Idaho National Engineering and Environmental Laboratory

Extensions of SCDAP/RELAP5-3D© for Analyses of Advanced LWRs and HTGRs

L. J. Siefken and E. A. Harvego

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Presentation Overview

- *ThO_2-UO_2 fuel designed for high burnup.*
- *Steady state and transient temperature behavior of ThO_2-UO_2 fuel.*
- *Sensitivity of calculated cladding temperature during LOCA to axial heat conduction.*
- *Models for analysis of High Temperature Gas Reactors (HTGRs).*
- *Future extensions in capabilities.*
- *Conclusions*

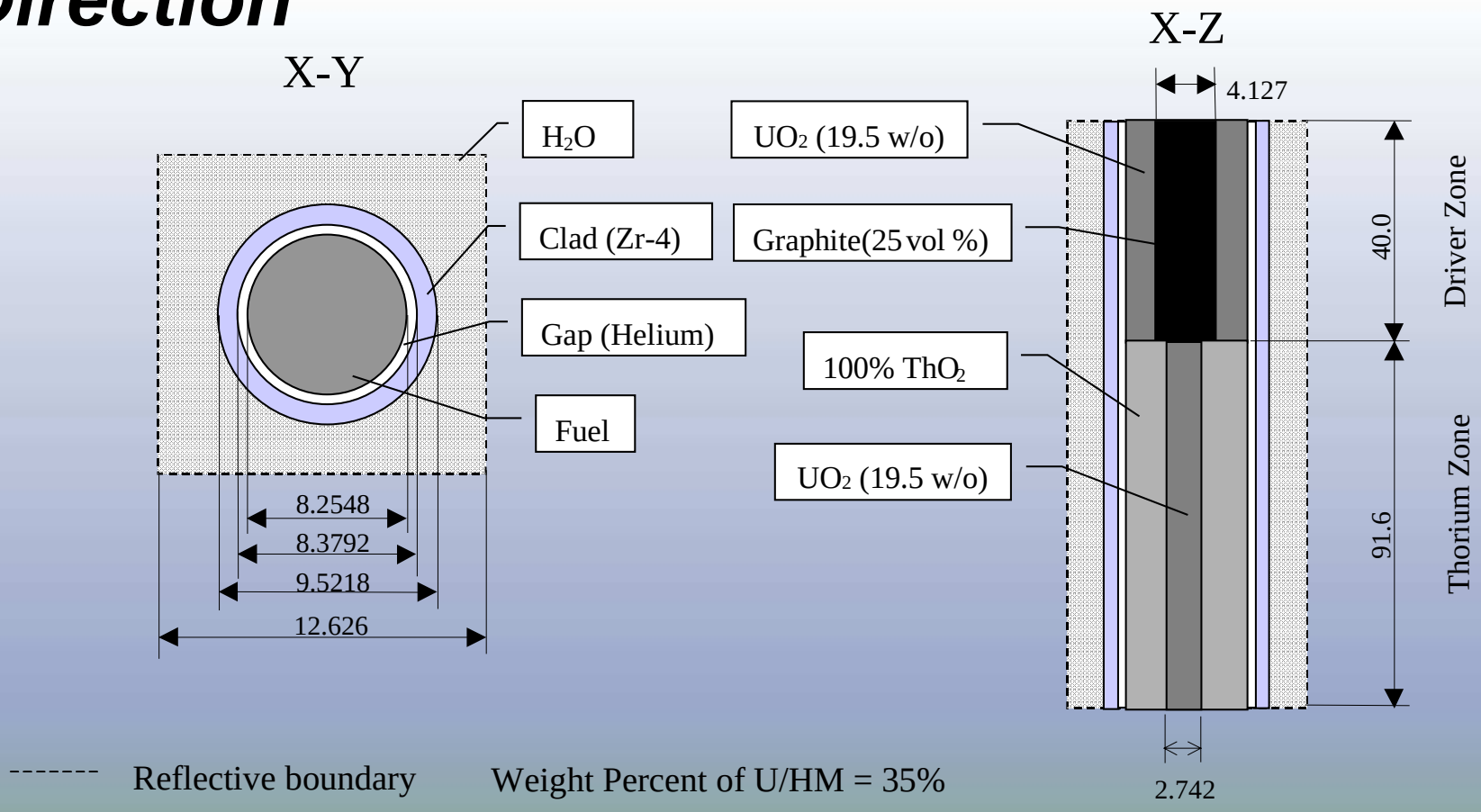
ThO_2-UO_2 fuel designs for LWRs evaluated by DOE NERI project.

- *Collaboration of INEEL, MIT, Framatome, KAERI, and others*
- *Evaluate ThO_2-UO_2 fuel designs with respect to economics, proliferation resistance, safety, and long term disposal.*
- *Evaluate fuel designs for burning weapons grade Pu and reactor grade Pu.*

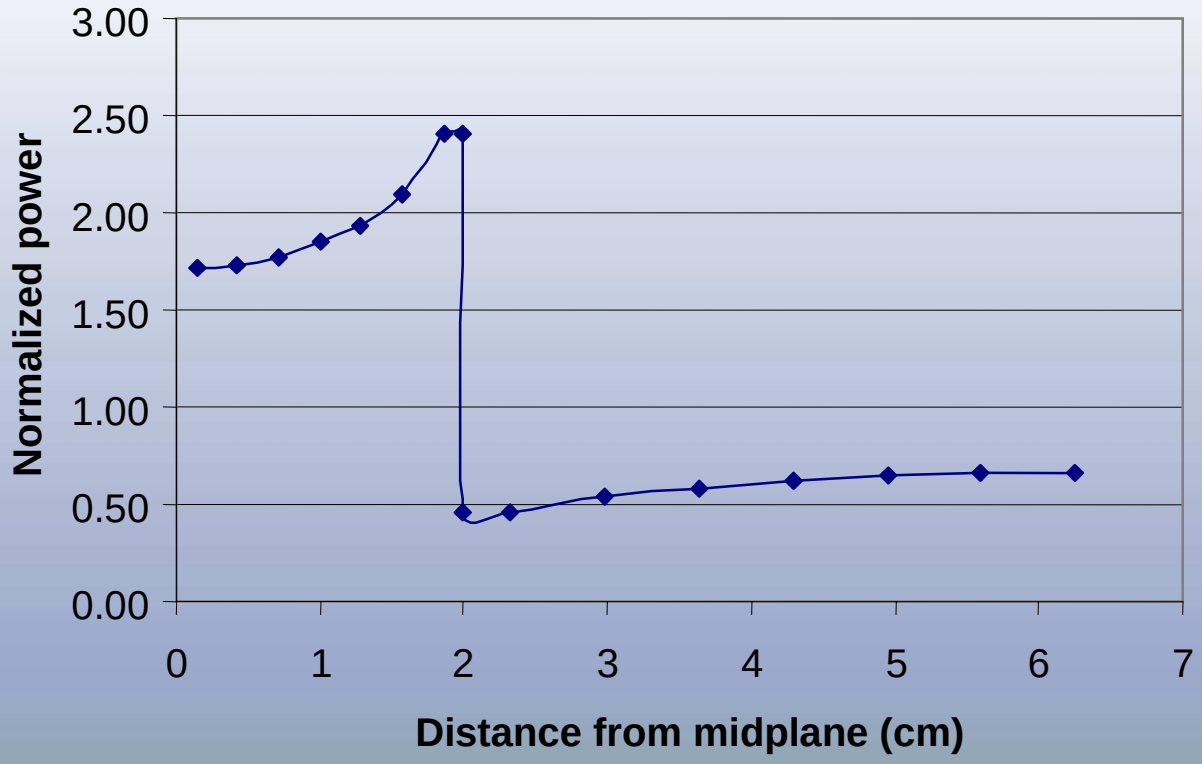
Models put into SCDAP/RELAP5-3D© for wide range of fuel designs and operating conditions.

