Idaho National Engineering and Environmental Laboratory

SCDAP/RELAP5-3D©: A State-of-the-Art Tool for Severe Accident Analyses

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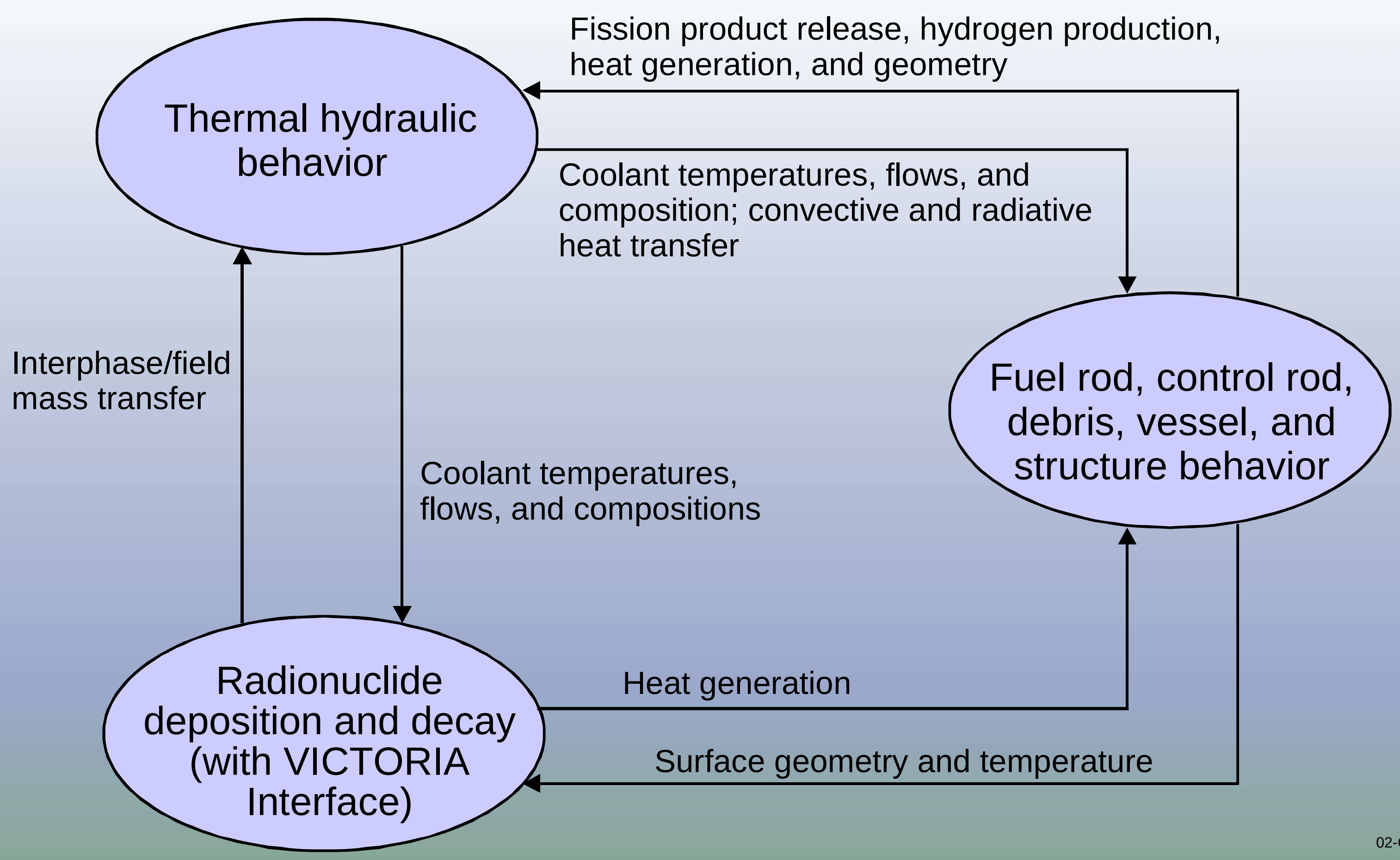
Objective and Outline

- *Objective*
  - *To highlight SCDAP/RELAP5-3D© capabilities and features**
- *Outline*
  - *Background*
  - *Comparisons between SCDAP/RELAP5-3D© and other codes*
  - *New features*
  - *Planned improvements*
  - *Summary*

** SCDAP/RELAP5-3D© & RGUI now free to IRUG members for limited time (also see http://www.inel.gov/relap5/scdap/scdap.htm)*

