BWR OWNERS' GROUP

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Proprietary Notice
This letter transmits GEH proprietary information in accordance with 10 CFR 2.390. Upon removal of Enclosure 1, the balance of the letter may be considered non-proprietary.

Project 691

BWROG-10004
January 13, 2010

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: Presentation Materials for the January 14, 2010 Meeting Between NRC and the BWR Owners' Group

Attention: Chief, Information Management Branch
Division of Program Management

The BWR Owners' Group (BWROG) is providing the attached final presentation materials to support the January 14, 2010, meeting between the NRC and the BWROG. This meeting is the third in a series of discussions regarding specific topics associated with BWR ECCS Suction Strainers conducted at the request of NRC management. At this meeting the BWROG intends to address NRC questions on the material presented to NRC on October 21, 2010, related to the discussion of results of the BWROG thermal/hydraulic analysis of the downstream effects on GEH fuel of debris that is not screened or filtered by the ECCS Suction Strainers in BWR plants.

We are providing the attached affidavit from GE Hitachi Nuclear Energy Americas LLC (GEH) and the attached final presentation materials to support this meeting with the NRC Staff. The nature of the proprietary information reflects GE Global Nuclear Fuel (GNF) fuel flow characteristics and GEH LOCA analysis information. In the January 14 meeting, we expect to touch on our general plans for addressing this issue with non-GNF BWR fuel types, but we will not be presenting any proprietary information related to other fuel types.

D044
NRO

If you have any questions concerning this letter, please do not hesitate to contact me or Robert Whelan, the BWROG Project Manager (910-819-1808).

Sincerely,

Douglas W. Coleman

Douglas W. Coleman
BWR Owners' Group Chairman

cc: F. P. "Ted" Schiffley, BWROG Vice Chairman
Joseph Golla, NRR
Michelle Honcharik, NRR
Craig Nichols, BWROG Program Manager
BWROG Primary Representatives

Enclosures:

1. Presentation – Proprietary Information
2. Redacted Presentation – Non-Proprietary Information
3. Affidavit

AFFIDAVIT

I, **Edward D. Schrull,** state as follows:

(1) I am Vice President, Regulatory Affairs, Services Licensing, GE-Hitachi Nuclear Energy Americas LLC ("GEH"). I have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 of the letter BWROG-10004, D.W. Coleman, BWR Owners' Group Chairman, to the Document Control Desk (USNRC), "Presentation Materials for the January 14, 2010 Meeting Between NRC and the BWR Owners' Group," dated January 13, 2010, containing presentation materials to be used in a proposed meeting between NRC and the BWR Owners' Group on January 14, 2010, related to addressing NRC questions about the analysis of downstream effects of debris on GNF fuel used in Boiling Water Reactors (BWRs). The proprietary information in Enclosure 1, is identified by a dark red font and dotted underline placed within double square brackets, [[This sentence is an example.{3}]]. Figures and other large objects are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without license from GEH constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. above.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains detailed methods, results, and conclusions regarding supporting evaluations of the effects on nuclear fuel performance of containment debris that bypasses the ECCS Suction Strainers for a GEH BWR. The analysis utilized analytical models and methods, including computer codes, which GEH has developed, obtained NRC approval of, and applied to perform evaluations of containment debris effects on the nuclear fuel for a GEH BWR.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(9) The information that GEH seeks to withhold addresses the results of analyses associated with debris in the suction of emergency core cooling system pumps and the downstream effects of this debris on GEH/GNF fuel. This information was developed for the BWR Owners' group and contains trade secrets and information that GEH/GNF maintains as confidential. More specifically, the proprietary information relates to fuel flow

characteristics and the GEH loss of coolant accident analysis for GNF fuel and BWR reactor designs.

Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 13th day of January 2010.

Edward D. Schrull
Vice President, Regulatory Affairs
Services Licensing
GE-Hitachi Nuclear Energy Americas LLC
3901 Castle Hayne Rd.
Wilmington, NC 28401
edward.schrull@ge.com

ENCLOSURE 2

BWROG-10004

Redacted Presentation

Non-Proprietary Information

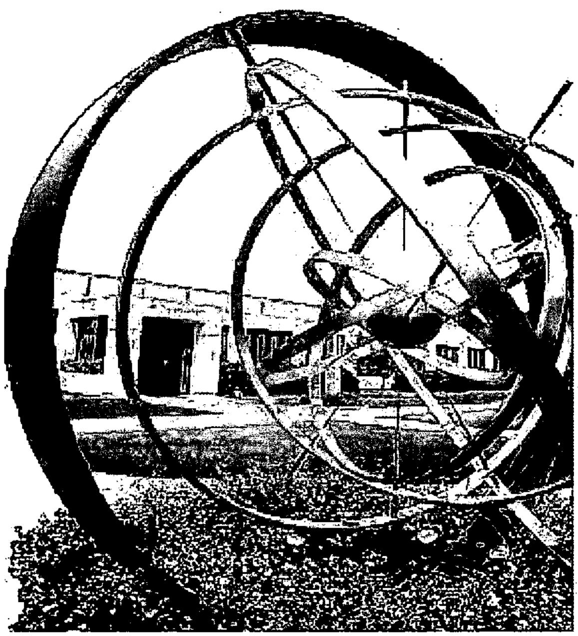
IMPORTANT NOTICE

Enclosure 2 is a non-proprietary version of the presentation from Enclosure 1, which has the proprietary information removed. Portions that have been removed are indicated by open and closed double brackets as shown here [[ ]].

NRC / BWROG Meeting

Follow-up BWR LOCA Long Term Cooling Fuel Effects to Debris Blockages

Jose Luis Casillas
Curt Robert
Charles Heck
GEH Nuclear Energy



January 14, 2009

HITACHI

Key Objectives of Follow-Up

- Review previous NRC approval of TRACG as it is used in LOCA licensing calculations
- Explain why debris blockage does not impact licensing methodology
- Describe debris transport to the fuel to illustrate conservative blockage assumptions including timing and location
- Discuss PCT and oxidation results of licensing and reference cases
- Demonstrate adequate cooling with assumed debris blockage including CCFL and cyclic flow

Key Objectives of Follow-Up

- Demonstrate adequacy of technical qualification for blocked channel analysis conditions
- Demonstrate basis for applicability of Fuel Blockage Effects analysis to all US BWRs
- Demonstrate basis of applicability of Fuel Blockage Effects analysis to address local blockage concerns

Agenda

- LOCA Licensing Model
- Hot Channel Boundary and Local Conditions
- BWR Plant Differences
- Blockage Characteristics

LOCA Licensing Model

Hot Channel Boundary and Local Conditions

BWR Plant Differences

Blockage Characteristics

Key LOCA Phenomena

- Critical Flow
- Interfacial Shear
  - Void Fraction
  - Two-Phase Levels
  - CCFL
  - Spray Distribution
- Interfacial Heat Transfer
  - Flashing
  - Condensation
  - Subcooled CCFL Break Down
- Wall Friction
- Heat Transfer
  - Boiling Transition
  - Film Boiling
  - Rewetting
  - Radiation Heat Transfer
  - Conduction Controlled Rewetting

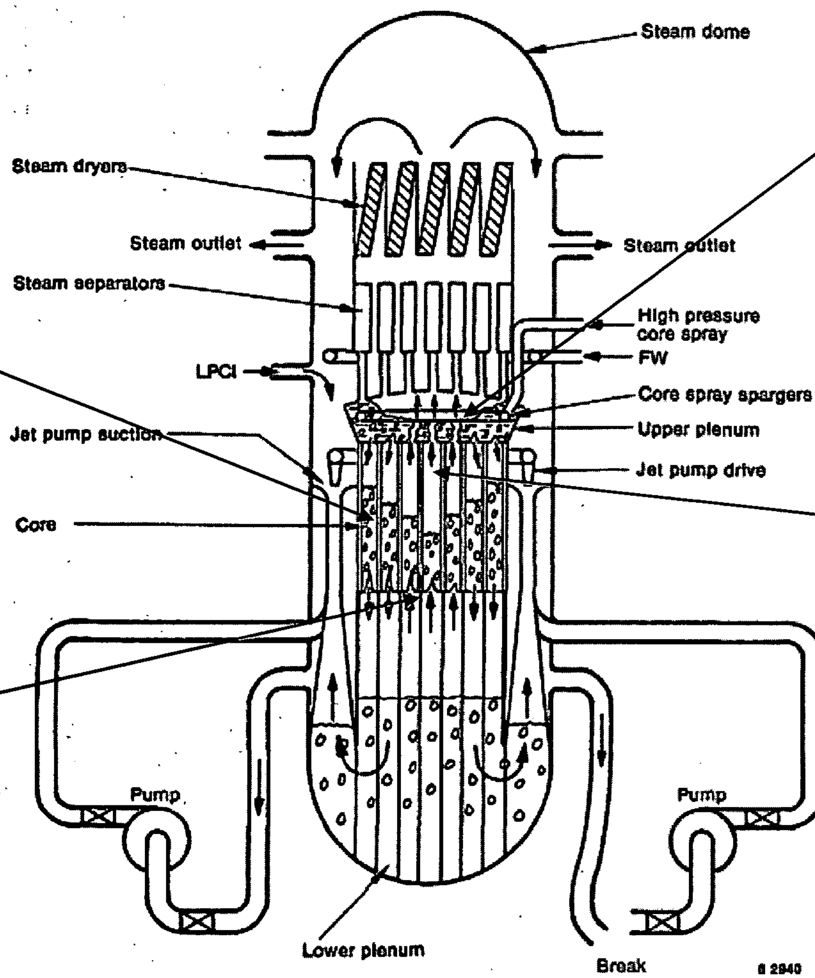
Metal-Water Reaction

Fuel Rod Perforation

Key BWR LOCA Phenomena

Bypass Leakage Provides Early Core Reflood

Steam from Lower Plenum Flashing Holds up Liquid in Core due to CCFL in Side Entry Inlet Orifice (SEO)



Holdup in Upper Plenum due to Steam from Lower Plenum (flashing) and Core (heat transfer)

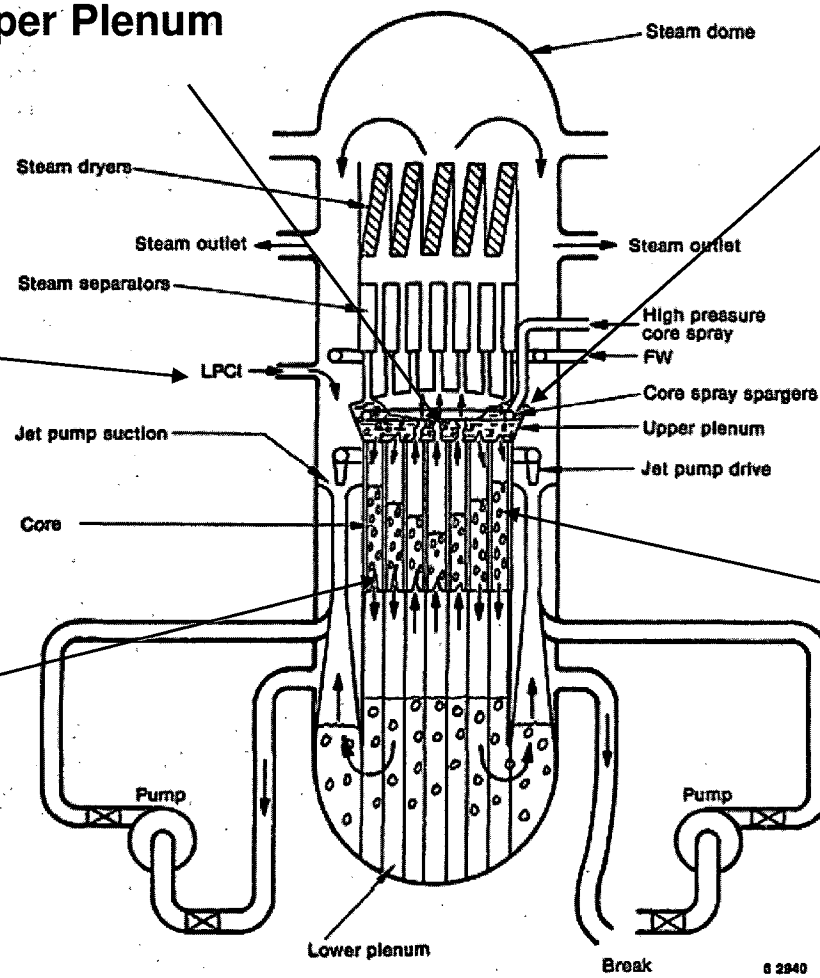
Uncovered Central Channels Cooled by Uprushing Steam and Droplets

