OCT 12 1976

Docket No. 50-331

Iowa Electric Light & Power Company
ATTN: Mr. Duane Arnold
President
Security Building
P. O. Box 351
Cedar Rapids, Iowa 52406

Gentlemen:

RE: DUANE ARNOLD ENERGY CENTER

By letter dated August 24, 1976, General Electric (GE) provided us information (enclosed) concerning the effects of core flow on loss of coolant accident (LOCA) analyses. This information indicates for some BWR-3 and BWR-4 facilities that a reduction in core flow should be accompanied by an associated reduction in maximum average planar linear heat generation rate (MAPLHGR) limits. Although a reduction in peak linear heat generation ordinarily follows a reduction in flow, technical specifications do not specifically address this for all core flow conditions. GE recommends application of a correction factor to the 100% core flow MAPLHGR limit and states that affected facilities have been informed of this recommendation.

We are currently reviewing the GE submittal. A copy of our recent request to GE for additional information is enclosed for your information. We request that you determine the impact of the GE studies discussed above on the operation of your facility and inform us of how these relate to your facility and, if appropriate, your intentions with respect to restricting MAPLHGR limits at reduced core flows. Please provide this information within 20 days of receipt of this letter.

OFFICE ➤						
SURNAME ➤						
DATE ➤						

This request for generic information was approved by GAO under a blanket clearance number B-180225(R0072). This clearance expires July 31, 1977.

Sincerely,

George Lear, Chief
Operating Reactors Branch #3
Division of Operating Reactors

Enclosures:
1. GE letter to NRC
   dtd. 8/24/76
2. NRC letter to GE
   dtd. 10/5/76 w/encl. 1

cc w/enclosures:
Jack R. Newman, Esquire
Harold F. Reis, Esquire
Lowenstein, Newman, Reis and Axelrad
1025 Connecticut Avenue, N. W.
Washington, D. C. 20036

Cedar Rapids Public Library
426 Third Avenue, S. E.
Cedar Rapids, Iowa 52401

DISTRIBUTION:
Docket
NRC PDR
Local PDR
ORB#3 Rdg
VStello
TJCarter
GLear
CParrish
JShea
CNelson
OELD
OI&E(3)
DEisenhut
TBAbernathy
JRBuchanan
ACRS (16)
File

OFFICE ➤	ORB#3	ORB#3	ORB#4	ORB#3		
SURNAME ➤	CParrish cp	JShea	CNelson:acr	GLear GL		
DATE ➤	10/ 12 /76	10/ 12 /76	10/ 12 /76	10/ 12 /76		

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, 175 CURTNER AVENUE, SAN JOSE, CALIFORNIA 95125
Phone (408) 297-3000 TWX No. 910-338-0116

August 24, 1976

Director of Nuclear Reactor Regulation
ATTN: Z.R. Rosztoczy, Chief
Analysis Branch
Division of Systems Safety
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Additional Effects of Core Flow on ECCS LOCA Analysis

Ref: Meeting, GE/NRC, 26 and 27 July 1976

Dear Mr. Rosztoczy:

The attachment to this letter documents the additional information on the effects of core flow on Emergency Core Cooling System Loss of Coolant Accident (ECCS LOCA) analyses requested by you during the referenced meeting. The attachment is prepared in the format of the General Electric Company Analytical Model for Loss-of-Coolant Analysis in Accordance with 10CFR50 Appendix K, GE Topical Report NEDO-20566. The information addresses in part, Section IIA of 10CFR50 Appendix K, Required Documentation, and supplements the information already provided in NEDO-20566, Section II.A.4, Transient Critical Power Model (SCAT Code), starting on page II-203 Subsection C.4.5, Inlet Flow.

The attached information will be incorporated into a future revision of NEDO-20566 and formally submitted to NRC through topical report channels. The results of the analyses have been forwarded to appropriate BWR operators in the form of a recommended multiplier on the approved exposure dependent maximum average planar linear heat generation rate (MAPLHGR) to be applied as a function of recirculation flow.

Very truly yours,

A.J. Levine, Manager
Project Licensing Unit I
Safety and Licensing
Mail Code 682, Ext. 3217

AJL:pg
cc: L.S. Gifford (GE-Bethesda)
Attachment: As noted (36 pages)
MFN:293-76

August 23, 1976

INFORMATION TO BE ADDED TO SUBSECTION C.4.5 INLET FLOW (CORE FLOW), pII-203 OF GE TOPICAL REPORT NEDO-20566

If, as a function of core inlet flow, nucleate boiling is lost at the highest power axial node prior to the time of jet pump suction uncovery, the calculated peak cladding temperature can be affected to a significant degree. The following subsections document the results of studies which analyze the effect of inlet flow, primarily as it is affected by the steady-state core flow prior to the postulated LOCA. The following studies show the effect of inlet flow on boiling transition, on the other important parameters (such as power variation with core flow), and finally, on the entire LOCA analysis.

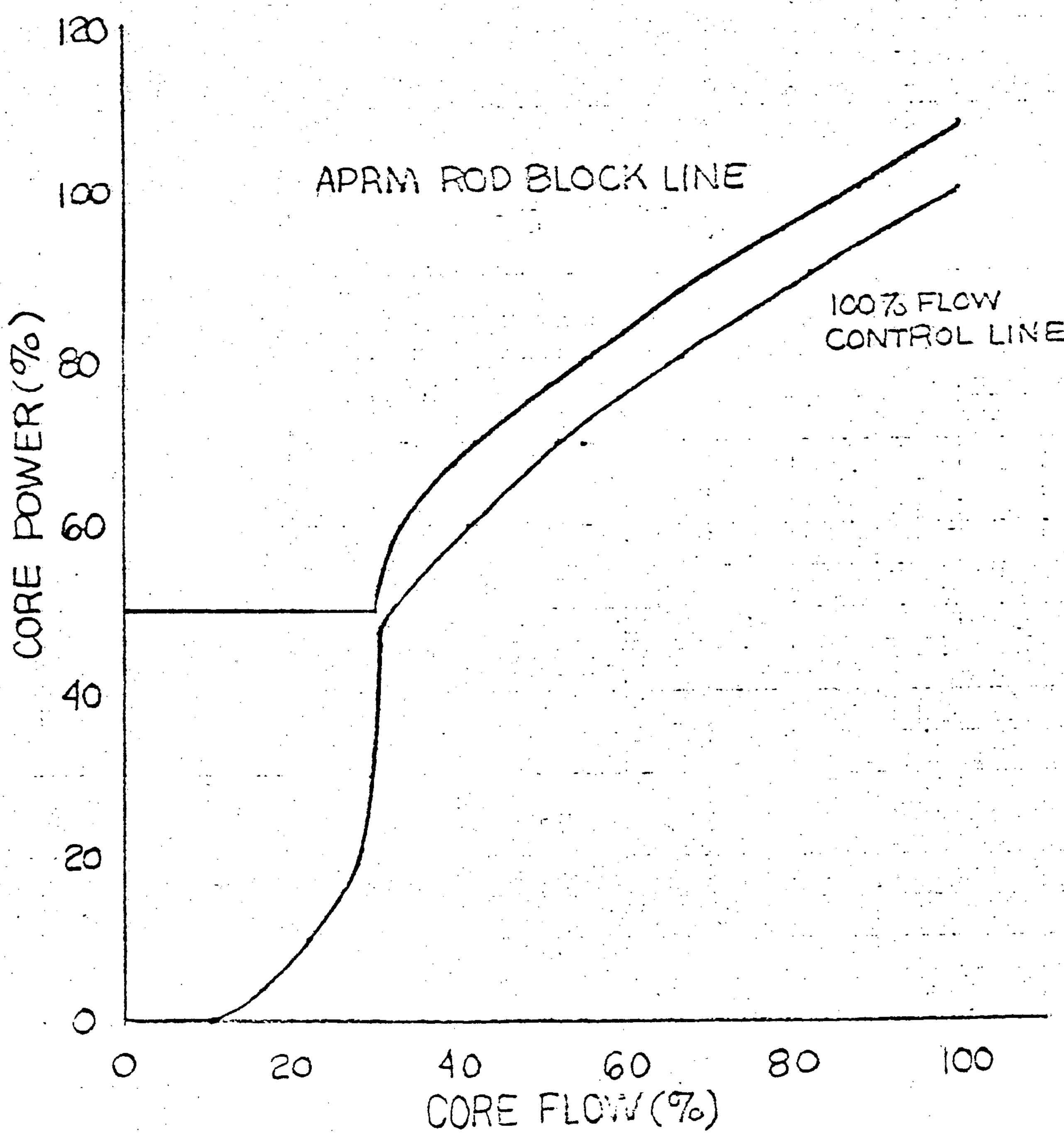
The three major parameters determining the flow sensitivity of the PCT in the design-basis LOCA calculation are the time of boiling transition at the high-power axial node in the limiting fuel assembly; the power variation with core flow; and the calculated reflooding time. Early boiling transition results in a less efficient removal of initial stored energy from the fuel. This tends to increase the calculated PCT. The power decrease as a result of decreasing core flow tends to decrease the PCT as a result of decreasing energy input to cause core heatup. Finally, the lower power input results in lower core spray vaporization, leading to less core spray CCFL and, consequently, an earlier flooding time with decreasing core power at lower core flows; this tends to decrease PCT with decreasing core flow.

The variation of the bundle inlet flow during a LOCA transient is determined by a number of parameters, the most important being the break size, the water inventory in the reactor at the start of the transient, and the steady-state core power and flow conditions. The first two of these are specifically accounted for when doing a standard LOCA analysis. The sensitivity of the LOCA results to the variation of core power are documented in section II.A.2, Appendix B, P II-163. The studies in this section describe the sensitivity of LOCA analysis to the simultaneous variation of core power and core flow within the constraints of the power-flow map. A typical power-flow map is shown in Figure C.4.5-1.

The analyses in this section have been conducted at the highest power corresponding to any core flow and as determined by the most limiting constraint on core and local assembly power (e.g., the rod block line or licensed core power). This represents the most conservative combination of initial conditions for initial core power and flow for use in the LOCA analysis. The decay heat variation during the transient is based on infinite exposure at the assumed initial condition.

FIGURE C.4.5-1

TYPICAL POWER FLOW MAP FOR BWR/3



C.4.5.1 Effect of Initial Core Flow on Boiling Transition

C.4.5.1.1 Results for Non Jet Pump Plants

C.4.5.1.1.1 BWR/1

A BWR/1 with recirculation pumps essentially operates at discrete flows determined by the number of pumps operating (the plants do not change power by flow control). The analysis for different numbers of pumps operating is accounted for on a plant by plant basis and does not form part of this study.

