WEC PROPRIETARY CLASS 3

Westinghouse Energy Systems

Westinghouse Class 3

WCAP-13195

NRC Presentation

Westinghouse ECCS Evaluation Model for Analysis of a CE-NSSS and Results of Large and Small Break Loss of Coolant Accident Analyses for Fort Calhoun Unit 1

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INTRODUCTION

This WCAP contains the material presented by J. J. Akers and K. J. Schrader of Westinghouse to Frank Orr and Steve Blume of the Nuclear Regulatory Commission on January 13, 1992 at the Nuclear Regulatory Commission Offices at White Flint. This information was provided to the Nuclear Regulatory Commission to aid them in their review of WCAP-13027-P, "Westinghouse ECCS Evaluation Model for Analysis of CE-NSSS," and to present the Fort Calhoun Unit 1 large and small break Loss of Coolant Accident (LOCA) analyses results. K. C. Holthaus, W. O. Weber, and T. G. Therkildsen of Omaha Public Power District (OPPD) also attended the presentation and requested that this material be formally documented.

WESTINGHOUSE LARGE BREAK AND SMALL BREAK LOSS-OF-COOLANT ACCIDENT (LOCA) ANALYSIS METHODS FOR ANALYSIS OF A COMBUSTION ENGINEERING NSSS

ANALYSIS OF LARGE AND SMALL BREAK LOCA FOR FORT CALHOUN UNIT 1

PRESENTATION TO THE
NUCLEAR REGULATORY COMMISSION
JANUARY 13, 1992

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C. SMALL BREAK LOCA

1. ASSUMPTIONS
2. SPECTRUM ANALYSIS RESULTS
3. SENSITIVITY RESULTS
4. ACCEPTABILITY OF RESULTS

D. CONCLUSIONS

III. DISCUSSION / QUESTIONS / COMMENTS

WESTINGHOUSE EVALUATION MODELS
AND METHODOLOGY
FOR THE ANALYSIS OF A CE NSSS

BACKGROUND

WHAT INSPIRED THE MODEL DEVELOPMENT

- OPPD ACCEPTED A CONTRACT FOR THE WESTINGHOUSE COMMERCIAL NUCLEAR FUEL DIVISION TO PROVIDE "CE-TYPE" FUEL FOR FORT CALHOUN UNIT 1. LARGE AND SMALL BREAK ANALYSIS IS INCLUDED IN THE FUEL CONTRACT.

HISTORY / EXPERIENCE

- WESTINGHOUSE HAS PREVIOUSLY PROVIDED LARGE AND SMALL BREAK LOCA ANALYSES FOR ANOTHER WESTINGHOUSE-FUELED CE NSSS - MILLSTONE 2

  LARGE BREAK - 1981 EM FOR CE
  WCAP-9528, SER CONTAINED IN
  WCAP-9220-P-A, REV. I (PROP.)

  SMALL BREAK - NOTRUMP EM FOR CE
  WCAP-10054-P-A, ADDENDUM 1 (PROP.)

BACKGROUND

WHY NOT USE THE EXISTING APPROVED MODELS?

- For Small Break LOCA

    The NOTRUMP EM represents the latest Westinghouse technology

    Adequate margin

    Contract calls for use of the NOTRUMP EM

    NOTRUMP WAS USED!

- For Large Break LOCA

    More recent technology is available in the BART EM and the BASH EM

    BART provides more margin than the 81 EM; BASH provides more margin than the BART EM

    Contract calls for use of the BASH EM

BACKGROUND

ORIGINAL GOAL

PROVIDE LICENSABLE
LARGE AND SMALL BREAK
LOCA ANALYSES
FOR FORT CALHOUN
USING THE MOST RECENT,
APPROVED APPENDIX K METHODS
MODIFIED FOR THE ANALYSIS OF A CE NSSS
AND APPLICABLE TO FT. CALHOUN

CE FEATURES (DIFFERENCES)

- LOOP LAYOUT

  CE design features 2 cross over legs, 2 Reactor Coolant Pumps & 2 cold legs for each steam generator. Cold leg is smaller and hot leg is larger than W design. Loop seal elevation is higher than W design.

- CEA DESIGN

  Assortment of CEA geometries in a given plant.

- UH BYPASS / UH TEMPERATURE

  No design cooling flow to the Upper Head.

- LOWER PLENUM DESIGN

  CE design feature Flow Skirt & relatively "open" LP volume

CE FEATURES (DIFFERENCES)

- CORE SHROUD BYPASS

  WHILE AN "UPFLOW" DESIGN, TYPES AND RELATIVE RESISTANCES OF FLOW PATHS ARE DIFFERENT THAN W DESIGN.

- REACTOR COOLANT PUMPS

  SIMILAR, BUT SMALLER.

- STEAM GENERATOR INLET NOZZLE ANGLE

  THE CE DESIGN FEATURES A GREATER ANGLE OF INCLINATION.

- SI / ACCUMULATOR NOZZLE ANGLE

  CE DESIGN INJECTION ANGLES DIFFER FROM THOSE USED IN A W DESIGNED NSSS.

CE FEATURES (DIFFERENCES)

- o SAFETY INJECTION TANK PRESSURE

  CE PASSIVE INJECTION MAY BE AT A SIGNIFICANTLY LOWER PRESSURE.

- o FUEL ASSEMBLY DESIGN

  "CE-TYPE" FUEL FEATURES LARGE GUIDE THIMBLES AND INSTRUMENTATION TUBES AND FEWER THIMBLES. GRID PARAMETERS VARY SLIGHTLY.

- o FUEL ROD / PELLET STACK

  THE "CE-TYPE" FUEL RADIAL CLADDING DIMENSIONS AND ROD PLENUM VOLUMES DIFFER FROM THE TYPICAL W DESIGNS. THE ACTIVE CORE REGION IS OFTEN SHORTER THAN FOR A W PLANT.

LARGE BREAK LOCA

LARGE BREAK EM - LICENSING - APPROVALS

THE WESTINGHOUSE MODELS -
81 EM, BART EM, BASH EM

- o THE 1981 EVALUATION MODEL
  WCAP-9220-P-A, Rev. I (Prop.)

  - * SATAN-VI System Blowdown
    WCAP-8302 (Prop.), SER in
    WCAP-8471-P-A (Prop.)

  - * WREFLOOD Refill/Reflood Hydraulics
    WCAP-8170 (Prop.), SER in
    WCAP-8471-P-A (Prop.)

  - * COCO Containment Response
    WCAP-8327 (Prop.), SER in
    WCAP-8471-P-A (Prop.)

  - * LOCTA-IV Rod Heat-up
    WCAP-8301 (Prop.), SER in
    WCAP-8471-P-A (Prop.)

LARGE BREAK EM - LICENSING - APPROVALS

o THE 1981 EVALUATION MODEL WITH BART (BART EM)
WCAP-9561-P-A (PROP.)

SATAN-VI — SYSTEM BLOWDOWN

* WREFLOOD — REFILL/REFLOOD HYDRAULICS (INTERIM REFLOOD)
AMENDED BY WCAP-9561-P-A (PROP.) AND WCAP-9561-P-A, ADDENDUM 3 (PROP.)

COCO — CONTAINMENT RESPONSE

* BART — HEAT TRANSFER COEFF.
WCAP-9561-P-A (PROP.)
WCAP-9561-NP-A, ADDENDUM 2 (NON-PROP.)
WCAP-9561-P-A, ADDENDUM 3 (PROP.)

* LOCTA-IV — ROD HEAT-UP
AMENDED BY WCAP-9561-P-A, ADDENDUM 3 (PROP.)

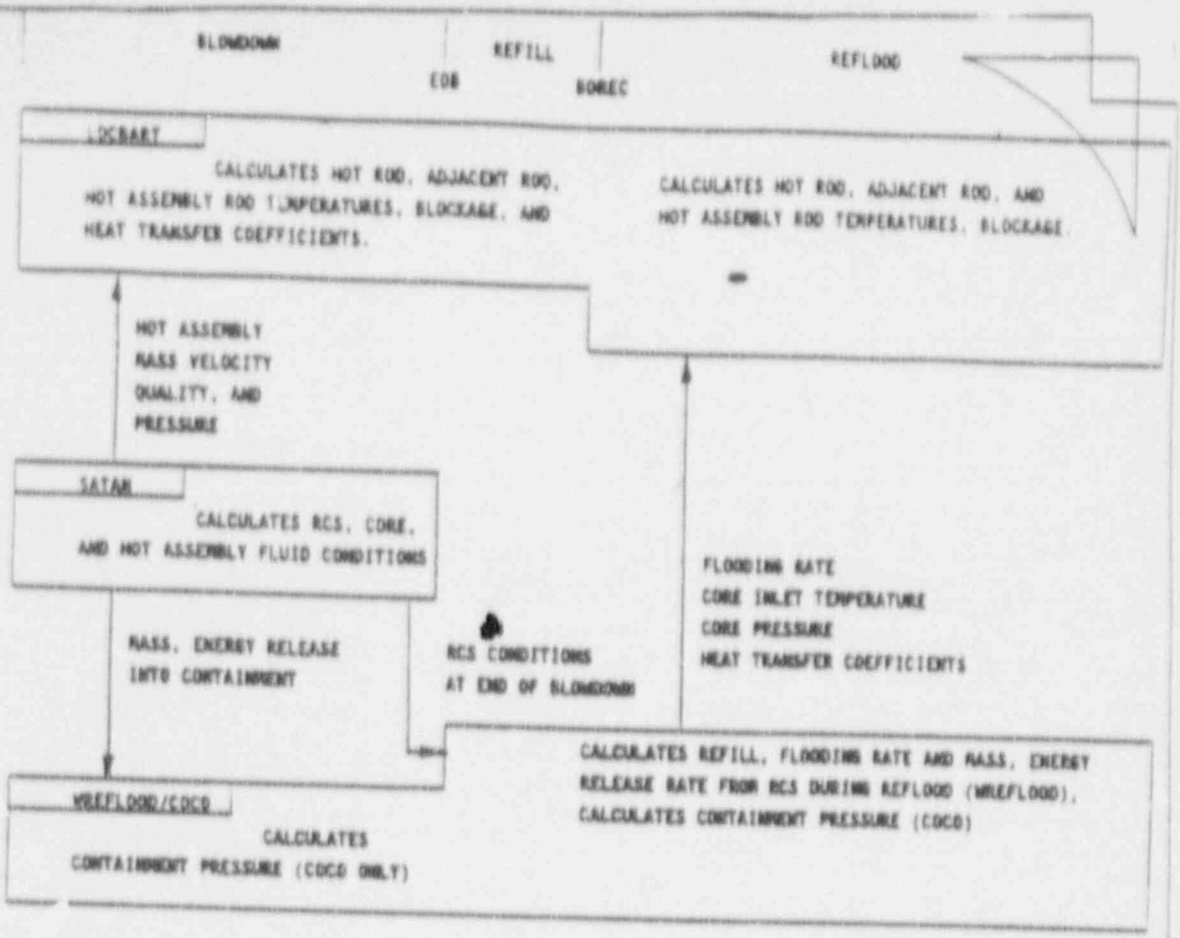
LARGE BREAK EM - LICENSING - APPROVALS

- THE 1981 EVALUATION MODEL WITH BART/BASH (BASH EM)
  WCAP-10266-P-A, Rev. 2 (Prop.)

	SATAN-VI	System Blowdown
	WREFLOOD	Refill / Cont. M & E Version compatible with BART (Interim)
	COCO	Containment Response
*	BASH	Reflood Hydraulics WCAP-10266-P-A, Rev. 2 (Prop.)
*	LOCBART	HTC / Rod Heat-up (Synthesis of BART and LOCTA-IV from the BART EM with minor modifications) WCAP-10266-P-A, Rev. 2 (Prop.)

ORIGINAL GOAL: MODIFY THE BASH EM FOR THE ANALYSIS OF A CE NSSS, APPLICABLE TO FT. CALHOUN

THE 1981 + BART FOR CE NSSS
LARGE BREAK LOCA ECCS EVALUATION MODEL
(BART FOR CE EM)



FORT CALHOUN
LOSS OF COOLANT ACCIDENT REPORT

Figure 2-1
Code Interface Description for Large Break Model

THE BART FOR CE EM

WHY BART?

THE BART FOR CE EM

- ORIGINALLY, CODE MODIFICATIONS WERE INITIATED FOR THE BASH EM CODES
- TEST RUNS WERE PERFORMED TO ASSESS PERFORMANCE OF THE CE VERSIONS OR USE OF FT. CALHOUN PLANT-SPECIFIC INPUT
- SATAN & WRELOOD (INTERIM) WITH COCO PERFORMED SATISFACTORILY
- THE BASH TEST RUN, USING SEVERAL THOUSAND HAND-INPUT, AS-YET UNVERIFIED, PIECES OF INPUT DATA DID NOT PERFORM SATISFACTORILY
- OPTIONS:

    1. DEBUG BASH
    2. ASSESS WHETHER THE MARGIN WHICH BASH WOULD MAKE AVAILABLE WOULD BE REQUIRED

THE BART FOR CE EM

- o THE MOST EXPEDITIOUS OPTION WAS THE ASSESSMENT OF MARGIN AVAILABILITY USING THE ALREADY COMPLETED RESULTS OF THE WREFLOOD TEST RUN, SO THIS OPTION WAS PURSUED FIRST (IN ESSENCE - TRY THE 81 EM AND SEE HOW CLOSE WE ARE)

- o SINCE THE ORIGINAL PLANS WERE BASED UPON THE MODIFICATION OF THE BASH EM, THE VERSION OF WREFLOOD COMPATIBLE WITH THE BART EM (AND BASH EM) AND THE LOCBART CODE HAD BEEN UPDATED FOR MODELING A CE NSSS

  THE 81 EM VERSIONS OF WREFLOOD AND LOCTA-IV HAD NOT BEEN UPDATED AND THE EARLIER VERSIONS USED FOR THE ANALYSIS OF MILLSTONE 2 WERE NOT READILY AVAILABLE

81 EM	CODES USED FOR TEST RUN
SATAN-VI	SATAN-VI
WREFLOOD	WREFLOOD (INTERIM)
COCO	COCO
LOCTA-IV	LOCBART (WITH FORMAT FIXES)

THE BART FOR CE EM

- RESULTS OF THE TEST RUN SUGGESTED THAT ADEQUATE LARGE BREAK LOCA MARGIN WOULD BE AVAILABLE TO MAINTAIN PCT < 2200°F WHILE STILL MEETING THE AGREED UPON LOCA KW/FT AND F_R LIMITS

- GIVEN ADEQUATE MARGIN WITHOUT THE BENEFITS OF THE IMPROVED BASH HYDRAULICS AND CONSIDERING SCHEDULAR RESTRAINTS ASSOCIATED WITH LICENSING REQUIREMENTS FOR CYCLE 14, IT WAS AGREED WITH OPPD THAT A VERSION OF AN EARLIER EM WOULD BE USED FOR THE FT. CALHOUN ANALYSIS

- SINCE THE AVAILABLE WREFLOOD VERSION WAS THE ONE COMPATIBLE WITH BART (INTERIM), BUT NOT PREVIOUSLY APPROVED FOR USE WITH THE 81 EM, USING THE 81 EM WOULD REQUIRE SPECIAL LICENSING CONSIDERATION SINCE SUCH A MIX OF CODES HAD NEVER PREVIOUSLY BEEN APPROVED

THE BART FOR CE EM

- THE AVAILABLE WREFLOOD (INTERIM) VERSION WAS COMPATIBLE WITH BART, BUT THERE WAS NO READILY AVAILABLE VERSION OF THE LOCTA-IV CODE FOR ANALYSIS OF A CE NSSS, AND USING THE BART EM WITH LOCBART, WHICH WAS AVAILABLE, WOULD REQUIRE SPECIAL LICENSING CONSIDERATION SINCE SUCH A MIX OF CODES HAD NEVER PREVIOUSLY BEEN APPROVED

- GIVEN SIMILAR DOCUMENTATION AND LICENSING REQUIREMENTS, THE BART EM, PROVIDING MORE MARGIN WAS CHOSEN

- THIS SEQUENCE OF CODES, USED FOR THE EARLY CODE "CHECKOUT" RUNS, BECAME THE BASIS FOR THE BART FOR CE EM

THE BART FOR CE EM

THE 1981 + BART FOR CE NSSS
LARGE BREAK LOCA ECCS EVALUATION MODEL
WCAP-13027-P (PROP.)

