January 29, 1997

MEMORANDUM TO: David B. Matthews, Chief
Generic Issues and Environmental
Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

FROM: Egan Y. Wang, Reactor System Engineer
Generic Issues and Environmental
Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

original signed by:

SUBJECT: MEETING SUMMARY OF JANUARY 9, 1997, REGARDING ANFB CORRELATION AND BWR REFLOOD CRITERIA

On January 9, 1997, representatives of Siemens Power Corporation (SPC) met with representatives of the Nuclear Regulatory Commission (NRC). Participants of this meeting also include representatives from Commonwealth Edison Company and Pennsylvania Power & Light Company. The purpose of this meeting was to provide an opportunity for SPC representatives to review and discuss ANFB correlation for Atrium-10 application and BWR reflood criteria issues. SPC representatives provided an introduction and a brief description on current activities with regard to the issues.

Most of the meeting involved presentation of proprietary information. Attachment 1 provides a list of meeting attendees. Attachment 2 is the non-proprietary version of the presentation material. Attachment 3 is the material presented by TU representative.

Attachments: As stated

cc w/att: See next page

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

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cc w/att: see next page

cc:

Mr. H. D. Curet, Manager
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Richland, WA 99352-0130

DISTRIBUTION: Mtg. Summary of January 9, Meeting with Siemens Power Corporation Dated January 29, 1997

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120059

NRC/SIEMENS POWER CORPORATION MEETING
ON CONTROL ROD INSERTION ISSUES
LIST OF ATTENDEES
January 9, 1997

NAME	ORGANIZATION
Copeland, R. A.	Siemens
Ingham, Jerry	Siemens
Curet, Don	Siemens
Keheley, Tom	Siemens
Garrett, Michael	Siemens
Lehmann, Chet	PP&L
Spadaro, John	PP&L
Kulick, John	PP&L
Maron, Drew	PP&L
Sgarro, R. R.	PP&L
Benes, Gary	Com Ed
Freeman, John	Com Ed
Wu, Shih-Liang	NRC/NRR/DSSA/SRXB
Phillips, Larry	NRC/NRR/DSSA/SRXB
Pulsifer, Bob	NRC/NRR/DRPW
Skay, Donna	NRC/NRR/DRPW
Ulses, Anthony	NRC/NRR/DSSA/SRXB
Matthews, Steven	NRC/NRR/DISP/PSIB
Kendrick, Edward	NRC/NRR/DSSA/SRXB
Huang, Tai	NRC/NRR/DSSA/SRXB
Wang, Egan	NRC/NRR/DRPM/PGEB

ATTACHMENT 1

NRC/SPC Meeting on BWR Methodology

January 9, 1997

Purpose of Meeting

- Review the application of ANFB correlation for the ATRIUM-10 design to show the application to be consistent with the NRC approval
- Describe the reflood criteria application in BWR LOCA analyses

Agenda

- Introduction--HD Curet
- ANFB Application for ATRIUM-10--TH Keheley
  - Safety Limit Analysis--JG Ingham
- BWR Reflood Criteria Application--ME Garrett
- Summary/Conclusions--HD Curet