LOCA results for a BWR/1 with natural circulation are not affected by the core flows assumed in the analysis, because the anlaysis is based on a conservatively determined void fraction.

C.4.5.1.1.2 BWR/2

The effect on the LOCA analysis of core flow for a BWR/2 is that at lower flows a higher hot bundle average void fraction is calculated. This results in a very slight change in the calculated dryout time. A study was done to estimate the effect on PCT of the hot bundle average void fraction. The results are given in Table C.4.5.1-1 and show a very small sensitivity to this variable. The effect of core flow on hot bundle average void fraction is given in Table C.4.5.1.-2 and based on the results in Table C.4.5.1-1, it can be concluded that the effect of initial core flow on PCT for a BWR/2 is very small (<10F).

TABLE C.4.5.1-1 EFFECT OF CORE FLOW ON HOT BUNDLE AVERAGE VOID FRACTION FOR TYPICAL BWR/2

Core Flow	Void Fraction	
% of Rated	8x8 Fuel	7x7 Fuel
61	.59	.55
80	.57	.53
100	.55	.51

TABLE C.4.5.1-2 EFFECT OF VOID FRACTION ON PCT FOR MOST LIMITING BREAK ($0.07\ ft^2$) FOR A TYPICAL BWR/2

Void Fraction	Time for Hot Node Boiling Transition, Sec.	Peak Cladding Temperature, F
0.05	2.77	2196
0.30	2.04	2190
0.55	1.35	2195
0.60	1.17	2191
0.75	0.73	2192
0.90	0.45	2196

C.4.5.1.2 Results for Jet Pump Plants

The effect of reduced initial core flow on hot bundle hydraulics for jet pump plants is a more rapid decay of the hot bundle inlet flow. The variation of core flow normalized to unity at the start of the transient, as a function of initial core flow, is shown in figures C.4.5.1-1 through C.4.5.1-3. Figure C.4.5.1-1 represents the flow for some earlier low power density plants (BWR/3). Figure C.4.5.1-2 and C.4.5.1-3 represent the flows for the later higher power density plants (BWR/4, 5, and 6) which have higher rated core flow per bundle than a BWR/3. These figures show that the normalized flow (which gives an indication of the relative flow decay) decays more rapidly and reaches a lower value early in the transient at lower core flows. Figure C.4.5.1-4 is a plot of the absolute value of the hot bundle inlet mass flux as a function of core flow for these plants early in the transient (before jet pump uncovery). This plot shows that some BWR/3's reach much lower absolute flows compared to other jet pump plants.

Hot bundle inlet flow decreases as a function of decreasing core flow early in the transient, and when combined with high heat flux can result in boiling transition at the hot node very early in the transient (before jet pump uncovery). Tables C.4.5.1-3 through C.4.5.1-5 show the results of core flow on the calculated boiling transition times at upper elevations and at the high power node as a function of core flow. The result shows that for flows close to rated core flow there is a slight change in the penetration of and time of boiling transition but that the high power node does not go into boiling transition before jet pump uncovery. Below a certain initial core flow (whose value is plant specific to some extent), the high power node is calculated to go into boiling transition before jet pump uncovery.

C.4.5.2 Variation of Power with Core Flow

Before the effect of early boiling transition on the LOCA analysis can be determined it is essential to define the core and local planar power variation as a function of core flow.

The variation of core power with core flow was discussed earlier: it is shown graphically in Figure C.4.5-1.

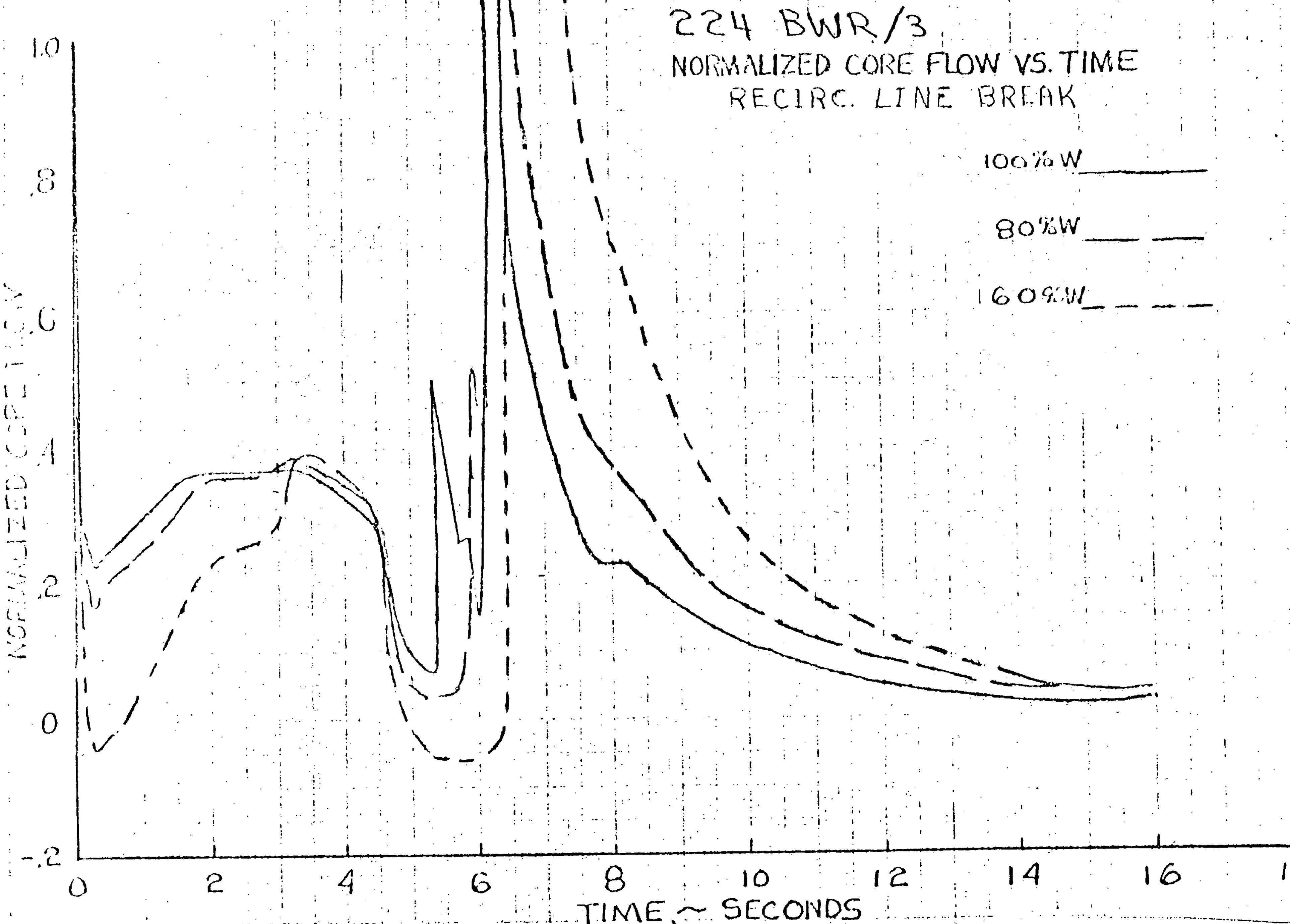
The variation of local power, which is very important in the determination of the PCT, is determined by the most limiting of a number of technical specifications, namely:

a) The design maximum planar power (typically 13.4 kw/ft for 8x8 fuel and 18.5 or 17.5 kw/ft for 7x7 fuel);

b) The planar power limit resulting from the ECCS calculation (MAPLHGR); or

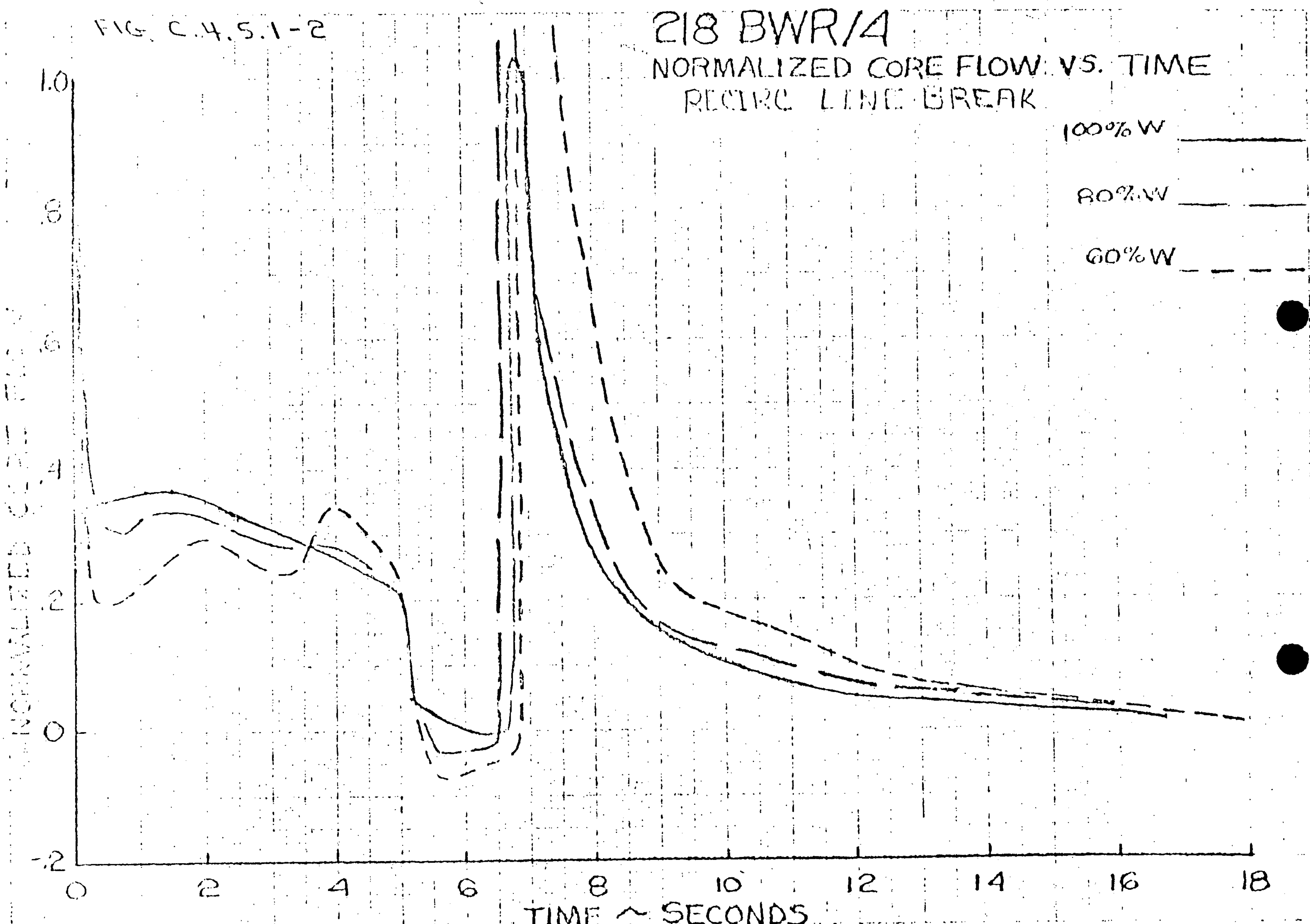
c) The planar power limit resulting from the rod block limit on the core power as a function of core flow.