	SATAN-VI	SYSTEM BLOWDOWN
*	WREFLOOD	REFILL / CONT. M & E
	VERSION COMPATIBLE WITH BART (INTERIM)	
	MODIFIED FOR APPLICATION TO A CE NSSS	
	COCO	CONTAINMENT RESPONSE
*	REFBASH	TAPE FORMAT AND FLOODING RATE INPUT TO LOCBART
	NOT PREVIOUSLY REVIEWED BY THE NRC	
*	LOCBART	HTC / ROD HEAT-UP
	MODIFIED FOR APPLICATION TO A CE NSSS	

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

MODIFICATIONS TO WESTINGHOUSE VERSIONS

- MODIFICATIONS TO STANDARD W CODES AND METHODOLOGY SINCE PUBLICATION OF THE 10/88 REVISION TO 10 CFR 50.46 NOT DESCRIBED IN THE ORIGINAL CODE AND MODEL REPORTS

  BRINGING THE BASE CODES UP TO 1991 STANDARDS

REFERENCES: LETTER NS-NRC-89-3463 (10/5/89)
WCAP-13027-P (APPENDIX A)

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

MODIFICATIONS TO EXISTING MODELS FOR ANALYSIS OF A CE NSSS

- o MODIFICATIONS TO MODELS AND METHODOLOGY DOCUMENTED AND USED PREVIOUSLY FOR THE ANALYSIS OF A CE NSSS

  SATAN-VI
  - * LOWER PLENUM NODING
  - * SI/SIT INTERACTION

  WREFLOOD
  - * SI/SIT INTERACTION
  - * METAL HEAT MODELING
  - * [ ]A,C

  COCO - NONE

  LOCTA-IV - NONE (USING LOCBART)

REFERENCES WCAP-9528 (PROP.)
WCAP-13027-P

a,c

Figure 3.2.2-1 1981 + BART for CE NSSS SATAN Diagram

a,c

Figure 3.2.2-2 1981 + BART for CE NSSS WREFLOOD Diagram

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

MODIFICATIONS TO OTHER CODES

- o MODIFICATIONS TO MODELS AND METHODOLOGY DOCUMENTED NOT PREVIOUSLY EMPLOYED FOR THE ANALYSIS OF A CE NSSS

  REFBASH
  * NEVER PREVIOUSLY REVIEWED BY THE NRC

  LOCBART
  * BART NEVER PREVIOUSLY USED FOR ANALYSIS OF A CE NSSS
    DIFFERENCES FROM MODELING USED PREVIOUSLY IN LOCTA-IV
    * NODING
    * CRACK AND DISH VOLUMES
    * THIMBLE MODELING
    * SPACER GRID MODEL

REFERENCES: WCAP-9528 (PROP.)
WCAP-13027-P
WCAP-10266-P-A, REV. 2
WCAP-10484 (PROP.)
LETTER FROM THOMAS (NRC) TO RAHE (W) - '10484 SER'

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

REFBASH CODE

- o Two functions

  Read WREFLOOD output tape information and "rewrite" in a format compatible with BASH output for use by LOCBART

  Adjust the flooding rates calculated by WREFLOOD in accordance with the approved methodology for the BART EM (WCAP-9561-NP-A, Addendum 2)

- o Integral part of the BART for CE EM sequence

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

- LOOP LAYOUT

  THE MODELING OF THE "AUXILIARY LOOP" IN THE SATAN-VI AND WREFLOOD CODES IS PERFORMED IN THE SAME MANNER AS DESCRIBED PREVIOUSLY FOR THE MODELING OF A CE NSSS USING THE W 1981 EM (WCAP-9528). ADDITIONAL GEOMETRIC INPUTS ARE MODELED THROUGH USE OF APPROPRIATE PLANT-SPECIFIC INPUT.

- CEA DESIGN

  MODELED IN SATAN-VI IN THE SAME MANNER AS DESCRIBED PREVIOUSLY FOR THE MODELING OF A CE NSSS USING THE W 1981 EM (WCAP-9528), USING PLANT-SPECIFIC INPUT.

- UH BYPASS / UH TEMPERATURE

  FLOW THROUGH THE ALIGNMENT KEYWAY IS MODELED IN SATAN-VI USING PLANT-SPECIFIC INPUT.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

- o LOWER PLENUM DESIGN

[ ][a,c]

- o CORE SHROUD BYPASS

THE CORE SHROUD MODELING IN SATAN-VI IS THE SAME AS THAT USED IN WCAP-9528. SPECIFICS OF GEOMETRY AND LOSSES ARE MODELED THROUGH PLANT-SPECIFIC INPUT IN BOTH THE SATAN-VI AND WREFLOOD CODES.

- o REACTOR COOLANT PUMPS

PUMP PERFORMANCE AND COASTDOWN CHARACTERISTICS ARE MODELED IN SATAN-VI VIA PLANT-SPECIFIC INPUT. LOCKED ROTOR, DUE TO HIGHER RESISTANCE, IS MODELED IN WREFLOOD THROUGH PLANT-SPECIFIC PUMP INPUTS.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

- STEAM GENERATOR INLET NOZZLE ANGLE

  PLANT-SPECIFIC SG INLET NOZZLE ΔP IS INPUT INTO THE SATAN-VI MODEL, WHILE OTHER NOZZLE CHARACTERISTICS HAVE A NEGLIGIBLE EFFECT ON BLOWDOWN BEHAVIOR.

- SI / ACCUMULATOR NOZZLE ANGLE

  THE NRC-SPECIFIED UNRECOVERABLE PRESSURE DROPS ACCOUNTING FOR LOW VELOCITY LOOP STEAM CONDENSATION HAVE BEEN INCORPORATED INTO THE WREFLOOD CODE FOR THE SI AND/OR SIT INJECTION ANGLES FEATURED IN THE CE NSSS DESIGN. THE APPROPRIATE ΔP IS SELECTED THROUGH PLANT-SPECIFIC INPUT.

- SAFETY INJECTION TANK PRESSURE

  AS IN WCAP-9528, SIT MODELING IN SATAN-VI AND WREFLOOD IS APPLICABLE TO TANKS WITH INITIAL PRESSURES ON THE ORDER OF 200 PSIG.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

- FUEL ASSEMBLY DESIGN

  FUEL ASSEMBLY GEOMETRY AND PRESSURE DROPS ARE INCLUDED IN THE HYDRAULIC CODES VIA FUEL-SPECIFIC INPUTS.

- FUEL ROD / PELLET STACK

  DIMENSIONAL DIFFERENCES BETWEEN TYPICAL WESTINGHOUSE FUEL RODS AND THE "CE-TYPE" HAVE BEEN CONSIDERED IN RELATION TO THE ROD BURST MODELING. FUEL-SPECIFIC CLADDING AND PELLET INPUT ARE USED IN THE ANALYSIS.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

APPLICABILITY OF THE MODEL

- o RESTRICTIONS AND REQUIREMENTS FOR CODES

  A REVIEW WAS CONDUCTED OF THE DOCUMENTATION ASSOCIATED WITH THE BART EM, WHICH SERVES AS THE BASIS FOR THE PROPOSED BART FOR CE EM, AND RELATED REPORTS, PLUS THE DOCUMENTATION OF THE APPLICATION OF THE 1981 EM TO A CE NSSS.

- o EIGHT PERTINENT RESTRICTIONS/REQUIREMENTS ASSOCIATED WITH THE PREVIOUSLY APPROVED CONSTITUENT CODES OF THE PROPOSED BART FOR CE EM WERE IDENTIFIED.

- o AS AN EXAMPLE OF THE METHOD OF APPLICABILITY CONFIRMATION, EACH WAS ADDRESSED BASED ON THE CURRENT FORT CALHOUN UNIT 1 ANALYSIS

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

BART MODEL RESTRICTED TO THE RANGE OF OPERATION BOUNDED BY THE DATA CONTAINED IN SECTION 2-7 IN THE NRC SER FOR THE BART EM. THESE CONDITIONS ARE:

PRESSURE (PSIA)	20 - 60
INITIAL TEMPERATURE (°F)	1100 - 1500
INITIAL POWER (KW/FT)	0.45 - 1.2
INLET SUBCOOLING (°F)	20 - 140
REFLOOD RATE (IN/SEC)	0.6 - 1.5

RESPONSE: THESE PARAMETERS SHOULD BE VERIFIED AGAINST THE FINAL LICENSING BASIS COMPUTER OUTPUT INFORMATION AND INTERNALLY DOCUMENTED.

PRESSURE	~50 PSIA
INITIAL TEMPERATURE	~1550°F
INITIAL POWER	~0.8 KW/FT
INLET SUBCOOLING	~80°F
REFLOOD RATE	$0.95 < V_{IN} < 1.4$

(THROUGH PCT TIME)

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

BART NODES MUST BE LESS THAN 6 INCHES IN LENGTH.

RESPONSE: VERIFY BART NODES <6 INCHES LONG (0.5 FT.)

LENGTH OF ALL BART NODES
0.25 FT. $\leq \Delta X \leq 0.5$ FT.

0.5 FT. NODES ARE ALL LOCATED IN LOWER CORE ELEVATIONS, FAR FROM BURST AND/OR PCT.

ERRATUM: A SINGLE 0.6003 FT. NODE IS LOCATED IN THE LOWER CORE, FAR FROM BURST AND/OR PCT.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

BART APPLICABLE ONLY TO PWR USING WESTINGHOUSE FUEL WITH ONLY COLD LEG INJECTION.

RESPONSE: CONFIRM CONDITIONS.

FORT CALHOUN IS A PWR WITH A 4/2 CE NSSS AND ONLY COLD LEG ECCS INJECTION (NO UPPER HEAD, UPPER PLENUM OR DIRECT VESSEL INJECTION). THE ANALYSIS PERFORMED ASSUMED THIS UNIT TO BE FUELED WITH WESTINGHOUSE DESIGNED/MANUFACTURED "CE-TYPE" FUEL.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

BART MODEL REQUIRES THAT CONDITIONS OF NO SINGLE FAILURE BEING WORST CASE SHOULD BE CONSIDERED.

RESPONSE: WILL BE CONSIDERED AS PART OF BART FOR CE EM (WCAP-13027-P, SECTION 3.3.2.3)

MAXIMUM SAFEGUARDS CASES PERFORMED FOR FORT CALHOUN. MAXSI RESULTS ARE INCLUDED IN THE PLANT-SPECIFIC RESULTS SUMMARY REPORT.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

SER FOR 1981 EM REQUIRES USE OF THE SKEWED POWER SHAPE OPTION FOR LESS THAN 12 FOOT CORES.

RESPONSE: SKEWED POWER OPTION WILL BE USED FOR THESE CONDITIONS.

FOR FORT CALHOUN, WITH A 128 INCH ACTIVE CORE LENGTH, THE SKEWED POWER OPTIONS WERE EMPLOYED IN SATAN-VI, WREFLOOD AND LOCBART, EVEN FOR CHOPPED COSINE POWER DISTRIBUTION STUDIES.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

1981 EM SER IDENTIFIES MODELING OF SI/ACCUMULATOR INTERACTION.

RESPONSE: EMPLOY THIS MODELING TO CE PLANTS FEATURING THIS ECCS ARRANGEMENT.

INTERACTION OF SIT/SI (COMMON INJECTION NOZZLE) HAS BEEN CONSIDERED IN THE SATAN-VI AND WREFLOOD MODELING FOR FORT CALHOUN.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

A BURNUP STUDY WAS SPECIFICALLY REQUESTED FOR THE APPLICATION OF THE WESTINGHOUSE EM TO A CE NSSS (WCAP-9528).

RESPONSE: BASED ON SUBSTANTIAL EXPERIENCE WITH THE EFFECTS OF FUEL BURNUP ON LARGE BREAK LOCA RESULTS FOR A WIDE RANGE OF FUEL DESIGN, TRANSIENT CONDITIONS AND EVALUATION MODELS (INCLUDING BART), LIMITING CONDITION IS AT THE BEGINNING OF LIFE. THE PREVIOUS WESTINGHOUSE EVALUATION MODEL FOR A CE NSSS (WCAP-9528) WAS USED TO PERFORM A STUDY OF FUEL BURNUP EFFECTS ON LBLOCA. RESULTS (WCAP-9220-P-A, REV. I) CONFIRMED THAT BOL REPRESENTS THE LIMITING CONDITION. BASED ON THIS INFORMATION, A SPECIFIC BURNUP STUDY WAS NOT PERFORMED FOR THE BART FOR CE EM.

N/A.

GENESIS OF THE MODEL - MODIFICATIONS TO THE WESTINGHOUSE EM

SPACER GRID MODEL APPLICABILITY RESTRICTED TO THE CONDITIONS IDENTIFIED IN THE SER FOR THE SPACER GRID MODEL.

RESPONSE: VERIFY AGAINST ANALYSIS.

THESE CONDITIONS ARE ROUGHLY EQUIVALENT TO THOSE HIGHLIGHTED IN SECTION 2.3 OF THE BART SER (PREVIOUSLY CONFIRMED)

APPLICATION OF THE MODEL

BREAK SPECTRUM

- o NO BASIS FOR ASSUMING A GENERICALLY ACCEPTABLE DISCHARGE COEFFICIENT FOR CE NSSS ANALYSES
- o SUBSTANTIAL CHANGES IN SI/SIT PARAMETERS, SGTP, ETC. CAN RESULT IN A SHIFT IN THE LIMITING DISCHARGE COEFFICIENT

CONCLUSION:

PERFORM BREAK SPECTRUM ANALYSIS FOR ALL APPLICATIONS UNLESS SPECIFIC JUSTIFICATION FOR EXCEPTION IS PROVIDED.

APPLICATION OF THE MODEL

MAJOR SENSITIVITY STUDIES

- o BREAK LOCATION
- o POWER AVAILABILITY
- o ECCS AVAILABILITY
- o AXIAL POWER DISTRIBUTIONS
- o FUEL BURNUP
- o INTEGRATED FUEL BURNABLE ABSORBERS (IFBA)

APPLICATION OF THE MODEL

o BREAK LOCATION

Double-Ended Cold Leg Break believed to be most limiting break location and break type based on break geometry and steam flow resistance.

Supported by W sensitivities in WCAP-8340 (Prop.).

Supported by CE sensitivities in CENPD-132, Rev. 01, Vol. II.

CONCLUSION:

Run only DECLG break for LBLOCA using BART for CE EM.

APPLICATION OF THE MODEL

- POWER AVAILABILITY

  IT IS NOT OBVIOUS THAT WESTINGHOUSE PLANT SENSITIVITIES, WHICH SHOW LOSS OF OFFSITE POWER (LOOP) TO BE LIMITING, CAN BE JUSTIFIABLY EXTENDED TO A CE NSSS.

  COMPETING EFFECTS INTRODUCE HIGH LEVEL OF UNCERTAINTY FOR LIMITED DATABASE OF LARGE BREAK ANALYSIS APPLYING W METHODS TO A CE NSSS.

CONCLUSION:

EXAMINE BOTH LOOP AND NO LOOP ASSUMPTIONS TO IDENTIFY THE LIMITING POWER AVAILABILITY ASSUMPTION UNLESS SPECIFIC JUSTIFICATION FOR EXCEPTION IS PROVIDED.

APPLICATION OF THE MODEL

- o ECCS AVAILABILITY

  "NO SINGLE FAILURE" (MAXSI) HAS BEEN SHOW TO BE A MORE LIMITING ASSUMPTION FOR SOME W NSSS LBLOCA ANALYSES USING W METHODS.

  "NO SINGLE FAILURE" (MAXSI) HAS BEEN SHOW TO BE A MORE LIMITING ASSUMPTION FOR SOME CE NSSS LBLOCA ANALYSES USING CE METHODS.

