

Use of Systems Analysis Codes in the Nuclear Industry:

***Perspective from experiences with one
particular vendor - GE Hitachi Nuclear Energy***

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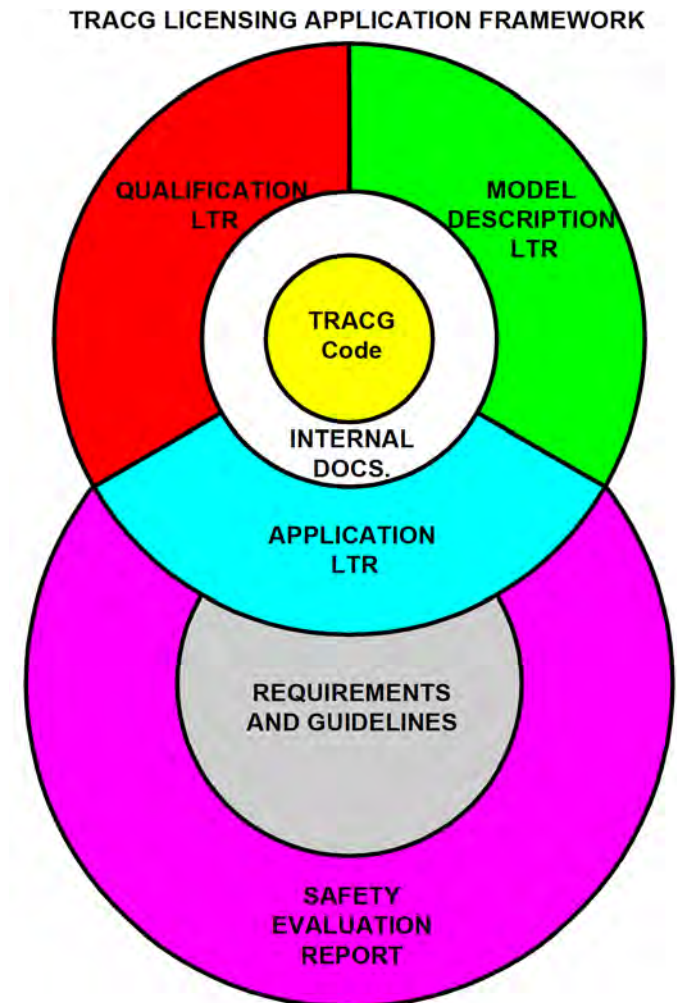
Outline:

- Safety Analysis Licensing Methodology
- Tools of the Trade
- LOCA Methodology Review and Approval
 - ENSI (Switzerland)
 - Application to KKM
 - USNRC
 - Results for Generic BWR/2
- Key Take Away's

Note: all information presented here is available in the public domain.

Safety Analysis and Licensing Methodology – *the GEH Approach*

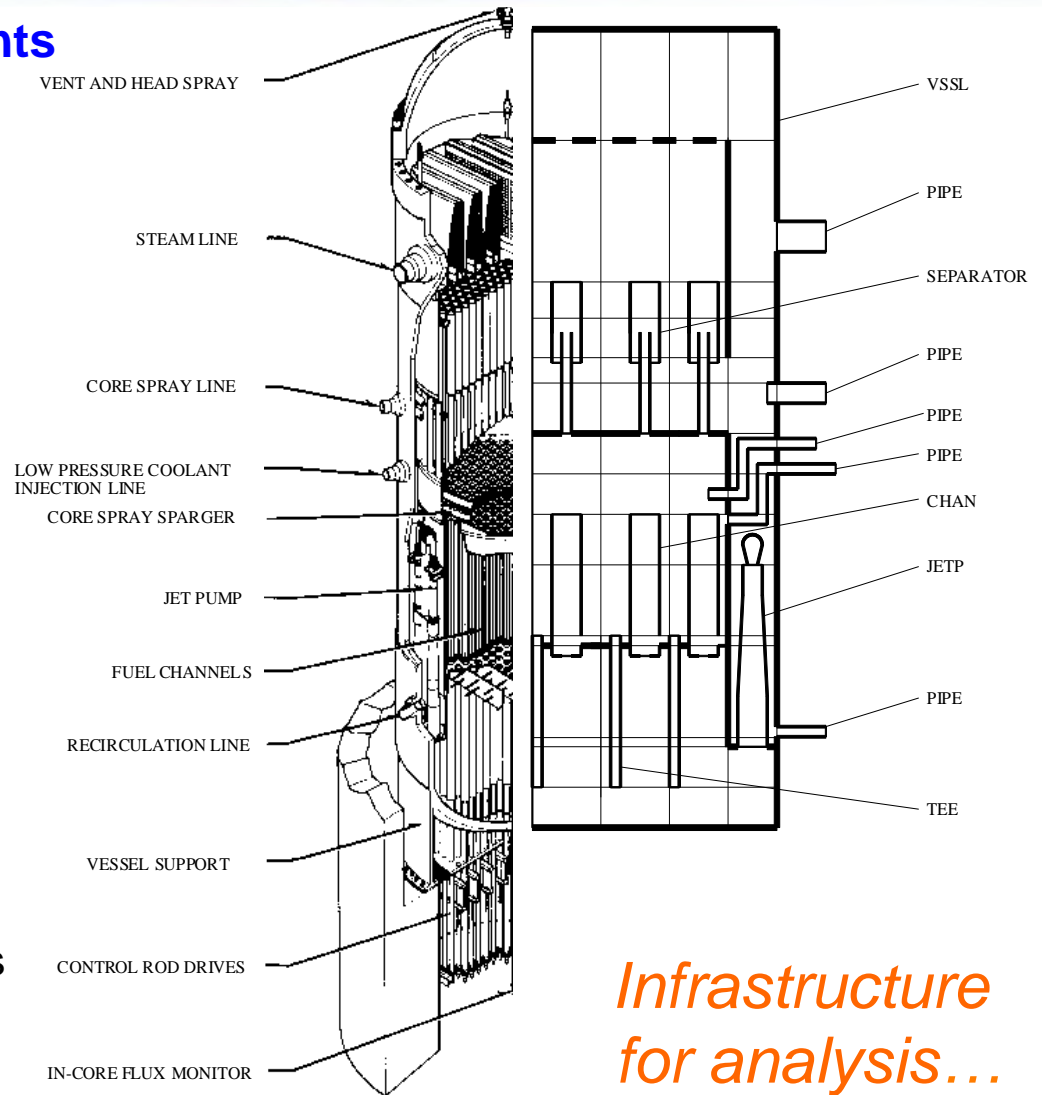
- Implements BEPU in analyses for plant safety evaluations and licensing bases (RG 1.157 and RG 1.203)
- Application-specific Licensing Topical Reports (LTR's) are submitted for USNRC approval
- Uncertainties are established for models, data, scale, and plant parameters
- Approved for ESBWR, BWR AOO's, Stability, and LOCA (pending); Containment under development



Tools of the Trade – What is TRACG?

- **Realistic Code for BWR Transients**

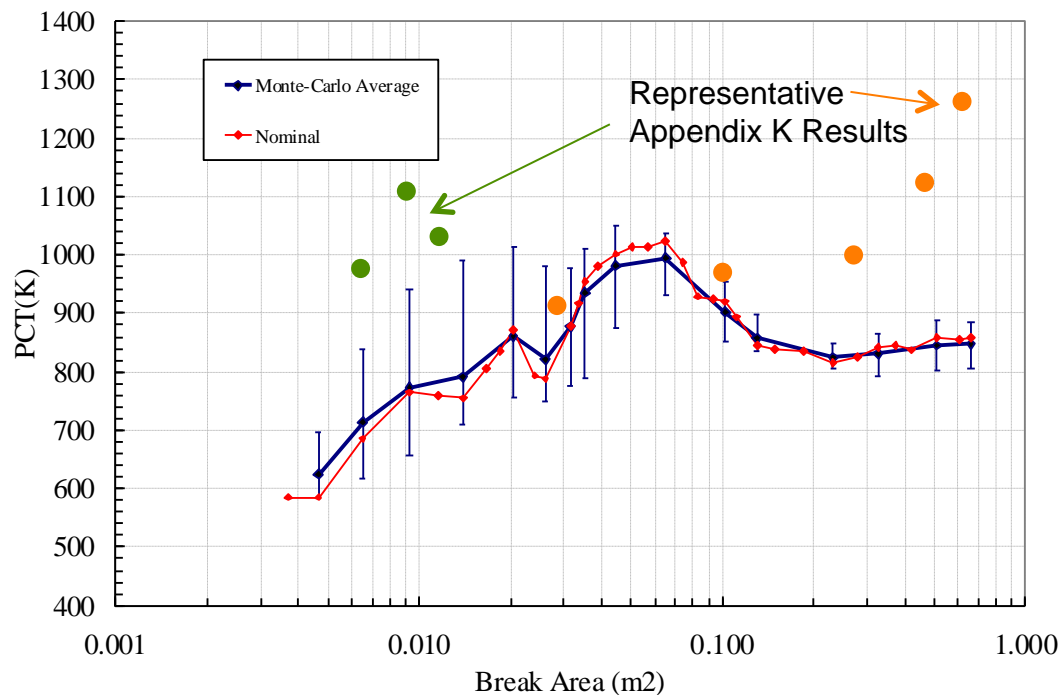
- Multi-dimensional vessel
- Flexible modular structure with control system capability
- Proven 3D nuclear kinetics consistent with GE core simulator
- Steam, liquid, boron and non-condensable gases
- Flow regime map covering all hydraulic conditions
- Consistent use of constitutive correlations
- BWR component models
- Extensive qualification
 - Simple separate effects tests
 - Scaled simulation
 - Full scale plant data