FIG. C.4.5.1-1



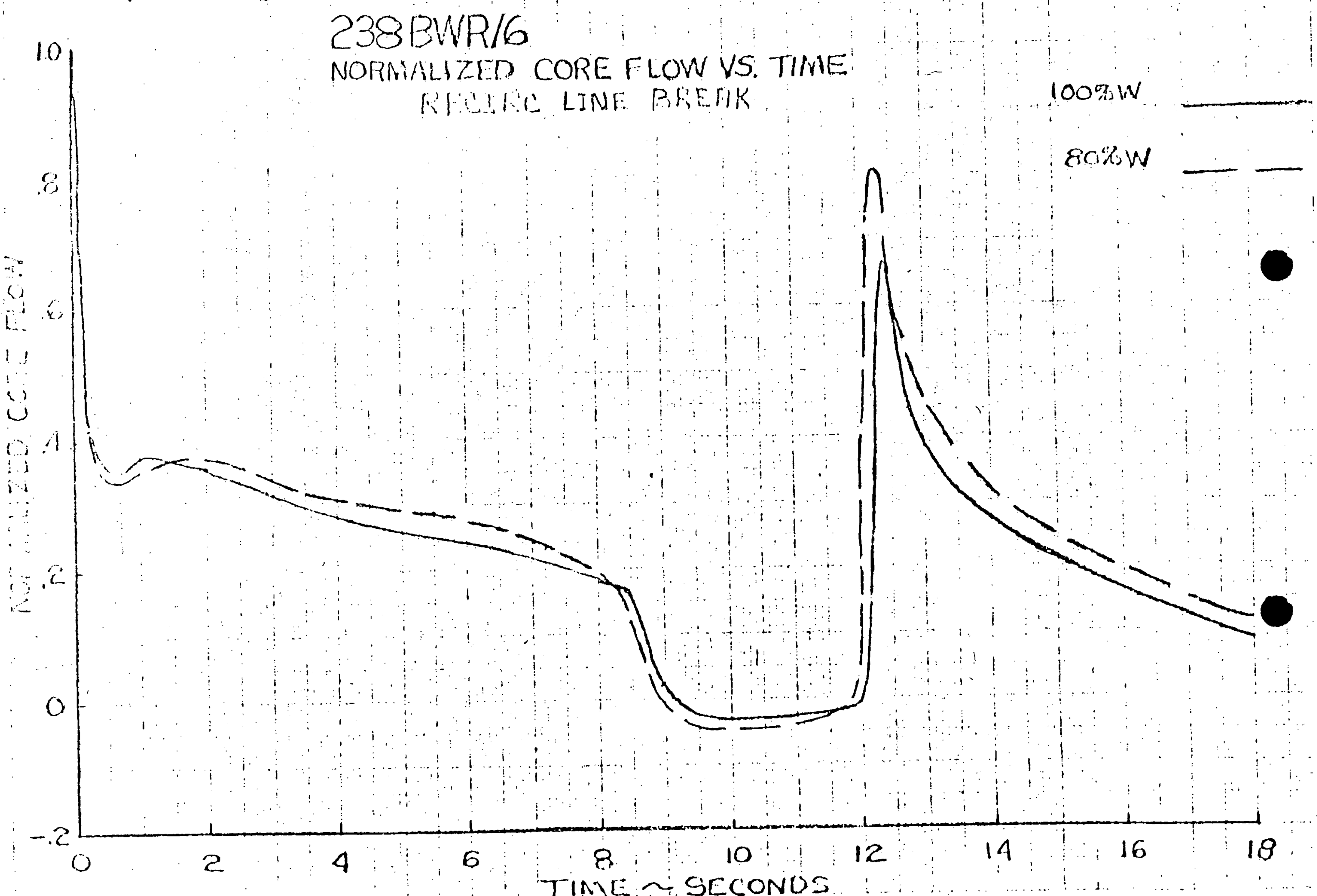
W = Initial Core Flow (% of rated)

-7-



W = Initial Core Flow (% of rated)

FIG. C.4.5.1-3



W= Initial Core Flow (% of rated)

-6-

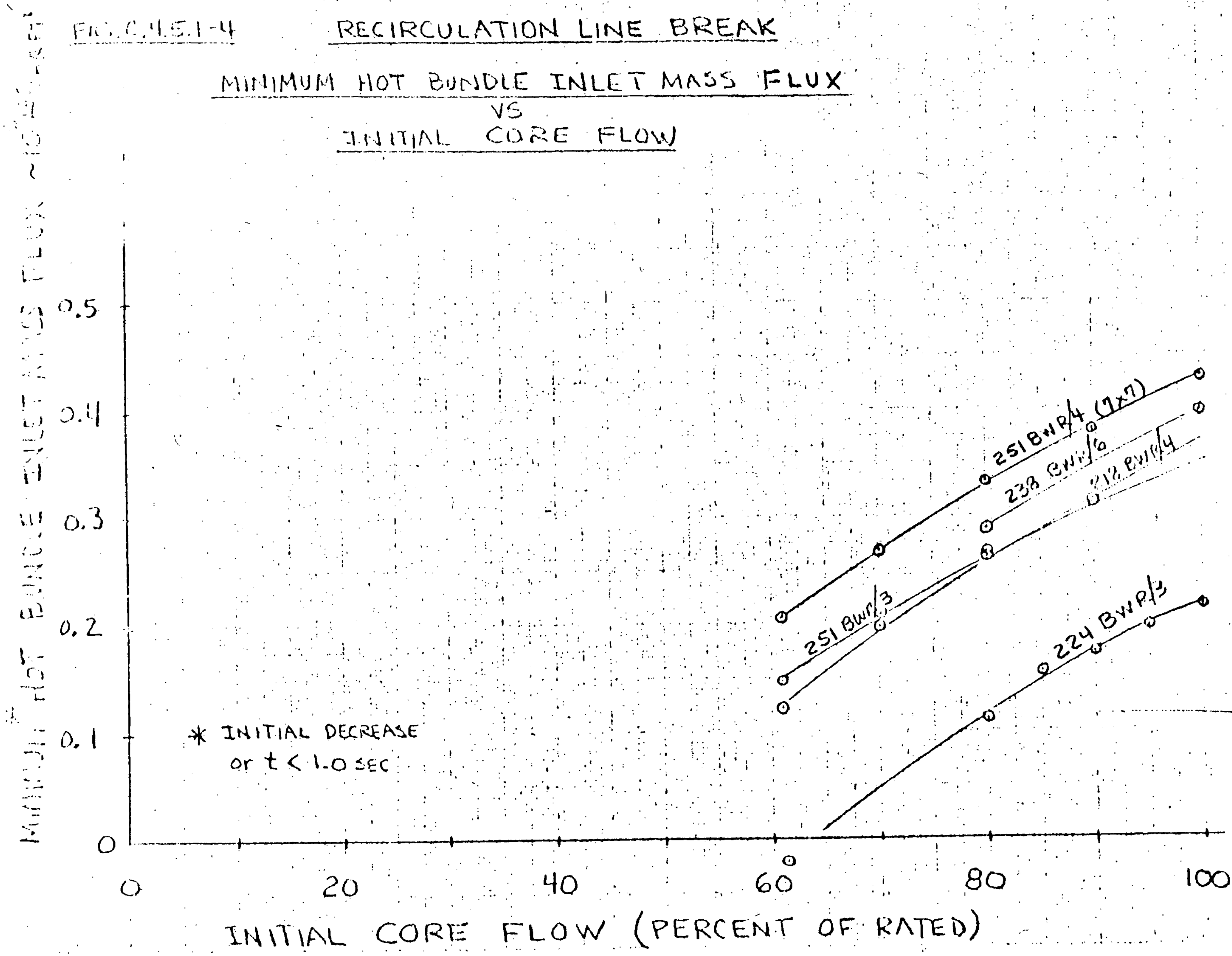


FIG. C.4.5.1-4
RECIRCULATION LINE BREAK
MINIMUM HOT BUNDLE INLET MASS FLUX
VS
INITIAL CORE FLOW
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
251 BWR/4 (7x7)
238 BWR/6
218 BWR/4
251 BWR/3
224 BWR/3
* INITIAL DECREASE
or t < 1.0 SEC
INITIAL CORE FLOW (PERCENT OF RATED)

TABLE C.4.5.1-3 EFFECT OF CORE FLOW ON BOILING TRANSITION (BT) CALCULATION IN THE HOT CHANNEL FOR A SAMPLE BWR/3 [ANALYSIS BASED ON AN INITIAL MCPR OF 1.22 (1.24/1.02)] - RECIRCULATION LINE BREAK

Core Flow, % of Rated	Time of BT for High Power Node, Sec.	Time of BT of Upper Node, Sec.	Elevation of Upper Node, Ft. from TAF*
61	0.14 (early)	0.14	3.52
80	0.3 (early)	0.3	3.52
85	0.3 (early)	0.12	2.44
90	5.66 (window)	0.3	2.44
95	5.66 (window)	0.3	2.44
100	5.66 (window)	0.22	2.44

* Top of active fuel

TABLE C.4.5.2-4 EFFECT OF CORE FLOW ON BOILING TRANSITION (BT) CALCULATION IN THE HOT CHANNEL FOR A 218 BWR/4 [Analysis based on an initial MCPR = 1.19 (1.21/1.02)] RECIRCULATION LINE BREAK

Core Flow % of Rated	Time of BT for High Power Node, Sec.	Time of BT of Upper Node, Sec.	Elevation of Upper Node, Ft. from TAF
For Suction Line Break			
*61	1.76 (early)	0.28	3.94
*70	6.08 (window)	0.78	3.94
80	5.88 (window)	0.82	3.94
100	5.96 (window)	1.28	3.94
For Discharge Line Break			
*61	12.42 (window)	1.3	3.94
100	12.42 (window)	0.88	2.261

*For these cases, credit was taken for variation of CPR and planar power with core flow.