- *Representation of fuel composition varying in radial and axial direction.*
- *Moving fine-mesh for calculation of 2-D axial-radial heat conduction during reflood period of LOCA.*
- *Models for fuel-cladding interface pressure and gap conductance.*
- *Account for radial power profile in fuel rod varying in axial direction for high burnup fuel rods.*
- *Initial fuel rod conditions obtained by link with FRAPCON-3 steady state fuel analysis code.*

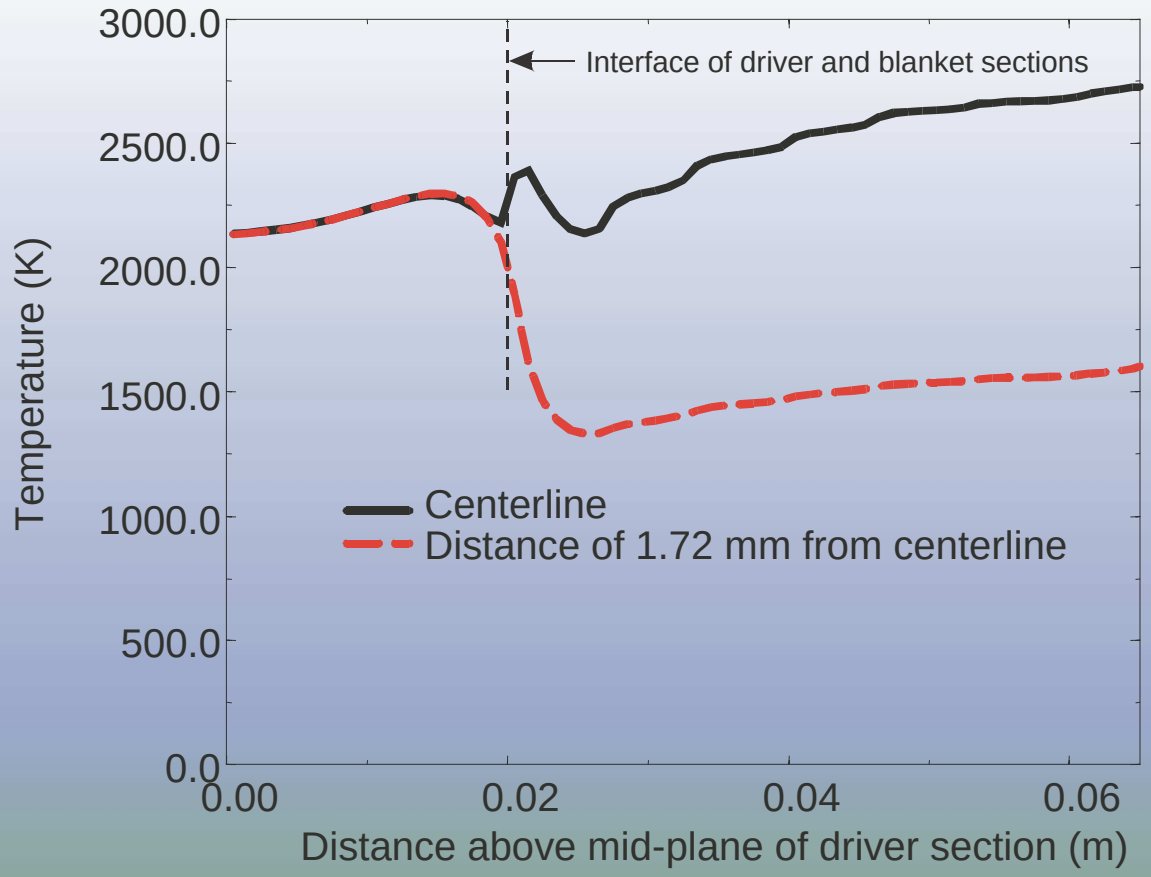
High Burnup for ThO_2-UO_2 Fuel Requires Composition Varying in Axial and Radial Direction