*Infrastructure
for analysis...*

LOCA Methodology Migration

- Eliminate excessive conservatism of Appendix K methods; enhanced plant safety when understand realistic systems behavior



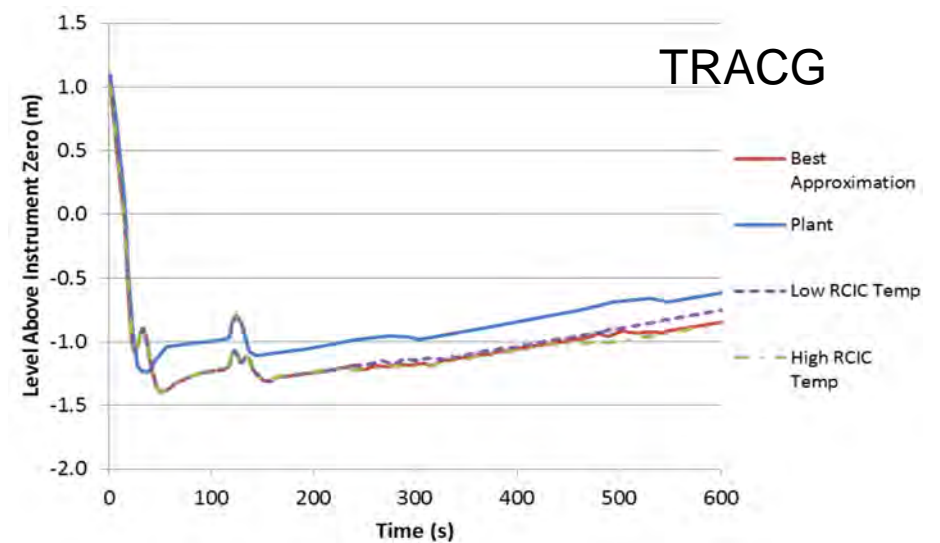
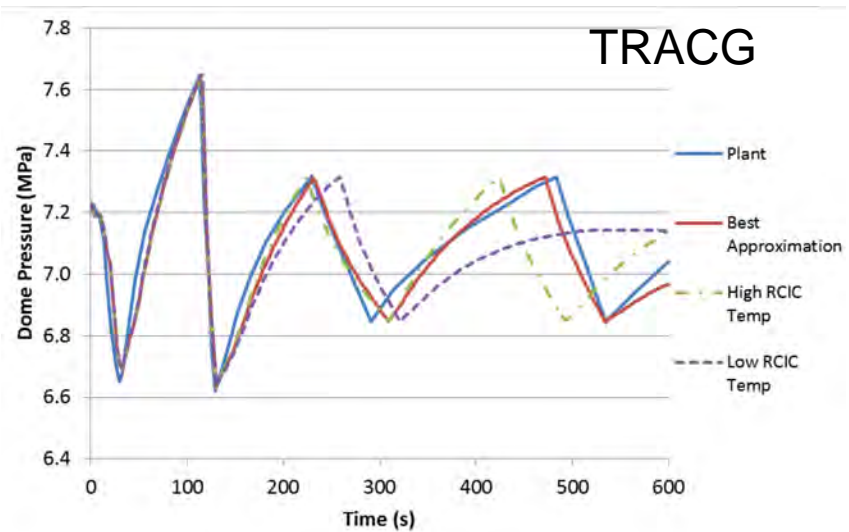
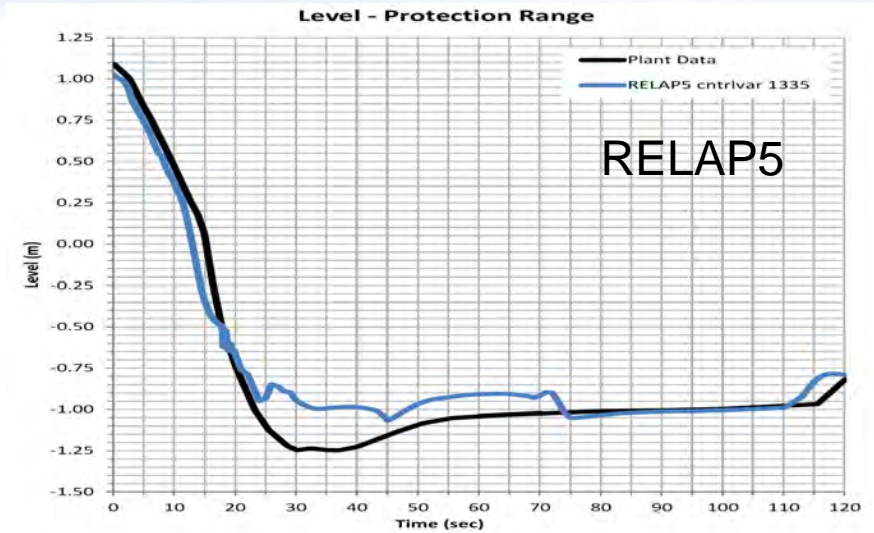
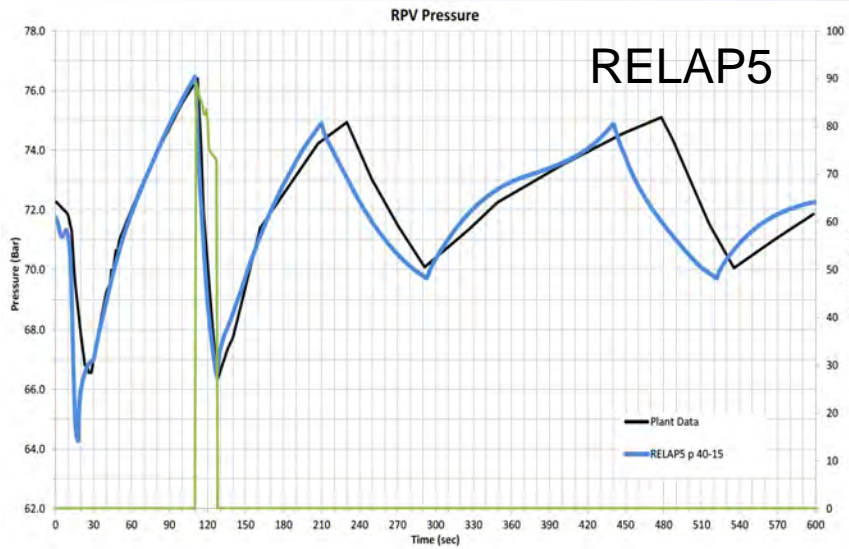
Generic BWR/4 Break Spectrum with quantified uncertainties

- Improve thermal limits (MAPLHGR) to optimize fuel utilization
- Relaxation of ECCS systems requirements, inspection and maintenance, or life-time related performance degradation (savings available for capture in Nuclear Promise?)