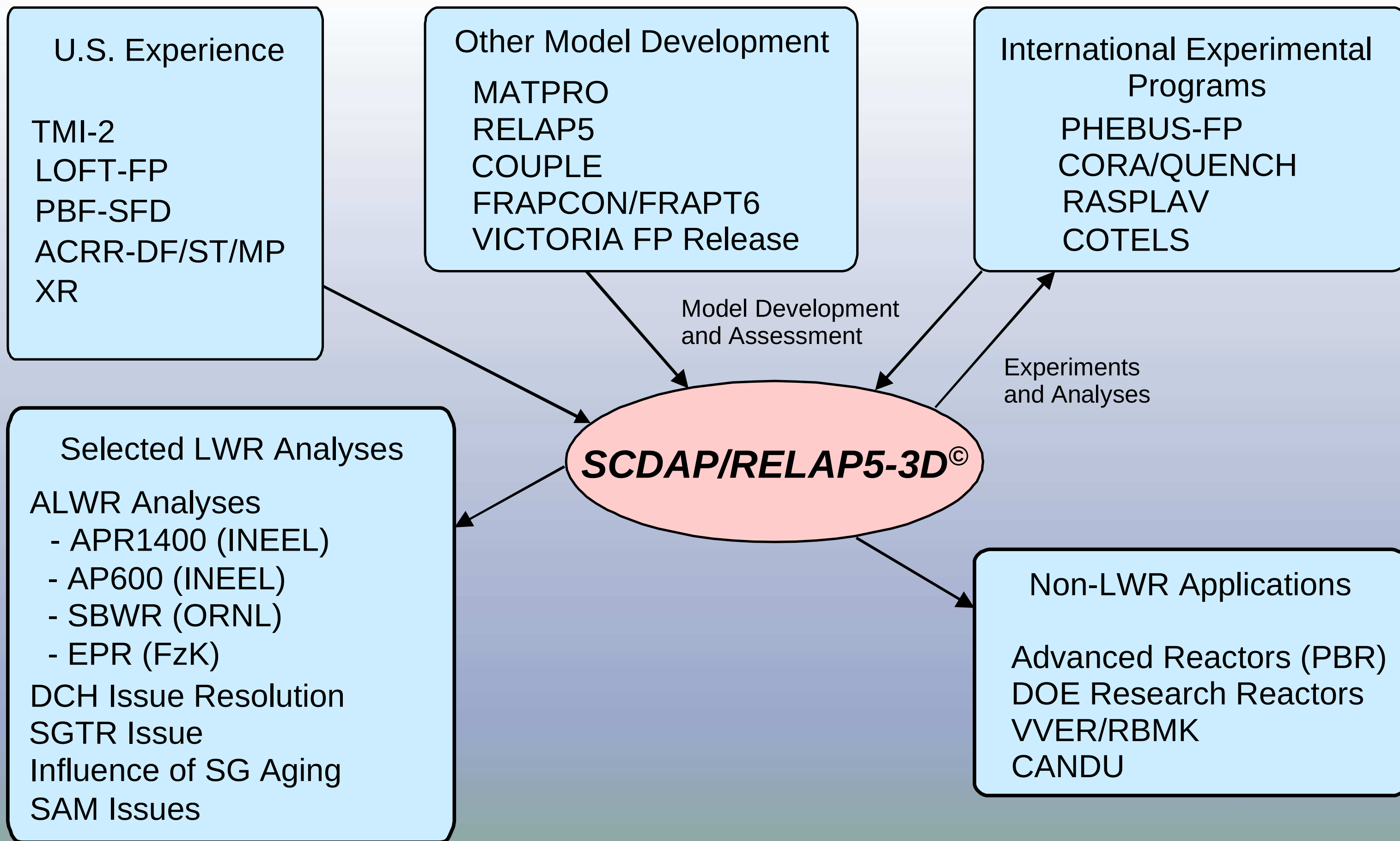
Background

SCDAP/RELAP5-3D© Simulates Wide Range of Accident Phenomena



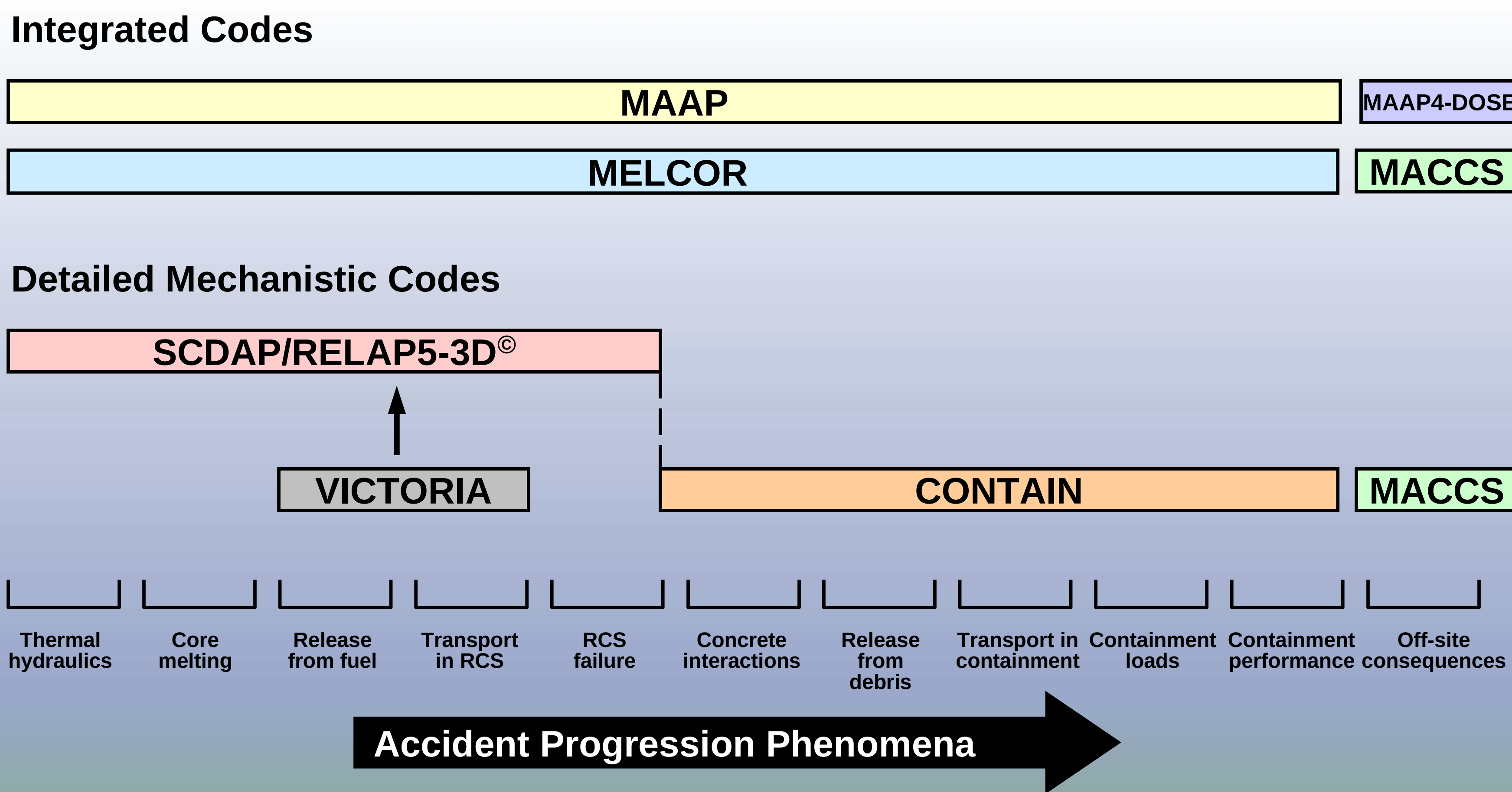
Background

SCDAP/RELAP5-3D© Embodies Understanding of Severe Accident Processes



Background

Phenomena Covered by U.S. Severe Accident Computer Codes



Background

Wide Range of SCDAP/RELAP5-3D© Analyses Completed

- Station blackout analyses supporting
  - NRC severe accident management programs
  - Resolution of direct containment heating issue
- Fuel pin failure timing analyses (PWRs and BWRs)
- Analyses of potential for SGTR
- Electrosleeving analyses for SG life extension
- Vessel lower head analyses supporting
  - AP600 design certification relative to external reactor vessel cooling (ERVC)
  - Assessment of IVR potential for NUPEC (Japan)
  - Addition of corium-to-vessel gap cooling for INSS (Japan)
  - APR1400 IVR in progress through K-INERI

S/R5-3D© Comparisons

Code Design Philosophies Differ

Code	Developer/Sponsor	Design Philosophy
SCDAP/RELAP5-3D©	INEEL / DOE / US	Detailed mechanistic models Limited to RCS Limited user parameters
MELCOR	SNL / NRC / US	Simplified or mechanistic models (depending on phenomena) Integrated RCS and containment analysis Extensive user parameters
MAAP	FAI / EPRI / US	Simplified, parametric models Integral RCS and containment analysis Extensive user dials Separate versions for each reactor type (BWR, PWR, etc.)