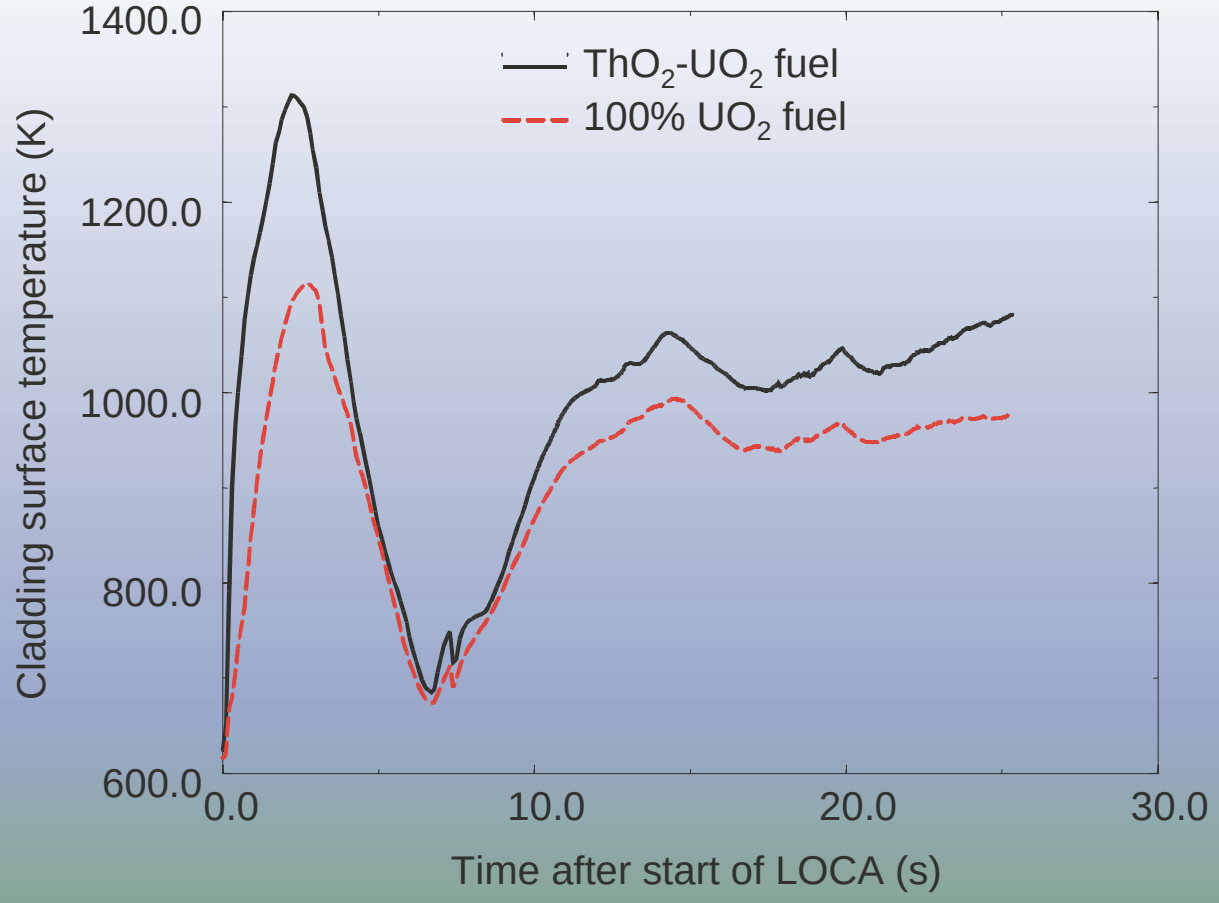
Power distribution in heterogeneous fuel varies sharply in axial direction.



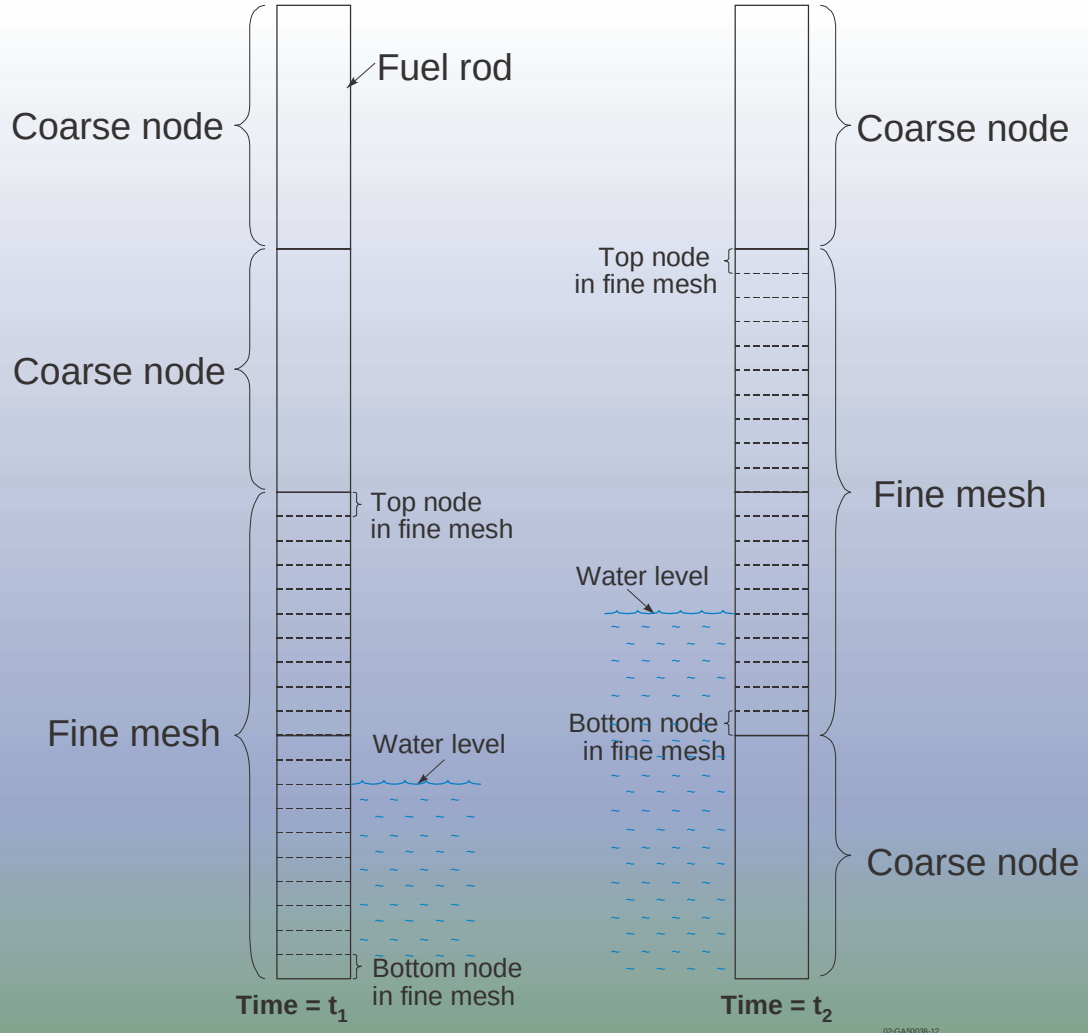
Axial node spacing of 1 mm used to calculate steady state 2-D temperature distribution in heterogeneous ThO_2-UO_2 fuel.