LOCA Licensing Review- ENSI

- Swiss Federal Ordinance A-01 requires implementation of best-estimate methodology; executed to existing plants after Fukushima
- Independency from USNRC review, however third-party review is required (PSI performed for KKM LOCA application)
- Extra-design basis event analysis required for “plant capability analysis”; considers greater than single failure, combinations of breaks, etc. Also considers less challenging conditions, e.g. pressurization events, minimum break size, non-safety system impact, etc.
- Plant-specific benchmarking required for basedeck assurance
 - KKM benchmarked to LOFW Test, and compared to RELAP5
- Review and approval invoked on plant-specific basis (KKM implemented TRACG LOCA MAPLHGRS with Aug 2016 startup)

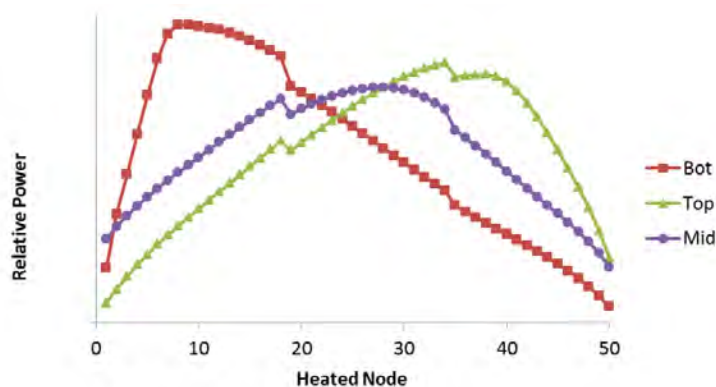
KKM Benchmark and Validation – LOFW Test



KKM LOCA Analysis – Licensing Application

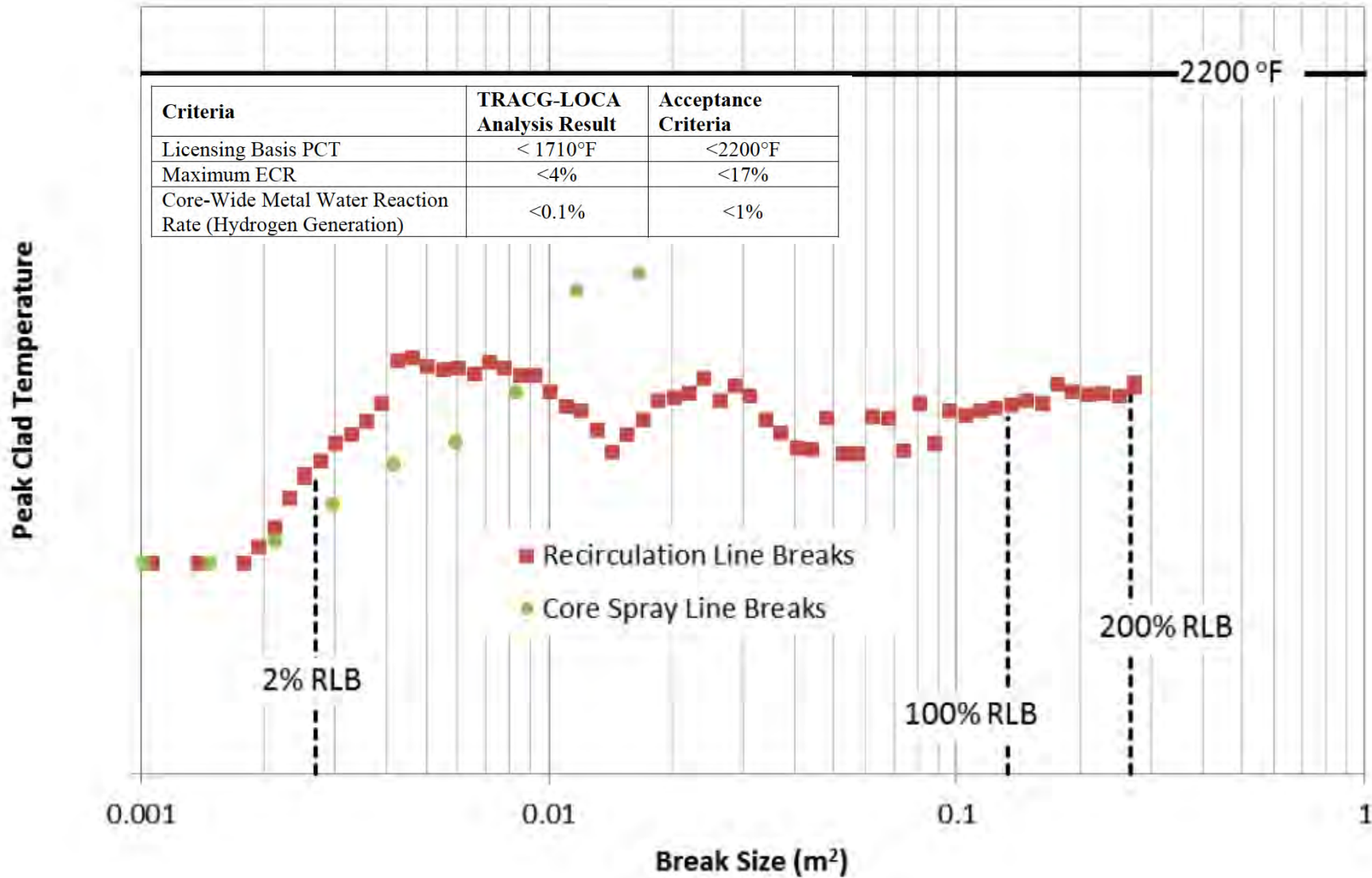
- KKM is a small BWR/4, but distinctive in that Core Spray is the only low pressure ECCS (RCIC is also part of ECCS)
- Installed supplemental pumping system (ALPS) for Core Spray in addition to main CS pumps
- Break Locations and Sizes Examined: Recirculation (full spectrum), Feedwater, Steam line (inside and outside containment, and core spray line (full spectrum))
- Single Failure Configurations:
- Limiting Realistic Core Power Distributions:

Assumed Single Failure	Remaining Systems
CS	2 RCIC + 1 CS + 2 ALPS + ADS
ADS (1 valve)	2 RCIC + 2 CS + 2 ALPS + ADS (N-1 valves)
RCIC	1 RCIC + 2 CS + 2 ALPS + ADS



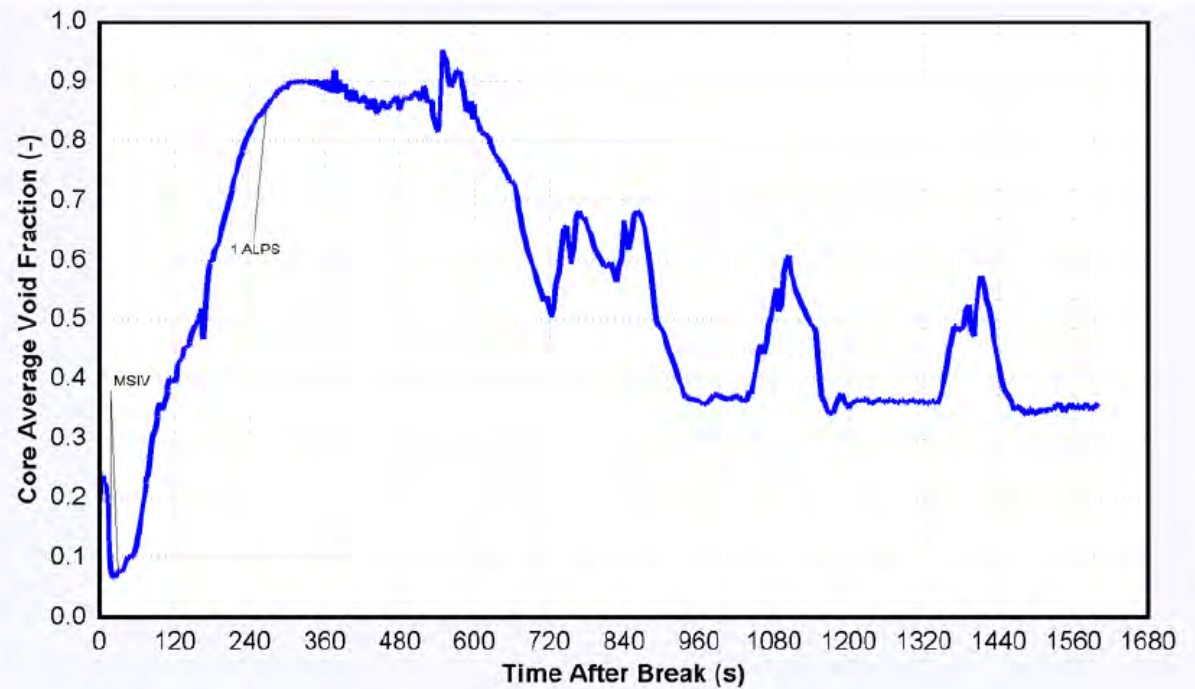
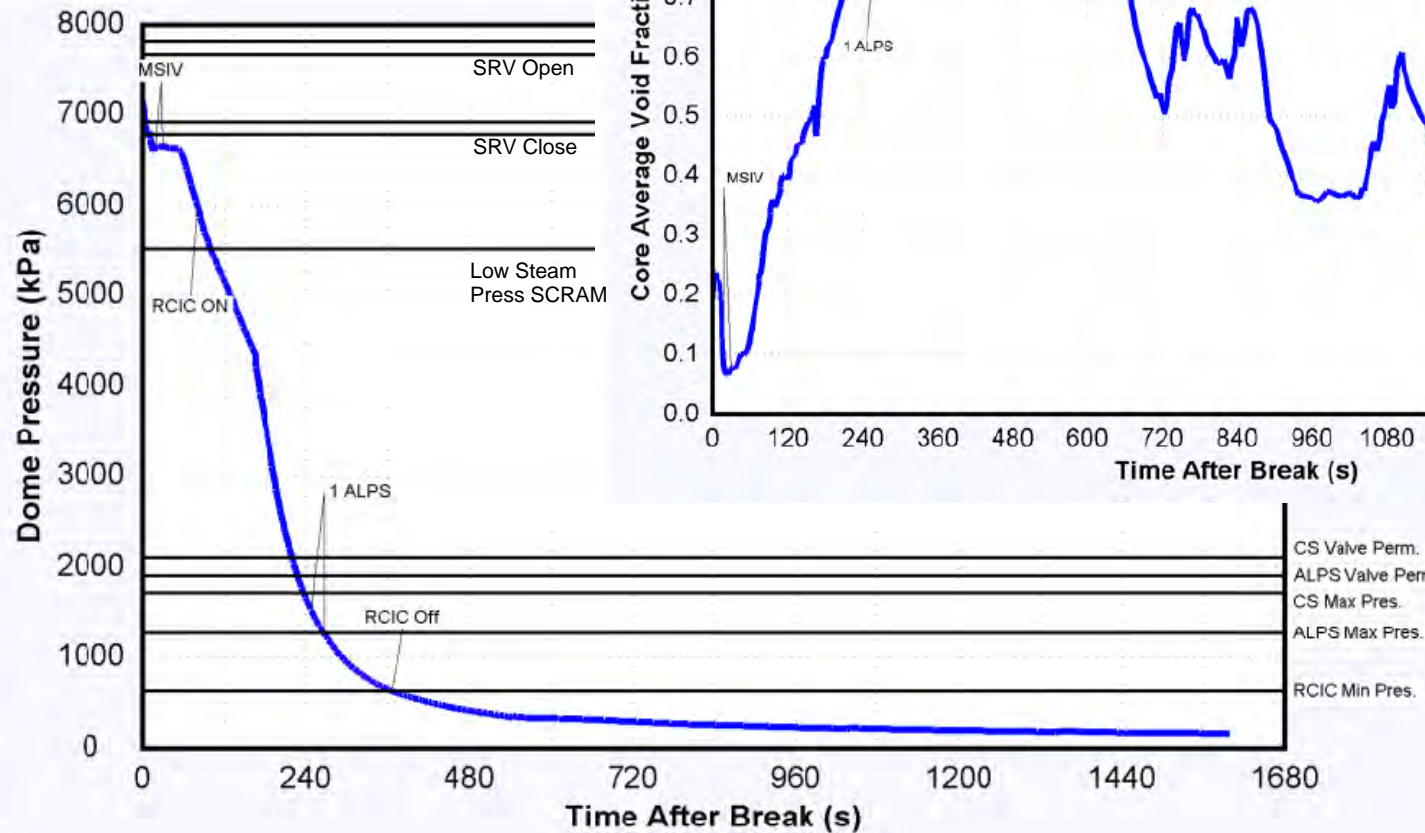
- Key Assumptions:
 - Most unfavorable LOOP timing
 - Steam break B/C at 1 atm
 - Failure of first initiating signal for safety system actuation