Key BWR LOCA Phenomena

Pool of Water Forms in Upper Plenum

LPCI Fills Bypass Region Liquid Enters Core through Channel Leakage Path

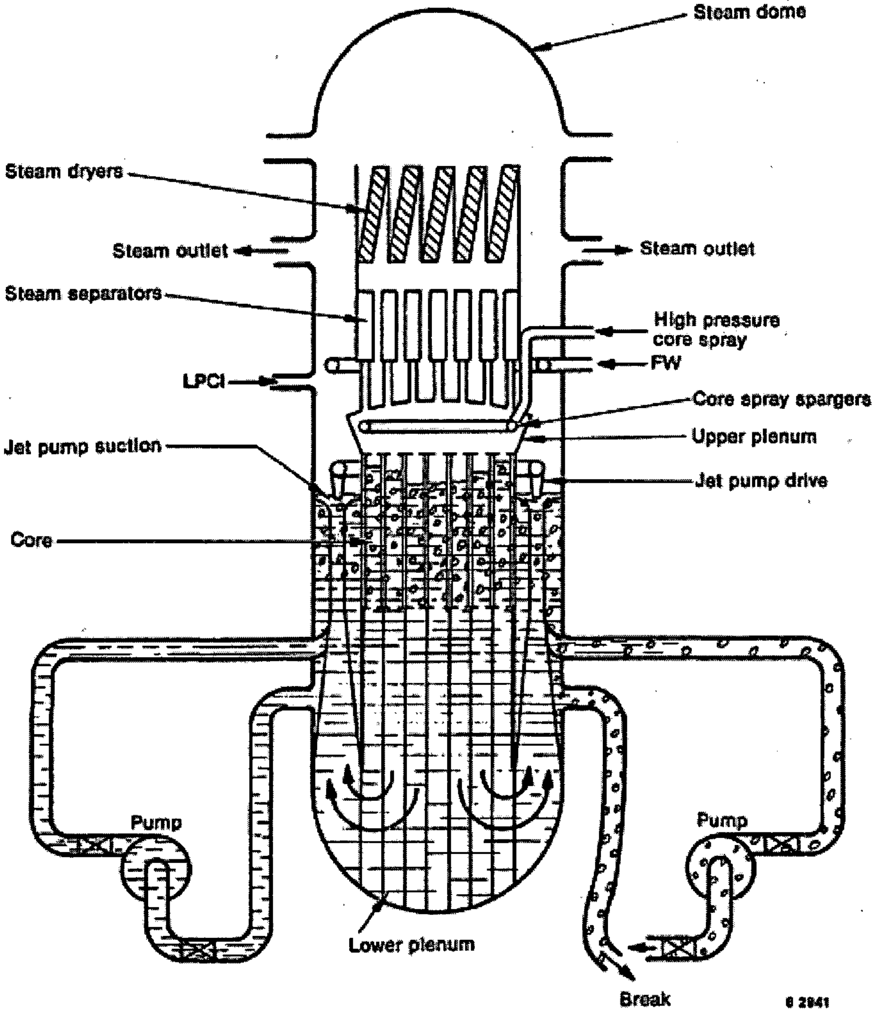
Bypass Leakage Provides Early Core Reflood



CCFL at the top of the fuel bundle delays downflow of injected core spray

CCFL Breakdown Peripheral Low Power Bundles Down Flow Helps Refill and Reflood Core Early

BWR LOCA Event (Jet Pump Plant)

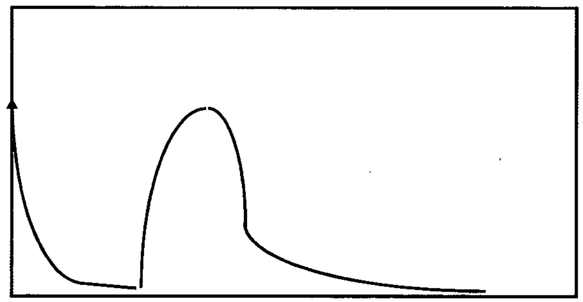


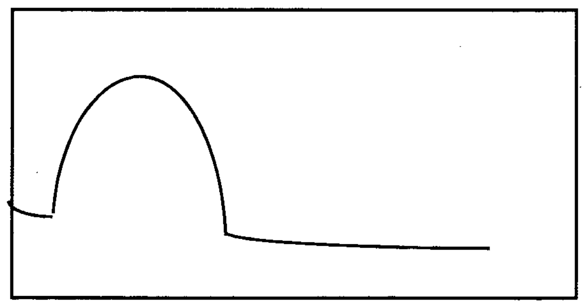
Break in Recirculation Suction Line

Scram, Loss of Power

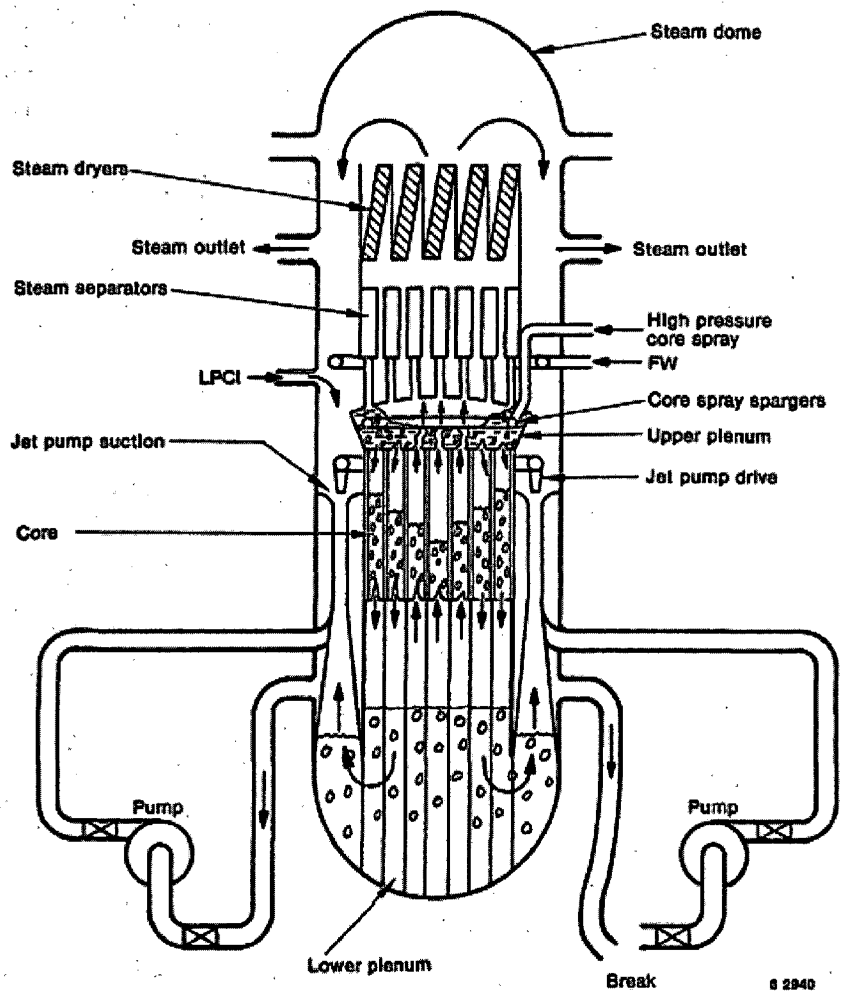
Flow Reversal in Broken Loop Jet Pump Coast Down of Intact Pump

Large Reduction in Core Flow and Early Boiling Transition (EBT).





BWR LOCA Event (Jet Pump Plant)

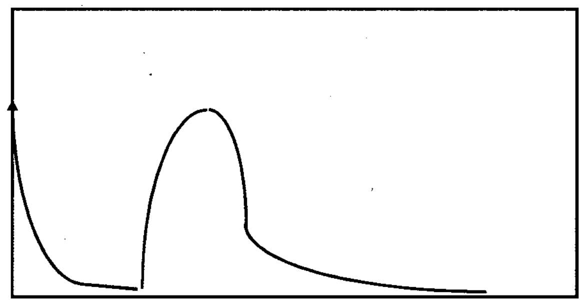


Increased Depressurization Following Jet Pump Uncovery

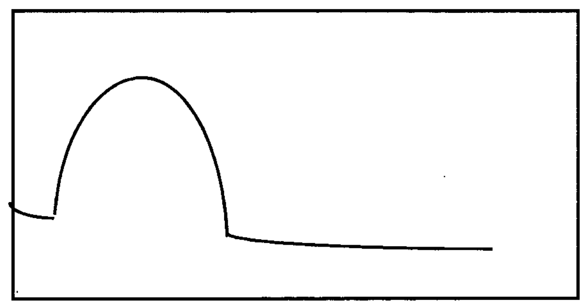
Flashing when T $_{sat(P)}$ < T_l

Increased Core Flow from Lower Plenum Flashing Quenches Fuel

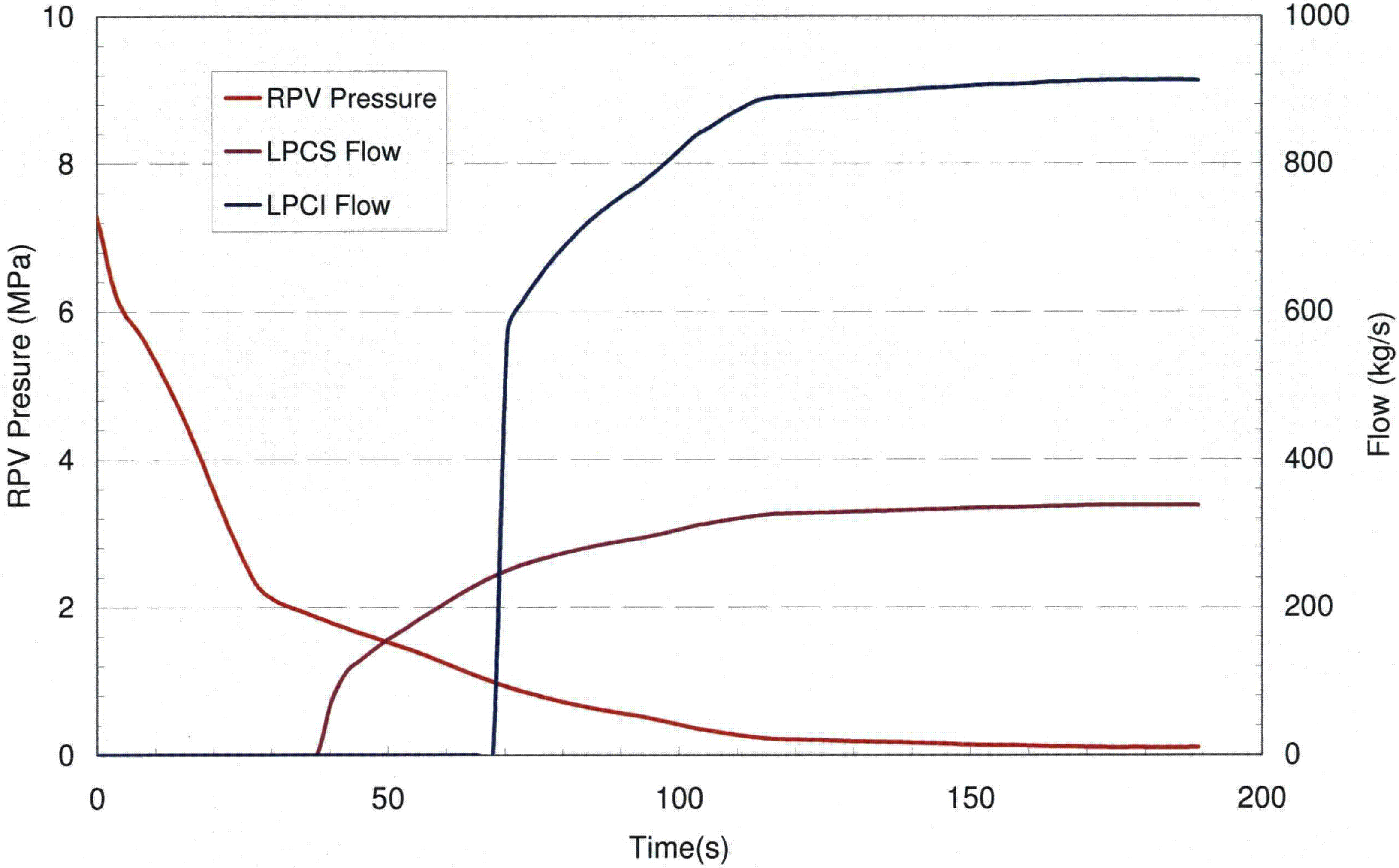
Core Flow



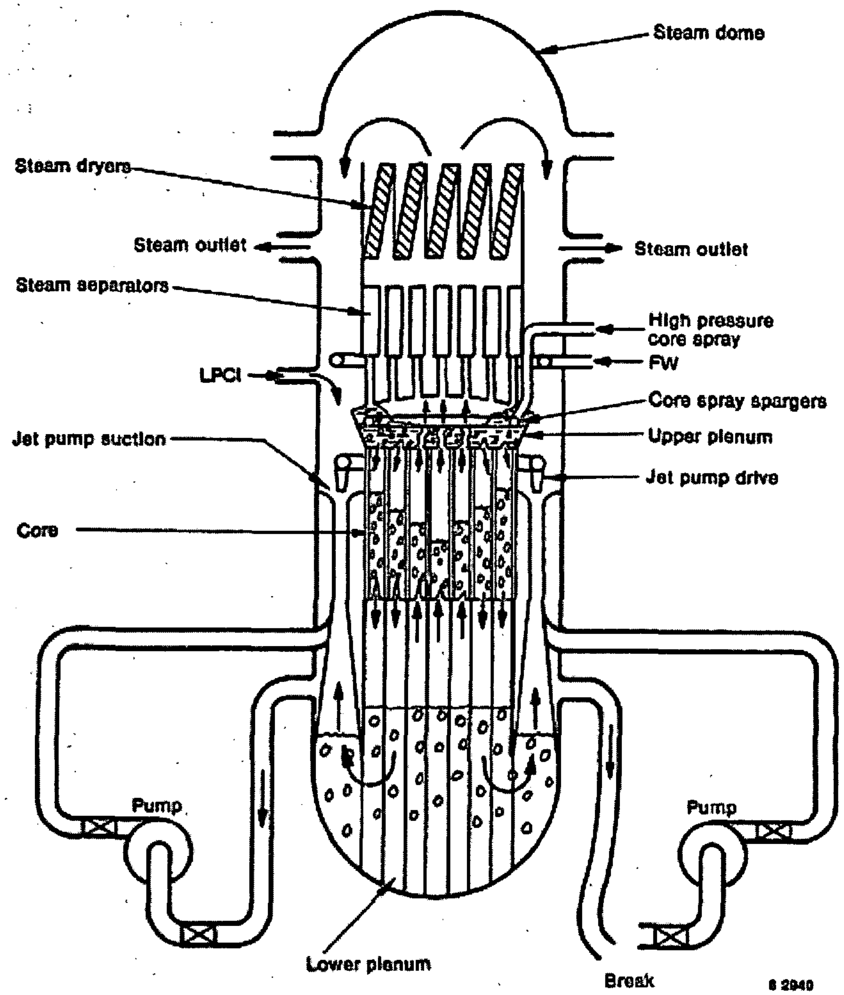
PCT



Debris Transport Delay Assumption



BWR LOCA Event (Jet Pump Plant)