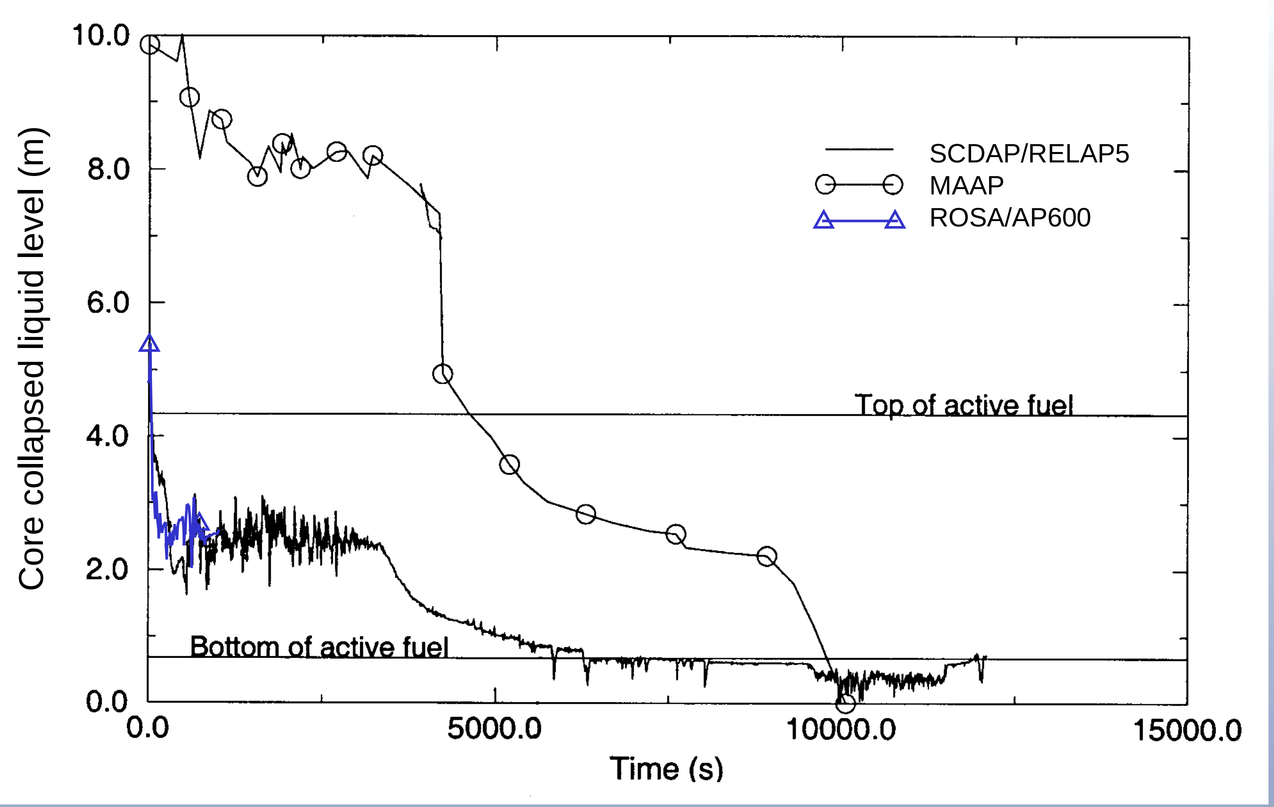
S/R5-3D© Comparisons

Code Models and Assumptions Impact 3BE AP600 Analysis Results

Phenomenon	SCDAP/RELAP5-3D©	MAAP	MELCOR
RCS Depressurization Model	Ransom/Trapp critical flow model (results consistent with ROSA/AP600 data)	Single phase critical flow model (unexplained mass retained in RCS)	Two-phase critical flow model (with user supplied discharge coefficients)
Fuel melting	At 2870 K due to eutectic formation	At 3100 K (UO_2 melting temperature)	At user-specified temperature.
Hydrogen generation	Throughout core degradation	Until first relocation	Until cladding failure temperature.
Relocation to vessel	If crust cannot support molten material	When melting temperature is predicted	When fuel melting occurs, material relocates to core plate and is retained until core plate reaches user-specified temperature.
Debris-to-vessel heat transfer	No enhanced debris cooling (model developed, data needed to validate)	Enhanced cooling from water in user-specified gaps with user-specified heat transfer	No enhanced debris cooling (model developed, data needed to validate)

S/R5-3D© Comparisons

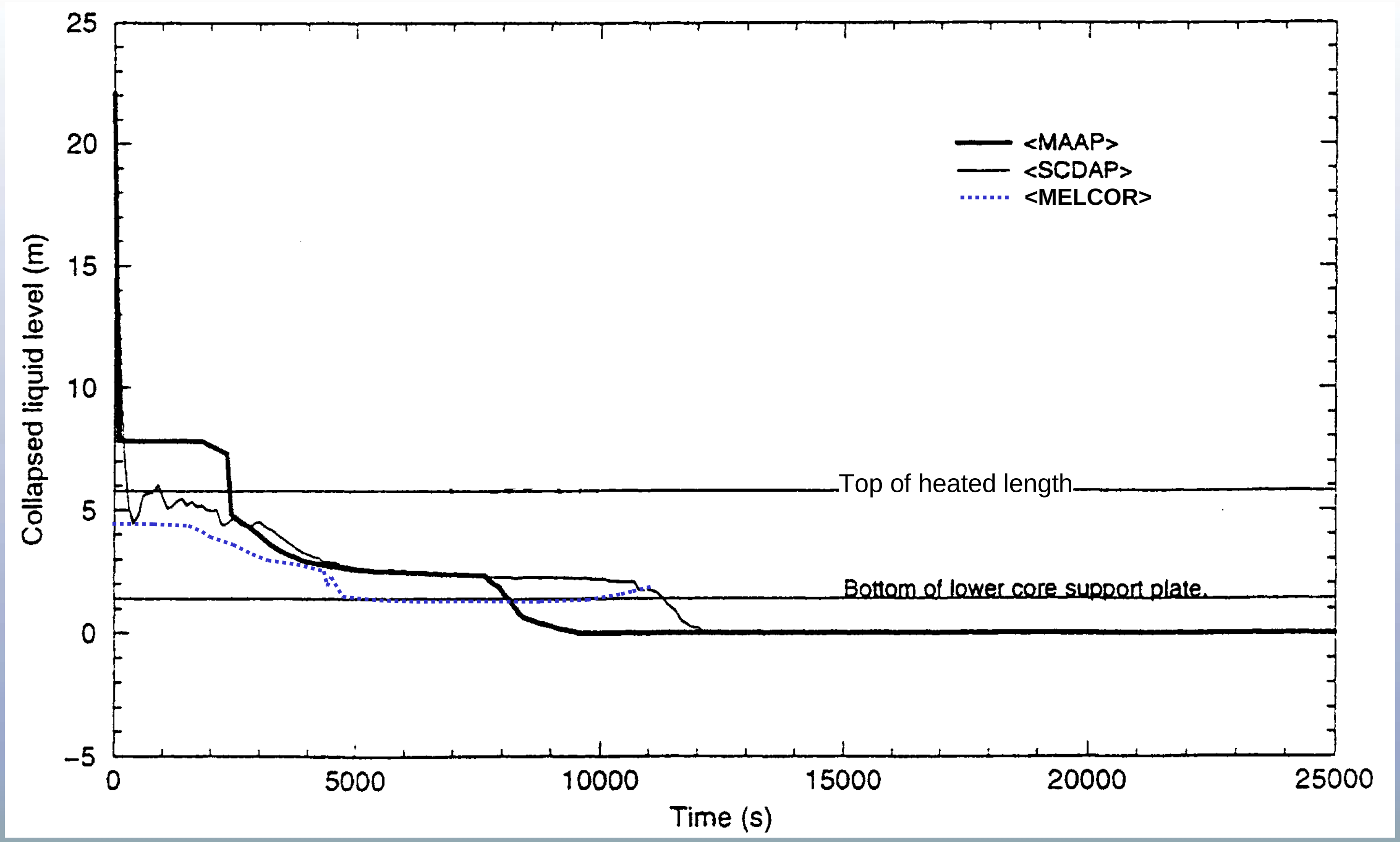
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



