U.S. Department of Energy
Energy Information Administration
Form EIA-412 (6/89)

Annual Report of Public Electric Utilities

Form Approved
OMB No. 1905-0129
Expires: 12/31/92
Burden: 33.2 hours

Identification Section

1. The information requested in this part of the form must be accurate. Item one (Exact Legal Name of Respondent) is repeated at the top of each page of the form, along with item 9 (Original or Resubmission), item 10 (Date of Report), and item 2 (Financial Reporting Year Ending). Please insure that the entries in these data fields are correct.

01 Exact Legal Name of Respondent 5300020160 Washington Public Power Supply System	02 Financial Reporting Year Ending (Month, Day, Year) 06/30/1989

03 Previous Name and Date of Change (If name changed during year)

04 Current Address of Principal Business Office (Street, City, State, Zip Code)
3000 George Washington Wa Richland WA 99352-0968

05 Name of Contact Person S B Gire	06 Title of Contact Person Manager/Corporate Accounting

07 Address of Contact Person (Street, City, State, Zip Code)
Attn: S B Gire 3000 George Washington Wa Richland WA 99352

08 Telephone of Contact Person (509) 372-5480	09 This Report is (1) [X] An Original (2) [ ] A Resubmission	10 Date of Report (Month, Day, Year) 04/30/90

11 Classes of Utility and Other Services Furnished by Respondent During the Year

- [X] Electric
- [ ] Natural Gas
- [ ] Water and Sewage
- [ ] Sanitation
- [ ] Irrigation
- [ ] Other (Specify): ____________________

Certification Section

The undersigned certifies that he/she has examined the accompanying report; that to the best of his/her knowledge, information, and belief, all statements of fact contained in the accompanying report are true and the accompanying report is a correct statement of the business and affairs of the above named respondent in respect to each and every matter set forth therein during the calendar or other established fiscal year stated above.

01 Name S. B. Gire	02 Signature S B Gire	
03 Title Manager, Corporate Accounting	04 Date Signed (Month, Day, Year) 4/30/90	

Title 18, U.S.C. 1001, makes it a crime for any person knowingly and willingly to make to any Agency or Department of the United States any false, fictitious or fraudulent statements as to any matter within its jurisdiction. This report is mandatory under Public Law 93-275. Failure to respond may result in criminal fines, civil penalties, and other sanctions as provided by law. Data reported on Form EIA-412 are not considered confidential.

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Schedule I: Electric Utility Balance Sheet

1. Some of the accounts listed below are defined in the General Instructions of this form.

2. Refer to the Uniform System of Accounts Prescribed for Public Utilities and Licensees for all other accounts.

Line No.	Assets and Other Debits (a)	Amount (b)
	ELECTRIC UTILITY PLANT	
1	TOTAL Electric Utility Plant (101-106,114)	$ 3,577,978,478
2	(Less) Electric Utility Plant Depr Amort Depl (108,111,115)	(646,863,801)
3	Net Electric Utility Plant (Line 1 less 2)	2,931,114,677
	OTHER PROPERTY & INVESTMENTS	
4	Nonutility Property (121)	
5	(Less) Accum Provision for Depreciation and Amortization (122)	
	Advances to Municipality	
	Invest & Special Funds (124-128)	159,757,249
8	TOTAL Other Property & Invest (Lines 4, 6, 7 less 5)	159,757,249
	CURRENT AND ACCRUED ASSETS	
9	Cash & Working Funds (131-135)	1,664,482
10	Temporary Cash Investments (136)	13,428,621
11	Notes & Accounts Receivable (141-143)	34,377,877
12	(Less) Accum Provision for Uncollected Accounts (144)	
13	Receivables from Municipality	
14	Materials & Supplies (151-156)	31,186,452
15	Prepayments (165)	1,783,010
16	Miscellaneous Current and Accrued Assets (174)	
17	TOTAL Current and Accrued Assets (Lines 9-11,13-16 less 12)	82,440,442
	DEFERRED DEBITS	
18	Unamortized Debt Expenses (181)	2,977,483
19	Extraordinary Prop Losses (182.1)	
20	Miscellaneous Deferred Debt (186)	2,822,819
21	Research, Dev & Demo Exp (188)	
22	Unamort Loss on Reacqr Debt (189)	
	Other (Specify):	
	TOTAL Deferred Debits (Lines 18 thru 23)	5,800,302
25	TOTAL Assets & Other Debits (Lines 3, 8, 17, and 24)	3,179,112,670

Line No.	Liabilities and Other Credits (a)	Amount (b)
	INVESTMENT OF MUNICIPALITY & SURPLUS	
26	Investment of Municipality	$
27	Constructive Surplus or Deficit	
28	Retained Earnings (215,215.1,216)	
29	TOTAL Investment & Surplus (Lines 26 thru 28)	
	LONG-TERM DEBT	
30	Bonds (221)	2,205,115,000
31	Advances from Municipality	
32	Other Long-Term Debt (224)	
33	Unamort Prem on Lg-Tm Debt (225)	755,097
34	(Less) Unamortization Discount on Long-Term Debt (226)	(60,089,239)
35	TOTAL Long-Term Debt (Lines 30 thru 33 less 34)	2,145,780,858
	OTHER NONCURRENT LIABILITIES	
36	Accum Prov for Prop Ins (228.1)	
37	Accum Prov for Inj & Dam (228.2)	
38	Accum Prov for Pensions (228.3)	
39	Accum Prov for Misc Oper (228.4)	3,343,000
40	TOTAL Other Noncurrent Liabilities (Lines 36 thru 39)	3,343,000
	CURRENT AND ACCRUED LIABILITIES	
41	Notes Payable (231)	
42	Accounts Payable (232)	67,831,334
43	Payables to Municipality	
44	Customer Deposits (235)	-
45	Taxes Accrued (236)	917,018
46	Interest Accrued (237)	299,736
47	Misc Curr & Accrd Liab (239,242)	37,647,506
48	TOTAL Curr & Accrd Liabilities (Lines 41 thru 47)	106,695,594
	DEFERRED CREDITS	
49	Customer Advances for Const (252)	
50	Other Deferred Credits (253)	922,280,211
51	Unamort Gain on Reacqr Debt (257)	1,013,007
52	TOTAL Deferred Credits (Lines 49 thru 51)	923,293,218
53	TOTAL Liabilities & Other Credits (Lines 29, 35, 40, 48, and 52)	3,179,112,670

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...hington Public Power Supply	(1) [X] An Original (2) [ ] A Resubmission	04/30/90	06/30/1989

Schedule II: Electric Utility Income Statement for the Year

2. Refer to the Uniform System of Accounts Prescribed for Public Utilities and Licensees for accounts listed below.

Line No.	Item (a)		Amount (b)
1	Electric Utility Operating Revenues	(400)	$ 458,038,930
2	Operating Expenses	(401)	109,597,029
3	Maintenance Expenses	(402)	42,075,293
4	Depreciation and Amortization	(403-405)	108,655,619
5	Taxes and Tax Equivalents (See Schedule IV)	(408.1,409.1)	2,288,086
6	Net Contributions and Services (See Schedule IV)		0
7	TOTAL Electric Utility Operating Expenses (Lines 2 thru 6)		262,616,027
8	Net Electric Utility Operating Income (Line 1 less line 7)		195,422,903
9	Income from Electric Plant Leased to Others	(412,413)	
10	Electric Utility Operating Income (Lines 8 thru 9)		195,422,903
11	Other Income Net (Explain significant amounts in a footnote) see footnote	(415,416,418,419)	20,091,071
12	Allowance for Other Funds Used During Construction	(419.1)	
13	Electric Utility Income (Lines 10 thru 12)		215,513,974
14	Income Deductions from Interest on Long-Term Debt	(427)	210,822,731
15	Other Income Deductions (Explain significant amounts in a footnote) see footnote	(428-432)	4,691,243
16	TOTAL Income Deductions (Lines 14 and 15)		215,513,974
17	Income Before Extraordinary Items (Lines 13 less line 16)		0
18	Extraordinary Income (See definition)	(434)	
19	Extraordinary Deductions (See definition)	(435)	
20	Net Income (Lines 17 plus line 18 less line 19)		0

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Schedule III: Electric Utility Plant

1. Report the original cost of electric plant in service according to the prescribed accounts.

2. Enclose in parenthesis credit adjustments of plant accounts to indicate the negative effect of such accounts.

Line No.	Item (a)	Balance Beginning of Year (b)	Additions During Year (c)	Retirements During Year (d)	Transfers & Adjustments (e)	Balance End of Year (f)
	Electric Plant in Service:					
1	Intangible Plant (301-303)	$	$	$	$	$
	Production Plant:					
2	Steam Production (310-316)					
3	Nuclear Production (320-325) see footnote	3,435,391,415	27,435,877	(17,599,331)	2,522	3,445,230,483
4	Hydraulic Production (330-336)	12,044,417			(1,544)	12,042,873
5	Other Production (Specify): see footnote (340-346)	22,922,224				22,922,224
	TOTAL Production Plant (Lines 2 thru 5)	3,470,358,056	27,435,877	(17,599,331)	978	3,480,195,580
7	Transmission Plant (350-359)	12,373,319				12,373,319
8	Distribution Plant (360-373)					
9	General Plant (389-399) see footnote	71,205,112	6,997,487	(89,026)	(266,899)	77,846,674
10	TOTAL Electric Plant in Service (Lines 1, 6 thru 9)	3,553,936,487	34,433,364	(17,688,357)	(265,921)	3,570,415,573
11	Electric Plant Leased to Others (104)					
12	Constr.Work in Progress-Electric (107)	5,731,604				7,562,905
13	Elec. Plant Held for Future Use (105)					
14	Electric Plant Acquisition Adjustments (See definition) (102)					
15	TOTAL Electric Plant (Lines 10 thru 14)	3,559,668,091	34,433,364	(17,688,357)	(265,921)	3,577,978,478

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[illegible]shington Public Power Supply	(1) [X] An Original (2) [ ] A Resubmission	04/30/90	06/30/1989

Schedule IV: Taxes, Tax Equivalents, Contributions, and Services During Year

1. Report below the information called for on contributions and services to the municipality or other government units by the electric utility and, conversely, by those bodies to the electric utility. Do not include: (a) loans and advances which are subject to repayment or which bear interest, (b) payment in retirement of loans or advances previously made, (c) contributions by the municipality of funds or property which are of the nature of investment in the electric utility department.

2. Enter in column (c) the total contributions made or received. Show in column (d) amounts included in column (c) which have been accounted for in the respondent's financial statements, i.e., balance sheet, income account, earned surplus, operating revenues, operating expenses, etc. Show in column (e) amounts which are unaccounted for in respondent's financial statements. For those amounts not included in respondent's financial statements, explain the reason for their omission in a footnote.

3. Report as "Taxes" the amounts due on the operations of the electric utility department. Exclude gasoline and other sales taxes which are included in the cost of transportation and materials.

4. Report as "Tax Equivalents" the amounts which are understood to consist of payments equivalent to or in lieu of amounts which would be paid if the electric utility department were subject to local tax levies.

5. Report as "To General Funds of the Municipality" the amounts considered as retained earnings that are transferred from the electric utility area.

6. Report as "Other" the amounts which are nonperiodic transfers to the municipality.

Line No.	Item (a)	MWh (b)	Amount of Contribution/Value of Service: Total (c)	Included in Financial Statements (d)	Not Included in Financial Statements (e)
	Subject Payments By Electric Utility to Municipality or Other Government Units:				
[illegible]	Taxes		$	$	$
[illegible]	Tax Equivalents				
3	Taxes & Tax Equivalents (Lines 1 & 2)		2,288,086	2,288,086	
4	To General Funds of the Municipality				
5	Other (Specify):				
6	TOTAL Contributions (Lines 4 and 5)				
7	Street and Highway Lighting				
8	Municipal Pumping				
9	Other Municipal Light and Power				
10	Other Electric Service				
11	Nonelectric Service (Specify):				
12	TOTAL Services (Lines 7 thru 11)				
13	TOTAL Contributions & Services By Electric Utility (Lines 6 and 12)		0	0	
	Subject Payments By Municipality or Other Government Units to Electric Utility:				
14	For Operations and Property Maintenance				
15	Other (Specify):				
16	TOTAL Contributions (Lines 14 thru 15)				
17	Office Space				
18	Water				
19	Engineering Service				
20	Legal Service				
21	Other Service (Specify):				
[illegible]	TOTAL Services (Lines 17 thru 21)				
23	TOTAL Contributions and Services By Municipality (Lines 16 and 22)		0	0	
24	Net Contributions and Services By Electric Utility to Municipality or Other Government Units (Line 13 less line 23)		0	0	

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Schedule V: Sales of Electricity for Resale

1. Report sales during the year to electric utilities, municipalities, co-operatives, or other public authorities for subsequent distribution and sale to ultimate consumers. Provide the full name that the sales were made to in column (a).

2. In column (b), provide one of the following codes: FP=Firm Power supplied for system requirements of the purchaser; UP=Unit Power provided on condition that specific generating unit is available for production; EP=Economy Power without capacity, interruptible, that replaced other energy available; DP=Dump or surplus power used to replace generation or other purchases; ME=Maintenance or Emergency power provided for scheduled or unplanned outages; OR=Operating Reserve used to satisfy operating reserve obligations; and OT=Other capacity and/or energy provided (provide explanation in footnote).

3. In column (c), if there are multiple delivery points within a county or city, provide the number after the state and county or city (e.g. IL, Cook (3)).

4. In column (d), report range of voltages in kilovolts (e.g., 13-69) if power is delivered at more than one voltage.

5. In columns (e) and (g), report the amounts as rendered on bills, including adjustments and other charges. If the megawatthours reported in column (e) represent the difference between energy received and delivered (i.e., net interchange), provide an explanation in footnote.

6. In column (f), enter "NO METER" if demand is not metered.

7. On the last line, provide the grand total for columns (e) and (g).

Line No.	Sales Made To: (Enter Name) (a)	Sale Code Type (b)	Point of Delivery State (postal abbrev) & County or City (c)	Kilovolts (kV) at Which Delivered (d)	Megawatt-hours (MWh) Sold (e)	Annual Maximum Demand (Circle MW/MVa) (f)	Cost ($) (g)
1	Bonneville Power Admin.	FP	WA Richland	540 kv	6,034,275	1,096,000	454,536,671
2	Bonneville Power Admin.	FP	WA Morton	69 kv	71,105	NA	
3	Clark County PUD	FP	WA Vancouver	69 kv	9,615	403,392	1,150,679
4	Lewis County PUD	FP	WA Mossyrock	69 kv	1,722	235,836	
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30							
31	TOTAL (Lines 1 thru 30)						

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Schedule VI: Electric Utility Operation and Maintenance Expenses

2. Refer to the Uniform System of Accounts Prescribed for Public Utilities and Licensees for accounts listed below.

Line No.	Item (a)		Operation (b)	Maintenance (c)	Total (d)
	Power Production Expenses				
1	Steam Power Generation (500-507,510-514)		$	$	$
2	Fuel (In Operation Exp) (501)	$			
3	Nuclear Power Generation (517-525,528-532)		85,127,728	30,403,325	115,531,053
4	Fuel (In Operation Exp) (518)	$ 31,283,224			
5	Hydraulic Power Generation (535-540,541-545)		119,305	134,241	253,546
6	Other Power Gen (Specify): (546-550,551-554)				
7	Fuel (In Operation Exp) (547)	$			
8	Purchased Power (555)				
9	Other Production Expenses (556,557)				
10	TOTAL Production Exp (Lines 1,3,5,6,8-9)		85,247,033	30,537,566	115,784,599
11	Transmission Expenses (560-567,568-573)		197,978	2,524	200,502
12	Distribution Expenses (580-589,590-598)				
13	Customer Accounts Expenses (901-905)				
14	Customer Service & Info Expenses (907-910)				
15	Sales Expenses (911-916)				
16	Administrative & General Expenses (920-935)		24,152,018	11,535,203	35,687,221
17	TOTAL Electric O & M Exp (Lines 10 thru 16)		109,597,029	42,075,293	151,672,322

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Schedule VII: Purchased Power

1. Report sales during the year to electric utilities, municipalities, cooperatives, or other public authorities for subsequent distribution and sale to ultimate consumers. Provide the full name of purchased from in column (a).
2. In column (b), provide one of the following codes: FP=Firm Power supplied for system requirements of the purchaser; UP=Unit Power provided on condition that specific generating unit is available for production; EP=Economy Power without capacity, interruptible, that replaced other energy available; DP=Dump or surplus power used to replace generation or other purchases; ME=Maintenance or Emergency power provided for scheduled or unplanned outages; OR=Operating Reserve used to satisfy operating reserve obligations; and OT=Other capacity and/or energy provided (provide explanation in footnote).
3. In column (c), if there are multiple delivery points within a county or city, provide the number after the state and county or city (e.g. IL, Cook (3)).
4. In column (d), report range of voltages in kilovolts (e.g., 13-69) if power is delivered at more than one voltage.
5. In columns (e) and (g), report the amounts as rendered on bills, including adjustments and other charges. If the megawatthours reported in column (e) represent the difference between energy received and delivered (i.e., net interchange), provide an explanation in footnote.
6. In column (f), enter "NO METER" if demand is not metered.
7. On the last line, provide the grand total for columns (e) and (g).

Line No.	Purchased From (Enter Name) (a)	Purchase Code Type (b)	Point of Receipt State (postal abbrev) & County or City (c)	Kilovolts (kV) at Which Received (d)	Megawatthours (MWh) Purchased (e)	Annual Maximum Demand (Circle MW/MVa) (f)	Cost ($) (g)
1	NA		NA				NA
2							
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30							
31	TOTAL (Lines 1 thru 30)						

↑ should equal Schedule VIII

↑ Should equal Schedule VI, Line 8

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Schedule VIII: Electric Energy Account

1. Report below the information called for concerning the disposition of electric energy generated, purchased, and interchanged during the fiscal year.

2. The Total Sources of Energy on line 16 must equal the Total Disposition of Energy on line 26.

Line No.	Item (a)	Megawatt-Hours (b)
	SOURCES OF ENERGY	
	Generation (Excluding Station Use):	
1	Steam - Fossil	
2	Nuclear	6,034,275
3	Hydro - Conventional	90,845
4	Hydro - Pumped Storage	
5	Other (Specify):	
6	(Less) Energy for Pumping	
7	Net Generation (Lines 1 thru 6)	6,125,120
8	Purchases - Utility	
9	Purchases - Non-Utility	
	Interchanges:	
10	In (gross)	
11	Out (gross)	
12	Net Interchanges (Lines 10 - 11)	
	Transmission for/by Others (Wheeling):	
13	Received	
14	Delivered	
15	Net Transmission (Lines 13 - 14)	
16	TOTAL Sources of Energy (Lines 7,8,9,12,15)	6,125,120
	DISPOSITION OF ENERGY	
17	Sales to Ultimate Consumers (Including Interdepartmental Sales)	
18	Sales for Resale	6,116,717
19	Energy Furnished Without Charge	
	Energy Used by the Company (Excluding Station Use):	
20	Electric Department Only	
	Energy Losses:	
21	Transmission and Conversion Losses	8,403
22	Distribution Losses	
23	Unaccounted for Losses	
24	TOTAL Energy Losses	8,403
25	Energy Losses as a Percent of Total on Line 16	.1372%
26	TOTAL Disposition of Energy (Lines 17,18,19,20 and 24)	6,125,120

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Instructions for Schedule IX: Steam-Electric Generating Plant Statistics (Large Plants)

1. Large plants are plants of 25,000 kW or more of maximum generator nameplate capacity operated by the utility. Include operated gas-turbine and internal combustion plants of 10,000 kW and more on this page. Also include operated nuclear plants.

2. If any plant is equipped with combinations of steam, hydro, internal combustion, or gas-turbine equipment, report each as a separate plant. If, however, a gas-turbine functions in a combined cycle operation with a conventional steam unit, include gas-turbine with the steam plant.

3. Operators of jointly owned plants must report for 100 percent of the plant; owners need not report. If total cost of plant (lines 9-12) is not available, report the available data and footnote the costs not given.

4. If net peak demand for 60 minutes is unavailable, report available data and footnote the period provided.

5. Report the average number of employees on the payroll whose costs are included in the production expense accounts (500-935), including part time and temporary employees. If employee(s) are assigned to more than one generating plant, include the number of employees assignable based on prorated expenses. If contractor costs are charged to any of the production expense accounts, footnote both the labor cost and the estimate of the number of contractors assignable to cost.

6. If you report rents due to a sale-leaseback arrangement, footnote the capacity (megawatts) sold and the asset (dollars) value removed from the plant accounts.

7. If gas is used and purchased on a therm basis, give Btu content of the gas and the quantity of fuel burned converted to Mcf (14.73 psi @ 60 degrees F).

8. Data on line 16 (Fuel) must be consistent with lines 32 (Quantity of Fuel Burned), 33 (Average Heat Content of Fuel Burned), 35 (Average Cost of Fuel per Unit Burned), and 36 (Average Cost of Fuel Burned per Million Btu).

9. If more than one fuel is burned in a plant, report the composite heat rate for all fuels burned.

10. The items under Cost of Plant represent accounts or combinations of accounts prescribed by the Uniform System of Accounts. Under Production Expenses exclude Purchased Power, System Control, Load Dispatch, and Other Expenses classified "Other Power Supply Expenses."

11. For gas-turbine and internal combustion plants, report Operating Expenses (account numbers 548 and 549) on line 21 (Electric Expenses), and Maintenance (account numbers 553 and 554) on line 27 (Maintenance of Electric Plant). Indicate plants designed for peak load service. Designate with an asterisk the automatically operated plants.

12. If the respondent operates a nuclear power generating plant, attach: (a) a brief explanation accounting for the cost of power generated, including any assignment of excess costs to research and development expenses, (b) a brief explanation of the fuel accounting, specifying the accounting methods and types of cost units used with respect to the various components of the fuel costs, and (c) additional information as may be informative concerning the type of plant, kind of fuel used, and other physical and operating qualities of the plant.

