Analysis of Transients in an Actinide Burner Reactor Cooled by Forced Convection of Lead Bismuth

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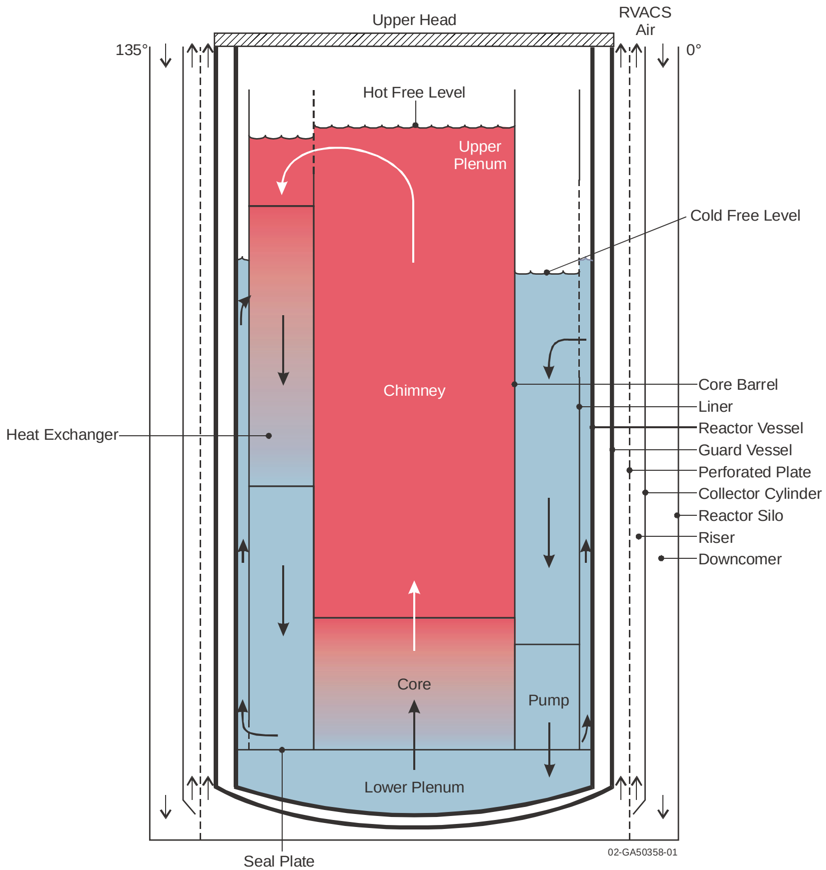
Introduction

- *The INEEL and MIT are investigating the potential of fast reactors cooled by lead bismuth and lead*
  - *Pool reactor operating at low pressure*
  - *Passive safety characteristics*
  - *Economic advantages due to simple design, high operating efficiency, and long core lifetime*
  - *Can burn actinides created by current LWRs*
  - *Coolant is chemically inert and has a high boiling point*
  - *Candidate Generation IV design*