SCDAP/RELAP5-3D© core uncovery consistent with ROSA/AP600 data.

S/R5-3D© Comparisons

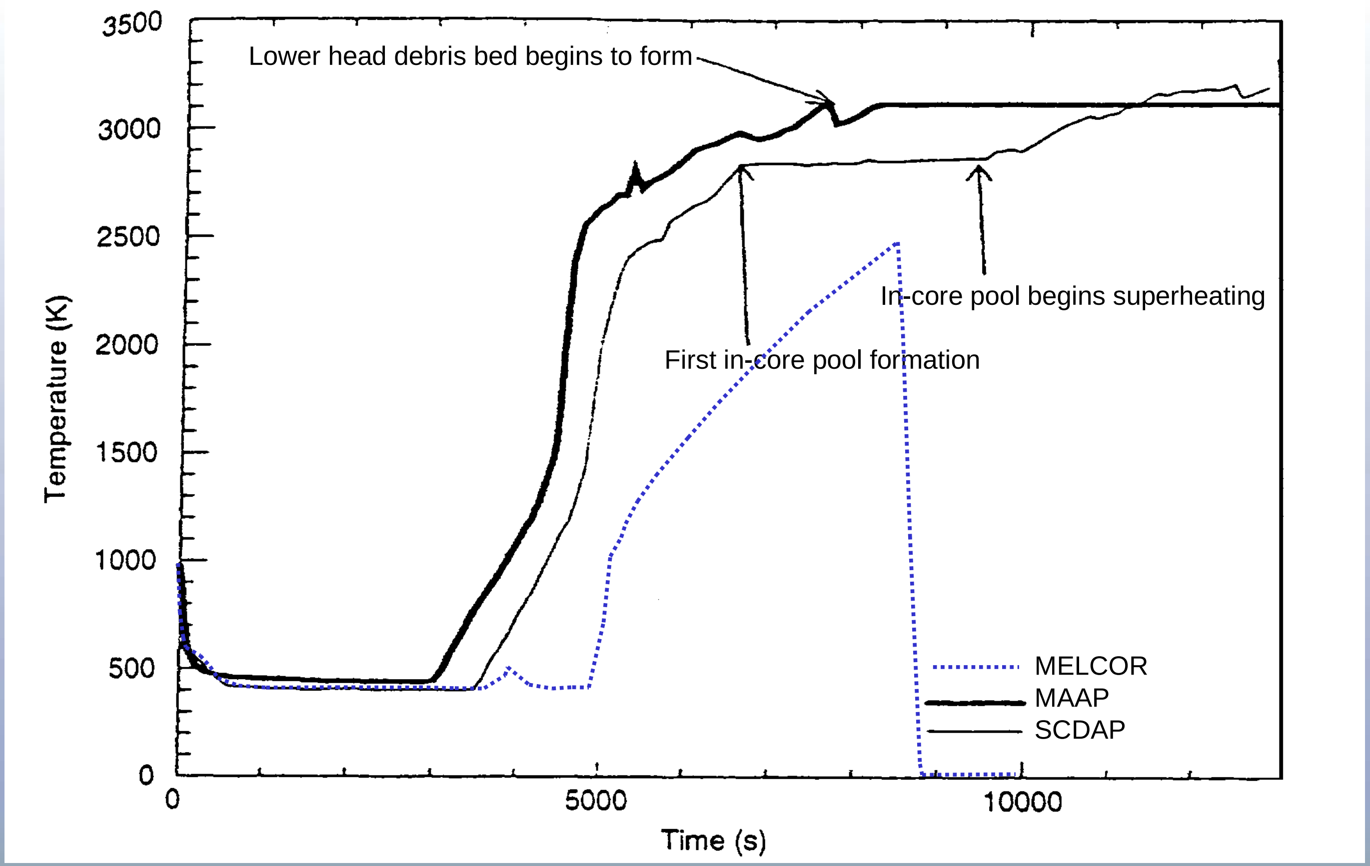
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



MELCOR shows early core uncovery.

