Designing a Mined Geologic Disposal System— When is a Thermal Loading Decision Needed?

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A Up-to-date Conceptual Design is Necessary to Conduct the Program Efficiently

- The site characterization plans, materials test plans, and the design of the storage, handling, and transportation sub-systems all are based on a repository conceptual design.

- The design in the 1988 Yucca Mountain SCP is out-of-date. New ideas:
  - Ramp versus shaft access for ESF
  - Drift vs borehole emplacement
  - Rail versus road underground access
  - MPC/MPU sealed at reactor for final disposal
  - Dry storage at the reactors
  - Extended performance of Engineered Barrier System
  - Extended Dry and "cold" concepts of heat management
  - Acknowledgement that average age of waste at emplacement will be 30 years, not 5 or 10.

- An up-to-date repository conceptual design is needed.

Effect of Thermal Loading on Repository Behavior in Unsaturated Tuff

- Under ambient conditions at Yucca Mountain, an opening into unsaturated tuff remains dry despite the rock's containing water in the pores.

- Introduction of heat into the rock mobilizes this water; under some circumstances it can drip into openings.

- Two other design input features are different for spent fuel in unsaturated tuff compared with reprocessed waste in salt or granite, which was the model in early thinking:

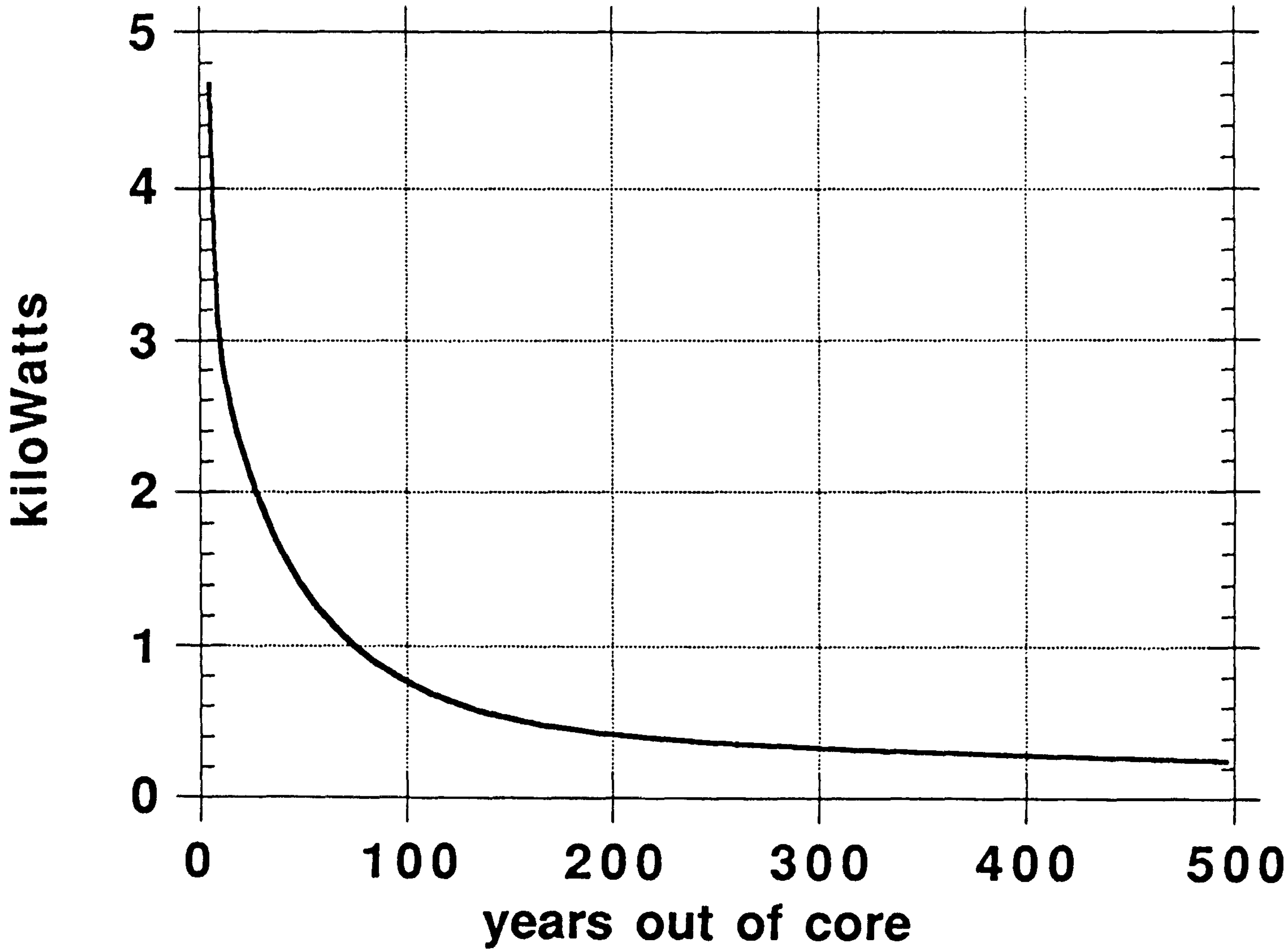
  — When heat in spent fuel is integrated for more than a hundred years, the majority of heat comes from actinides and persists for thousands of years