TABLE C.4.5.2-5 EFFECT OF CORE FLOW ON BOILING TRANSITION (BT) IN THE HOT CHANNEL FOR 238 BWR/6 [Analysis based on initial MCPR = 1.18 (1.2/1.02)]

RECIRCULATION LINE BREAK

Core Flow, % of Rated	Time of BT for High Power Node, Sec.	Time of BT for Upper Node, Sec.	Elevation of Upper Node, Ft. from TAF
80	9.92 (window)	0.9	4.106
100	9.98 (window)	1.24	4.106

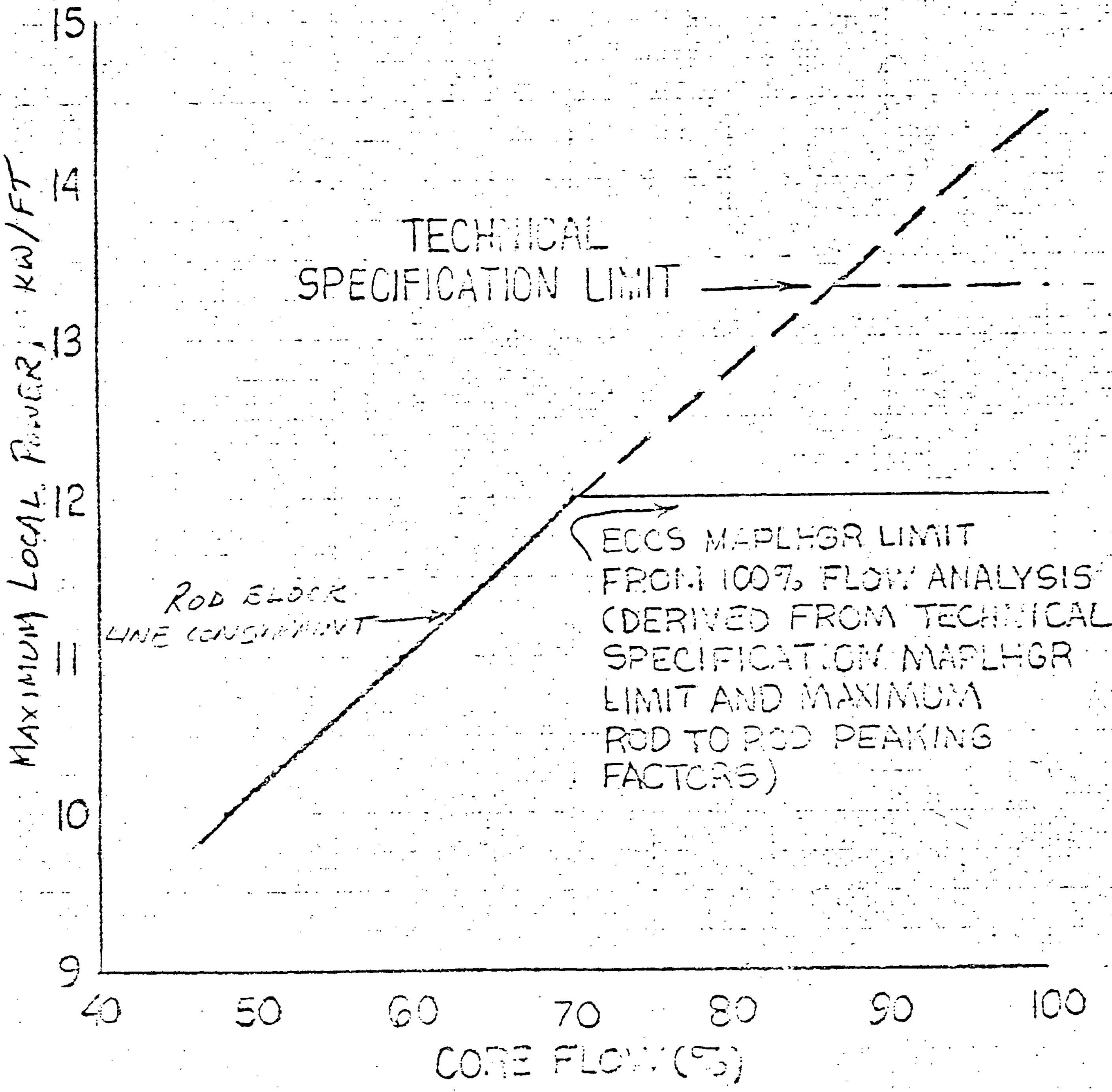
The rod block constraint on local power is typically expressed as:

$$\text{Maximum kw/ft} = \frac{\text{Design kw/ft limit}}{100}\,(0.58W + 50)$$

Where W = core flow, expressed as percent of rated.

A plot of the local power variation, considering all of these limits, is shown in Figure C.4.5.2-1. The solid line in this figure is representative of the local power/core flow relationship assumed in these analyses.

FIGURE C.4.5.2-1
ROD BLOCK LINE CONSTRAINT ON MAX KW/FT



C.4.5.3 Effect of Initial Core Flow on Reflooding Time

The effect of the reduction of core power with flow on the reflooding time is shown for a typical BWR/3 in Table C.4.5.3-1. As the core flow is decreased, the calculated reflooding time is decreased and hence the calculated peak cladding temperature is lower.

C.4.5.4 Overall Effect on Calculated PCT

The calculated PCT at a particular flow is determined by the relative effect of time to boiling transition, planar power, and reflooding time. If the last two effects are greater than the first, as is true for most BWR's, the PCT calculated for the 100% flow case is the most limiting.

C.4.5.4.1 Effect on Peak Cladding Temperature for Design Basis Accidents

For certain plants at certain core flows the effect of early boiling transition is not completely compensated for by the power decrease and reflooding time decreases as a function of decreasing core flow. For these situations, the calculated peak cladding temperature would be higher than that calculated for the 100% core flow condition. The only plants for which this situation is calculated to occur are some BWR/3's and 4's. The typical variation of PCT with core flow for BWR/3's as determined by the conditions described above in Sections C.4.5.2 and C.4.5.3 is shown in Figure C.4.5.4-1. The results for the few BWR/4's with calculated PCT at lower flows higher than that for the 100% flow case, show similar trends except that the core flow at which a higher PCT is calculated is much lower than that for the BWR/3's (see Table C.4.5.1-3 and 4). For all other BWR's the reduced flow PCT is calculated to be less than the PCT for the 100% flow case. Justification for this general statement is given in section C.4.5.5.

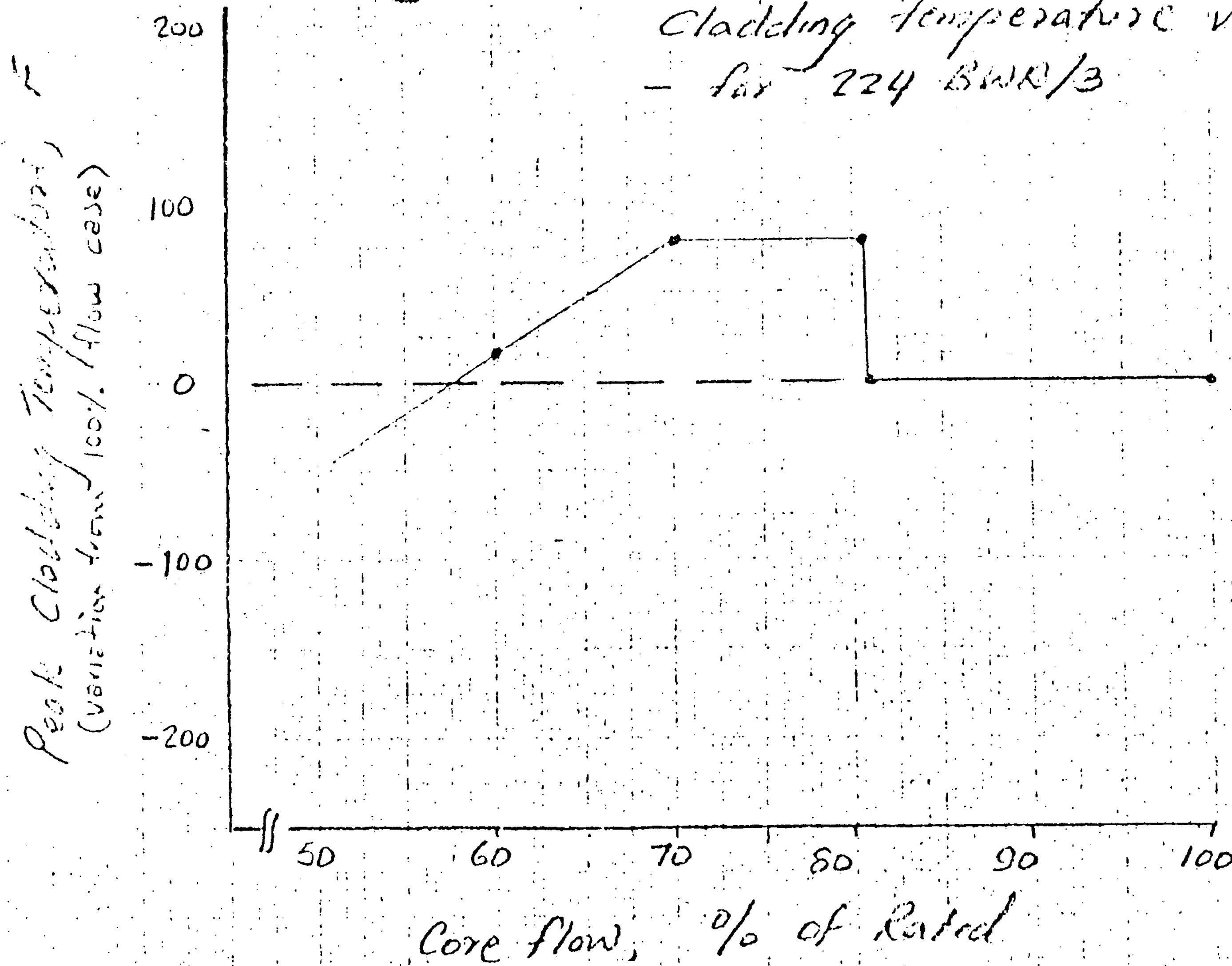
TABLE C.4.5.3-1

Effect of Core Flow on Flooding Time For A Typical BWR/3*

Core Flow, % of rated	Calculated Reflooding Time, sec	Calculated * PCT, °F
45	247	2148
61	282	2183
80	307	2195
100	330	2200

* Considering the effect of reflooding time only

Figure C.4.5.4-1 Variation of calculated Peak Cladding Temperature versus Core Flow – for 224 BWR/3



C.4.5.4.2 EFFECTS ON BREAK SPECTRUM

The break spectrum analysis has considered a wide range of liquid and/or steam line break sizes including those equivalent to the core-spray, feedwater, main-steam, and recirculation lines. All the previous results and discussions have been presented for the most limiting (generally the largest) break. This subsection describes the study done to show that there is no change in the most limiting break after consideration of all the effects of core flow. The results presented here are for a typical BWR/3 but the phenomena that determine the most limiting break are common to all jet pump BWR's. The analysis is general enough to justify the choice of the worst break for all jet pump BWR's.