S/R5-3D© Comparisons

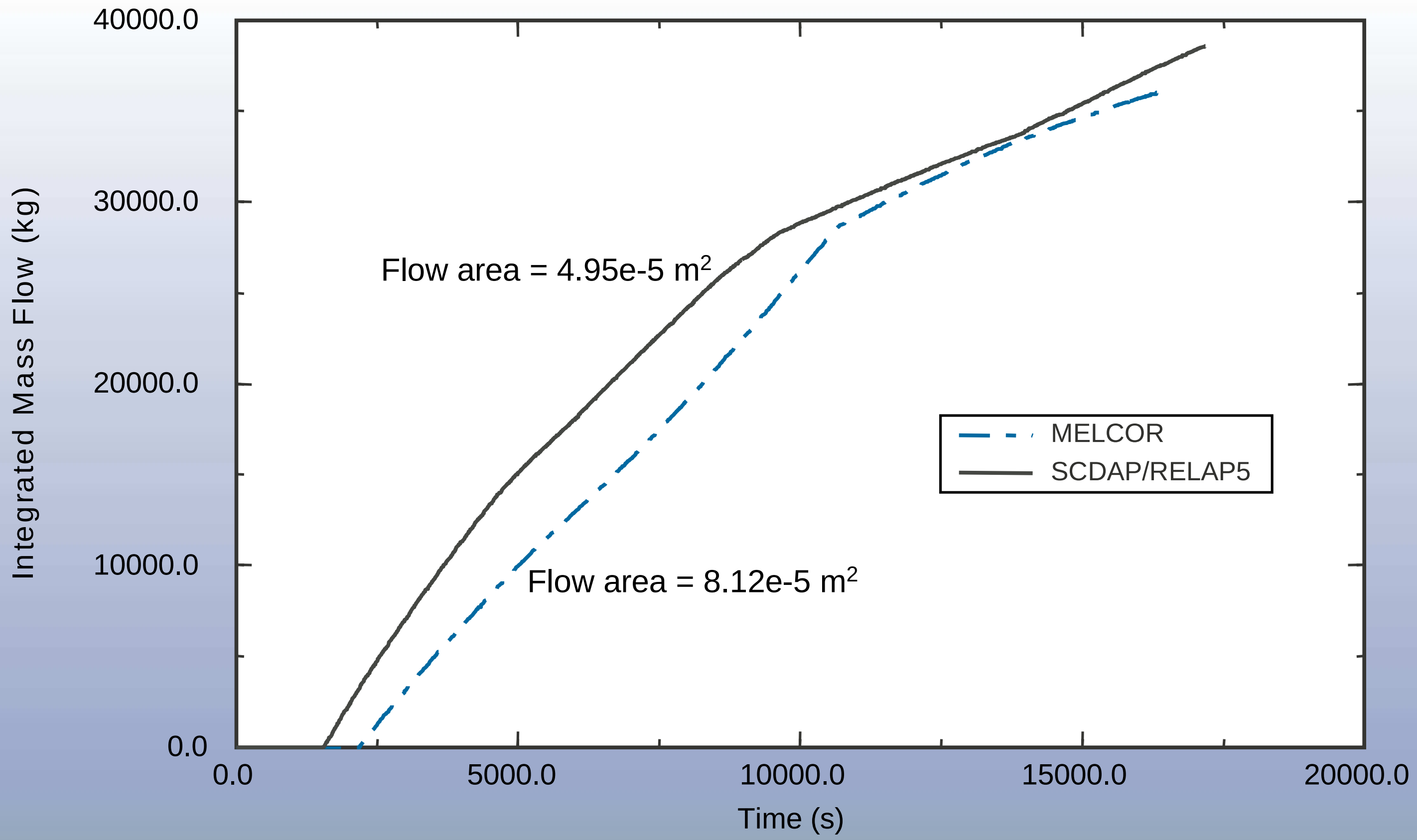
Code Models and Assumptions Impact 3BE AP600 Analysis (continued)



MELCOR shows delayed core heatup despite early core uncovery.

S/R5-3D© Comparisons

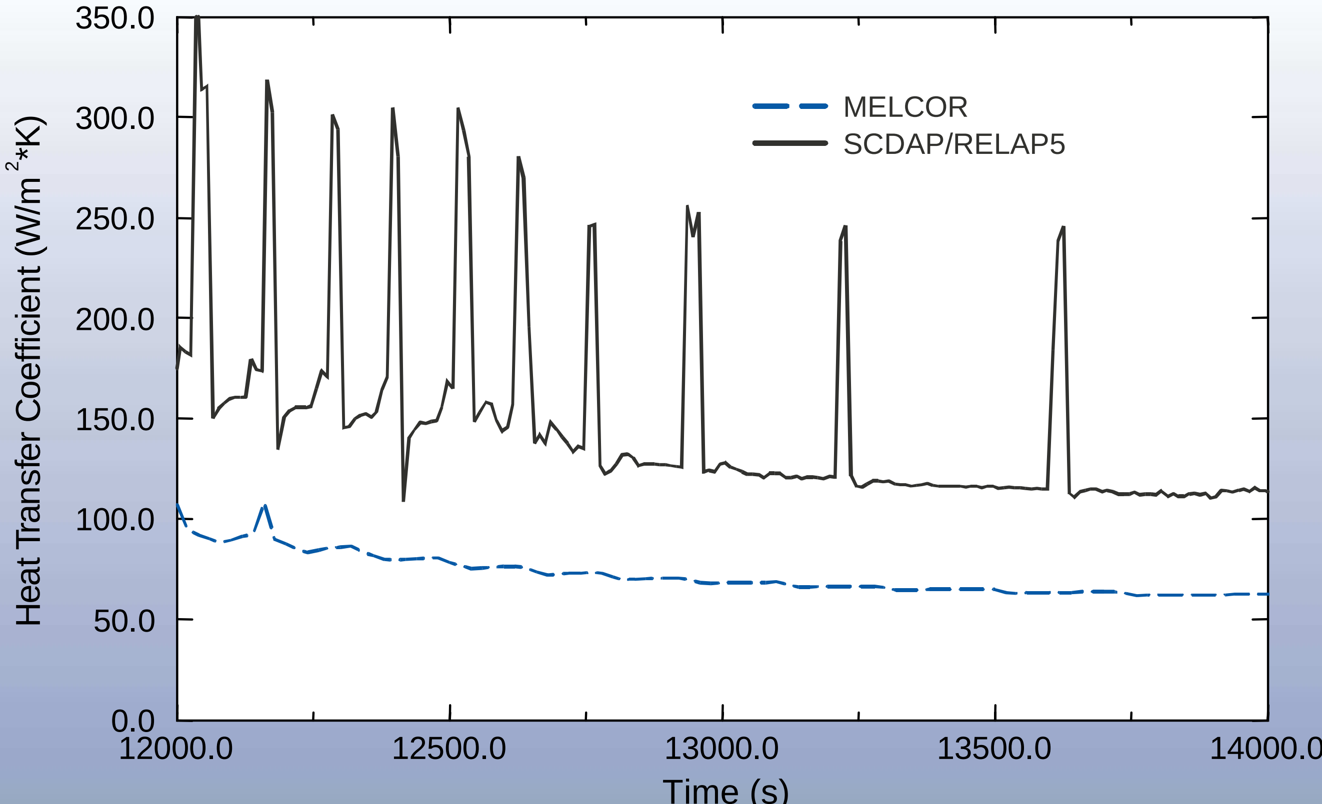
Code Models and Assumptions Impact Westinghouse PWR SBO Analysis



MELCOR requires larger flow area to match flow prediction.

S/R5-3D© Comparisons

Code Models and Assumptions Impact Westinghouse PWR SBO Analysis (continued)



Unexplained absence of heat transfer response in MELCOR.