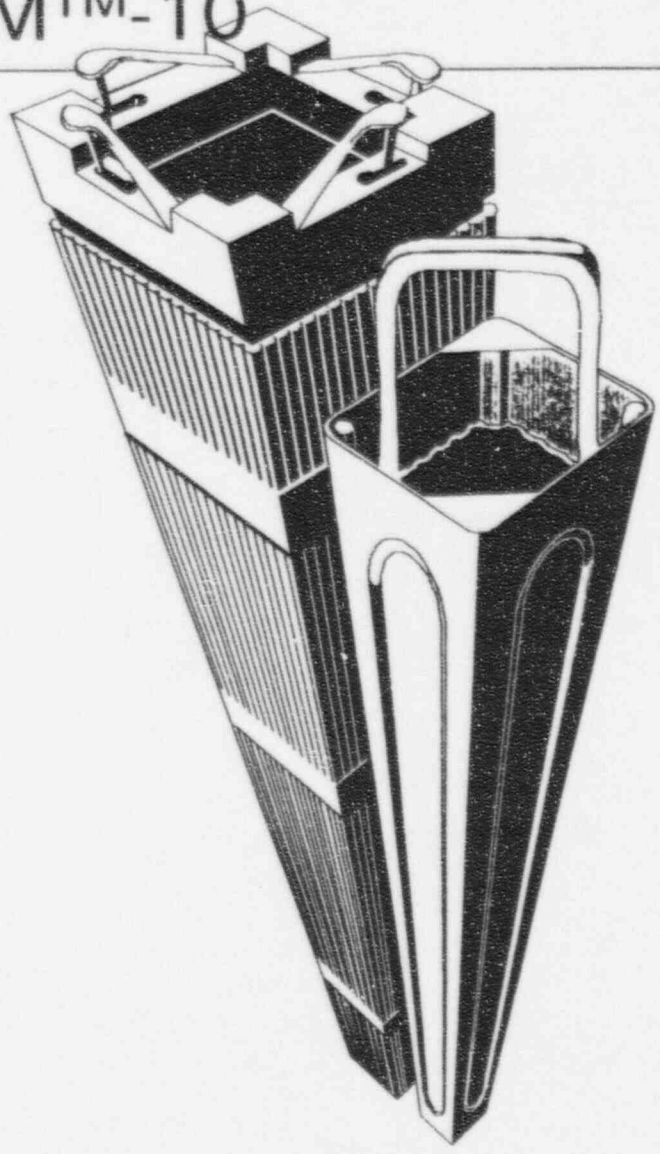
ANFB for the ATRIUM-10 design

- SPC did not change or alter the ANFB methodology for the ATRIUM-10 fuel
- SPC established the additive constants on the most restrictive data
- The predicted margins to limits are more conservative than would be predicted with a modified ANFB correlation supported by all CHF test data

SPC is using a supplementary reflood criterion

- SPC was concerned about the relative reflood criterion in FLEX and applied a supplementary, conservative quantitative criterion
- Based on entrainment tests, SPC proposes the use of a less conservative supplementary criterion
- Annual notification procedures are anticipated to be appropriate for reporting the reflood criteria change

ANFB Performance with ATRIUM™-10



Thomas H. Keheley

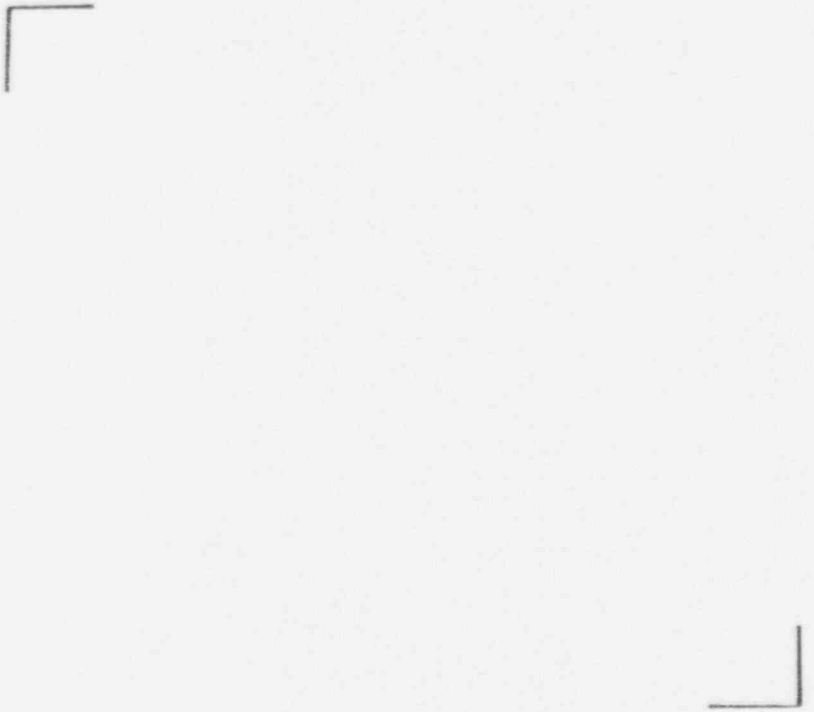
Staff Engineer, Safety Analysis Methods

ANFB Performance with ATRIUM™-10

- The ANFB data base contains [ ] data points with a mean ECPR of [ ] and standard deviation of [ ].
- The data base contains tests on [ ] rod arrays.
- The axial profiles in the data base are [ ] and uniform.