CONCLUSION:

EXAMINE BOTH MINIMUM AND MAXIMUM SAFEGUARDS TO IDENTIFY THE LIMITING ECCS AVAILABILITY ASSUMPTION UNLESS SPECIFIC JUSTIFICATION FOR EXCEPTION IS PROVIDED.

APPLICATION OF THE MODEL

- AXIAL POWER DISTRIBUTIONS

WITH AN ELEVATION INDEPENDENT PEAK LINEAR HEAT RATES FOR CE PLANTS AND COMPARATIVELY SHORT ACTIVE FUEL REGIONS, TOP-SKEWED POWER DISTRIBUTIONS ARE EXPECTED TO BE LIMITING, BUT NO "GENERICALLY APPLICABLE" DISTRIBUTION HAS BEEN IDENTIFIED.

CONCLUSION:

EXAMINE AXIAL POWER DISTRIBUTIONS USING THE METHODOLOGY IDENTIFIED IN APPENDIX B OF WCAP-13027-P TO IDENTIFY THE LIMITING AXIAL DISTRIBUTION FOR ALL APPLICATIONS UNLESS SPECIFIC JUSTIFICATION FOR EXCEPTION IS PROVIDED.

APPLICATION OF THE MODEL

POWER SHAPE METHODOLOGY

PERFORM SENSITIVITIES FOR A RANGE OF SHAPES INCLUDING CHOPPED COSINE (MID-PLANE PEAK), SKEWED COSINES AND REPRESENTATIVE TOP SKEWED SHAPES.

ALL SHAPES MUST CHALLENGE THE PLHR LIMIT.

EXTEND PEAK ELEVATIONS TO CHALLENGE ASI LIMITS.

Shape No.	Zp (ft)	Normalized Zp	- ASI (%)
1	5.333	0.5	0%
2	6.33	0.593	9.2%
3	7.33	0.687	17.2%
4	8.75	0.820	16%

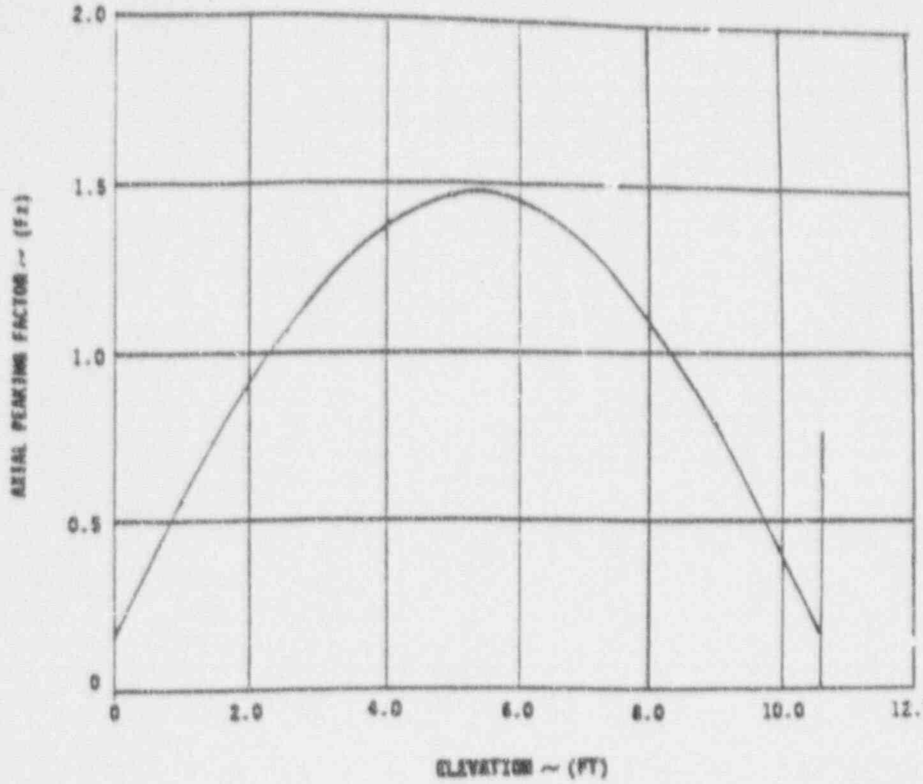


Figure B-1.

Cosine Power Shape, Zp = 5.334 ft., ASI = 0%

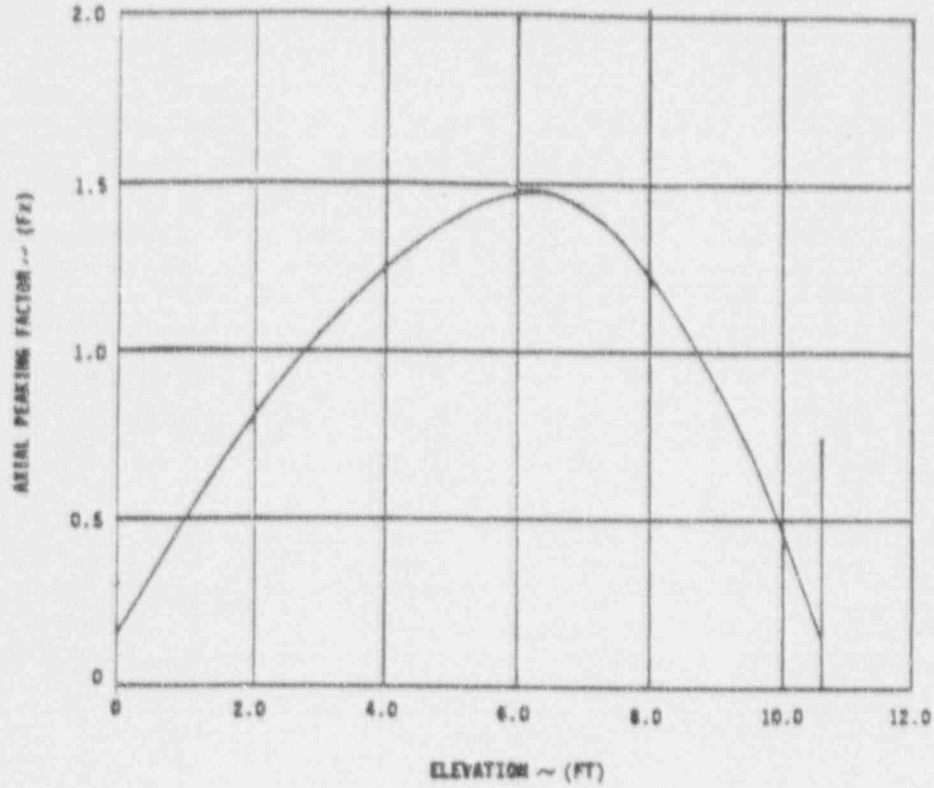


Figure B-2.

Skewed Cosine Power Shape, Zp = 6.33 ft., ASI = 9.2%

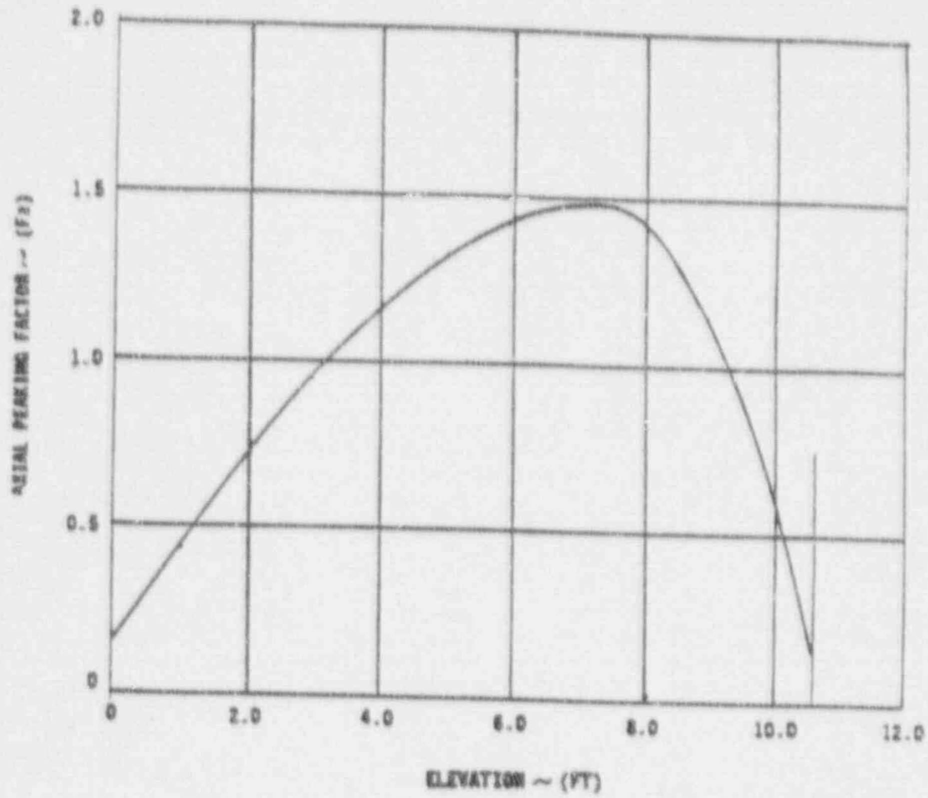


Figure B-3.

Skewed Cosine Power Shape, Zp = 7.33 ft., ASI = 17.2%

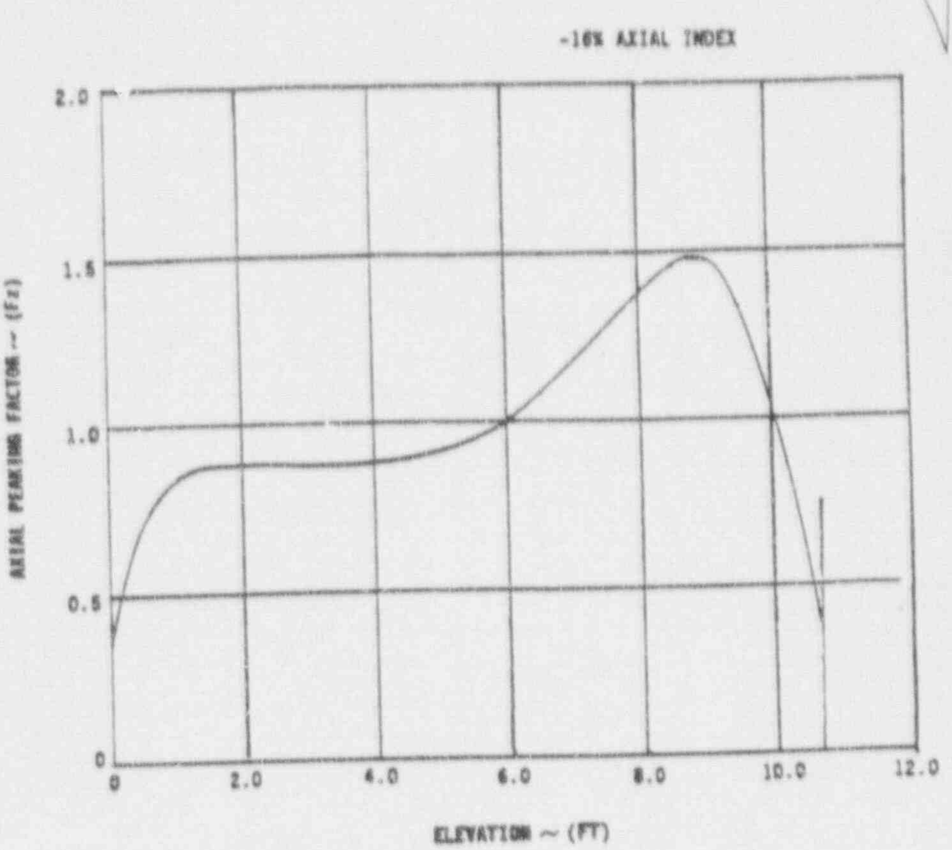
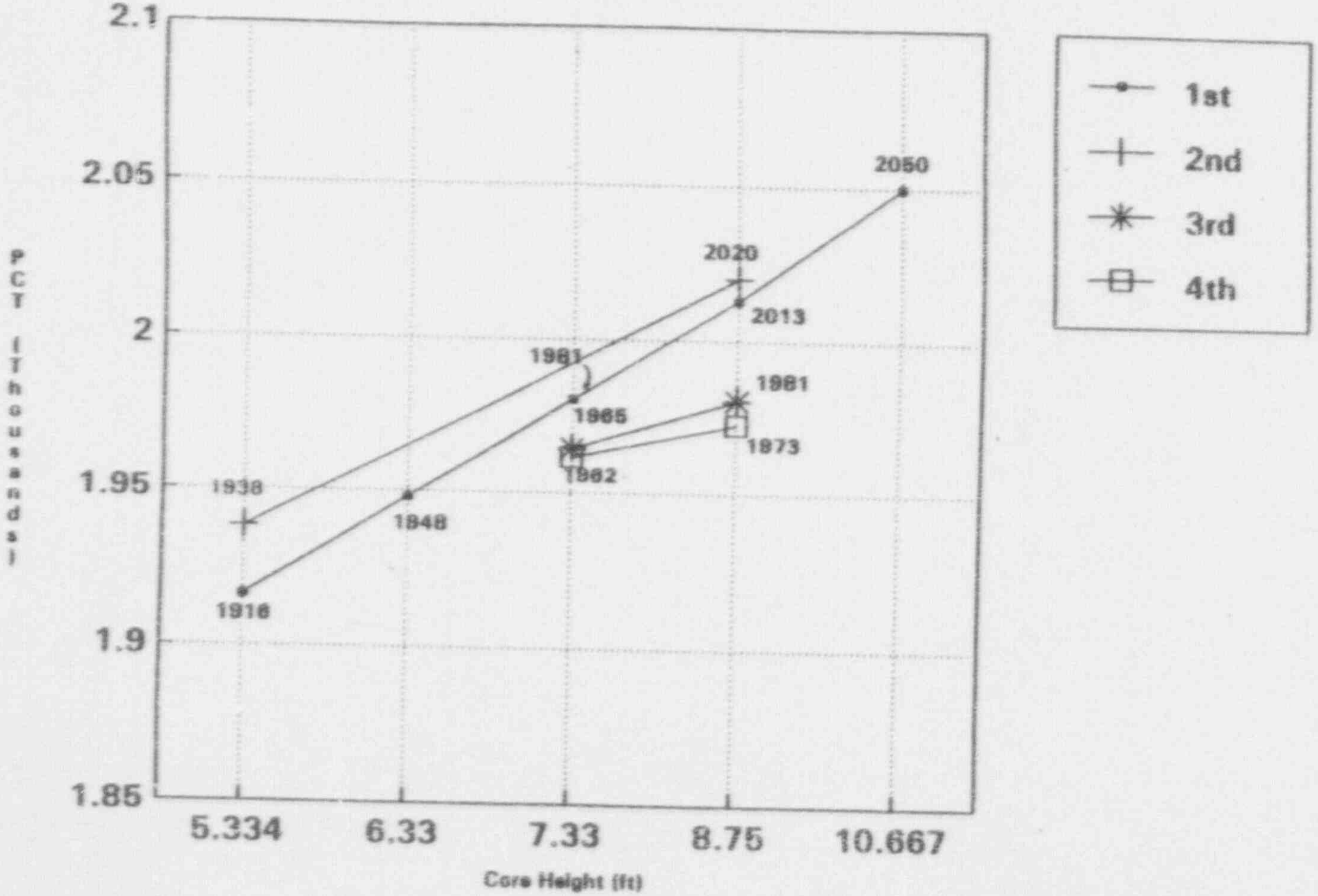


Figure B-4.

Top Skewed Power Shape, Zp = 8.75 ft., ASI = 16%

Figure 8-5
Power Shape Study Zpeak vs PCT



APPLICATION OF THE MODEL

- o FUEL BURNUP

    BASED ON EXISTING STUDIES (INCLUDING MILLSTONE 2), MOST LIMITING TIME IN LIFE CAN BE IDENTIFIED AS BEGINNING-OF-LIFE.

    NO BURNUP STUDY PERFORMED FOR BART FOR CE EM.

CONCLUSION:

PERFORM ANALYSIS USING LIMITING BOL (TIME OF MAXIMUM DENSIFICATION) CONDITIONS UNLESS SPECIAL CONDITIONS WARRANT OTHERWISE.

