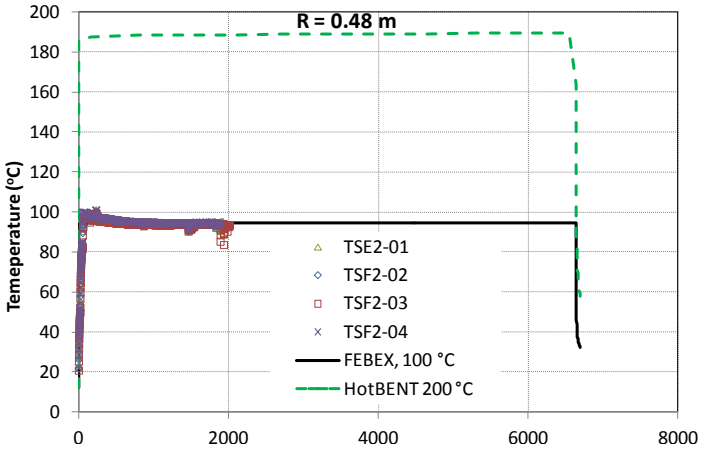


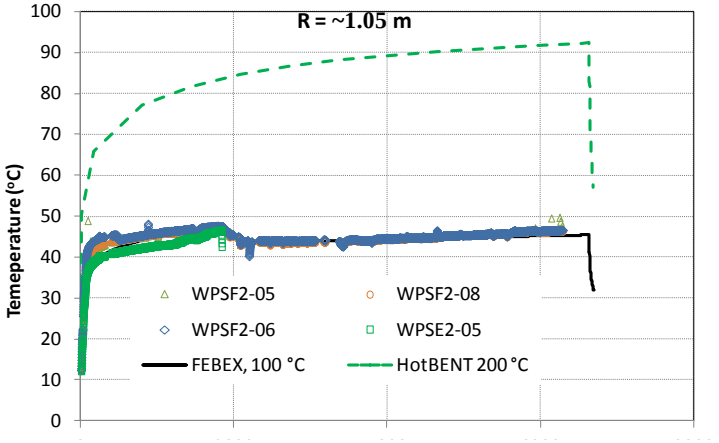

NAB 16-012, Villar et al.

# HotBENT - Scoping calculations

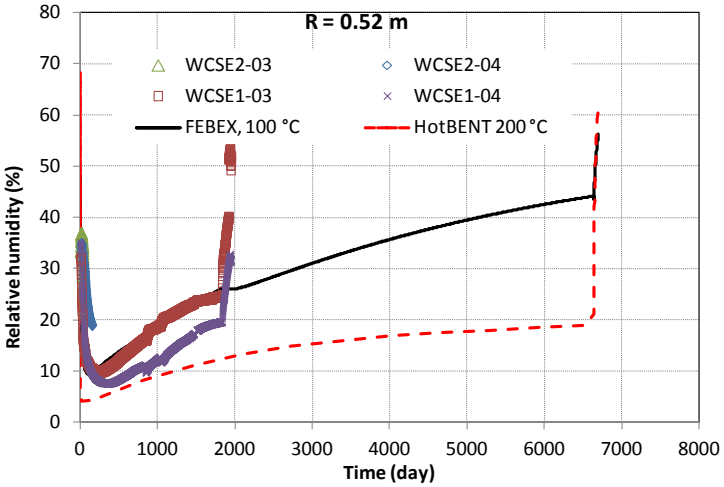
Comparison with FEBEX modelling and data