The important parameters that determine the effect of core flow on the PCT variation with break size ("break spectrum") are:

a) The initial core flow at which boiling transition is calculated for the high power node before jet pump uncovery. This is a function of break size and will increase with increasing break size,

b) The blowdown heat transfer as a result of "a",

c) The local power at different core flows, and

d) The reflooding times for different size breaks.

The combined effect of all these parameters determines whether the break spectrum for the 100% flow calculation is generally limiting for all core flows. The following study shows that the most limiting break determined for the 100% flow case is also the most limiting at lower core flows.

C.4.5.4.2.1 DETERMINATION OF THE MAXIMUM INITIAL CORE FLOW CAUSING EARLY BOILING TRANSITION

The maximum initial core flow causing early Boiling Transition was determined by performing a parameter study of recirculation line break areas smaller than the DBA at different initial core flow rates. The penetration of boiling transition into the fuel bundle can be attributed to the hot bundle inlet flow rate during the early part of the transient. The first step is to calculate the minimum hot bundle inlet mass flux during the initial dip in flow. The results of this calculation are plotted as a function of initial core flow and normalized break area (with respect to the recirculation line break area) in Figure C.4.5.4-2.

The next step is to determine the time of boiling transition and penetration of boiling transition into the bundle using the results of Figure C.4.5.4-2 (determined using LAMB) and the SCAT code. This

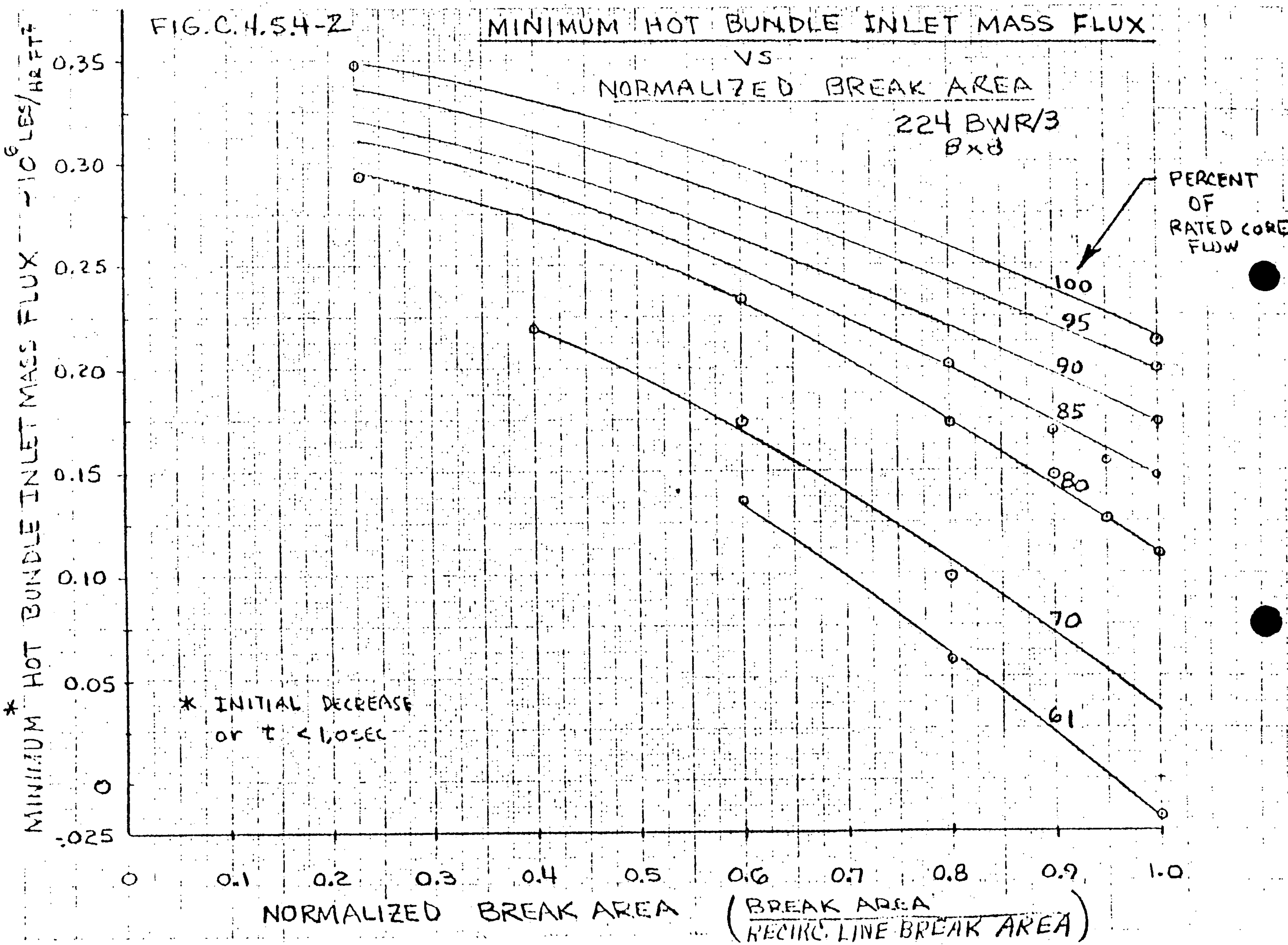


FIG. C.4.5.4-2
MINIMUM HOT BUNDLE INLET MASS FLUX
VS
NORMALIZED BREAK AREA
224 BWR/3
8x8
PERCENT OF RATED CORE FLOW
100
95
90
85
80
70
61
* INITIAL DECREASE or t < 1.0 SEC
* MINIMUM HOT BUNDLE INLET MASS FLUX - 10⁶ LBS/HR FT²
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
-.025
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
NORMALIZED BREAK AREA (BREAK AREA / RECIRC. LINE BREAK AREA)

determines the maximum initial flow rate for which early BT is calculated at the high powered node. This result as a function of normalized break area is presented in Figure C.4.5.4-3. As can be seen from the figure, the highest value of core inlet flow required to prevent boiling transition from occurring at the high powered axial node before jet pump uncovery, is calculated for the largest break. Therefore, the use of the largest break for the determination of the maximum core flow at which early BT is calculated, is conservative.

C.4.5.4.2.2 Determination of PCT for Intermediate Breaks

The previous paragraphs show that as the break size is decreased the high power node is calculated to go into BT at lower initial core flows. This result combined with the fact that at lower flows the local power is lower, results in a monotonically decreasing PCT as the break size gets smaller. The effect of core flow on the break spectrum is illustrated in Figure C.4.5.4-4. The solid line in Figure C.4.5.4-4 is the PCT at a 100% core flow for the BWR/3 lead plant, which can be considered to be representative (see section III.B) of the break spectrum for all BWR/3's. The dashed line is the PCT which is expected for the 224 BWR/3 at 70% core flow, determined using Figure C.4.5.4-3 to estimate the break size at 70% core flow where no early BT is calculated. Below that break size the PCT will be equal to or lower than that calculated for the 100% core flow calculation, as the boiling transition will be the same or later and the flooding time will be earlier for the 70% case compared to the 100% calculation.

The results for other core flows will be similar to that for the 70% core flow case. The 70% core flow case was studied in detail as it is the condition that is expected to result in the highest calculated effect on PCT compared to the 100% case because at 70% core flow no credit is taken for decreasing planar power. Also, the change in BT time is the largest as the break area at which early BT is calculated gets smaller. Hence, a calculation at 70% flow would represent the flow at which there would be the biggest difference from the 100% flow calculation. This assertion has been justified by two calculations at 0.6 and 0.8 normalized break area as shown on the figure. The calculations verify the assertions made about the break spectrum in the preceding paragraphs.

Figure C.4.5.4-4 shows that there is a change in the shape of the break spectrum as a function of core flow but that the largest break is still limiting at all core flows. This is primarily because the hot node uncovery time and reflooding times are essentially unaffected by core flow and primarily determine the slope of the PCT plot as a function of break area. The hot node early BT affects the slope but not the basic shape of the curve.

C.4.5.4.2.3 Determination of PCT for Other Breaks

The initial core flow will only affect the calculated PCT for liquid break sizes between about 1 ft^2 and the largest recirculation line break. For breaks smaller than 1 ft^2 the core flow does not decrease to very low values early in the transient when the heat fluxes are high. It has already been shown in Section III.B, that it is appropriate to assume nucleate boiling until the two phase level is calculated to drop below a particular node. This assumption will be valid at all core flows. This is based on calculations and the results in Figure C.4.5.4-3, where it is shown that for the 1 ft^2 break the calculated core flow below which early boiling transition is calculated for the high power node is less than 60% initial core flow. The calculated PCT at 60% core flow and lower for the 1 ft^2 break is then lower than the 100% core flow calculation since the blowdown characteristics are unchanged, but the local power is lower.

Hence, the discussion of the break spectrum and core flow effects are only shown in detail for intermediate breaks of the recirculation line. The analysis for the core spray feedwater and steamline breaks will remain essentially unchanged at low core flows because the margin to boiling transition is very great for these breaks and they are not subject to the short-duration flow "dip" characteristic of recirculation line breaks at low flow.

