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Sandia National Laboratories

SDI Long-Term Thermal Effects

EPA/DOE Technical Exchange

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Long-term Thermal Effects

- SNL thermal calculation was bounding, not realistic for operational predictions at small distance and short times
  - From large distance (>100 m) small-scale variability in properties and source arrangement is unimportant – *all appear as a point source*
  - At late time (>50 yr) exact temporal behavior of a ≈2 year test is unimportant – *all appear nearly as a pulse source*
  - Energy conservation is most important thing (§2.1 in Kuhlman, 2011)
    - Total energy added to system E = 8.5 kW/heater × 5 heaters × 2 years
    - Spread total energy out across cylindrical volume of salt with radius 700m and a given heat capacity and density leads to very low temp

$$E = \rho V C \Delta T \rightarrow \Delta T = 0.0513^{\circ} C$$

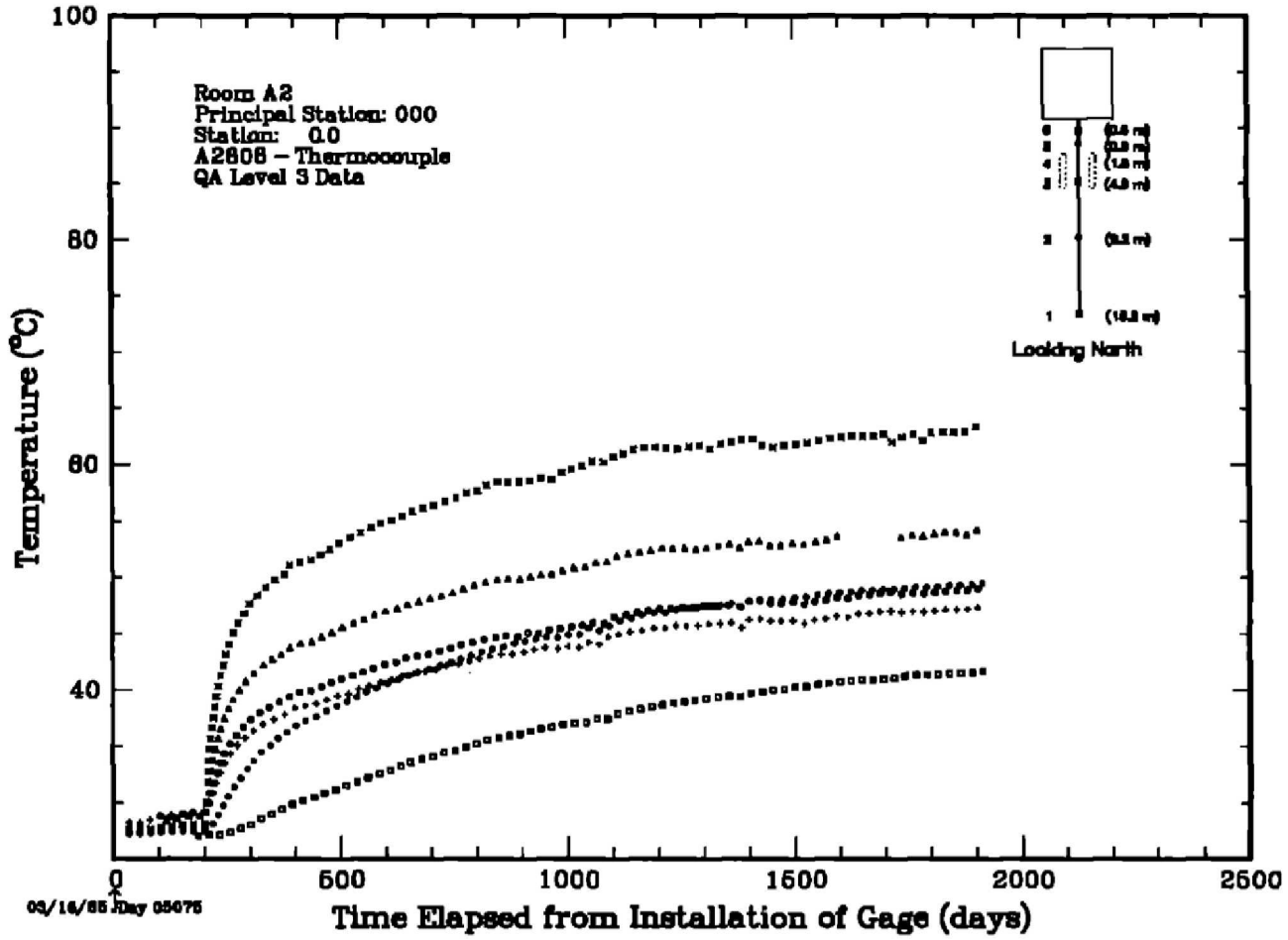
    - density ρ=2190 kg/m^3; heat capacity C=931 J/(kg °C); volume V=2.6E+6 m^3
    - Thermal conductivity is not a factor in this calculation