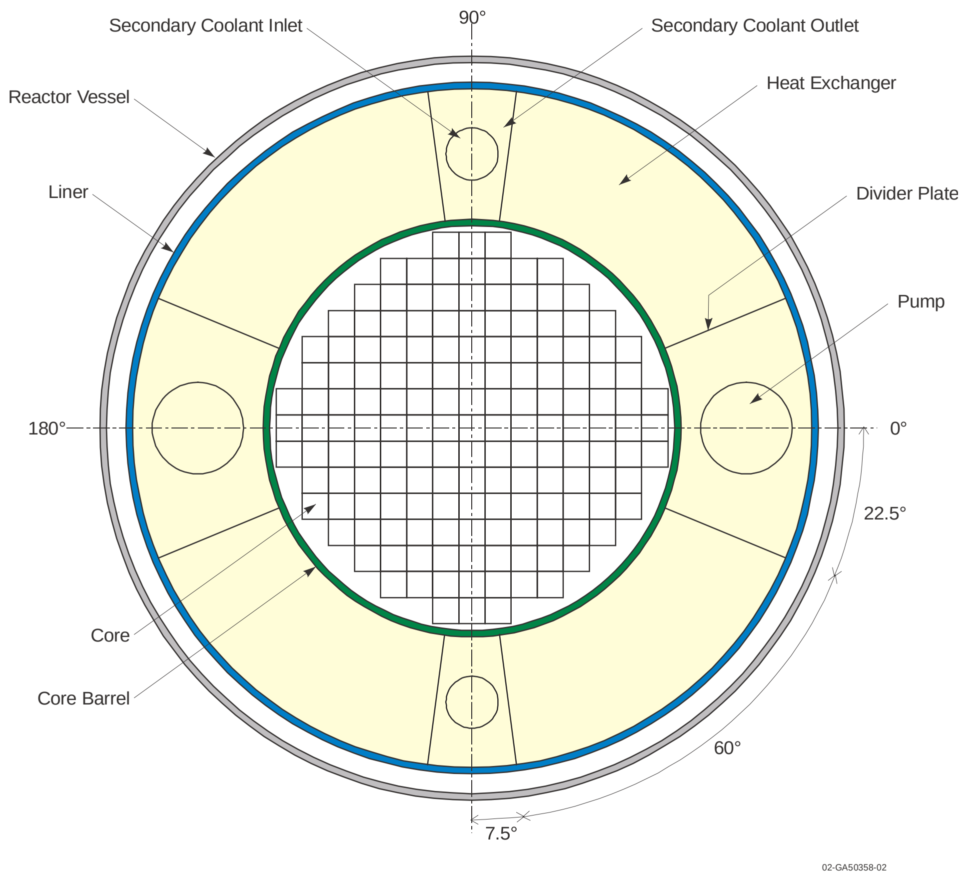
Introduction (continued)

- *MIT is optimizing the thermal-hydraulic design for steady, full-power operation*
- *INEEL is responsible for performing the thermal-hydraulic analyses of transients*
  - *The ATHENA computer code is used for system analysis*
  - *Lead-bismuth properties have been added to ATHENA*

Reactor layout



Reactor layout (top view)



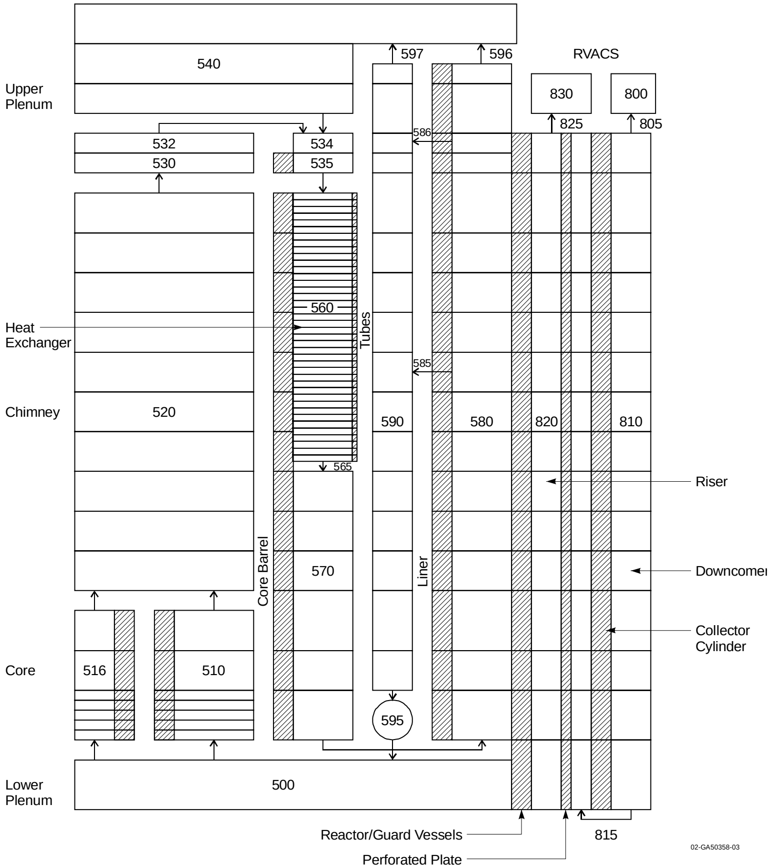
Design features enhance safety

- *Core contains 157 fuel bundles with low peaking factors and low reactivity swings over core lifetime*
- *Forced convection using centrifugal pumps, but with a tall chimney for enhanced natural circulation*
- *Dual free levels with hot and cold pools below an inert cover gas limits core voiding following a heat exchanger tube rupture*
- *Reactor Vessel Auxiliary Cooling System (RVACS) that passively removes decay heat*
- *LOCAs unlikely because of guard vessel and lack of external loops*