ANFB Performance with ATRIUM™-10

- The ANFB correlation has the form of:



ANFB Performance with ATRIUM™-10

- The [ ] in the [ ] term is used to account for the physical differences in test bundles, such as array type, rod pitch, or spacer type.
- When a new bundle is tested, the [ ] is determined from the test data to give the best fit of predicted to measured data.
- The [ ] is then used to calculate an additive constant that is applied to the fuel assembly.

ANFB Performance with ATRIUM™-10

- In September of 1992, Siemens performed dry out tests on the ATRIUM™-10 assembly (test series STS-17). The ATRIUM™-10 assembly has 8 part length rods.
- The dry out tests were performed on a bundle with a [
  ].
- A total of [ ] data points were tested.
- The overall ECPR for the STS-17 series of tests was [ ] with a standard deviation of [ ].

ANFB Performance with ATRIUM™-10

- In the Spring of 1994, GE presented a paper suggesting that GEXL did not predict up skew axials when part length fuel rods were present.
- By the Spring of 1995, Siemens had allocated R&D funds to confirm ANFB performance with up skew and down skew axial power profiles with part length rod assemblies.
- Testing commenced during the Summer of 1996. Data for the up skew tests were received during the first week of November, 1996.
- Analysis of the test data indicated that ANFB is about [ ] conservative for down skew axial power profiles and on average about [ ] non-conservative for up skew axial power profiles when part length rods are present.