New Features

SCDAP/RELAP5-3D© Represents Major Processes Affecting IVR

- *Molten pool natural convection heat transfer*

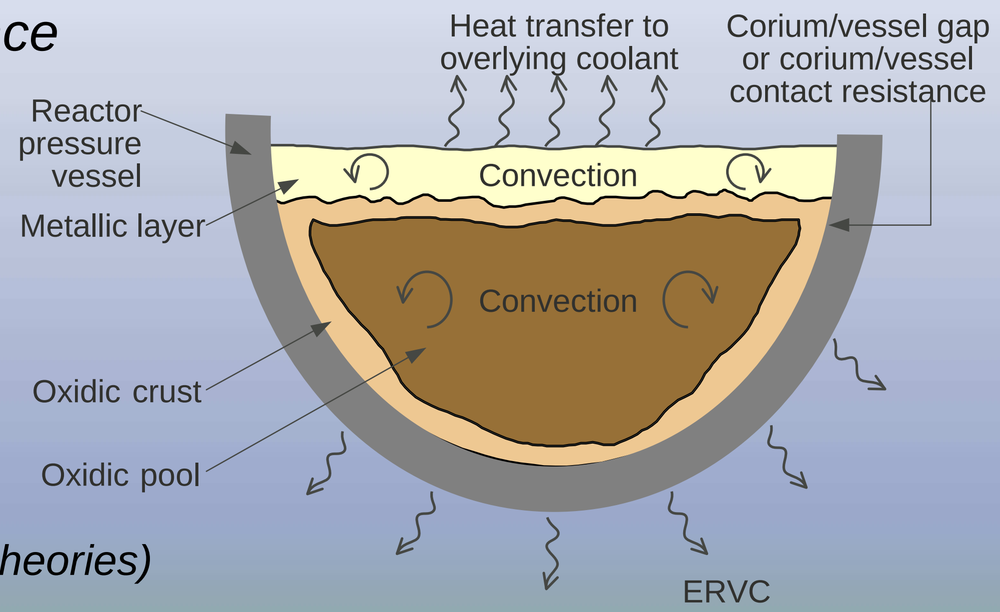
  (stratified and homogeneous options)

- *Corium/vessel contact resistance*
- *Corium/vessel gap cooling*
- *ERVC*

  (user specified heat transfer or subcooled flooding correlations)

- *Lower head failure*

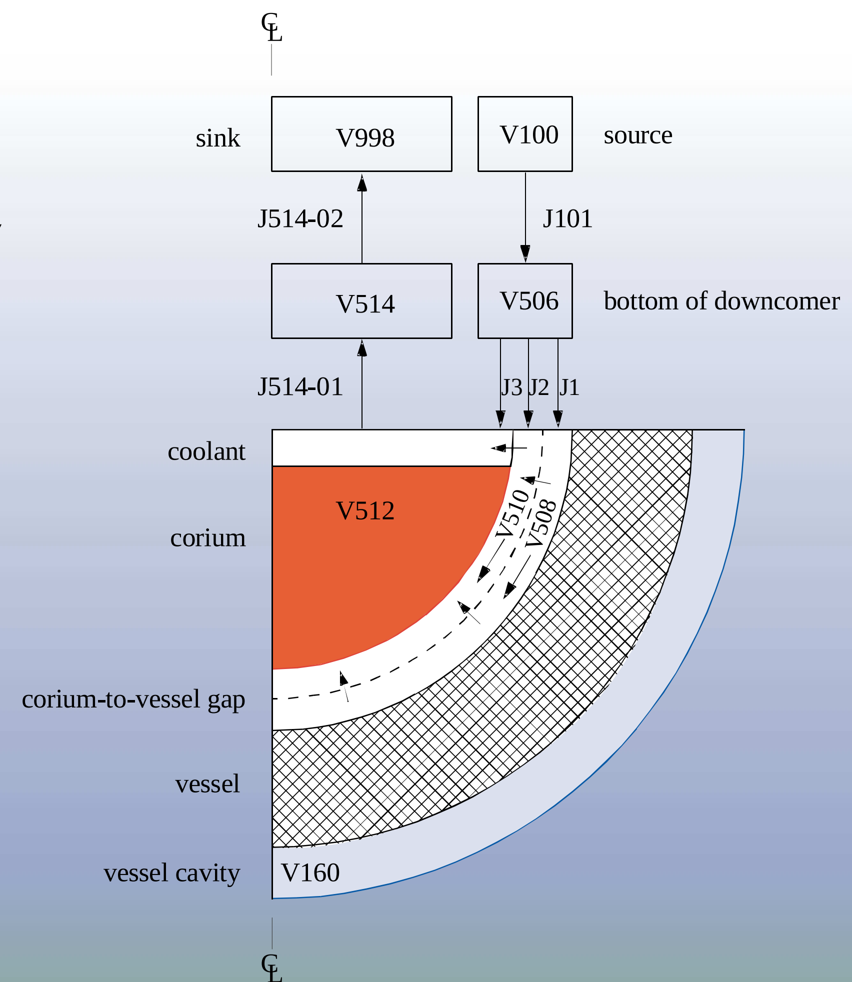
  (Larson-Miller and Manson-Haferd theories)



New Features

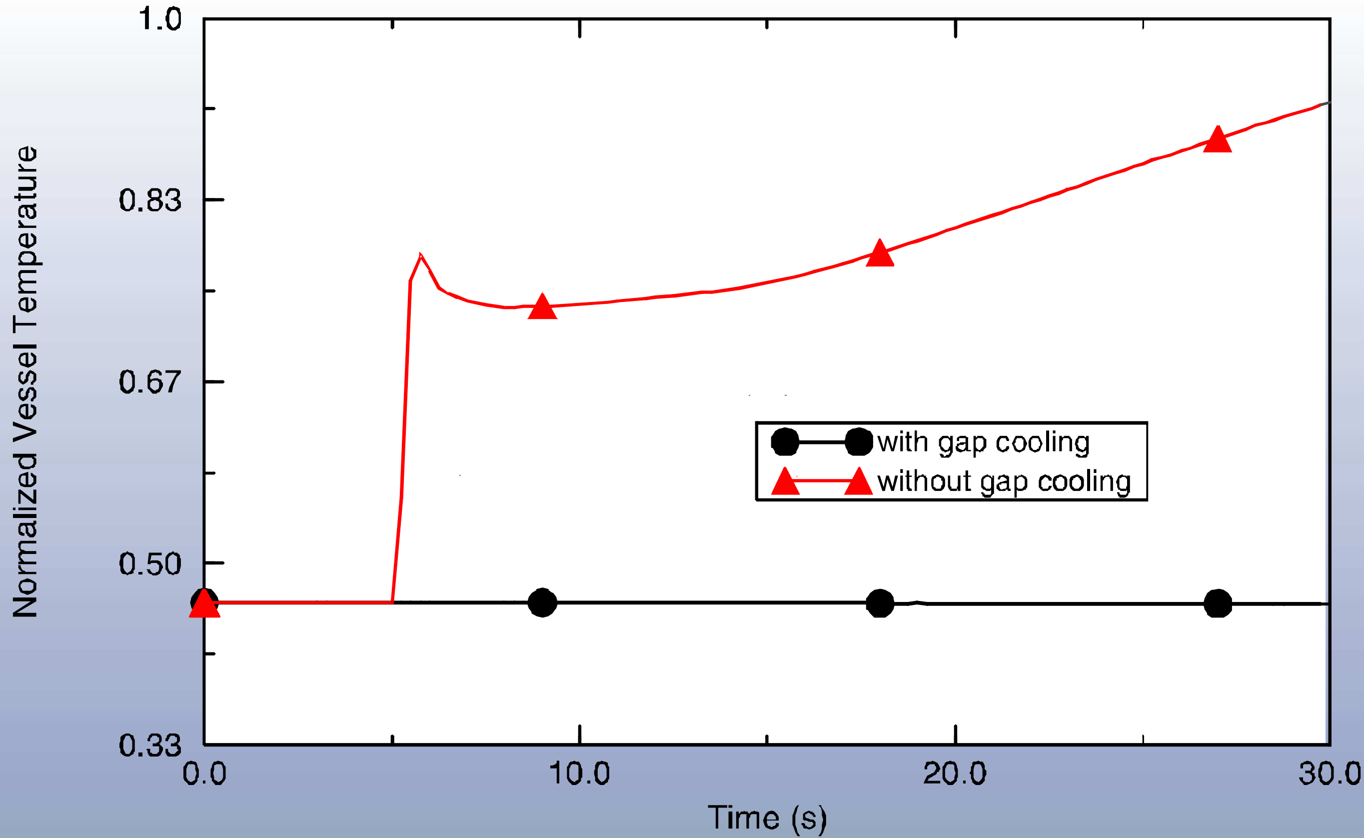
Typical Configuration Used for Corium/Vessel Gap Cooling