APPLICATION OF THE MODEL

o IFBA

[ ] a,c

MAY YIELD A LATER, BUT HIGHER TEMPERATURE BURST. THE COMPETING EFFECTS OF LOCAL ZIRC/WATER REACTION AND HIGHER STEAM FLOW/ENTRAINMENT MAY YIELD IFBA PCTs HIGHER THAN PCTs CALCULATED FOR NON-IFBA RODS AT BOL (IFBA BURNUP FOLLOWS THE SAME TRENDS AS NON-IFBA).

IFBA DESIGNS MAY VARY FROM CYCLE TO CYCLE.

CONCLUSION:

APPLICATION OF THE MODEL SHOULD INCLUDE EXAMINATION OF BOTH IFBA AND NON-IFBA FUEL TO IDENTIFY WHICH RESULTS IN THE MORE LIMITING PCT UNLESS SPECIFIC JUSTIFICATION FOR EXCEPTION IS PROVIDED.

APPLICATION OF THE MODEL

o OTHER SENSITIVITIES

ITEMS IDENTIFIED IN WCAP-9258

DISCUSSION IN APPENDIX C OF WCAP-13027 FOR BART FOR CE EM

1. Power Shapes

   Discussed previously.

2. Core Shroud Region Nodalization

   Discussed previously.

3. Burnup

   Discussed previously.

4. Cold RCS Volume in SATAN

   SATAN-VI sensitivity study (WCAP-8341, Prop.). None of the changes to SATAN-VI would be expected to significantly affect the sensitivity results.

APPLICATION OF THE MODEL

5. Sensitivity to Number of Nodes

[ ]a,c

APPLICATION OF THE MODEL

6. Artificial Pressure in the SATAN Momentum Equation
7. Effect of Critical Flowchecks on SATAN Momentum with Momentum Flux
8. Cross Flow Effects
9. Reactor Coolant System Thick Metal Heat Release in SATAN
10. Distribution Parameter (C_0) Study
11. Steam Generator Reverse Heat Transfer Effects
12. Accumulator Injection in the Broken Loop During Blowdown

Items 6 through 12 are SATAN-VI sensitivity studies [22]. None of the changes to SATAN-VI would be expected to significantly affect the sensitivity results.

APPLICATION OF THE MODEL

13. LOCTA Pellet Noding

    Discussed previously.

14. LOCTA Time Step Studies

    Item 14 is related to time step size in the rod heat-up calculation. Definition of the iteration scheme used in the approved Westinghouse version of LOCBART is provided in WCAP-10266-P-A, Rev. 2

15. Sensitivity of Peak Cladding Temperature to Steam Cooling

    The BART code which is included in LOCBART has sufficient capability to accurately model heat transfer from fuel rod to fluid at all anticipated steam flow rates (WCAP-9561-P-A).

16. WREFLOOD Sensitivity to Reactor Coolant Pump Conditions

    Discussed previously.

17. Core Heat Flow Rate during REFLOOD

    Core heat flow rate is a relatively insensitive parameter in WREFLOOD (WCAP-9528). No modifications have been introduced to WREFLOOD to alter this sensitivity, so the sensitivity for Item 17 remains valid.

APPLICATION OF THE MODEL

18. Containment Pressure

Changes to the containment code, COCO, have not been implemented since this sensitivity was addressed in WCAP-9528. The item 18 sensitivity remains valid.

19. Single Failure Criterion

Single failure criteria has been previously addressed for Westinghouse plants (WCAP-8240, WCAP [illegible]) concluding that the limiting single failure for Large break LOCA is loss of a single Low Pressure Safety Injection pump. Combustion Engineering has confirmed this assumption in similar studies for a CE NSSS design (CENPD-132, Rev. 01, Vol. I). Consideration of no single failure being the worst case has been previously discussed.

20. Nitrogen Gas Injection Impact

The impact of accumulator (SIT) gas injection has been addressed in WCAP-8341. In the BART for CE EM, as in previous Westinghouse Evaluation Models, the effects of nitrogen gas on reflooding will conservatively be neglected.

APPLICATION OF THE MODEL

21. RCP Assumptions

    Discussed previously.

22. Break Location

    Discussed previously.

23. Flow Blockage Considerations

    Discussed previously.

SMALL BREAK LOCA ECCS EVALUATION MODEL FOR THE ANALYSIS OF A COMBUSTION ENGINEERING (CE) NSSS

REVISED NOTRUMP EM FOR CE - A SMALL BREAK LOCA ECCS EVALUATION MODEL FOR THE ANALYSIS OF A CE NSSS

- o PRIMARILY BASED ON PREVIOUSLY APPROVED NOTRUMP EM FOR CE DEVELOPED FOR THE ANALYSIS OF MILLSTONE UNIT 2 AND DOCUMENTED IN WCAP 10054-P-A, ADDENDUM 1

- o INCLUDES MINOR MODIFICATIONS TO PREVIOUSLY APPROVED NOTRUMP EM FOR CE WHICH HAVE BEEN IMPLEMENTED TO MORE APPROPRIATELY MODEL THE CE NSSS AND TO BRING THE EM UP TO 1991 TECHNOLOGY AND STANDARDS.

PREVIOUS NOTRUMP EM FOR CE

- APPROVED IN WCAP 10054-P-A, ADDENDUM 1
- DEVELOPED TO VERIFY THE APPLICATION OF THE WESTINGHOUSE SMALL BREAK EVALUATION MODEL USING NOTRUMP AND LOCTA-IV TO A CE NSSS MEETS REQUIREMENTS OF APPENDIX K TO 10 CFR 50 AND ITEM II.K.3.30 OF NUREG-0737
- BASED ON WESTINGHOUSE NOTRUMP EVALUATION MODEL APPROVED IN WCAP 10054-P-A AND USED UNALTERED CODE VERSIONS OF:

  NOTRUMP (SYSTEM HYDRAULIC CALCULATION)
  AND
  LOCTA-IV (FUEL ROD HEATUP CALCULATION)
- NRC STAFF DETERMINED APPLICATION OF NOTRUMP CODE TO THE CE NSSS COMPLIES WITH REQUIREMENTS OF APPENDIX K TO 10 CFR 50, WITH THE EXCEPTION THAT A BREAK SPECTRUM WOULD NEED TO BE PERFORMED IF THE METHODOLOGY WAS APPLIED TO CE NSSS DESIGNS OTHER THAN MILLSTONE 2.
- NRC STAFF ALSO DETERMINED THAT WCAP 10054-P-A, ADDENDUM 1 ADDRESSES CONCERNS OF NUREG-0635, NUREG-0611, AND NUREG-0737 ITEM II.K.3.30

REVISED NOTRUMP EM FOR CE

DOCUMENTED IN WCAP 13027-P

CONSISTS OF:

- CODE MODIFICATIONS REPORTED IN 1989 AND 1990 ECCS EVALUATION MODEL CHANGES REPORTS REQUIRED BY 10 CFR 50.46
- CODE MODIFICATIONS MADE BETWEEN AUGUST 1990 AND MAY 1991 WHICH WERE REPORTED TO UTILITIES
- CODE MODIFICATIONS TO MORE ACCURATELY MODEL SAFETY INJECTION CONFIGURATION
- SYSTEM NODING MODIFIED TO MORE APPROPRIATELY MODEL ADDITIONAL COLD LEGS
- VERIFICATION THAT CODE AND INPUT METHODOLOGY CHANGES REQUIRED IN PREVIOUS NOTRUMP EM FOR CE CONTINUE TO APPLY TO FORT CALHOUN UNIT 1

MORE DETAILS OF THESE MODIFICATIONS FOLLOW

REVISED NOTRUMP EM FOR CE MODEL UPDATES DETAILED IN ECCS EM CHANGE REPORTS

ON OCTOBER 17, 1988, THE NRC IMPLEMENTED REVISED ECCS EVALUATION MODEL REPORTING REQUIREMENTS THROUGH A RULE CHANGE TO 10 CFR 50.46

SINCE THAT TIME, WESTINGHOUSE HAS ISSUED DOCUMENTS DETAILING MODEL CHANGES FOR TWO ANNUAL REPORTING PERIODS (1989 AND 1990)

- THE MODIFICATIONS TO THE WESTINGHOUSE NOTRUMP AND LOCTA-IV CODES IDENTIFIED IN THE 1989 REPORT WERE DETERMINED TO BE EQUALLY APPLICABLE TO THE NOTRUMP EM FOR CE

- IT WAS CONCLUDED THAT THE COMBINED EFFECT OF THE 1989 MODIFICATIONS TO THE NOTRUMP AND LOCTA-IV CODES WOULD RESULT IN A NET REDUCTION IN PEAK CLADDING TEMPERATURE

- THESE MODIFICATIONS TO THE REVISED NOTRUMP EM FOR CE ARE SUMMARIZED IN WCAP 13027-P

- FOR THE 1990 PERIOD (AUGUST 1989 TO AUGUST 1990), NO REPORTABLE EVALUATION MODEL CHANGES OCCURRED.

REVISED NOTRUMP EM FOR CE ADDITIONAL MODEL UPDATES TO BE REPORTED IN FUTURE

IN JUNE 1991, REPORTS WERE ISSUED TO UTILITIES WHICH ARE CURRENTLY LICENSED WITH WESTINGHOUSE ECCS EVALUATION MODELS IDENTIFYING CHANGES TO THE VARIOUS EVALUATION MODELS IMPLEMENTED BETWEEN THE TIME PERIOD FROM AUGUST 1990 TO MAY 1991

- FOUR MODIFICATIONS WERE IDENTIFIED WHICH EFFECT THE CODES WHICH CONSTITUTE THE NOTRUMP EM

- THESE MODIFICATIONS ALSO APPLY TO THE NOTRUMP EM FOR CE AND THEREFORE WERE INCLUDED AND ARE DESCRIBED IN WCAP 13027-P

NOTRUMP MODEL UPDATES FOR ANALYSIS OF THE FORT CALHOUN UNIT 1 CE NSSS

IN WCAP 10054-P-A, ADDENDUM 1, THE DIFFERENCES BETWEEN A WESTINGHOUSE AND CE NSSS WERE EVALUATED TO DETERMINE WHAT MODEL CHANGES WERE REQUIRED. AS A RESULT OF THESE DIFFERENCES, SEVERAL MODEL CHANGES WERE REQUIRED

THESE DIFFERENCES AND MODEL CHANGES WERE REVIEWED TO ASSESS THEIR APPLICABILITY TO FORT CALHOUN UNIT 1

THIS REVIEW IDENTIFIED SEVERAL ADDITIONAL MODIFICATIONS REQUIRED FOR THE APPROPRIATE MODELING OF FORT CALHOUN UNIT 1 WHICH WERE BEYOND THOSE DESCRIBED IN WCAP 10054-P-A, ADDENDUM 1.

THE NSSS DIFFERENCES AND ADDITIONAL MODIFICATIONS ARE SUMMARIZED BELOW

NOTRUMP MODEL UPDATES FOR ANALYSIS OF THE FORT CALHOUN UNIT 1 CE NSSS CONT.

o LOOP LAYOUT REPRESENTATION

IN THE PREVIOUS MODEL, THE STANDARD WESTINGHOUSE SYSTEM MODELING WAS MODIFIED TO ACCURATELY REPRESENT THE CE TWO HOT LEG, FOUR COLD LEG DESIGN BY [

]a,c

[

]a,c

FORT CALHOUN UNIT 1 HAS A "TRIP-2 LEAVE-2" REACTOR COOLANT PUMP TRIP EMERGENCY OPERATING PROCEDURE FOLLOWING AN ABNORMAL CONDITION WITH NO LOSS OF OFFSITE POWER

IN ORDER TO EXPLICITLY MODEL THIS PROCEDURE FOR THE NO LOSS OF OFFSITE POWER SCENARIO, [

]a,c

a,c

Figure 4-1

Fort Calhoun NOTRUMP Noding Diagram

NOTRUMP MODEL UPDATES FOR ANALYSIS OF THE FORT CALHOUN UNIT 1 CE NSSS CONT.

ALSO IN ORDER TO EXPLICITLY MODEL DIFFERENT COMBINATIONS OF LOW AND HIGH PRESSURE SAFETY INJECTION INTO EACH COLD LEG FOR FORT CALHOUN UNIT 1, [ ]a,c

- LARGE DIAMETER HOT LEG

  ACCOUNTED FOR VIA NOTRUMP CODE INPUT

- HOT LEG SG INLET ANGLE AND PLENUM FLOODING CORRELATION

  FORT CALHOUN UNIT 1 SG INLET NOZZLE INCLINATION [ ]a,c PERFORMED IN WCAP 10054-P-A, ADDENDUM 1

- LOOP SEAL BEHAVIOR

  THE FORT CALHOUN UNIT 1 ANALYSIS CONTAINS NO CHANGES IN LOOP SEAL NODING OR CODE INPUT METHODOLOGY FROM THAT DEVELOPED IN WCAP 10054-P-A, ADDENDUM 1

NOTRUMP MODEL UPDATES FOR ANALYSIS OF THE FORT CALHOUN UNIT 1 CE NSSS CONT.

- CONTROL ELEMENT ASSEMBLY DESIGN

  FORT CALHOUN UNIT 1 CEA DESIGN IS SIMILAR TO THAT ASSUMED IN 10054-P-A, ADDENDUM 1. THEREFORE SAME MODELING ASSUMED.

- UPPER HEAD BYPASS FLOW AND TEMPERATURE

  FORT CALHOUN UNIT 1 BYPASS FLOW AND TEMPERATURE IS SIMILAR TO THAT ASSUMED IN 10054-P-A, ADDENDUM 1. THEREFORE SAME MODELING ASSUMED.

- SAFETY INJECTION ANGLE

  THE FORT CALHOUN UNIT 1 ANALYSIS CONSERVATIVELY ASSUMED A VALUE OF [ ][a,c] EVEN THOUGH THE ACTUAL PLANT SI ANGLE IS 75 DEGREES

- SAFETY INJECTION FLOW GEOMETRY

  THE FORT CALHOUN UNIT 1 SAFETY INJECTION FLOW GEOMETRY IS SIMILAR TO THAT ASSUMED IN WCAP 10054-P-A, ADDENDUM 1.

NOTRUMP MODEL UPDATES FOR ANALYSIS OF THE FORT CALHOUN UNIT 1 CE NSSS CONT.

- POLYTROPIC EXPANSION COEFFICIENT

  [

  ].[a,c] THE FORT CALHOUN UNIT 1 COVER GAS PRESSURE OF 255 IS WITHIN THE BOUNDS OF THE EVALUATION.

- REACTOR COOLANT PUMPS

  WCAP 10054-P-A, ADDENDUM 1 CONCLUDED THAT THE [

  ].[a,c] FORT CALHOUN UNIT 1 HAS BYRON-JACKSON PUMPS WHICH ARE SIMILAR IN DESIGN TO CE AND WESTINGHOUSE PUMPS. THE USE OF FORT CALHOUN UNIT 1 PUMP HOMOLOGOUS CURVES AND PARAMETERS PROVIDES REALISTIC MODELING.

NOTRUMP MODEL UPDATES FOR ANALYSIS OF THE FORT CALHOUN UNIT 1 CE NSSS CONT.

- FUEL ASSEMBLY DESIGN

  THE STEAM COOLING CORRELATIONS USED IN NOTRUMP AND LOCTA-IV WERE DETERMINED TO BE APPLICABLE TO FUEL ASSEMBLY HYDRAULIC DIAMETERS OVER A RANGE ENCOMPASSING BOTH CE AND WESTINGHOUSE DESIGNS. THE FORT CALHOUN FUEL HAS A HYDRAULIC DIAMETER WITHIN THIS RANGE

- ROD BURST CALCULATION

  WCAP 10054-P-A, ADDENDUM 1 DETERMINED THAT FOR FUEL BEING LOADED INTO THE CE NSSS, THE PRESSURE DIFFERENTIAL REQUIRED FOR BURST AT A GIVEN TEMPERATURE WAS [

  ].[a,c] THE FUEL FOR FORT CALHOUN WILL ALSO BE MORE RESISTENT TO CLAD BURST. CLAD BURST IS A PCT PENALTY FOR SMALL BREAK LOCA. [

  ].[a,c]

NOTRUMP MODEL UPDATES FOR ANALYSIS OF THE FORT CALHOUN UNIT 1 CE NSSS CONT.