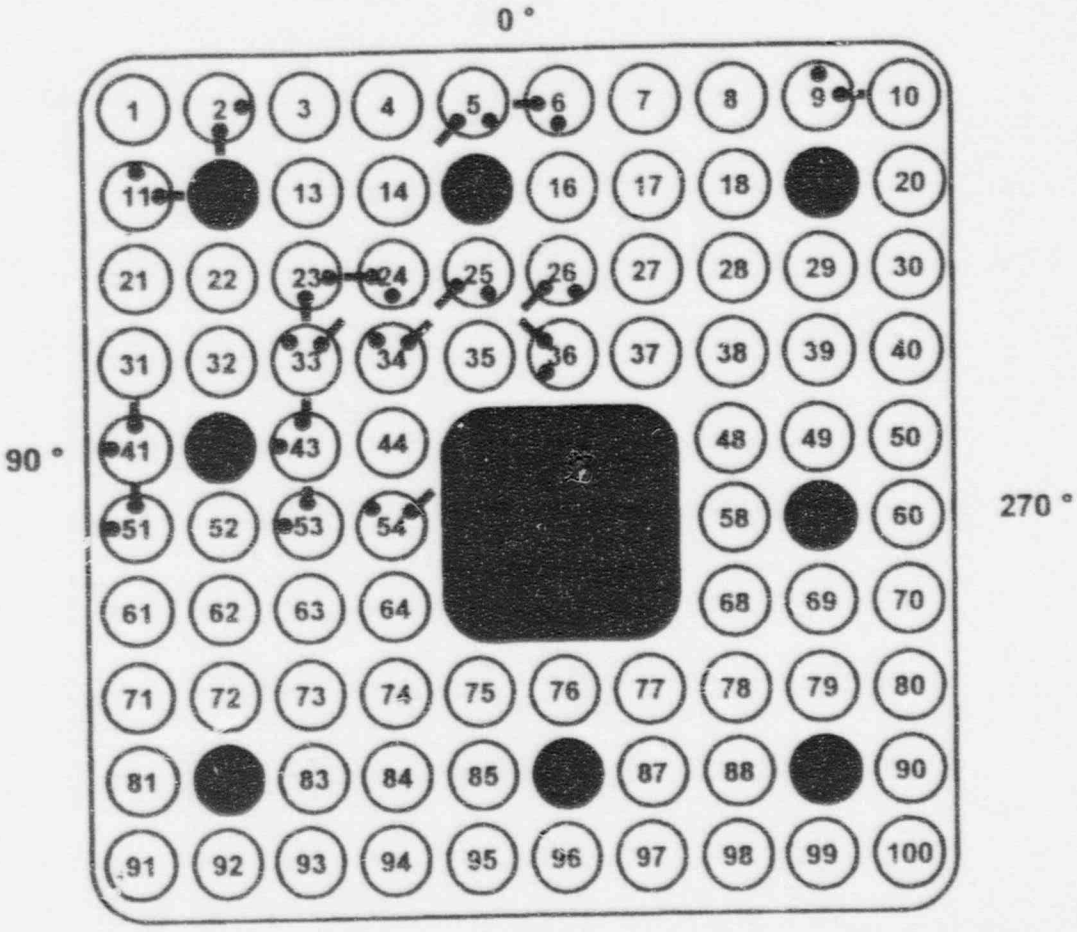
ANFB Performance with ATRIUM™-10

ANFB Performance with ATRIUM™-10

ANFB Performance with ATRIUM™-10

- The up skew test performed was a repeat of [ ] test STS-17.4.
- This test was chosen because the trends and statistics of the test indicated that it should be the [ ] performer.
- Because there are [ ] tests and [ ] test, the [ ] tests were examined closely for trends that would predict the [ ] of the up skew test.

ANFB Performance with ATRIUM™-10



View from the top

ANFB Performance with ATRIUM-10

- Four tests from the [ ] axial power tests showed a trend of [ ] the critical power performance at the lowest test flow rate.

  STS-17.4 STS-17.9

  STS-17.10 STS-17.11

- The FEFF's for these tests were adjusted such that ANFB predicted the [ ] performance.
- The additive constants for the rods affected and their symmetric rods were adjusted to conform with the new FEFF's.
- All rods then had an additional [ ] applied to the additive constants.

ANFB Performance with ATRIUM-10

ANFB Performance with ATRIUM-10

Test	Old ECPR	New ECPR
STS-17.4	[ ]	[ ]
STS-17.9	[ ]	[ ]
STS-17.10	[ ]	[ ]
STS-17.11	[ ]	[ ]

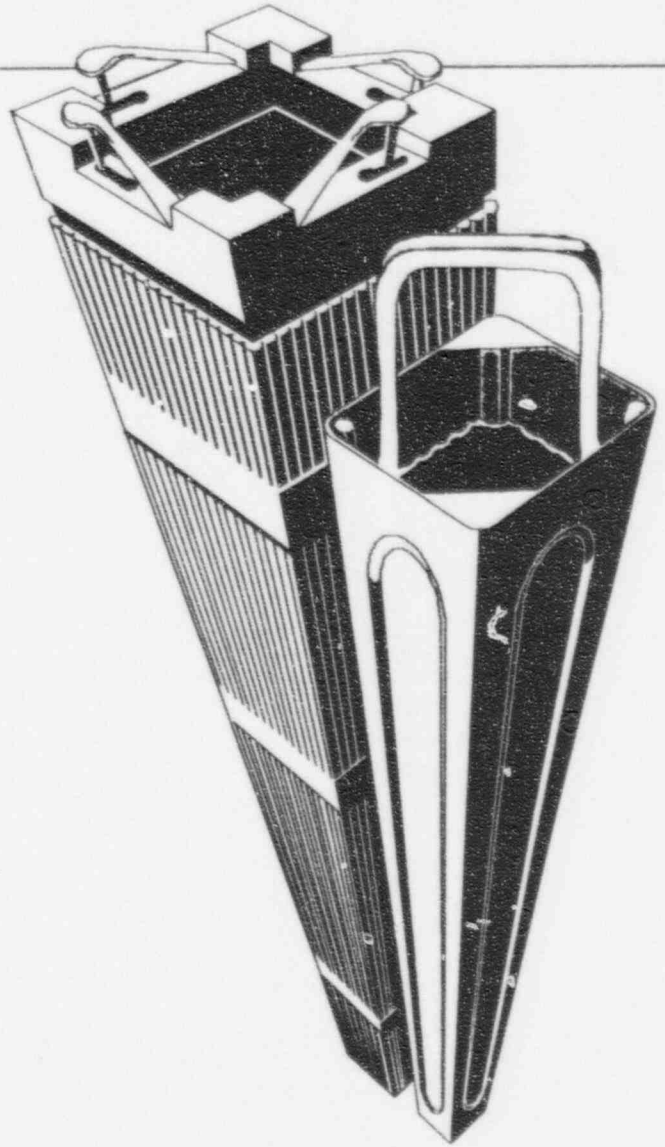
ANFB Performance with ATRIUM-10

ANFB Performance with ATRIUM™-10

ANFB Performance with ATRIUM™-10

- When ANFB is used to predict up [ ] power profiles for part length rods, it is [ ].
- The cosine data was examined to find the same type of [ ]; the FEFF for those tests were evaluated to get an [ ].
- All additive constants were [ ] for added conservatism; the result is that the STS-17 series has an [ ].
- The evaluation of the up skew test then resulted in an [ ].
- There are no changes in methodology for data reduction or in the correlation to account for [ ]; the down skew conservatism remains.

