NRC FORM 195
(2-76)

U.S. NUCLEAR REGULATORY COMMISSION

NRC DISTRIBUTION FOR PART 50 DOCKET MATERIAL

DOCKET NUMBER: 50-269/270/287

FILE NUMBER:

TO:	FROM:	
Mr. Benard C. Rusche	Duke Power Company Charlotte, North Carolina Mr. William O. Parker, Jr.	DATE OF DOCUMENT: 1/13/77 DATE RECEIVED: 1/17/77

		PROP	INPUT FORM	NUMBER OF COPIES RECEIVED
☒ LETTER ☒ ORIGINAL ☐ COPY	☐ NOTORIZED ☒ UNCLASSIFIED			One signed

DESCRIPTION

Ltr. re our 12/6/76 ltr. and B&W's 12/20/76 ltr...trans the following:

(1-P)

PLANT NAME:
Oconee Units 1-2-3

ENCLOSURE

Consists of Revision of the Babcock and Wilcox ECCS evaluation model...

(8-P)

ACKNOWLEDGED

DO NOT REMOVE

FOR ACTION/INFORMATION

	SAFETY			ENVIRO 1/18/77 RJL
X	ASSIGNED AD:	Goller		ASSIGNED AD:
X	BRANCH CHIEF:	Schwencer		BRANCH CHIEF:
X	PROJECT MANAGER:	Neighbors		PROJECT MANAGER:
X	LIC. ASST. :	Sheppard		LIC. ASST. :
X		Vassallo		
X		H. Smith		

INTERNAL DISTRIBUTION

X	REG FILE		SYSTEMS SAFETY	PLANT SYSTEMS		SITE SAFETY &
X	NRC PDR		HEINEMAN	TEDESCO		ENVIRO ANALYSIS
X	I & E (3)		SCHROEDER	BENAROYA		DENTON & MULLER
X	OELD			LAINAS		
	GOSSICK & STAFF		ENGINEERING	IPPOLITO		ENVIRO TECH.
	MIPC		MACARRY	KIRKWOOD		ERNST
	CASE		KNIGHT			BALLARD
	HANAUER		SIHWEIL	OPERATING REACTORS		SPANGLER
	HARLESS		PAWLICKI	STELLO		
X						SITE TECH.
	PROJECT MANAGEMENT		REACTOR SAFETY	OPERATING TECH.		GAMMILL
	BOYD	X	ROSS	EISENHUT		STEPP
	P. COLLINS		NOVAK	SHAO		HULMAN
	HOUSTON	X	ROSZTOCZY	BAER		
	PETERSON		CHECK	BUTLER		SITE ANALYSIS
	MELTZ			GRIMES		VOLLMER
	HELTEMES		AT & I			BUNCH
	SKOVHOLT		SALTZMAN			J. COLLINS
X			RUTBERG			KREGER

EXTERNAL DISTRIBUTION

				CONTROL NUMBER
X	LPDR: Walhalla, S.C.	NAT. LAB:	BROOKHAVEN NAT. LAB.	
X	TIC:	REG V.IE	ULRIKSON (ORNL)	535 269
X	NSIC:	LA PDR		D ECCS 1
	ASLB:	CONSULTANTS:		
X	ACRS 16 CYS ~~HOLDING~~/SENT: Cat. B. (1/18/77)			

NRC FORM 195 (2-76)

DUKE POWER COMPANY
POWER BUILDING
422 SOUTH CHURCH STREET, CHARLOTTE, N. C. 28242

WILLIAM O. PARKER, JR.
VICE PRESIDENT
STEAM PRODUCTION

January 13, 1977

TELEPHONE: AREA 704
373-4083

Mr. Benard C. Rusche, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. A. Schwencer, Chief
Operating Reactor Branch #1

Reference: Oconee Nuclear Station
Docket Nos. 50-269, -270, -287

Dear Sir:

Your letter of December 6, 1976 stated that review of the Babcock & Wilcox (B&W) ECCS evaluation model used for Oconee Nuclear Station has shown that a nucleate boiling heat transfer correlation was used during blowdown after critical heat flux (CHF) is first predicted. This may not be in conformance with the requirements of Appendix K to 10CFR50. A letter was also sent to B&W requesting that a corrected ECCS model be submitted.

The attached proposed revision to the B&W THETA computer code, BAW 10094, was submitted by B&W letter dated December 20, 1976 to Mr. S. A. Varga. This revision is not considered to be a significant ECCS evaluation model change since the results show a peak cladding temperature change of less than 20°F. LOCA calculations performed for Oconee class reactors at the two and six foot elevations indicates that no change occurs to the peak clad temperature. It is therefore concluded that the Oconee Nuclear Station Technical Specification remain valid to assure that the requirements of Appendix K to 10CFR50.46 are met.