- o FUEL CRACK AND DISH VOLUMES

  STANDARD WESTINGHOUSE VALUES WERE REPLACED WITH FORT CALHOUN SPECIFIC DATA FOR LOCTA-IV INPUT

APPLICABILITY OF REVISED NOTRUMP EM FOR CE

AS STATED IN WCAP 10054-P-A, ADDENDUM 1, NRC STAFF DETERMINED APPLICATION OF NOTRUMP CODE TO THE CE NSSS COMPLIES WITH REQUIREMENTS OF APPENDIX K TO 10 CFR 50, WITH THE EXCEPTION THAT A BREAK SPECTRUM WOULD NEED TO BE PERFORMED IF THE METHODOLOGY WAS APPLIED TO CE NSSS DESIGNS OTHER THAN MILLSTONE 2.

REVISED NOTRUMP EM FOR CE

- IS BASED ON 10054-P-A, ADDENDUM 1 MODEL
- CONTAINS ONLY MINOR CHANGES TO LOOP NODING AND CODE ERROR UPDATES
- REQUIRES BREAK SPECTRUM TO BE PERFORMED

THEREFORE REVISED NOTRUMP FOR CE MEETS PAST NRC REQUIREMENTS AND WILL COMPLY WITH REQUIREMENTS OF APPENDIX K TO 10 CFR 50

REVISED NOTRUMP EM FOR CE SENSITIVITIES

- BREAK SPECTRUM ANALYSIS

  WESTINGHOUSE EXPERIENCE HAS SHOWN THAT IT IS DIFFICULT TO IDENTIFY A "GENERICALLY LIMITING" BREAK SIZE

  THEREFORE APPLICATION OF REVISED MODEL REQUIRES BREAK SPECTRUM TO BE PERFORMED

  FORT CALHOUN UNIT 1 WAS FOUND TO HAVE A LIMITING BREAK OF 3"

- BREAK LOCATION

  WESTINGHOUSE EXPERIENCE HAS SHOWN THAT THE LIMITING BREAK LOCATION FOR SMALL BREAK LOCA IS THE COLD LEG.

  THIS WAS CONFIRMED FOR THE APPLICATION OF THE NOTRUMP EM TO CE PLANTS IN WCAP 10054-P-A, ADDENDUM 1

  SIMILAR STUDIES BY COMBUSTION ENGINEERING ALSO SHOW COLD LEG BREAK TO BE LIMITING

REVISED NOTRUMP EM FOR CE SENSITIVITIES

- POWER AVAILABILITY

  SENSITIVITIES FOR THE WESTINGHOUSE NSSS DESIGN HAVE SHOWN THAT THE LOSS OF OFFSITE POWER SCENARIO RESULTS IN THE LIMITING PCT

  IN ORDER TO CONFIRM THE LOSS OF OFFSITE POWER ASSUMPTION IS CONSERVATIVE FOR FORT CALHOUN UNIT 1, A SENSITIVITY WAS PERFORMED ASSUMING NO LOSS OF OFFSITE POWER. THIS SENSITIVITY INCLUDED THE REACTOR COOLANT PUMP TRIP STRATEGY CONTAINED IN THE FORT CALHOUN UNIT 1 EMERGENCY OPERATING PROCEDURES

  THE RESULTS OF THE SENSITIVITY CONFIRMED THE LOSS OF OFFSITE POWER ASSUMPTION IS CONSERVATIVE

REVISED NOTRUMP EM FOR CE SENSITIVITIES

- FUEL BURNUP

  THE LIMITING TIME IN LIFE OF FUEL FOR SMALL BREAK LOCA DEPENDS ON WHETHER CLAD BURST IS CALCULATED TO OCCUR. THEREFORE A BURNUP STUDY IS REQUIRED TO DETERMINE THE LIMITING TIME IN LIFE.

  SENSITIVITY STUDIES FOR THE FORT CALHOUN FUEL DETERMINED THAT BEGINNING OF LIFE FUEL WAS LIMITING AND NO CLAD BURST OCCURS.

- INTEGRAL FUEL BURNABLE ABSORBERS

  THE LIMITING TIME IN LIFE OF IFBA FUEL ALSO DEPENDS ON WHETHER CLAD BURST OCCURS. THEREFORE SENSITIVITY STUDIES ARE REQUIRED TO DETERMINE LIMITING TIME IN LIFE AND IF IFBA FUEL IS LIMITING WITH RESPECT TO NON-IFBA FUEL.

  SENSITIVITY STUDIES FOR FORT CALHOUN DETERMINED BEGINNING OF LIFE IFBA FUEL RESULTED IN THE SAME PCT AS NON-IFBA FUEL.

REGULATORY COMPLIANCE

- 10 CFR 50, APPENDIX K
  NUREG-0737

  THE WESTINGHOUSE ECCS EVALUATION MODELS USED FOR THE ANALYSIS OF A CE NSSS ARE BASED ON WESTINGHOUSE EVALUATION MODELS WHICH ALREADY COMPLY WITH THESE REQUIREMENTS.

  MODIFICATIONS FOR THE MODELING OF A CE NSSS DID NOT CHANGE ANY OF THE "BUILT IN" APPENDIX K MODELING FEATURES.

REGULATORY COMPLIANCE

- 10 CFR 50.46

PEAK CLADDING TEMPERATURE

MAXIMUM CLADDING OXIDATION

MAXIMUM HYDROGEN GENERATION

COOLABLE GEOMETRY

LONG TERM COOLING

REGULATORY COMPLIANCE

PEAK CLADDING TEMPERATURE

CRITERION: THE CALCULATED MAXIMUM FUEL ELEMENT TEMPERATURE SHALL NOT EXCEED 2200°F.

PEAK CLAD TEMPERATURE IS A DIRECT OUTPUT OF THE LOCBART CODE IN THE BART FOR CE EM AND THE LOCTA-IV CODE IN THE NOTRUMP EM FOR CE, AND IS A REPORTED ANALYSIS RESULT.

REGULATORY COMPLIANCE

MAXIMUM CLADDING OXIDATION

CRITERION: THE CALCULATED TOTAL OXIDATION OF THE CLADDING SHALL NOWHERE EXCEED 0.17 TIMES THE TOTAL CLADDING THICKNESS BEFORE OXIDATION.

THE LOCBART AND LOCTA-IV CODES CALCULATE LOCAL CLADDING OXIDATION THROUGHOUT THE LARGE BREAK AND SMALL BREAK TRANSIENTS RESPECTIVELY. THE GREATEST LOCAL CLADDING OXIDATION (USUALLY AT THE HOT ROD BURST LOCATION) IS A REPORTED ANALYSIS RESULT.

REGULATORY COMPLIANCE

MAXIMUM HYDROGEN GENERATION

CRITERION: THE CALCULATED TOTAL AMOUNT OF HYDROGEN GENERATED FROM THE CHEMICAL REACTION OF THE CLADDING WITH WATER OR STEAM SHALL NOT EXCEED 0.01 TIMES THE HYPOTHETICAL AMOUNT THAT WOULD BE GENERATED BY ALL THE METAL IN THE CLADDING CYLINDERS SURROUNDING THE FUEL, EXCLUDING THE CLADDING SURROUNDING THE PLENUM VOLUME, WERE TO REACT.

LOCBART HAS RECENTLY BEEN UPDATED TO PROVIDE A CONSERVATIVE ESTIMATE OF HOT ASSEMBLY WIDE AVERAGE ZIRC/WATER REACTION REPLACING GENERIC VALUES PREVIOUSLY REPORTED FOR CORE WIDE ZIRC/WATER. A CONSERVATIVE ESTIMATE CAN ALSO BE CALCULATED BASED ON LOCTA-IV OUTPUT. THE CONSERVATIVE ESTIMATE IS COMPARED TO THE REGULATORY LIMIT FOR VERIFICATION. UPON VERIFICATION, A VALUE OF < 1.0% IS REPORTED.

REGULATORY COMPLIANCE

COOLABLE GEOMETRY

CRITERION: CALCULATED CHANGES IN CORE GEOMETRY SHALL BE SUCH THAT THE CORE REMAINS AMENABLE TO COOLING.

AN ACCURATE GEOMETRIC REPRESENTATION OF THE CORE IS MODELED IN THE BART FOR CE EM AND THE NOTRUMP EM FOR CE. THIS MODELING WILL INCLUDE PREDICTED ALTERATIONS IN CORE GEOMETRY RESULTING FROM A DESIGN BASIS LOCA (HYDRAULIC FORCES) AND/OR SEISMIC EVENT AS REQUIRED AS A CONDITION OF THE PLANT LICENSE. IT IS NOTED THAT THE BART FOR CE EM AND NOTRUMP EM FOR CE DO NOT CALCULATE CHANGES IN CORE GEOMETRY (OTHER THAN ROD BURST), BUT USE INFORMATION SUPPLIED BY THE NSSS VENDOR OR UTILITY AS INPUT TO ACCURATELY MODEL THE EXPECTED CORE GEOMETRY. GIVEN AN ACCURATE MODELING OF CORE GEOMETRY, CALCULATION OF A PCT NOT GREATER THAN 2200°F CONFIRMS THAT GEOMETRY'S AMENABILITY TO COOLING.

REGULATORY COMPLIANCE

LONG TERM COOLING

CRITERION: 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.

LONG TERM HEAT REMOVAL

BORON PRECIPITATION

REGULATORY COMPLIANCE

LONG TERM HEAT REMOVAL

THE WESTINGHOUSE COMMITMENT FOR ASSURANCE OF LONG TERM COOLING IS IDENTIFIED IN WCAP-8339. THE REACTOR CORE IS RECOVERED BY BORATED ECCS WATER HAVING A HIGH ENOUGH BORON CONCENTRATION TO MAINTAIN CORE SHUTDOWN. FOLLOWING SWITCHOVER TO THE RECIRCULATION PHASE, THE MIXING OF THE VARIOUS SOURCES OF BORATED AND UNBORATED WATER (I.E. RCS, SIRWT, SITS, AND OTHER SOURCES DUMPED DIRECTLY TO THE CONTAINMENT SUMP OR INTO THE BROKEN RCS) MUST PROVIDE A SUFFICIENTLY LARGE BORON CONCENTRATION TO MAINTAIN THE REACTOR CORE IN A SUBCRITICAL STATE. NOTE THAT THIS EVALUATION OF LONG TERM EFFECTS IS SEPARATE FROM THE SHORT TERM CALCULATION PERFORMED WITH THE BART FOR CE EM AND NOTRUMP EM FOR CE. BECAUSE THE ABILITY TO MAINTAIN THE REACTOR SUBCRITICAL ON BORON ONLY IS LARGELY RELATED TO THE SPECIFICS OF THE CYCLE ENERGY REQUIREMENTS, THIS EVALUATION IS PERFORMED ON A CYCLE-BY-CYCLE BASIS, INDEPENDENT OF THE PCT, CLADDING OXIDATION, AND HYDROGEN GENERATION RESULTS.

REGULATORY COMPLIANCE

BORON PRECIPITATION

ANOTHER FACET OF ENSURING LONG TERM COOLING CAPABILITY POST-LOCA IS TO PRECLUDE THE PRECIPITATION OF BORON FROM THE HIGHLY BORATED INJECTION WATER. PLATING OUT OF BORON ON THE FUEL ROD SURFACE CAN DETERIORATE HEAT TRANSFER, OR BLOCK CORE FLOW PATHS, YIELDING A CLAD HEAT-UP TRANSIENT BASED ON THE REMAINING DECAY HEAT. TO PREVENT STAGNATION IN THE CORE REGION FOR A COLD LEG BREAK WITH COLD LEG SI FLOW TRAVERSING THE DOWNCOMER TANGENTIALLY AND TRAVELING DIRECTLY OUT THE BREAK, THE RECIRCULATION PHASE IS SWITCHED FROM COLD LEG INJECTION TO HOT LEG INJECTION. THE MAXIMUM ALLOWABLE TIME FOR THIS SWITCHOVER IS A FUNCTION OF BORON CONCENTRATION REACHING THE CORE FROM THE SUMP, CORE INITIAL POWER, ETC. AGAIN, THIS EVALUATION OF LONG TERM EFFECTS IS SEPARATE FROM THE SHORT TERM CALCULATION PERFORMED WITH THE BART FOR CE EM AND THE NOTRUMP EM FOR CE.

CONCLUSION OF WCAP 13027-P

THE REPORT PRESENTED THE DESCRIPTIONS, APPLICATIONS, LIMITATIONS, AND LICENSING HISTORY FOR THE WESTINGHOUSE ECCS EVALUATION MODELS FOR THE COMBUSTION ENGINEERING NSSS.

THE LARGE BREAK MODEL, THE 1981 + BART FOR CE NSSS EVALUATION MODEL HAS BEEN DEVELOPED BY MODIFYING EXISTING LARGE BREAK ECCS CODES TO INCORPORATE FEATURES OF THE CE DESIGN. THIS NEW CODE SEQUENCE, INCLUDING THE MODIFICATIONS FOR CE NSSS DESIGN, CONSTITUTES AN EM IN COMPLIANCE WITH THE REQUIREMENTS OF 10 CFR 50, APPENDIX K. THIS MODEL IS ACCEPTABLE FOR USE IN FINAL SAFETY ANALYSIS REPORT (FSAR) LARGE BREAK LOCA ANALYSES TO DEMONSTRATE ACCEPTABILITY OF THE ECCS FOR THE CE NSSS.

THE SMALL BREAK MODEL, THE NOTRUMP EM FOR CE NSSS HAS BEEN PREVIOUSLY DEVELOPED AND REVIEWED FOR THIS APPLICATION. REFERENCE INFORMATION RELATING TO THIS MODEL HAS BEEN UPDATED TO REFLECT CURRENT TECHNOLOGY. THIS EM SATISFIES THE REQUIREMENTS OF 10 CFR 50, APPENDIX K, AS WELL AS NUREG-0737, ITEM II.K.3.30. THIS MODEL IS ACCEPTABLE FOR USE IN FSAR SMALL BREAK LOCA ANALYSES TO DEMONSTRATE ACCEPTABILITY OF THE ECCS FOR THE CE NSSS.

MIXED VENDOR CORE DATA LIST (MVCDL)

A DOCUMENT WHICH CONTAINS ALL FORT CALHOUN UNIT 1 DATA REQUIRED TO PERFORM THE LARGE AND SMALL BREAK LOCA ANALYSES

THE DOCUMENT MET THE QUALITY ASSURANCE REQUIREMENTS OF BOTH WESTINGHOUSE AND OMAHA PUBLIC POWER DISTRICT

EACH ITEM IN THE LIST CONTAINS THE SOURCE DOCUMENT FOR THE ITEM. THE SOURCES FOR THE DATA INCLUDED DRAWINGS, VENDOR TECHNICAL MANUALS, THE FORT CALHOUN UNIT 1 TECHNICAL SPECIFICATIONS, THE FORT CALHOUN UNIT 1 USAR, AND WESTINGHOUSE AND OMAHA PUBLIC POWER DISTRICT INTERNAL DOCUMENTS.

WESTINGHOUSE ENGINEERS SPENT SEVERAL WEEKS AT THE OMAHA PUBLIC POWER DISTRICT OFFICES IN OMAHA TO BECOME FAMILIAR WITH THE PLANT AND ASSIST IN THE COLLECTION OF THE DATA. DURING THIS TIME, OMAHA PUBLIC POWER DISTRICT PERSONNEL WERE ADVISED OF THE INTENDED APPLICATION OF THE DATA AND NORMAL WESTINGHOUSE PROCEDURES USED FOR DATA COLLECTION. THIS INSURED THAT THE DATA PROVIDED WOULD BE CONSISTENT WITH THAT USED IN STANDARD WESTINGHOUSE LOCA ANALYSES.