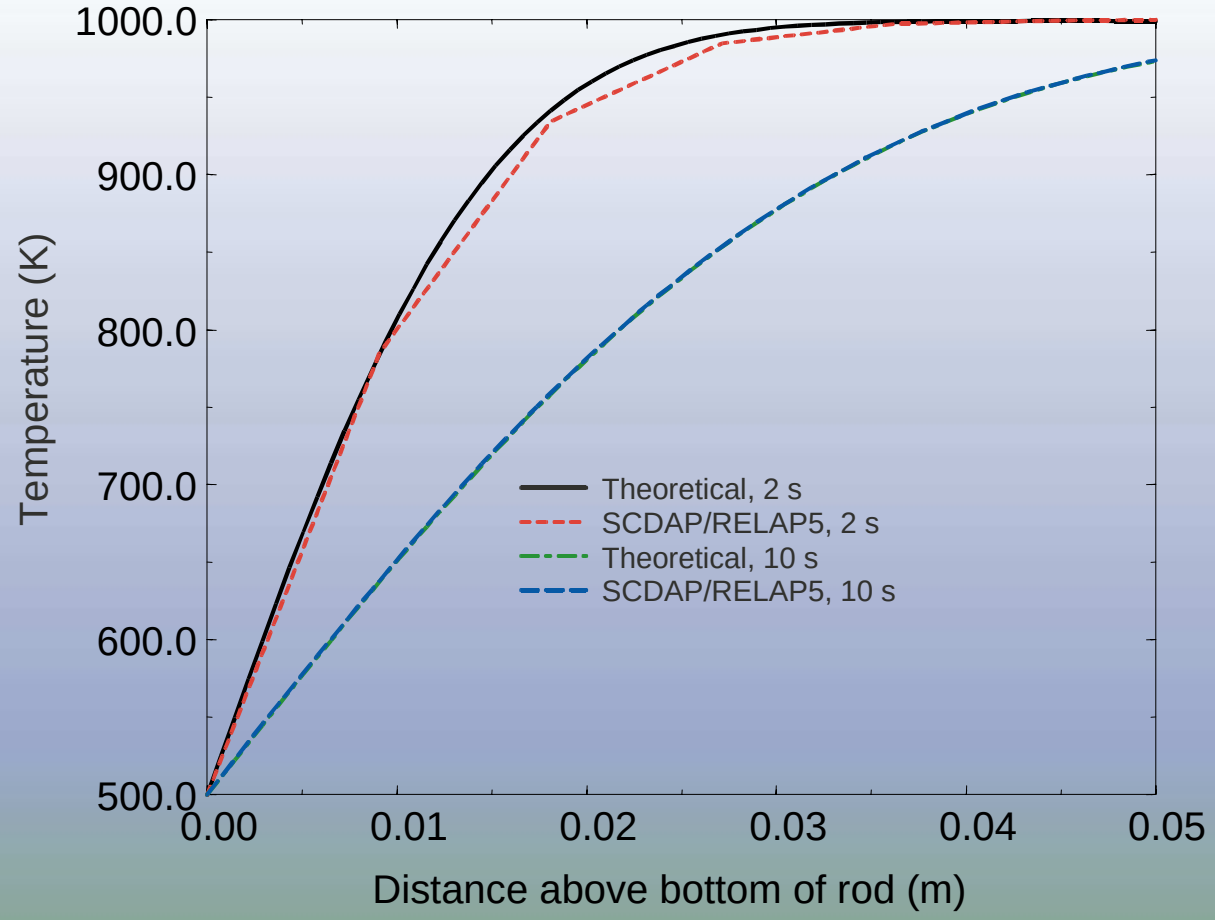
Maximum cladding temperature of ThO_2-UO_2 fuel during LOCA less than NRC limit of 1477 K.



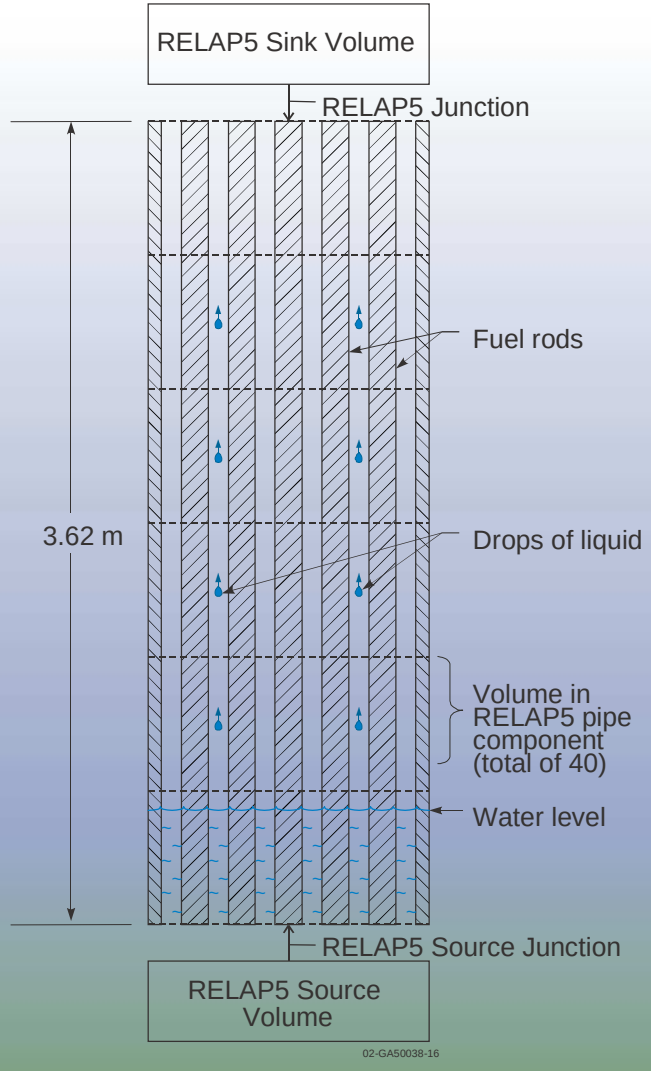
Capability for moving fine mesh implemented for LOCA analyses.