KKM LOCA Analysis – TRACG Licensing Results

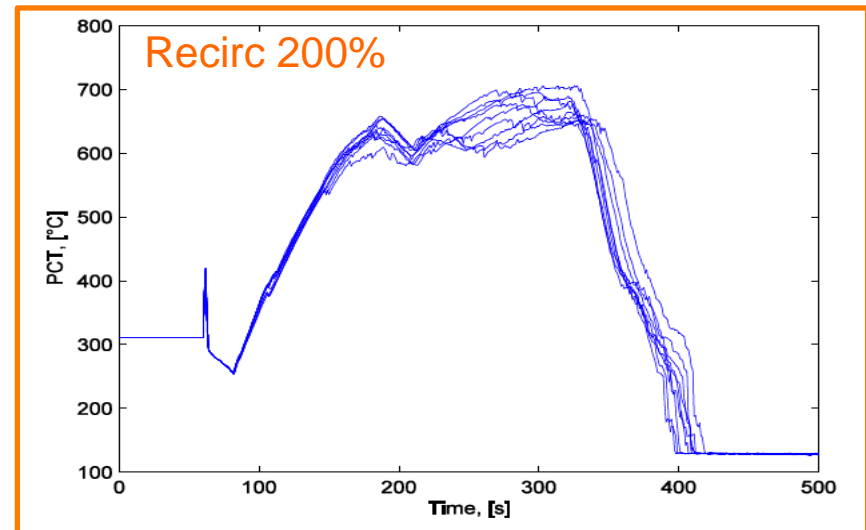
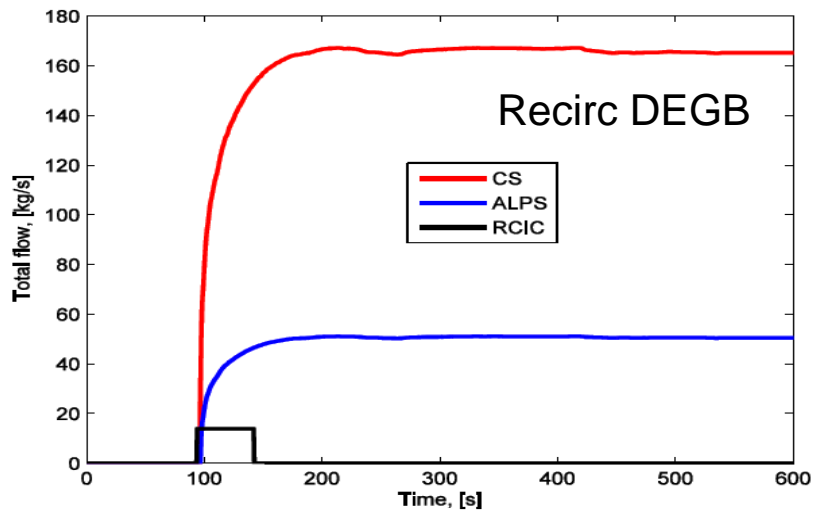
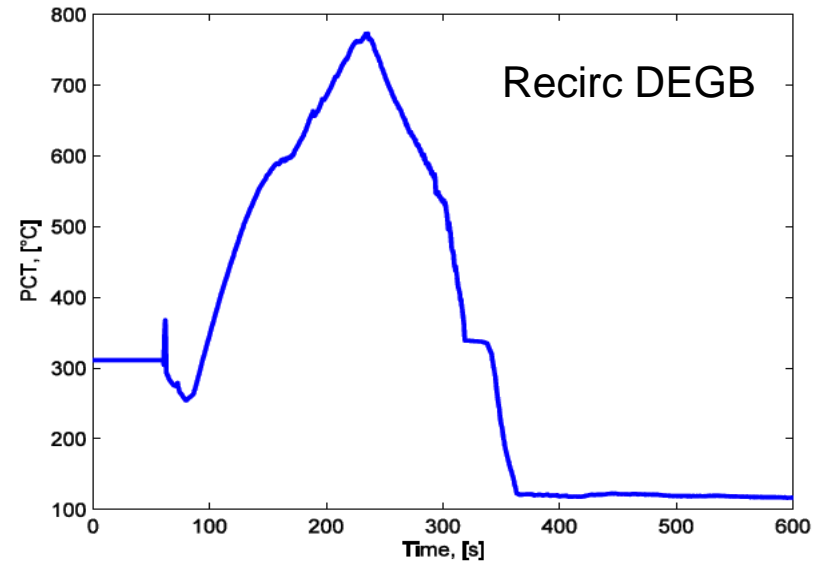
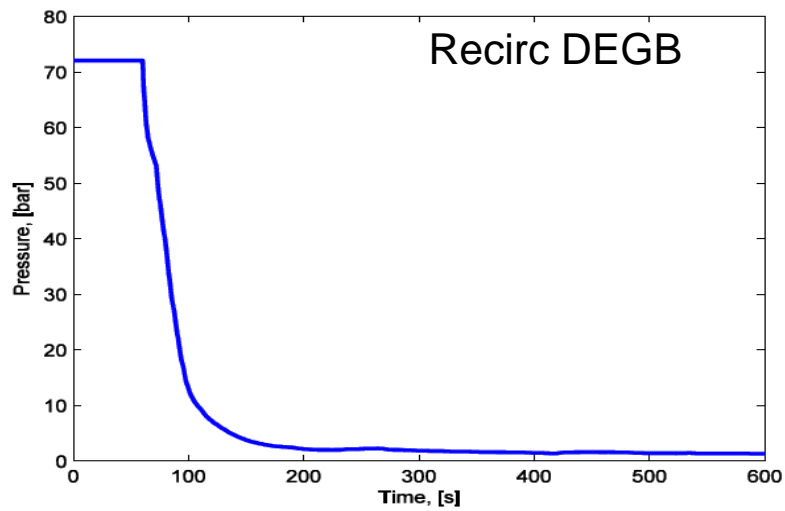