Continued Depressurization

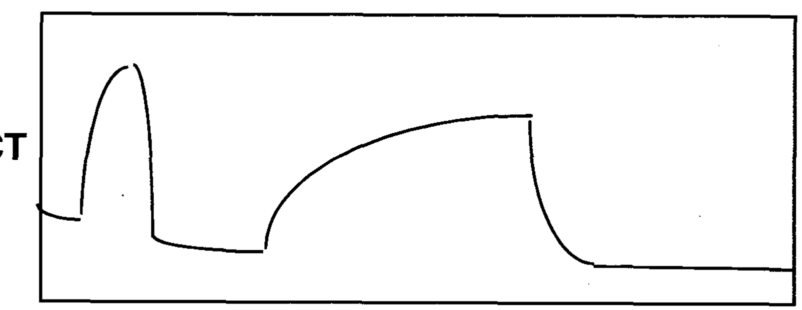
Loss of Liquid Inventory

Core Uncovery Leads to Second BT

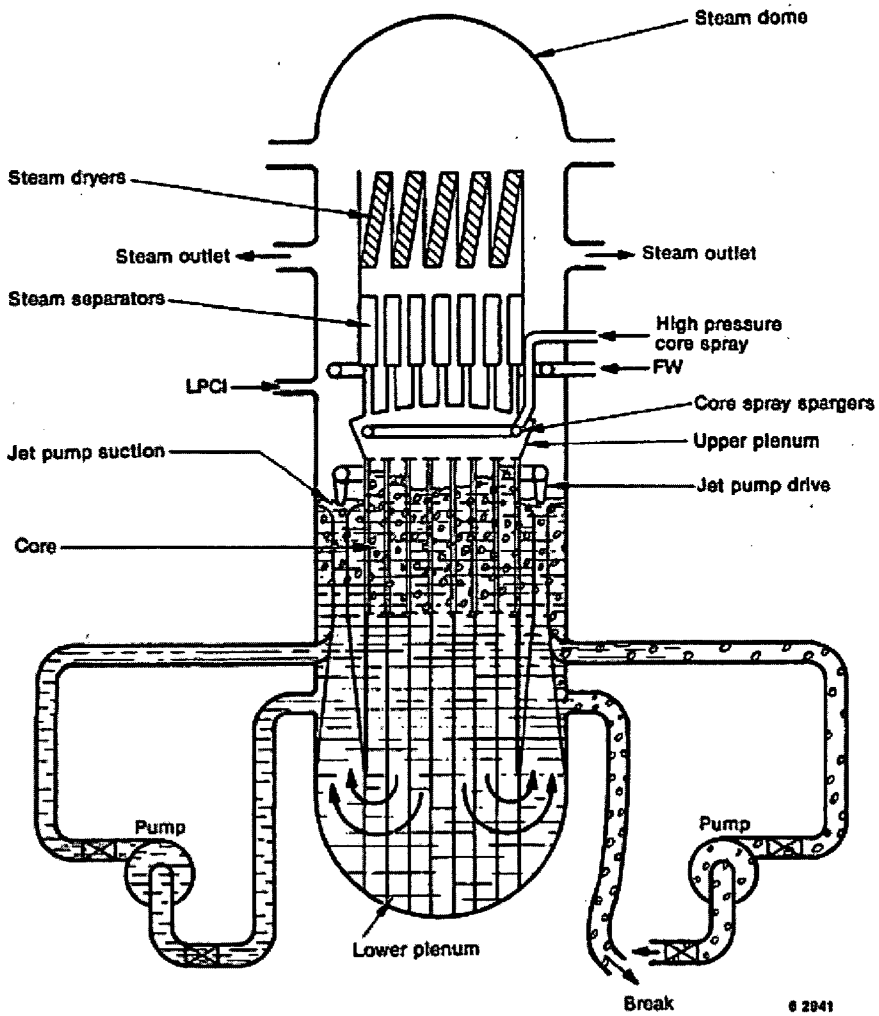
HPCS injects after (D/G Startup)

LPCS and LPCI inject when P < Shutoff Head

PCT



BWR LOCA Event (Jet Pump Plant)

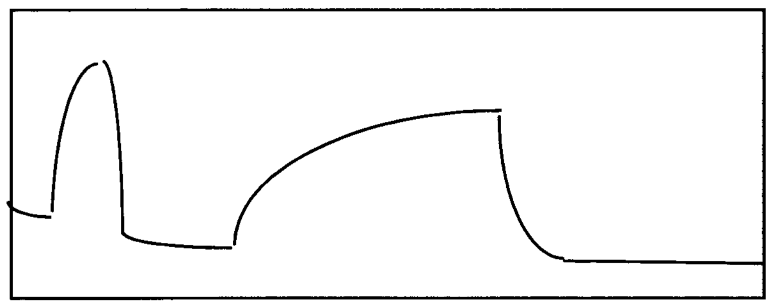


Refilling and Reflooding Restores Liquid Inventory and Quenches Core

Downcomer Level at Top of Jet Pump

Two-Phase Level Above Core

PCT



LOCA Regulatory History

Original acceptance limit - no core melt (~3300°F)

- GE used 2700°F PCT design limit

Early 1970s - ECCS Rulemaking

- 2300°F interim PCT limit

1974 - 10CFR50.46, Appendix K

- Defined acceptance criteria, required models

1988 - 10CFR50.46 revised

- Realistic models allowed

GEH LOCA Analysis & Methods History

Original Design Models

- 1960s, simple, conservative
- Used for ECC system design through BWR/6

SAFE/REFLOOD/CHASTE

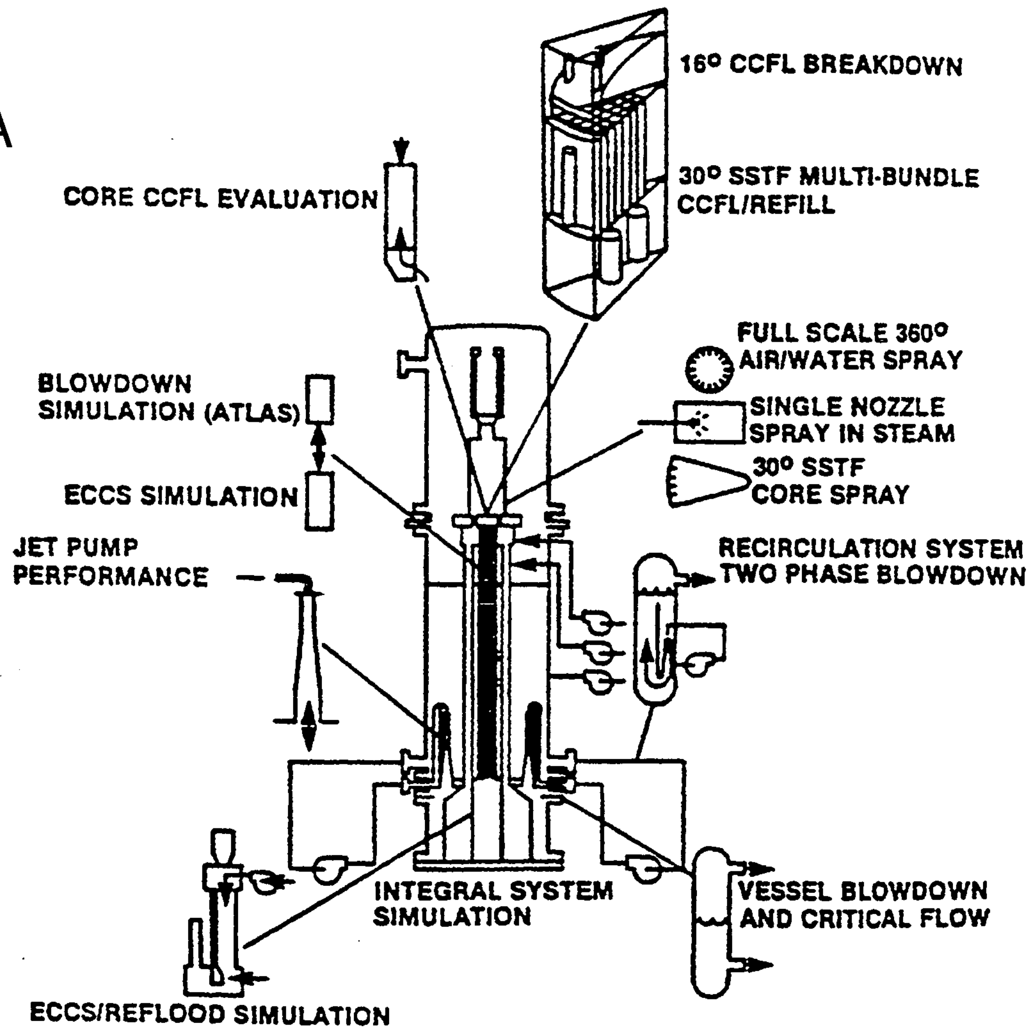
- 1970s, met Appendix K requirements (NEDE-20566P, 1978)
- Conservative model

SAFER/GESTR-LOCA

- 1984, based on integrated system tests
- "Realistic" model (benchmarked with TRACG)

Evaluation Models

- 10CFR50 Appendix K provides two options to evaluate the LOCA response
  - One detailed code
  - Series of codes
- SAFER/GESTR LOCA - 6 separate codes to evaluate 3 distinct phases of the LOCA response
  - Blowdown
  - Refill/Reflood
  - Core Heatup



LOCA Experimental Development

Individual phenomena studied first

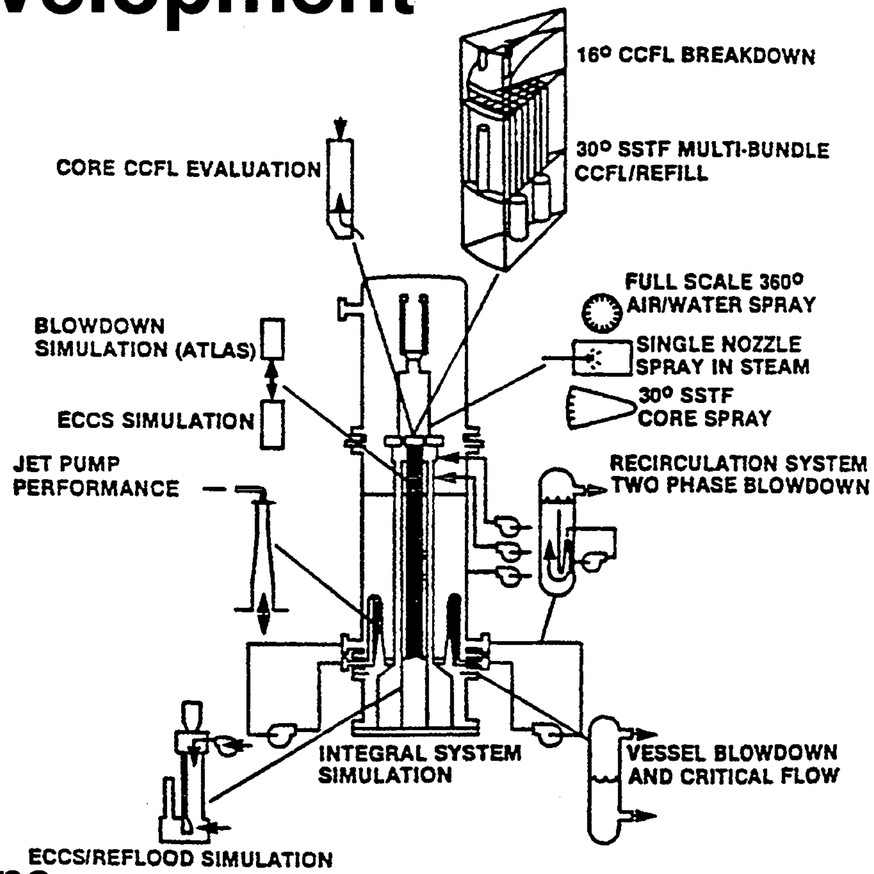
Separate effects tests (1960s)

- Break flow
- Fuel heatup
- Spray cooling
- Boiling transition

Integrated System Tests (1970s)

- Reactor and ECCS modeled
- 30° Sector core spray test

Demonstrated margin in ECCS designs

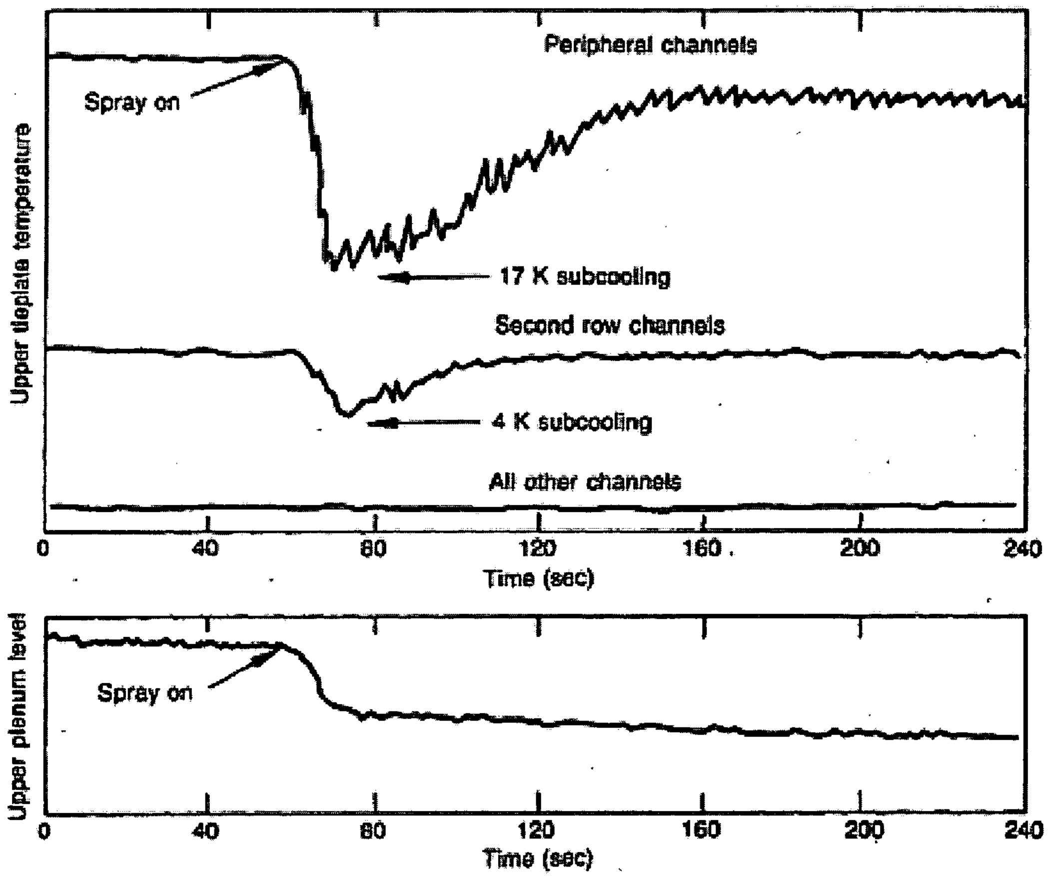


Regulations were revised to allow more realistic models like SAFER based on testing experience