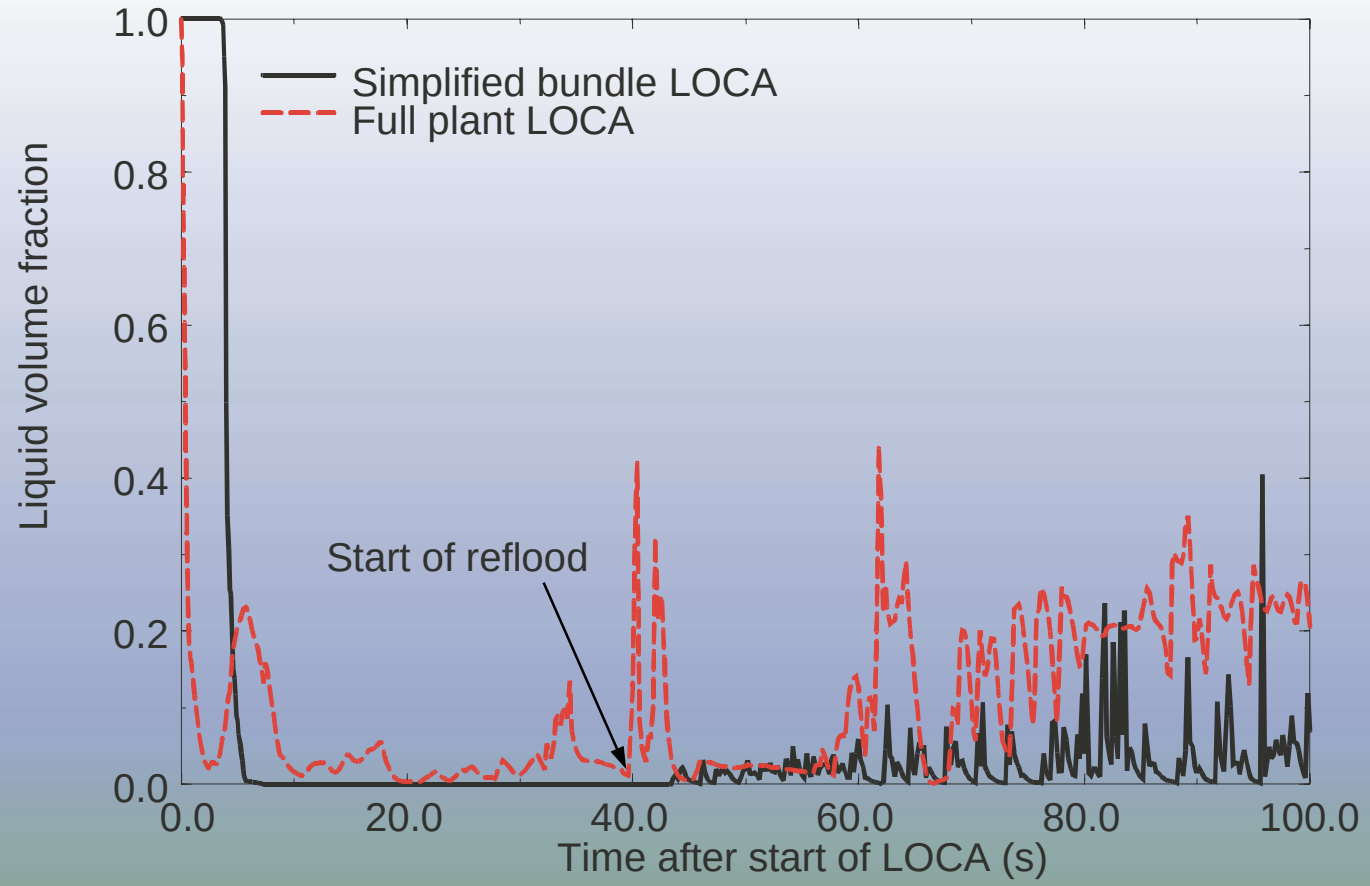
Axial node spacing of 3 mm results in good agreement with theoretical solution.



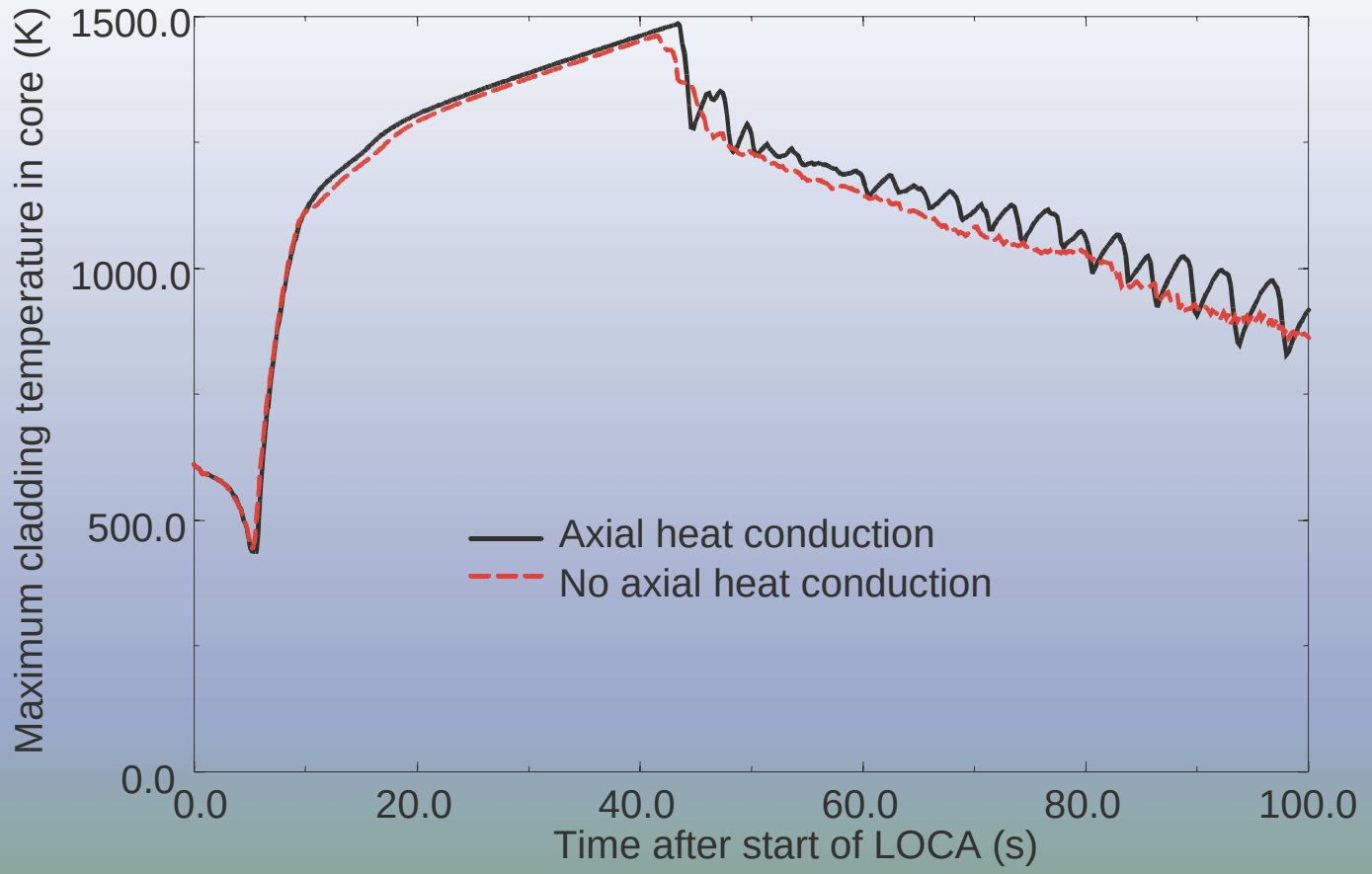
Affect of axial heat conduction during LOCA studied using simplified system.