KKM LOCA Analysis – TRACG Licensing Results

System response to limiting CSLB

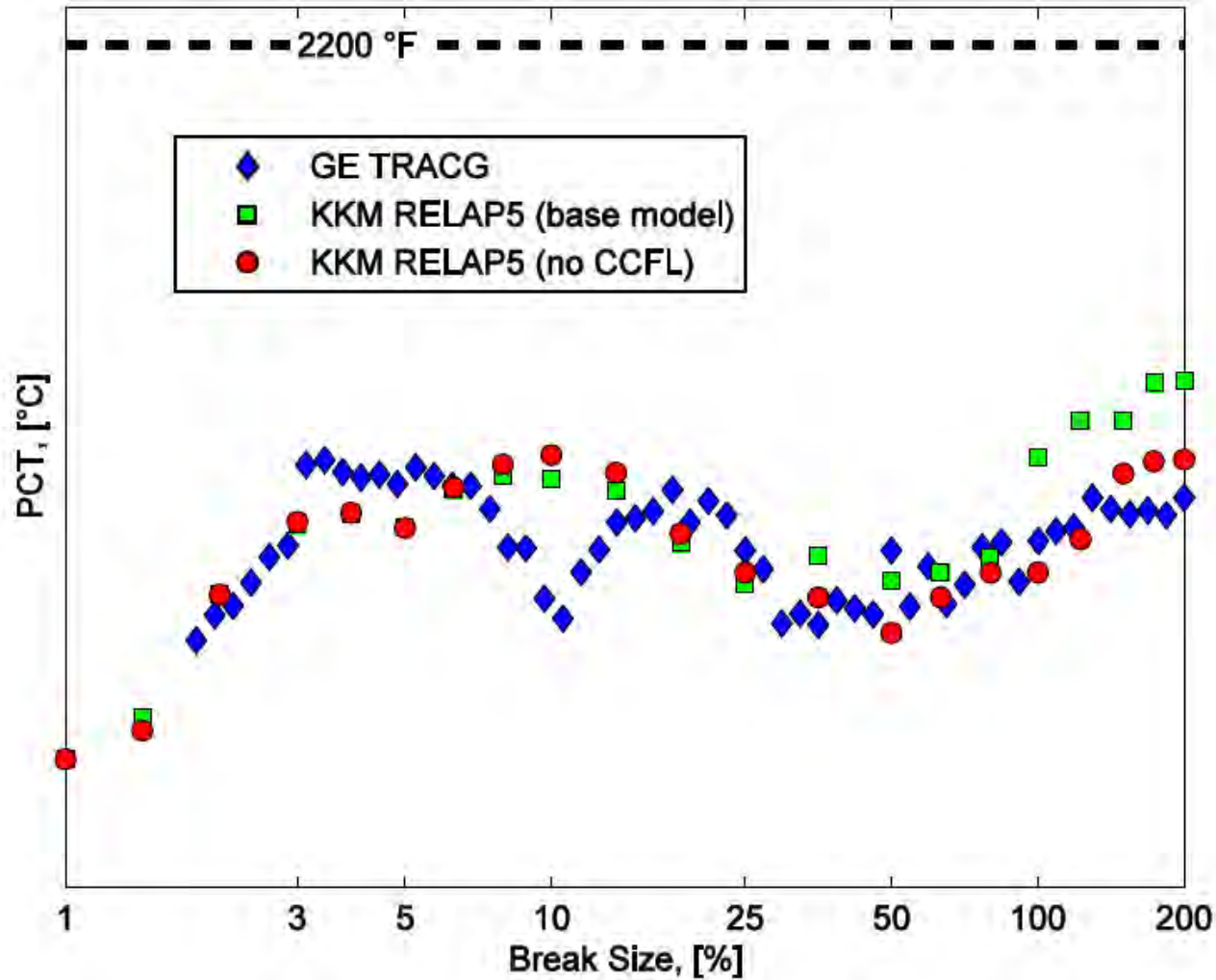


KKM LOCA Analysis – RELAP5 Analysis



KKM LOCA Analysis – TRACG and RELAP5

Recirculation Line Break Spectrum



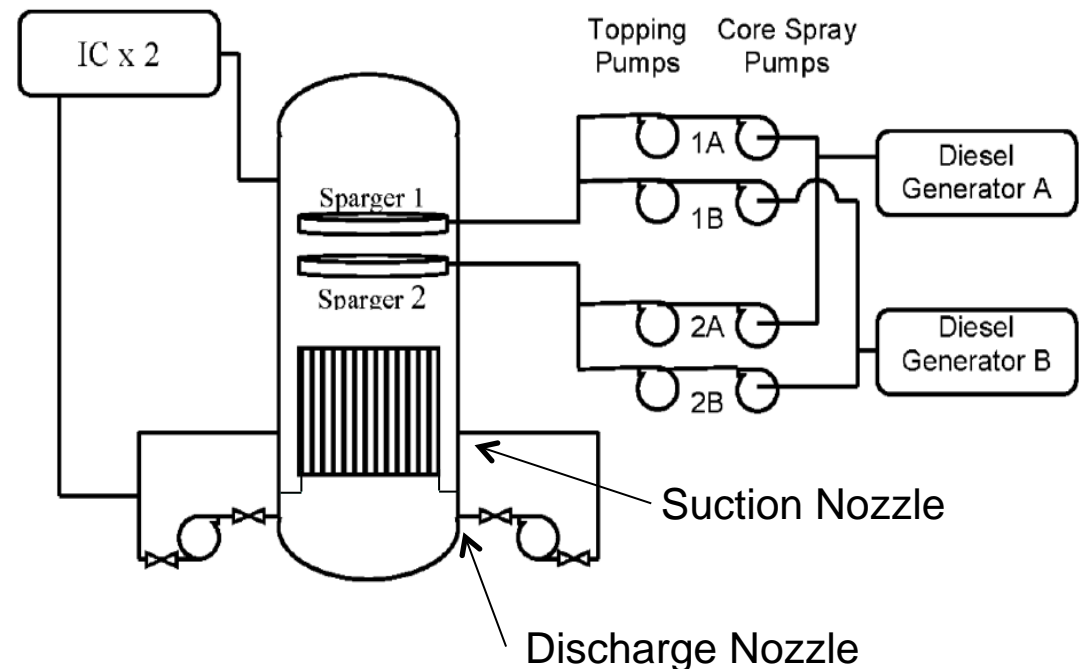
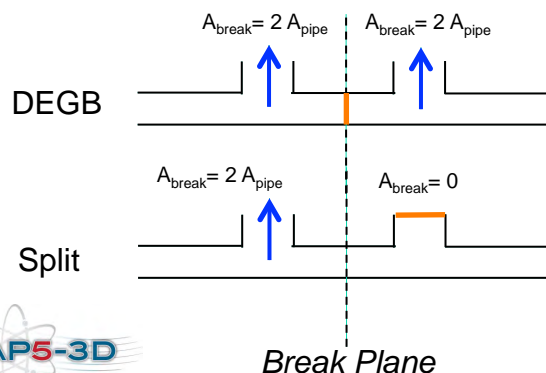
LOCA Licensing Review- USNRC

- TRACG LOCA Analysis Methodology LTR, NEDO-33005 (applies for BWR/2 – BWR/6), prepared and submitted to USNRC on 27 January 2011. Acceptance review completed on 20 June 2011.
- Review commenced, and included 3rd party reviewers, but delayed due to reassignment of lead review to Fukushima Response activities.
- Review re-instated in April 2014, with RAI's and responses ongoing since... Expect Safety Evaluation Report soon (end of 2016).
- Demonstration evaluations performed for the LTR execute the (approved) analysis process; plant licensing will require plant-specific analysis but not require additional NRC review.
- Review and approval performed independent of pending 10 CDR 50.46 rulemaking, however many aspects are covered.