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Schedule IX: Steam-Electric Generating Plant Statistics (Large Plants)

1. Refer to page 10 for instructions concerning this schedule.

2. Refer to the Uniform System of Accounts Prescribed for Public Utilities and Licensees for accounts listed below.

Line No.	Item (a)	Plant Name: (b) Nuclear Plant No. 2	Plant Name: (c) Hanford Generating Project
1	Kind of Plant (Steam, Internal Combustion, Gas-Turbine, or Nuclear)	Nuclear	Nuclear
2	Year Originally Constructed	1972	1966
3	Year Last Unit Was Installed	1984	1966
4	Total Maximum Generator Nameplate Capacity in kW	1,200,000	862,000
5	Net Peak Demand on Plant (kW for 60 Minutes)	1,096,000	0
6	Plant Hours Connected to Load	6437.83	0
7	Average Number of Employees	1,029	3
8	Net Generation, Exclusive of Plant Use - kWh	6,034,275,000	0
	Cost of Plant:		
9	Land and Land Rights (310, 320)	-	9,975
	Structures and Improvements (311, 321)	1,095,230,044	11,947,502
	Equipment Costs: (312-316, 322-325)	2,130,425,564	48,158,605
12	Total Cost	3,225,655,608	60,116,082
13	Cost/kW of Nameplate Capacity (line 4)	2,688	70
14	Gross Annual Capital Expenditures	36,254,705	6,200
	Production Expenses:		
15	Operation Supervision and Engineering (500, 517)	22,676,272	
16	Fuel (501, 518)	31,283,224	
17	Coolants and Water (Nuclear Plants Only) (519)	2,725,918	7,198
18	Steam Expenses (502, 520)	13,134,383	
19	Steam From Other Sources (503, 521)	-	
20	Steam Transferred (Credit) (504, 522)	-	
21	Electric Expenses (505, 523)	206,657	
22	Misc. Steam (Nuclear) Power Expenses (506, 524)	15,246,176	(152,100)
23	Rents (507, 525)		
24	Maint. Supervision and Engineering (510, 528)	8,573,870	278,732
25	Maintenance of Structures (511, 529)	673,820	
26	Maintenance of Boiler (Reactor) Plant (512, 530)	8,642,425	
27	Maintenance of Electric Plant (513, 531)	6,631,816	
28	Maint. of Misc. Steam (Nuclear) Plant (514, 532)	5,602,662	
29	TOTAL Production Expenses	115,397,223	133,830
30	Expenses per Net kWh (Mills -- 2 Places)	19.1	NA

Line No.	Fuel: (Kind)	(b) Coal	(b) Gas	(b) Oil	(c) Coal	(c) Gas	(c) Oil
31	Unit: (Coal - Tons of 2,000 Lb.) (Gas - Mcf) (Oil - Barrels of 42 Gals.) (Nuclear - Grams)	- Nuclear -			NA	NA	NA
32	Quantity (Units) of Fuel Burned						
	Average Heat Content of Fuel Burned (Btu/Lb of Coal, per CuFt of Gas, or per Gal of Oil)						
34	Average Cost of Fuel per Unit, as Delivered F.O.B. Plant During Year						
35	Average Cost of Fuel per Unit Burned						
36	Average Cost of Fuel Burned per Million Btu	47.82					
37	Avg Cost of Fuel Burned per KWh Net Generation	5.18					
38	Average Btu per kWh Net Generation	10,337					

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Schedule IX: Steam-Electric Generating Plant Statistics (Large Plants) (Cont'd)

1. Refer to page 10 for instructions concerning this schedule.

2. Refer to the Uniform System of Accounts Prescribed for Public Utilities and Licensees for accounts listed below.

Plant Name: (d)			Plant Name: (e)			Plant Name: (f)			Item (g)	Line No.
NA			NA			NA			Kind of Plant (Steam, Int Cmb, Gas-Trb, Nuc)	1
									Year Constructed	2
									Year Last Unit	3
									Nameplate Capacity (kW)	4
									Net Peak Demand	5
									Plant Hours	6
									Number of Employees	7
									Net Generation - kWh	8
									Cost of Plant:	
									Land and Land Rights	9
									Structures & Improvmts	10
									Equipment Costs:	11
									TOTAL Cost	12
									Cost per kW	13
									Gross Expenditures	14
									Production Expenses:	
									Operation Supervision	15
									Fuel	16
									Coolants (Nuc. Only)	17
									Steam Expenses	18
									Steam Other Sources	19
									Steam Transferred	20
									Electric Expenses	21
									Misc. Steam Expenses	22
									Rents	23
									Maint. Supervision	24
									Maint. Structures	25
									Maint. Boiler Plant	26
									Maint. Electric Plant	27
									Maint. of Misc. Steam	28
									TOTAL Prod. Expenses	29
									Expenses/Net kWh	30
Coal	Gas	Oil	Coal	Gas	Oil	Coal	Gas	Oil	Fuel: (Kind)	
									Unit: (Tons, Mcf, Barrels, Grams)	31
									Quantity (Units) Fuel	32
									Average Heat Content of Fuel Burned	33
									Average Cost of Fuel per Unit, F.O.B.	34
									Average Cost Burned	35
									Average Cost Btu	36
									Average Cost kWh	37
									Average Btu per kWh	38

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Schedule X: Hydroelectric Generating Plant Statistics (Large Plants)

1. Large plants are hydroelectric plants of 10,000 kW or more of maximum generator nameplate capacity operated by the utility.
2. Indicate by an asterisk and explain in a footnote if any plant operated under a license from the Federal Energy Regulatory Commission. If a licensed project, give project number. Operators of jointly owned plants must report 100% of the plant; owners should not report. If the total cost of the plants (lines 9 - 13) is not available, the operator should report the cost that is available and indicate in a footnote what costs are not included.
3. For line 5, if net peak demand for 60 minutes is not available, give that which is available, specifying period.
4. Report the average number of employees on the payroll whose costs are included in the production expense accounts (500-935), including part time and temporary employees. If employee(s) are assigned to more than one generating plant, include the number of employees assignable based on the prorated expenses. If contractor costs are charged to any of the production expense accounts, footnote both the labor cost and the estimate of number of contractors assignable to this cost.

Line No.	Item (a)	FERC Licensed Project No. and Plant Name: P2244 Packwood Lake Hydroelectric Project (b)	FERC Licensed Project No. and Plant Name: (c)
1	Kind of Plant (Run-of-River or Storage)	Storage	
2	Year Originally Constructed	1964	
3	Year Last Unit was Installed	1964	
4	TOTAL Maximum Generator Nameplate Capacity in Kilowatts (kW)	26,125	
5	Net Peak Demand on Plant (kW for 60 minutes)	31,500	
6	Plant Hours Connected to Load	6,675	
7	Average Number of Employees	2	
8	Net Generation, Exclusive of Plant Use - kWh	82,441,854	
	Cost of Plant:		
9	Land and Land Rights (330)	54,776	
10	Structures and Improvements (331)	479,993	
11	Reservoirs, Dams, and Waterways (332)	9,182,672	
12	Equipment Costs (333-335)	1,906,370	
13	Roads, Railroads, and Bridges (336)	419,063	
14	TOTAL Cost (Lines 9 thru 13)	12,042,874	
15	Cost/kW of Nameplate Capacity (Line 4)	461	
16	Gross Annual Capital Expenditures	3,760	
	Production Expenses:		
17	Operation Supervision and Engineering (535)	17,128	
18	Water for Power (536)	722	
19	Hydraulic Expenses (537)	20,374	
20	Electric Expenses (538)	16,488	
21	Misc. Hydraulic Power Generation Exp. (539)	64,593	
22	Rents (540)	-	
23	Maintenance Supervision & Engineering (541)	3,972	
24	Maintenance of Structures (542)	10,490	
25	Maint. of Reservoirs, Dams, & Waterwys (543)	20,753	
26	Maintenance of Electric Plant (544)	57,270	
27	Maintenance of Misc. Hydraulic Plant (545)	41,756	
28	TOTAL Production Expenses (Lines 17 thru 27)	253,546	
29	Expenses per Net kWh (Mills -- 2 Places)	3.08	

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Schedule X: Hydroelectric Generating Plant Statistics (Large Plants) (Cont'd)

5. If you report rents due to a sale-leaseback arrangement, footnote the capacity (megawatts) sold and the asset (dollars) value removed from the plant accounts.

6. The items under Cost of Plant represent accounts or combinations of accounts prescribed by the Uniform System of Accounts. The items under Production Expenses do not include Purchased Power, System Control, Load Dispatching, or Other Expenses classified as "Other Power Supply Expenses."

7. If any plant is equipped with combinations of steam, hydro, internal combustion engine, or gas turbine equipment, report each as a separate plant.

FERC Licensed Project No. and Plant Name: NA (d)	FERC Licensed Project No. and Plant Name: NA (e)	FERC Licensed Project No. and Plant Name: NA (f)	Item (g)	Line No.
			Kind of Plant	1
			Year Constructed	2
			Year Last Unit	3
			TOTAL Nameplate Capacity in kW	4
			Net Peak Demand	5
			Plant Hours	6
			Number of Employees	7
			Net Generation - kWh	8
			Cost of Plant:	
			Land & Land Rights	9
			Structures	10
			Reservoirs	11
			Equipment	12
			Roads, etc.	13
			TOTAL Cost	14
			Cost/kW	15
			Gross Expenditures	16
			Production Expenses:	
			Oper. Supervision	17
			Water for Power	18
			Hydraulic Expenses	19
			Electric Expenses	20
			Misc. Expenses	21
			Rents	22
			Maint. Supervision	23
			Maint. Structures	24
			Maint. Reservoirs	25
			Maint. Elec. Plant	26
			Maint. Hydrl. Plant	27
			TOTAL Prod. Exp.	28
			Expenses/Net kWh	29

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Schedule XI: Transmission Line Statistics

1. Report below information requested concerning each transmission line owned. If more space is required, use supplemental page using the column headings shown on this page.
2. For column (c), if the voltage used is different from operating, report the difference in a ftn.
3. Indicate in column (d) whether the type of supporting structure is: (1) single pole, wood, or steel; (2) H-frame, wood, or steel poles; (3) tower; or (4) underground construction.
4. Indicate in column (g), whether the material is aluminum conductor steel reinforced (ACCR), aluminum (A), copper (C), or other (O) and the cross-sectional area per phase in thousands of circular mils (MCM).
5. Designate any transmission line or portion thereof for which the respondent is not the sole owner. If such property is leased from another, give name of lessor in a footnote.
6. Designate in a footnote any transmission line leased to another and give name of lessee.

Line No.	Designation (Name of Terminal Station)		Operating Voltage (KVa)	Type of Supporting Structure	LENGTH (Pole Miles)		Material and Size of Conductor	Number of Circuits
	From	To			On Structures of Line Designated	On Structures of Another Line		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	BPA Hanford Substation	Vantage Substation	500 kv	Steel	23.85 mi	NA	1780 MCM ASCR chukar	2 Conductors per phase
	Total of 6 lines on structure. Bonneville Power Administration (BPA) owns 5 and WPPSS owns 1 as detailed.							
2	Packwood Lake	Lewis County	69 kv	Woodpole	2.2	NA	A/O ASCR	1
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Schedule XII: Footnote Data

Page Number (a)	Part Number (b)	Line Number (c)	Column Number (d)	Comments (e)
3	II	11	b	Other Income includes: Investment income $ 19,164,342 Revaluation of investments 741,773 Accretion of deferred gain on redemption of revenue bonds 133,342 Gain on redemption of revenue bonds 51,614 $ 20,091,071
3	II	15	b	Other Income Deductions include: Amortization of Debt Discount & Expense $ 2,745,832 Loss on Redemption of Revenue Bonds 26,752 Other 1,918,659 $ 4,691,243
3	II	20	b	The projects have no equity and, therefore, no retained earnings. Power sales and net-billing agreements with the project participants allow for complete recovery of project costs including debt service. The participants are billed for project costs with an adjustment to actual at year-end.
88 Balance Beginning of Year Adjustments (Reclassification from prior ending balances):				
4	III	3	b	Nuclear Production (320-325) $3,379,863,138 Steam Production (310-316) should be Nuclear Production (320-325) 60,113,560 Reflect CWIP (107) as a separate line item (4,585,283) Revised Balance Beginning of Year $3,435,391,415
		5	b	Other Production (186) $ 16,684,124 Reflect U.S. Gov't Owned Facilities gross of amortization 6,238,100 Revised Balance Beginning of Year $ 22,922,224
		9	b	General Plant (389-399) $ 61,655,268 Reflect CWIP (107) as a separate line item (1,146,321) Reflect Agency Clearing Accounts allocation gross of depreciation 10,696,165 Revised Balance Beginning of Year $ 71,205,112
7	VI	3&16	b,c,d	Benefits accrued reclassified from operation and maintenance categories to administrative and general.
10	IX	12 of the instructions		Nuclear Plant No. 2 a. The cost of power is equal to total expenses divided by the net generation: Total Expenses (pg. 3, line 1) $ 454,536,671 New Generation (pg. 11, line 8) 6,034,275,000 Net Cost of Power 75.92 Mills/KW

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Schedule XII: Footnote Data

Page Number (a)	Part Number (b)	Line Number (c)	Column Number (d)	Comments (e)
10	IX	12 of the instructions (Continued)		b. The Fuel Accounting System uses cost principles of the public utility industry as given under the Federal Energy Regulatory Commission (FERC) Chart of Uniform Accounts. This includes recording of the acquisition and manufacturing cost of fuel and the amortization of the capitalized fuel cost based on heat production. In addition to the amortization of fuel burnup, the current period nuclear fuel operating expense includes a charge for future spent nuclear fuel storage and disposal to be provided by the Department of Energy. This charge is based on a one mill per killowatt hour of energy generated.
11	IX	8	c	The Hanford Generating Project, an 860 MWe plant which utilizes by-product steam from the Department of Energy's dual-purpose New Production Reactor (NPR), was completed in 1966 and was in normal operation through 1986. In January 1987, the NPR was shut down for safety improvements. In February 1988, the Department of Energy placed the NPR on standby status for an undetermined length of time, eliminating the Hanford Generating Project's present energy source. The Supply System has completed a study of alternative power sources to be used for continued energy generation, and further studies are being conducted.
13	X			Packwood Lake Hydroelectric Project is located in Lewis County, Washington and in part occupies government lands in the Gifford Pinchot National Forest in the Goat Rock section of the Cascade Mountains. The plant is operated under a license from the Federal Energy Regulatory Commission (Project No. P-2244).

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RESPONSE TO THE SECOND ROUND OF QUESTIONS ON TOPICAL REPORT WPPSS-FTS-129

QUESTION 1:

Provide a summary of the sensitivity analysis performed on core noding for the limiting transients.

RESPONSE:

The dynamic response of the core in a limiting transient such as load rejection without bypass has a significant effect on the safety limits in the thermal margin calculations. In particular, the interactions between the core thermal-hydraulic control volumes, the heat conductors and the neutronic regions are known to influence the magnitude in power transients. The WPPSS best-estimate model contains 12 nodes for the active core region (Reference 1 Figure 2.2). To study the sensitivity of the core noding scheme, the number of the active core regions is increased from 12 to 24 (Figure 1). The change involves dividing each thermal-hydraulic volume and heat conduction region into two equal sized volumes and regions except the top active volume and region. In the base model, the top active volume and region (Volume 62 and Heat Conductor 12) interact with three neutronic regions (Numbers 24, 25 and 26). In the sensitivity case, Volume 62 and Conductor 12 are divided into two regions, one (Volume 73 and Conductor 23) interacts with Neutronic Region 24 and the other (Volume 74 and Conductor 24) interacts with Neutronic Regions 25 and 26. Thus the top active region in the sensitivity case is twice as large as the other regions.

The sensitivity case was run and the results are given in Figures 2 through 7. Since Power Ascension Test (PAT) 027 simulates the load rejection which is limiting in the licensing basis model, it was selected as the case for this sensitivity study. Figure 2 gives the power versus time. Four different data points were plotted in the figure. Plant data is from the measured APRM signal in percent power. Case 001 data is the RETRAN results based on a transient initiated from the rated condition (same results as presented in Reference 1). Case 002 is the RETRAN results based on a transient initiated from the actual plant steady-state condition at the initiation of the test(see Reference 2). It should be noted that in Reference 2, Table 1.7-1, the system pressure for PAT 027 was mistakenly quoted as 1014.7 psia. It should be 999.7 psia. The corrected value is given in Table 1. Case 002 presented in this document reflects this correction. Case 003 is the same as Case 002 except that the number of core nodes is increased from 12 to 24. As seen in Figure 2, the 24-node case yields essentially the same

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results as the 12-node case. This leads to the conclusion that the 12-node core model is sufficient in yielding accurate results. Since the measured power was given in percentage, the plot is based on fraction of power rather than their absolute values.

Figure 3 gives the flow for recirculation loop A. As seen from the plot, Cases 002 and 003 starts the transient at the same recirculation flow as the measured data as expected. However, Case 001 starts at the rated flow rate which is higher. Again, the 24-node case (003) yields essentially identical results as the 12-node case (002). The measured flow stayed higher initially and then converged to the calculated flow rates. As stated in Reference 2, the shape of the curves for the computed coast down flow is concave with a sharp "knee" at the time the pump is tripped while the data show a less pronounced "knee" with a more convex shape. The recirculation loop flows during pump coastdown are strong functions of the pump inertia and system characteristics. From review and comparison with analysis done by other organizations and the data for PAT Test 030A, the shape of the calculated loop flow is more consistent with other results than are the data from PAT 027. As stated in Reference 2, the plant operations indicated that the signal was "filtered" before it was recorded. However, this data is not recoverable. This could account for part, if not most, of the discrepancy. The plant data and the computed results converge after about four seconds into the transient. This is because the flow is not as sensitive to the pump inertia at the later stage of the coastdown as at the beginning. Instead it is mostly determined by the system hydrodynamics. The pump inertia uncertainty has been included in the licensing basis model (Reference 1) through the use of a bounding (upper limit) value for the pump inertia to ensure a conservative result.

Figure 4 gives the flow for recirculation loop B. The RETRAN calculated flow is identical to that in Figure 3 because of the symmetry of the two loops.

The larger difference between the RETRAN calculated flow and the measured flow when compared to loop A flow is partly due to the fact that the measured flows for both loops started at about the same flow rate (see Table 1) at the initiation of the transient, but gradually deviated from each other as the transient progressed. One of the possible causes for the asymmetrical results in the measured flows is the instrument discrepancies between the two loops due to calibration differences and drifts. The data was taken in 1984 and it is difficult to analyze the exact cause of the asymmetrical behavior in an otherwise symmetrical test. As mentioned previously, it is attributed to measurement and test data inaccuracies. The RETRAN simulation of the PAT 027 was based on the two recirculation loops being symmetrical because the geometries, the operating conditions and the tripping of the pumps were all the same in the test. Again, the 24-node and 12-node models yield no differences.

Figure 5 gives the total core flow (active and bypass). The RETRAN model using the measured initial conditions simulates the Recirculation Pump Trip (RPT) reasonably well. Again, there is no difference between Cases 002 and 003.

Figure 6 gives the dome pressure versus time. The RETRAN results using the measured initial conditions trace the plant data closely throughout the transient. The difference between Case 001 (rated initial condition) and Case 002 (measured initial condition) in the pressure behavior is due to the difference in the initial pressure and its effect on the rest of the transient. In Case 001, higher initial pressure results in higher peak pressure exceeding the pressure setpoint (1091 psia) for Group 1 safety and relief valves (SRVs) causing the dome pressure to turn around faster than the case without Group 1 SRV opening as in Cases 002 and 003. As stated in the Topical Report, there was an indication that one SRV cycled repeatedly. This sensitivity study indicates that the peak pressure is very close to the pressure setpoint for the SRV opening, supporting the observation in the actual test. The 24-node case yield the same results as the 12-node case.

Figure 7 shows the steam flow behavior. As indicated, the change between the three sensitivity cases are small.

It should be noted that the RETRAN version used here is the MOD5UEM version written for UNIX-based workstations. This version (MOD5UEM) went through the Supply System's "Program Validation and Verification" process according to the NRC-approved QC procedure as documented in Chapter 17 of the WNP-2 FSAR. Appendix A gives a summary of the validation and verification performed on Version MOD5UEM.

In summary, the sensitivity study on the core noding found that the 12-node core model yields essentially the same results as those from a 24-node model, supporting the use of the current 12-node model as the base model for transient analysis.

QUESTION 2:

Provide justification for using a single nodalization scheme for all of the transients instead of different nodalization schemes for different transients.

RESPONSE:

There are five basic types of transient analysis to consider: (a) decrease in reactor coolant temperature, (b) increase in reactor pressure, (c) decrease in reactor coolant flow rate, (d) increase in reactor coolant inventory, and (e) increase in reactor coolant flow.

(a) decrease in reactor coolant temperature

Events that directly decrease the reactor coolant temperature are those that either increase the flow of cold water or reduce the temperature of water being delivered to the reactor vessel. Reducing the reactor coolant temperature increases core reactivity, which in turn increases core power. The resulting negative moderator void reactivity shifts power towards the bottom of the core. These changes will lead to a new steady-state power level. Sufficiently high levels of thermal power or neutron flux will cause a scram. Events in this category include: (1) loss of feedwater heating, (2) inadvertent high pressure core spray startup and (3) inadvertent residual heat removal shutdown cooling operation. Even though for a typical reload design for WNP-2, these transients are not limiting in setting the operating thermal limits, the neutronics and fluid transport models and the feedwater control systems must be modeled correctly.

The core noding scheme in the base model (12-node model as described in Reference 1) is adequate for this type of transients. An important phenomenon in a thermally limited transient is the power increase due to void collapse. From the responses to Questions 1 and 9, one finds that the 12-node model gives either a converged or a slightly conservative result in the void prediction and the feedback calculation for core power for the most limiting transient (load rejection) when compared to the 24-node model. For the type of transients where there is a decrease in coolant temperature, the phenomenon of power increase is similar to load rejection but not as severe. Therefore, the 12-node model is also adequate for this type of transients.

With regard to the steam line noding, Reference 2 provides a detailed discussion on its sensitivity to the system behavior. The number of nodes were increased from 7 to 10 and then to 13 for the limiting transient of load rejection. The results indicate that the base model of 7 steam line nodes gives a slightly conservative result in terms of the thermal limit in ΔCPR (see Table 2).

Transients with decreases in reactor coolant temperature typically result in less severe pressurization in the steam lines. Therefore the 7-node model is adequate for these transients as well.

Further analysis performed supports the use of the base model in this type of transients. A transient analysis performed for the topical report (Reference 1) is the feedwater controller failure transient. Even though this transient is not one of the three listed above, it is investigated here because it is to a degree similar to a transient with reduction in coolant temperature and it has a potential of becoming the limiting transient in determining the thermal limits. The sudden increase in the feedwater flow rate causes the core inlet temperature to drop. Figure 8 shows the RETRAN calculated axial power shift towards the bottom as the colder water enters the core consistent with the description of the behavior in this category of transients. Other results were presented in Section 4.3 in Reference 1. Even though this calculation is based on the licensing basis model, the noding scheme is identical to the best-estimate model. The power shift would be more profound if there is an actual temperature reduction in addition to the flow rate increase. Nevertheless, it provides additional evidence that the neutronic and thermal-hydraulic modeling and their interactions are correctly modeled. In the same analysis, the results as presented in Reference 1 (which is for Cycle 4 core) showed that the transient behaved in a similar way as documented in WNP-2 FSAR, which is for the initial core, providing support that other systems, such as high water level trip logic, scram control system, recirculation pump trip, SRV opening and closing are modeled correctly.

In addition, from the power ascension test for water level setpoint change (PAT 23A) as given in Reference 1, the feedwater control system is verified through comparison with the plant data.

(b) increase in reactor pressure

Events that increase reactor pressure significantly are usually initiated by a sudden reduction in steam flow. The increased pressure collapses the voids in the core, which increases core reactivity. This causes an increase in the core power level, which further increases core pressure. A scram will terminate this event. Safety analysis events in this category include: (1) digital-electric-hydraulic (DEH) pressure regulator failure in the closed position, (2) generator load rejection, (3) turbine trip, (4) closure of the main-steam-line isolation valve, and (5) loss of the condenser vacuum.

Among the above events, the generator load rejection is typically most limiting in determining the thermal limits. RETRAN simulation of the load rejection test (PAT 027) as given in Reference 1 and in response to Question 1 in this document and the sensitivity

analyses on the steam line noding and core noding (see Reference 2 and Question 1) on this transient indicate that the RETRAN model can adequately simulate this category of transients. Particularly significant is the fact that the PAT 027 simulation yields a pressure history which matches the plant data closely (see Figure 6). This is significant because the pressure behavior is important in predicting the power increases in this kind of transients.

The capability of the model in predicting the scram worth correctly is verified through the close match of the RETRAN calculated power with the measured data after scram in PAT 027 (see Figure 2).

(c) decrease in reactor coolant flow rate

Events that reduce recirculation flow also reduce the reactor coolant flow rate, which increases core voids and decreases core reactivity. The decrease in reactor coolant flow increases the water level because of the swelling of moderator voids. The increase in core voids decreases the power level. Events in this category include: (1) recirculation pump trip (RPT), (2) recirculation flow control failure in the decreasing flow position.