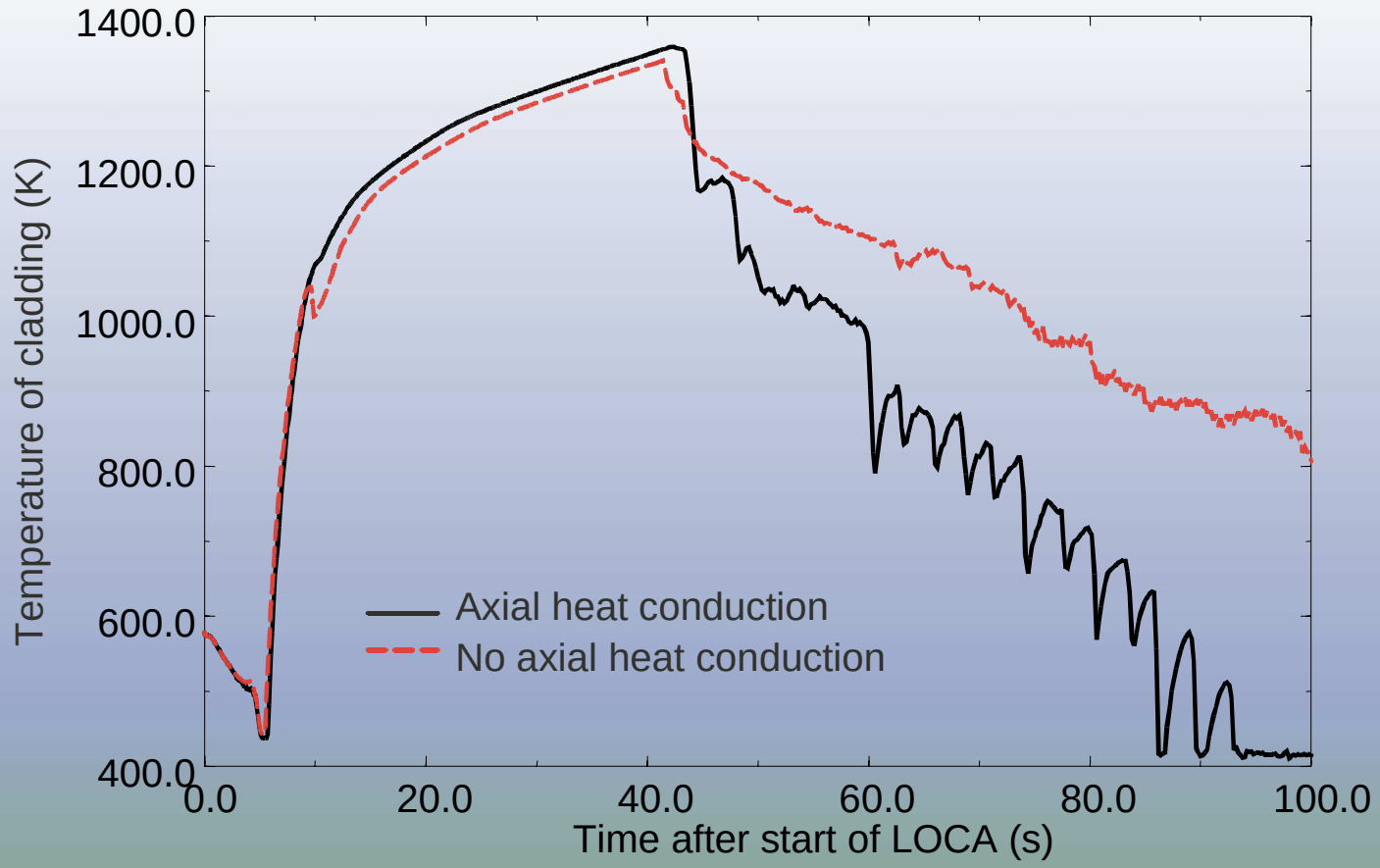
Coolant conditions in simplified bundle LOCA approximate those in reactor core of full plant.



Calculated maximum cladding temperature is not sensitive to axial heat conduction for LOCA.