BWR/2 LOCA Analysis – Demonstration Analysis

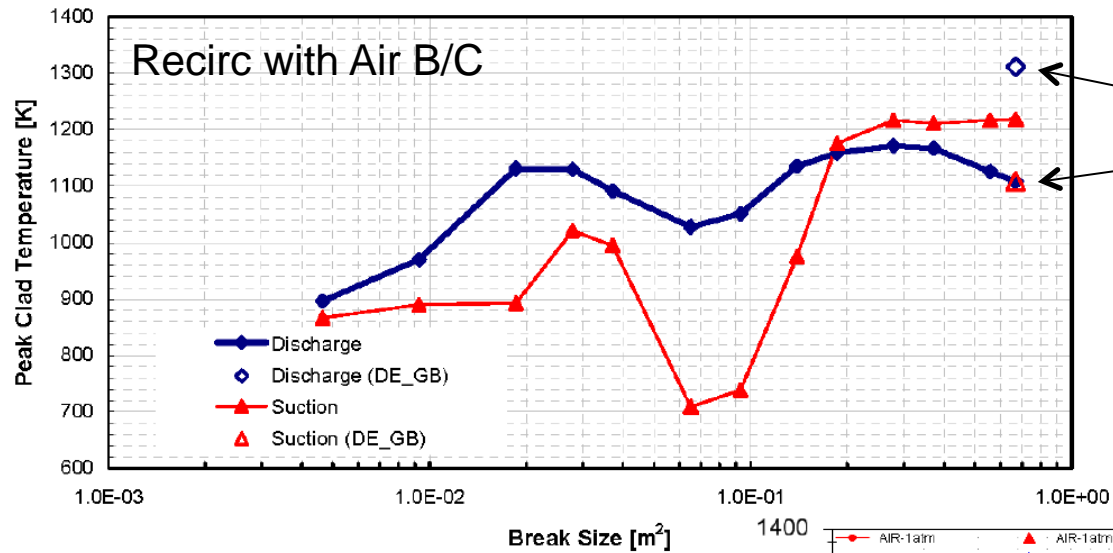
- BWR/2 is LOCA-limited as bottom vent will not allow stable core reflood (as jet pumps do in later models)
- Two Core Spray trains; IC's determined as limiting single failure (ADS is non-limiting)
- Recirculation line break shown as limiting (from CS, FW, and Steam lines)

- *Break location - Suction and discharge*
- *Effect of DW vapor conditions – steam or air, backpressure*
- *Break type - Double-ended and split breaks*



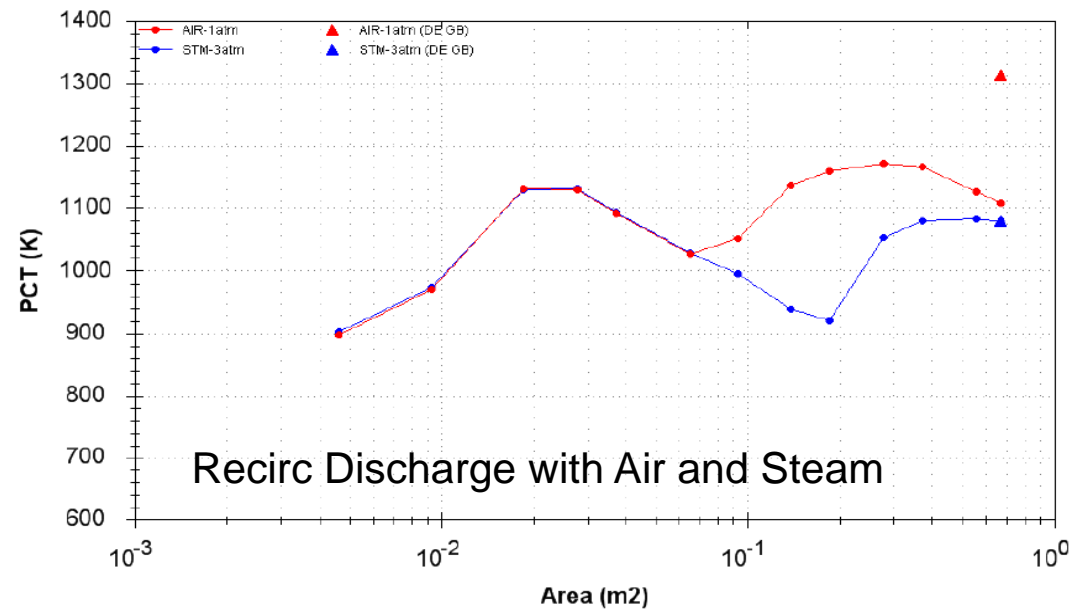
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BWR/2 LOCA Analysis – Demonstration Analysis



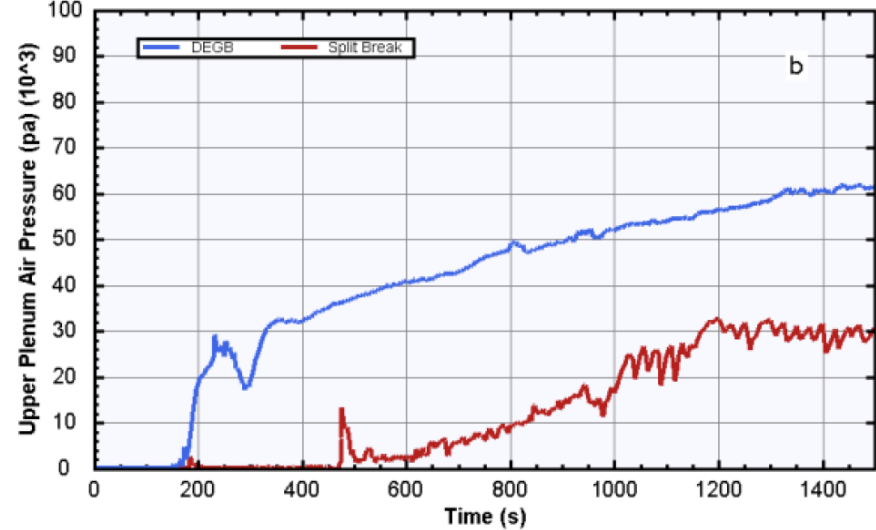
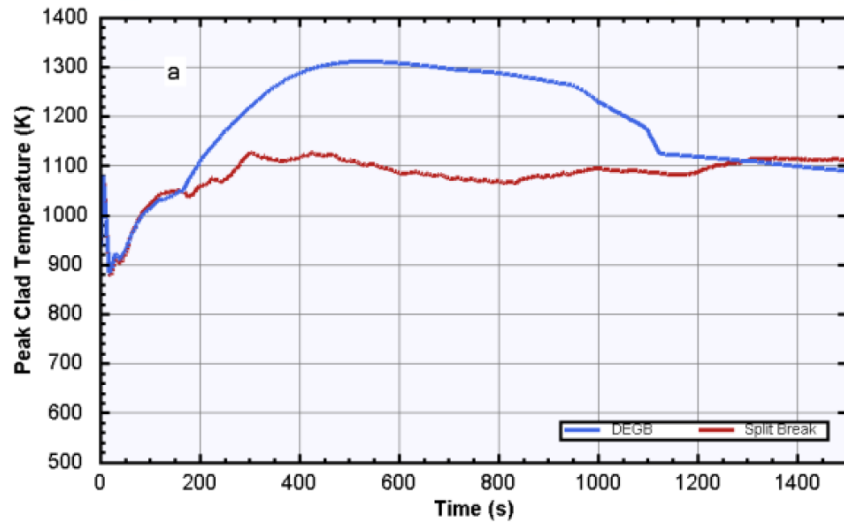
Unexpected behavior

Effect of Steam?

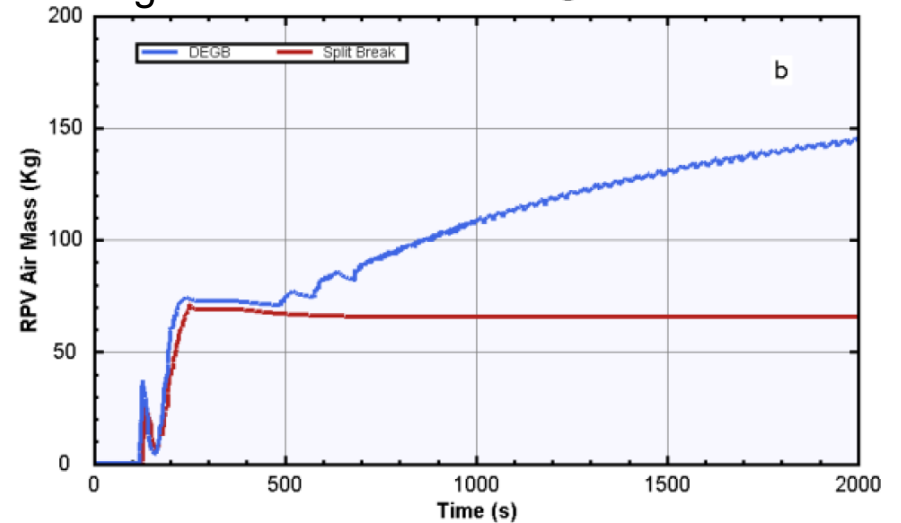
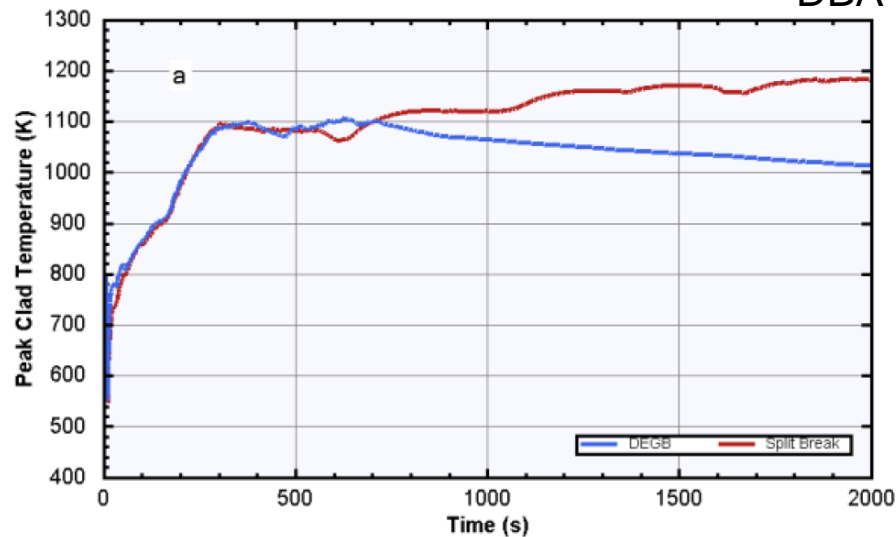