Because of the nature of this types of transients that limits the increase of power, they are not limiting in setting the operating limit minimum critical power ratios (OLMCPR). The base model is adequate for this type of transient because the 12-node core model has been demonstrated to be adequate or conservative for a transient with a larger void feedback and power increase (see Question 1) and the 7-node steam line model has been demonstrated to be adequate or conservative for a transient with a larger pressurization (cf. Table 2 and Reference 2 Questions 1.1).

The RETRAN base model has been further verified to correctly calculate this type of transients as a part of a PAT 027 simulation, i.e., the RPT sequence. In the load rejection test, the turbine control valve closure initiates the recirculation pump trip which contributes to the power decrease. Figures 3 and 4 show the plant data comparison with the RETRAN simulation. As discussed in Response to Question 1 and in References 1 and 2, the capability of the model in predicting the recirculation loop flow was verified. More importantly, the capability in predicting the core flow as a consequence of the RPT is verified by comparing the calculated core flow with the plant data as shown in Figure 5. Core flow is the one of the key parameters in determining the core power.

(d) increase in reactor coolant inventory

Events that lead to a feedwater flow rate higher than the steam production rate increase the amount of water (coolant inventory) in the reactor vessel, and may initiate a turbine and feedwater trip

on high water level. A turbine trip will, in turn, result in increased core pressure, with a concomitant void collapse and reactivity increase. The resulting increase in power level will be terminated by the reactor scram initiated by the turbine trip. The one event in this category is the feedwater controller failure.

In the early stages of the feedwater controller failure transient, the system behavior is relatively mild. The rate of power increase due to the reduction of the void is slow. The sensitivity on the core and steam line noding is small. Thus, the base model with 12-node core and 7-node steam line is adequate. As the water level increases to the trip setpoint, the turbine trip will set off a series of responses that follow closely a load rejection pressurization event. Since the pressurization is not expected to be as severe as the load rejection (see Reference 1 Section 4), the sensitivity study performed on the core and steam line noding for load rejection is valid for the feedwater controller failure also. Therefore, the base model with 12-node core and 7-node steam line is adequate.

Even though no Power Ascension Test data were available for this type of transients, a simulation of the feedwater controller failure transient using the licensing basis model was presented in Reference 1 (Section 4.3 of Reference 1). The transient sequence of events does follow the scenario described above. Particularly, the sequence of the events after the turbine trip on high water level follows essentially those for the load rejection which have been verified separately through the PAT 027 simulation as discussed above.

In addition to the qualitative statement based on the feedwater controller failure simulation, quantitative comparisons can be made in regard to the key parameters in this type of transient. One of the parameters is the water level. PAT 23A (Water Level Setpoint Change) data comparison as presented in Section 3.1.1 in Reference 1 leads to the conclusion that the base model can predict the water level with reasonable accuracy. When the setpoint was changed to 6 inches higher, the model responded to that amount when the new water level was established (Figure 3.1.2 of Reference 1). Other calculations show that the RETRAN model generally yields conservative water level calculations (see Response to Question 6).

(e) increase in reactor coolant flow

Events that increase recirculation flow also increase the reactor coolant flow rate, which decreases coolant temperature and voids. These changes cause an increase in core reactivity and power level. A slow increase in coolant flow may lead to a new steady-state operating condition, which can be terminated by operator action. A

rapid increase will initiate a scram on high neutron flux. Events in this category include: (1) recirculation flow control failure in the increasing flow position, (2) startup of an idle recirculation pump.

This type of transients are typically milder than a pressurization transients such as load rejection, but the determining phenomenon is the same, i.e., a power increase due to a decrease in void (see below for a detailed case analysis). Therefore, the sensitivity performed on core and steam line noding for the load rejection case (see Table 2 and References 1 and 2) applies to this types of transient and the base model with 12 core nodes and 7 steam line nodes is adequate.

Even though these types of transients are typically nonlimiting, a RETRAN simulation of the recirculation pump control failure in the increasing flow position was performed to verify the capability of the WNP-2 RETRAN model. Because plant data are not readily available for this transient, no attempt was made to compare the RETRAN results with measured data. This simulation is performed to show the reasonableness of the model.

Because of the mild nature of the transient, the simulation is based on the best-estimate model using point kinetics. At the rated condition, the valve stem openings for the recirculation flow control valves are at 84% of full opening position for both loops. Using the maximum valve stroke rate of 11% per second (Reference 3 Section 15.4.5), the valves are simulated to reach full open position in 1.455 seconds.

Figures 9 and 10 show the recirculation flows for loops A and B. As in Response to Question 1, the RETRAN code simulated a symmetrical behavior for both loops as expected. Figure 11 gives the total core flow which follows the recirculation pump flow closely. As the core flow increases, the void fraction decreases. This is shown in Figures 12 and 13. The void collapsing leads to a power increase as shown in Figure 14. This increased power tends to increase the void fractions, which will in turn slow the increase in core power. As the recirculation flow stabilizes at a new level, the core power and the void fractions will reach a new steady state as shown by the plotted results.

The simulation of the recirculation flow control failure transient indicates that the WNP-2 RETRAN model has the capability of analyzing the transients with increasing core flow rates.

QUESTION 3

Redo RETRAN simulation for PAT Tests 30A and 027 using the actual plant initial conditions instead of the rated conditions and discuss the impact of the changes. The RETRAN code used should have the correction on recirculation pump flow symmetry. In addition, the results should be compared to the plant data in a non-normalized form.

RESPONSE

PAT 30A and 027 were recalculated using the plant initial conditions instead of the rated conditions as reported in the Topical Report (Reference 1). As stated in the response to Question 1, the IBM RISC6000 version of the RETRAN code was used in these analyses.

The results for PAT 027 have been presented in the response to Question 1 when the core noding sensitivity issue was addressed.

Test PAT 30A was initiated by tripping one recirculation pump. The RETRAN simulation was initiated by introducing a recirculation pump trip in Recirculation Loop A at time zero. The point-kinetics base model as given in the RETRAN topical report (Reference 1) was used except that the initial conditions were changed to the measured conditions as given in Table 1. Figures 15 through 20 give the results of the simulation. All plots are done in a non-normalized fashion except the power and heat flux. The measured data for these two parameters were given in fractions of rated values. Both the results for the rated conditions (designated Case 001 in the plots) and the actual plant conditions (designated Case 002) are given in the plots. Figure 15 shows the recirculation drive flow for the tripped loop (Loop A). The effect of using the actual plant condition on the flow coastdown is not significant. Figure 16 shows the recirculation drive flow for the unaffected loop (Loop B). As seen, the revised calculation follows the measured plant data more closely than that at rated conditions.

Figures 17 and 18 show the jet pump flows (sum of driving and suction flows) for Loops A and B respectively. The behaviors are very similar to the recirculation flow comparisons. The revised calculation for the unaffected loop gives a closer comparison with the plant data. The coast down rates for the tripped loop for Cases 001 and 002 (Figure 17) are slightly different. Case 002 gives a slower coast down rate than Case 001. The difference is mainly caused by the differences in the driving flows as shown in Figure 15. If the two RETRAN curves in Figure 15 are normalized so that they start at the same value, the Case 002 curve will show a slower coast down rate than Case 001. As the driving flow increases or decreases, the suction flow will also increase or decrease. Thus,

the total flow through the jet pump will follow the driving flow closely. The difference in the driving flows is caused by the lower initial driving flow in Case 002. From Table 1, the measured driving flows (i.e., recirculation pump flows) for Loops A and B are 4430.0 and 4335.0 lb/sec, respectively. They are lower than the rated flow of 4527.78 lb/sec. Therefore, as one loop trips, the lower initial flow (for Case 002) in the unaffected loop will result in a slightly less resistance in the affected loop than the case where the unaffected loop has higher flow (Case 001). This will cause the rate of decrease of the affected loop flow in Case 002 to be lower (i.e., slower coast down) as evidenced in Figure 15. As explained above, the suction flow in the jet pump varies directly with the driving flow. Therefore the jet pump flow, which is the sum of the driving and suction flows, for Case 002 also indicates a slower coast down in Figure 17.

Figure 19 indicates that the effect of changing the initial conditions is small on the core power calculations. This is also true for the core average heat flux as evidenced in Figure 20.

In summary, using the measured plant data at the initiation of the transient for PAT 30A generally gives a better comparison with the plant data throughout the transient. The effects on key parameters such as power and heat flux are small. The same conclusion is also true for PAT 027 (see Question 1).

QUESTION 4

In support of using the non-equilibrium model in the upper downcomer, perform a Peach Bottom turbine trip analysis using the equilibrium model and compare the power history with both the non-equilibrium model and the measured data.

RESPONSE

Two simulations of the Peach Bottom turbine trip test TT1 were performed. A full description of the model is provided in Reference 1. In one simulation, thermodynamic equilibrium between phases was assumed for the upper downcomer control volume, while the other simulation used a non-equilibrium model for the upper downcomer control volume. The predictions for steam dome pressure and core neutron power, along with the measured data, are shown in Figures 21 and 22. As discussed in Reference 2, the non-equilibrium model allows the existence of superheated steam in the upper downcomer region, producing higher dome and vessel pressures than the equilibrium model, leading to a larger void collapse and higher core power. In Figure 21, the non-equilibrium model gives the dome pressure which is in better agreement with the measured data than the equilibrium model for the time period when the pressure reaches its maximum value. Matching the peak pressure is important in a potentially limiting transient such as turbine trip because it determines the total amount of reactivity increase that will be introduced into the core due to void decrease. The non-equilibrium model slightly overpredicts the measured peak pressure. The pressure behavior is largely reflected in the neutron power comparisons as shown in Figure 22. Due to the higher pressure, the non-equilibrium model results in a slightly higher peak power. However, it follows the measured data more closely than the equilibrium model. The slight overprediction in neutron power provides a conservative ΔCPR.

QUESTION 5

In RETRAN steady-state initialization, what are the key parameters that influence the transient results and how do they match the plant data? If the plant data is not consistent (within instrument accuracy), which parameters are keyed upon for model steady-state initialization and why?

RESPONSE

The key parameters in RETRAN steady-state initialization that will influence the transient results are the initial power level, the system pressure, the steam and feedwater flow rates, the total core flow, the water level and the recirculation flow. Table 1 gives a list of key parameters and their values for the four Power Ascension Tests analyzed in Reference 1. Another important parameter that is not measured directly is the core inlet enthaply. This parameter is obtained through a standard loop heat balance calculation using other key parameters such as those listed above and input to RETRAN.

It is apparent that the RETRAN calculated results from the initialization process will not match every data that are printed out by the Plant Process Computer. However, as explained above, the important parameters affecting the thermal limits are the ones given in Table 1. Therefore, the RETRAN initialization process is keyed to these parameters. For the Power Ascension Test Cases, the input to RETRAN all resulted in an initialization that matched these parameters to within the instrument accuracy. If we look at Table 1, the measured flow rates for the feedwater and steam are different. By definition, these flow rates should be equal if a true steady state exits. The difference in measured flow could be due to the differences in instruments, calibration, drift or due to fluctuations from the true steady state. The RETRAN initialization will force the equalization by taking the average of the two measured flow as the initial conditions. The same is true for the recirculation pump flows for Loops A and B. It should be noted that the initialization process is not sensitive to the initial water level input to the RETRAN. This means that RETRAN can match the measured water level at the start of the transient without upsetting other parameters.

The question of the consistency of measured plant data used in the RETRAN initialization may also be addressed by looking at the comparisons of the RETRAN results with the plant data and with the initialization performed at the rated conditions. In response to Question 1, comparisons were made between the RETRAN results using the rated initial conditions and the measured initial conditions. From Figure 7, the rated initial steam flow is larger than the measured steam flow. This higher initial flow causes slightly larger increase in dóme pressure as seen in Figure 6. In addition,

Figure 6 indicates that the SRV operation depends on the initial pressure as discussed in Response to Question 1. This observation is consistent with what one would expect if the plant were running at the rated condition at the time of PAT 027 initiation.

Through the comparison of measured data and RETRAN calculations as presented in Responses to Questions 1 and 3 for PAT 027 and 30A, it is realized that by using the measured conditions as the basis for steady-state initialization (i.e., data in Table 1), the RETRAN calculations reached true steady state with converged loop heat and mass balance and the subsequent transient behavior matched the plant data closely, similar to the cases where the calculations were based on an initialization at the rated conditions, which by definition are within a consistent set of parameters. This gives an indication that the key parameters as measured at the initiation of the PAT tests for Tests 027 and 30A (see Table 1) have the same degree of consistency as those at the rated conditions and the RETRAN initialization process is properly set up.

QUESTION 6

Discuss the impact of the discrepancies in water level predictions such as given in response to Question 1.6 in Reference 2 on transient results.

RESPONSE

Based on the Supply System reload methodology applied to Cycle 4, the limiting transient is the load rejection without bypass (Reference 4). This transient trips on the loss of generator load, not on the water level. Therefore, there is no impact in determining the operating limit MCPR.

Another less limiting transient which could potentially become limiting is the feedwater controller failure, which initiates a main turbine trip based on water level and a subsequent control rod scram.

To verify that RETRAN model yields reasonable results in water level, a comparison of the RETRAN calculation for the feedwater controller failure transient with the reload vendor's calculation is made. The licensing basis model as discussed in Reference 1 was used for the RETRAN analysis because that was the model basis used by the reload vendor (Reference 5), even though a different code (COTRANSA2) was used. In addition, since the vendor's results for water level for cycle 4 were not available, COTRANSA2 analysis for Cycle 7 was used in the comparison. The impact of different cycles is small because the fuel designs are essentially identical (i.e., they are identical with regard to the key parameters used in the RETRAN simulation) and both licensing models use the same bounding conditions. Figure 23 shows the plot of the water levels calculated by RETRAN and by Siemens Nuclear Power Corp. (Reference 5). From the figure, it is seen that the WNP-2 RETRAN model predicts a water level lower than that predicted by the vendor. This is conservative because lower water level would delay the main turbine trip on high water level leading to the initiation of the vessel pressurization at a higher power level. It will also delay the time to scram, resulting in further conservatism. To confirm the conservatism of the delayed turbine trip, a sensitivity case with an earlier trip of the main turbine was performed. In this study, the turbine and feedwater pumps are forced to trip at the time when the water level as predicted by the vendor reached Level 8. From Figure 23, the time when the vendor-calculated water level reaches Level 8 is about 17.5 seconds. Using this time instead of the 23.4 seconds in the original RETRAN calculation for the turbine and feedwater trips, the transient was recalculated. The peak power and the peak core average heat flux are compared below.

	Peak Power (%NBR)	Peak Heat Flux (%NBR)
Trips at 17.5 seconds	239.9	120.2
Trips at 23.4 seconds	242.2	121.4

From the above comparison, the case with delayed trips will result in a more limiting condition in terms of thermal limits because of the higher core peak heat flux.

It should be noted that the result of the RETRAN calculation is different from that given in Figure 4.3.3 in Reference 1. This is because in Reference 1, the feedwater flow rate was assumed to have a "step" change from 100% NBR to 146% NBR (Figure 4.3.1 of Reference 1) which is the most limiting condition. In the analysis performed here, a slightly slower flow ramp rate used by the vendor is incorporated to allow a meaningful comparison. In addition, the vendor results in Reference 5 had to be shifted because they were presented as the level above the separator skirt whereas the RETRAN model gives the level above the "instrument zero".

QUESTION 7

Explain the feedwater flow behavior at 24 seconds into the transient for PAT 023 (i.e, cross-over of the measured data and calculated results, see Figure 3.1.1 of Reference 1) given the water level trend in Figure 3.1.2.

RESPONSE

A study of Figure 3.1.1 and Figure 3.1.2 indicates that the RETRAN results in feedwater flow and water level changes are more consistent than the measured data. The feedwater flow as calculated by RETRAN starts to level off at about the time when the water level approaches a new steady state. The measured feedwater flow, however, continues to decrease after the water level has already reached a steady state at about 24 seconds. This flow decrease causes a cross over between measured and calculated feedwater flow. The cause for the inconsistency between the measured feedwater flow and the measured water level can be several. Events such as the initiation of the high pressure injection system or reactor core isolation cooling system would lead to a situation of continuing feedwater decrease while keeping water level constant. The exact cause of the inconsistency is difficult to identify because the test was performed in 1984 and not all of the data are available.

QUESTION 8

In response to Question 1.1(ii) in Reference 1, the algebraic slip model was verified using steady state data, justify the model for transient applications.

RESPONSE

For transient applications, it is important to correctly account for the reactivity effects due to changes in void fraction. As reported in section 3.2 of Reference 1, the calculated power and reactivity for Peach Bottom turbine trip tests agree well with the measured data. The calculated results are slightly on the conservative side in terms of the peak and integrated power (Table 3.2.4 through 3.2.7 in Reference 1). This indicates that the algebraic slip model in the subcooled void modelling is adequate for predicting void fraction changes for transient applications.

QUESTION 9

What areas of RETRAN sensitivity studies are covered in the Applications Topical that are related to the RETRAN Topical Report (WPPSS-FTS-129)?

RESPONSE

The Applications Topical (Reference 4) covers the entire spectrum of the reload analysis methodology beginning with the reference core design, including the selection and the safety analysis of the limiting events. These analyses provide the bases for any changes in core operating limits or technical specifications. The Applications Topical Report was submitted to the NRC in October 1991 for approval in licensing applications.

As part of the safety analysis methodology, the WNP-2 RETRAN model as described in WPPSS-FTS-129 was used to analyze certain limiting transients that involve system functions, such as load rejection without bypass and feedwater controller failure. As presented in the Applications Topical, the load rejection without bypass transient (LRNB) was selected for detailed sensitivity analysis because it was the most limiting transient for the reference core (Cycle 4) analyzed for WNP-2. A total of 28 cases were studied. The results in terms of the change in RCPR (ratio of ΔCPR to initial CPR) are presented in Section 5 of the Topical. The same table is reproduced here (Table 2) with the percent changes in peak core power, peak core average heat flux, and peak dome pressure added to give an indication of the range of sensitivity parameters covered in the study. It should be pointed out that the studies performed for the Applications Topical both provide a sensitivity of the effects of different parameters on the model, and the contributing values of ΔRCPR from each parameter used to calculate the combined uncertainties in ΔCPR as part of the Statistical Combination of Uncertainties Methodology in determining the final OLMCPR for a given cycle.

It should be noted that the case on core noding (last case in Table 2) shows a change of -10.5% in peak power when the number of core nodes is changed from 12 to 24 during the LRNB. This is significantly more sensitive than that for PAT 027 (Response to Question 1). This is due to the severity of the transients simulated. In the LRNB transient, conservative operating parameters were deliberately selected to cause the plant to become supercritical for a short period of time (about 0.5 sec) due to an increase in reactivity. The magnitude of the reactivity increase is highly sensitive to the change in void fractions. Thus, a small change in void will lead to a large change in reactivity, thus in core power. This phenomenon is not nearly as profound for the case of PAT 027 where the reactivity never became positive.

The above observation is supported by the void fraction comparisons for the LRNB transient as given below. The void fractions are taken at 1.0 second into the transient which is close to the time of peak power (0.9 second). It is seen that the sensitivity on void fraction per se is significantly lower than that on the core power.

Comparison of the Void Fractions for 12- and 24-Node Models for LRNB Transient

	12-Node	24-Node	% Difference
Mid-Core	0.455*	0.463**	1.8
Core Exit	0.682+	0.685++	0.4

* Void fraction for Vol. 57 (See Reference 1)
** Volume averaged void fraction for Vol. 63 and 64 (see Figure 1)
\+ Void fraction for Vol. 62 (see Reference 1)
++ Volume averaged void fraction for Vol. 73 and 74 (see Figure 1)

It is further supported by the sensitivity results in the heat flux (-1.89%) and the dome pressure (-0.07%) as presented in Table 2, which have a secondary effect as a result of the slight change in voids. Even with higher power sensitivity for the LRNB transient, the 12-node model yielded a conservative result in terms of peak power and ΔRCPR.

Some of the parametric studies were performed to quantify the CPRs under a new condition which is independent of the base model, and thus were not considered as part of the sensitivity study to quantify the RETRAN model uncertainty. These are: (1) initial core flow at 106% NBR, (2) no RPT, and the combination of (1) and (2).

Since the main purpose of the RETRAN sensitivity analysis in the Applications Topical Report is to establish the model uncertainties for the licensing basis model, bounding values were used for the uncertainties of the parameters leading to conservative results in terms of ΔRCPR.

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7. C.E. Peterson et al., "RETRAN02 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 4: Applications", NP-1850-CCM, Electric Power Research Institute, Palo Alto, California, January 1983.

TABLE 1

COMPARISON OF RETRAN INITIAL CONDITIONS TO
WNP-2 POWER ASCENSION TEST INITIAL CONDITIONS

Parameter	RETRAN-02 Initial Conditions	PAT Test 023A	PAT Test 022	PAT Test 030A	PAT Test 027
System Pressure (psia)	1,015.00	1,010.0	1,004.2	1,003.6	999.7
Total Feedwater Flow (lb/sec)	3,970.97	3,638.9	3,710.6	3,694.4	3,788.8
Total Steam Flow (lb/sec)	3,970.97	3,666.7	3,737.5	N/A	3,811.1
Recirc. Pump A Flow (lb/sec)	4,527.78	4,444.4	4,104.7	4,430.0	4,169.08
Recirc. Pump B Flow (lb/sec)	4,527.78	4,444.4	4,000.1	4,335.0	4,208.7
Normalized Power	1.0	0.951	.975	0.962	0.975
Water Level (in)	36.05	37.0	36.20	32.78	36.49
Total Core Flow (lb/sec)	30,138.8	29,166.7	28,903.2	30,166.7	28,744.4

TABLE 2

Results of Generator Load Rejection Without Bypass Sensitivity Studies

	Percent Change: Peak Core Power	Percent Change: Peak Heat Flux	Percent Change: Peak Dome Press.	ΔRCPR
Nuclear Model Parameters				
Void Coefficient (+13%)	+4.1	+2.3	---	+0.018
Doppler (-10%)	+3.5	+0.77	---	+0.005
Prompt Moderator Heating (-25%)	+8.9	+2.6	+0.13	+0.013
Scram Reactivity (-10%)	-0.19	+0.68	+0.09	+0.004
Scram Speed (normal scram time)	-14.4	-5.6	-0.47	-0.045
Core Thermal Hydraulics Parameters				
Code Correlation (kappa1±0.20)	+1.6	-0.23	-0.09	+0.001
Code Correlation (CGL±30%)	+2.0	+0.37	+0.03	+0.003
Code Correlation (CDB±20%)	+0.83	+0.23	+0.02	+0.001
Code Correlation (CHN±20%)	+0.44	+0.08	+0.0	+0.001
Initial Core Flow at 106%	+7.80	+1.51	-0.02	+0.014
Initial Core Flow at 106%, no RPT	+48.5	+9.46	+0.39	+0.056
Core Pressure Loss Coefficients (-20%)	-0.88	-0.08	+0.0	-0.002
Initial Core Bypass Flow (-20%)	+0.19	+0.08	+0.0	+0.003
Fuel Pin Radial Nodes (+50%)	+1.78	-0.23	+0.03	+0.004
Core Power (+4%)	+3.51	+4.77	+0.60	+0.003
Recirculation System Parameters				
Recirculation Loop Inertia (+100%)	+5.26	+1.14	+0.06	+0.007
Recirculation Pump Head (-10%)	+2.17	+0.45	+0.03	+0.003
Jet Pump Inertia (+100%)	+6.43	+1.29	+0.07	+0.008

TABLE 2 (Cont.)