Core Reflood Time With the EXEM BWR LOCA Evaluation Model



Presented by:

Michael E. Garrett, Manager

BWR Safety Analysis
Nuclear Engineering

January 9, 1997

Purpose

- Describe how SPC determines the time of core reflood in applications using the NRC-approved EXEM BWR LOCA methodology

- Describe an SPC internal requirement that is used to supplement the core reflood criterion described to the NRC

Background

- The FLEX computer code is used to determine the reactor core and system response during the refill and reflood phases of a LOCA
- FLEX calculates the time when two-phase flow reaches the hot node in the core. This is referred to as the "time of hot node reflood" or more simply as the time of core reflood
- The time of core reflood is an input to the fuel assembly heatup analysis performed using the HUXY computer code
- At core reflood, the heat transfer coefficients (HTCs) used in the heatup analysis increase by about an order of magnitude from the Appendix K spray HTC to the Appendix K reflood HTC
- The higher reflood HTC is sufficient to remove decay heat from the fuel rods and results in the termination of the fuel rod temperature excursion

Core Reflood Criterion

- FLEX calculates the level of the two-phase mixture entering the core, the entrainment of liquid from the mixture, and the movement of the entrained liquid flow through the core
- Because it is the entrained liquid and not the mixture level itself that initially results in increased heat transfer effectiveness, FLEX uses the time that two-phase entrained liquid reaches the plane of interest as the definition of the time of hot node (core) reflood
- Approach is consistent with the Appendix K definition for using the reflood heat transfer coefficient "after the two-phase reflooding fluid reaches the level under consideration"
- Approach for determining the time of core reflood is discussed in the EXEM BWR LOCA methodology topical reports XN-NF-80-19(P)(A) and ANF-91-048(P)(A)

Core Reflood Criterion (continued)

- The parameter used in the FLEX calculation to determine the time of core reflood is the relative entrainment (RELENT) at the plane of interest
- RELENT is the . The parameter is a measure of the
- A value of RELENT indicates that and that liquid is available to cool the fuel rods and terminate the cladding heatup
- A sustained value of RELENT is the criterion used to determine the time of core reflood for LOCA analyses using the 1982 EXEM BWR LOCA methodology

Core Reflood Criterion (continued)

- The benchmarking of FLEX to test data indicates that the relative entrainment criterion is sufficient to predict when adequate cooling is available at the hot node

Supplementary Requirement for Core Reflood

- During the development of the revised EXEM BWR LOCA methodology (approved in 1993), SPC had a concern about the need for an absolute entrainment criteria
- Although experimental data indicates that the initiation of liquid entrainment leads to a significant increase in heat transfer, a supplementary reflood requirement was introduced to address this concern
- With the supplementary requirement, the time of core reflood is determined based on the relative entrainment criterion described in the topical report combined with a requirement related to the absolute entrained liquid flow rate

Supplementary Requirement for Core Reflood (continued)

- Initially, a very conservative value of per assembly was used
- The entrained liquid flow requirement was based on COBRA-TF simulations of experiments from the SPC Fuel Cooling Test Facility (FCTF) and included an estimated factor of conservatism
- The supplementary requirement ensured conservative analysis results until additional data was available to fully justify the use of RELENT alone

Supplementary Requirement for Core Reflood (continued)

- At the time the value was established internally, it was recommended that additional experimental data be obtained to justify a more realistic value
- Based on recently reduced (July 1996) experimental data, an absolute entrained liquid flow rate of was established to supplement the approved relative entrainment criterion
- For an ATRIUM™-9B fuel assembly, the revised entrained flow rate is equivalent to about
- This entrained liquid flow rate was the lowest value used in the test series and was sufficient to cool the fuel rods.
- It is fully expected that a lower value of entrained liquid flow could be demonstrated to be sufficient based on future tests