Very truly yours,

William O. Parker Jr.

William O. Parker, Jr. by WAH

MST:ge

Attachment

535

1. Introduction

It has been determined by NRC Staff that the post-CHF heat transfer calculations performed in the B&W THETA6F computer code may not be consistent with the requirements set forth in Appendix K of 10 CFR 50. In particular, the calculation of local heat transfer by nucleate boiling subsequent to the occurrence of CHF as is performed in THETA6F was considered questionable. An investigation was undertaken at B&W to establish an alternate post-CHF heat transfer model for implementation in the THETA code. The scope of the resulting modifications to be proposed includes both revisions of the DNB switching logic and elimination of the post-CHF return to nucleate boiling.

2. THETA Code Modification

According to BAW-10094 (p 26-4):

"If departure from nucleate boiling (DNB) has been calculated to have occurred for a particular axial node, both transition flow boiling and nucleate boiling will be calculated; the lower heat flux is used." Examination of the THETA6F switching logic showed that the comparison of transition boiling heat flux to nucleate boiling heat flux was not made. Rather, referring to Figure 1, a trial value of the heat flux was calculated for a particular axial node according to the fluid void fraction:

for	$0 \leq \alpha \leq .80$	nucleate boiling (mode 2)
	$.80 < \alpha < .90$	interpolation between nucleate boiling (mode 2) and forced convection vaporization (mode 3)
	$.90 \leq \alpha < 1.0$	forced convection vaporization

If the trial heat flux was less than CHF, the trial value was taken as the local heat flux. If the trial value exceeded CHF, transition boiling (mode 4) heat flux was used. To correct this, the post-DNB switching logic was modified so that, subsequent to CHF at a particular node,
regression on the transition boiling curve is restricted by the critical heat flux.

In the event that the transition boiling (mode 4) heat flux is calculated to be greater than the critical heat flux, two modes were considered:

1. forced convection vaporization (mode 3)
2. film boiling (mode 5,7).

As a result of the case studies described in the next section, it was concluded that, with the corrected switching logic, the return to nucleate boiling could be replaced by a temporary switch to film boiling.

3. Case Studies

Five versions of the THETA code were prepared to investigate the separate and combined effects of modifications to the post-CHF switching logic and elimination of "return to nucleate boiling" calculations. Hot channel thermal analyses were performed using each of the five THETA versions for an 8.55 ft^2 split break (C_D = 0.8) on a 177 FA lowered loop plant. These case studies and code versions are described below and summarized in Table 1.

Case 1

This case was the benchmark case, based upon the present recognized evaluation model THETA6F version. A return to pre-CHF heat transfer regimes, nucleate boiling (mode 2) or forced convection vaporization (mode 3), was permitted when the heat flux calculated for these modes was less than CHF. Both the ruptured and unruptured peak temperature nodes showed a rapid return from transition boiling (mode 4) to forced convection vaporization (mode 3) subsequent to initial CHF. Heat transfer at these locations remained in mode 3, switching to film boiling at about 1 second into the transient. Elevations below the peak temperature nodes showed a sustained return to nucleate boiling (mode 2) during the same period. The peak clad temperature calculated for the unruptured node was 1992 F and for the ruptured node was 1746 F.

Case 2

For this case study, the switching logic of the base version (case 1) was retained. However, no access to nucleate boiling (mode 2) was permitted subsequent to initial CHF. As in case 1, "switching back" from transition boiling was based on comparing a trial heat flux using modes 2 and 3 to the CHF value; however, the return to mode 2 was replaced by a switch to film boiling. Return to mode 3 was still permitted for void fractions greater than 90 percent. The THETA calculations for case 2 showed essentially the same mode-switching behavior at the peak temperature nodes as case 1, i.e., a sustained return to forced convection vaporization (mode 3) from transition boiling (mode 4) subsequent to initial CHF. However, at the lower elevations, the return to nucleate boiling was replaced by switching to film boiling. The reduced heat transfer at these lower elevations produced two effects: (1) lower void fraction fluid at the downstream high temperature nodes and (2) increased cladding and fuel temperatures at the low elevations. The first effect produced a reduction in forced convection vaporization heat transfer at both high temperature elevations and, consequently, slightly higher clad temperatures after the first 1 second than were observed in case 1. The second effect resulted in higher superheat temperatures later in the transient. For this case the peak clad temperature of the unruptured node was 2018 F, 26 F higher than case 1. At the ruptured elevation, the peak clad temperature was 1782 F, 36 F higher than that calculated for case 1.