C.4.5.4.2.4 Generality of Break Spectrum Results

Figure C.4.5.4-5 is a plot of the minimum inlet mass flux for the hot bundle as a function of normalized break area. Results are presented for various lead plant analyses at 100% core flow. The plot shows that the minimum hot bundle mass flux for the plant used in the break spectrum analysis (224-BWR/3) is the lowest for all jet pump reactor types studied, and that the minimum inlet flow increases with decreasing break area for all reactors studied. Because it was shown

FIG. C.4.54-3 REQUIRED MAXIMUM INITIAL CORE FLOW VS NORMALIZED BREAK AREA

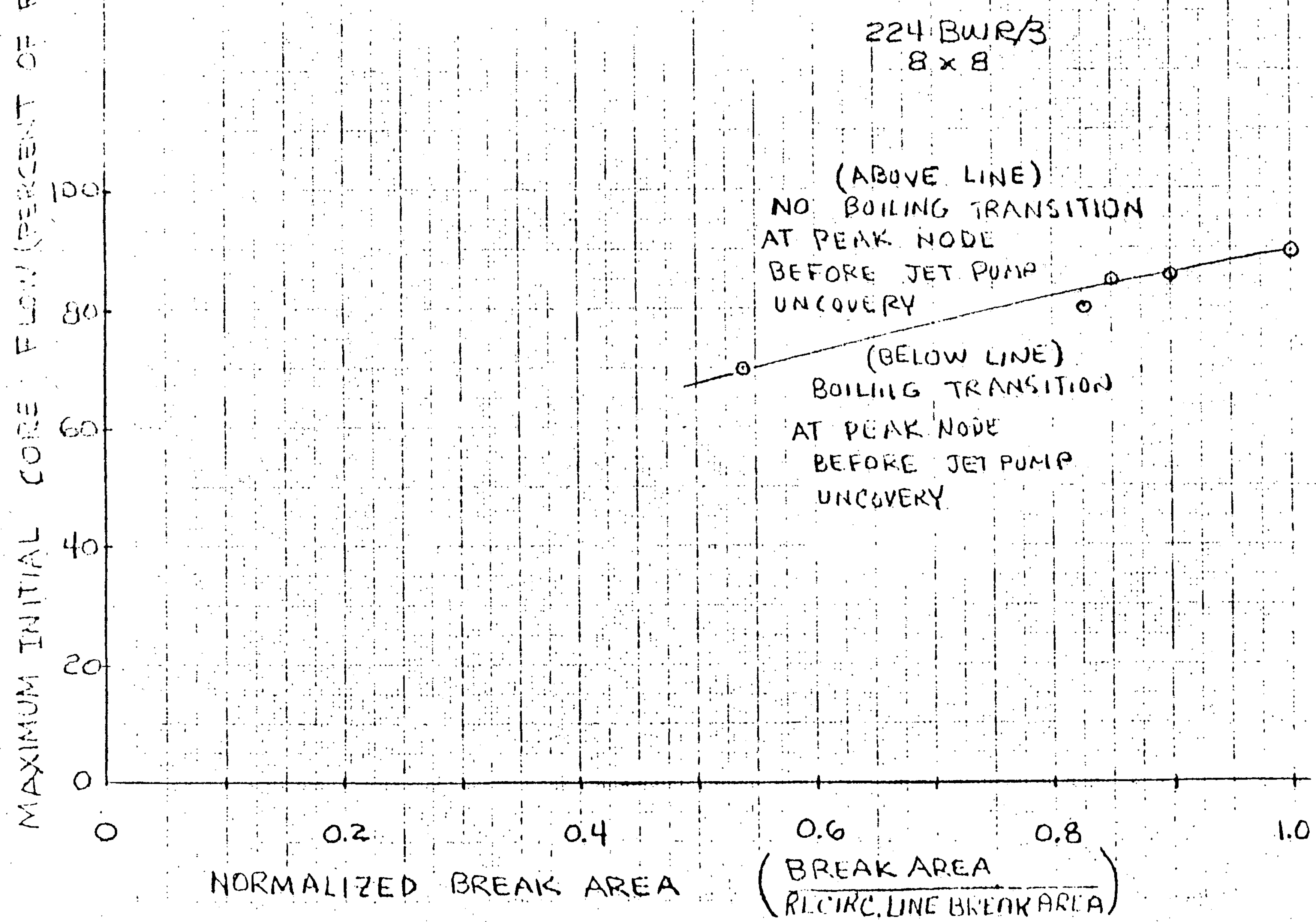
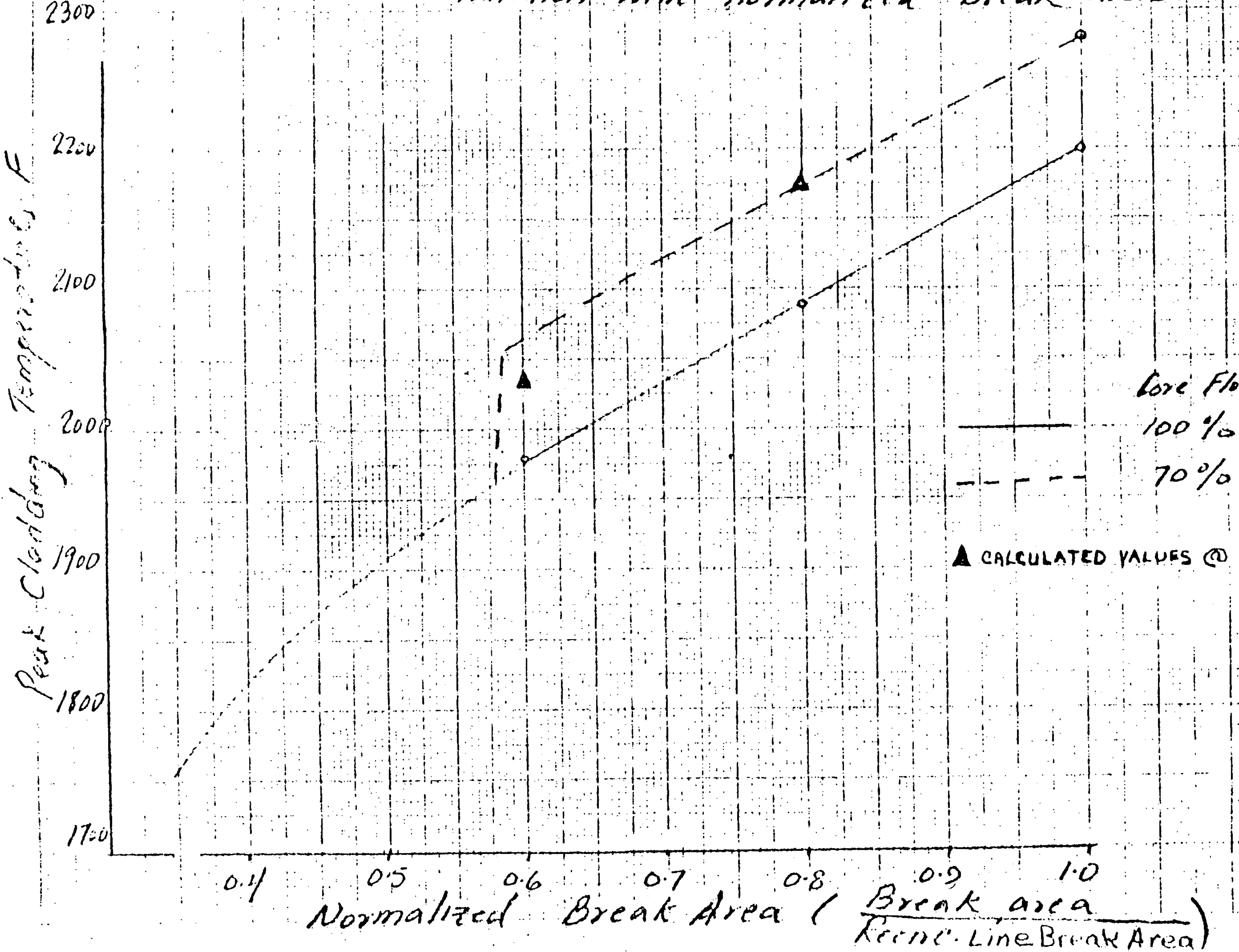


Figure C.4.5.4-4 Effect of Core Flow on calculated PCT variation with normalized break area



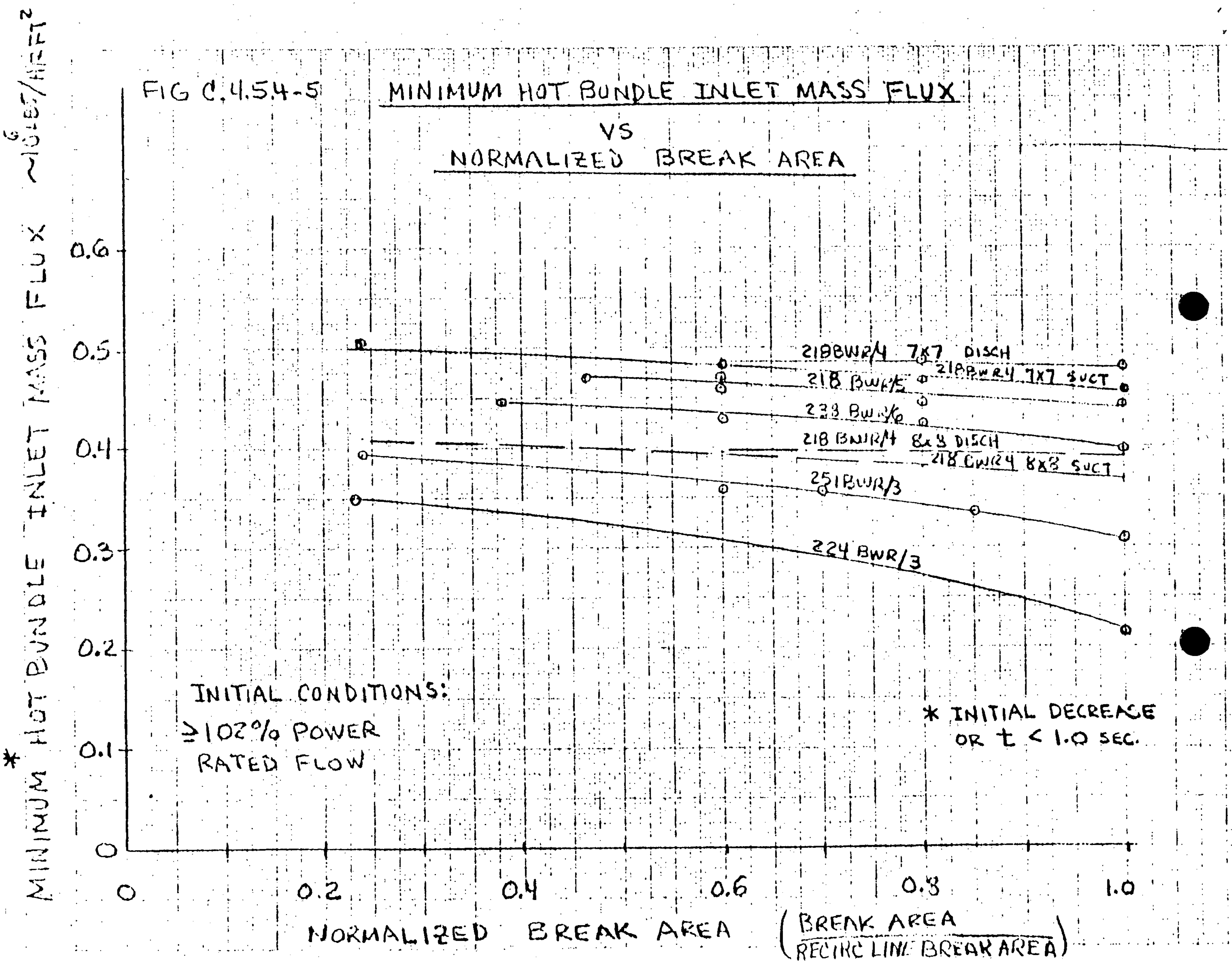


FIG C.4.54-5 MINIMUM HOT BUNDLE INLET MASS FLUX VS NORMALIZED BREAK AREA for the 224-BWR/3 that the largest break remains the most limiting at lower core flows, the same conclusion can be drawn for all reactors studied and presented in Figure C.4.5.4-5. Because of the similarity of geometry and thermal-hydraulic characteristics of all jet pump BWR's, the same conclusion can be inferred for all units not explicitly considered.