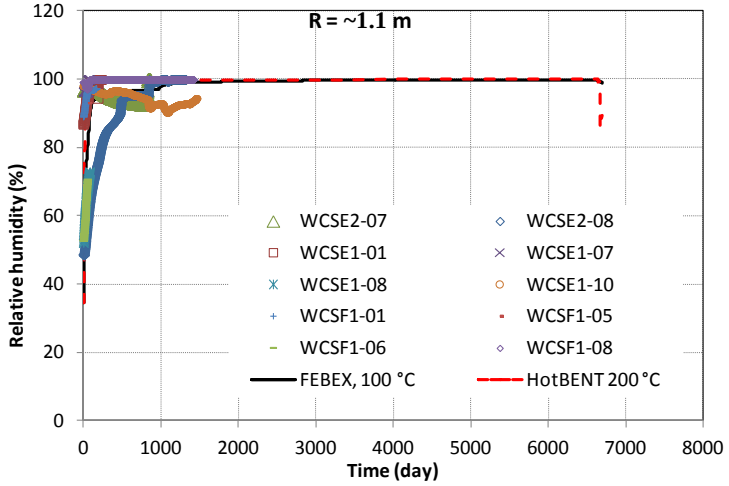
**Temperature**




**Relative humidity**

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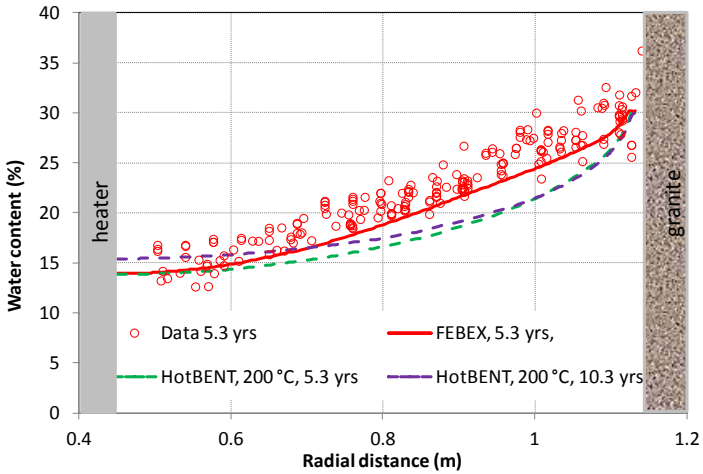
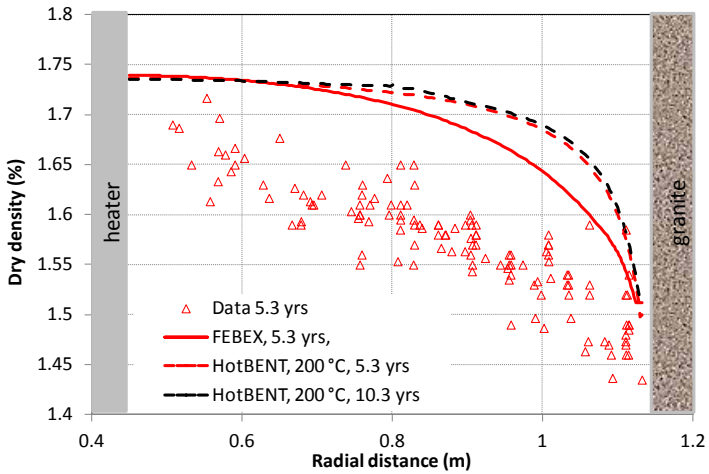
# HotBENT - Scoping calculations

Comparison with FEBEX modelling and data

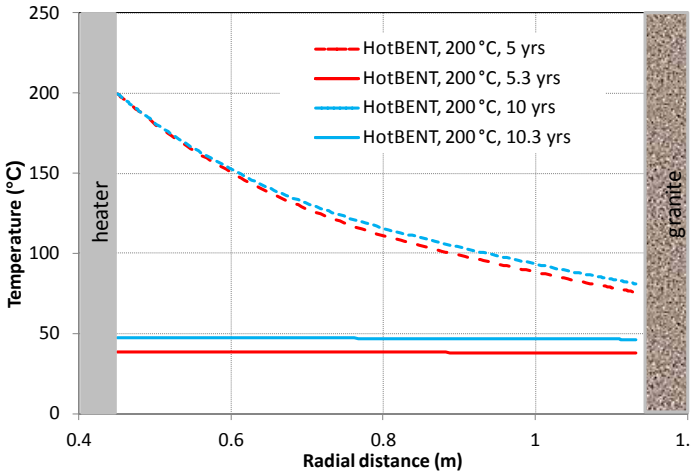
**Water content & Dry Density**
**AFTER COOLING**