Separate Effects Tests

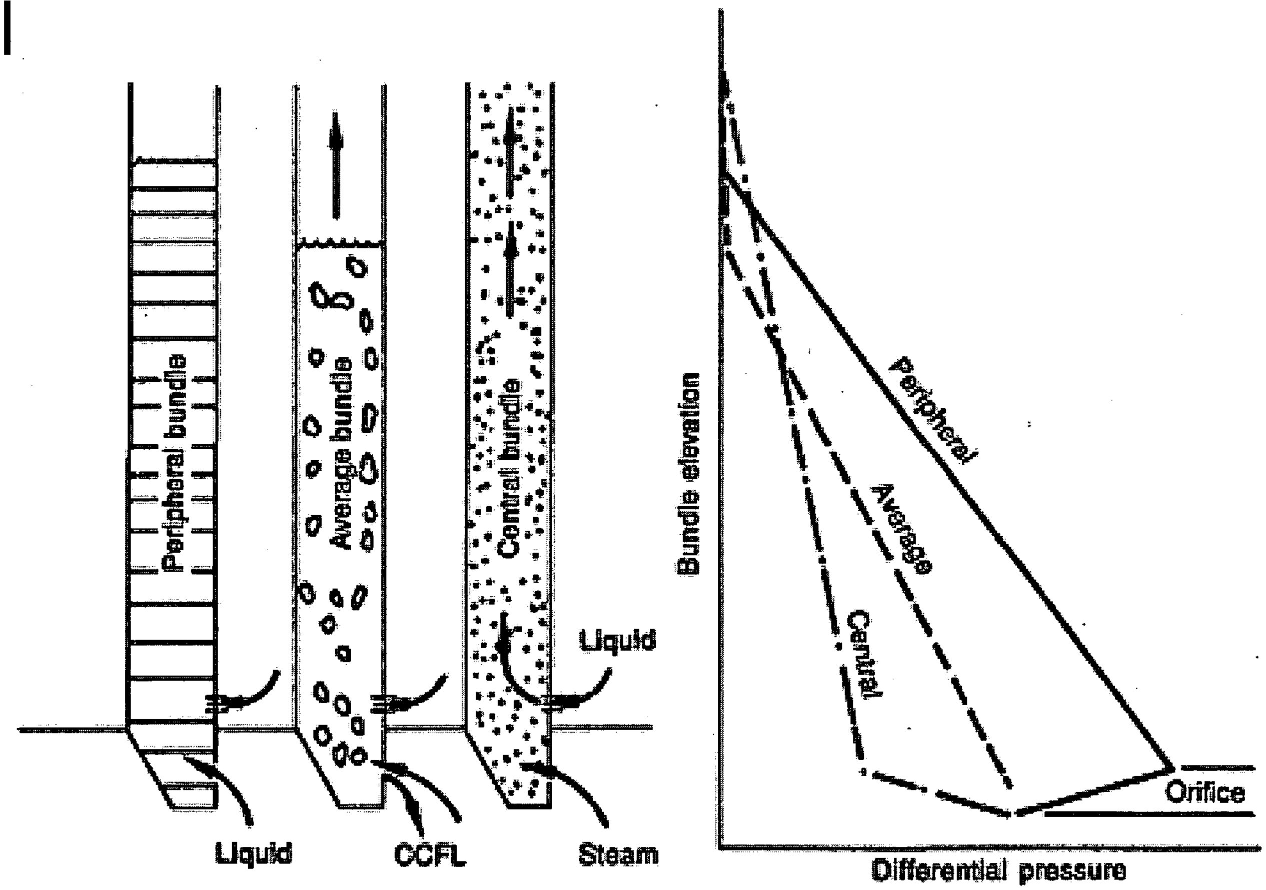
Upper plenum mixing test results from the Steam Sector Test Facilty (30^0 SSTF)

Rapid subcooled CCFL breakdown in peripheral bundles caused by the subcooled core spray



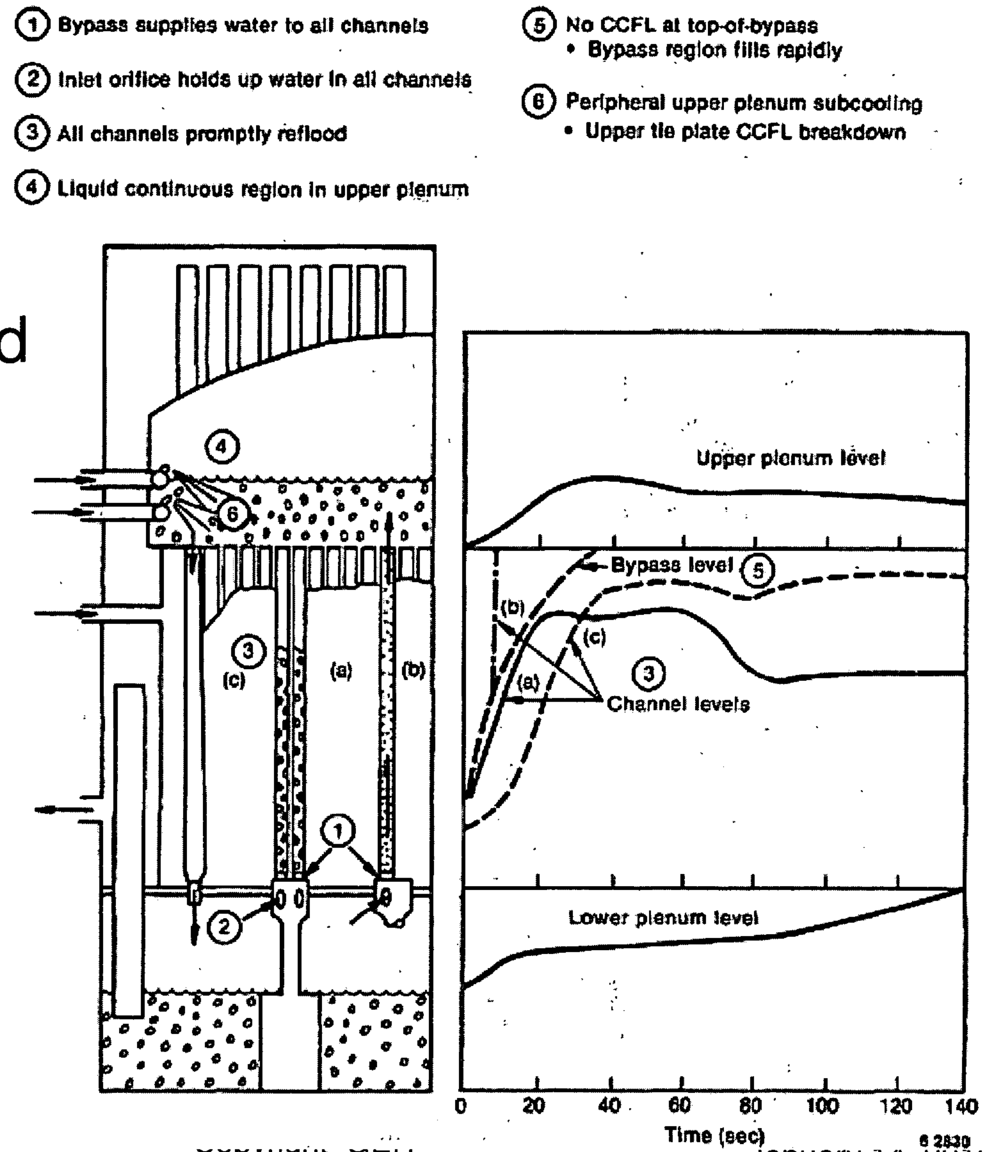
Separate Effects Tests

Multi-channel behavior

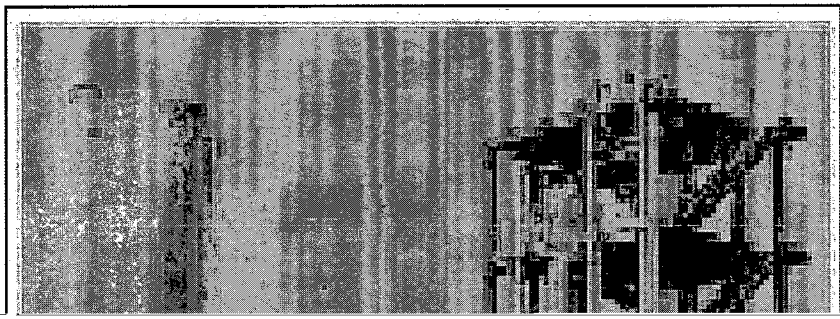


Separate Effects Tests

Large-scale separate-effects tests conducted under the BWR refill/reflood program showing that multidimensional effects enhance refilling of the core region by ECCS fluid injected above the core.



Two-Loop Test Apparatus (TLTA)



Located in San Jose, California

System Simulator volumetrically scaled to BWR/6-218

One full-size electrically heated bundle

TLTA Reference Test

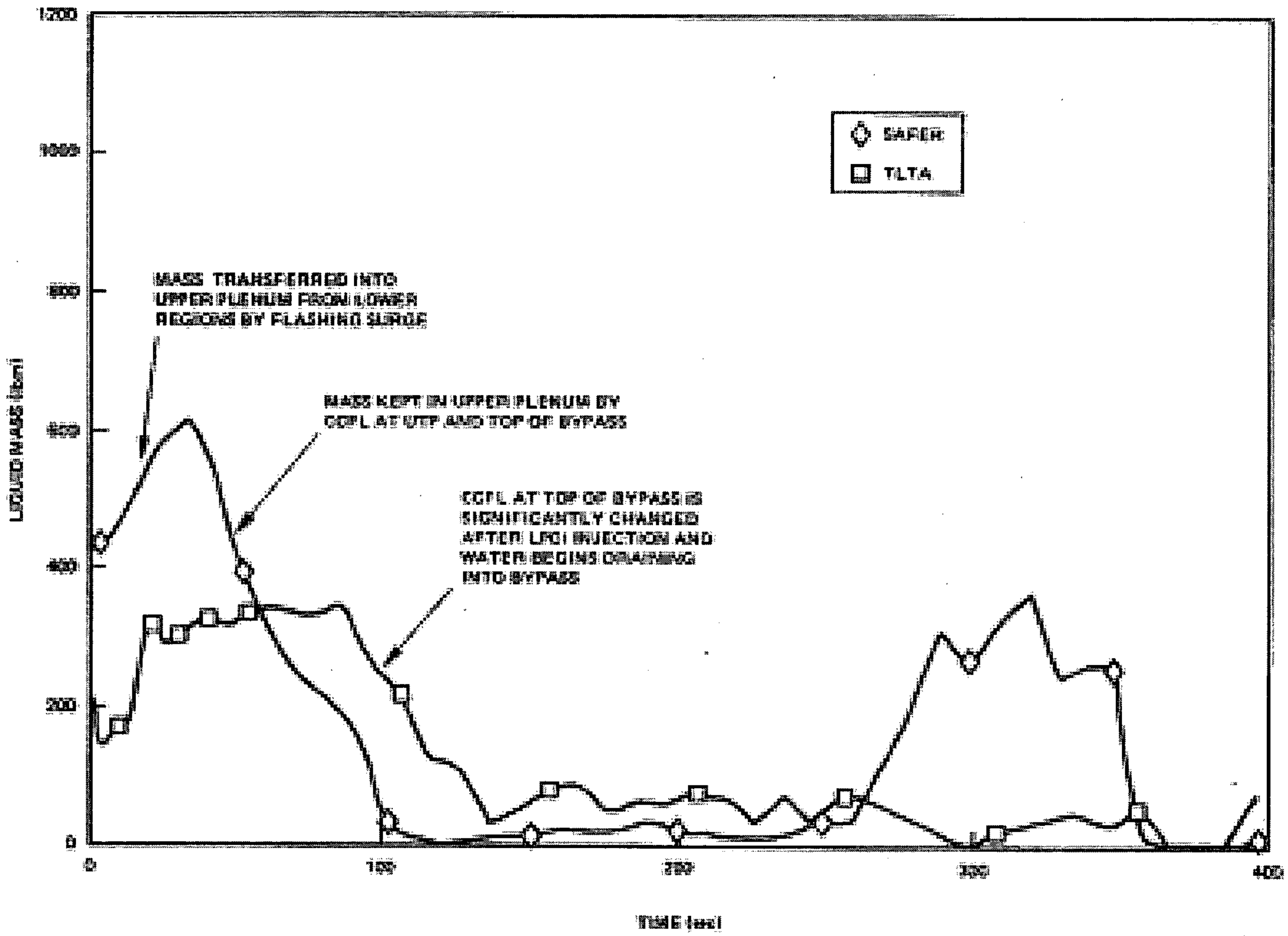


Figure 5-15. Upper Plenum Mass (6425/R2)