Conservatism Introduced With the Use of the Supplementary Reflood Requirements

- The following tables summarize results obtained from the sample problems presented in the EXEM BWR LOCA methodology topical reports and illustrate the level of conservatism introduced with both the original and revised supplementary reflood requirements

- The topical report does not discuss the use of a supplementary reflood requirement; however the sample problems presented included the supplementary requirement

- Changing the required supplementary requirement to the PCT for the sample problems but does not change the conclusions of the reports

Sample Problems From ANF-91-048

		Relative Criterion With Supplemental Requirement
BWR/3	Reflood Time(s)	
	PCT (°F)	
	ΔPCT (°F)*	
BWR/4	Reflood Time(s)	
	PCT (°F)	
	ΔPCT (°F)*	
BWR/6	Reflood Time(s)	
	PCT (°F)	
	ΔPCT (°F)*	

* Relative to using only the approved reflood criterion

Sample Problems From ANF-91-048 Supplement 1

		Relative Criterion With Supplemental Requirement
BWR/5	Reflood Time(s)	
	PCT (°F)	
	ΔPCT (°F)*	
BWR/5	Reflood Time(s)	
	PCT (°F)	
	ΔPCT (°F)*	

* Relative to using only the approved reflood criterion

Summary

- SPC plans to continue to determine core reflood time based on the relative entrainment reflood criterion originally used in the EXEM BWR LOCA methodology supplemented by a required absolute entrained liquid flow rate at the plane of interest

- The supplementary requirement is established based on experimental data to provide a conservative upper bound for the amount of entertained liquid flow required to provide adequate cooling

- The supplementary requirement on the entrained liquid flow introduces conservatism in the calculated PCT relative to the PCT calculated using the original reflood criterion alone

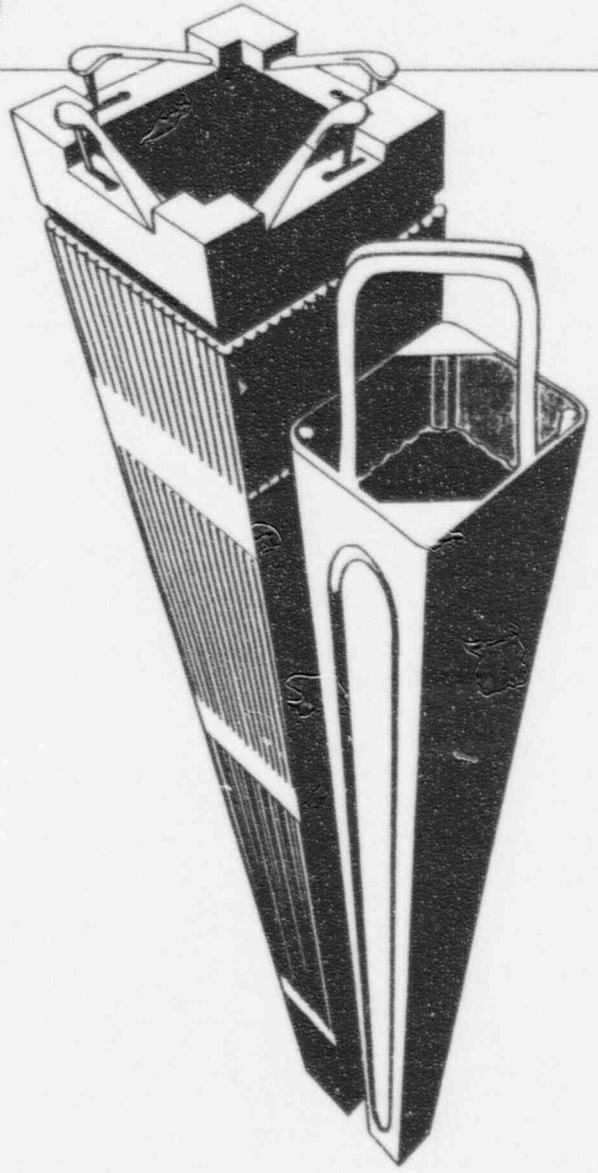
Summary (continued)