BWR/2 LOCA Analysis – Demonstration Analysis

DBA Suction

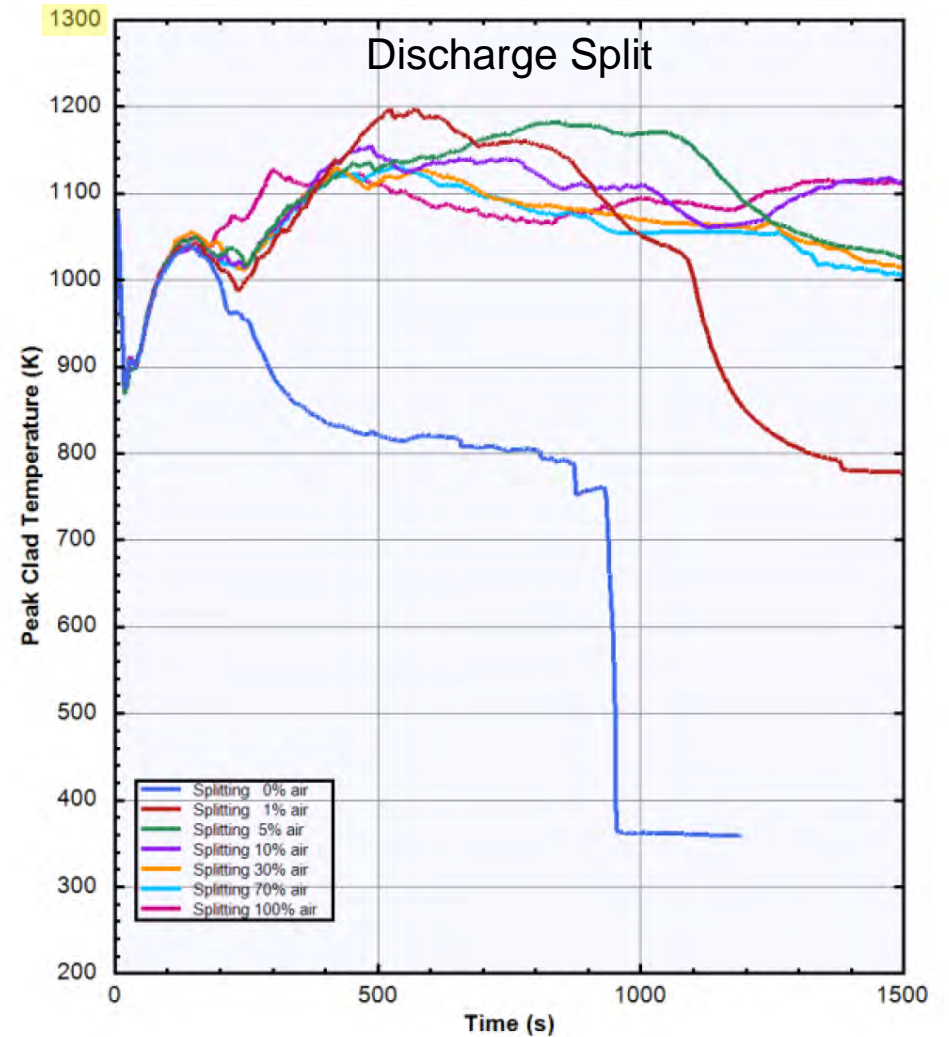
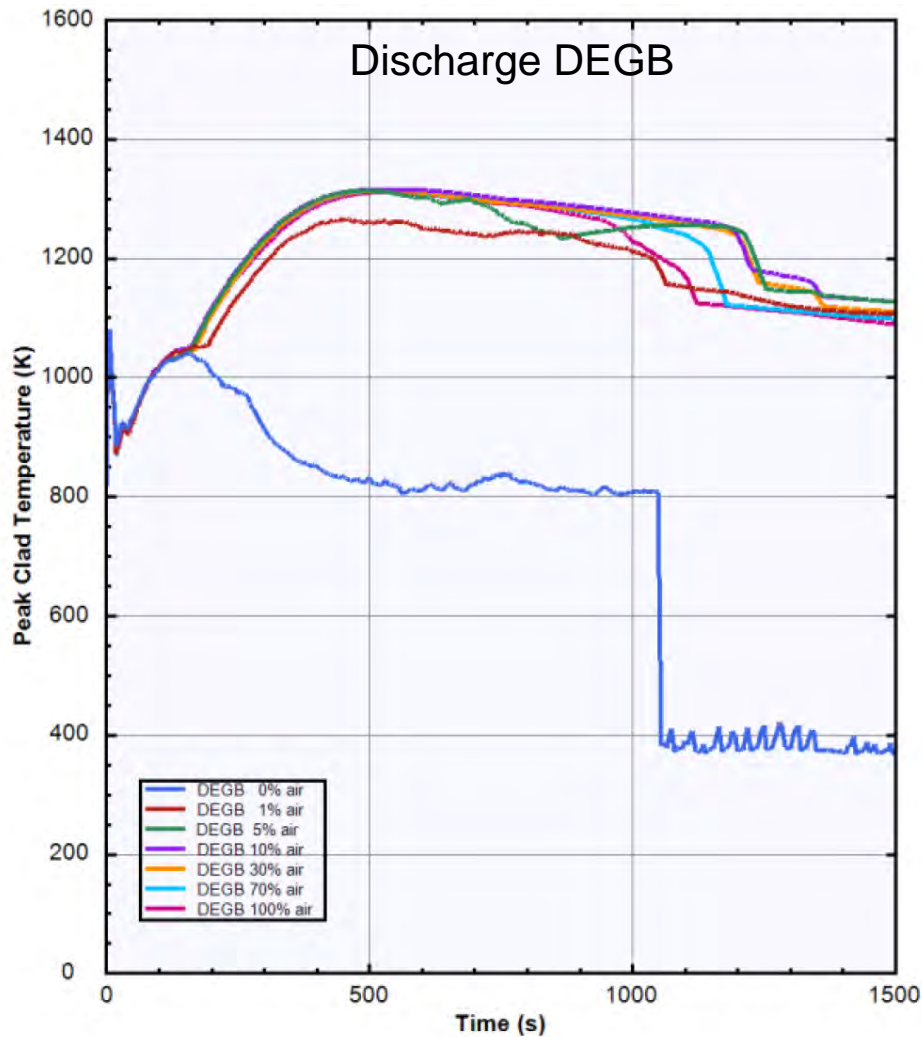