Cases 3, 4, 5

The THETA versions utilized in cases 3, 4, and 5 contained modified switching logic such that the "return" from transition boiling (mode 4) was possible only if the transition boiling heat flux exceeded CHF. The versions differed in the heat transfer modes applied subsequent to the "return" condition:

Case 3: nucleate boiling (mode 2) and forced convection vaporization (mode 3)

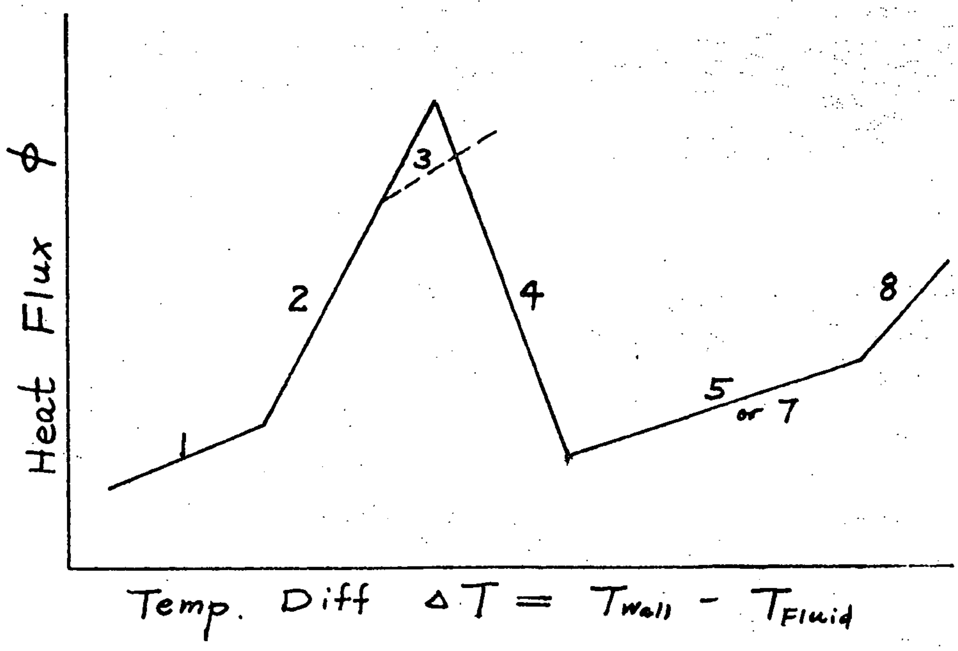
Case 4: forced convection vaporization (mode 3) and film boiling (modes 5, 7)

Case 5: film boiling (modes 5, 7).

The analyses for all three cases showed that the modification to the switching logic was the overriding factor in the heat transfer calculations. The rapid return from transition boiling at the high temperature elevations which had been observed in case 1 and case 2 was not evident in cases 3, 4, and 5. Rather the initial CHF was followed by a longer period of transition boiling. During this period, the clad temperatures at the peak locations showed an initial increase over those calculated in case 1 for the same time interval. However, with decreasing surface temperature, the transition boiling heat flux was observed to be greater than that obtainable by forced convection vaporization (mode 3). Consequently, the peak locations in cases 3, 4 and 5 showed a regression up the transition curve to the CHF point followed by intermittent switching between high transition boiling heat transfer and lower heat fluxes produced by forced convection vaporization or film boiling. At 3 seconds, the clad temperatures at the peak locations for these were nearly equal to those calculated in case 1. From 3 seconds on, the heat transfer calculations for the peak temperature locations for cases 3, 4 and 5 were consistent with those of case 1. In all three cases, the peak ruptured node clad temperature was 1745 F, 1 degree lower than case 1, and the unruptured node peak clad temperature was 1988 F, 4 degrees lower than case 1.

On the basis of these case studies, it was decided that the THETA version prepared for case 5 would best meet the acceptance criteria requirements.

FIGURE 1 HEAT TRANSFER MODES



Mode 1: Forced Convection to Liquid

Mode 2: Nucleate Boiling

Mode 3: Forced Convection Vaporization

Mode 4: Flow Transition Boiling

Mode 5: Flow Film Boiling

Mode 7: Pool Film Boiling

Mode 8: Forced Convection to Gas

Mode 10: Reflood Cooling

TABLE 1

CASE COMPARISON

CASE	1	2	3	4	5
VERSION	ORIGINAL 6F	CY=1	CY=2	CY=3	CY=5
Post-CHF Switch Logic	Old (Mode 2 or 3)	Old Mode 2 or 3	New (Mode 4)	New (Mode 4)	New (Mode 4)
Returnable Modes from Mode 4	Mode 2 and 3	Mode 3 5 or 7	Mode 2 and 3	Mode 3 5 or 7	Mode 5 or 7
Peak T ^{o}F Ruptured Node	1746 (Base)	1782 (+36^{o}F)	1745 (-1^{o}F)	1745 (-1^{o}F)	1745 (-1^{o}F)
Peak T ^{o}F Unruptured Node	1992 (Base)	2018 (+26^{o}F)	1988 (-4^{o}F)	1988 (-4^{o}F)	1988 (-4^{o}F)