- *Two volume gap allowing countercurrent cooling flow*
- *Crossflow connections incorporated in finite element mesh*
- *Without impacting corium/vessel contact resistance heat transfer option*



New Features

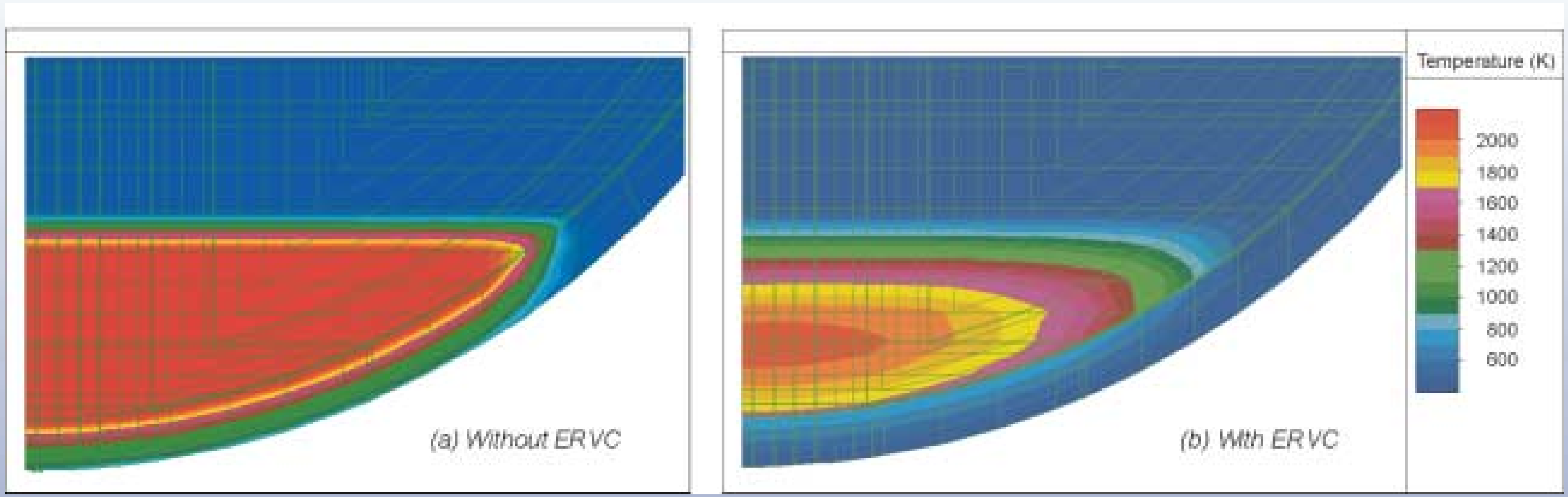
Results Indicate Corium/Vessel Gap Cooling Significant



Results currently a function of RELAP5-3D© correlations for pipe flow.

New Features

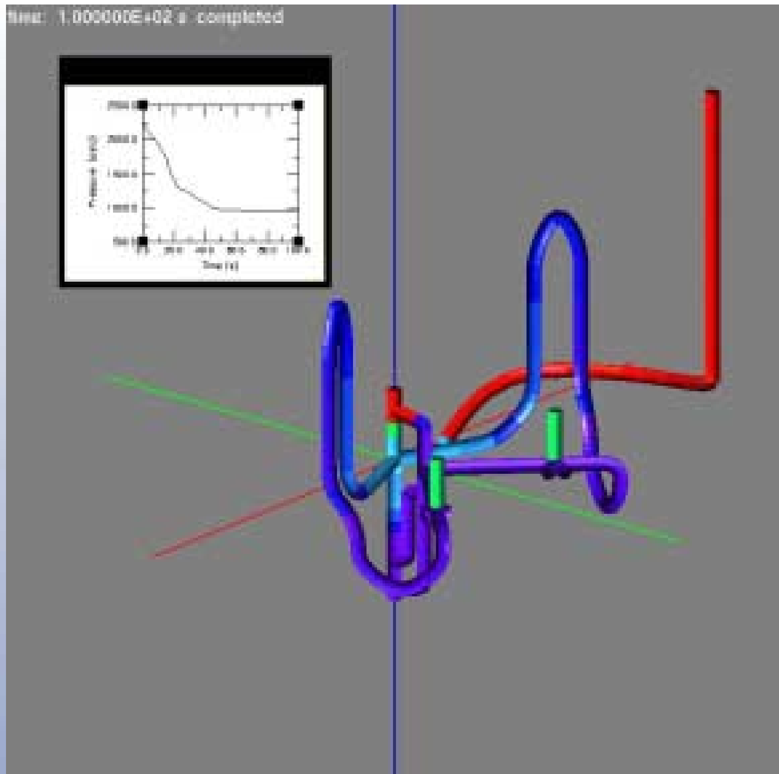
ERVC Significantly Reduces Vessel Temperatures