The ATHENA model

- *Represents both hot and average core channels*
- *Uses a detailed nodalization (40 volumes) to represent the counter-flow heat exchangers*
- *Uses mixture level tracking model in the vessel riser and pump downcomer regions*
- *Represents RVACS with a combination of heat structures, flow paths, and radiation enclosure models*
- *Uses a point kinetics model with reactivity feedback*
- *The feedwater flow was adjusted slightly to match the steady state predicted by MIT*

The ATHENA model represents all the major features of the reactor



ATHENA was used to model various thermal-hydraulic transients without scram

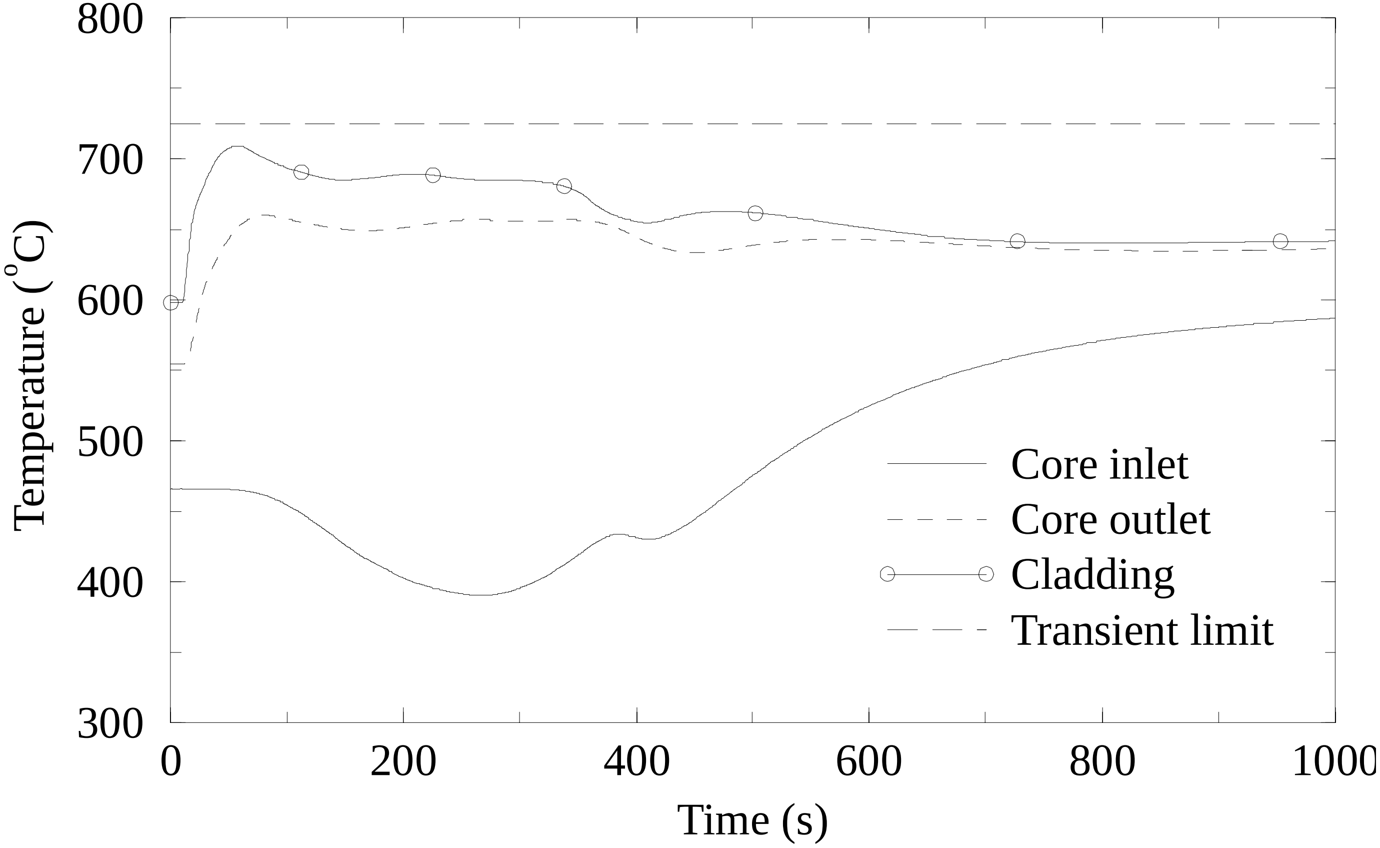
- Primary coolant pump trip*
- Station blackout*
- Step reactivity insertion*
- Heat exchanger tube rupture
- Turbine stop valve closure
- Steam line break
- Loss of feedwater preheating
- LOCA in cleanup system