  — Unsaturated tuff has one-third the thermal conductivity of salt and two-thirds that of granite.

- Ambient conditions at Yucca Mountain will be perturbed for up to 100,000 years under all thermal loading options.

WP Heat Load for PWR Spent Fuel

(SCP-CDR, 3kW @ 10y out of core)



Thermal Loading Concepts Fall into Three Groups

- The Site Characterization Plan Conceptual Design (SCP-CD)

  — Borehole emplacement of 10 years-out-of-core (YOC) spent fuel or high-level waste in thin wall, corrosion-resistant, unshielded containers at about 57 kW/acre, maximum drift wall about 130 C and maximum borehole wall about 230 C.

- Sub-boiling drift emplacement

  — Self-shielded casks containing 30 YOC fuel

  — Maximum 50 C, 1-4 PWR per cask, maximum 20 kW/acre

  — Maximum 90 C, 8-12 PWR per cask, maximum 40 kW/acre

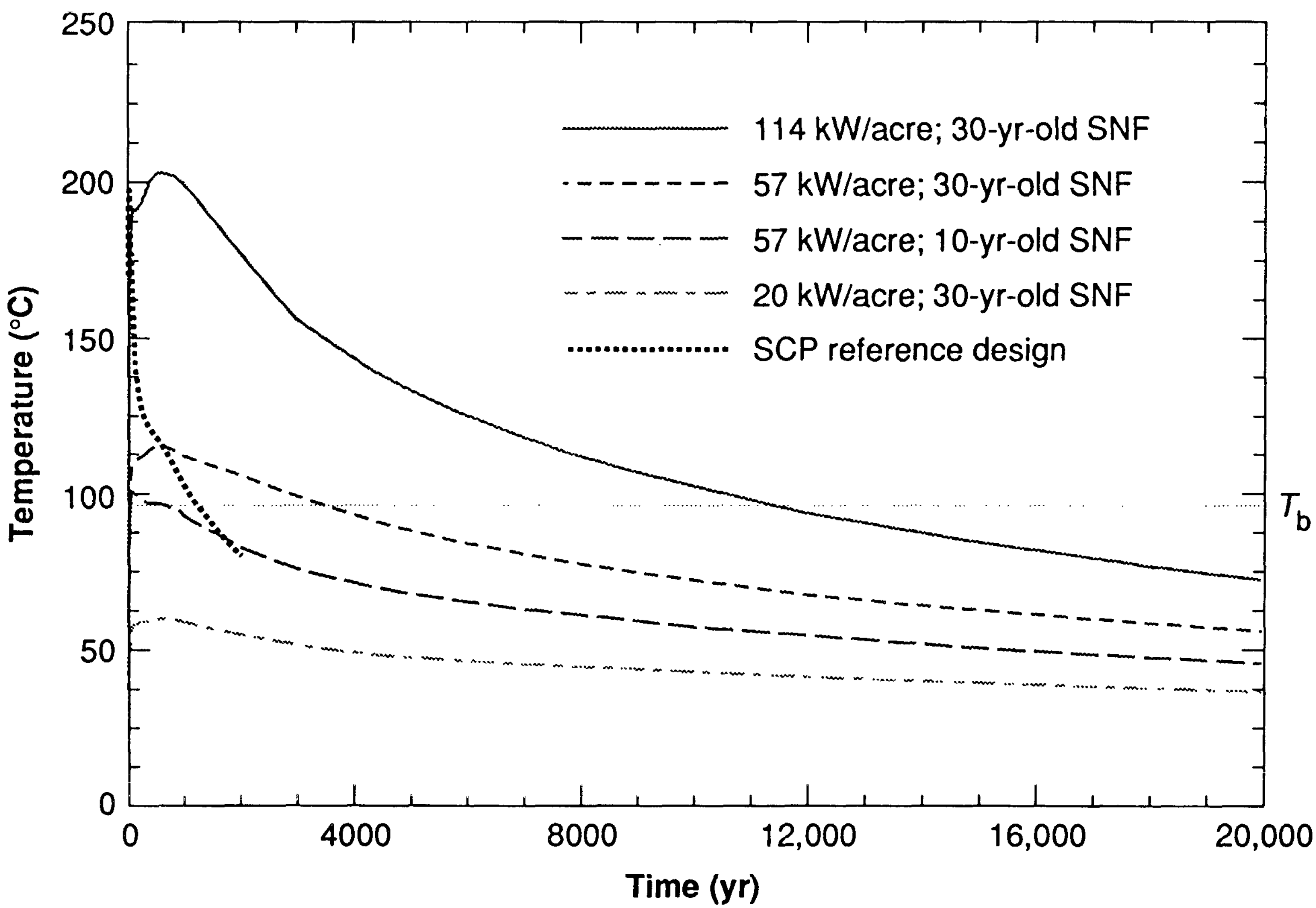
- Extended Dry drift emplacement

  — Self-shielded casks containing 30 YOC fuel

  — Maximum 205 C allows 21-24 PWR per cask at 114 kW/acre

  — Maximum 125 C allows 21-24 PWR per cask at 57 kW/acre

Temperature history along the repository centerline for various thermal loading conditions at the repository horizon.



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Issues Common to SCP reference, Extended Dry, and Sub-Boiling Repositories

- Heat will affect the system
  - The real question: is the effect deleterious?
- Water will be mobilized
  - Hydrologic behavior of the system must be predicted .