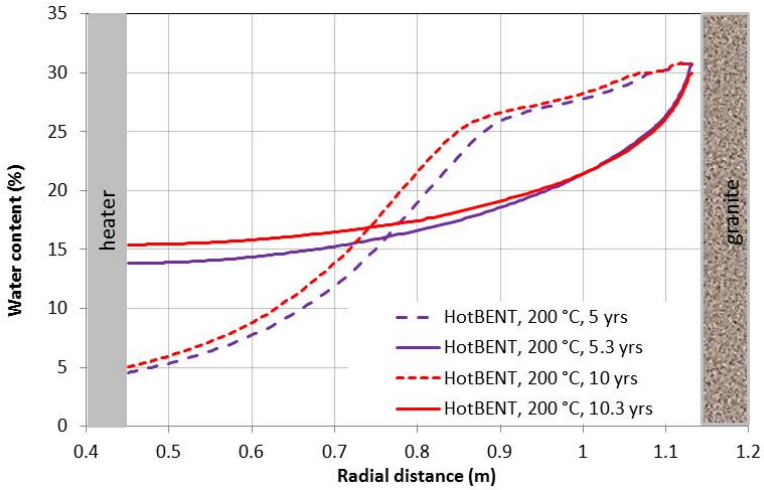



**Observations: After 10 years, the majority part of bentonite is still unsaturated.**

**Temperature & Water content**
**AFTER COOLING**




**Observations: HotBENT undergoes significant re-distribution of moisture during the cooling period**

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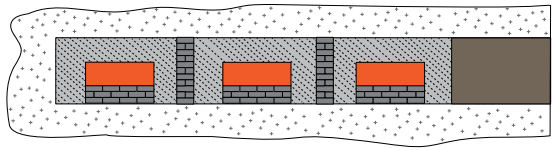
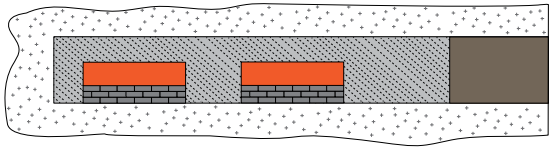
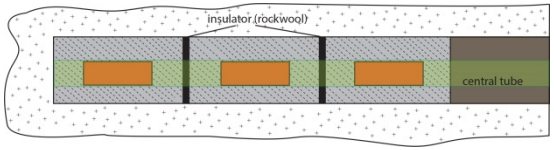
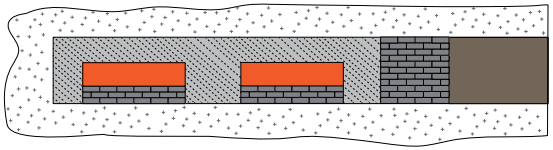
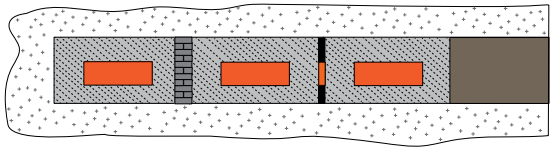
# HotBENT – Possible Designs



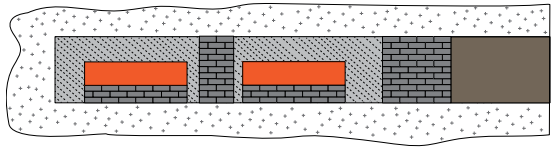


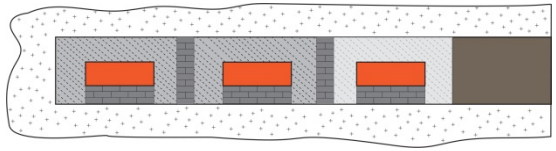


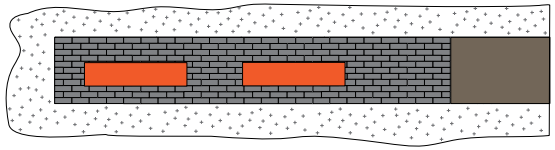



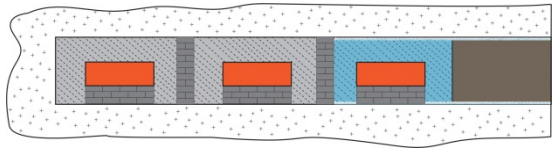


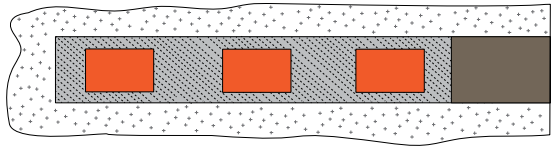
**Possible set-ups**











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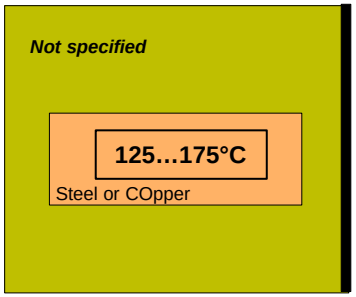
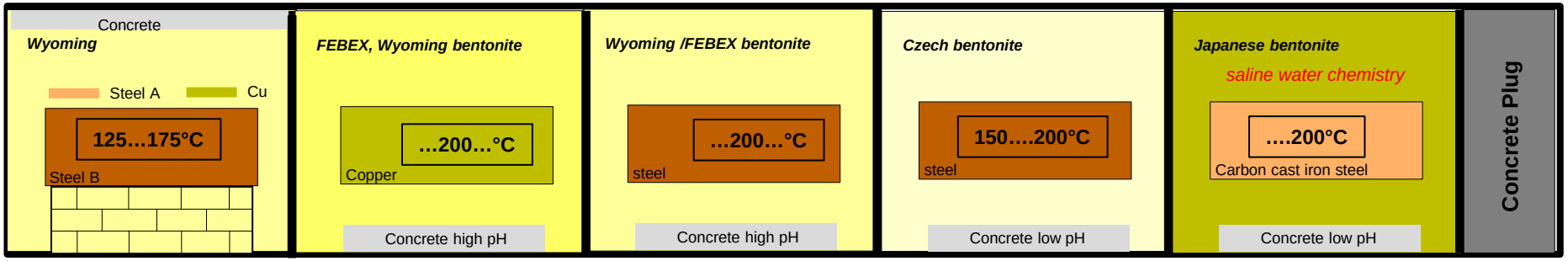
# HotBENT – Potential Modules