TLTA – Leakage Flow Paths

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TLTA Reference Test Summary

SAFER predicts the system response and phenomena observed in the test very well

SAFER correctly predicts CCFL at the UTP, SEO, top of bypass and top of guide tube

Mixture level and mass inventory in various regions generally well predicted

Bundle uncovery and recovery due to ECC injection agree with the test

SAFER calculates a Higher PCT –[[

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Clad Swell and Rupture Data NEDE-20566-P-A VOL I

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NUREG-1230 Section 6.6 Flow Blockage FLECHT-SEASET

6.6.4 Conclusions

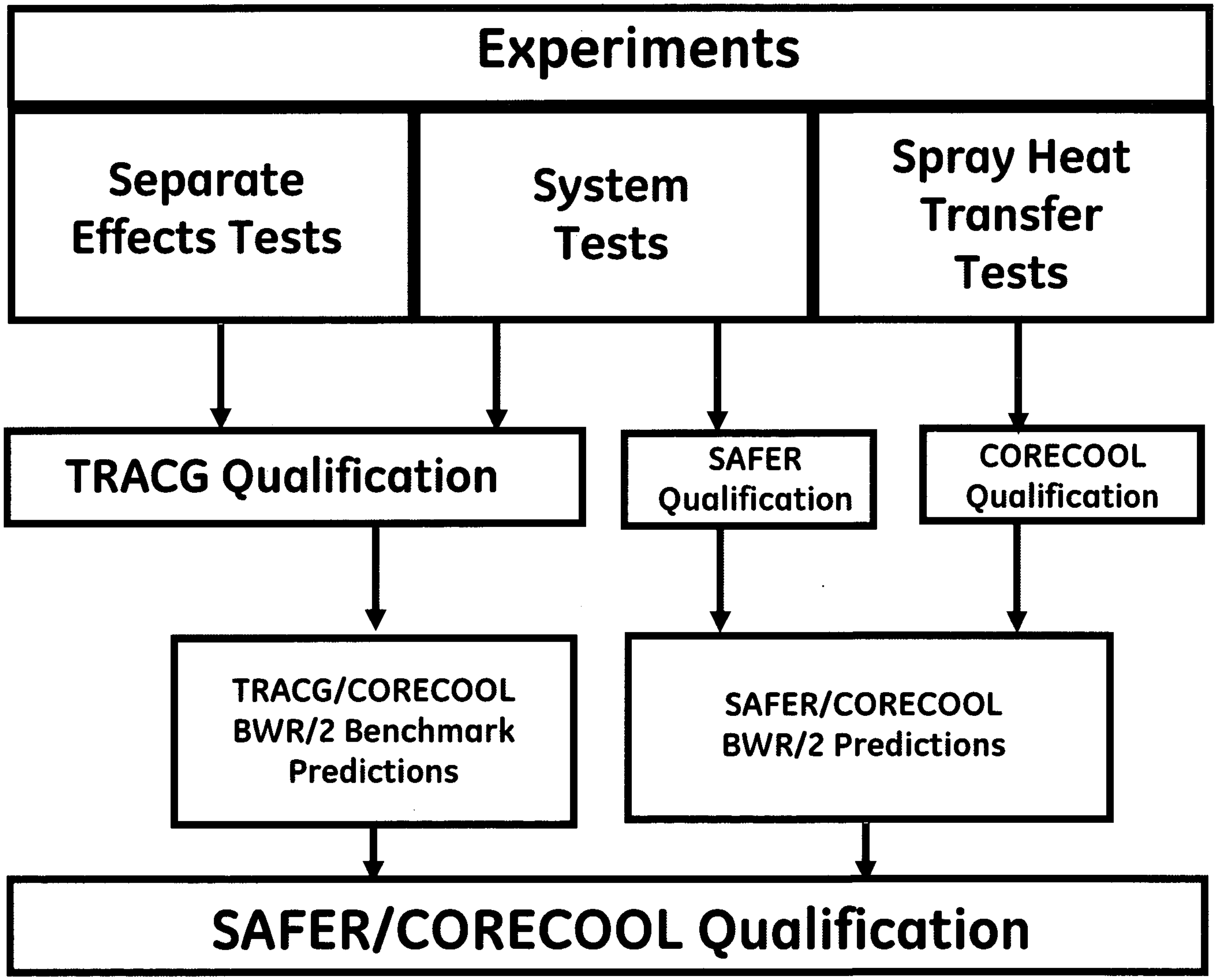
Section 6.6.3 has presented the results of experiments performed in the FLECHT, FLECHT-SEASET, FEBA and SCTF test facilities. These experiments have shown that:

- o Flow blockage at the midplane was found to improve heat transfer both upstream and downstream of the blocked region. This was due to increased turbulence and atomization of entrained liquid droplets and was found to be enhanced near the region of blockage.

- o Core rod heat transfer for a blocked and unblocked channel is dependent on the stage of reflood, that is, whether in the early violent steam generation stage or the later steady reflood phase (see Chapter 6.4). During the early stage, intense steam generation entrains liquid into the blocked portion which atomizes water droplets and increases the heat transfer significantly. Later during steady reflood the atomization effect is diminished because the entrainment of liquid to the blocked position is diminished.

- o On an overall heat transfer basis, large scale testing has shown that flow blockage of up to 62% (local blockage) produces an insignificant affect on core heat transfer.

SAFER/CORECOOL Strategy



SAFER-GESTR LOCA ANALYSIS METHODS

Application	Original Approved Method/Application NEDE-23785-1-PA, VOL II and III, October 1984	Enhanced Approved Method NEDE-30996P-A, VOL I and II, October 1987	Current Refined Method NEDC-32950P, Rev 1 July 2007
Short-Term System Blowdown	LAMB	LAMB	LAMB
Short-Term Hot Channel Heat Transfer	SCAT	SCAT	TASC
Long-Term System Inventory (Refill)	SAFER02 (1984)	SAFER03 (1987)	SAFER04V (1988)
Fuel Rod Heatup	CHASTE	CORECOOL (If needed)	CORECOOL (If needed)
Fuel Rod Model	GESTR	GESTR	GESTR

SAFER Application
NRC SE Requirements

Licensing Basis PCT ≤ 2200°F

Upper Bound PCT < Licensing Basis PCT

Upper Bound PCT < 1600°F (jet pump plants)

- ELIMINATED (Feb. 2002 – NEDC-23785P VOL III Sup. I)

Break spectrum consistent with generic LTR

ECCS configuration, operating parameters consistent with generic LTR

Other SAFER-GESTR References

Letter, H.C. Pfefferlen, GE to J.A. Norberg, NRC, "ECCS Evaluation Model Improvement," July 14, 1988.

Stuart A. Richard (NRC) to James F. Klapproth (GENE), "Review of NEDE-23785, Vol. III, Supplement 1, Revision 1, "GESTR-LOCA and SAFER Models for Evaluation of Loss-of-Coolant Accident Volume III, Supplement 1, Additional Information for Upper Bound PCT Calculation," (TAC No. MB2774) February 1, 2002.

Letter, M. C. Honcharik, (NRC) Office of Nuclear Reactor Regulation, to R. E. Brown, (GE) Manager, Regulatory Affairs, "TOPICS TO BE ADDRESSED IN UPDATED GENERAL ELECTRIC NUCLEAR ENERGY (GENE) TOPICAL REPORT (TR) NEDC-32096P, 'COMPILATION OF IMPROVEMENTS TO GENE'S SAFER ECCS [EMERGENCY CORE COOLING SYSTEM]-LOCA [LOSS-OF-COOLANT] EVALUATION MODEL," May 23, 2007.

NEDC-32950P, "COMPILATION OF IMPROVEMENTS TO GENE'S SAFER ECCS-LOCA EVALUATION MODEL", July 2007.

NRC Approved LOCA Methodology

SAFER/GESTR

- NEDE-23785P-A, VOL II and III, October 1984
- NEDE-30996P-A, VOL I and II, October 1987
- 1988 - 10CFR50.46 revised, realistic models allowed
- NEDE-23785P-A, Supplement 1, Rev. 1 March 2002 (MB2774)

TRACG

- Benchmarking of SAFER (including plant modeling uncertainty)
  - NEDE-23785P-A - 1984
  - NEDE-30996P-A - 1987
- NEDE-32906-P TRACG AOO July 2001 (MC5039)
- ESBWR LOCA/ECCS/Containment Analysis
  - NEDC-33083P – Approved 2004

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SAFER TRACG Benchmarking

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SAFER TRACG Benchmarking

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SAFER/TRACG Comparisons

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SAFER Calculations

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Table 3-1 NEDE-30996-PA VOL II

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Upper Bound PCT

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Upper Bound PCT

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SAFER and TRACG PCTs

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Licensing Basis PCT

[[

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UBPCT and LBPCT

[[

As the PCT increases, the difference between the licensing basis PCT and the upper bound PCT increases.

{3}]]

SAFER TRACG Benchmarking

SUBJECT: REVIEW OF NEDE-23785P, VOL. III, SUPPLEMENT 1, REVISION 1, "GESTR-LOCA AND SAFER MODELS FOR EVALUATION OF LOSS-OF-COOLANT ACCIDENT VOLUME III, SUPPLEMENT 1, ADDITIONAL INFORMATION FOR UPPER BOUND PCT CALCULATION" (TAC NO. MB2774)

GENE has performed additional comparison calculations using the TRACG thermal-hydraulic analysis code. While TRACG has not been reviewed and approved by the staff for this purpose, the code performs in a similar fashion to the staff's TRAC-B code. Also as documented in Reference 8, the staff reviewed and approved TRACG for anticipated operational occurrence analysis. In all cases analyzed for a typical BWR/4 design, SAFER predicts a higher second cladding temperature peak than does TRACG.

8. Safety Evaluation by the Office of Nuclear Reactor Regulation for NEDE-32906P, "TRACG Application for Anticipated Operational Occurrences (AOO) Transient Analyses," July 2001.

DBA Recirculation Line Break – SAFER (App K)

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DBA Recirculation Line Break – SAFER (App K)

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Long Term Cooling Compliance

- Criterion 5 – Long-Term Cooling: After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

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Long Term Cooling Compliance

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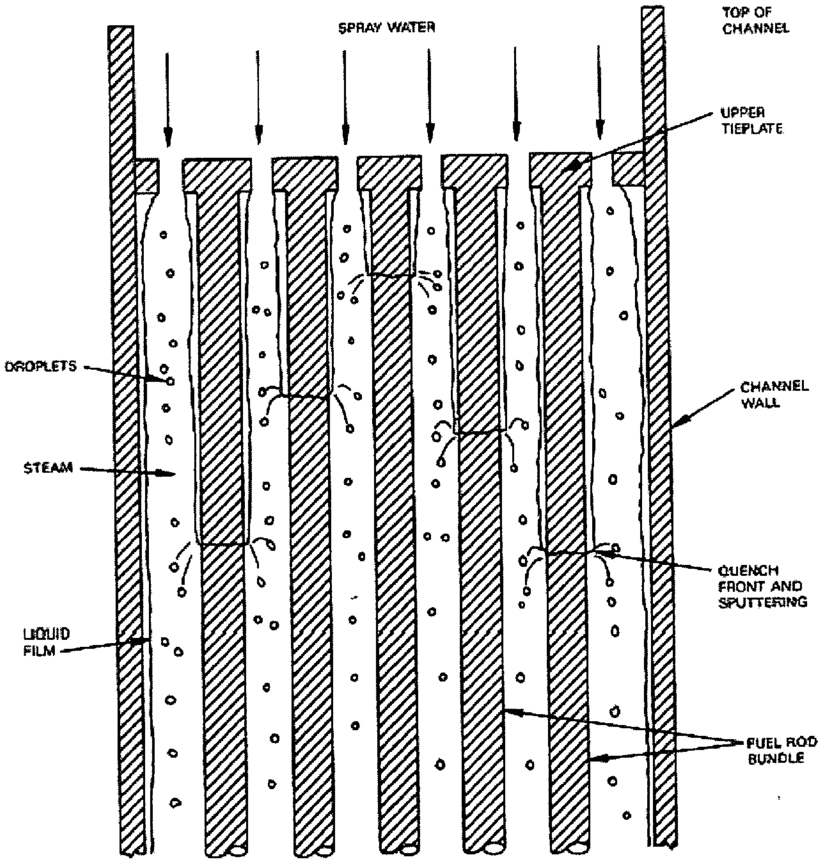
Long Term Cooling Phenomena

- Core Spray following Level Collapse



Long Term Cooling Phenomena

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Long Term Cooling Phenomena

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Counter Current Flow Limiting (CCFL)

Modified Wallis Model

$$j_g^* = j_g \sqrt{\frac{\rho_g}{g\Delta\rho}} = \frac{W_g}{A\sqrt{g\Delta\rho\rho_g}}$$