DBA Discharge



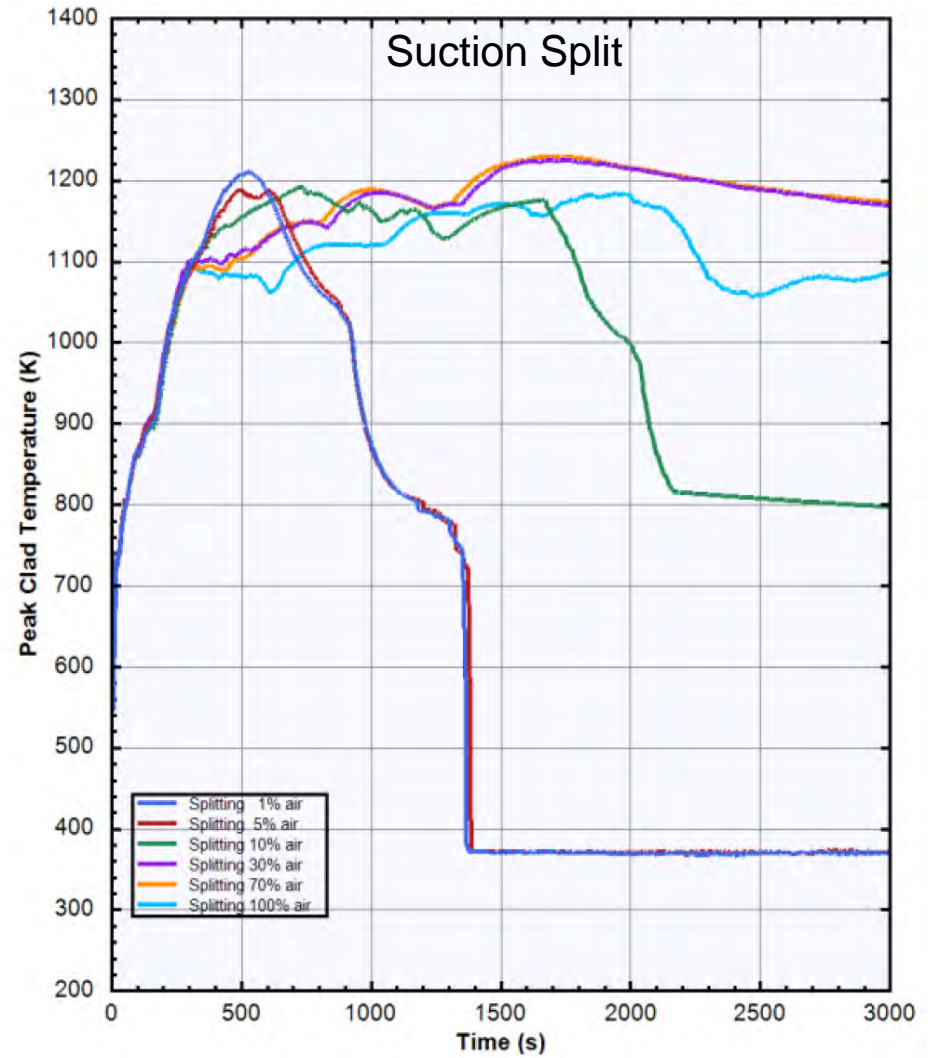
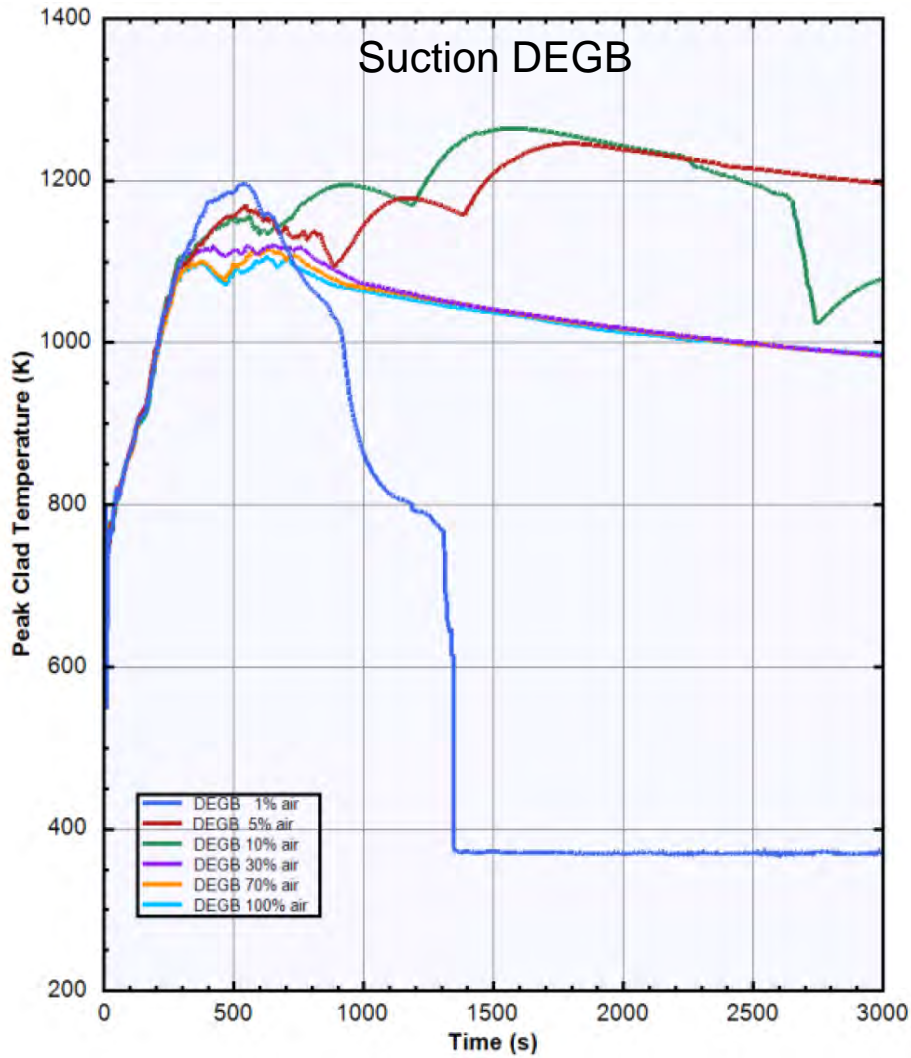
BWR/2 LOCA Analysis – Alternate Air Model

Air vent introduced into suction line



BWR/2 LOCA Analysis – Alternate Air Model

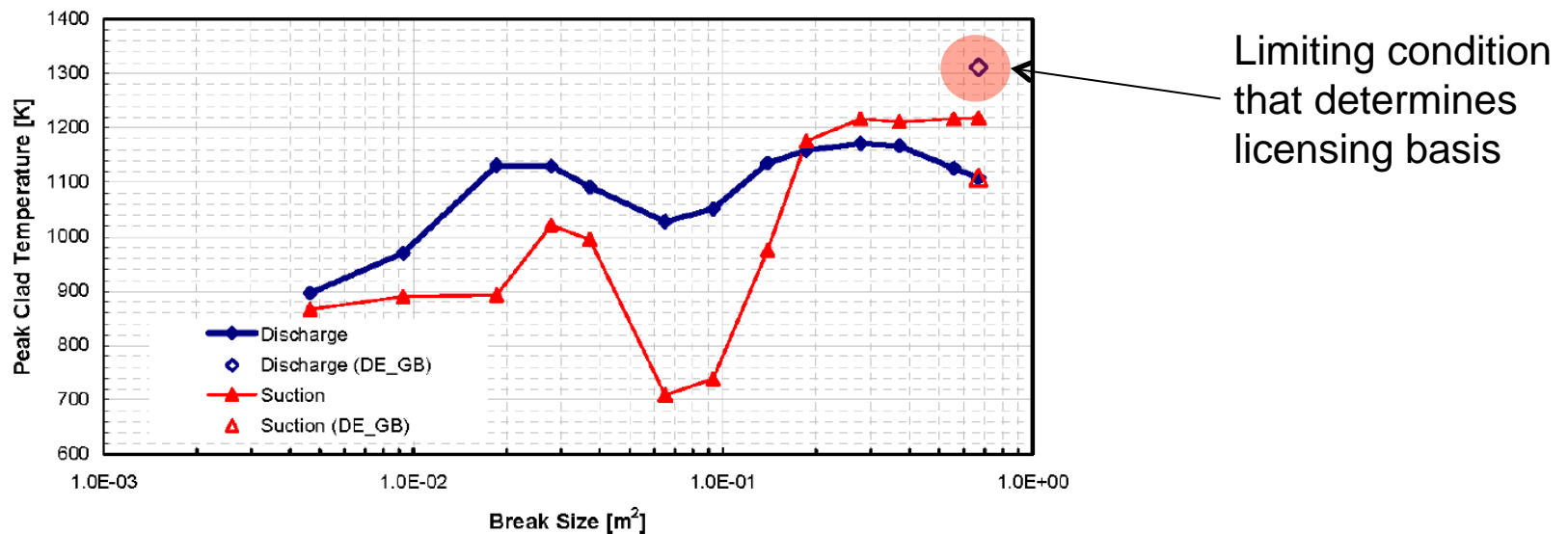
Air vent introduced into suction line



BWR/2 LOCA Analysis – Influence on Licensing?

Break spectrum analysis for BWR/2 requires examination of alternate air model with each break type. Reasonably detailed explanation is demanded...

Aims to ensure capture of most limiting condition consistent with assumptions and established limitations.



Key Takeaways:

- Deploying BEPU methodology into licensing calculations requires a substantial computational infrastructure.
- Capability to diagnose results in efficient and effective manner, adding to the infrastructure need.
LOCA analysts creed: Decoding the complex interactions of competing phenomena.
- Regulatory engagement early and often is an absolute necessity.
- It is possible to evolve a research tool into a licensing tool – *Just need money!*



Idaho National Laboratory