Separator Liquid Outlet Inertia (+100%)	+1.32	+0.23	+0.03	+0.001
Separator Inlet Inertia (-30%)	+14.9	+0.98	+0.04	+0.003
Jet Pump Loss Coefficient (-20%)	+4.29	+0.68	+0.03	+0.004
No RPT	+36.0	+8.10	+0.46	+0.040
Steam Line Model Parameters				
Steam Line Inertia (+7%)	+1.85	+0.76	+0.08	+0.007
Pressure Loss Coefficient (-20%)	+3.14	+0.91	+0.20	+0.007
Vessel and Loop Geometry Parameters				
Vessel Dome Volume (-5%)	+3.46	+0.83	+0.14	+0.005
Steam Line Volume (-5%)	+0.73	-0.15	+0.08	-0.002
Steam Line Noding (7 → 13)	+0.41	-0.38	+0.02	-0.003
Active Core Noding (12 → 24)	-10.5	-1.89	-0.07	-0.011

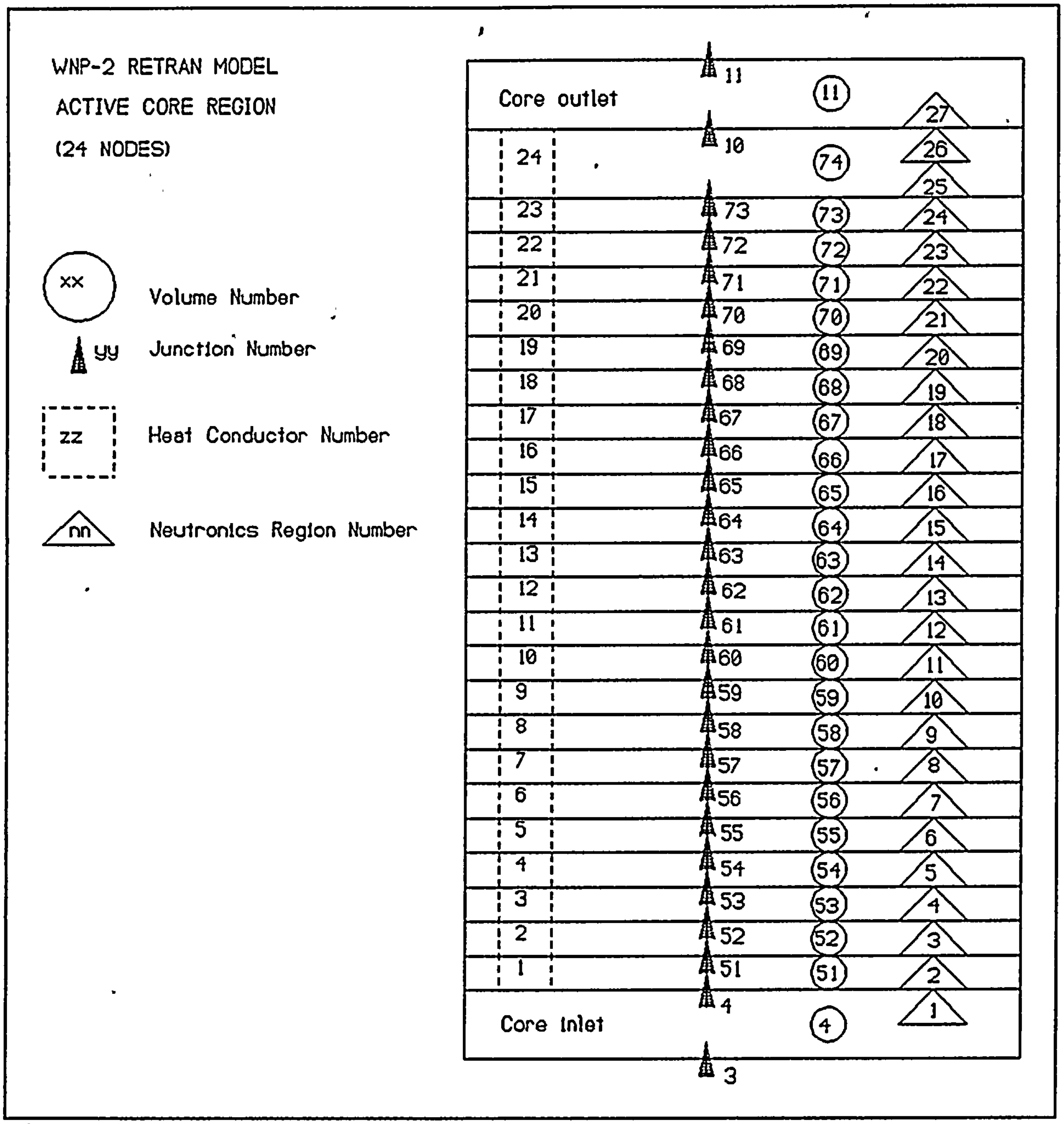
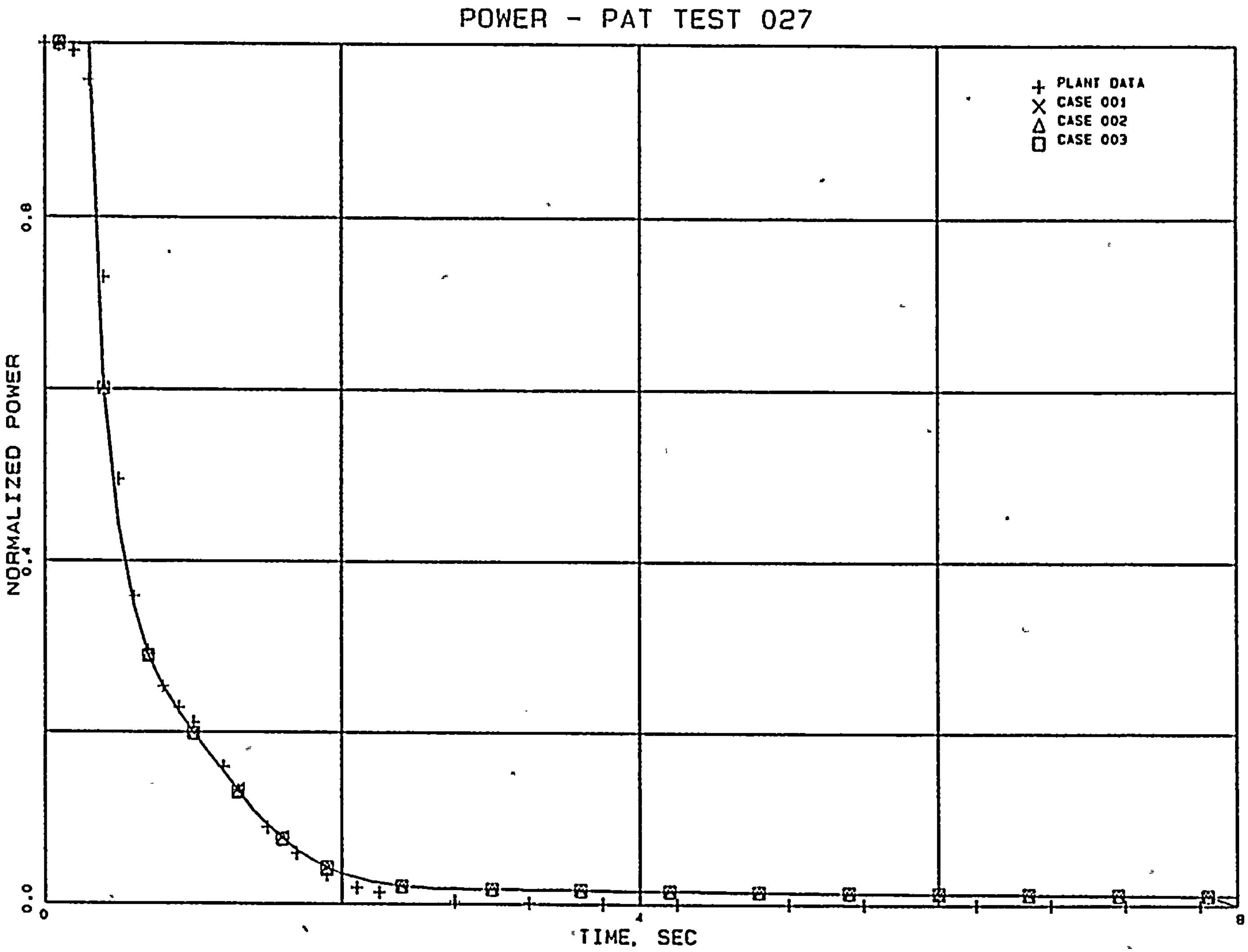
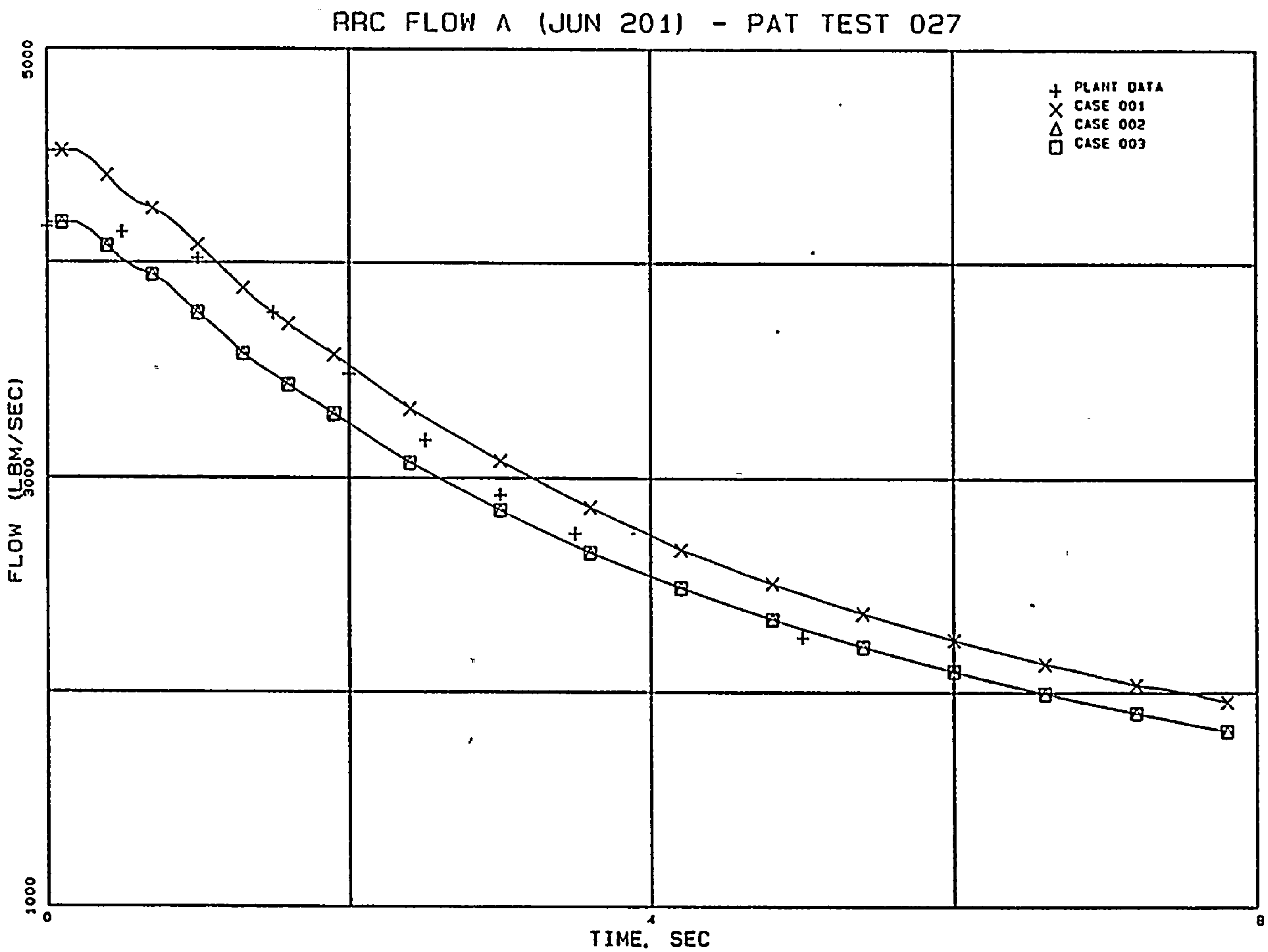

WNP-2 RETRAN MODEL
ACTIVE CORE REGION
(24 NODES)
xx Volume Number
yy Junction Number
zz Heat Conductor Number
nn Neutronics Region Number
Core outlet
Core inlet

Figure 1



POWER - PAT TEST 027
PLANT DATA
CASE 001
CASE 002
CASE 003
NORMALIZED POWER
0.8
0.4
0.0
0
4
8
TIME, SEC

Figure 2



RRC FLOW A (JUN 201) - PAT TEST 027
PLANT DATA
CASE 001
CASE 002
CASE 003
FLOW (LBM/SEC)
5000
3000
1000
0
4
8
TIME, SEC

Figure 3

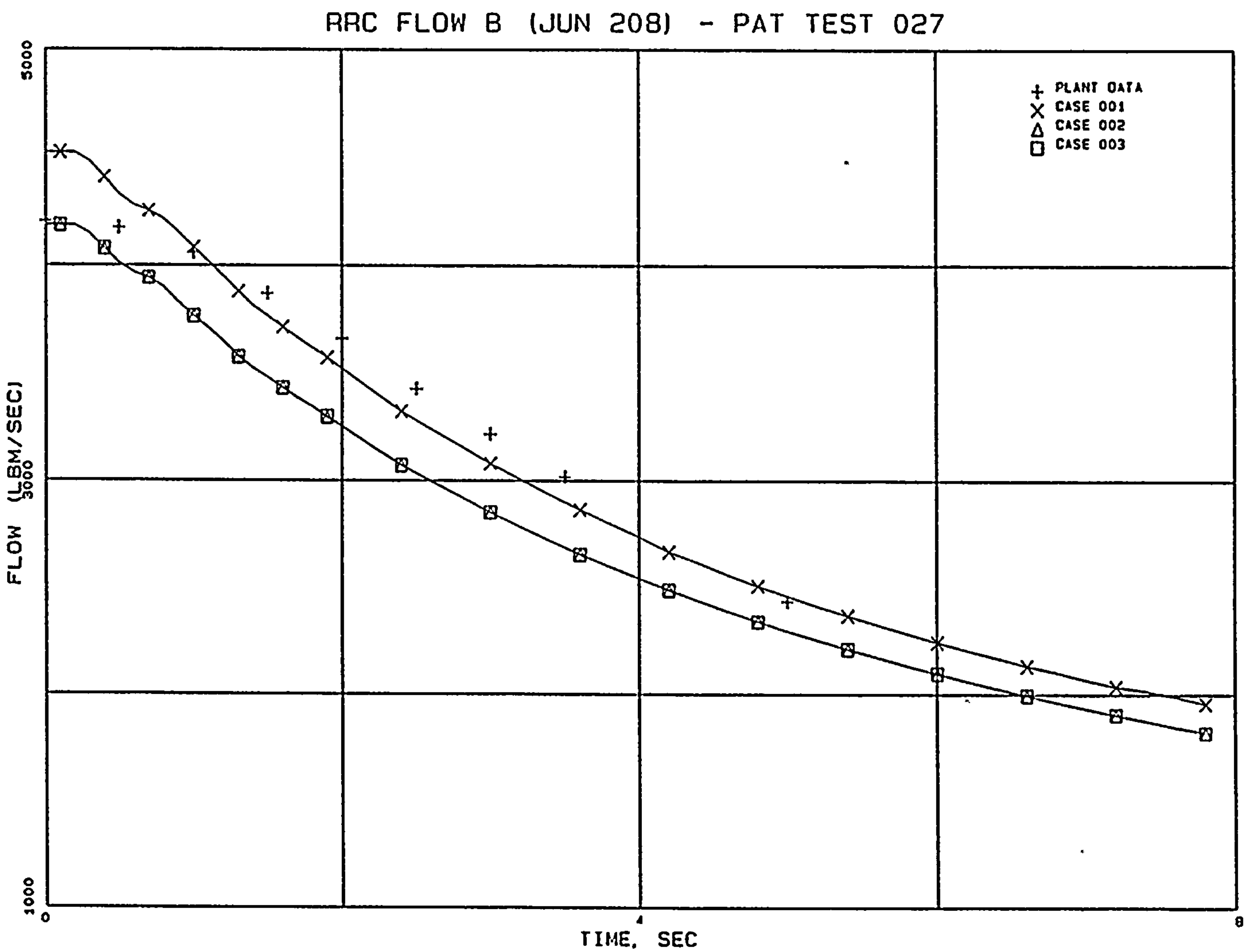

RRC FLOW B (JUN 208) - PAT TEST 027
PLANT DATA
CASE 001
CASE 002
CASE 003
FLOW (LBM/SEC)
5000
3000
1000
0
4
8
TIME, SEC

Figure 4

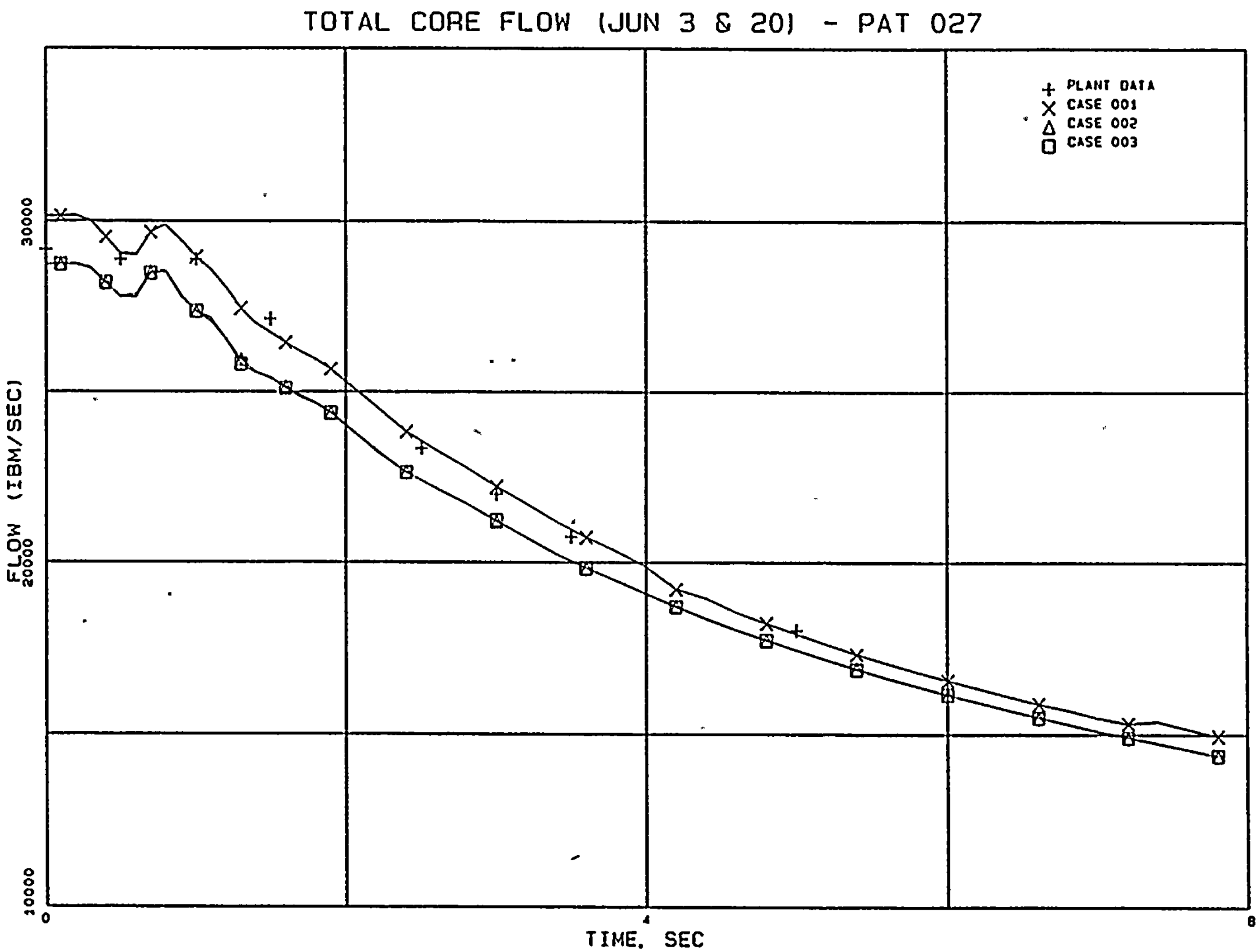

TOTAL CORE FLOW (JUN 3 & 20) - PAT 027
PLANT DATA
CASE 001
CASE 002
CASE 003
FLOW (IBM/SEC)
30000
20000
10000
0
4
8
TIME, SEC