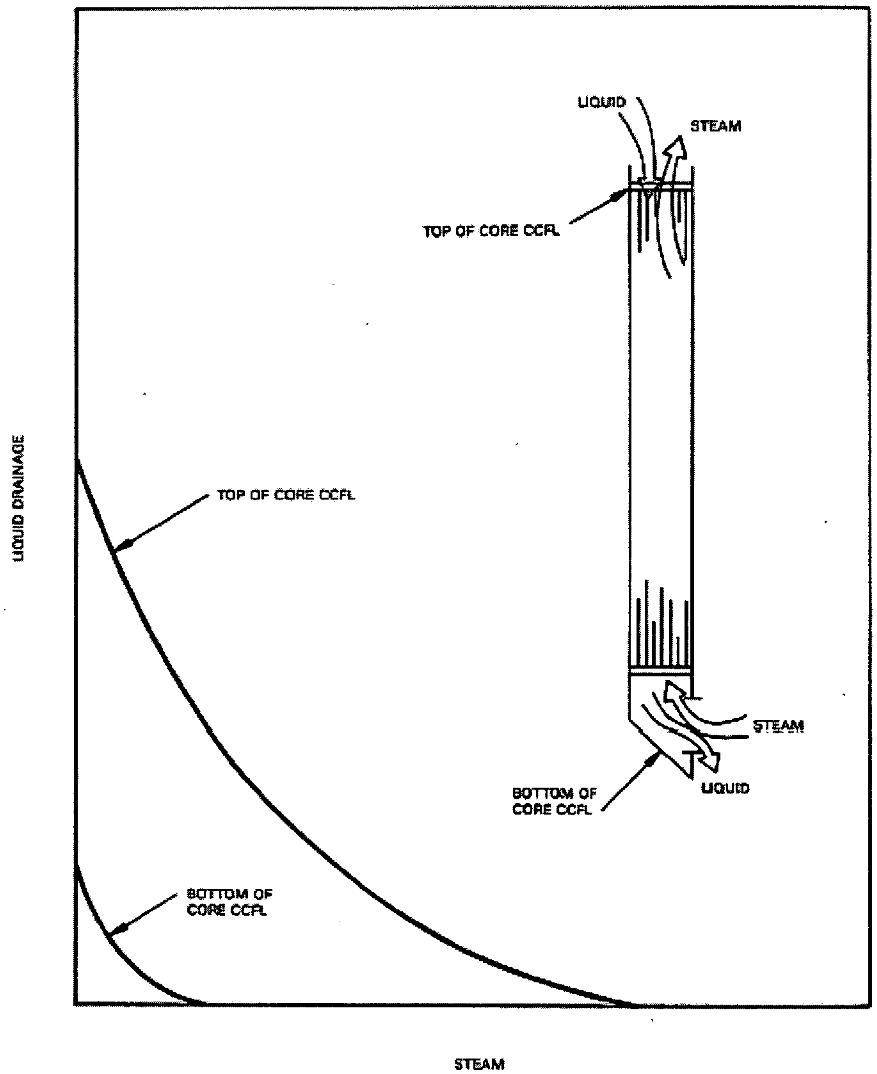
$$j_f^* = j_f \sqrt{\frac{\rho_f}{g\Delta\rho}} = \frac{W_f}{A\sqrt{g\Delta\rho\rho_f}}$$

$$\Delta\rho = \rho_f - \rho_g$$

Wallis-Kutateladze Model

$$j_f^* = j_f \sqrt{\frac{\rho_f}{\left(g g_c \sigma_f \Delta\rho\right)^{1/2}}} = \frac{W_f}{A[g g_c \sigma_f \rho_f^{\,2} \Delta\rho]^{1/4}}$$

$$j_g^* = j_g \sqrt{\frac{\rho_g}{\left(g g_c \sigma_g \Delta\rho\right)^{1/2}}} = \frac{W_g}{A[g g_c \sigma_g \rho_g^{\,2} \Delta\rho]^{1/4}}$$



Counter Current Flow Limiting (CCFL)

Modified Wallis Model

$$j_g^* = j_g \sqrt{\frac{\rho_g}{g\Delta\rho}} = \frac{W_g}{A\sqrt{g\Delta\rho\rho_g}}$$

$$j_f^* = j_f \sqrt{\frac{\rho_f}{g\Delta\rho}} = \frac{W_f}{A\sqrt{g\Delta\rho\rho_f}}$$

$$\Delta\rho = \rho_f - \rho_g$$

j_f^*, j_g^* have units of $ft^{1/2}$, C_2 has units of $ft^{1/4}$, and C_1 is dimensionless.

- CCFL locations, correlations and constants are determined based on experimental data

Wallis-Kutateladze Model

$$j_f^* = j_f \sqrt{\frac{\rho_f}{(gg_c\sigma_f\Delta\rho)^{1/2}}} = \frac{W_f}{A[gg_c\sigma_f\rho_f^2\Delta\rho]^{1/4}}$$

$$j_g^* = j_g \sqrt{\frac{\rho_g}{(gg_c\sigma_g\Delta\rho)^{1/2}}} = \frac{W_g}{A[gg_c\sigma_g\rho_g^2\Delta\rho]^{1/4}}$$

j_f^*, j_g^*, and C_1 and C_2 are all non-dimensional.

- CCFL locations, correlations and constants are described in SAFER LTRs
  - NEDE-23785P-A
  - NEDE-30996P-A

Blockage Assumptions

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PCT Sensitivity to Blockage at LTP and UTP (Reference Blockage Scenario)

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LOCA Licensing Model

Hot Channel Boundary and Local Conditions

BWR Plant Differences

Blockage Characteristics

Closer Examination of Previously shown TRACG LOCA Simulation Results

TRACG Qualification using CCFL Test Data

TRACG Qualification using Core Spray Heat Transfer (CSHT) Test Data

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Inlet Blockage Consequences

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Peak Clad Temperatures (PCT) for the Extreme (x) and Reference (r) scenarios defined on previous slide

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Maximum Oxide Thickness Fraction

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Total Fluid Mass in Hottest Bundle

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Total Fluid Energy in Hottest Bundle

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Average Static Quality in Limiting Bundle

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Average Static Quality in Limiting Bundle

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Energy Balance in terms of Power
(Decay Heat Power vs. Power being removed by Coolant)

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Energy Balance in terms of Power
(Decay Heat Power vs. Power being removed by Coolant)

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Energy Balance in Terms of Flow
(Min. Flow to remove Decay Heat vs. Calculated Flows)

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Energy Balance in Terms of Flow
(Min. Flow to remove Decay Heat vs. Calculated Flows)

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Void Distribution for 0-5 seconds
Node 3 = BAF, Node 27 = TAF

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Void Distribution for 0-1800 seconds

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Void Distribution for 0-1800 seconds

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Void Distribution for 1800-3600 seconds

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Void Distribution for 1800-3600 seconds

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Void Distribution for 3600-5400 seconds

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Void Distribution for 3600-5400 seconds

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Void Distribution for 5400-7200 seconds

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Void Distribution for 5400-7200 seconds

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Void Distribution for 7140-7260 seconds

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Void Distribution for 7140-7260 seconds

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Rod Groups in Peak Power Bundle (CHAN27) Control Blade Upper Left Corner, 5 = Hot Rod

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Rod Temp. by Rod Group for Hottest Axial Node

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Rod Temp. by Rod Group for Hottest Axial Node

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Hot Rod Temperature Profile: 0-1800 seconds

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Hot Rod Temperature Profile: 0-1800 seconds

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Hot Rod Model vs Hot Rod Group

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Hot Rod Model vs Hot Rod Group

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Summary of Observations from Calcs.

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Closer Examination of Previously shown TRACG LOCA Simulation Results

TRACG Qualification using CCFL Test Data

TRACG Qualification using Core Spray Heat Transfer (CSHT) Test Data

Selective CCFL Testing and Qualification

GNF-2

1. P.R. Diller, D. Abdollahian, J.G.M. Andersen, "GNF2 Counter-Current Flow Limitation Testing", , (Paper 8419), Proceedings of ICAP '08, Anaheim, CA USA, June 8-12, 2008.

GE 8x8 testing for SAFER/GESTR qualification

2. D. D. JONES and S. S. Dua, *General Electric Company Analytical Model for Loss-of-Coolant Analysis in Accordance with 10CFR50 Appendix K Amendment No. 4 -- Saturated Countercurrent Flow Characteristics of a BWR Upper Tieplate*, NEDO-20566-4, (1978).

TRACG04 Qualification

3. T*RACG Qualification*, NEDE-32176P, Revision 3, August 2007.

Other Selective CCFL References

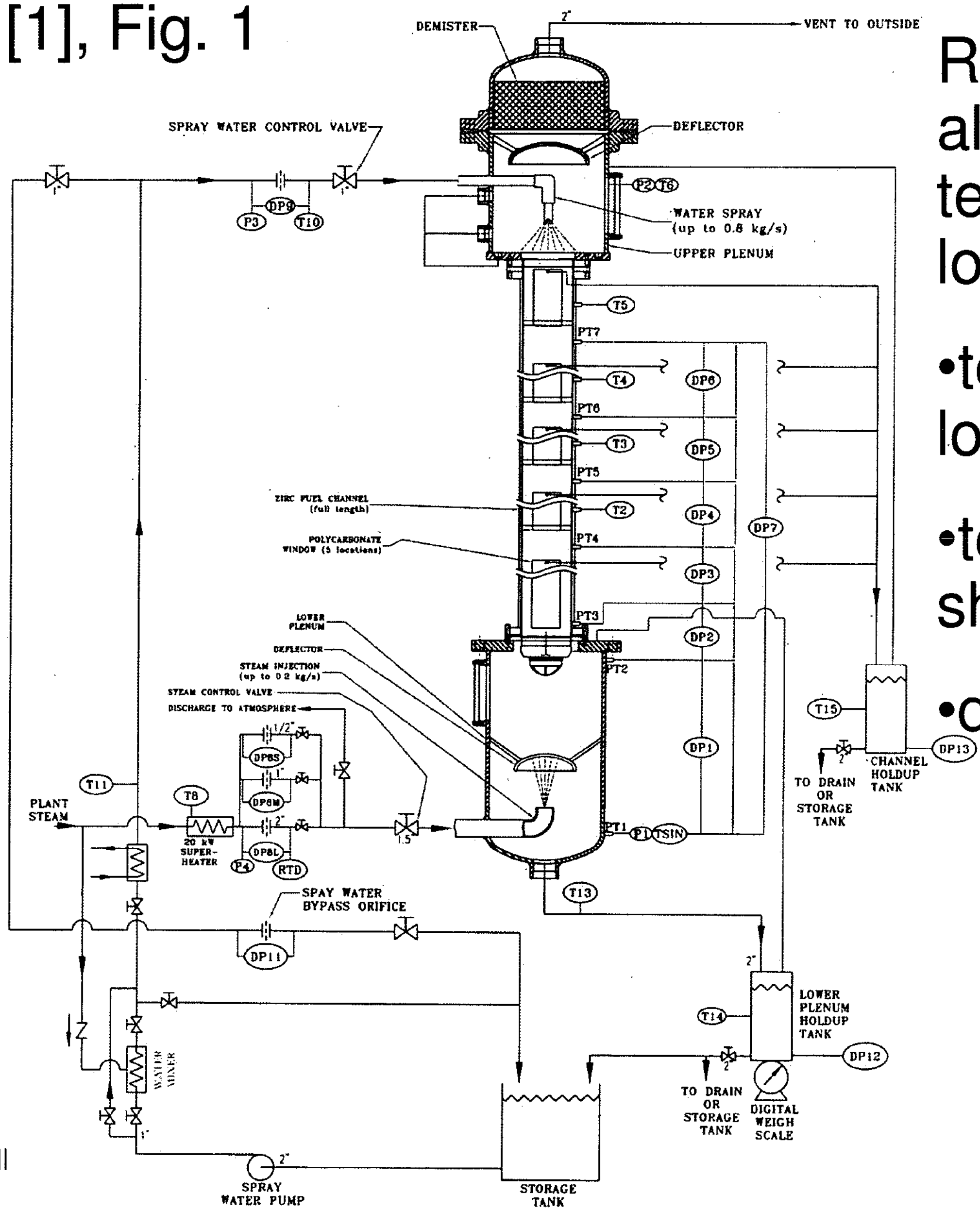
A. D. D. Jones, *Sub-cooled Counter Current Flow Limiting Characteristics of the Upper Region of a BWR Fuel Bundle*, NEDG-NUREG-23549, 1977.

B. Reactor Safety Issues Resolved by the 2D/3D Program, NUREG/IA-0127, July 1993.

C. S. S. KUTATELADZE, "Elements of Hydrodynamics of Gas-Liquid Systems", *Fluid Mechanics-Soviet Research*, **Vol. 1**, *No. 4*, pp. 29-50 (1972).

Schematic of Full-Scale BWR CCFL Test Loop

from Ref. [1], Fig. 1

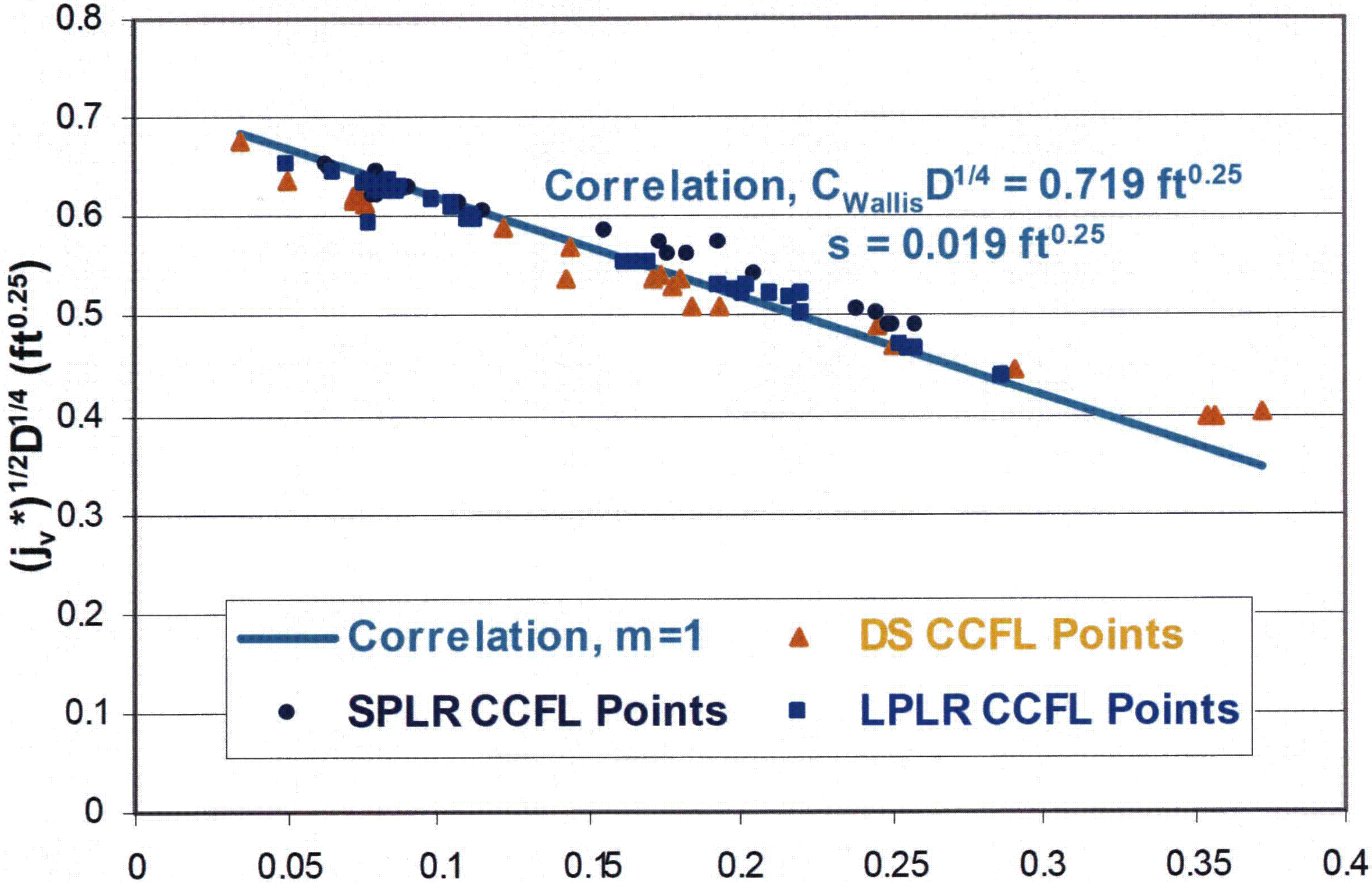


Reconfigurable rig allowed CCFL testing at 3 locations:

- top spacer of longer PLRs
- top spacer of shorter PLRs
- debris shield LTP

Same Correlation formula for All 3 Locations

(from Reference [1], Figure 8)



CCFL Constants with Standard Deviations

(from Reference [1], Tables I and II and the Conclusions)

Modified Wallis Constants and Sample Standard Deviation

	DS	SPLR	LPLR	All data
$C_{Wallis}D^{1/4}$ ($ft^{0.25}$)	0.712	0.732	0.717	0.719
s ($ft^{0.25}$)	0.025	0.017	0.011	0.019

Kutateladze Constants and Sample Standard Deviation

	DS	SPLR	LPLR	All data
K	2.37	2.43	2.38	2.39
s	0.081	0.055	0.034	0.061

Analyses of the test data confirmed that each test series experienced CCFL at the desired location. …the CCFL points were correlated for each component using a modified form of the Wallis correlation. The test data from different components were found to be in very good agreement, allowing for the correlation of all data as one dataset with a comparable standard deviation as any individual component.

CSHT CCFL Test Rig
(Ref. [4], Section 3.3)

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TRACG04 CCFL Qualification

(Ref. [4], Section 3.3)

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TRACG04 CCFL Qualification

[[(Ref. [4], Section 3.3)

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Closer Examination of Previously shown TRACG LOCA Simulation Results

TRACG Qualification using CCFL Test Data

TRACG Qualification using Core Spray Heat Transfer (CSHT) Test Data

Selective CSHT Testing and Qualification

SAFER/CORECOOL qualification

1. *SAFER Model for Evaluation of Loss-of-Coolant Accidents for Jet Pump and Non-jet Pump Plants,* NEDE-30996P-A, Vol. 1*, SAFER – Long Term Inventory Model for BWR Loss-of-Coolant Analysis*, Class III, October 1987. (Chapter 7: CORECOOL Qualification)

TRACG04 Qualification

2. T*RACG Qualification*, NEDE-32176P, Revision 3, August 2007.

CORECOOL CSHT Qualification (Ref.[1])

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CORECOOL CSHT Qualification (Ref.[1])

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TRACG04 CSHT Qualification
(Ref.[2], Sec.3.2)

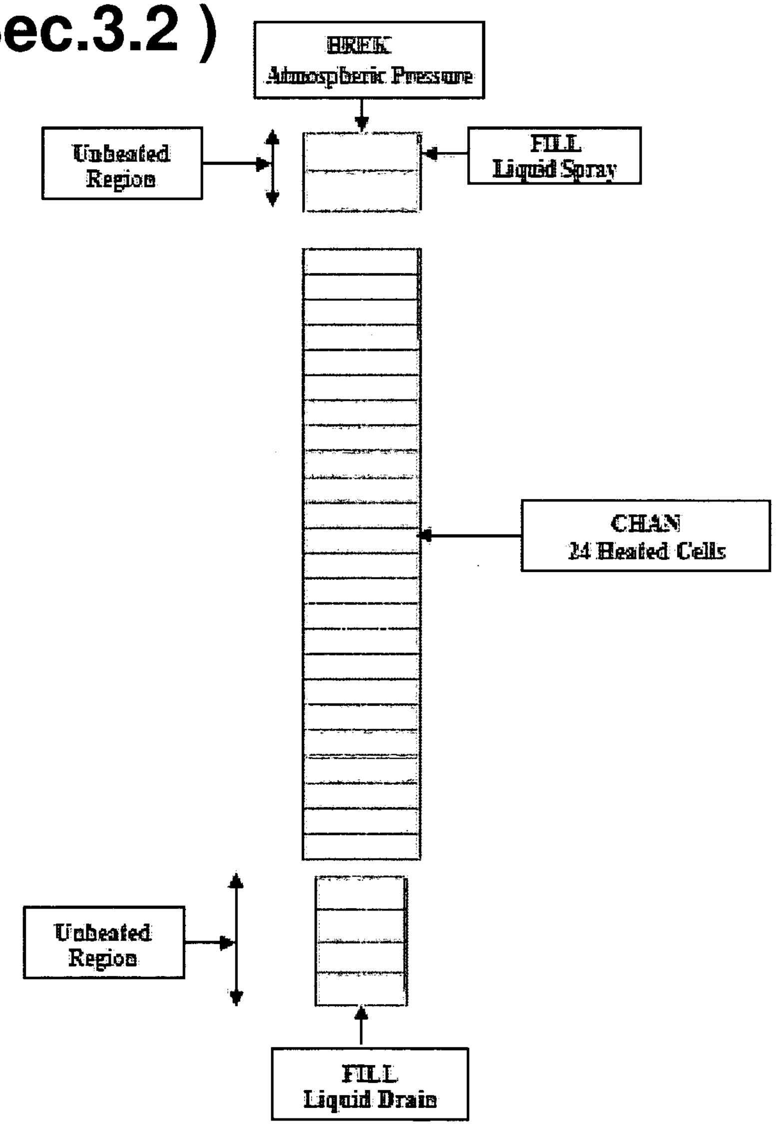

Figure 3.2-11. TRACG Nodalization of the CSHT Facility Bundle

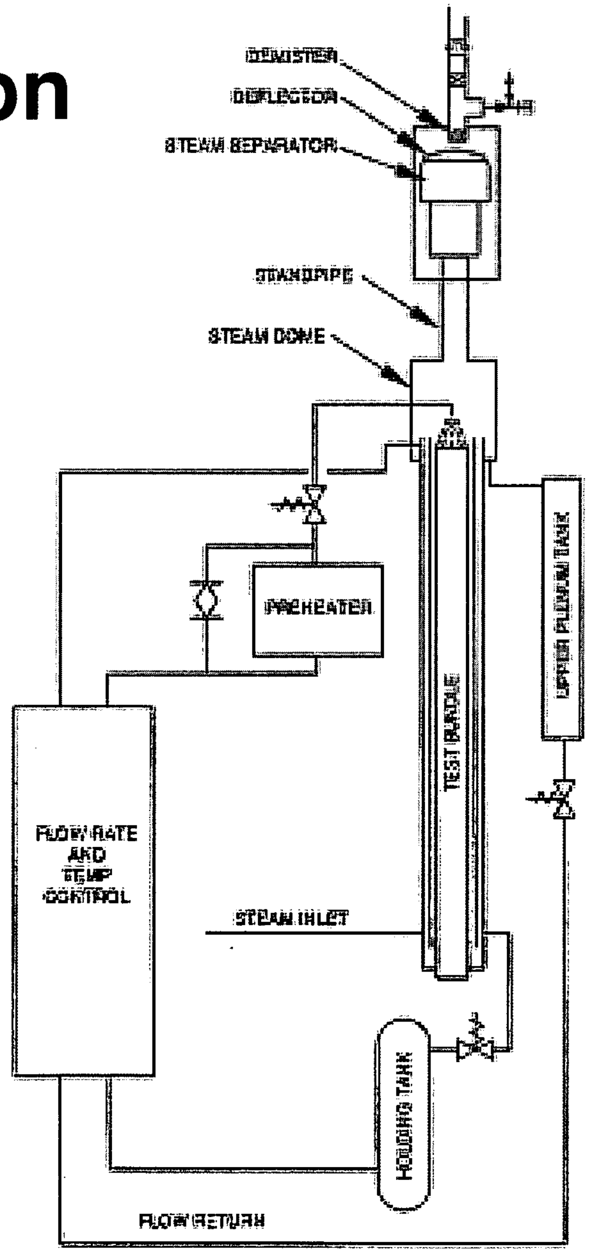

Figure 3.2-7. CSHT Facility Test Loop Schematic

TRACG04 CSHT Qualification (Ref.[2], Sec.3.2)

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TRACG04 CSHT Qualification (Ref.[2], Sec.3.2)

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TRACG04 CSHT Qualification (Ref.[2], Sec.3.2)

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TRACG04 CSHT Qualification (Ref.[2], Sec.3.2)

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Conclusions for Hot Channel Boundary and Local Conditions Calculated by TRACG04

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LOCA Licensing Model

Hot Channel Boundary and Local Conditions

BWR Plant Differences

Blockage Characteristics

BWR Plant Differences

- Large Recirculation Line Breaks
  - Jet Pump BWRs:
    - Short Term Reflooding
    - Low Pressure Core Injection (4 pumps)
    - Core Spray (2 pumps)
    - Minimum ECCS: 2CS or 1CS+2LPCI
  - Non-Jet Pump BWRs
    - No Reflooding
    - Two Failure Proof Core Sprays
    - Minimum ECCS: 2CS

BWR Plant Differences

- Small Recirculation and Other Line Breaks
  - Jet Pump BWRs:
    - Short Term Reflooding
    - Fail all high pressure injection
    - Actuate depressurization
    - Minimum ECCS: 2CS+2LPCI
  - Non-Jet Pump BWRs:
    - Short Term Reflooding (exc Recirc Breaks)
    - High pressure injection not significant
    - Actuate depressurization
    - Minimum ECCS: 2CS (exc CS break)

BWR Plant Differences

- LOCA Core Cooling Effectiveness
  - Jet Pump BWRs:
    - Short Term Reflooding for All Breaks
    - PCT Correlated to Uncovery Duration
    - Minimal Oxidation
    - Long Term Re-Uncovery (Large Recirc only)
  - Non-Jet Pump BWRs:
    - No Reflooding Recirc Break only
    - Cooling by CS alone
    - PCT and Oxidation Large Break Limited

BWR Plant Differences

- ECCS Strainer Debris Effects
  - Jet Pump BWRs:
    - Inlet Collection for covered core
    - Outlet Collection for fully blocked inlet
    - Outlet Collection for Re-Uncovery Long Term
  - Non-Jet Pump BWRs:
    - Inlet Collection for covered core [non-recirc breaks]
    - Outlet Collection for fully blocked inlet [non-recirc bks]
    - Outlet Collection for Short/Long Term uncovered core

BWR Plant Differences

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LOCA Licensing Model

Hot Channel Boundary and Local Conditions

BWR Plant Differences

Blockage Characteristics

Blockage Characteristics

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Blockage Characteristics

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Blockage Characteristics

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Review of NRC Questions

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Review of NRC Questions

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Review of NRC Questions

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Review of NRC Questions

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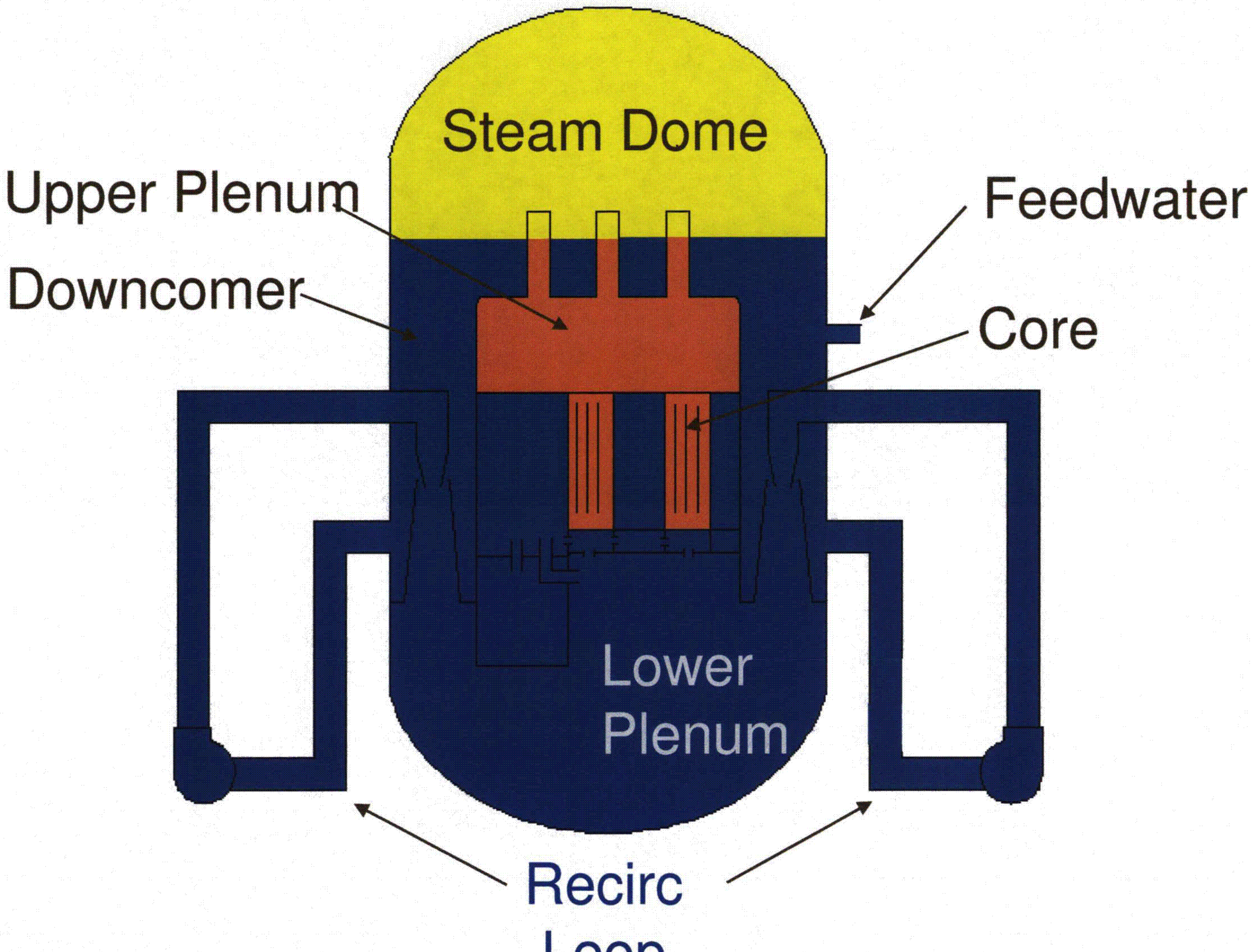
THANK YOU !