C.4.5.4.3 EFFECT ON SINGLE FAILURE ANALYSIS

The single failure analysis required by Appendix K is conducted to determine that combination of ECCS pumps which results in the least favorable reflooding time. As shown in Table C.4.5.3-1, the reflooding time decreases slightly with decreasing core flow. The depressurization rate of the reactor is essentially unaffected by initial core flow, so ECCS injection times and flow rates are little affected. All of these effects are small compared to the large differences in reflooding time caused by various postulated single failure conditions. As a result, the single failure analysis conducted in the 100% flow analysis is valid at lower core flows.

C.4.5.5 GENERALITY OF ANALYSIS FOR ALL JET-PUMP BWR'S

Results presented in the previous sub-sections have been stated to be generally typical of the particular class of plants specified. This subsection provides the basis for that generalization and the applicability of the results to all plants of that class. Because the major effect of core flow on the analysis is its impact on the calculated blowdown heat transfer characteristics, the primary basis for grouping plants into different categories are the blowdown characteristics. The plants can thus be classified on the basis of pressure vessel size (initial inventory), break size (rate of liquid loss), and core power density (because higher power density cores have higher recirculation flow per bundle). These characteristics determine the rate and absolute value of flow decay and the time of calculated boiling transition for the high power node.

C.4.5.5.1 BWR/1 AND 2

See section C.4.5.1

C.4.5.5.2 BWR/3's

The BWR/3's can be grouped into two subgroups for the determination of the effects of core flow based primarily on the vessel size and blowdown characteristics at 100% core flow. The first group consists of those reactors with vessel ID less than 250". These plants are calculated to have the results shown in Table C.4.5.5-1. These results (the time to boiling transition) show that an early boiling transition (before jet pump uncovery) will have the most pronounced effect on Plant 1 (the 224-BWR/3 studied extensively in the previous sections). Further, the minimum hot bundle flow is the lowest for Plant 1 so the maximum initial flow for which early boiling transition is calculated would be highest for Plant 1. The Plant 1 results are, therefore, bounding for this subgroup.

Table C.4.5.5-1 - Comparison of Important Results (at 100% Core Flow) for Different BWR/3's

Plant	Time to Boiling Transition for High Power Node, sec		Minimum Hot Bundle Mass Flux Early in the Transient, $lb/hr\ ft^2$	
Subgroup 1 (vessel ID < 250")				
	8x8 fuel	7x7 fuel	8x8 fuel	7x7 fuel
Plant 1	5.66	5.58	$.21 \times 10^6$	$.23 \times 10^6$
Plant 2	4.96	4.84	$.273 \times 10^6$	$.285 \times 10^6$
Plant 3	5.84	5.68	$.257 \times 10^6$	$.278 \times 10^6$
Subgroup 2 (vessel ID = 251")				
Plants 4 thru 7	7.8	7.56	$.31 \times 10^6$	$.335 \times 10^6$

The second subgroup comprises the BWR/3's with 251" vessel ID. These have slightly different blowdown characteristics. An analysis was performed for this subgroup. The results are shown in Table C.4.5.5-2. The results show that even at 61% core flow no boiling transition is calculated for the high power node before jet pump uncovery. Below 61% flow the decreasing planar power results in calculated PCT's at lower flows which are much less than that calculated for the 100% flow calculation. Hence, it is concluded that the LOCA calculations at 100% flow provide the bounding PCT for 251-BWR/3's.

Table C.4.5.5-2 - Effect of Core Flow on LOCA Analysis

for Subgroup 2, BWR/3

Core Flow, % of Rated	Time to Boiling Transition for Hot Node, Sec.	Time to BT for Upper Node, Sec.	Elevation of Upper Node, ft from TAF
61	8.16 (window)	0.32	2.44
70	7.98 (window)	0.88	2.44
80	7.76 (window)	0.8	2.44
90	7.76 (window)	1.16	2.44
100	7.8 (window)	1.2	2.44

C.4.5.5.3 BWR/4's

The BWR/4 subgroups are based on pressure vessel size (initial inventory) and on whether or not the plant has an LPCI modification. The important characteristics and results are summarized in Table C.4.5.5-3.

The results show that a bounding assessment of the effect of core flow can be obtained for all BWR/4 by studying the blowdown characteristics for the 218 BWR/4, because this size has the most rapid blowdown. Results of that analysis were presented in section C.4.5.1. The results show that early BT for the hot node is calculated for 61% core flow for the suction break and for a much lower core flow for the discharge break. Hence any plants limited by the discharge break will not be calculated to go into early BT for the hot node at core flows above 60%. A calculation was also done to show that for such a case the discharge break still remains more limiting than the suction break (see Table C.4.5.5-4).

The 251-BWR/4's, although limited by the suction break, do not have higher calculated PCT's at lower flows than those for the 100% core flow case, because for these plants the early BT for the hot node is more than compensated for by the decreasing planar power at the low core flows.

The only plants for which calculated PCT may increase at some initial flow less than 100% are the 218 BWR/4 without the LPCI modification and the 183 BWR/4 without the LPCI modification. These are limited by the suction break. For these plants, at less than 70% rated core flow, the calculated PCT's will be higher than that calculated for the 100% core flow case. The increase in PCT for these units was calculated to be approximately the same as calculated for the 224-BWR/3 (See Figure C.4.5.4-1).

C.4.5.5.4 BWR 5/6

Because these plants have much smaller recirculation lines than the other product lines the effect of core flow for the LOCA analysis is comparable to the results for the 218 BWR/4 discharge break. No BT is calculated for the hot node before jet pump uncovery at initial flows much less than 60% of rated. At such low flow the decreasing planar power more than compensates for any early BT for the hot node. Hence it is concluded that the 100% core flow analysis is bounding for all core flows for BWR 5/6.

C.4.5.6 Operating Characteristics of BWR's at Low Core Flows

In the previous sections it was shown that for a few BWR's the calculated PCT would be slightly higher than in the standard (100% flow) analysis if the calculation were done at an initial core flow less than rated. This could lead to a calculated PCT greater than 2200F if the operating MAPLHGR were greater than the ECCS limit. Although operation at low flow and high MAPLHGR is not the usual case, there are certain circumstances under which this combination of conditions is possible - e.g.

1. Surveillance testing (e.g., turbine stop valves and control valves, control rod drive exercising).

TABLE C.4.5.5-3 COMPARISON OF IMPORTNAT RESULTS (AT 100% CORE FLOW) FOR BWR/4's

Plant	LPCI Modification	Limiting Break	Fuel Type	Typical Time to BT for High Power Node, Sec.	Typical Minimum Hot Bundle Mass Flux, lb/hr ft^2
251-BWR/4	Yes	Suction	8 x 8	8.1	0.39×10^6
			7 x 7	8.1	0.43×10^6
218-BWR/4	Yes	Discharge	8 x 8	10.4	0.39×10^6
			7 x 7	10.3	0.48×10^6
218-BWR/4	No	Suction	8 x 8	5.5	0.37×10^6
			7 x 7	5.8	0.46×10^6
205-BWR/4	Yes	Discharge	8 x 8	8.4	0.32×10^6
			7 x 7	8.0	0.36×10^6
183-BWR/4	No	Suction	8 x 8	7.0	0.37×10^6

TABLE C.4.5.5-4

Effects of early hot node BT for a 218 BWR/4* - Suction Break versus Discharge Break

Break	Core Flow, % of Rated	PCT, F
Discharge	100	1899
	** 70	1899
Suction	100	1677
	*** 70	1850

* An early flooding, plant was used in this calculation to exaggerate effect of changes in blowdown heat transfer

** No early BT

*** Assumed BT for hot node before jet pump uncovery

2. Fuel preconditioning (e.g. initial and periodic preconditioning ramps, preconditioned envelope maintenance and extensions).

3. Load following maneuvers.

4. Plant equipment problems leading to reduced core flow operation.

5. Derated plant operation (e.g., self-imposed derated operation, plants derated due to MCPR limits, MAPLHGR limits, etc.)

Operation within regions 1 through 4 is primarily dependent on plant operating margins relative to the MAPLHGR limit. It may also be dependent upon xenon transient effects. Operation within low core flow region 5 is dependent upon the reason for such operation, the operating margin to MAPLGHR limits (if any), and the operating flexibility desired by such plants. Figure C.4.5.6-1 gives a graphical illustration of the operating MAPLHGR versus core flow.

C.4.5.7 Summary and Conclusion

The previous sections have shown that:

1. Non-jet pump BWRs which use recirculation flow control are not substantially affected by initial flow; those which do not use recirculation flow control have plant-specific limits for operation with recirculation pumps out of service.

2. For all jet pump BWRs there is some initial recirculation flow less than rated, at which boiling transition could occur at the high-power node in the thermally limiting fuel assembly earlier than calculated in the standard (100% flow) analysis. This effect by itself would increase the calculated PCT.

3. For most units, this effect is more than compensated for by the decrease in local planar power and the decrease in reflooding time with decreasing core flow, thus analysis at 100% flow is limiting.

4. For some units, the effect of early boiling transition is not completely compensated for as described in (3). There exists for these units a range of low-recirculation flow / high-MAPLHGR operation at which a calculated PCT greater than that at 100% flow is possible.