Historic Heater Effects in Halite

- SDI proposal
  - 2 years
  - 5 heaters (8.5 kW/heater) = 42.5 kW total
- Lyons, KS (Project Salt Vault, ORNL-4555)
  - 1.5 years (beginning 1965)
  - 4 different experiments, each 10.5 kW total
- WIPP Rooms A1, A2 & A3 (SAND90-2749, p. 486)
  - 4+ years (beginning 1985)
  - 68 heaters (~0.4 kW/heaters and ~1.4 kW/heaters) = 63.9 kW total
- Historically no significant long-term effects or observed heat storage/conduction at large distances.
  - No observed heat pulse at WIPP due to 1985 tests which imparted more energy to the rock than is proposed in SDI.

Historic Heater Effects in Halite

- WIPP Rooms A1, A2 & A3 (SAND90-2749, p. 172)
  - Observed temperature below middle of room A2 between four 1.4kW heaters



EPA Thermal Questions - 1

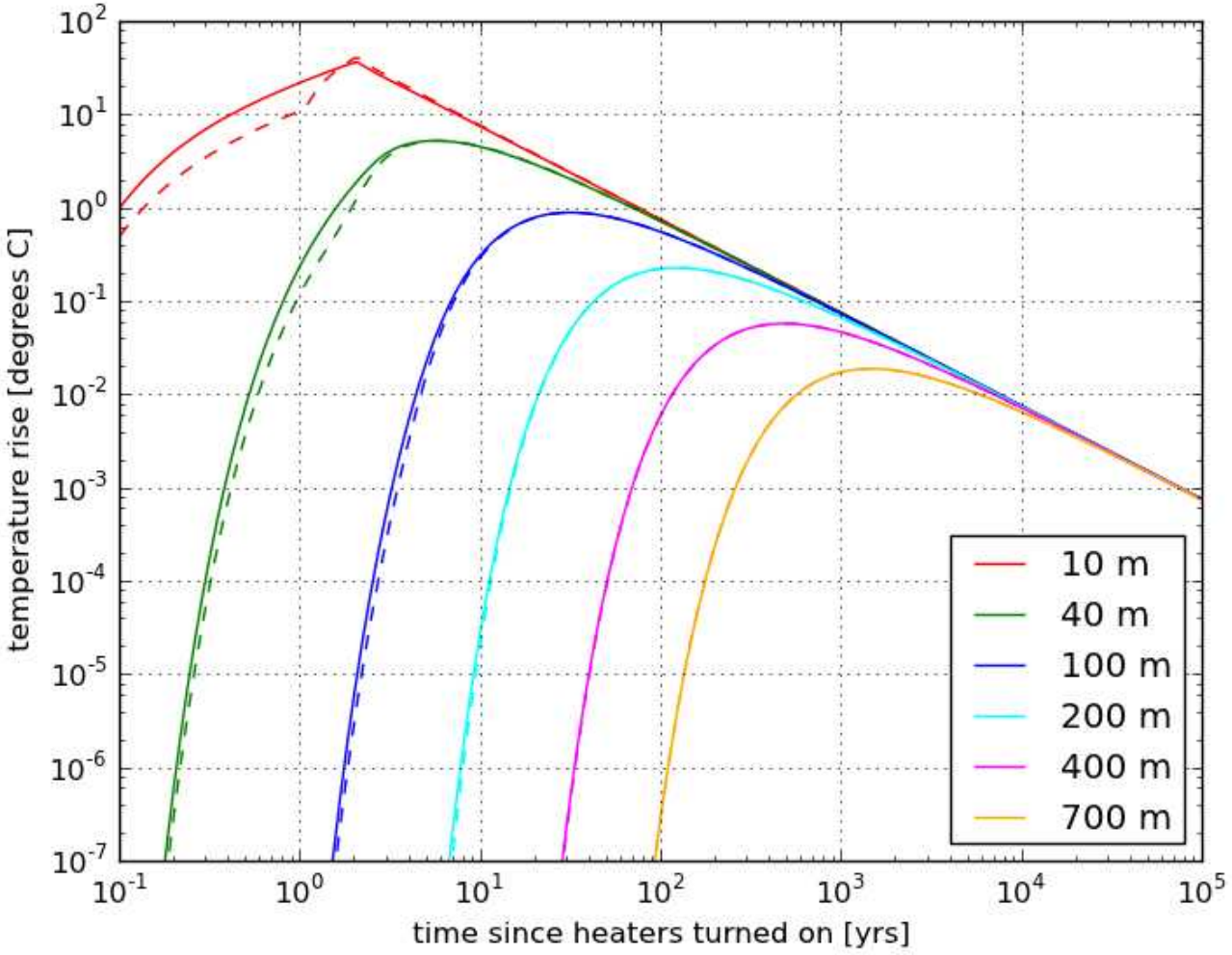
- **SDI(HC) -1** *DOE needs to provide additional information of lower thermally conductive -higher porosity 'run-of-mine' salt emplaced around the heaters.*
- ***Background:*** *Halite thermal conductivity (k) is inversely related to porosity. The higher porosity of the run-of-mine salt would conduct less heat away from the heater than that analyzed here, and potentially produce higher temperatures at the waste panels than currently predicted.*
- Near-source configuration and material properties have little or no effect on long-term predicted temperature rise.
  - The low-k region will conduct the same amount of heat (not less) away from the heaters, just at a slightly slower rate. The heaters surrounded with run-of-mine salt can then be effectively viewed as a slightly larger source.
  - This effective source is still transferring the same amount of energy to the system as the heaters alone; it is unphysical for the effective source to produce a higher temperature at the waste panels.