Typical BWR Normal Operation



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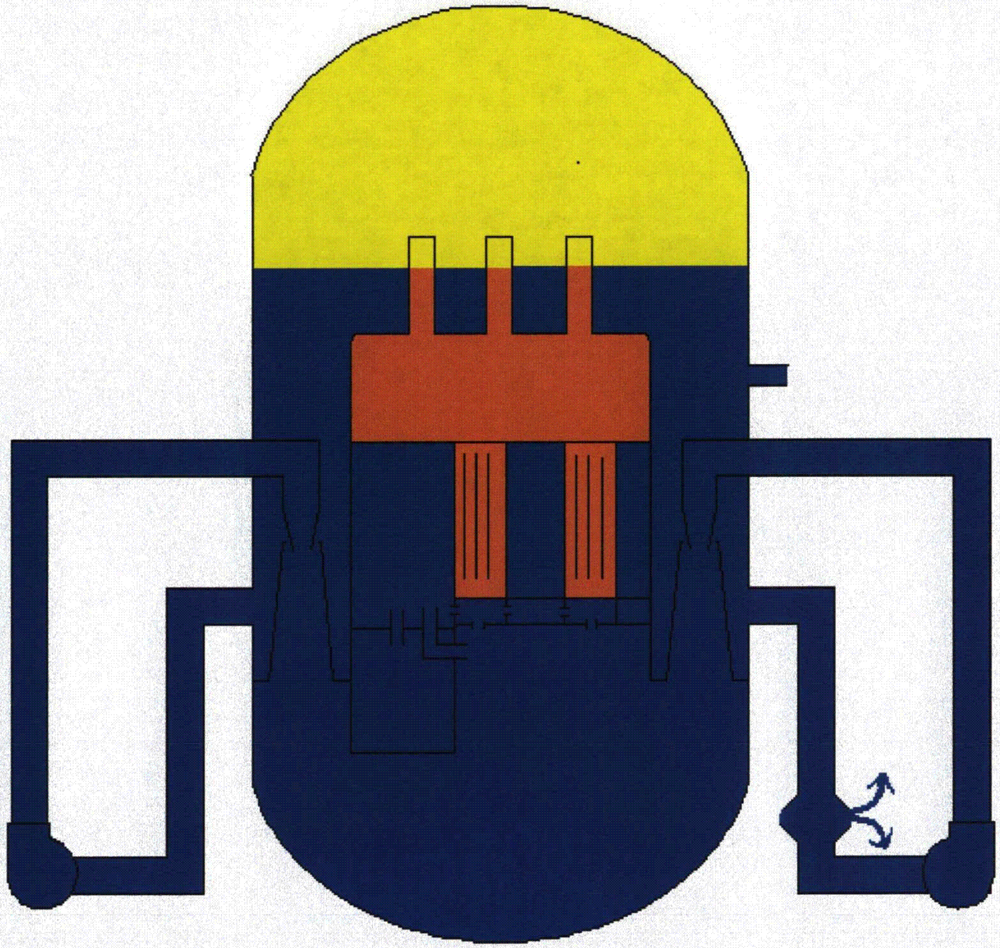
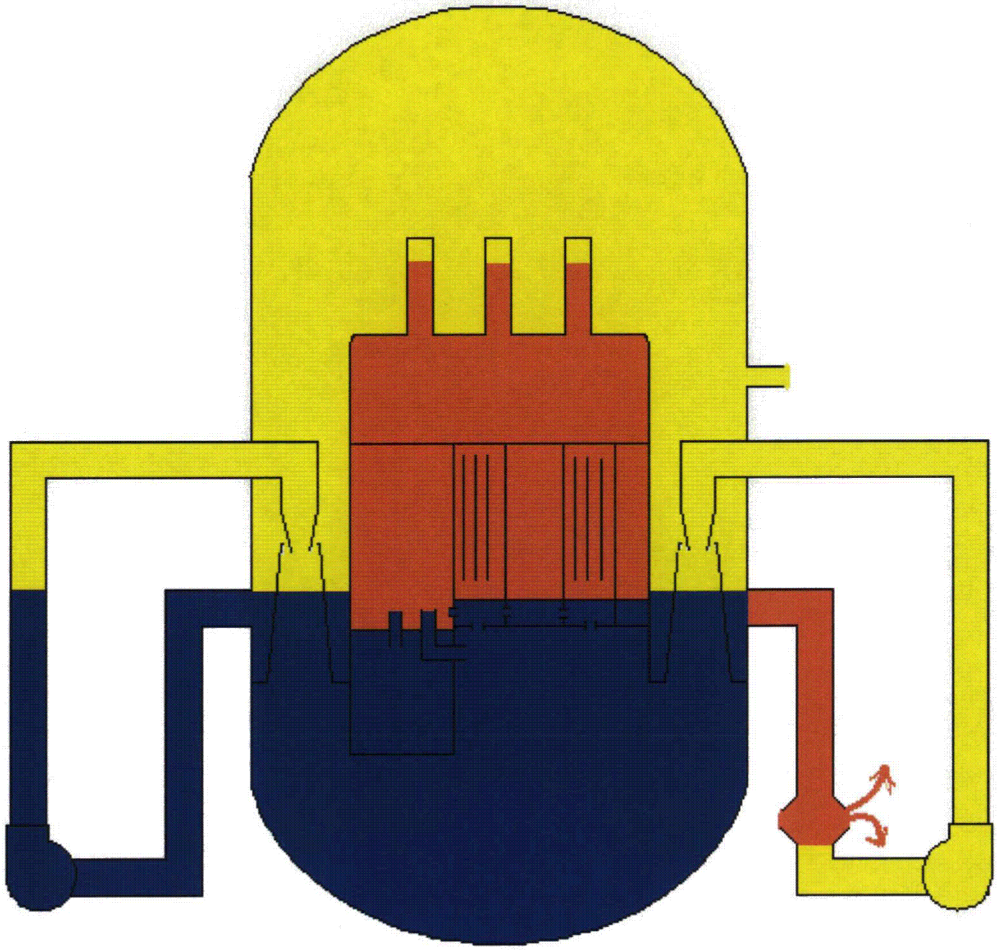
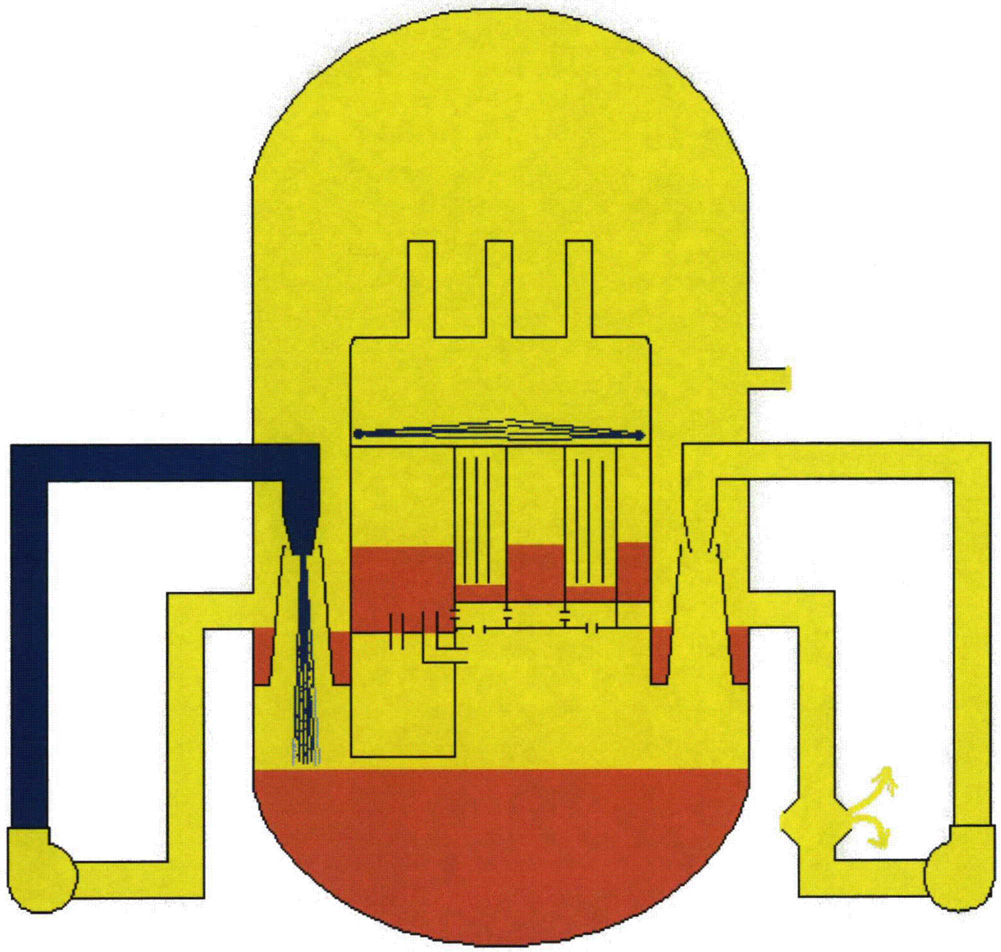
BWR LOCA Event – Initial Pipe Rupture



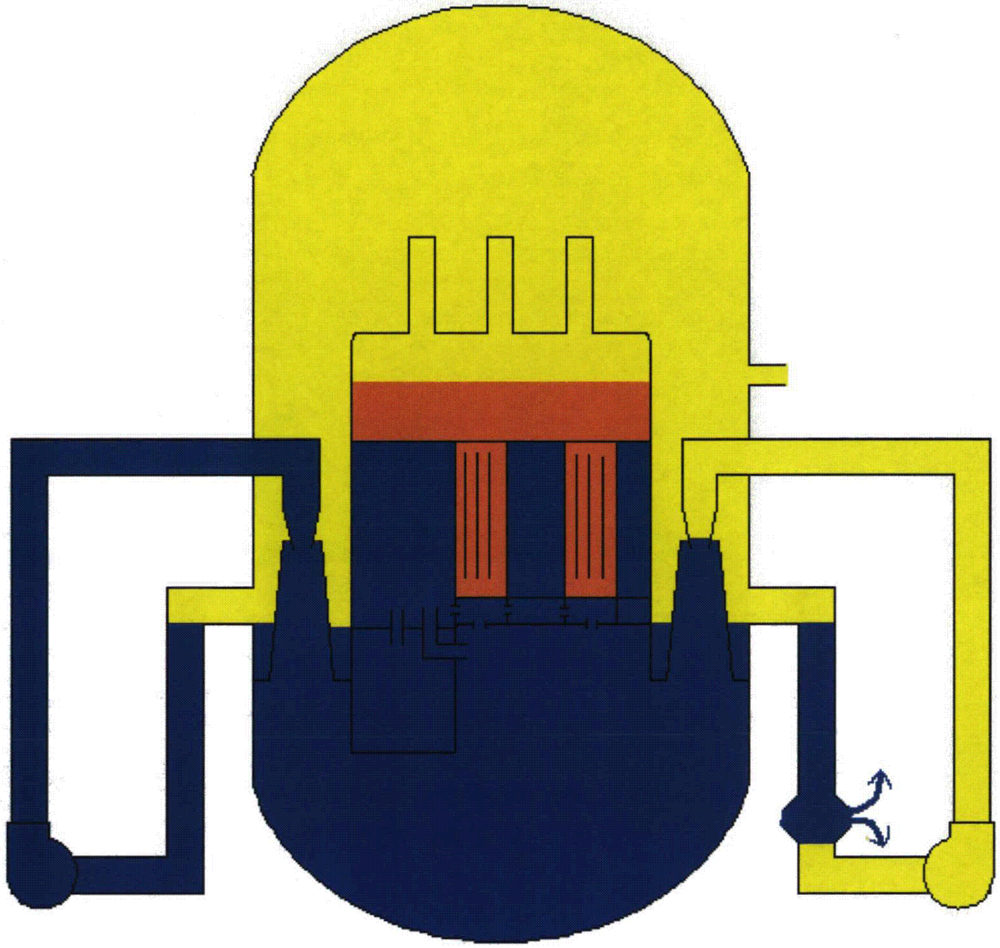
BWR LOCA Event – Prior to ECCS Injection



BWR LOCA Event – Initial ECCS Injection



BWR LOCA Event – Core Reflood



BWR LOCA Event – Long Term Cooling