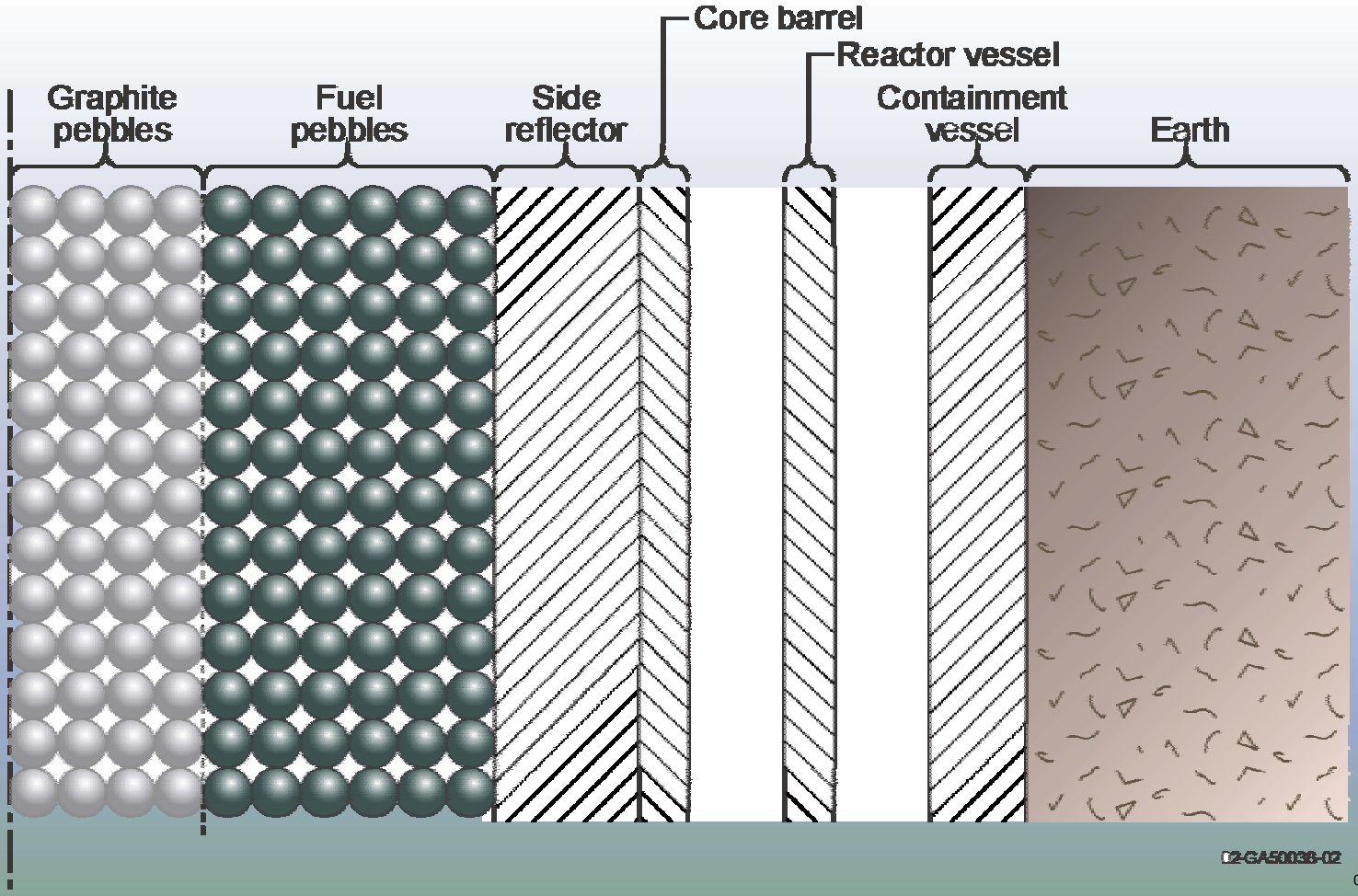
Modeling of axial heat conduction results in earlier calculation of quench at 0.81 m elevation.



ThO_2 based fuel may be useful for disposition of weapons grade and reactor grade Pu.

- *Framatome: Homogeneous mixture of 94% ThO_2 and 6% weapons grade Pu fuel can achieve burnup and safety levels of 100% UO_2 fuel.*
- *INEEL: Fuel bundle with 50% of rods composed of homogeneous mixture of 80% ThO_2, 10% recovered U and 10% reactor grade Pu can consume Pu and increase proliferation resistance.*
- *MIT: Mixed ThO_2-Pu fuel can be used for Pu disposition in conventional PWRs with some changes in reactivity control systems.*

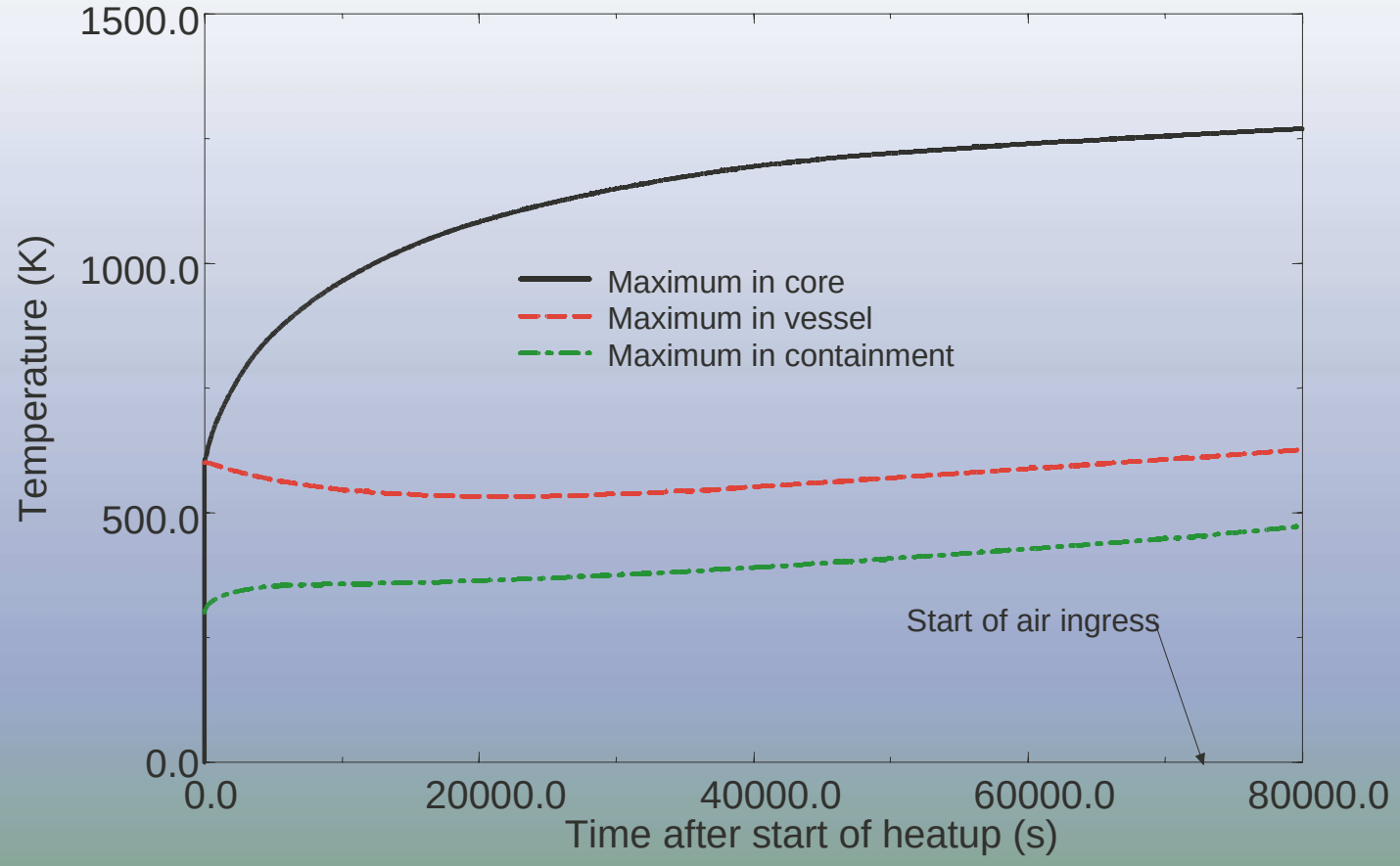
An important feature of HTGRs is their capability to be passively cooled.