A SAMPLE PAGE OF THE MVCDL FOLLOWS

IV LOCA-Small and Large Break

A Reactor Vessel Subregions

1 Inlet nozzle (SR-1)			
a. Volume per nozzle (ft³)	10.996	SEC-SAII-3584-C2	11/90
b. Heat transfer area (ft²)	N.A.		
c. Maximum elevation from vessel bottom (ft)	28.341	SEC-SAII-3584-C2	11/90
d. Minimum elevation from vessel bottom (ft)	24.341	SEC-SAII-3584-C2	11/90
e. Flow area (ft²)	3.142	SEC-SAII-3584-C2	11/90
f. Transit length (ft)	3.5	SEC-SAII-3584-C2	11/90
g. Hydraulic diameter (ft)	2.0	SEC-SAII-3584-C2	11/90
h. Loss coefficient	See Section J	O-CA-064	11/86
i. Metal mass (lbm)	6046	E-232-412	
k. Metal surface area (ft²)	22.64	E-232-412	
2 Downcomer region from top of cold leg to bottom of cold leg (SR-2)			
a. Volume (ft³)	34.030	SEC-SAII-3584-C2	11/90
b. Heat transfer area (ft²)	N.A.		
c. Maximum elevation from vessel bottom (ft)	28.341	SEC-SAII-3584-C2	11/90
d. Minimum elevation from vessel bottom (ft)	24.341	SEC-SAII-3584-C2	11/90
e. Flow area (ft²)	18.990	SEC-SAII-3584-C2	11/90
f. Transit length (ft)	1.893	SEC-SAII-3584-C2	11/90
g. Hydraulic diameter (ft)	0.977	SEC-SAII-3584-C2	11/90
h. Loss coefficient	See Section J	O-CA-064	11/86
i. Metal mass (lbm)	20461	SEC-SAII-3584-C2	11/90
j. Metal surface area (ft²)	125.97	SEC-SAII-3584-C2	11/90
3. Downcomer region from bottom of cold leg to top of shield (SR-3)			
a. Volume (ft³)	77.28	SEC-SAII-3584-C2	11/90
b. Heat transfer area (ft²)	N.A.		
c. Maximum elevation from vessel bottom (ft)	24.341	SEC-SAII-3584-C2	11/90
d. Minimum elevation from vessel bottom (ft)	21.112	SEC-SAII-3584-C2	11/90
e. Flow area (ft²)	23.927	SEC-SAII-3584-C2	11/90
f. Transit length (ft)	3.229	SEC-SAII-3584-C2	11/90
g. Hydraulic diameter (ft)	1.385	SEC-SAII-3584-C2	11/90
h. Loss coefficient	See Section J	O-CA-064	11/86
i. Metal mass (lbm)	40079.7	SEC-SAII-3584-C2	11/90
j. Metal surface area (ft²)	223.1	SEC-SAII-3584-C2	11/90
4. Downcomer region from top of thermal shield to bottom of thermal shield (SR-4)			
a. Volume (ft³)	247.02	SEC-SAII-3584-C2	11/90
b. Heat transfer area (ft²)	N.A.		
c. Maximum elevation from vessel bottom (ft)	21.112	SEC-SAII-3584-C2	11/90
d. Minimum elevation from vessel bottom (ft)	7.445	SEC-SAII-3584-C2	11/90
e. Flow area (ft²)	18.074	SEC-SAII-3584-C2	11/90
f. Transit length	13.667	SEC-SAII-3584-C2	11/90
g. Hydraulic diameter (ft)	0.527	SEC-SAII-3584-C2	11/90
h. Loss coefficient	See Section J	O-CA-064	11/86
i. Metal mass (lbm)	208381.	SEC-SAII-3584-C2	11/90
j. Metal surface area (ft²)	1874.88	SEC-SAII-3584-C2	11/90

LARGE BREAK LOCA ANALYSIS

METHOD OF ANALYSIS

- 1981 + BART FOR CE NSSS LARGE BREAK LOCA ECCS EVALUATION MODEL LOCA EM (BART FOR CE EM)

  WCAP-13027-P

LARGE BREAK ANALYSIS
LIMITING RESULTS AND LIMITING ASSUMPTIONS

	ANALYSIS RESULT	10CFR50.46 LIMIT
o PEAK CLAD TEMPERATURE	2066	2200°F
MAXIMUM CLADDING OXIDATION	5.77%	17%
TOTAL HYDROGEN GENERATION	<1%	1%

- o LIMITING BREAK - DOUBLE-ENDED COLD LEG GUILLOTINE (DECLG) $C_D = 0.4$

  BASED ON SPECTRUM SENSITIVITY STUDY EXAMINING 0.4, 0.6, AND 0.8 DISCHARGE COEFFICIENTS. CONSISTENT WITH BART FOR CE EM METHODOLOGY DESCRIBED IN WCAP-13027-P.

- o BREAK LOCATION - COLD LEG BREAK

  CONSISTENT WITH BART FOR CE EM METHODOLOGY DESCRIBED IN WCAP-13027-P.

LARGE BREAK ANALYSIS
LIMITING RESULTS AND LIMITING ASSUMPTIONS

- POWER AVAILABILITY - LOSS OF OFFSITE POWER

  CONSISTENT WITH BART FOR CE EM METHODOLOGY DESCRIBED IN WCAP-13027-P, A SENSITIVITY STUDY WAS PERFORMED TO EXAMINE LOSS OF OFFSITE POWER AND NO LOSS OF OFFSITE POWER ASSUMPTIONS. RESULTS OF THE STUDY SHOWED THAT THE NO LOSS OF OFFSITE POWER ASSUMPTION YIELDS A HIGHER PCT (~60°F) FOR THE LIMITING FT. CALHOUN C_D = 0.4 CASE.

- ECCS AVAILABILITY - MINIMUM SAFEGUARDS

  CONSISTENT WITH BART FOR CE EM METHODOLOGY DESCRIBED IN WCAP-13027-P, A SENSITIVITY STUDY WAS PERFORMED TO EXAMINE ECCS AVAILABILITY ASSUMPTIONS. RESULTS OF THE STUDY SHOWED THAT THE MINIMUM SAFEGUARDS (LOSS OF A LOW PRESSURE SI PUMP) ASSUMPTION YIELDS A HIGHER PCT (~34°F) FOR THE LIMITING FT. CALHOUN C_D = 0.4 NO LOSS OF OFFSITE POWER CASE BREAK.

- LIMITING TIME IN LIFE - BEGINNING OF LIFE (0 MWD/MTU)

  CONSISTENT WITH BART FOR CE EM METHODOLOGY DESCRIBED IN WCAP-13027-P.

LARGE BREAK ANALYSIS
LIMITING RESULTS AND LIMITING ASSUMPTIONS

- LIMITING AXIAL POWER DISTRIBUTION -

  8.75 FT. PEAK, $F_R^T = 1.80$,

  ASI = -0.16 ASIU

  CONSISTENT WITH BART FOR CE EM METHODOLOGY DESCRIBED IN WCAP-13027-P, A SENSITIVITY STUDY WAS PERFORMED TO IDENTIFY THE LIMITING LB POWER DISTRIBUTION FOR FT. CALHOUN. RESULTS OF THIS STUDY APPEAR IN APPENDIX B OF WCAP-13027-P.

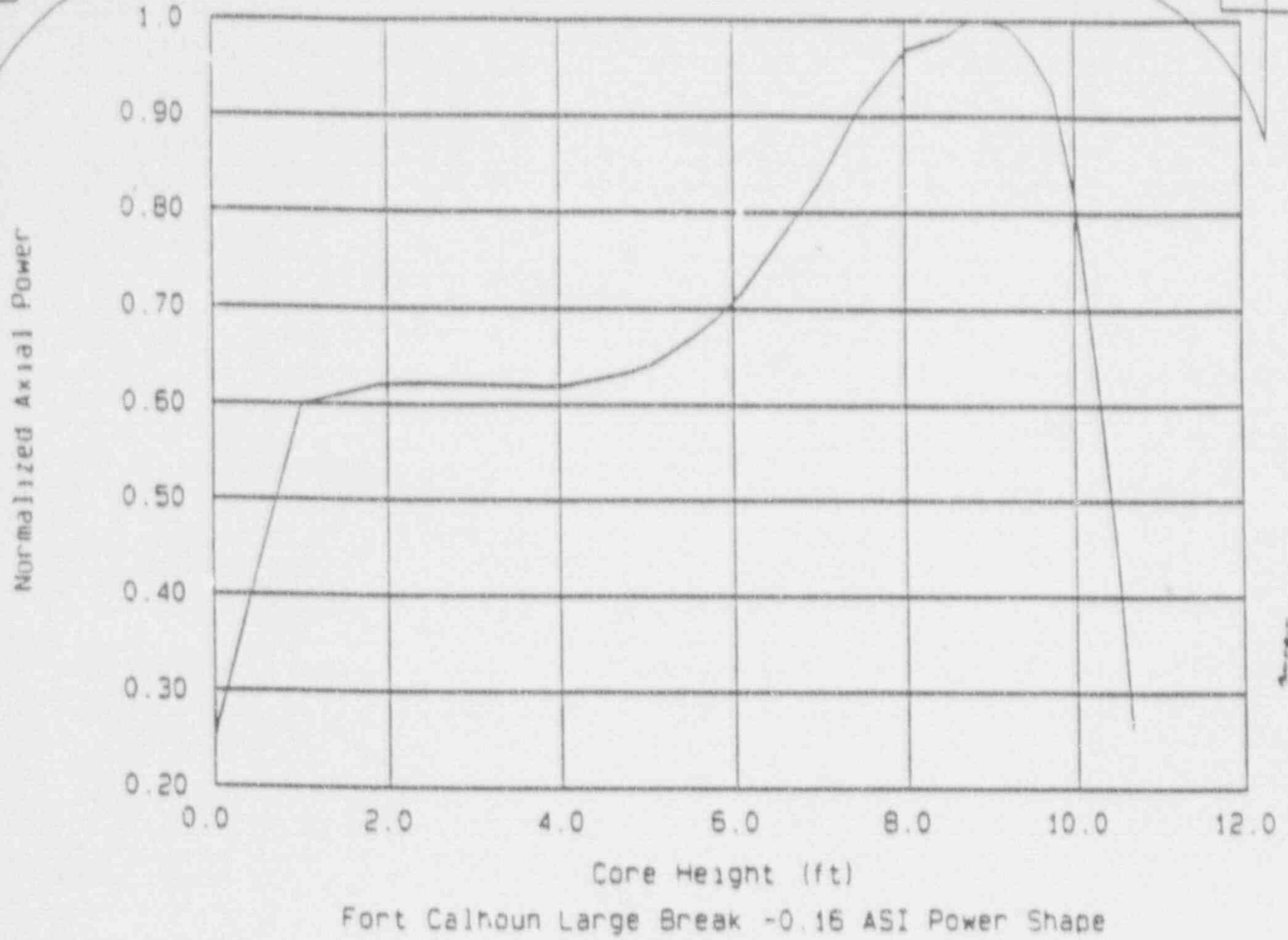
- LIMITING FUEL TYPE - NON-IFBA

  CONSISTENT WITH BART FOR CE EM METHODOLOGY DESCRIBED IN WCAP-13027-P, A PLANT-SPECIFIC, FUEL-SPECIFIC SENSITIVITY STUDY FOR FT. CALHOUN EXAMINING IFBA AND NON-IFBA FUEL WAS PERFORMED. RESULTS DEMONSTRATED THE NON-IFBA FUEL TO BE LIMITING (~15°F).

FORT CALHOUN LARGE BREAK LOCA ANALYSIS

INPUT PARAMETERS AND ASSUMPTIONS

NSSS Power - 102% of 1500 Mwt	1530 Mwt
Peak Linear Heat Rate - at 102% of 1500 Mwt	15.5 Kw/ft
Radial Peaking Factor (F_R^T)	= 1.80
Maximum Allowable Peaking Factor (F_q)	= 2.545
Axial Power Distribution	See Figure 3-2
Reactor Coolant System Pressure	= 2100 psia
Reactor Coolant System Flow Rate	= 196,000 gpm
Reactor Inlet Temperature	= 545 °F
Reactor Trip Signal (Including uncertainties)	= 1728 psia, Pressurizer Pressure LOW
SI Signal (Including uncertainties)	= 1578 psia, Pressurizer Pressure LOW-LOW
Safety Injection Tank Water Volume	= 825 ft³/Tank
Safety Injection Tank Minimum Pressure	= 255 psia
Steam Generator Tube Plugging Level	= 6% (Uniform)



FORT CALHOUN
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Figure 2-2

Large Break LOCA Power Shape

FORT CALHOUN LARGE BREAK LOCA ANALYSIS

BREAK SPECTRUM SENSITIVITY ANALYSIS RESULTS

RESULTS	MIN. SI FLOW F^T_Q = 1.75 DECLG C_D=0.4	MIN. SI FLOW F^T_Q = 1.75 DECLG C_D=0.6	MIN. SI FLOW F^T_Q = 1.75 DECLG C_D=0.8
Peak Clad Temperature (°F)	1981.	1869.	1815.
Peak Clad Temp. Elevation (Ft.)	9.25	9.25	9.25
Peak Clad Temperature time (Sec)	113.9	98.3	86.8
Max Local Zr/H_2O Reaction (%)	2.98	2.88	2.38
Total Zr/H_2O Reaction (%)	<1.0	<1.0	<1.0
Hot Assy. Burst Time (sec.)	47.4	69.5	61.1
Hot Assy. Burst Elevation (Ft.)	8.75	9.00	8.75
Blockage on Hot Rod (%)	41.0	35.2	38.8

FORT CALHOUN LARGE BREAK LOCA ANALYSIS

LARGE BREAK LOCA RESULTS

RESULTS	MIN. SI FLOW, $F_R^T = 1.80$ LOSS OF OFFSITE POWER, DECLG C_D=0.4	MIN. SI FLOW, $F_R^T = 1.80$ NO LOSS OF OFFSITE POWER, DECLG C_D=0.4	MAX. SI FLOW, $F_R^T = 1.80$ LOSS OF OFFSITE POWER, DECLG C_D=0.4
Peak Clad Temperature (°F)	2006.	2066.	2032.
Peak Clad Temp. Elevation (Ft.)	9.50	9.25	9.50
Peak Clad Temperature Time (Sec)	118.5	94.4	117.1
Max Local Zr/H_2O Reaction (%)	3.38	5.77	3.66
Total Zr/H_2O Reaction (%)	<1.0	<1.0	<1.0
Hot Assy. Burst Time (sec.)	51.2	51.1	51.2
Hot Assy. Burst Elevation (Ft.)	8.75	8.75	8.75
Blockage on Hot Assembly (%)	39.0	37.6	38.8

FORT CALHOUN LARGE BREAK LOCA ANALYSIS

LARGE BREAK SEQUENCE OF EVENTS

	MIN. SI FLOW DECLG C_D=0.4	MIN. SI FLOW DECLG C_D=0.6	MIN. SI FLOW DECLG C_D=0.8
Start	0.0	0.0	0.0
Rx Trip Signal	0.60	0.59	0.59
S.I. Actuation Signal	0.97	0.77	0.67
S.I. Tank Injection	22.80	16.80	14.00
Pump Injection Begins	31.87	31.67	31.57
End of Bypass	28.92	20.59	17.48
End of Blowdown	28.92	20.59	17.48
Bottom of Core Recovery	39.34	31.73	28.52
S.I. Tanks Empty	94.92	90.14	88.01

Note: All times are in seconds.