- This revised supplementary reflood requirement is being used in LOCA analyses to support the introduction of ATRIUM™-9 fuel at and ATRIUM™-10 fuel at

- For the use of the overly conservative supplementary requirement would result in

- For the use of the overly conservative supplementary requirement would result in flexibility

MCPR Safety Limit Evaluation



Jerry G. Ingham

Staff Engineer, BWR Safety Analysis

MCPR Safety Limit Evaluation

- Performed for each plant on a cycle specific basis
- Uses approved methodology - ANF-524(P)(A), Revision 2
- Input includes additive constants for each fuel design

MCPR Safety Limit Evaluation

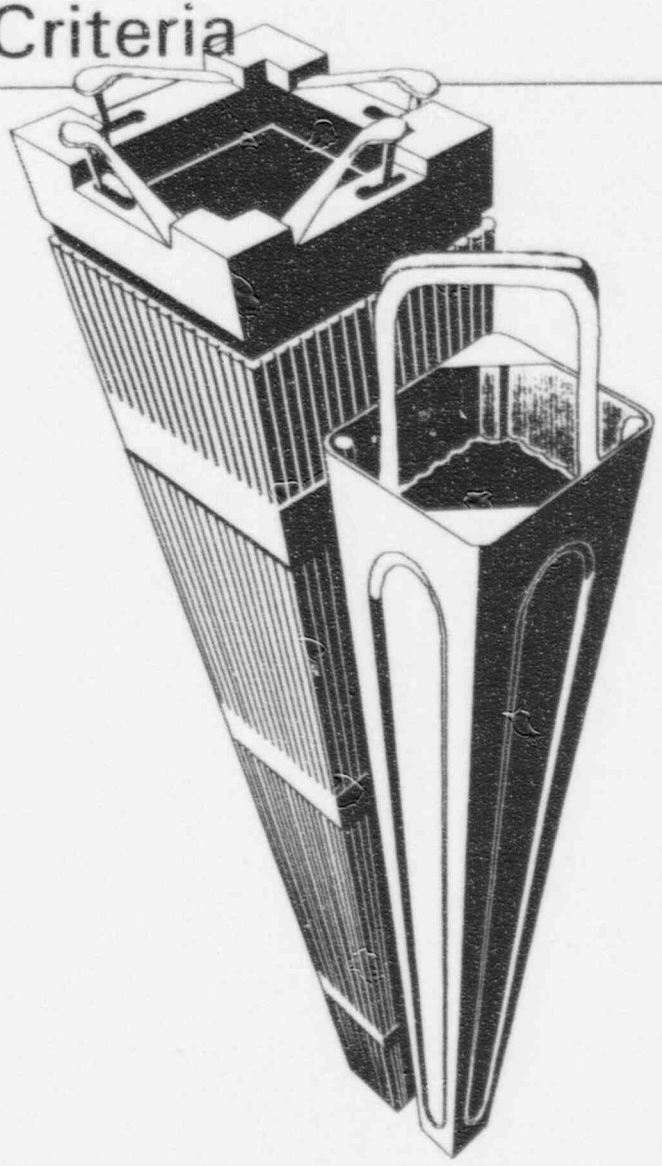
- Susquehanna Unit 2, Cycle 9 model includes 312 assemblies of ATRIUM™-10* and 452 assemblies modeled as 9x9-2

- The revised additive constants for the ATRIUM-10 were used in the analysis

- The safety limit is with 0.0772% rods in boiling transition (<0.10%)