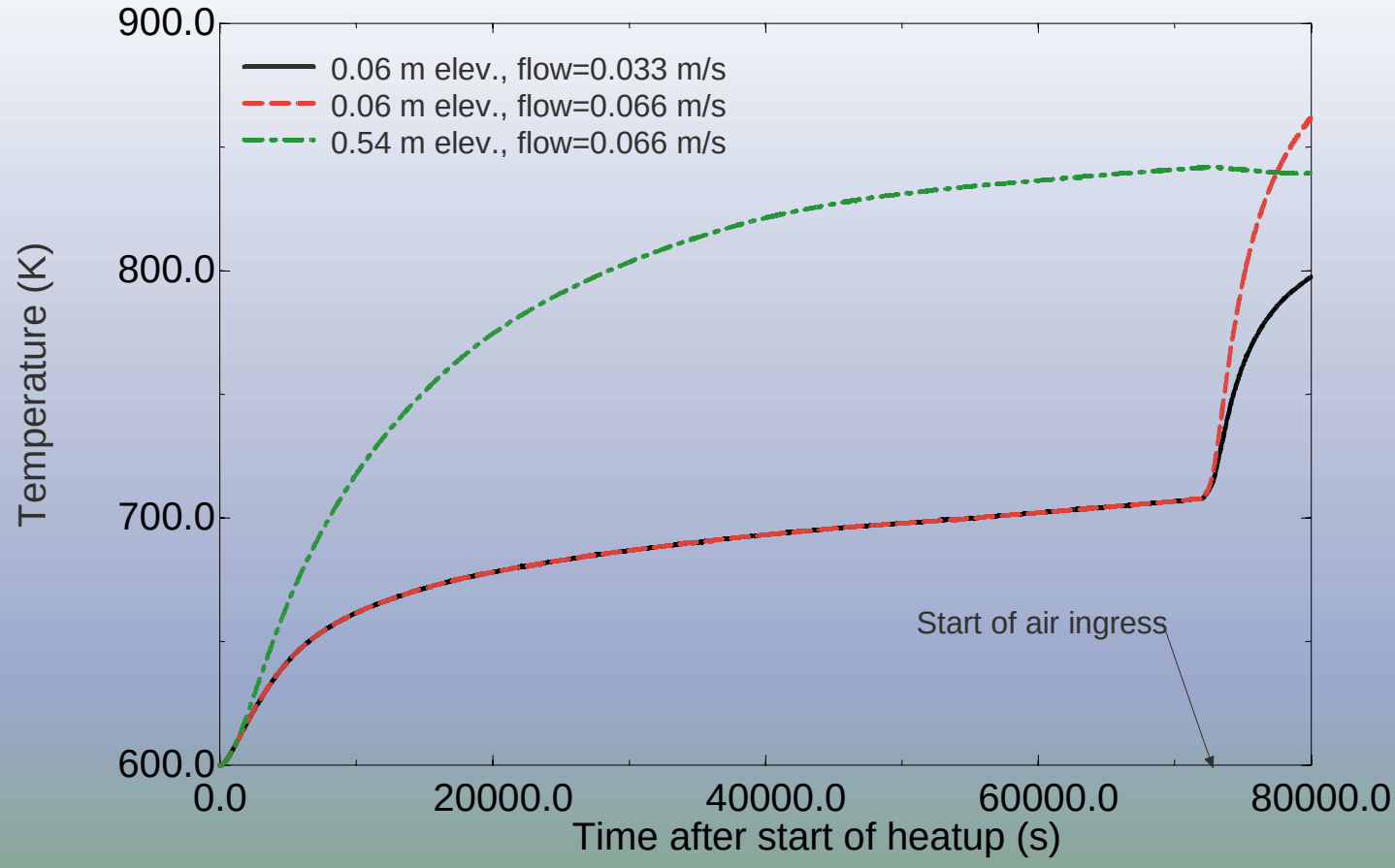
Several new models were added to SCDAP/RELAP5-3D© for the analysis of HTGRs.

- *2-D temperature distribution in pebble bed and block-type HTGRs.*
- *Flow losses and convective heat transfer in pebble bed HTGRs.*
- *Oxidation of graphite and affect of oxidation on composition of gases in reactor system.*
- *2-D heat transfer from reactor core to ultimate heat sink beyond reactor vessel for passive cooling analysis.*

Example of long term temperature distribution in core, vessel and containment for generic HTGR.



Ingress of air causes heatup of bottom part of reactor core due to oxidation of graphite.



Some Future Options for extending capabilities of SCDAP/RELAP5-3D©

- *Modeling of transient performance of ThO_2-Pu fuel rods.*
- *Modeling of mass diffusion of air from pipe break to reactor core for HTGRs.*
- *Assessment and application of HTGR capabilities.*
- *Corrosion, fission gas release, convective heat transfer and structural behavior models for fuel rods in supercritical pressure water reactors.*
- *Fission gas release and structural behavior in metallic fuel in metal-cooled reactors.*
- *Modeling of fission product transport.*

Conclusions

- *Heterogeneous ThO_2-UO_2 fuel has satisfactory temperature behavior during large break LOCA.*
- *Maximum calculated cladding temperatures during a large break LOCA does not require modeling of axial heat conduction.*
- *ThO_2 fuel may provide framework for economical and safe burnup of Pu.*
- *Capability for analyses of HTGRs has been implemented into SCDAP/RELAP5-3D©.*
- *Future development of SCDAP/RELAP5-3D© aimed at enabling the code to perform transient analyses of wide range of Generation IV reactors.*