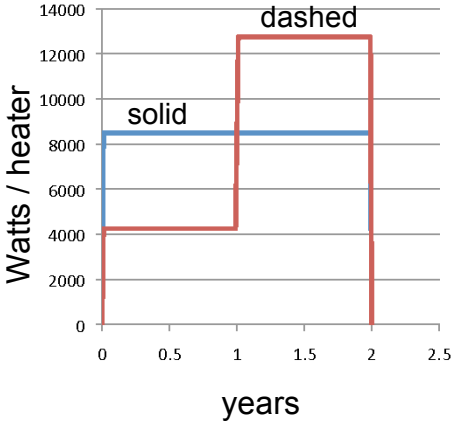
EPA Thermal Questions - 2a

- ***SDI(HC) -2*** *DOE needs to provide additional information on the higher temperature-lower thermally conductive nature of halite and its affect on distal temperatures.*
- ***Background:*** *Halite thermal k is inversely related to temperature. A higher temperature halite and run-of-mine salt would conduct less heat away from the heater and potentially produce a thermal dam and EPA is looking for information to address the issue.*
- Near-source configuration and material properties have little or no effect on long-term predicted temperature rise.
- Non-linear thermal properties of salt are:
  - Noted in SNL thermal analysis report (see §2.3.3 of Kuhlman, 2011)
  - *Weakly* non-linear over the range of temperatures expected (less than an order of magnitude)
  - Even if non-linear effects taken into account, would likely still be unimportant at large distance