- Most of the water that affects the repository doesn't flow from the surface
  - Already underground.
- There will be zones where hot water contacts rock for decades.
- Saturated zone will be heated, resulting in convective flow.

The Emergence of Drift Emplacement is Based on Many Features Beside Thermal Loading

- Cheaper and simpler
- Allows self-shielding, which makes retrievability more believable.
- Facilitates the use of a more robust waste package
- Makes the MPC/MPU concepts feasible.
- May reduce risk from seismic activity.
- Eliminates the "bathtub" scenario around a single waste package.
- May lessen consequences of human intrusion

Drift emplacement facilitates both Extended Dry and sub-boiling repository concepts

- For the same peak wall-rock temperature

  — drift emplacement allows a much greater loading density, which combined with older fuel facilitates the Extended Dry concept.

- For the same loading density

  — drift emplacement gives a lower peak wall-rock temperature, which combined with older fuel facilitates a sub-boiling repository.

The Main Distinction Between the Two Drift-Emplaced Options is Thermal Loading

- For 30 year old fuel, Extended Dry ranges from 60 to 120 kW/acre whereas sub-boiling ranges from 20 to 40 kW/acre.

- The Extended Dry option implies a smaller area, less miles of drift, fewer but larger waste packages (therefore rail haulage), and a greater challenge to designing emplacement drift backfill.

