U.S.NRC
United States Nuclear Regulatory Commission
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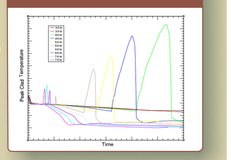
Office of Nuclear Regulatory Research

TRACE Development and Analysis Activities

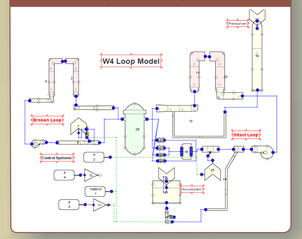
TRACE

- TRACE stands for TRAC-RELAP Advanced Computational Engine.
- TRACE allows a user to create a model of a reactor and simulate various accident scenarios:
  - Large-Break Loss-Of-Coolant-Accident (LOCA)
  - Small-Break LOCA
  - Boiling-water reactor (BWR) Anticipated Transient Without Sram (ATWS) Instability
  - Station Blackout
- TRACE can be coupled to Purdue Advanced Reactor Core Simulator (PARCS) for 3D neutronics and kinetics response.
- TRACE has a vast assessment set and is benchmarked against over 400 separate effects and integral tests.
- User guidelines for modeling of light-water reactors (LWRs) have been established.
- TRACE provides confirmatory analysis capabilities, allowing the NRC to run independent assessment of licensee calculations.
- TRACE Version 5 Patch 4 is ready for imminent release and adds important new features.

TRACE Break Spectrum Analysis Results



Sample TRACE Plant Nodalization: Westinghouse 4-Loop Reactor



Recent TRACE Applications

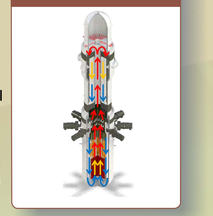
Station Blackout Analysis

- Station Blackout Analysis is in progress for existing and new reactor designs in support of licensing actions.
- Very long problem timescales (72 hours) present unique challenges and put additional importance on fast and robust code execution.

Modeling New Small Modular Reactors (SMR) in Support of Licensing Actions

- New reactor designs such as Westinghouse SMR, Babcock & Wilcox (B&W) mPower, and NuScale present new modeling challenges for a traditional pressurized-water reactor (PWR) and BWR Reactor Systems Code.
- Containment modeling is of added importance because primary systems are often much more tightly coupled with containment in reactors with passive safety systems.

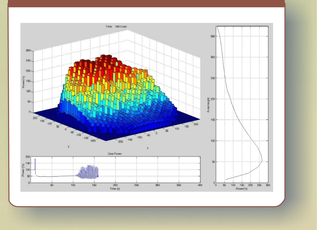
Westinghouse SMR



BWR ATWS Instability Analysis

- Power oscillations and instability have become important phenomena to understand as BWR plants submit requests for power uprate license amendments.
- Within the MELLLA+ (Maximum Extended Load Line Limit Analysis Plus) expanded operating domain, BWRs may experience power and flow oscillation phenomena following certain postulated events.
- These ATWS events must be understood in order to make informed decisions regarding uprate licenses.

ATWS Out-Of-Phase Instability Core Power Distribution from TRACE/PARCS



Support for the 10 CFR 50.46c Proposed Rulemaking:

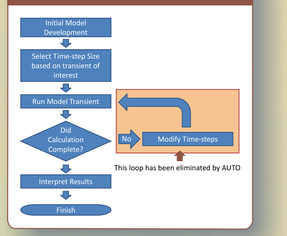
- TRACE has been used for studying the variation in Equivalent Clad Reacted (ECR) as a function of fuel burnup and cladding hydrogen content.
- TRACE is being linked with the fuel-performance codes named FRAPCON and FRAPTRAN to evaluate the safety significance of fuel fragmentation, relocation, and dispersal during a LOCA.

Recent Improvements to TRACE

Adaptive User-Independent Timestep Optimization (AUTO)

- AUTO introduces functionality to Patch 4 that allows TRACE to return to a previous point in problem time and repeat the calculation with a different timestep size.
- This is done without user interaction or additional input.
- This solves a large number of robustness issues that were previously seen in certain types of calculations.
- By allowing the user to run at a larger timestep, calculation time can be cut by up to a factor of 8.
- In addition to code run-time, user intervention has been drastically reduced. Models that used to take 2 weeks of constant user intervention now may be completed overnight.
- This new feature has the potential to improve all TRACE models, but is especially important for the long (72-hour) station blackout calculations.

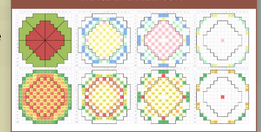
Improvement to TRACE Model Development and Analysis Workflow



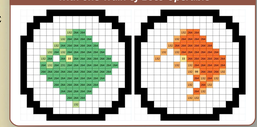
Advanced Fuel Modeling from FRAPCON

- TRACE Version 5 Patch 4 includes new, more sophisticated fuel models taken from FRAPCON.
- The new features provide more accurate fuel properties such as gas gap thermal conductivity, fuel pellet relocation, and gap pressure.
- These models have been instrumental to the use of TRACE in support of Title 10 of the Code of Federal Regulations (10 CFR) 50.46c proposed rulemaking, "Emergency Core Cooling System Performance during Loss-of-Coolant Accidents."

Fuel Assembly Grouping for TRACE and FRAPCON



Ballooned (green) and Ruptured (red) Rods Following a LBLOCA with one Train of ECCS Operable



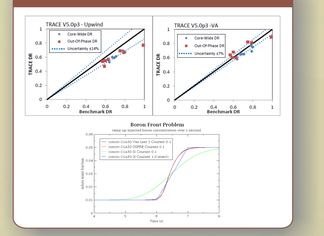
New Containment Modeling Features

- In order to provide a more advanced model of containment, the CONTAN component in TRACE has been given expanded functionality in Patch 4.
- New CONTAN features include:
  - Improved film condensation models
  - New signal variable capabilities
  - A new fan cooler sub-component
  - Boron tracking
- These features are useful for existing reactor modeling, but are particularly important for small modular reactor applications with passive safety systems because these reactors typically feature tighter coupling between containment and primary systems.

Higher-Order Spatial Methods and Mixed Numerics

- In finite volume codes with first-order methods (such as TRACE), numerical diffusion can negatively impact results.
- Several higher-order methods have been implemented for the mass, energy, and solute tracking equations that greatly reduce this diffusion.
- This feature can be turned on and off for different parts of the model to improve results while minimizing the effects on run time.
- This feature has many uses but specifically improves prediction of decay ratio for BWR instability calculations.

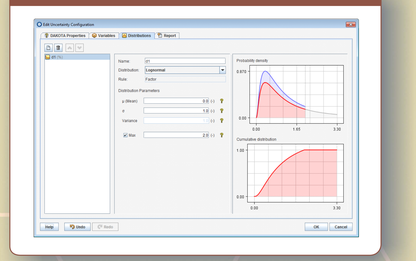
Improvement in Decay Ratio (DR) Prediction Using Higher-Order Methods



Uncertainty Quantification/Sensitivity Analysis

- Uncertainty Quantification capabilities have been added to TRACE for the Patch 4 release.
- Symbolic Nuclear Analysis Program (SNAP) has a plugin using DAKOTA that allows the variation of the parameters according to various statistical distributions.
- Parameters have been selected that may have multipliers or additive modifiers applied, allowing sensitivity analysis to be performed.
- Examples of parameters include:
  - Time-step size
  - Heat-transfer coefficients
  - Transition boiling temperature
  - Drag coefficients

Uncertainty Distribution Selection in SNAP



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