* Most limiting transients and described in this paper

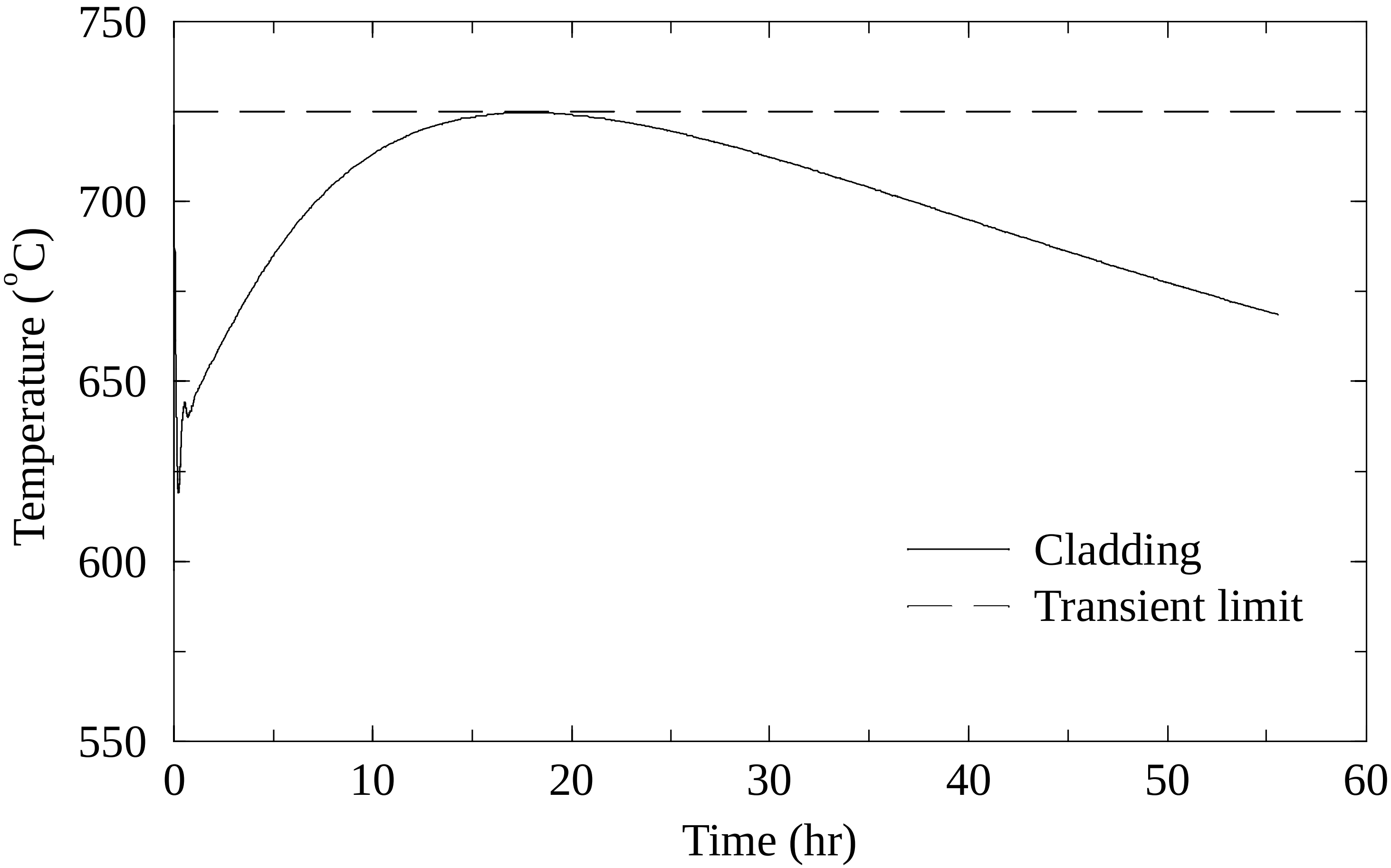
Safety margins were determined by comparing maximum calculated temperatures with limiting values