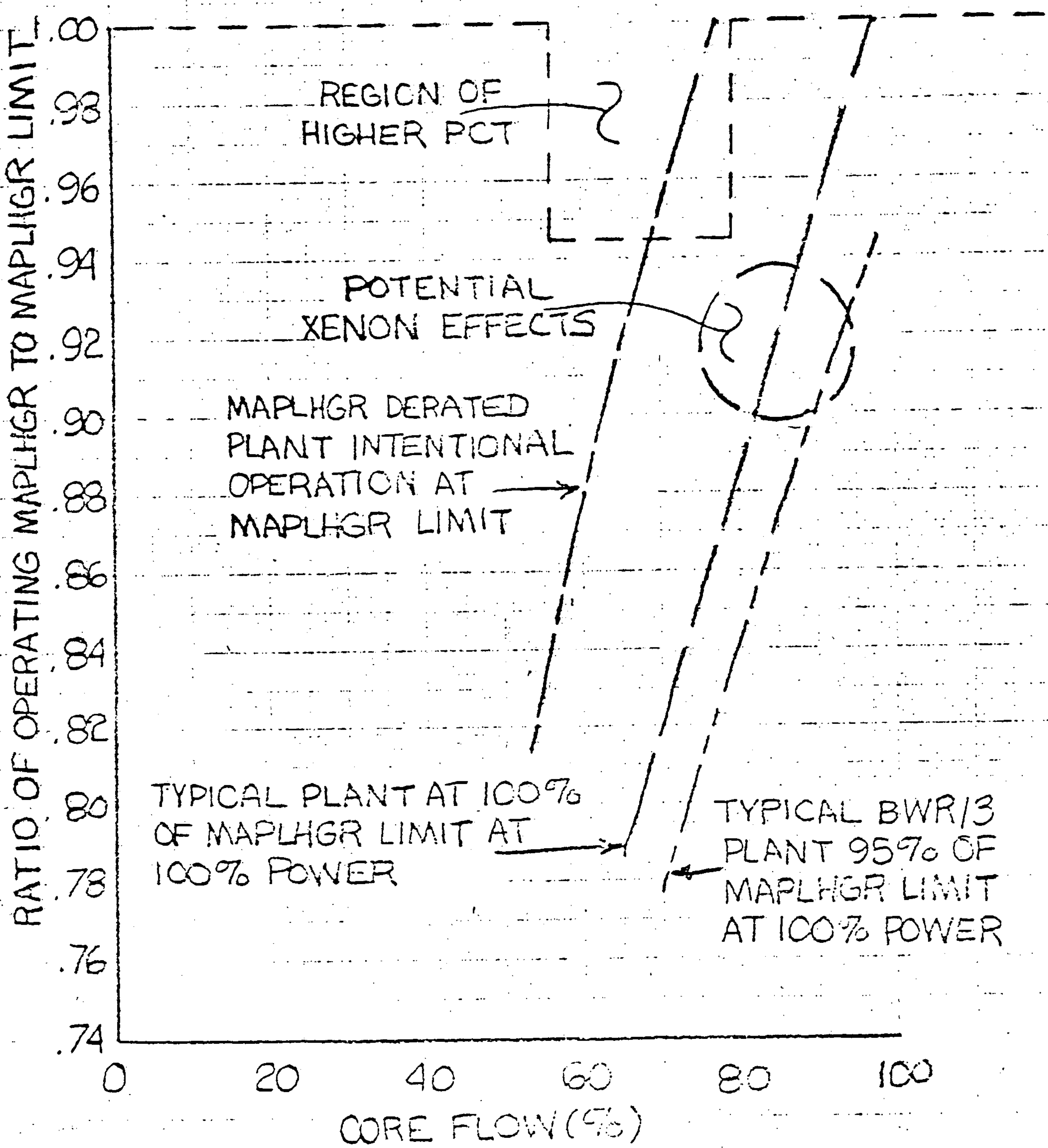
5. The subject range of core flows is small (although its lower bound has not been addressed in this discussion), and operation within this range at the 100%-flow MAPLHGR limit, while possible, is not expected to occur for a large percentage of the time.

It is concluded that for nearly all units, operation at or below the MAPLHGR limit calculated in the 100% flow Appendix K analysis will result in a calculated peak cladding temperature less than or equal to the 10 CFR 50.46 limit of 2200F.

FIGURE [illegible].5.6-1

OPERATING MAPLHGR PROPORTIONALITY

ASSUMING OPERATION ALONG THE 100% FLOW CONTROL LINE FOR FLOW REDUCTIONS WITH EQUILIBRIUM XENON CORRESPONDING TO 100% POWER



It is also concluded that for those few units whose peak cladding temperature is calculated to be greater at less than 100% flow over a small range of flows, the 100% flow analysis MAPLHGR limit must be multiplied by a correction factor within this range to ensure that the calculated peak cladding temperature remains below 2200F.

The maximum effect on PCT due to early boiling transition is about 80F (see figure C.4.5.4-1). This sensitivity ignores the beneficial effect of decreased reflooding time at lower initial flow. The sensitivity of PCT to 1% change in MAPLHGR is approximately 20F. The effect can thus be bounded by multiplying the standard-analysis MAPLHGR limit by 0.95 within the flow range of interest. The lower limit of this narrow flow range is of no practical interest, so the multiplier will be applied during operation at all flows less than that calculated to result in boiling transition prior to the flow "window". The MAPLHGR multipliers and flow ranges are summarized in Table C.4.5.7-1 for all affected units.

Table C.4.5.7-1 - MAPLHGR Multipliers for BWR's at Low Core Flows

Plant	Multiplier on MAPLHGR Based on 100% Core Flow	Core Flow Below Which Multiplier is to be Applied
All BWR/3's with vessel I.D <250"	0.95	90%
183 and 218 BWR/4, without LPCI modification	.95	70%
All other BWR's	None	not applicable

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

OCT 5 1976

Mr. Gail C. Ross, Manager
Operating Reactor Licensing
Nuclear Energy Division
General Electric Company
175 Courtner Avenue
San Jose, California 95125

Dear Mr. Ross:

On August 24, 1976 the General Electric Company submitted a document entitled "Additional Effects of Core Flow on ECCS LOCA Analysis," which contains calculations for certain plant configurations and extrapolations to justify application of the results to all plant types and postulated break sizes.

This information supports the continued safe operation under your proposed restrictions for an interim period until further information (see attachment) can be provided. However, we find that further calculations are required to provide final justification for the overall conservatism of your conclusions for all plants and break sizes. We have specified the minimum set of calculations needed for final justification of your conclusions (see question #1). In addition, other questions are included to clarify and provide additional support for the extrapolations you present regarding extension of your results to different plant types and break sizes.

We are also requesting that individual licensees address this issue on each of their dockets. An example of the letter being sent to licensees is enclosed for your information. Your timely response to this request for additional information will allow an orderly evaluation of licensee submittals.

Please advise us of your schedule for providing the requested information within a few days of receipt of this letter.

Sincerely,

Darrell Eisenhut

D. G. Eisenhut, Assistant Director
for Operational Technology
Division of Operating Reactors
Office of Nuclear Reactor Regulation

Enclosures:
As stated

"REQUEST FOR ADDITIONAL INFORMATION"
CONCERNING
"ADDITIONAL EFFECTS OF CORE FLOW ON ECCS LOCA ANALYSIS"

1. For each of the classes of BWR/3 and BWR/4 reactors discussed in your document, please provide the following information.

   a. Identify the minimum initial flow at which steady state operation with a local plane at the MAPLHGR limit is possible while remaining within the rod block Technical Specifications and the design peaking factors (define this as "flow A"). Identify the maximum initial flow at which early boiling transition (BT) (before jet pump uncovery) in the highest power plane is predicted in the DB-LOCA analysis (define this as "flow B").

   b. Provide results (including flow, pressure and PCT vs time) of a complete DBA-LOCA analysis at the lower of the two flows (flow A or B) for a plane operating at the highest MAPLHGR consistent with that flow. The analysis should be based on the highest core total power consistent with these conditions that is possible within Technical Specifications (worst rod pattern, position, etc. to give highest total core power for conservatism in calculating reflood time). This calculation is needed to establish PCT for the highest power-lowest flow combination where early boiling transition can be experienced, and will probably be the maximum PCT possible for early BT cases.

   c. If flow B > flow A, provide results of a DBA-LOCA analysis assuming an initial flow equal to flow B assuming the MAPLHGR limit local power and the highest possible core power. This will establish whether or not the later reflooding due to higher core power makes this case worse than part b.

d. If flow A > flow B, provide results of a DB-LOCA analysis for the lowest elevation (highest APLHGR) plane that experiences BT before jet pump uncovery assuming flow A as the initial flow, the appropriate APLHGR, and the highest core power consistent with those conditions. This establishes the "trade-off" between local power and time to boiling transition. It is possible that a plane at only slightly lower power may experience BT many seconds earlier and therefore reach a higher PCT than the peak power plane.

e. Provide results of a LOCA, as described in part b above, except assuming a break size a few percent smaller than the DBA. It will be necessary to identify a new "flow B" for this smaller break. The complete LOCA analysis to be provided is for an initial flow equal to the smaller of the previously defined "flow A" or this new "flow B".

2. In Table C.4.5.1-1, provide the local powers (MAPLHGR) values assumed for each of the initial flows, and justify conservatism of the flow - MAPLHGR values used. Indicate the MAPLHGR vs flow range where reactor operation is not allowable due to the Technical Specification involving limits on the non-void-to-local-power ratio (the "B" values) that exist on all BWR/2 reactors.

3. In Table C.4.5.1-3, explain the nomenclature "MCPR of 1.22 (1.24/1.02)" and explain why this value was chosen. Is this table for a top-peaked core (the 61% and 80% flow cases indicate that the high power node is at 3.52 ft

from TAF). What would be the effects of assuming other axial power shapes, i.e., is this table for a core with the worst axial shape?

4. In Table C.4.5.2-4, please explain the footnote "*For these cases, credit was taken for variation of CPR and planar power with core flow".

5. Please add to Table C.4.5.2-5 the results of a calculation assuming minimum initial core flow for which operation at the MAPLHGR limit is possible (at "flow A", see question number 1.a).

6. In Table C.4.5.3-1, specify the MAPLHGR values assumed for each of the flows and justify the conservatism of the MAPLHGR - flow values assumed. Describe what is meant by "*Considering the effect of reflooding time only".

7. Explain why Figure C.4.5.4-1 indicates the early DNB occurs at <81% core flow for a 224 inch BWR/3, whereas Figure C.4.5.4-3 indicates the same for <90% flow, and Table C.4.5.1-3 indicates the effect begins between 85% and 90% flow.

8. Describe whether or not all of the plotted points on Figure C.4.5.4-2 represent specific calculations using the LAMB code for the flow and break areas indicated. (19 individual LAMB runs are indicated).

9. For each class (size, classification) of plant which has the LPCI modification and is limited by the discharge line break, provide analyses of the largest suction line break assuming initial flows equal to flow A and flow B (flow B as redefined for the larger, suction line break), and assuming the highest MAPLHGR and core power consistent with those conditions.

10. Explain why "Plant 1" in Table C.4.5.5-1 is considered limiting, whereas Plant 3 has a longer time to BT at 100% flow and therefore more potential change could occur if early BT happens. What is the time to BT for each of these plants at flow A or flow B, whichever is lower?