Figure 5

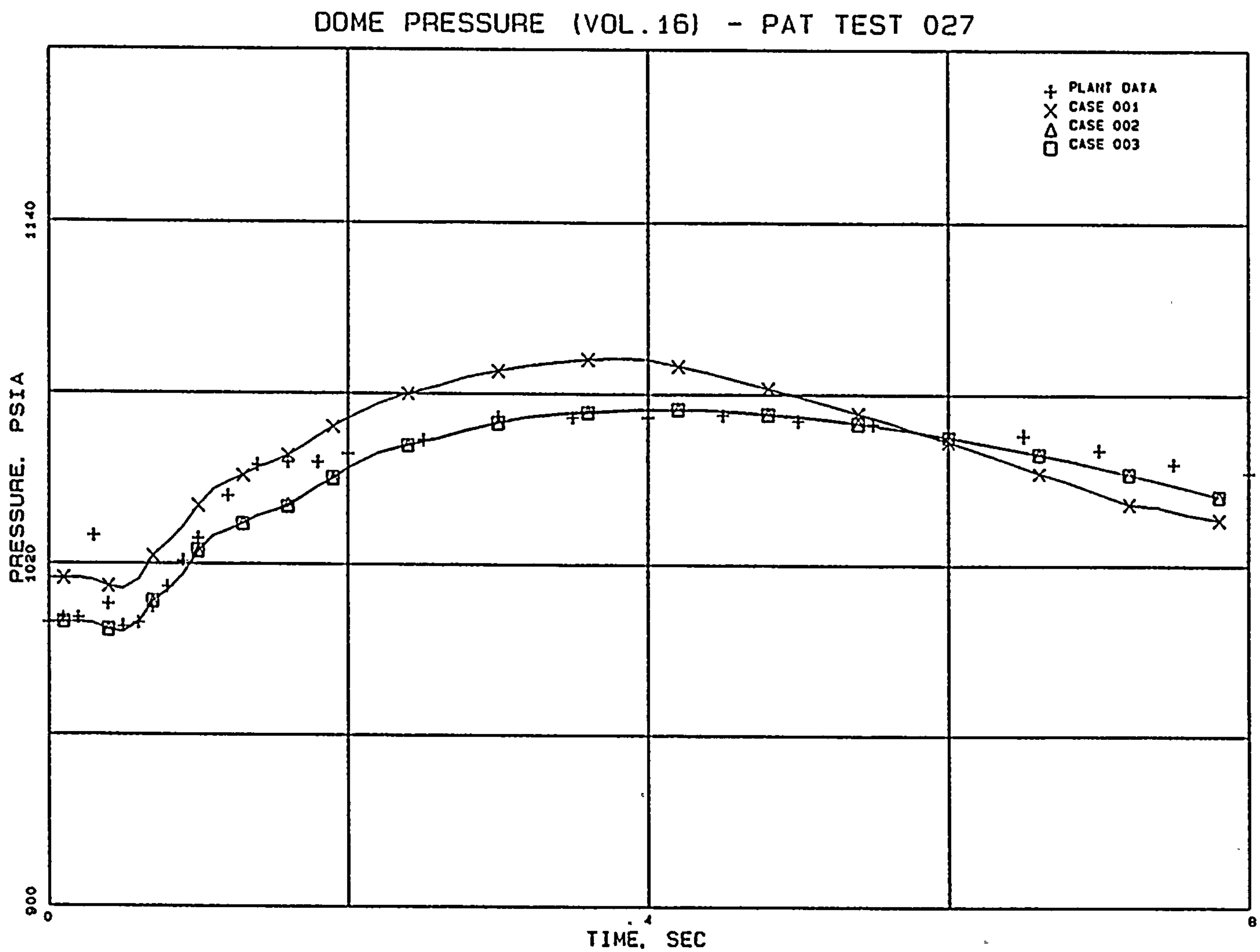
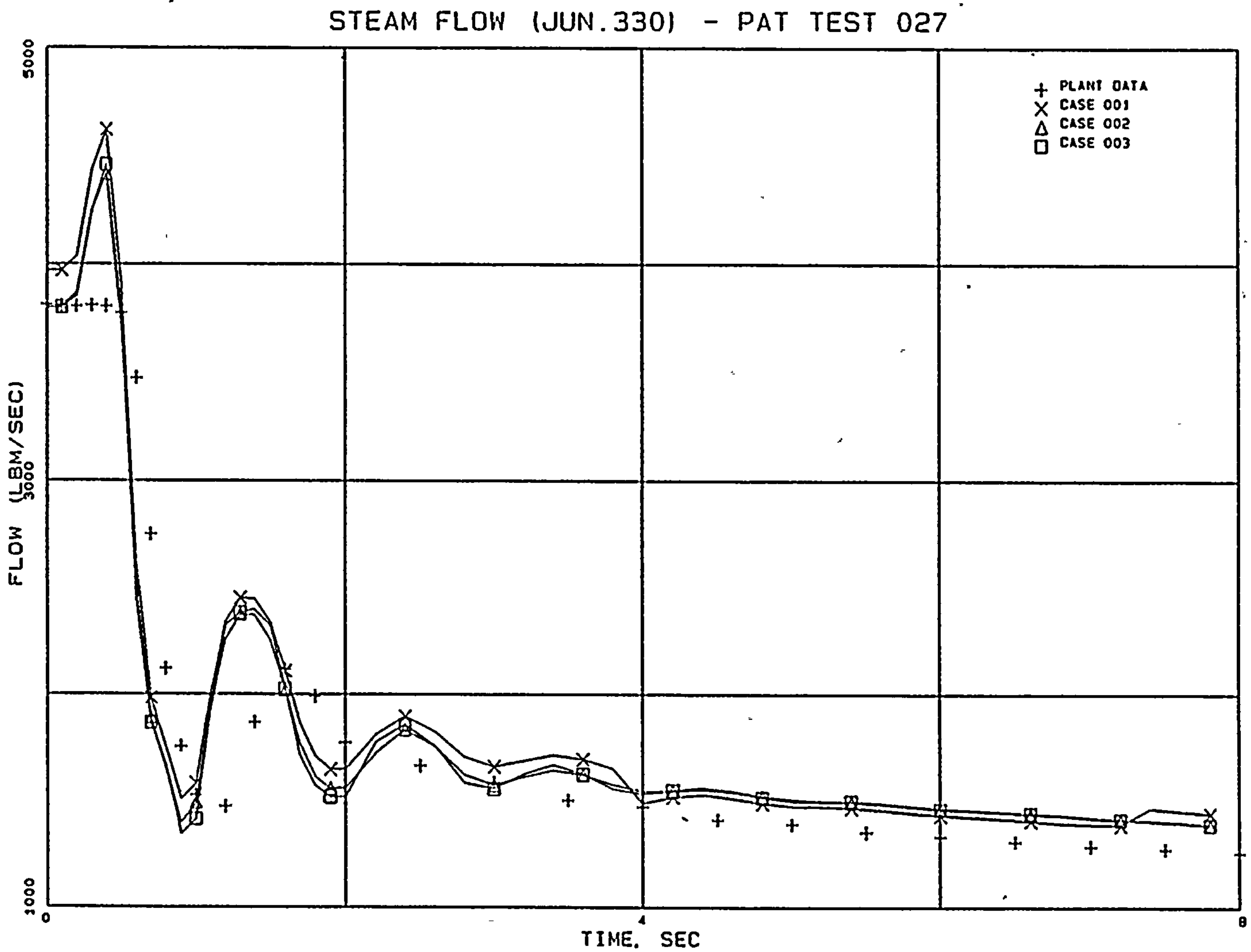

DOME PRESSURE (VOL.16) - PAT TEST 027
PLANT DATA
CASE 001
CASE 002
CASE 003
PRESSURE, PSIA
1140
1020
900
0
4
8
TIME, SEC

Figure 6



STEAM FLOW (JUN.330) - PAT TEST 027
PLANT DATA
CASE 001
CASE 002
CASE 003
FLOW (LBM/SEC)
5000
3000
1000
0
4
8
TIME, SEC

Figure 7

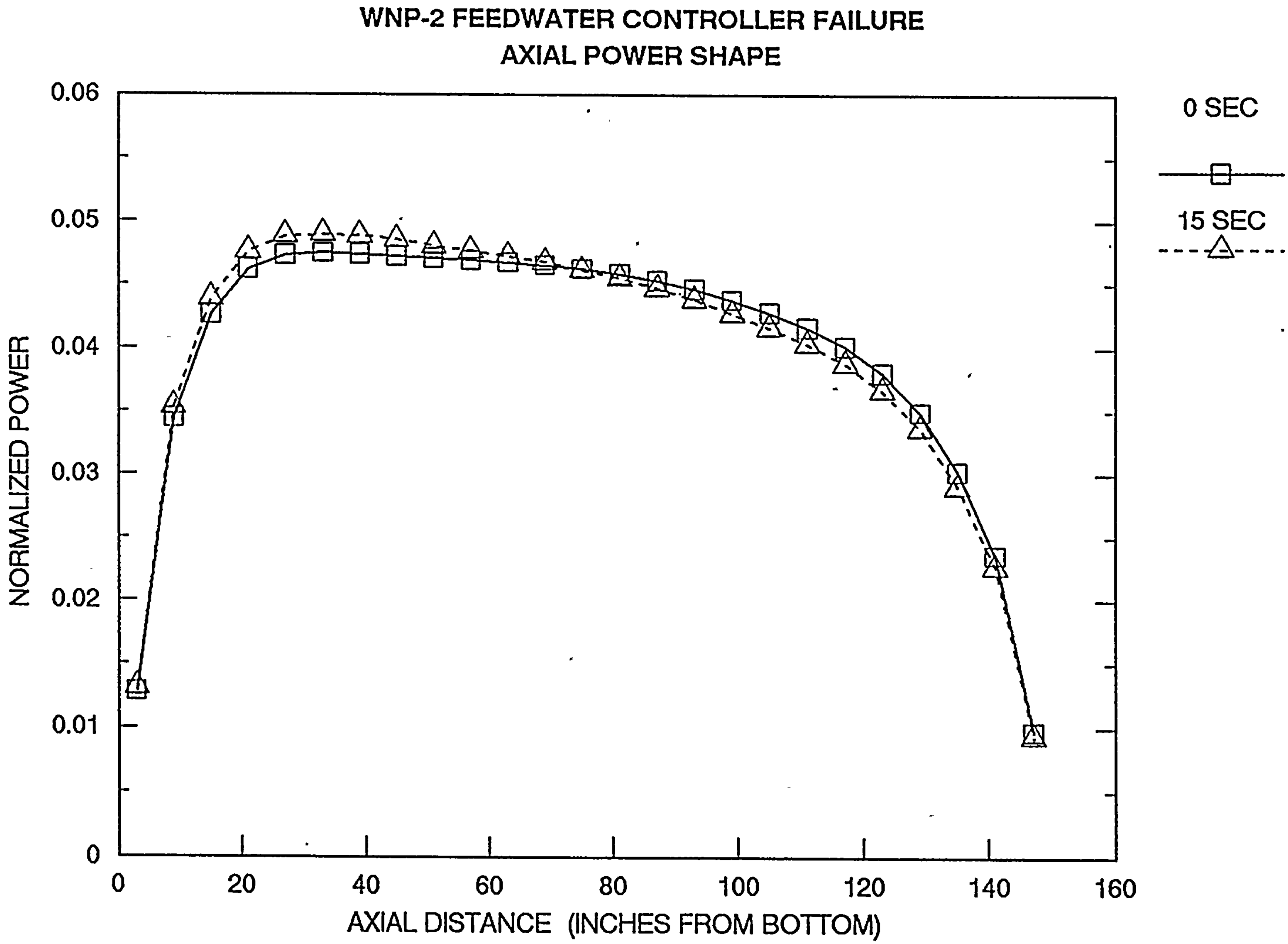
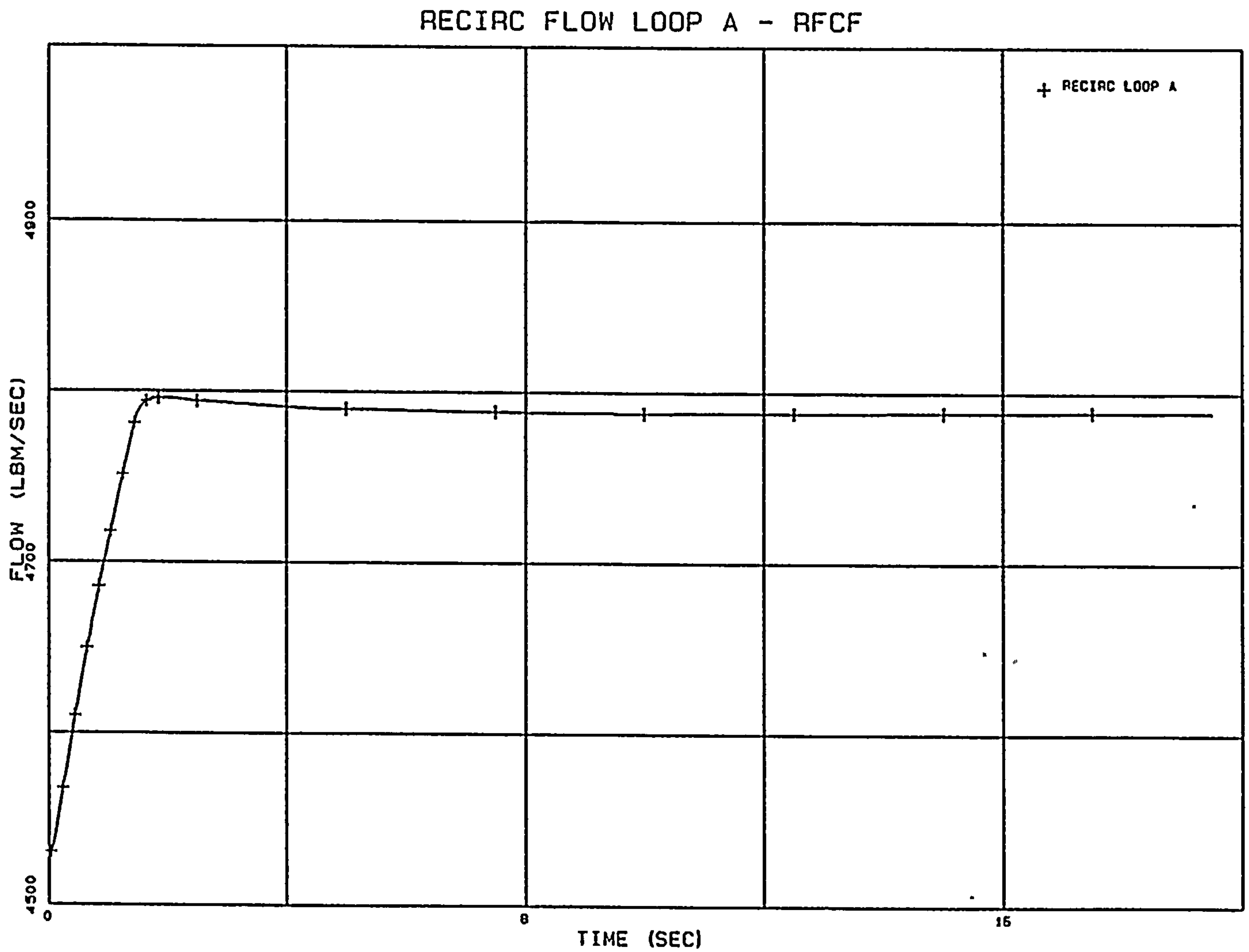

WNP-2 FEEDWATER CONTROLLER FAILURE
AXIAL POWER SHAPE
NORMALIZED POWER
0.06
0.05
0.04
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
AXIAL DISTANCE (INCHES FROM BOTTOM)
0 SEC
15 SEC

Figure 8



RECIRC FLOW LOOP A - RFCF
RECIRC LOOP A
FLOW (LBM/SEC)
4900
4700
4500
0
8
15
TIME (SEC)

Figure 9

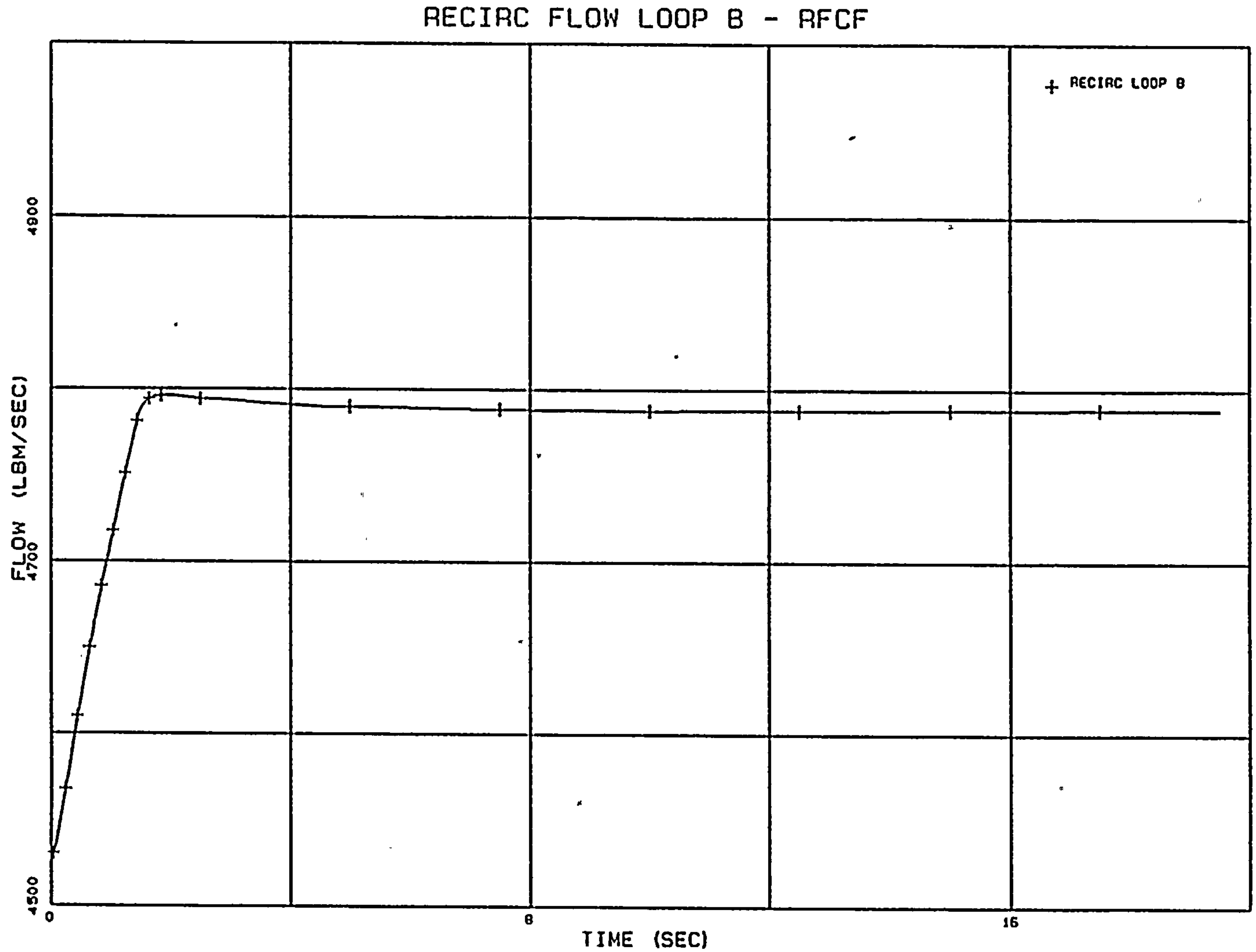

RECIRC FLOW LOOP B - RFCF
+ RECIRC LOOP B
FLOW (LBM/SEC)
4900
4700
4500
0
8
16
TIME (SEC)

Figure 10

TOTAL CORE FLOW - RFCF

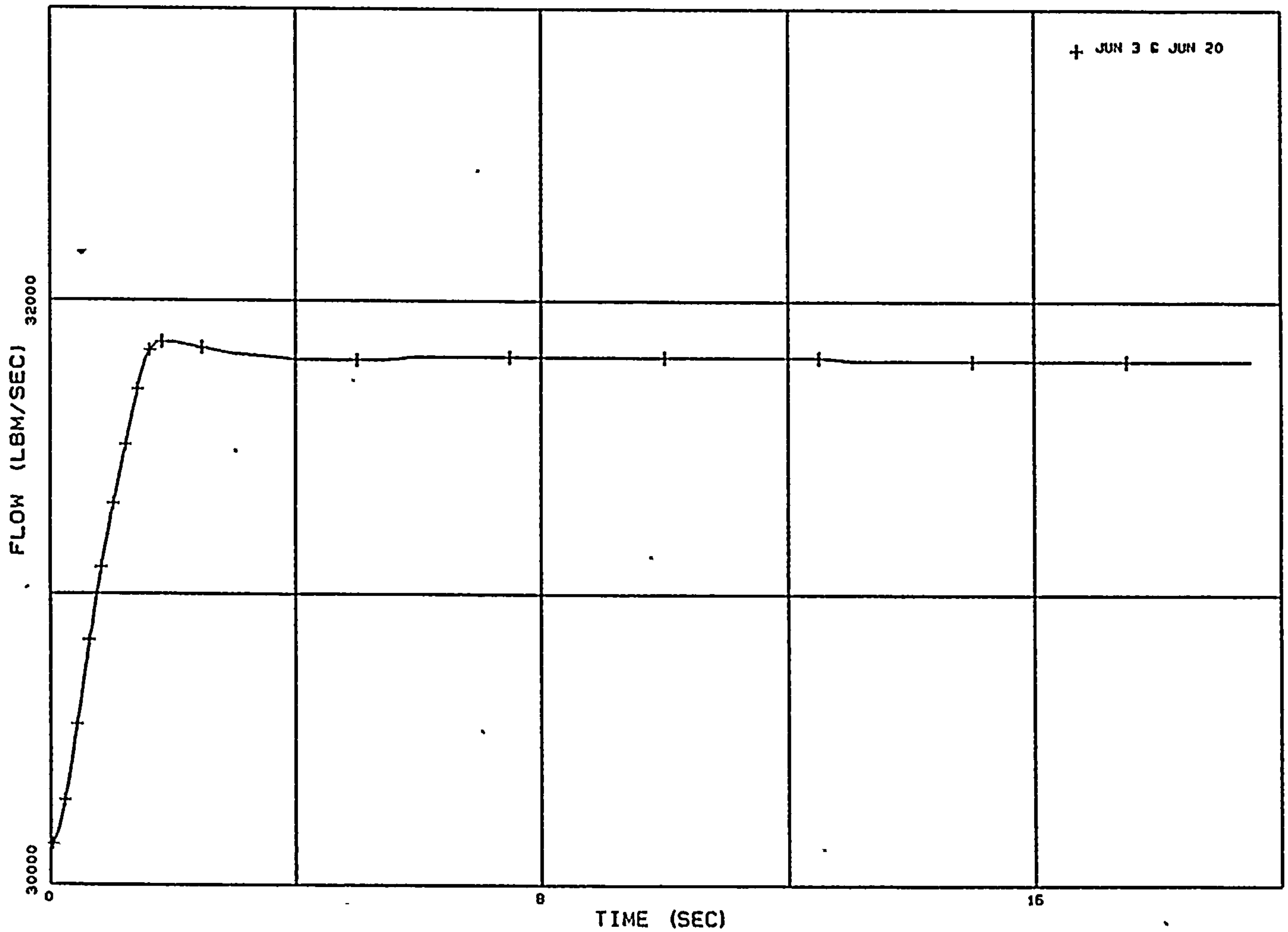
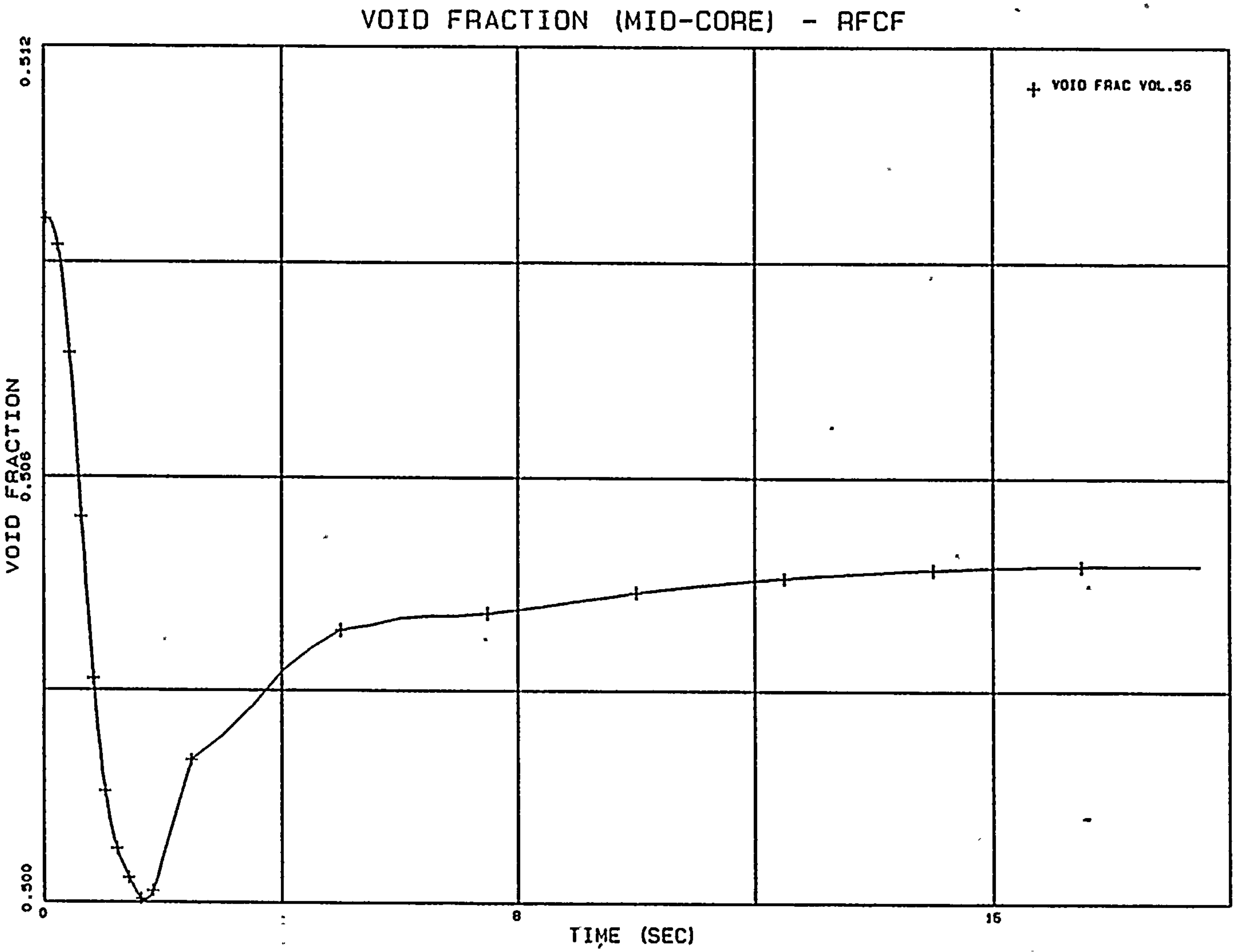
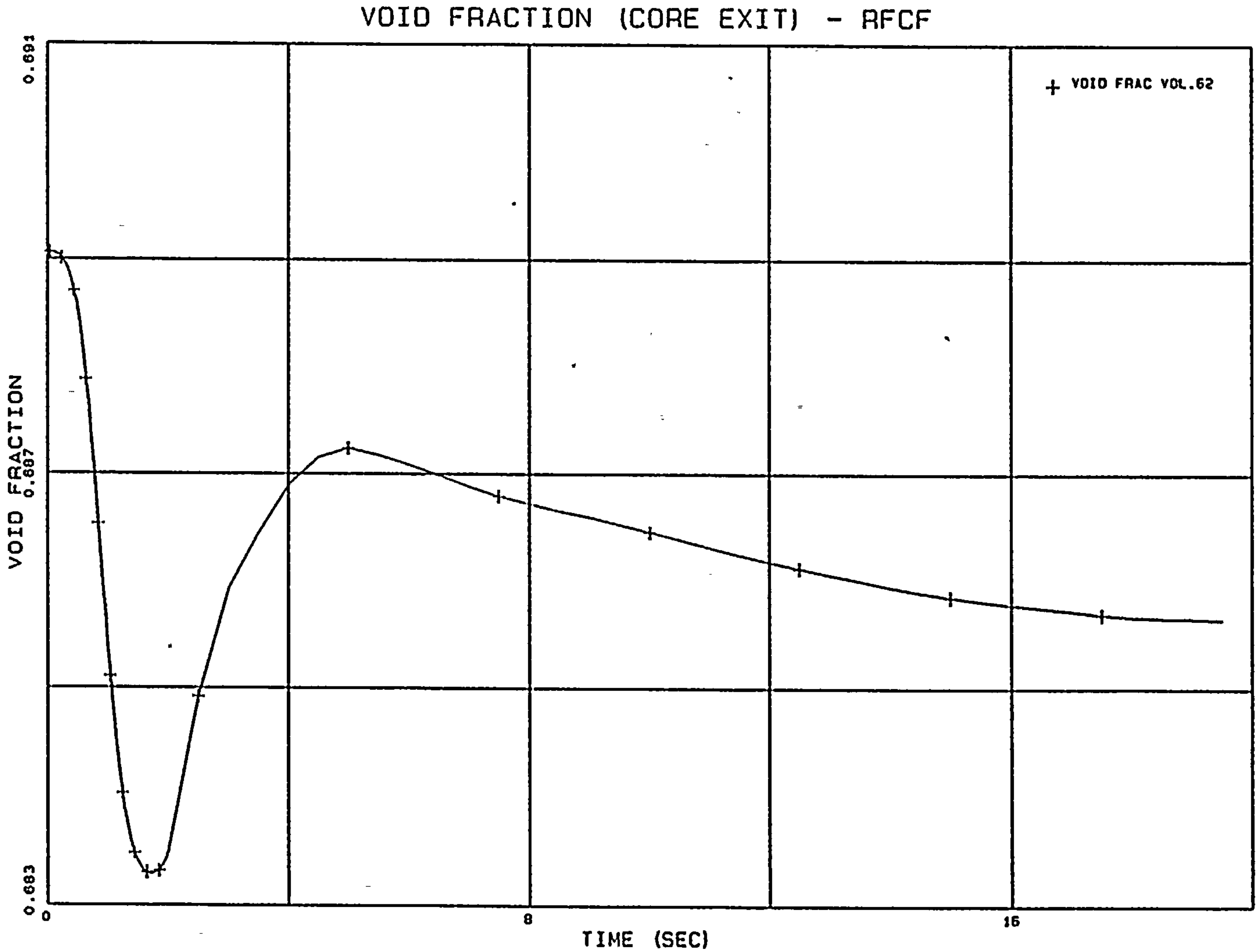