- *Fuel rod cladding* *725ºC*
- *Fuel* *1000ºC*
- *Guard vessel* *750ºC*
- *For the analyzed transients, the cladding temperature was always the most limiting parameter*

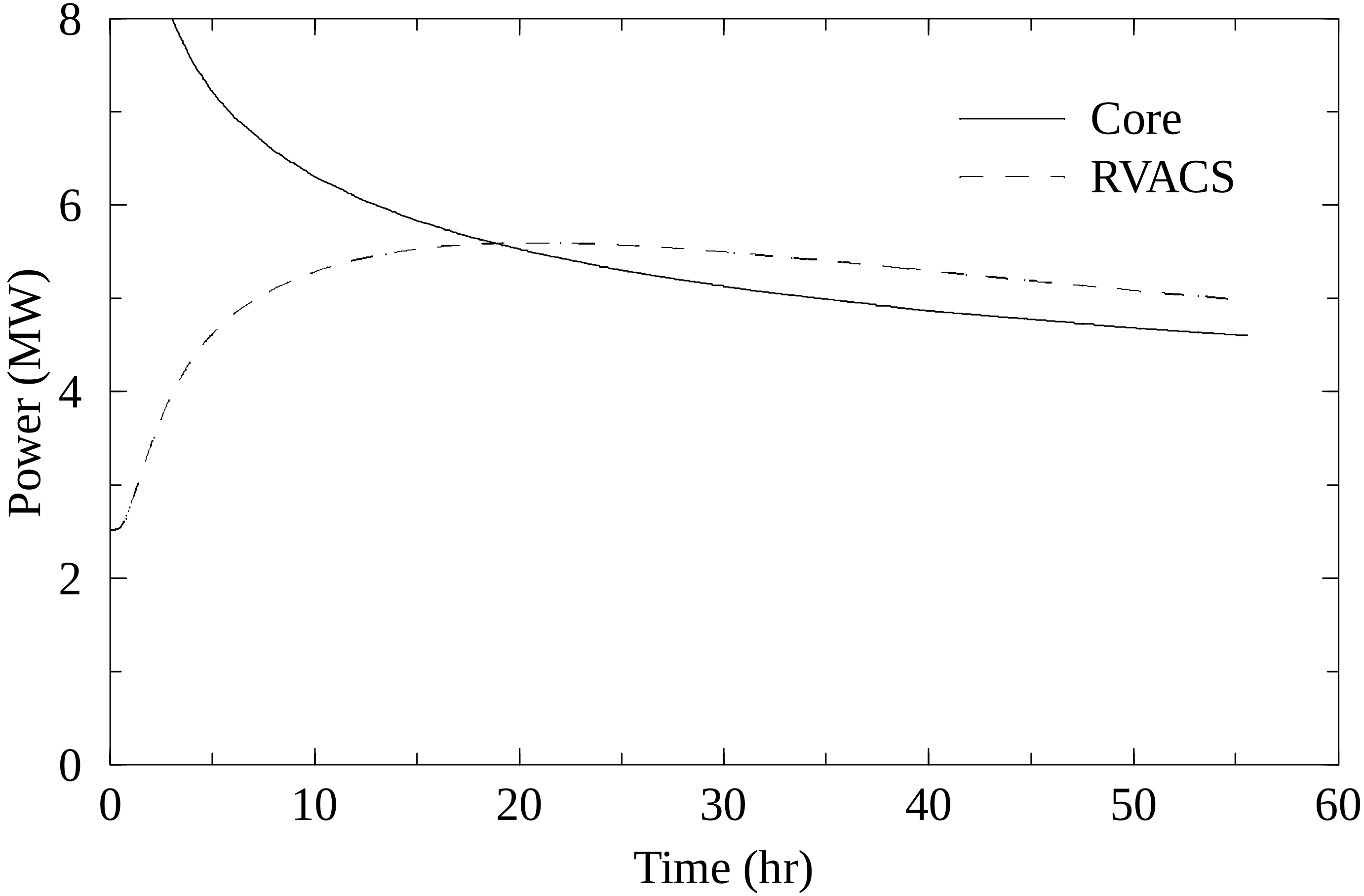
Cladding temperatures remained below the transient limit following a trip of the primary coolant pumps