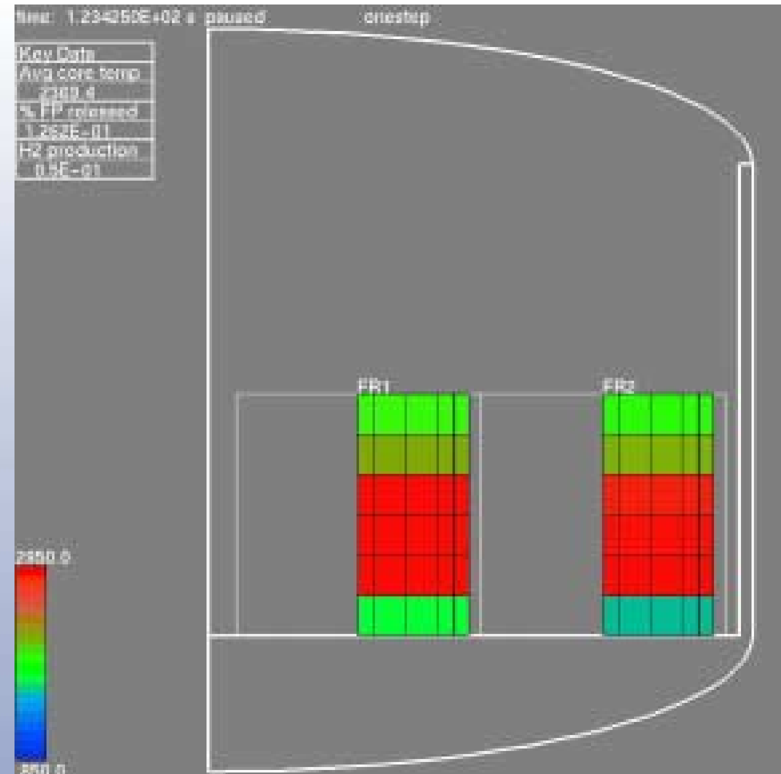
Results obtained with Penn State correlation.
(Other correlations will be added through on-going K-INERI program.)

New Features

SCDAP/RELAP5-3D© RGUI Allows Users to Identify Input Errors and View Run-Time Results



RELAP5



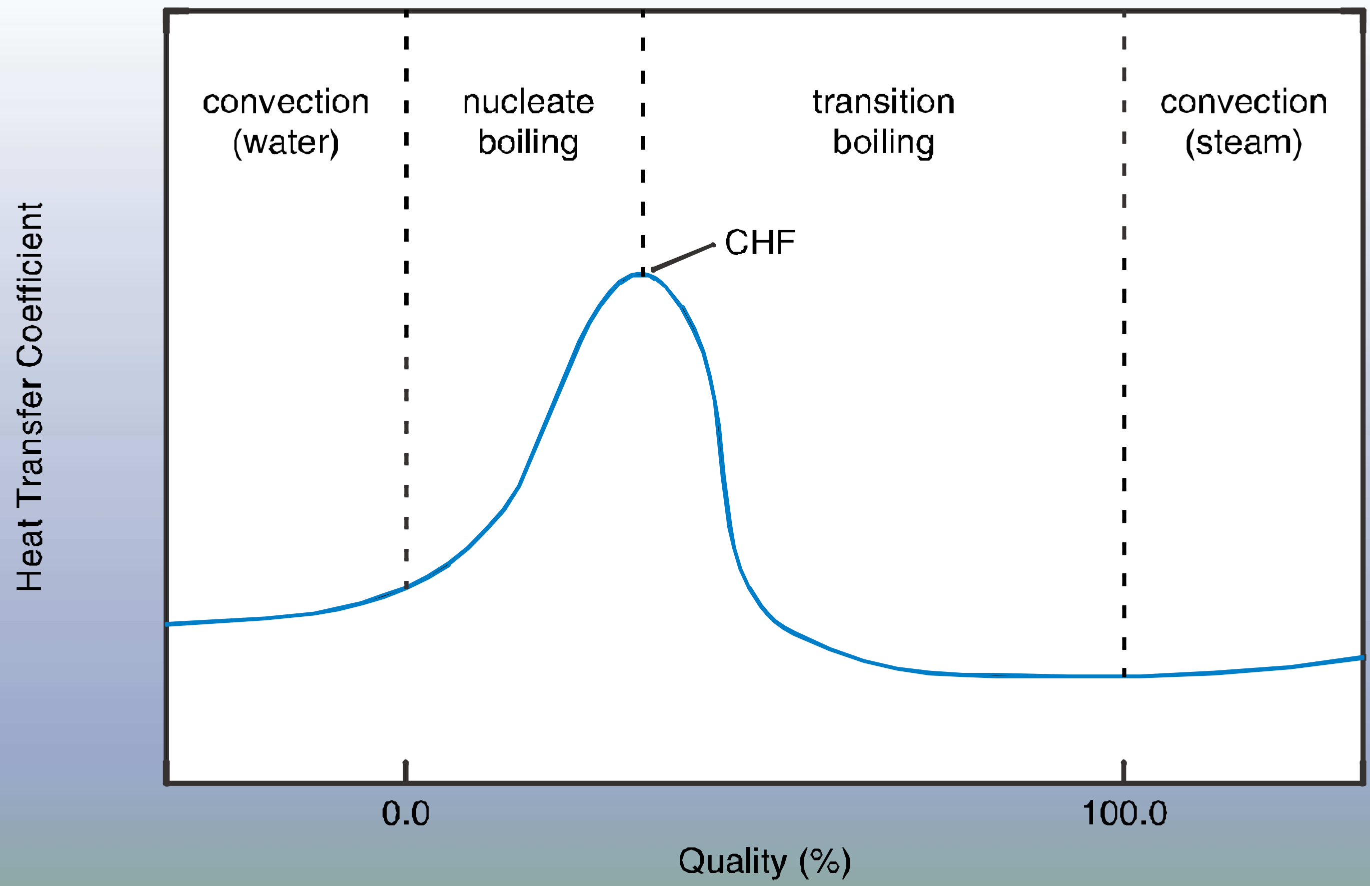
SCDAP

Planned SCDAP/RELAP5-3D© Improvements

- Core catcher modeling capabilities
- ERVC simulation refinements for effects of
  - Vessel insulation
  - External coatings
  - Heat transfer in “tap” water
- Development of narrow gap flow and heat transfer correlations (from existing sources and K-INERI experiments)
- Fission product transport model
- SCDAP/RELAP5-3D© / CONTAIN PVM link
- Addition of GEN IV models

Planned Improvements

Development of Complete Narrow Gap Boiling Curve Anticipated



Summary

- *SCDAP/RELAP5-3D© embodies state-of-the-art thermal-hydraulic and severe accident models*
- *SCDAP/RELAP5-3D© results consistently serve as the industry standard*
- *New features contribute to better understanding of IVR aspects of severe accidents*
- *Additional modeling fidelity (i.e., CONTAIN link, GEN IV, and advanced heat transfer) part of planned SCDAP/RELAP5-3D© development*