4. LOCA Limit Studies

The final step in the study was to determine the impact of the THETA code changes on the LOCA limits reported in reference 4, 5 and 6, (BAW-10102, BAW-10103, and BAW-10105). A study was conducted for the two foot elevation, which is ruptured node limited, and for the six foot elevation, which is unruptured node limited, for 205 FA type plants, 177 FA lowered loop type plants, and 177 FA raised loop type plants.

Based on the case studies described in Section 3, no change (greater than $20^{\circ}F$) in the peak clad temperatures (PCT) for the LOCA limits reported in references 4, 5 and 6 is expected. This has been confirmed by LOCA limits studies summarized in Table 2. From Table 2 it can be seen that the effects of the THETA program changes on PCT and rupture time (and consequently metal-water reaction and blockage) are minimal. In view of this lack of change at the two and six foot elevations, it was concluded that significant deviations would not occur at the four, eight, and ten foot elevations. Therefore, it has been determined that the LOCA limits reported in BAW-10102, BAW-10103, and BAW-10105 remain valid and conservative.

6. References

1. B. M. Dunn, et. al., B&W's ECCS Evaluation Model, BAW-10104, Rev. 1, Babcock & Wilcox, December, 1975.

2. R. H. Stoudt and K. C. Heck, THETA1-B Computer Code for Nuclear Reactor Core Thermal Analysis - B&W Revisions to IN-1445, (Idaho Nuclear, C. J. Hocevar and T. W. Wineiger), BAW-10094, Rev. 1, Babcock & Wilcox, April, 1975.

3. Letter from D. F. Ross, Jr. to K. E. Suhrke, Dec. 2, 1976.

4. BAW-10102, Rev. 02

5. BAW-10103, Rev. 02

6. BAW-10105, Rev. 1

Table 2

Summary of LOCA Limits Studies

Topical Report	Core Elevation, ft	KW/FT	Rupture Time, s	Ruptured Node Temp, °F/Time, s	Unruptured Node Temp, °F/Time, s	THETA Code Version	THETA Code Version Date	Run Number	Run Date	Purpose	Effect
BAW 10102, Rev 02 (205-FA)	2 "	14.9 "	25.9 "	2097/44.5 2101/44.5	1931/50.5 1930/50.5	THETA1-B-6F THETA1-B-6F.5	1/23/75 11/17/76	VTR26JT TR05239	4/14/75 12/10/76	Base Case From Topical Report CHF Fix Comparison To Base Case	+[illegible]°F Ruptured Node -1°F Unruptured Node
	6 "	16.8 "	25.4 "	2017/42.5 2027/42.5	2126/97. 21[illegible]/97.	THETA1-B-6F THETA1-B-6F.5	1/23/75 11/17/76	VTR2300 TR051JC	4/10/75 12/9/76	Base Case From Topical Report CHF Fix Comparison To Base Case	+10°F Ruptured Node +1°F Unruptured Node
BAW 10103, Rev 02 (177-FA, Low Loop)	2 "	15.5 "	12.25 "	2002/43.5 2002/43.5	1978/43.5 1978/43.5	THETA1-B-6F THETA1-B-6F.5	1/23/75 11/17/76	T131516 T177055	6/3/75 12/11/76	Base Case From Topical Report CHF Fix Comparison To Base Case	0°F Ruptured And Unruptured Nodes
	6 "	18.0 "	15.55 "	2066/45 2066/45	2146/61 2146/61	THETA1-B-6F THETA1-B-6F.5	1/23/75 11/17/76	T1230CN T177158	5/13/75 12/11/76	Base Case From Topical Report CHF Fix. Comparison To Base Case	0°F Ruptured And Unruptured Nodes
BAW 10105, Rev 02 (177-FA, Raised Loop)	6 "	18.4 "	16.04 16.03	2020/43.5 202[illegible]/43.5	2166/66 2166/66	THETA1-B-6F THETA1-B-6F.5	1/23/75 11/17/76	T415828 T177368	3/28/75 12/11/76	Base Case From Topical Report CHF Fix Comparison To Base Case	+2°F Ruptured Node 0°F Unruptured Node