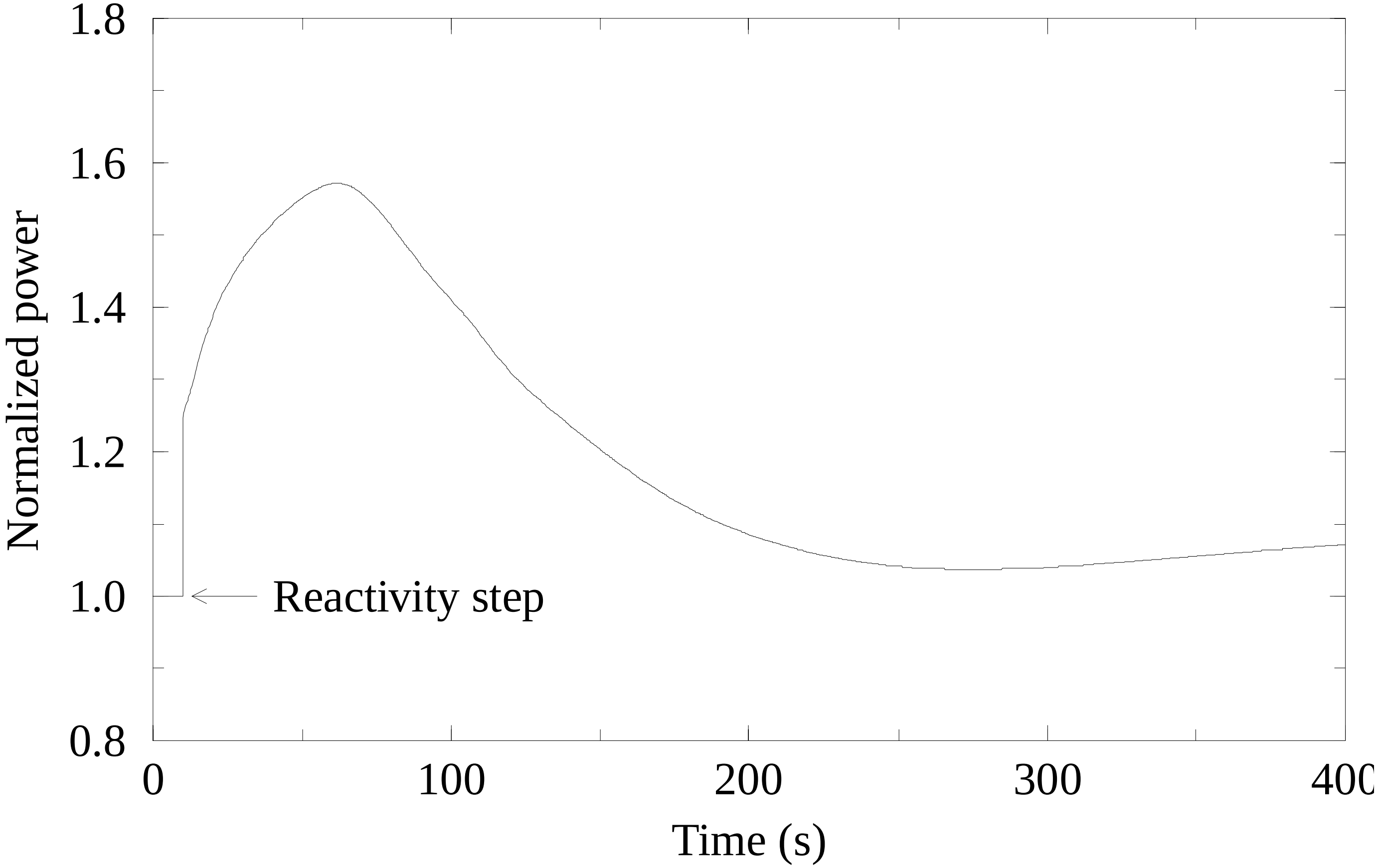
The cladding temperature reached the transient limit during a station blackout