Figure 11



VOID FRACTION (MID-CORE) - RFCF
VOID FRAC VOL.56
VOID FRACTION
0.512
0.506
0.500
0
8
16
TIME (SEC)

Figure 12



VOID FRACTION (CORE EXIT) - RFCF
VOID FRAC VOL.62
VOID FRACTION
0.691
0.687
0.683
0
8
16
TIME (SEC)

Figure 13

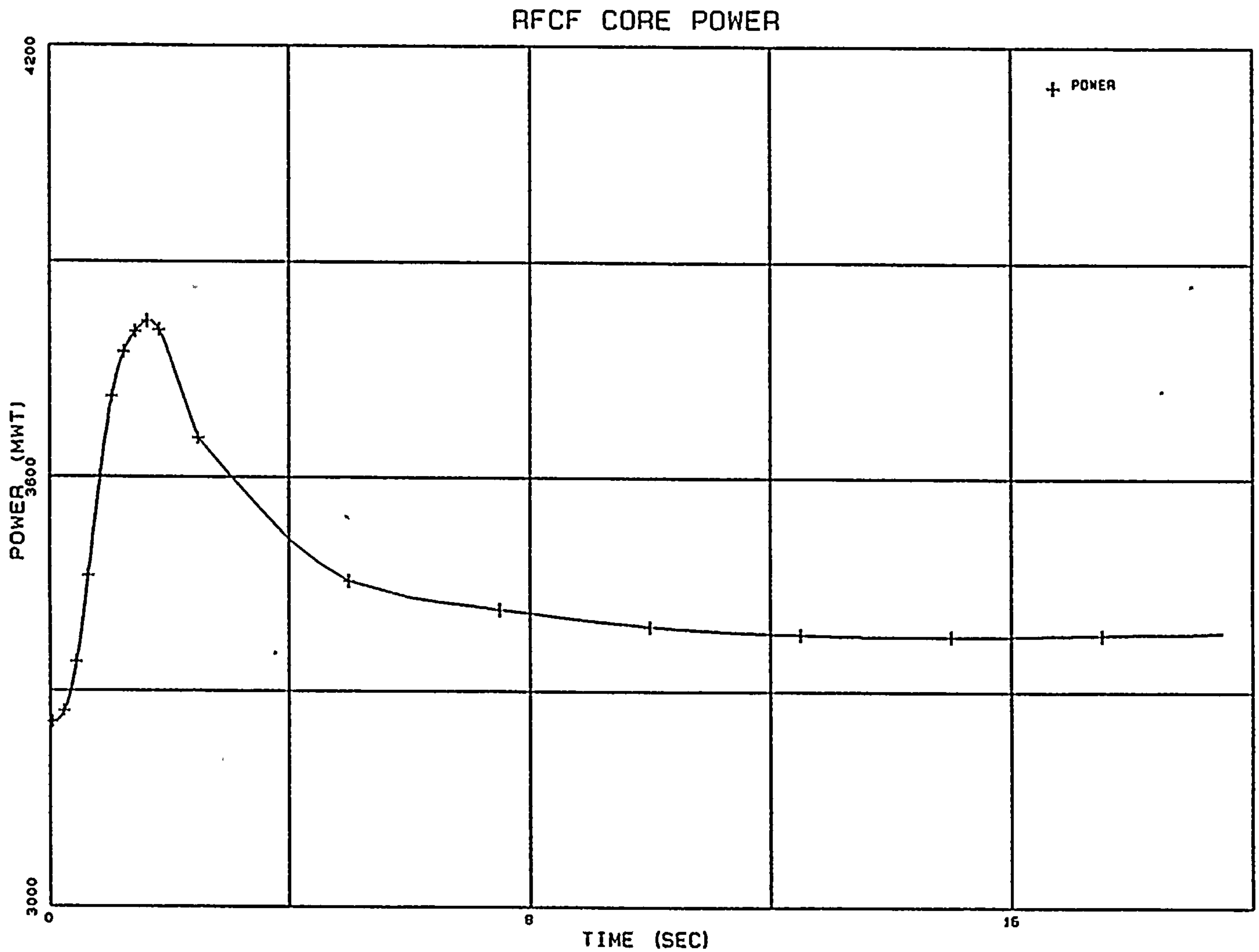


Figure 14

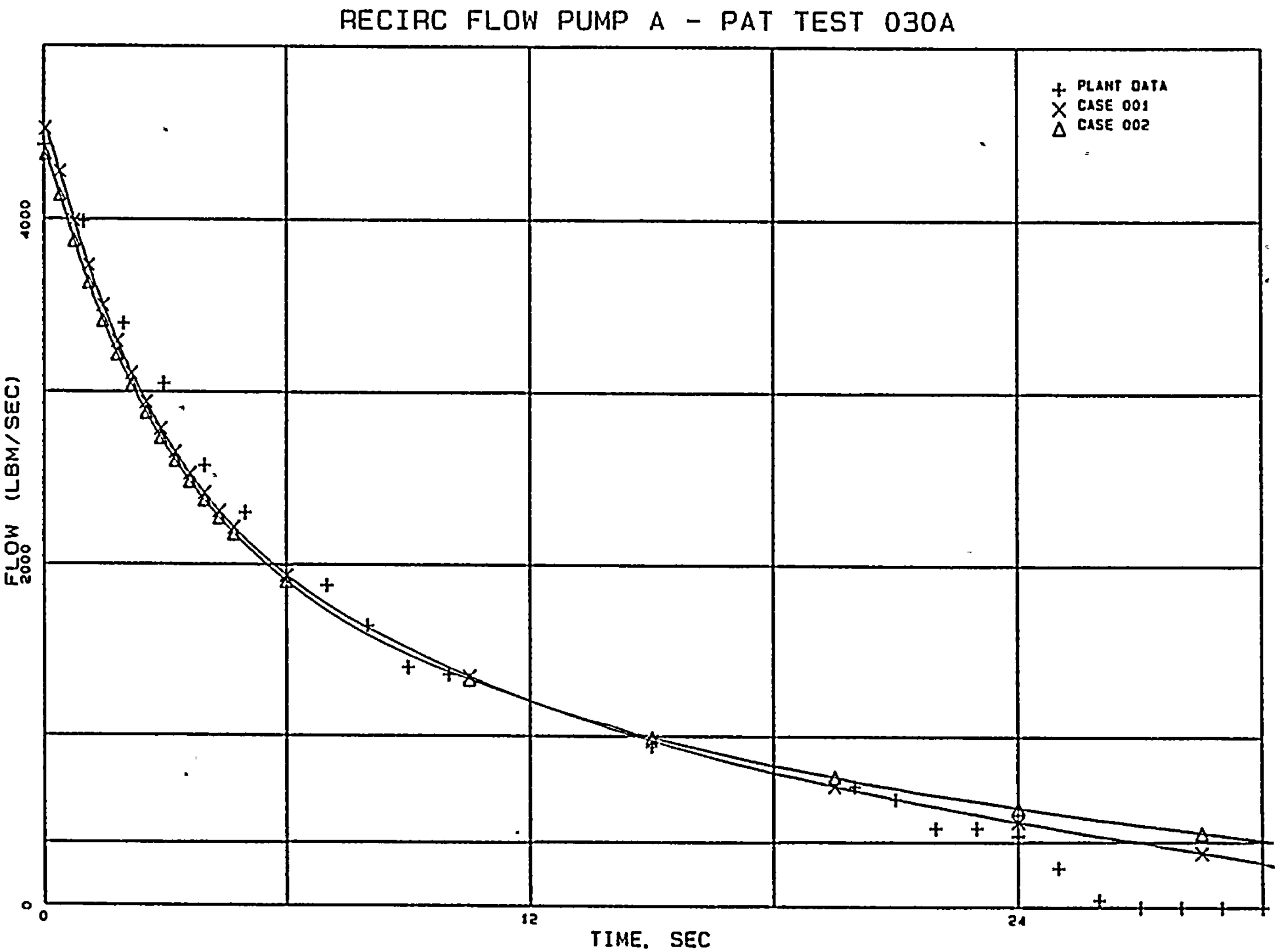

RECIRC FLOW PUMP A - PAT TEST 030A
PLANT DATA
CASE 001
CASE 002
FLOW (LBM/SEC)
4000
2000
0
TIME, SEC
0
12
24

Figure 15

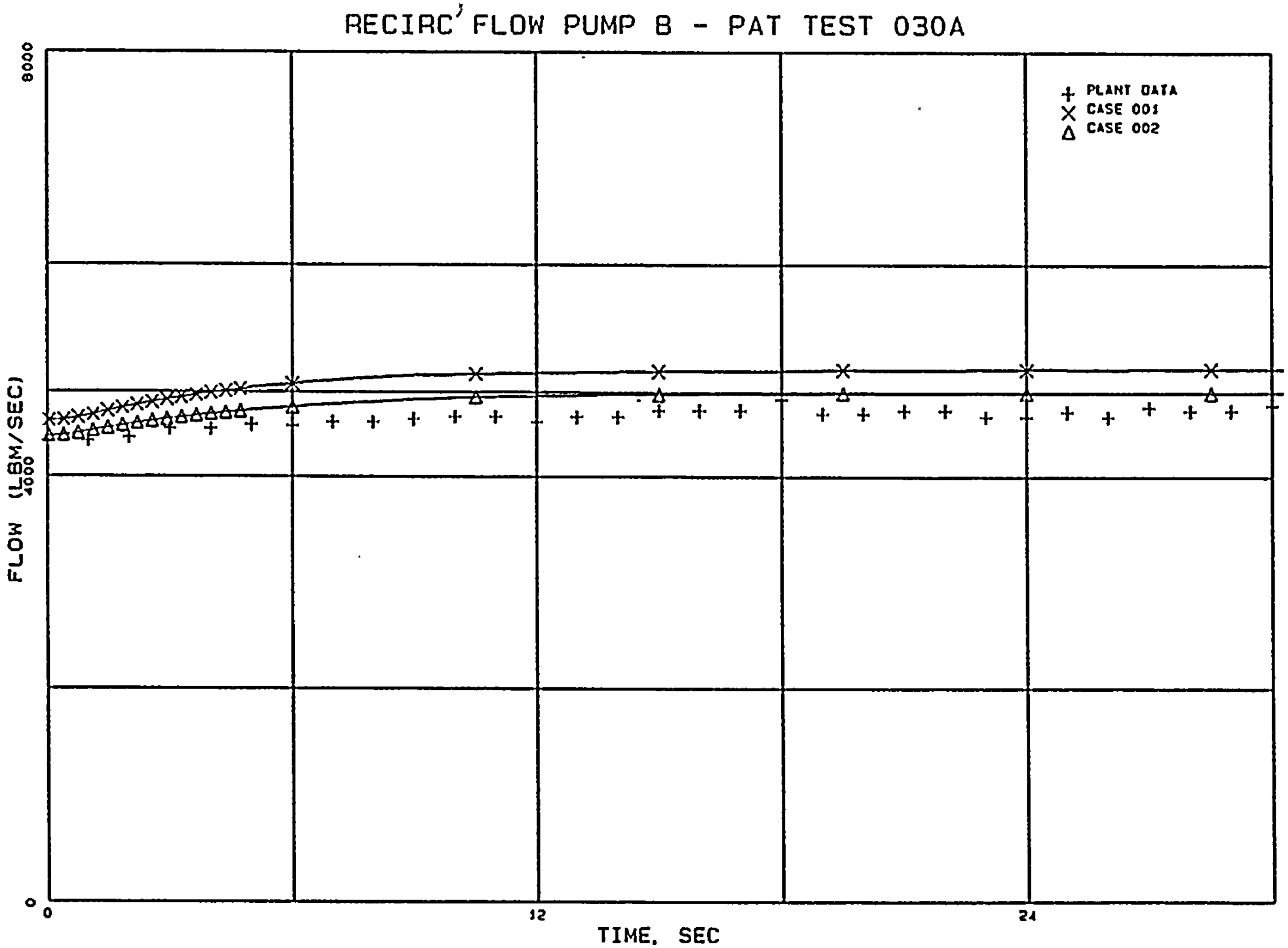

RECIRC FLOW PUMP B - PAT TEST 030A
PLANT DATA
CASE 001
CASE 002
FLOW (LBM/SEC)
8000
4000
0
TIME, SEC
12
24

Figure 16

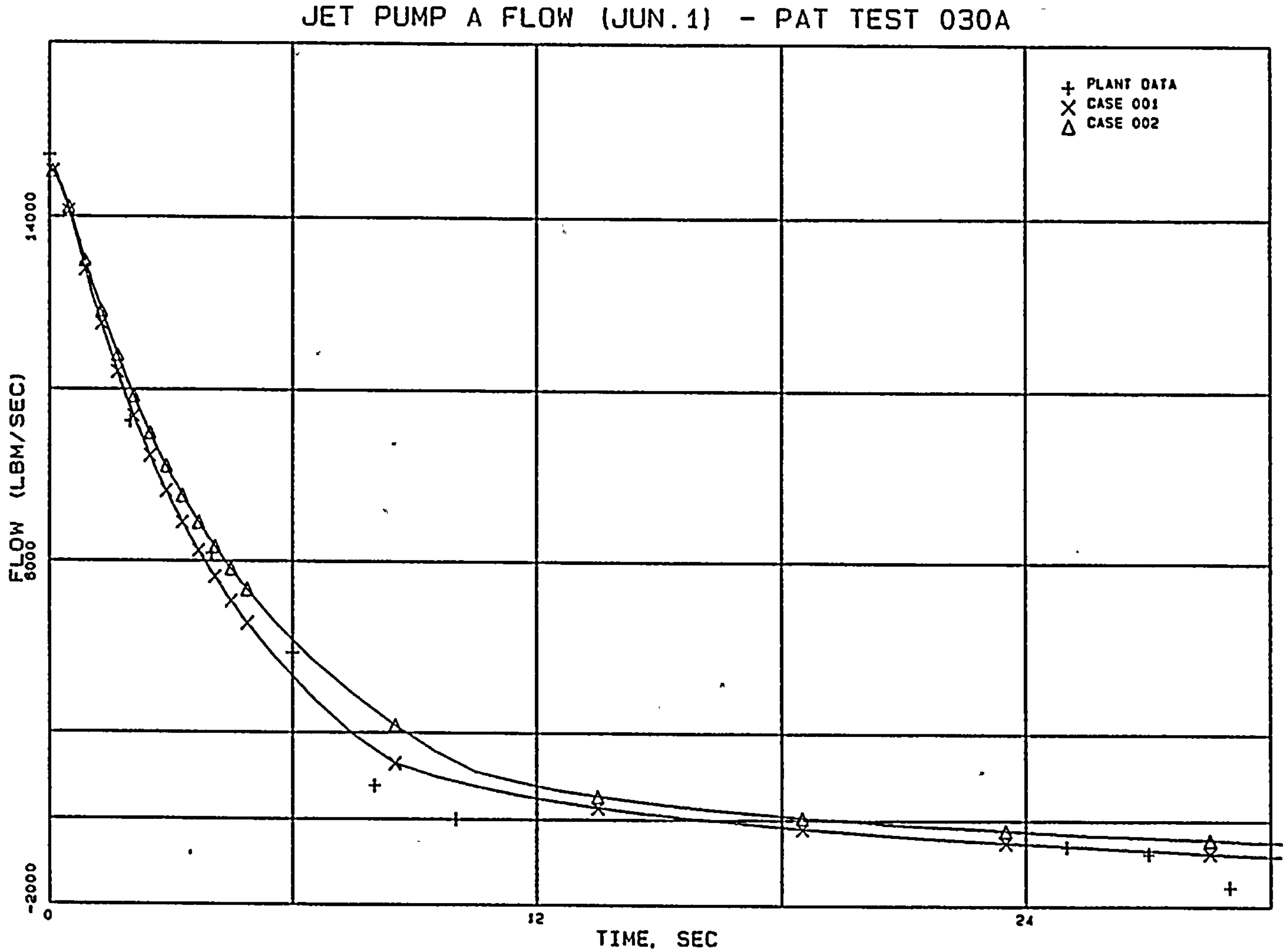
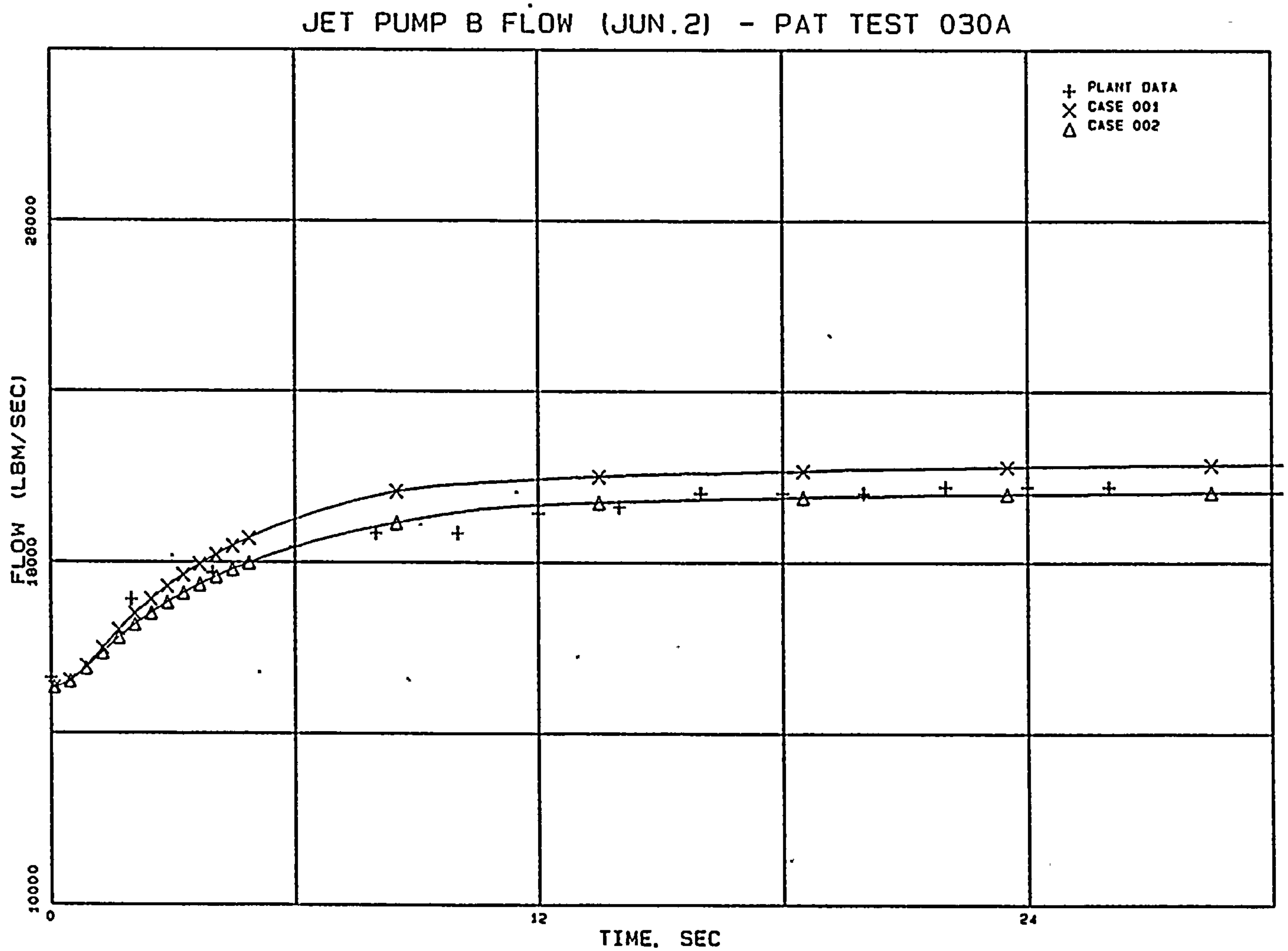
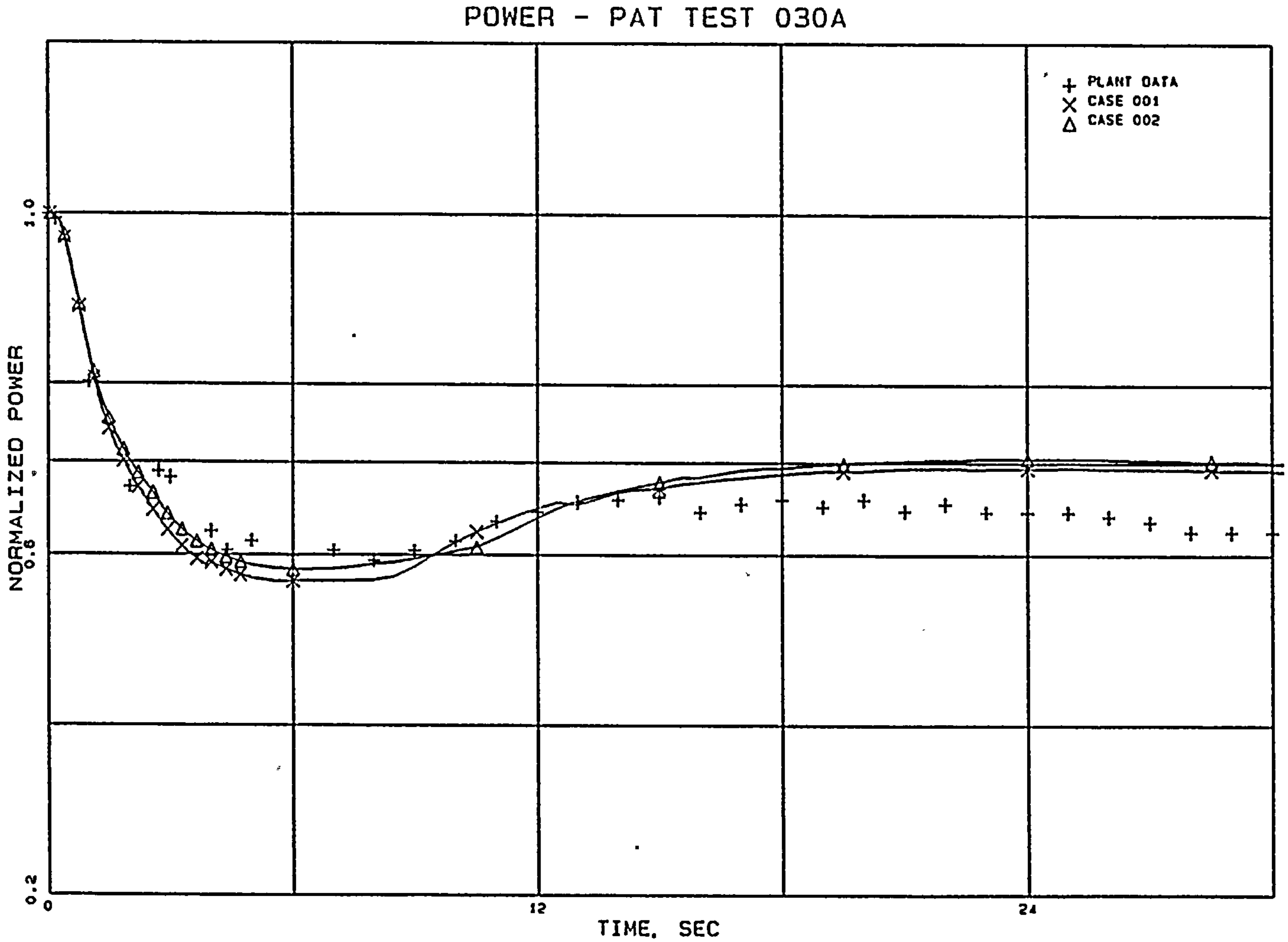