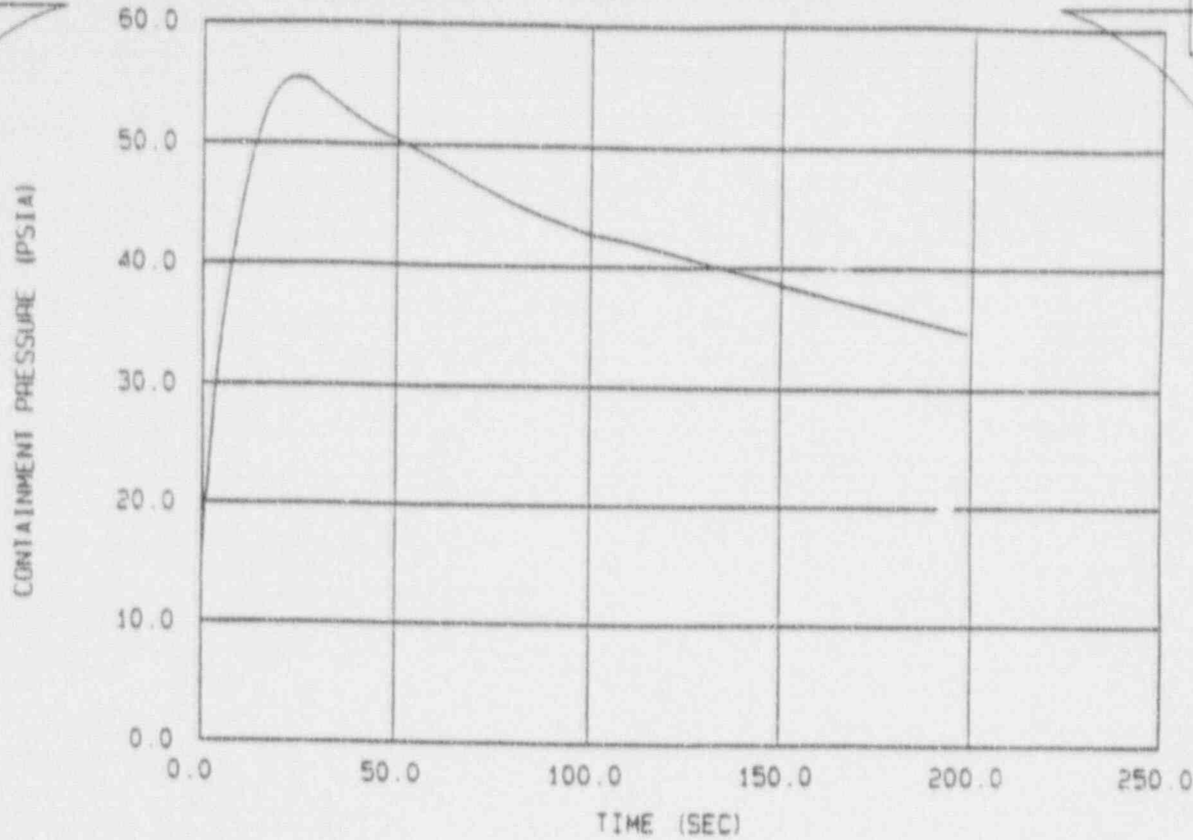

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Figure 2-8

Containment Pressure
No Loss of Offsite Power
DECLG (CD=0.4)

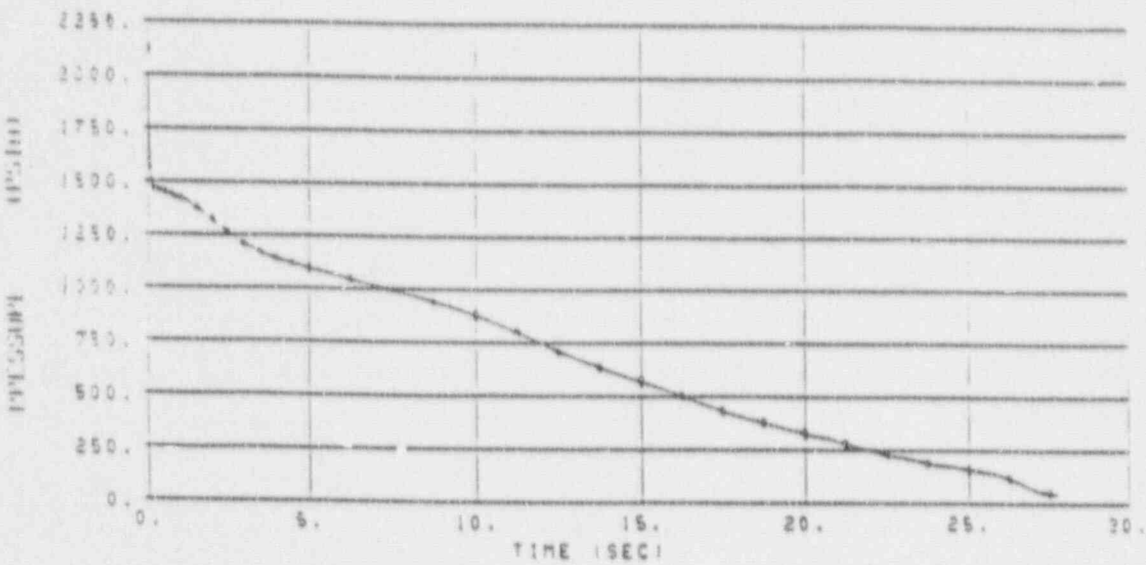

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Figure 2-4

Core Pressure Transient
No Loss of Offsite Power
DECLG (CD=0.4)

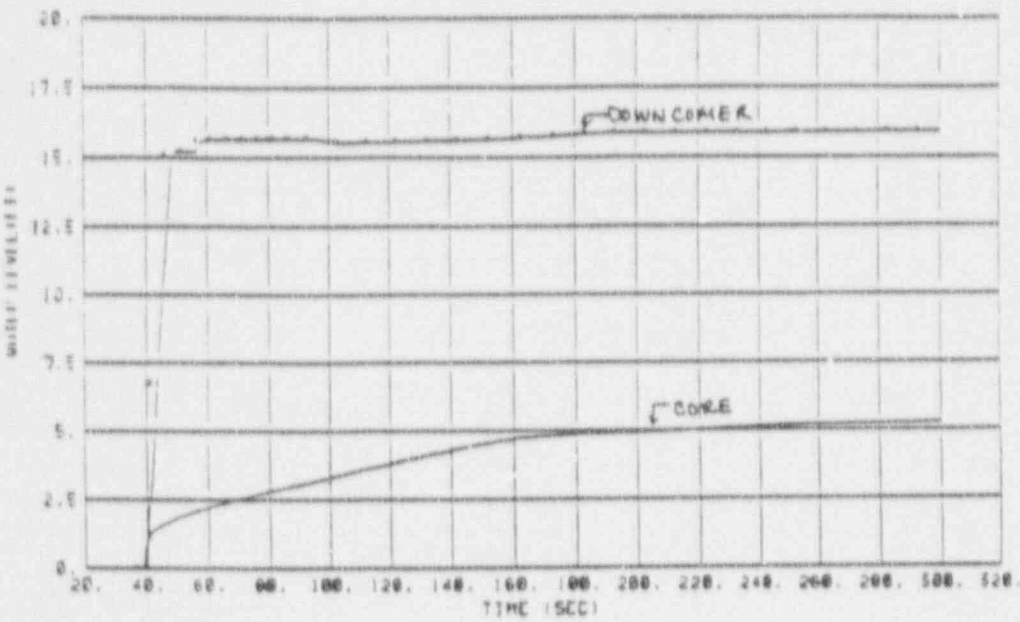

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Figure 2-11

Reflood Transient
Core and Downcomer Levels
No Loss of Offsite Power
DECLG (CD=0.4)

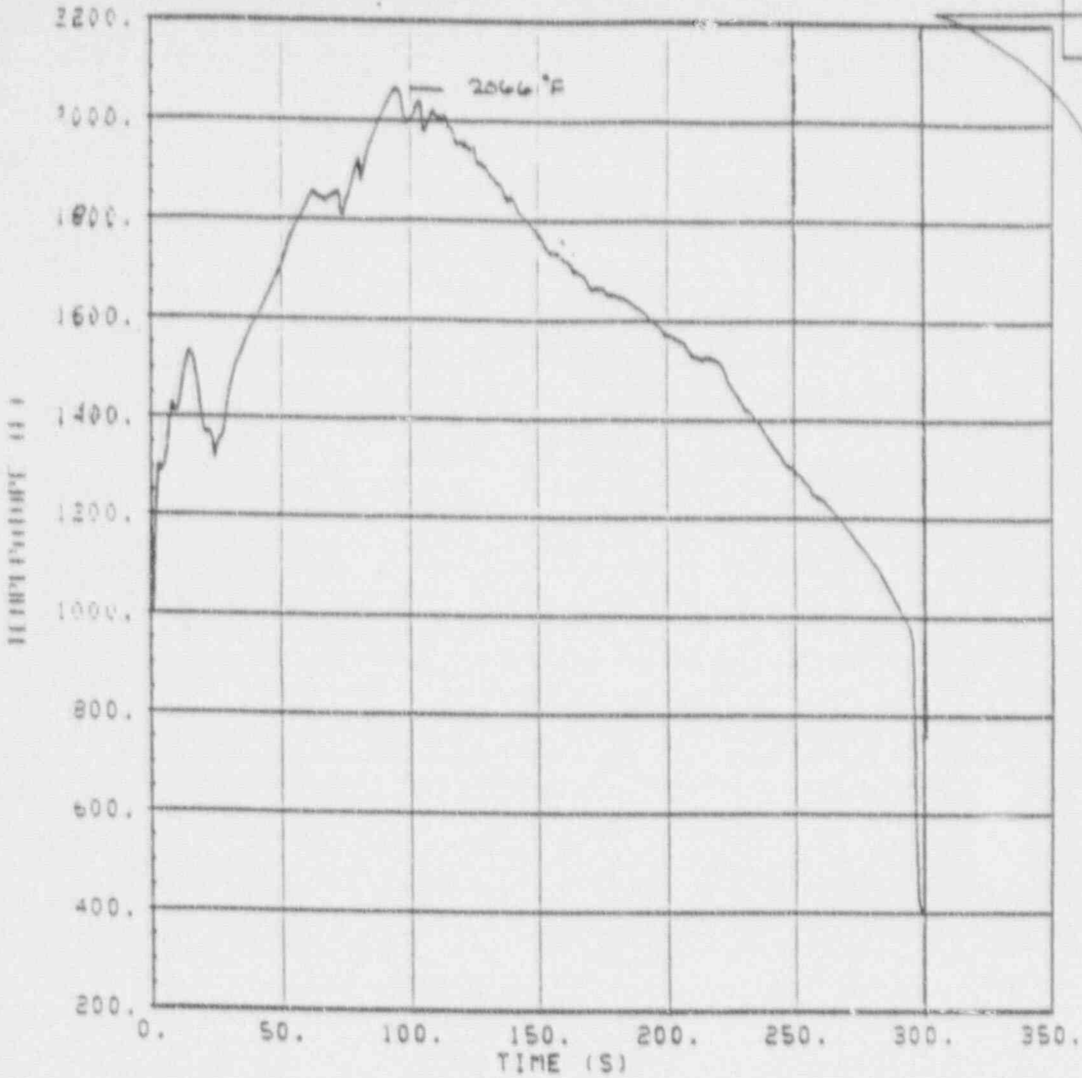

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Figure 2-18

Peak Cladding Temperature
No Loss of Offsite Power
DECLG (CD=0.4)

SMALL BREAK LOCA ANALYSIS

METHOD OF ANALYSIS

- NOTRUMP (SYSTEM HYDRAULIC CALCULATION)

WCAP-10054-P-A	NOTRUMP SB LOCA EM FOR W PLANTS
WCAP-10054-P-A, ADDENDUM 1	PREVIOUS NOTRUMP SB LOCA EM FOR CE PLANTS
WCAP-13027-P	REVISED NOTRUMP SB LOCA EM FOR CE PLANTS

- LOCTA-IV (FUEL ROD CLAD HEATUP CALCULATION)

WCAP-8301	LOCTA-IV CODE DESCRIPTION
WCAP-10054-P-A, ADDENDUM 1	PREVIOUS NOTRUMP SB LOCA EM FOR CE PLANTS
WCAP-13027-P	REVISED NOTRUMP SB LOCA EM FOR CE PLANTS

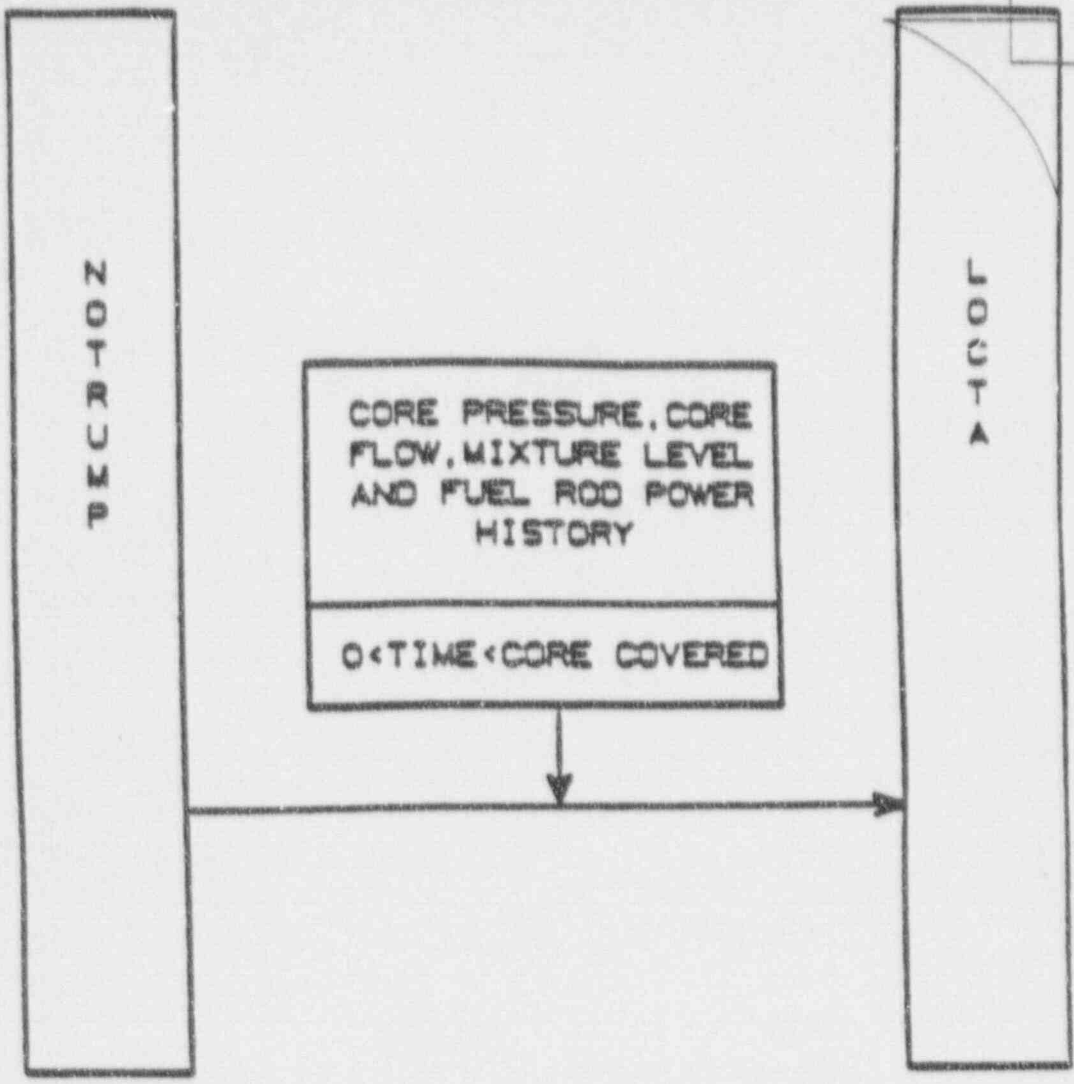

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Figure 3-1

Code Interface Description for Small Break Model

FORT CALHOUN SMALL BREAK LOCA ANALYSIS

INPUT PARAMETERS AND ASSUMPTIONS

NSSS Power - 102% of 1500 Mwt	= 1530 Mwt
Peak Linear Heat Rate - at 102% of 1500 Mwt	= 15.5 Kw/ft
Radial Peaking Factor (F_R^T)	= 1.80
Maximum Allowable Peaking Factor (F_q)	= 2.545
Axial Power Distribution	See Figure 3-2
Reactor Coolant System Pressure	= 2100 psia
Reactor Coolant System Flow Rate	= 196,000 gpm
Reactor Inlet Temperature	= 545 °F
Reactor Trip Signal (Including uncertainties)	= 1728 psia, Pressurizer Pressure LOW
SI Signal (Including uncertainties)	= 1578 psia, Pressurizer Pressure LOW-LOW
Safety Injection Tank Water Volume	= 825 ft^3/Tank
Safety Injection Tank Minimum Pressure	= 255 psia
Steam Generator Tube Plugging Level	= 6% (Uniform)
MSSV Setpoint Uncertainties	= ±3% Nominal setpoint pressure ±3% Valve accumulation pressure