* ATRIUM is a trademark of Siemens

FCTF Testing for BWR Reflood Criteria



Thomas H. Keheley

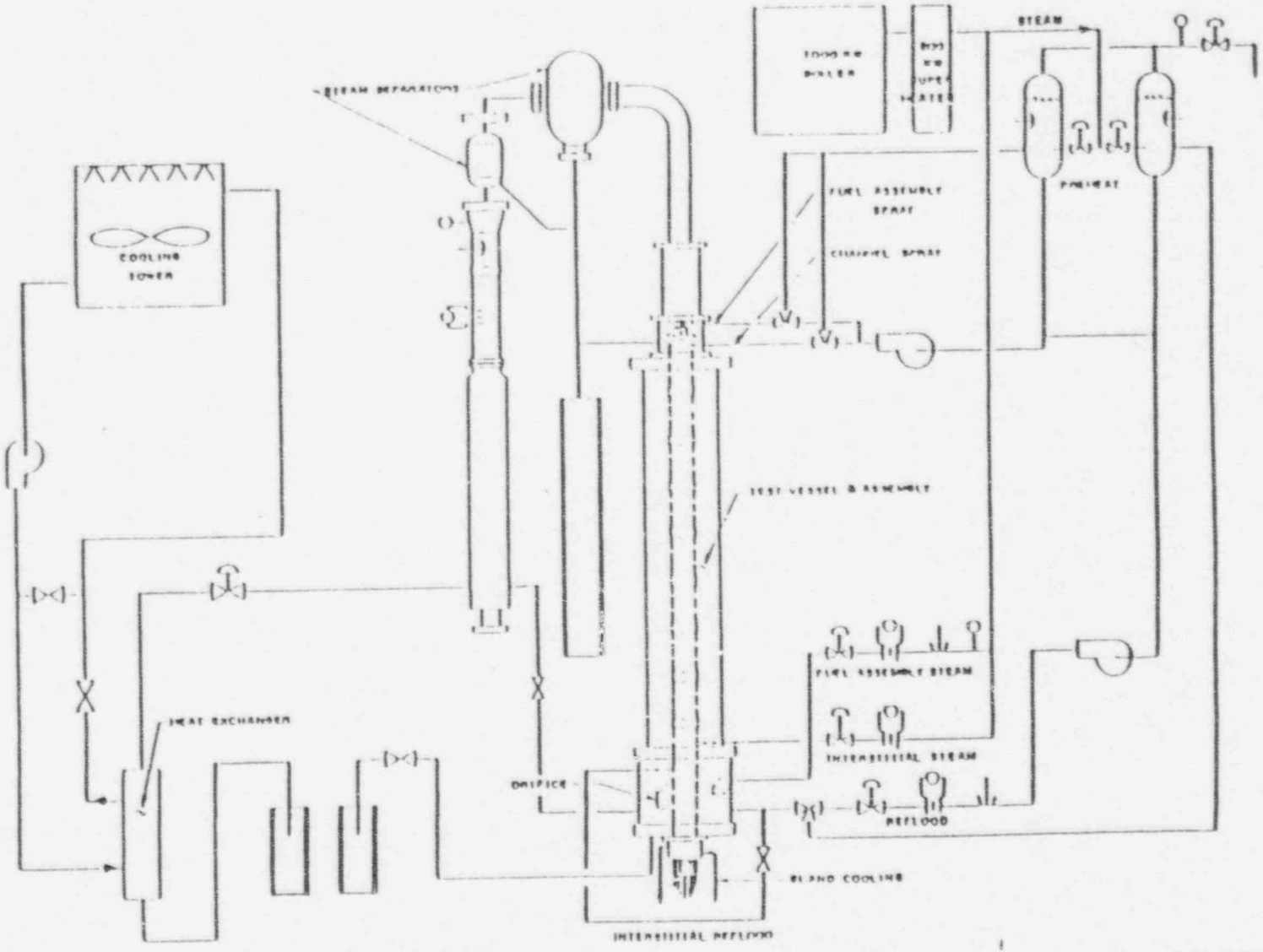
Staff Engineer, Safety Analysis Methods

FCTF Testing for BWR Reflood Criteria

- In 1990, Siemens Power Corporation performed BWR spray heat transfer tests in the Fuel Cooling Test Facility (FCTF) for the 9x9 internal canister fuel designs.
- As part of the spray heat transfer test program, entrainment tests were also performed.
- The test assembly was a full size 9x9 test bundle with indirect electrically heated rods and a 1.4 peak to average axial power profile.

SIEMENS

FCTF



FCTF Testing for BWR Reflood Criteria

- For the entrainment testing, water that was supplied by the reflood pump was sprayed into [ ].
- On the opposite side of the [ ] steam was injected.
- Steam picked up a portion or all of the injected water and carried it through the bundle.
- Power to the bundle was [ ] throughout the test.
- The entrainment criteria was set on the amount of water available at the inlet to the bundle which caused the rod temperatures [ ].

FCTF Testing for BWR Reflood Criteria

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