JET PUMP A FLOW (JUN.1) - PAT TEST 030A
PLANT DATA
CASE 001
CASE 002
FLOW (LBM/SEC)
14000
8000
-2000
0
12
24
TIME, SEC

Figure 17



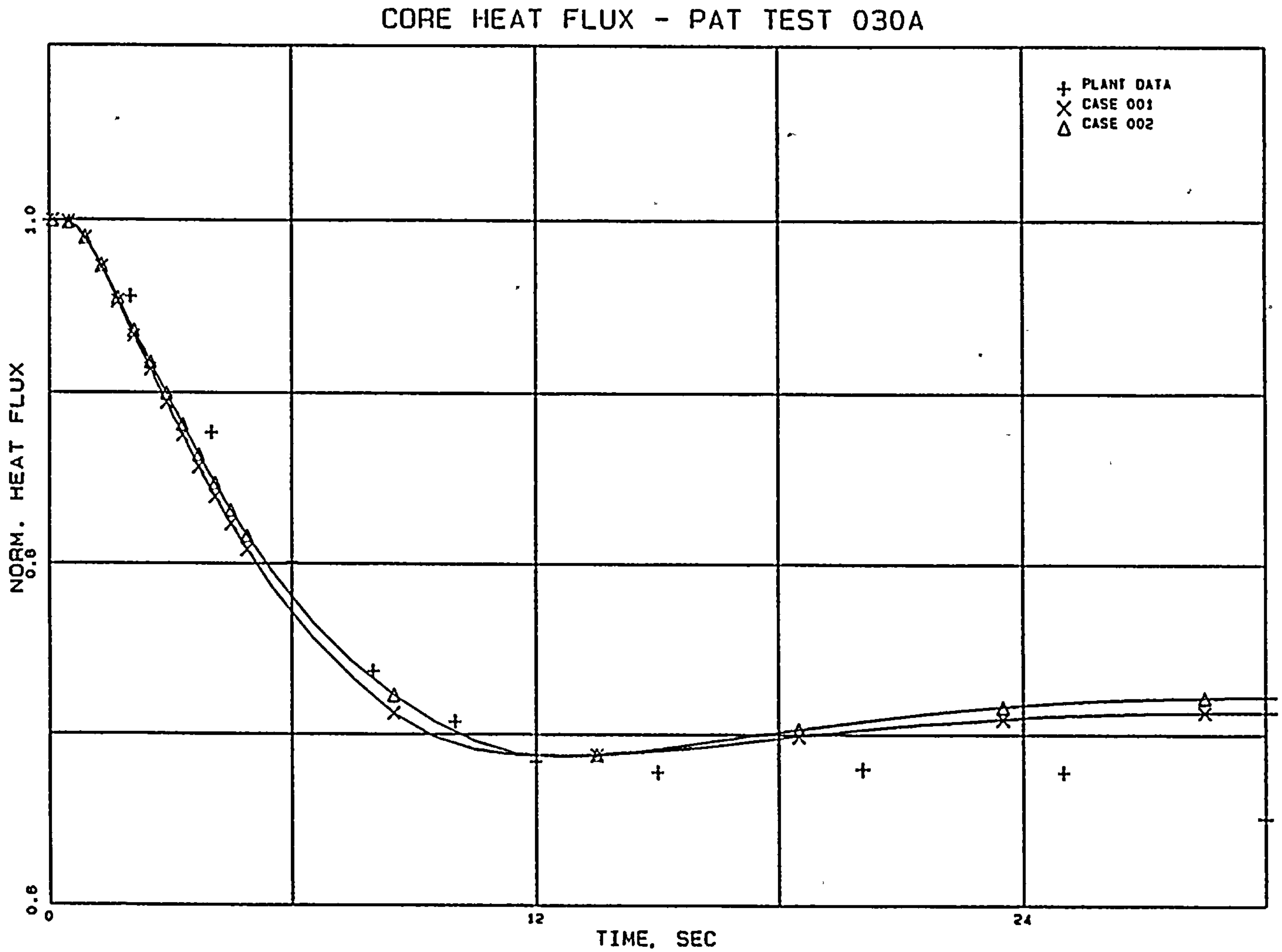
JET PUMP B FLOW (JUN.2) - PAT TEST 030A
PLANT DATA
CASE 001
CASE 002
FLOW (LBM/SEC)
28000
18000
10000
0
12
24
TIME, SEC

Figure 18



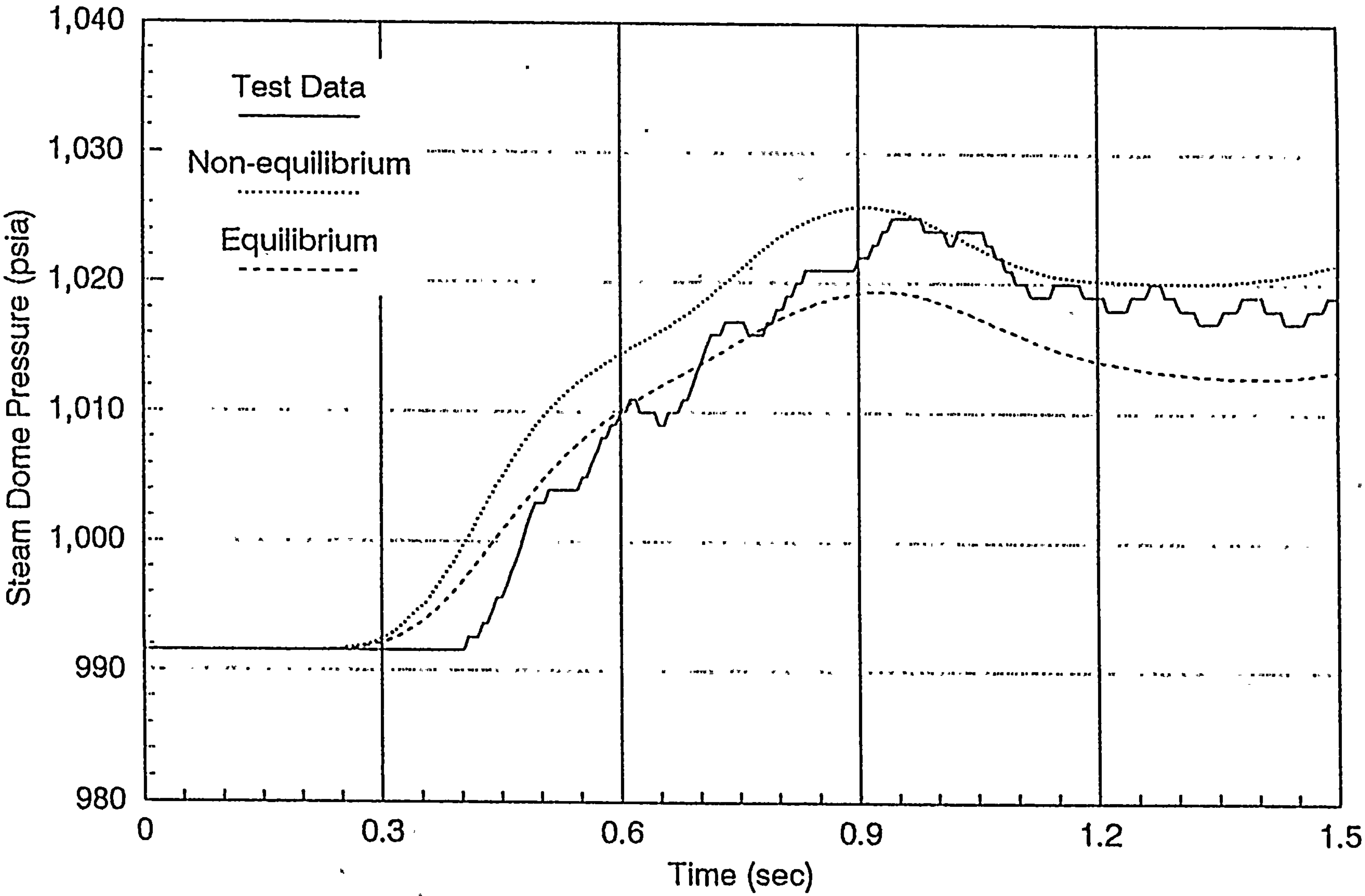
POWER - PAT TEST 030A
PLANT DATA
CASE 001
CASE 002
NORMALIZED POWER
1.0
0.6
0.2
0
12
24
TIME, SEC

Figure 19



CORE HEAT FLUX - PAT TEST 030A
PLANT DATA
CASE 001
CASE 002
NORM. HEAT FLUX
1.0
0.8
0.6
0
12
24
TIME, SEC

Figure 20



Steam Dome Pressure Comparison,
PB2 TT1 Test

Figure 21

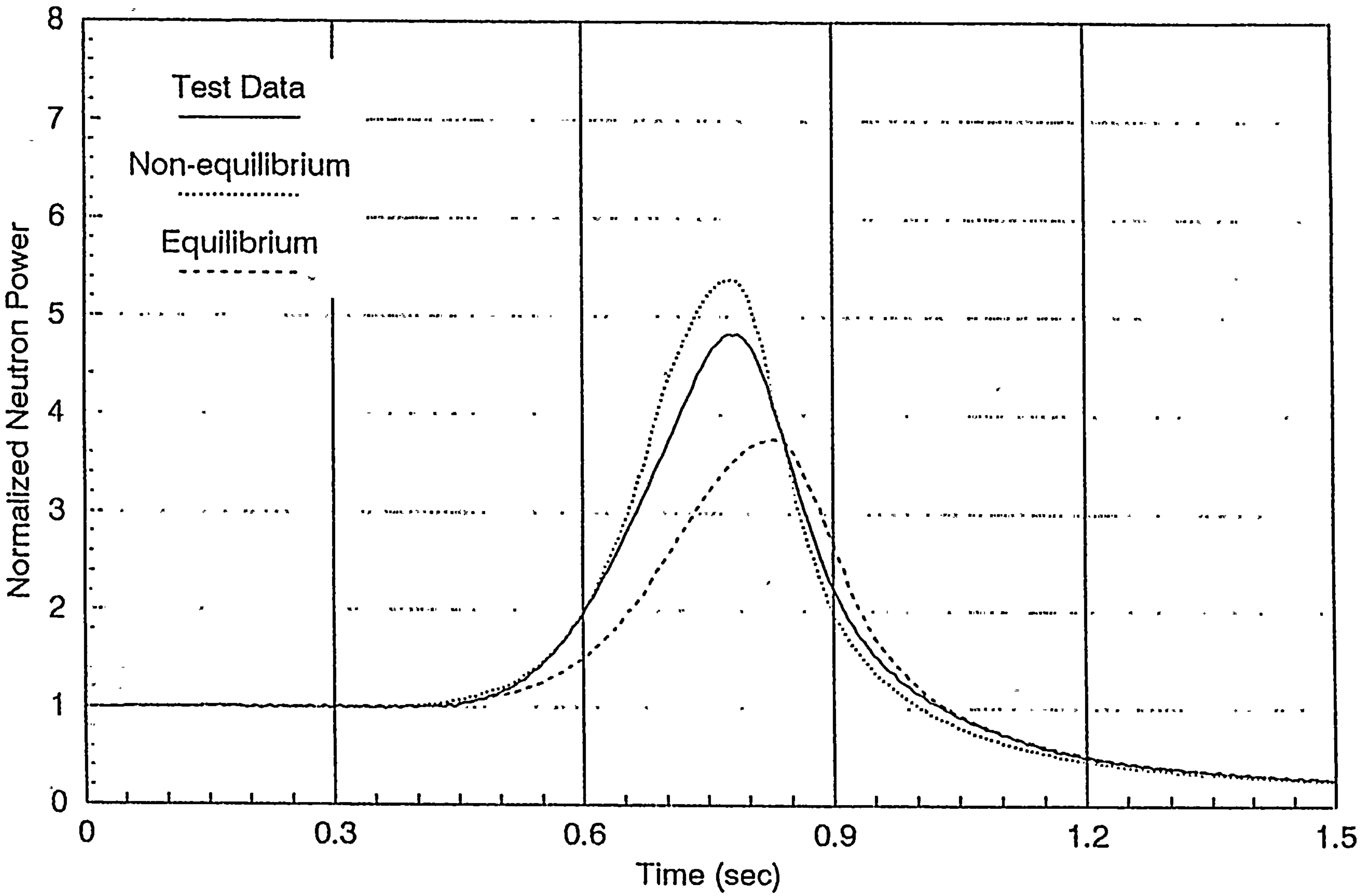
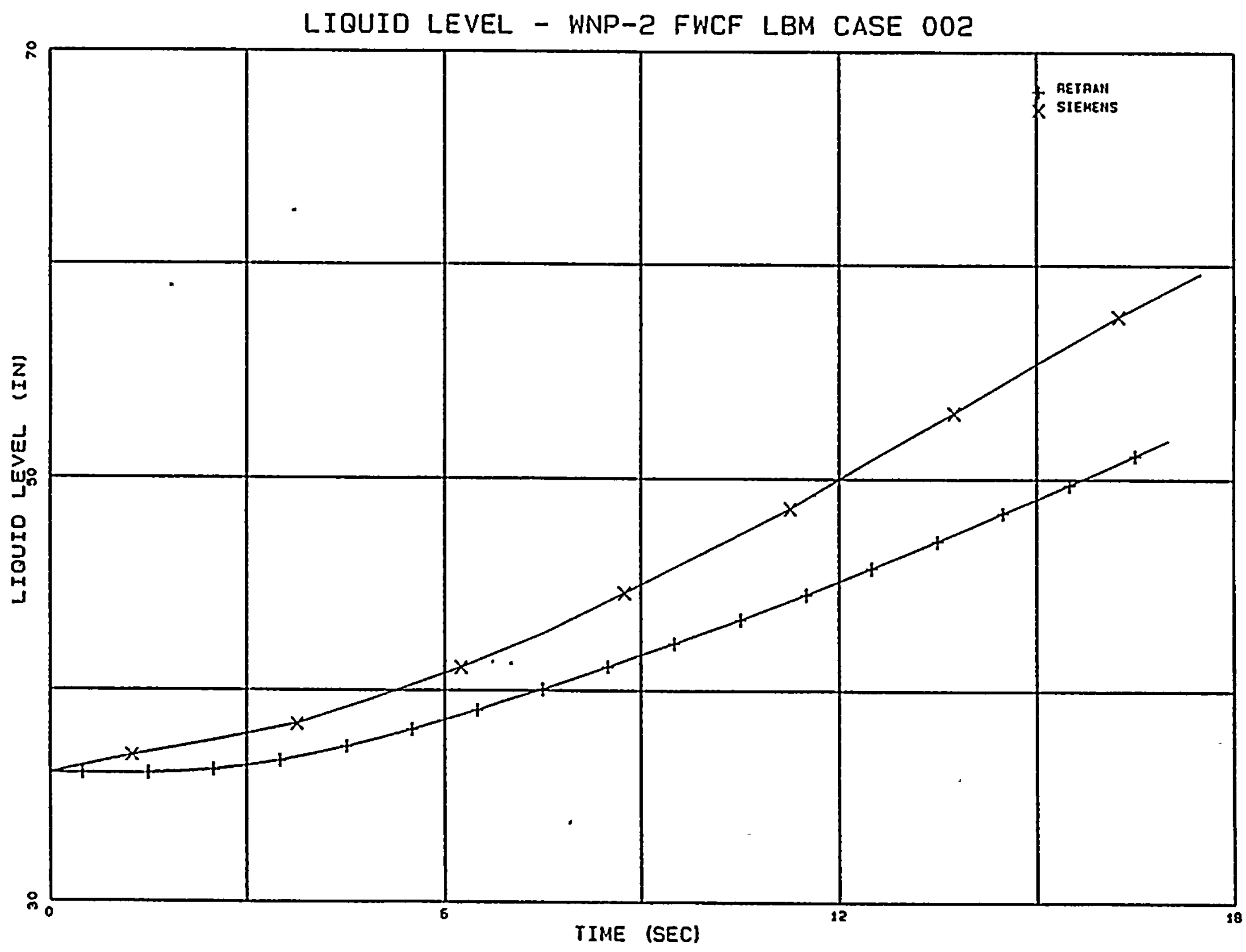


Figure 1. Core Neutron Power Comparison, PB2 TT1 Test

Figure 22



LIQUID LEVEL - WNP-2 FWCF LBM CASE 002
RETRAN
SIEMENS
LIQUID LEVEL (IN)
70
50
30
0
6
12
18
TIME (SEC)

Figure 23

APPENDIX A

VERIFICATION AND VALIDATION
OF
IBM RISC6000 VERSION OF RETRAN (RETRAN02 MOD5UEM)

Version MOD5UEM is basically an adaptation of RETRAN02 MOD005.0, which has received NRC approval, to UNIX-based workstations. In the RETRAN-02 MOD005.0 code, the source code is written in FORTRAN 77 and the routines in the environmental library are written in FORTRAN and assembly or machine language code. The integer variables in the FTB arrays are single precision vectors that are set equivalent to real variables in the FTB files. This code compiles directly on CDC computers that have a 60-bit word structure. On IBM mainframe computers, the RETRAN coding is treated as a double precision code to overcome the limitations of inaccuracy due to arithmetic round-off associated with single precision, 32-bit words. This double precision version is obtained by invoking the "autodbl" option of the IBM FORTRAN 77 compiler. This feature elevates data constants to double precision, selects the double precision form for intrinsic functions, and provides automatic padding of the integer variables in the FTB arrays so that word alignment problems are not encountered.

The RETRAN-03 computer program was under development in 1989 and that code was written totally in FORTRAN 77. This feature was a design objective of the overall development program and was undertaken to provide single source code that could be installed on a variety of computers with minimum changes. Mainframe computers, workstation computers, and IBM compatible microcomputers were all considered to be potential computers on which RETRAN-03 would be used. The requirements that were placed on the operating systems were that they comply with ANSI Standard FORTRAN 77 and that they support either 60-bit or 64-bit word structure.

The progress of this aspect of the RETRAN-03 development effort was demonstrated to be successful by the various users in the prerelease checkout activities and in late 1989, EPRI began the process to provide a similar version of RETRAN-02 for the RETRAN Maintenance Group. It relied mainly on the experiences of the RETRAN-03 work. The version of RETRAN-02 that was sent to the Supply System from EPRI (designated MOD5UEM) had been developed as an interim version in the process of moving from RETRAN-02 MOD005.0 to a version of MOD005.0 that was completely compliant with FORTRAN 77 and that could be readily installed on a variety of computers.

The changes made to the MOD005.0 code that were in the version sent to the Supply System are of two types:

- Those associated with providing an environmental library written

in FORTRAN 77

- Those associated with providing a general source code for 32 bit computers

The changes associated with the library were made to library routines and to some routines in the RETRAN source code that interact with the library routines during input and output processing. The functionality of the library routines was not changed. The changes in the source code associated with the integer padding and the intrinsic functions were made in a general manner that would permit the code to be installed on various 32-bit computers provided that double precision features were implemented. Other modifications of this nature included changes to format statements and the method of handling hollerith characters.