- The sub-boiling option implies a larger area, more miles of drift, many more but smaller waste packages (possible non-rail haulage), and less difficulty to designing emplacement drift backfill.

- Only a detailed study would show how much similarity could exist for the two options (i.e., is a "generic" design possible?)
  - — drift diameter and spacing?
  - — ventilation requirements?
  - — handling equipment?

Thermal Tests and a Thermal Loading Decision

- There would be no need for a thermal loading decision except for its potential effect on licensing for isolation. Otherwise, the most cost effective design would be automatically adopted.

- A specific thermal loading is needed for a final (licensing) repository design.

- At that point, a decision must be based on test data and analysis, not calculations alone.

- With respect to an earlier decision

  — Is a thermal loading decision needed for repository conceptual design?

  — If yes, are thermal test data needed for the decision?

  — If no, how can design of the storage and transportion sub-systems proceed?

The Technical Basis for a Final Thermal Loading Decision Does Not Exist at Present

- Debate about the SCP reference design vs a sub-boiling design vs Extended Dry misses the point — we don't understand <u>any</u> of these well enough at this time.

- Calculations of both the "cool" and SCP designs show effects from heat similar to those attributed to Extended Dry.
  - SCP: very high temperatures at rock wall
  - "Cool": long times with rock in contact with hot water
  - Both: perturbation of water flow in saturated zone, mobilization of water in unsaturated zone.

- Some of the thermal loading issues are not resolvable by more or better calculations.

- Therefore heater test results are needed to choose a final thermal loading strategy
  - how much testing of what kind for how long?
  - need formal analysis of several options for EIS.

Fortunately, a Thermal Loading Decision Is Not Needed for Conceptual Design

- What is needed for conceptual design
  - — understanding the constraints among the sub-systems
  - — the bounds for plausible thermal loading strategies.

- Neither a thermal loading decision nor underground thermal tests at the repository site are needed
  - — to do a conceptual design of the entire system
  - — to allow construction design of the storage and transportion sub-systems.

- However, there will be programmatic consequences from not making a thermal loading decision for conceptual design.

Consequences of Not Making an Early Thermal Loading Decision

- The Repository Advanced Conceptual Design will have to accommodate thermal loads ranging from 20 to 140 kW/acre.
  - Single flexible design
  - Multiple optimized designs

- The Storage and Transportation subsystems will have to maintain flexibility to accommodate thermal loads ranging from 20 to 140 kW/acre.
  - Loading of the MPU would be in the range of 1 to 4 PWR assemblies.
  - This would not prevent loads of up to 24 PWR assemblies in the storage, transport and disposal casks.
  - Selection of a 21 or 24 PWR MPC would pre-select for the Extended Dry option and introduce risk into the MGDS program.

- Cost projections for the MGDS may need to show a range rather than a single value.

Options for Advanced Conceptual Design Without Thermal Tests in Repository Block

- Carry out early heater tests in offsite test facility.

- Show that selected thermal loading option is acceptable even without field tests.

- Adopt a repository design that is not sensitive to heat load of the unit capsules.

- Carry multiple designs through Advanced Conceptual Design.

Technically supportable approaches to selecting a thermal loading option

In order of technical desirability

- Avoid selection until heater test results are available.

- Identify a favored option, but assure that no irreversible steps are taken that might preclude an alternate which relied on different technical mechanisms.

- Identify and quantify the programmatic risk of each option, select the apparently most favorable, and proceed at risk.

Conclusions

- The basis of a technically sound thermal loading decision is underground test data.

- A thermal loading decision can be made now by accepting the consequences
  — Added risk and required flexibility for future changes.

- A near-term thermal loading decision is not needed in the repository sub-system
  — Advanced conceptual design of the repository can be done without making a thermal loading decision
  — A thermal loading decision is not needed until license application design.

- Design of the transport and storage sub-systems would be affected by the absence of a thermal loading decision
  — Some MPC designs are compatible only with an Extended Dry repository.