FORT CALHOUN SMALL BREAK LOCA ANALYSIS

SMALL BREAK SEQUENCE OF EVENTS

	COLD LEG BREAK .022 SQ FT	COLD LEG BREAK .049 SQ FT	COLD LEG BREAK .087 SQ FT
Start	0.0 Sec	0.0 Sec	0.0 Sec
Reactor trip Signal	23.0 Sec	10.6 Sec	7.2 Sec
SI Actuation Signal	36.6 Sec	17.2 Sec	10.5 Sec
Pumped SI Begins	67.5 Sec	48.1 Sec	41.4 Sec
Top of Core Uncovered	2178.5 Sec	1095.1 Sec	710.7 Sec
S.I. Tank Injection Begins	NA	NA	932.9 Sec
PCT Occurs	3075.8 Sec	1898.0 Sec	1022.1 Sec
Top of Core Recovered	4713.8 Sec	3100.3 Sec	1368.9 Sec

FORT CALHOUN SMALL BREAK LOCA ANALYSIS

SMALL BREAK RESULTS

RESULTS	BOC IFBA COLD LEG BREAK .022 SQ FT	BOC IFBA COLD LEG BREAK .049 SQ FT	BOC IFBA COLD LEG BREAK .087 SQ FT
Peak Clad Temperature (°F)	1076.	1444.	1166.
Peak Clad Temp. Elevation (Ft.)	10.25	10.25	10.00
Peak Clad Temperature time (Sec)	3075.8	1898.0	1022.1
Max Local Zr/H_2O Reaction (%)	0.05	0.40	0.03
Max Local Zr/H_2O Rxn Elev (Ft.)	10.25	10.25	10.00
Total Zr/H_2O Reaction (%)	<1.00	<1.00	<1.00
Hot Rod Burst Time (sec.)	NO BURST	NO BURST	NO BURST
Hot Rod Burst Elevation (Ft.)	NA	NA	NA

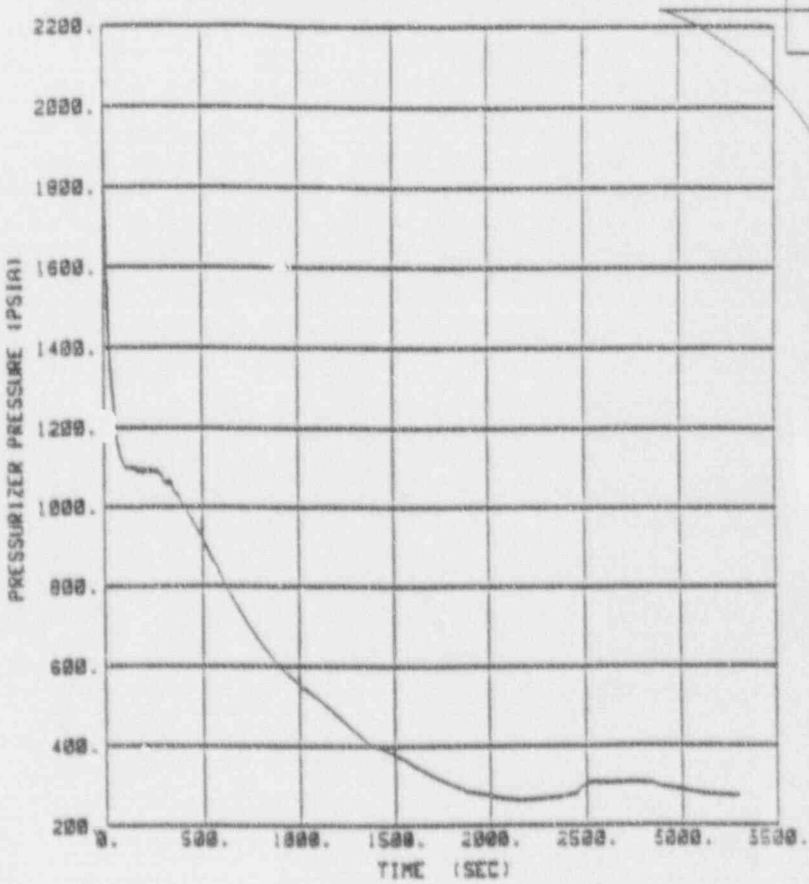

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Figure 3-9

Small Break LOCA (.049 ft^2)
RCS Depressurization

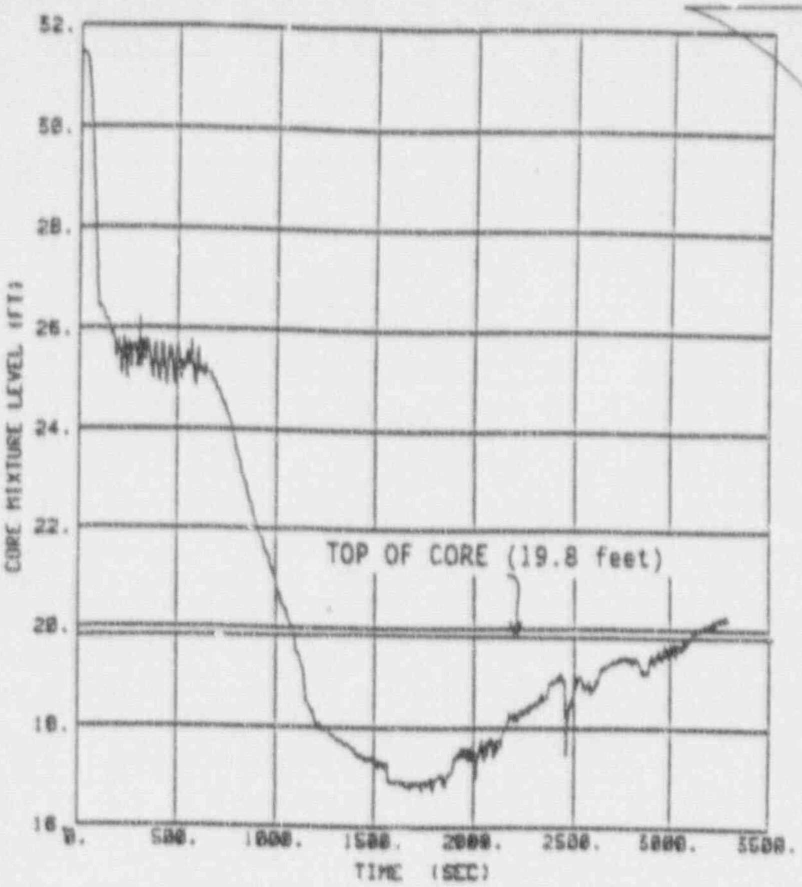

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Figure 3-10

Small Break LOCA (.049 ft^2)
Core Mixture Height

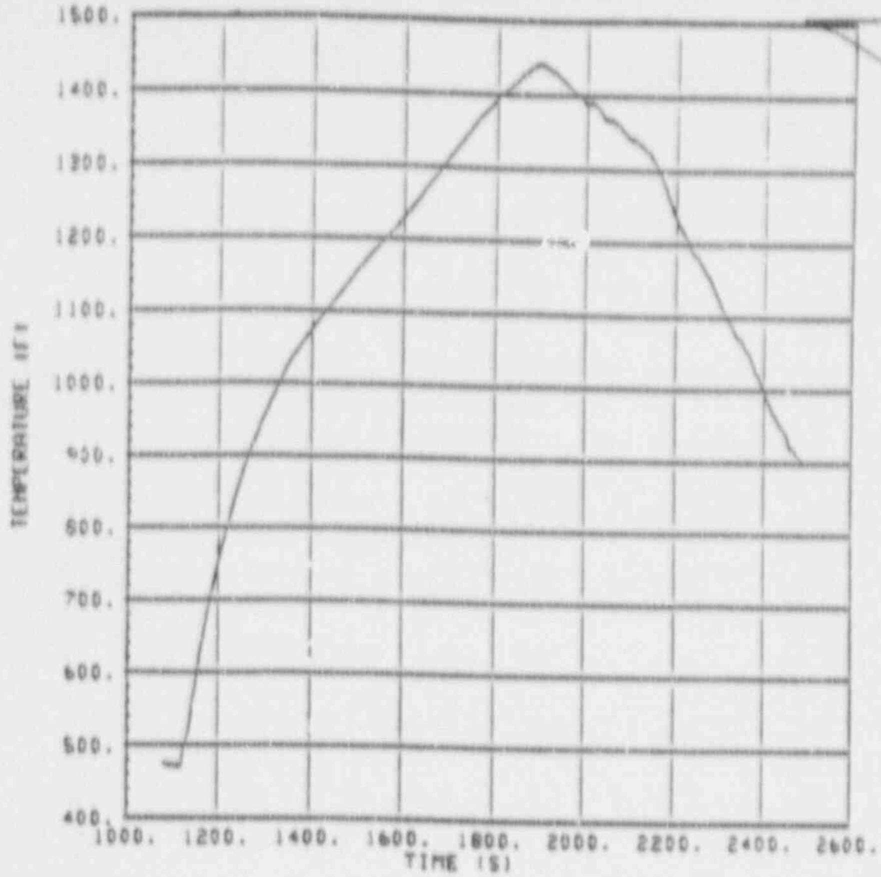

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Figure 3-11

Small Break LOCA (.049 ft^2)
Peak Cladding Temperature

SMALL BREAK ANALYSIS RESULTS

	ANALYSIS RESULT	10CFR50.46 LIMIT
o PEAK CLAD TEMPERATURE	1444	2200°F
MAXIMUM CLADDING OXIDATION	0.40%	17%
TOTAL HYDROGEN GENERATION	<0.4 %	1%

- o LIMITING BREAK - 0.049 FT^2 (3 INCH DIAMETER) COLD LEG BREAK

  THIS IS THE LARGEST BREAK SIZE WHICH RESULTS IN PRIMARY PRESSURE EQUALIZATION ABOVE THE SAFETY INJECTION TANK AND LOW PRESSURE SAFETY INJECTION CUT IN PRESSURES.

- o LIMITING TIME IN LIFE - BEGINNING OF LIFE (0 MWD/MTU)

  NO CLADDING BURST OCCURRED FOR LOW AND MEDIUM BURNED FUEL. THEREFORE, BEGINNING OF LIFE FUEL WHICH HAS THE SMALLEST PELLET-CLAD GAP IS LIMITING.

- o LIMITING FUEL TYPE - IFBA AND NON-IFBA SAME

  SINCE THE LIMITING PCT WAS LOW AND NO CLAD BURST OCCURRED, BOTH NON-IFBA AND IFBA FUEL RESULTED IN THE SAME PCT.

ADDITIONAL SMALL BREAK SENSITIVITIES

- POWER AVAILABILITY - LOSS OF OFFSITE POWER

  SENSITIVITY WAS PERFORMED ASSUMING NO LOSS OF OFFSITE POWER.

  SENSITIVITY INCLUDED THE REACTOR COOLANT PUMP TRIP STRATEGY CURRENTLY CONTAINED IN THE EMERGENCY OPERATING PROCEDURES.

  STUDY CONFIRMED THAT THE LOSS OF OFFSITE POWER ASSUMPTION IS CONSERVATIVE.

- BREAK LOCATION - COLD LEG BREAK

  SENSITIVITY STUDIES FOR THE NOTRUMP EM AS APPLIED TO THE CE NSSS (PERFORMED IN WCAP 10054-P-A ADDENDUM 1) DEMONSTRATED THAT THE COLD BREAK RESULTS IN THE MOST LIMITING PCT FOR A CE NSSS.

  SIMILAR STUDIES PERFORMED BY COMBUSTION ENGINEERING ALSO SHOWED THE COLD LEG LOCATION TO BE LIMITING FOR SMALL BREAK LOCA.

CONCLUSIONS

RESULTS OF THE FORT CALHOUN UNIT 1 LARGE BREAK AND SMALL BREAK LOCA ANALYSES HAVE DEMONSTRATED THE ADEQUACY OF THE ECCS SYSTEM AND MEET THE APPLICABLE REQUIREMENTS OF 10 CFR 50.46 PARAGRAPH (B)

(1) PEAK CLADDING TEMPERATURE

THE CALCULATED MAXIMUM FUEL ELEMENT CLADDING TEMPERATURE SHALL NOT EXCEED 2200 DEGREES FAHRENHEIT

(2) MAXIMUM CLADDING OXIDATION

THE CALCULATED TOTAL OXIDATION OF THE CLADDING SHALL NOWHERE EXCEED 0.17 TIMES THE TOTAL CLADDING THICKNESS BEFORE OXIDATION.

(3) MAXIMUM HYDROGEN GENERATION

THE CALCULATED TOTAL AMOUNT OF HYDROGEN GENERATED FROM THE CHEMICAL REACTION OF THE CLADDING WITH WATER OR STEAM SHALL NOT EXCEED 0.01 TIMES THE HYPOTHETICAL AMOUNT THAT WOULD BE GENERATED IF ALL OF THE METAL IN THE CLADDING CYLINDERS SURROUNDING THE FUEL, EXCLUDING THE CLADDING SURROUNDING THE PLENUM VOLUME, WERE TO REACT.

CONCLUSIONS

- COOLABLE GEOMETRY

  BASED ON THE MAXIMUM HYPOTHETICAL FUEL GRID DEFORMATION RESULTING FROM MAXIMUM LOADS WITHIN THE DESIGN BASIS FOR FT. CALHOUN, INCLUDING LOCA LOADS, CONSERVATIVE ASSUMPTIONS WERE INPUT INTO THE LARGE BREAK LOCA ANALYSIS CONSERVATIVELY TO REFLECT CORE GEOMETRY. AT UPPER ELEVATIONS OF THE A PERIPHERAL ASSEMBLY, CONSERVATIVELY ASSUMED TO BE THE HIGHEST POWERED ASSEMBLY, HYDRAULIC LOSSES WERE INCREASED TO SIMULATED THE LOCALIZED GRID DEFORMATION. THE RESULTS OF THE LARGE BREAK ANALYSIS BASED ON THESE ASSUMPTIONS DEMONSTRATED PCT NOT GREATER THAN 2200°F WITH CLAD TURN-AROUND OF THE CLAD HEAT-UP. CONSISTENT WITH THE WESTINGHOUSE POSITION ON COOLABLE GEOMETRY (WCAP-8339), THIS CRITERION IS SATISFIED.

CONCLUSIONS

- LONG-TERM COOLING

RECENTLY, STUDIES HAVE BEEN COMPLETED TO ADDRESS POST-LOCA LONG-TERM COOLING FOR FT. CALHOUN.

AN EVALUATION OF THE AVAILABLE BORON IN THE CONTAINMENT SUMP FOLLOWING A POSTULATED LARGE BREAK LOCA VERIFIED THAT A SUFFICIENTLY HIGH CONCENTRATION OF BORON WOULD BE INJECTED TO MAINTAIN THE CORE SUBCRITICAL FOLLOWING A POSTULATED LOCA.

A CONSERVATIVE ANALYSIS OF THE POTENTIAL FOR BORON PRECIPITATION FOLLOWING A POSTULATED LOCA WILL BE PRECLUDED IF SWITCHOVER TO SIMULTANEOUS HOT AND COLD LEG INJECTION AT 8.5 HOURS AFTER THE EVENT.

AN EVALUATION OF THE AVAILABLE ECCS FLOW RATES FOR THE VARIOUS LONG-TERM POST-LOCA SCENARIOS WOULD PROVIDE SUFFICIENT SI FLOW TO MAINTAIN CORE LEVEL AND PROVIDE ADEQUATE LONG-TERM COOLING FLOW.

CONSISTENT WITH THE WESTINGHOUSE POSITION ON COOLABLE GEOMETRY (WCAP-8339), THIS CRITERION IS SATISFIED.