OPTIONS

**Module 6**




**Module 1** **Module 2** **Module 3** **Module 4** **Module 5**




*Not to scale*

**To be run for 5…10…15 years**

# HotBENT – Initial “Designs” for first very preliminary cost estimates

**“classic” model**

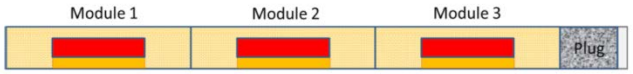
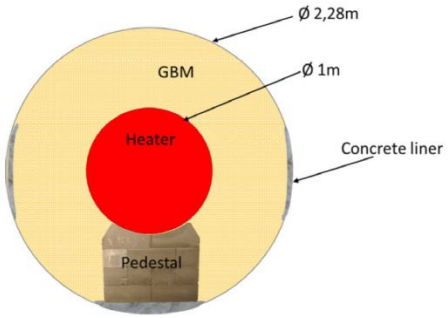
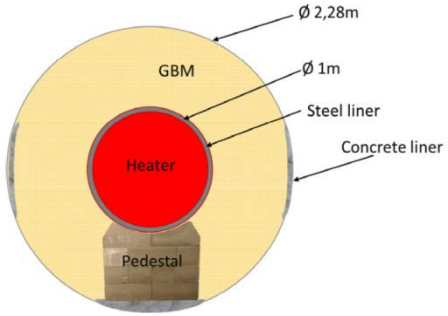



Figure 3: Classic arrangement

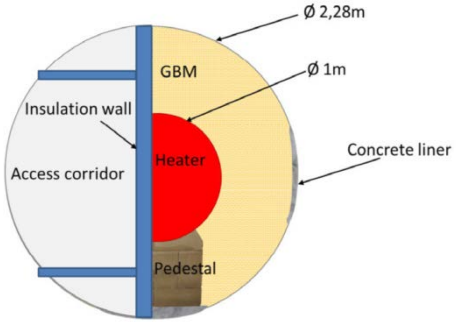



**“HE-E type” model**

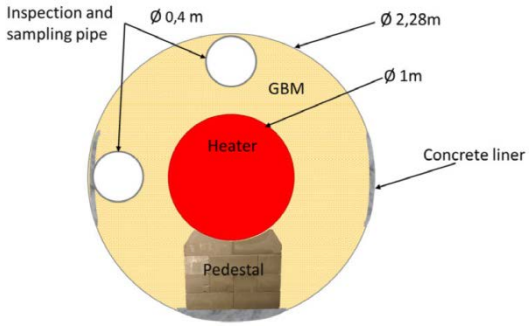

Figure 5: HE-E type arrangement




**“half-tunnel”/”half-pipe” model**




**“long-sampling-pipe” model**



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# HotBENT - Next Actions

- Technical refinements for further design optimizations on
  - General risk assessment, project risks and risk mitigation
  - Monitoring at high temperatures
  - Material evaluation (bentonite, heater, …)
  - Gas/steam/vapor-evolution and risk of overpressure, interaction with hydrosphere, boiling effects
  - Sampling and sampling techniques
  - Artificial hydration (compositions) options and limitations
  - …

**thank you**

**for your interest**

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# HotBENT - timeline (proposal)

| 2016 | | | 2017 | | | | | | | | | | | 2018 | | | | | | | | | | | | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | | | | | | | |
| **Conceptual design and modelling (budget)** | | | | | | **Formalise partici-pation** | | **Site and experiment preparation** | | | | | | | **Experiment construction** | | | | | | | | | | | | **Experiment runing/monitoring** | | | | | **Excavation/ analysis/ modelling/ reporting** | |
| 6 month | | | | | | 2 month | | 6- 8 month | | | | | | | 7 month | | | | | | | | | | | | 5 years (-->2023) | | | | | 1- 2 yeras | |