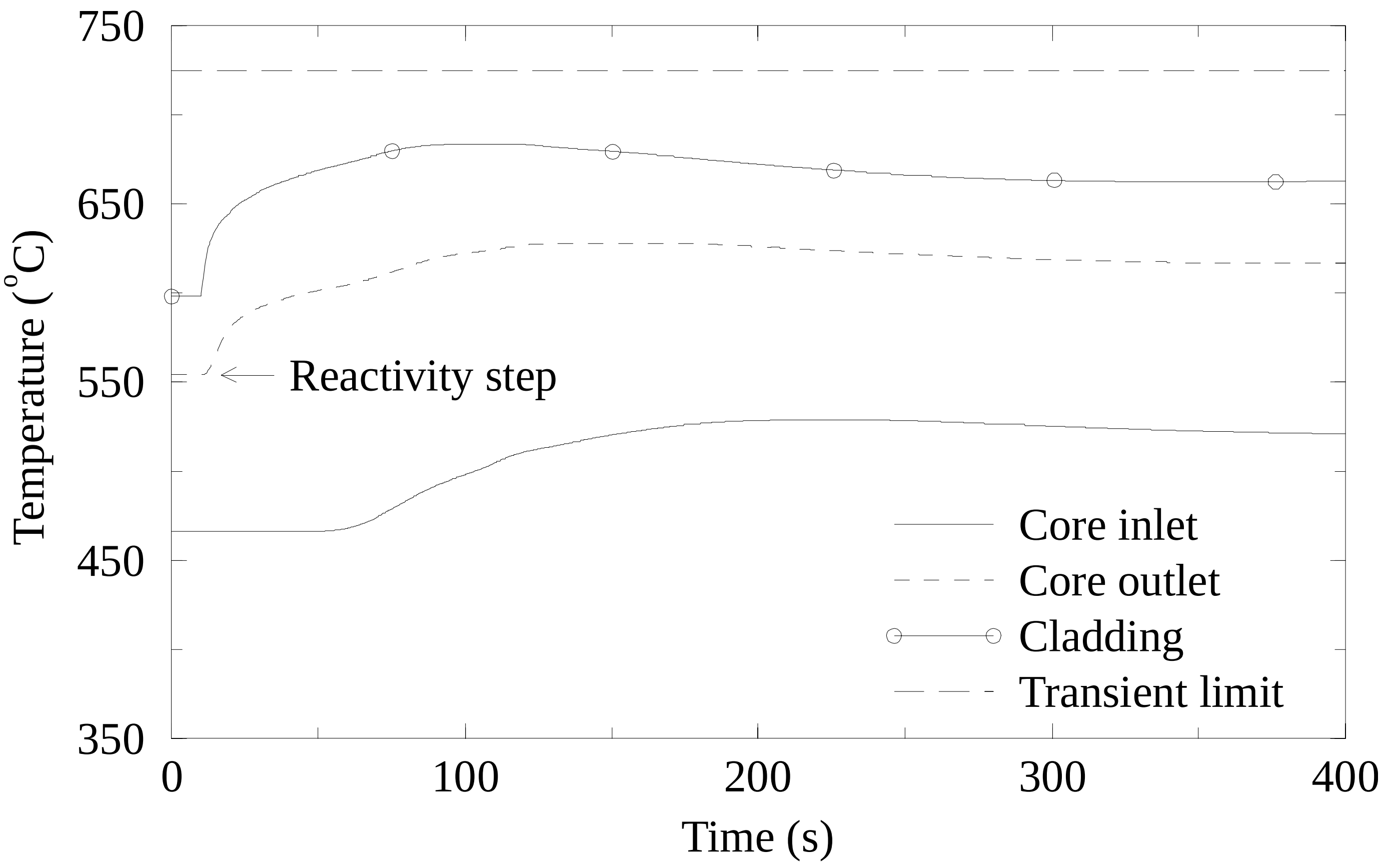
The RVACS was able to remove the decay heat during a station blackout



Reactivity feedback limited the effects of a 0.2$ step reactivity insertion



The cladding temperature remained below the limit following the 0.2$ step reactivity insertion



The actinide burner reactor exhibits excellent safety characteristics, even with a failure to scram

- *The maximum calculated temperatures remained below the identified limits for all transients evaluated*
- *The cladding temperature limit was more restrictive than the fuel and guard vessel temperature limits*
- *The station blackout was the most limiting transient evaluated, and resulted in two temperature peaks*
  - *The first peak occurred within the first minute and was caused by the power-to-flow mismatch following the pump trip*
  - *The second peak occurred at 18 hours and is associated with the balance between the power generated by the core and removed by RVACS*