EPA Thermal Questions - 2b

- Example: move more of 2-year pulse to second year



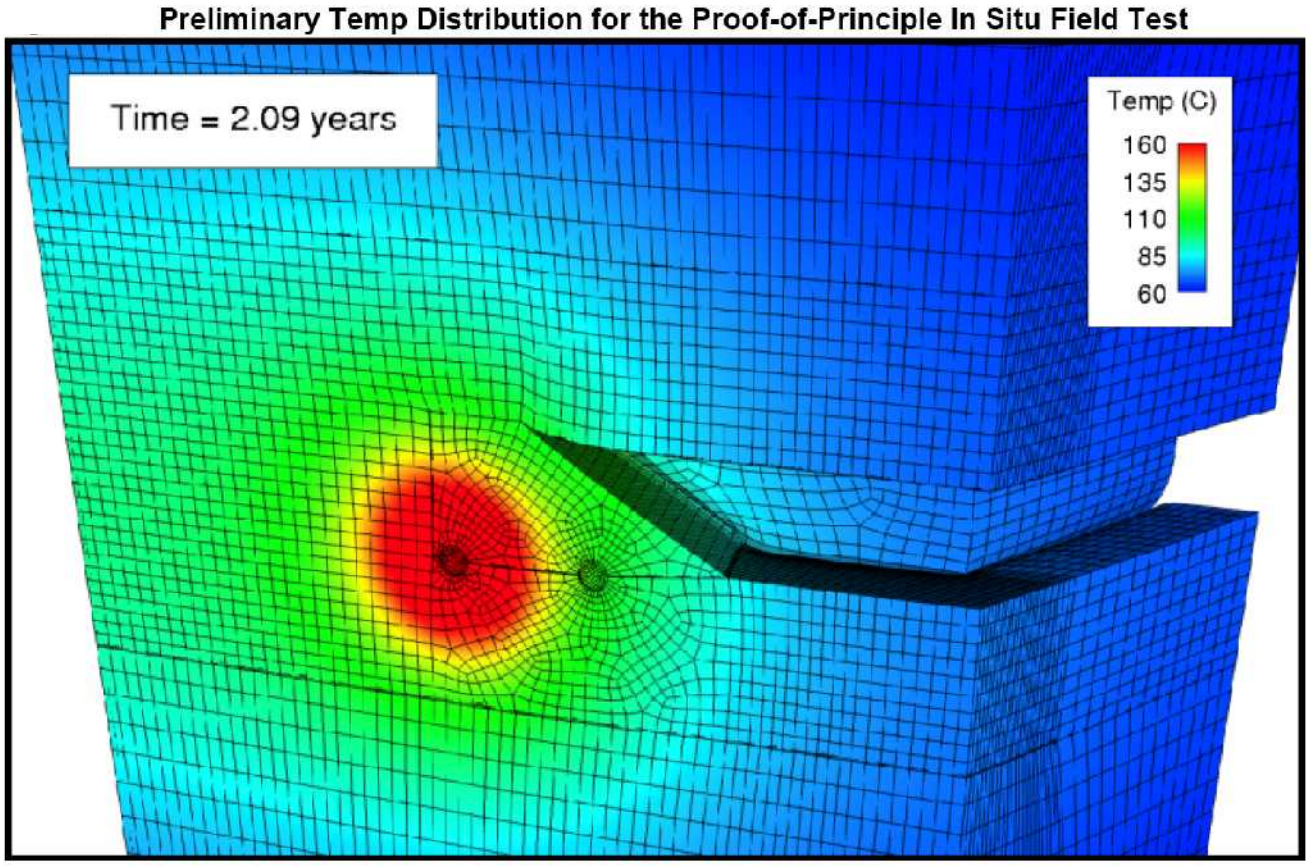


EPA Thermal Questions – 3a

- ***SDI-(HRP) -1*** *What are the expected effects of a 300°C temperature source on the clay inter-beds properties located in the SDI experimental area?*
- ***Background:*** *In the development of the Salado conceptual and numerical flow and transport model there has been significant effort to incorporate the clay seam properties. We are interested to have information that addresses the expected affect on moisture and stability.*
- Any significant rises in temperature will be
  - Very localized to the vicinity of the heaters
  - Have little effect on long term heat transfer properties of Salado
- Observing effects of heat on material properties (crushed salt, native Salado) is one goal of SDI research.

EPA Thermal Questions – 3b

- Thermal pulse simulated using thermal-mechanical FEM qualitatively shows extend of thermal effects.



EPA Thermal Questions - 4

- ***SDI(HRP)-2*** *What are the expected effects of a 300°C temperature source on the anhydrite layer properties?*
- ***Background:*** *There has been significant effort to incorporate the properties of the anhydrite layers in the development of the Salado conceptual and numerical flow and transport model. Would the temperatures be expected to affect the fracture formation threshold pressure or propagation length?*
- Any potential effects will be far too small and far too localized to be included in other PA codes like BRAGFLOW.
- Observing effects of heat on material properties is the goal of the SDI research.

Long-term thermal effects

- Long-term thermal effects of SDI on waste panels are insignificant
- No effects of 1985 testing have been observed
- SNL Analytic thermal calculation was bounding
  - Not intended to represent operational or near-field behavior
  - At long distance and late time any test will appear as a pulse point source of equal total energy.
  - Other simulations required to predict localized thermal behavior
  - Local material properties and short-scale timing do not have a measurable effect on long-term heat flow
- In reality much of the total energy will be removed by the ventilation system, greatly reducing long-term temperature rise