The ten sample problems in the standard RETRAN distribution package (Reference A-1) were run on the IBM RISC6000 workstation using the MOD5UEM version. The combination of these ten cases covers all of the important modeling features in the RETRAN02 code (cf. Reference A-1).

Key parameters as recommended by the RETRAN developer (Ref. A-2) were selected to ensure that the comparisons would adequately reflect the accuracy of the entire simulation in each sample case The values calculated by Version MOD5UEM were compared to the values given in Ref. A-1 which were based on the NRC-approved RETRAN02 MOD005.0. The comparison results are given below.

For Standard Problem One, six parameters were selected. They are given in Table A-1. Parameter "Time" is not a comparison parameter. The last time step is used for all sample problem comparisons. It would reflect the largest error between the two versions because of the cumulative effects. It should be noted that Ref. A-2 listed void fractions instead of the average densities for Volumes 2, 5, and 8. Since void fractions from the MOD005.0 run in Ref. A-1 are not listed, the related parameter of average density is used.

For the Eight Volume Sample Problem, six parameters were selected. The comparison is given in Table A-2. Again, due to unavailability of the temperature for heat conductor 20 node 3 in the RETRAN MOD005.0 manual (Ref. A-1), the surface temperature is compared.

For Standard Problem Five, five parameters were selected. They are given in Table A-3. For the Standard Problem Four, seven parameters were selected (see Table A-4). For Turbine Trip without Bypass with Point Kinetics, 12 parameters were selected (see Table A-5). For Uncontrolled Rod Withdrawal, 10 parameters were selected (see Table A-6). For Two-Dimensional Flow Field, 6 parameters were selected (see Table A-7). For Secondary System Sample Problem, 5 parameters were selected (see Table A-8). For Turbine Trip without Bypass with Space-Time Kinetics, 8 parameters were selected (see Table A-9).

For PWR ATWS Sample Problem, 12 parameters were selected (see Table A-10). The control block outputs (COUT 1, -2 and -1) and the liquid region mass and temperature and vapor region temperature for Volume 1 are not compared because these edits are not available in the RETRAN MOD005.0 manual (Ref. A-1).

Table A-1

Standard Problem One Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	0.465	0.465	---
Number of time steps	223	223	---
Vol.4 pressure (psia)	2.18507E1	2.18507E1	0.0
Jct.4 Flow (lb/sec)	2.13352	2.13352	0.0
Vol.2 Avg Density(lb/ft^3)	2.46875E-1	2.46875E-1	0.0
Vol.5 Avg Density(lb/ft^3)	2.73454E-1	2.73454E-1	0.0
Vol.8 Avg Density(lb/ft^3)	2.81773E-1	2.81773E-1	0.0

Table A-2

Eight Volume Sample Problem Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	0.4	0.4	---
Number of time steps	997	997	---
Heat conductor #20 surface temperature (F)	4.52738E2	4.52738E2	0.0
Vol. 201 temperature (F)	5.31412E2	5.31412E2	0.0
Vol. 131 pressure (psia)	2.23015E2	2.23015E2	0.0
Jct. 9 flow (lb/sec)	-1.05506E3	-1.05506E3	0.0
Jct. 999 flow (lb/sec)	7.74393E3	7.74393E3	0.0

Table A-3

Standard Problem Five Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	5.02	5.02	---
Number of time steps	486	486	---
Vol. 6 pressure (psia)	9.60029E2	9.60029E2	0.0
Vol.6 Avg Density(lb/ft^3)	2.32948E1	2.32948E1	0.0
Jct. 8 flow (lb/sec)	9.59106	9.59106	0.0
Jct. 9 flow (lb/sec)	4.90702	4.90702	0.0

Table A-4

Standard Problem Four Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	1.0	1.0	---
Number of time steps	422	422	---
Vol. 1 pressure (psia)	1.01149E3	1.01149E3	0.0
Vol. 11 temperature (F)	5.43824E2	5.43824E2	0.0
Jct.1 flow (lb/sec)	3.14727E1	3.14727E1	0.0
Jct. 21 flow (lb/sec)	2.57385E1	2.57385E1	0.0
Jct. 28 flow (lb/sec)	9.07339	9.07339	0.0
Jct. 32 flow (lb/sec)	9.65325	9.65325	0.0

Table A-5

Turbine Trip Without Bypass With Point Kinetics

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	2.01	2.01	---
Number of time steps	224	224	---
Vol. 10 pressure (psia)	1.17724E3	1.17724E3	0.0
Vol. 9 mixture level (ft)	4.28014	4.28015	-2.3E-4
Normalized core power	0.4739057	0.4739058	-2.1E-5
Jct. 1 flow (lb/sec)	2.05946E4	2.05946E4	0.0
Jct. 15 flow (lb/sec)	9.52889E3	9.52889E3	0.0
Jct. 16 flow (lb/sec)	2.19671E4	2.19671E4	0.0
Jct. 17 flow (lb/sec)	3.03026E3	3.03026E3	0.0
Total reactivity ($)	-1.52936	-1.52936	0.0
Void reactivity ($)	1.01524	1.01524	0.0
Doppler reactivity ($)	-0.132250	-0.132250	0.0
Control reactivity ($)	-2.41234	-2.41234	0.0

Table A-6

Uncontrolled Rod Withdrawal Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	3.05	3.05	---
Number of time steps	71	71	0.0
Vol. 1 pressure (psia)	2.26351E3	2.26351E3	0.0
Vol. 18 pressure (psia)	2.24268E3	2.24268E3	0.0
Vol. 20 pressure (psia)	8.71323E2	8.71323E2	0.0
Normalized core power	0.8291161	0.8291161	0.0
Vol. 2 temperature (F)	6.07335	6.07335	0.0
Vol. 10 temperature (F)	5.50436E2	5.50436E2	0.0
Jct. 13 flow (lb/sec)	2.73438E4	2.73438E4	0.0
Jct. 19 flow (lb/sec)	-1.41591E-2	-1.41591E-2	0.0
Jct. 21 flow (lb/sec)	1.41461E2	1.41460E2	7.1E-4

Table A-7

Two-Dimensional Flow Field Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	0.1	0.1	---
Number of time steps	663	663	0.0
Vol. 4 pressure (psia)	4.96934E2	4.96934E2	0.0
Vol. 6 pressure (psia)	4.96934E2	4.96934E2	0.0
Jct. 6 flow (lb/sec)	1.58139E1	1.58139E1	0.0
Jct. 7 flow (lb/sec)	1.58139E1	1.58139E1	0.0
Jct. 8 flow (lb/sec)	6.49958E1	6.49958E1	0.0

Table A-8

Secondary System Sample Problem Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	0.5	0.5	---
Number of time steps	745	745	0.0
Vol. 12 pressure (psia)	0.997917	0.997917	0.0
Vol. 16 pressure (psia)	9.51819E1	9.51819E1	0.0
Jct. 20 flow (lb/sec)	3.82086E3	3.82086E3	0.0
Jct. 29 flow (lb/sec)	2.24888E2	2.24888E2	0.0

Table A-9

Turbine Trip without Bypass with Space-Time Kinetics Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	1.0	1.005	---
Number of time steps	222	223	---
Normalized core power	0.6033136	0.6005210	4.6E-1
Vol. 10 pressure (psia)	1.10459E3	1.10516E3	-5.2E-2
Jct. 17 flow (lb/sec)	1.68626E3	1.68807E3	-1.1E-1
Jct. 24 flow (lb/sec)	2.59335E3	2.58640E3	2.7E-1
Vol. 9 mixture level (ft)	4.69237	4.69237	0.0
Total reactivity	-7.377669E-3	-7.480861E-3	-1.4
Rod reactivity	-1.126763E-2	-1.127351E-2	-5.2E-2

Table A-10

PWR ATWS Sample Problem Comparison

Parameter	MOD5UEM	MOD005.0	Diff. (%)
Time (sec)	150.3309	150.3309	---
Number of time steps	1211	1217	---
Vol. 34 pressure (psia)	2.31009E3	2.31441E3	-1.9E-1
Vol.34 mixture level (ft)	3.29200E1	3.29200E1	0.0
Jct. 51 flow (lb/sec)	1.33831E4	1.33855E4	-1.8E-2
Vol.51 mixture level (ft)	1.31993E-2	1.30159E-2	1.4E-2
Vol. 51 pressure (psia)	6.82093E2	6.82288E2	-2.9E-2
Vol. 51 liquid mass (lb)	4.31636E1	4.25627E1	1.4
Vol. 25 temperature (F)	6.51378E2	6.51430E2	-8.0E-3
Vol. 30 temperature (F)	6.55266E2	6.55338E2	-1.1E-2
Jct. 82 flow (lb/sec)	0.0	0.0	0.0
Jct. 89 flow (lb/sec)	-2.04578E2	-2.06070E2	-7.2E-1
Jct. 90 flow (lb/sec)	0.0	0.0	0.0

Comparison of the outputs of the sample problems between MOD005.0 and MOD5UEM indicates that they yield identical results (at least to six significant figures) for the first 8 sample problems. For Sample Problem 9 (Turbine Trip without Bypass with Space-Time Kinetics), the maximum difference is in the total reactivity (-1.4%). Since the absolute value of the total reactivity is a very small number, it is usually more sensitive to the changes made to the code or platform it is run on. For Sample Problem 10 (PWR ATWS Sample Problem), the comparison yields a maximum difference in Volume 51 liquid mass (1.4%) at the end of the 150-second simulation. This difference is apparently caused by the accumulated deviation of the calculations using different processors and operating systems. The comparisons on pressure, temperature and flow for Sample Problem 10 give much smaller differences as seen in Table A-10.

To further verify the MOD5UEM version, the most limiting transient identified in the Transient Topical Report (Ref. A-4) was run on both the MOD5UEM and MOD004 versions. The selected transient is the WNP-2 Licensing Basis Model Load Rejection Without Bypass (LRNB)

which yields the highest peak power and smallest thermal margins. The MOD004 run was made on a CDC NOS/BE operating system at Power Computing. The comparisons are given in Table A-11 and A-12.

Table A-11

Comparison of Key Parameters for
WNP-2 Load Rejection Without Bypass

Parameter	MOD5UEM	MOD004	Diff.(%)
Time	2.0	2.0	---
Number of time steps	973	973	---
Normalized core power	0.4046764	0.4035891	2.7E-1
Vol. 4 pressure (psia)	1.21450E3	1.21460E3	-8.2E-3
Vol. 11 pressure (psia)	1.20776E3	1.20784E3	-6.6E-3
Jct. 4 flow (lb/sec)	2.26415E4	2.26509E4	-4.1E-2
Vol. 4 temperature (F)	5.34560E2	5.34561E2	-1.9E-4
Vol. 11 temperature (F)	5.67760E2	5.67768E2	-1.4E-3
Jct. 310 flow (lb/sec)	3.71439E3	3.71639E3	-5.4E-2
Jct. 201 flow (lb/sec)	3.52832E3	3.53126E3	-8.3E-2
Control block -88	2.53116E1	2.53317E1	-7.9E-2
Total reactivity	-9.59095E-3	-9.640133E-3	-5.1E-1
Vol. 4 density (lb/ft^3)	4.73151E1	4.73151E1	0.0
Vol.11 density (lb/ft^3)	1.39558E1	1.39484E1	5.3E-2

Table A-12

Power History for
WNP-2 Load Rejection Without Bypass

Time into Transient (sec)	Normalized Core Power		
	MOD5UEM	MOD004	Diff. (%)
0.0	1.0	1.0	0.0
0.5	0.930005	0.930065	-6.5E-3
0.6	1.03888	1.03923	-3.4E-2
0.7	1.61492	1.61697	-1.3E-1
0.8	2.27940	2.28641	-3.1E-1
0.9	2.94521	2.96032	-5.1E-1
1.0	3.89955	3.91851	-4.8E-1
1.1	2.50341	2.50561	-8.8E-2
1.2	1.04774	1.04983	-2.0E-1
1.3	0.654647	0.655916	-1.9E-1
1.5	0.479288	0.479418	-2.7E-2
2.0	0.4046764	0.4035891	2.7E-1

The locations for the parameters given in Table A-11 may by identified using the noding diagram in the Transient Topical Report (Ref. A-4). The Control Block -88 output is the water level in feet. The maximum deviation of 0.27% occurs in the normalized core power.

For the licensing basis model LRNB, the most important parameter for determining the thermal margins is the core power. Therefore its values as a function of time are compared. The results are given in Table A-12. The peak power occurs at about 1.0 second into the transient. From Table A-12, it is seen that the maximum deviation is about 0.48%. Even though Version MOD5UEM under estimates the peak power, the difference is small and will not result in any significant deviations in the ΔCPR calculations. Part of the differences between MOD5UEM and MOD004 is caused by the RETRAN revision from MOD004 and MOD005.0. As stated earlier, MOD5UEM is derived from MOD005.0. WNP-2 transient analysis performed in the Topical Report (Ref. A-4) are all based on MOD004.

From the above comparisons, it is concluded that the differences are mainly caused by the differences in computer hardware and the operating systems. These differences are orders-of-magnitude smaller than the error bands of the comparisons between the predicted and the actual measured data given in the RETRAN02 qualification report (Reference A-3). From these case comparisons, it was concluded that RETRAN02 Version MOD5UEM was correctly modified and installed on the Supply System's IBM RISC6000 Workstation.

REFERENCES

A-1. C.E. Peterson et al, "RETRAN02 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 3: User's Manual (Revision 4)", NP-1850-CCM-A, Electric Power Research Institute, Palo Alto, California, November 1988.

A-2. Letter, J.H. McFadden (CSA, Inc) to S.H. Bian (WPPSS), CSA-095-92, Computer Simulation and Analysis, Inc, February 17, 1992.

A-3. C.E. Peterson et al., "RETRAN02 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 4: Applications", NP-1850-CCM, Electric Power Research Institute, Palo Alto, California, January 1983.

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APPENDIX B

BWR TRANSIENT ANALYSIS MODEL

LICENSING BASIS TRANSIENT ANALYSIS

TABLE OF CONTENTS

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1.0 INTRODUCTION

At the request of the Nuclear Regulatory Commission (NRC), the Washington Public Power Supply System (the Supply System) performed an analysis of a test problem with the RETRAN-02 ("RETRAN") code[B-1]. The test problem, referred as the Licensing Basis Transient (LBT), is a hypothetical turbine trip without steam bypass for Peach Bottom Unit 2. It is a limiting operational transient that is important in the safety analysis of a boiling water reactor (BWR). The analysis results provide a basis for comparison with audit calculations performed by other organizations using different methodologies.

A description of the RETRAN model inputs is given in Section 2. Comparisons of the calculated results with General Electric (GE) and Brookhaven National Laboratory (BNL) results[B-2,B-3] are presented in Section 3. Section 4 contains the conclusions and section 5 the References.

2.0 MODEL INPUTS

Reference B-2 provides the basic description of the LBT. Additional information (e.g., scram insertion times, steam line length) was obtained from References B-3 and B-4.

The SIMULATE-E[B-5] and SIMTRAN-E[B-6] codes were used to generate the RETRAN one-dimensional (1-D) kinetics data at the initial conditions. First, a stepwise depletion of cycle 1 and a Haling depletion of cycle 2 were used to determine the core power distribution and nodal cross sections at the end-of-cycle 2 (fuel

exposure used for LBT), all rods out state point. The 3-D to 1-D collapsing and the adjustment to account for the differences in the SIMULATE-E and RETRAN calculated moderator densities were then performed. The Supply System's process to generate the 1-D kinetics data is fully described in Section 2.6 of Reference B-7.

The RETRAN model used for the LBT analysis was nearly identical to that used in Reference B-7 for the Peach Bottom turbine trip benchmark analysis. The following modifications were made to conform to the licensing inputs specified in the BNL and GE analyses of the LBT (References B-2 and B-3). The transient was initiated from 104.5% of rated power and 100% of rated flow. The fuel rod gap conductance was held at a constant value of 1000 Btu/(hr-ft^2-°F). The steam separator inlet loss coefficient was adjusted to produce the initial pressure distribution consistent with the BNL's data reported in Reference B-2. Table 2.1 summarizes the initial conditions for the LBT. Note that the core inlet enthalpy was determined by heat balance calculation and the active core flow was calculated by SIMULATE-E. The recirculation pump trip to mitigate the transient was inactivated. The reactor scram was assumed functional and activated by the turbine trip scram setpoint with a 0.27 second delay. The scram bank insertion velocity was specified by the standard "67B" scram scheme. Safety/Relief (S/R) valve characteristics (setpoints, delays and stroke times) were changed to those defined in Reference B-2. Table 2.2 lists the S/R valve and scram bank characteristics used for the LBT analysis. The stroke time for the turbine stop valve was assumed to be 0.1

second. The steam line length was reduced to 400 ft to be consistent with the value used by other organizations (Reference 4). The length and volume of the steam line have a significant effect on the timing and magnitude of the pressure wave. The delayed neutron yield fractions (ßi/ß) and decay constants were taken from Reference B-2 and are listed in Table 2.3.

3.0 RESULTS

The important transient results obtained with the RETRAN model are compared to those obtained by GE and BNL. They are presented in the following sections.

3.1 Initial Conditions

The initial axial power and axial heat flux distributions are presented in Figures 3.1 and 3.2. As shown, they are in reasonable agreement with the distributions reported by GE and BNL. Steady state comparisons for the initial void fraction and fuel temperature are shown in Figures 3.3 and 3.4. The RETRAN calculated initial axial fuel temperature profile agrees well with the GE values. The initial fuel temperatures are highly dependent on the fuel-to-clad gap conductance and the fuel pin model. RETRAN predicted higher void fraction in the top half of the core, most likely due to the differences in the void models. The large difference in the lower portion of the core between T/H void and neutron void is due to the fact that neutron void includes the subcooled boiling effects. It should be noted that the void

reactivity in RETRAN is determined by the neutron void which matches well with both GE and BNL results.

3.2 Thermal-Hydraulic Response

The core average void fraction during the transient is plotted in Figure 3.5. The variation on void fraction is similar for all the calculations. The RETRAN results show a slightly higher initial void fraction and a larger reduction than the GE and BNL data. The variation in core average void fraction is closely related to variations in core pressure, inlet flow and differences in void models. The larger drop in void fraction is due to the more rapid pressure rise and the earlier leveling off in pressure causes the earlier turnaround of void fraction.

The comparisons of transient core midplane pressures and core inlet flow are presented in Figures 3.6 and 3.7. The RETRAN core midplane pressure rises more rapidly than the BNL and GE calculations. Differences in vessel modeling (e.g., separator inlet inertia, separator inlet and exit loss coefficients) could significantly affect the pressure wave transmission through the vessel to the core. The information available in References B-2 and B-3 does not allow complete resolution of these differences. The leveling off of the pressure near 1.0 seconds is caused by the rapid, successive opening of the second and third safety/relief valve groups. The GE and BNL calculated pressures continue to increase, though at a slower rate possibly due to a slower decrease in core power and heat flux as shown in Figures 3.8 and 3.9. The RETRAN core inlet

flow is similar to the GE calculation with RETRAN predicting higher flow at the first peak and less flow at the second peak. The first pressure wave calculated by RETRAN apparently reaches the lower plenum sooner than that calculated by GE. The oscillation frequency is very similar to both GE an BNL results as indicated by Figure 3.7.

3.3 Neutronic Response

The transient core power is presented in Figure 3.8. Comparing to GE results, the RETRAN calculation shows that the maximum power occurs slightly earlier and the power increase peak is narrower and higher. These differences reflect the change of the core power response to the variations in the core average void fraction presented in Figure 3.5. The BNL transient core power is similar in magnitude but differs from the GE and RETRAN calculations in timing. This shifting of the power peak is mainly due to the reduction of pressure rise between 0.6 sec and 0.7 sec (Figure 3.6).

Of primary interest from a safety viewpoint is the clad surface heat flux in the core as the surface heat flux dominates the critical power ratio (CPR) during the transient. As shown in Figure 3.9, the transient heat flux calculated by RETRAN is similar to the GE results. The higher heat flux peak predicted by RETRAN increases the change in CPR and consequently, yields a more conservative thermal limit. The BNL transient heat flux is significantly different from both the RETRAN and GE calculations. This may be

attributed to differences in fuel pin modeling as indicated by the large differences in the transient core average fuel temperature shown in Figure 3.10 (GE data not available for comparison). Comparisons of the axial heat flux profiles at 0.8 and 1.2 seconds are shown in Figures 3.11 and 3.12. Note that the BNL heat flux profiles were obtained from calculation using GE pressure and flow curves. Both the magnitude and axial shape change of the heat flux from the initial values are in reasonable agreement for all the three calculations.

The RETRAN transient total core reactivity (Figure 3.13) is similar to the BNL calculation (GE calculation not available) in trend and magnitude. The peak reactivity occurs earlier and is consistent with the differences shown in the transient core average void fraction (Figure 3.5) and the transient core power (Figure 3.8).

4.0 CONCLUSIONS

The results of the LBT analysis performed by the Supply System are in reasonable agreement with the GE and BNL results. Although not presented here, the Supply System's results are quite similar to that reported by Tennessee Valley Authority[B-4] and Philadelphia Electric Company[B-8], both of whom used the RETRAN code. The differences between the calculations shown here have been attributed to different modeling assumptions and computer code variations. It is concluded that the Supply System's methodology in performing the licensing calculations is consistent with the NRC approved methodologies used by other organizations.

TABLE 2.1

LICENSING BASIS TRANSIENT INITIAL CONDITIONS

Parameter	Initial Value
Core Thermal Power (MWth)	3440.0
Turbine Steam Flow (lbm/sec)	3900.0
Total Core Flow (Mlbm/hr)	102.5
Active Core Flow (Mlbm/hr)	95.34
Core Inlet Enthalpy (Btu/lbm)	522.7
Steam Dome Pressure (psia)	1034.0
Core Exit Pressure (psia)	1044.9
Core Inlet Pressure (psia)	1069.7
Recirculation Flow (Mlbm/hr)	34.2
Core Average Gap Conductance (Btu/hr-ft^2-°F)	1000.0

TABLE 2.2

LICENSING BASIS TRANSIENT S/R VALVE AND SCRAM BANK CHARACTERISTICS

Relief Valve Setpoints

4 Valves: 1090.8 psia open; 1070.8 psia close; 872 lbm/sec capacity

4 Valves: 1100.9 psia open; 1080.9 psia close; 872 lbm/sec capacity

3 Valves: 1111.0 psia open; 1091.0 psia close; 654 lbm/sec capacity

Safety valve Setpoints

2 Valves: 1242. psia open; 1222. psia close; 518.5 lbm/sec capacity

Scram Bank Insertion Specifications

% Control Rod Bank Inserted	Time after initial motion (sec)
0	0.000
5	0.175
10	0.350
20	0.700
30	1.067
40	1.433
50	1.800
60	2.175
70	2.550
80	2.925
90	3.300
100	3.775

TABLE 2.3

LICENSING BASIS TRANSIENT DELAYED NEUTRON DATA

Delayed Group	Yield Fraction	Decay Constant (sec^{-1})
1	0.000207	0.0127
2	0.001163	0.0317
3	0.001027	0.1150
4	0.002222	0.3110
5	0.000699	1.4000
6	0.000142	3.8700
Total:	0.005460	

5.0 REFERENCES

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B-7. Y.Y. Yung, S.H. Bian and D.E. Bush, "BWR Transient Analysis Model," WPPSS-FTS-129, Rev. 1, September 1990.

B-8. A.M. Olson, "Methods for Performing BWR Systems Transient Analysis," PECO-FMS-0004-A, November 1988.

FIGURE 3.1
LBT INITIAL AXIAL POWER DISTRIBUTION

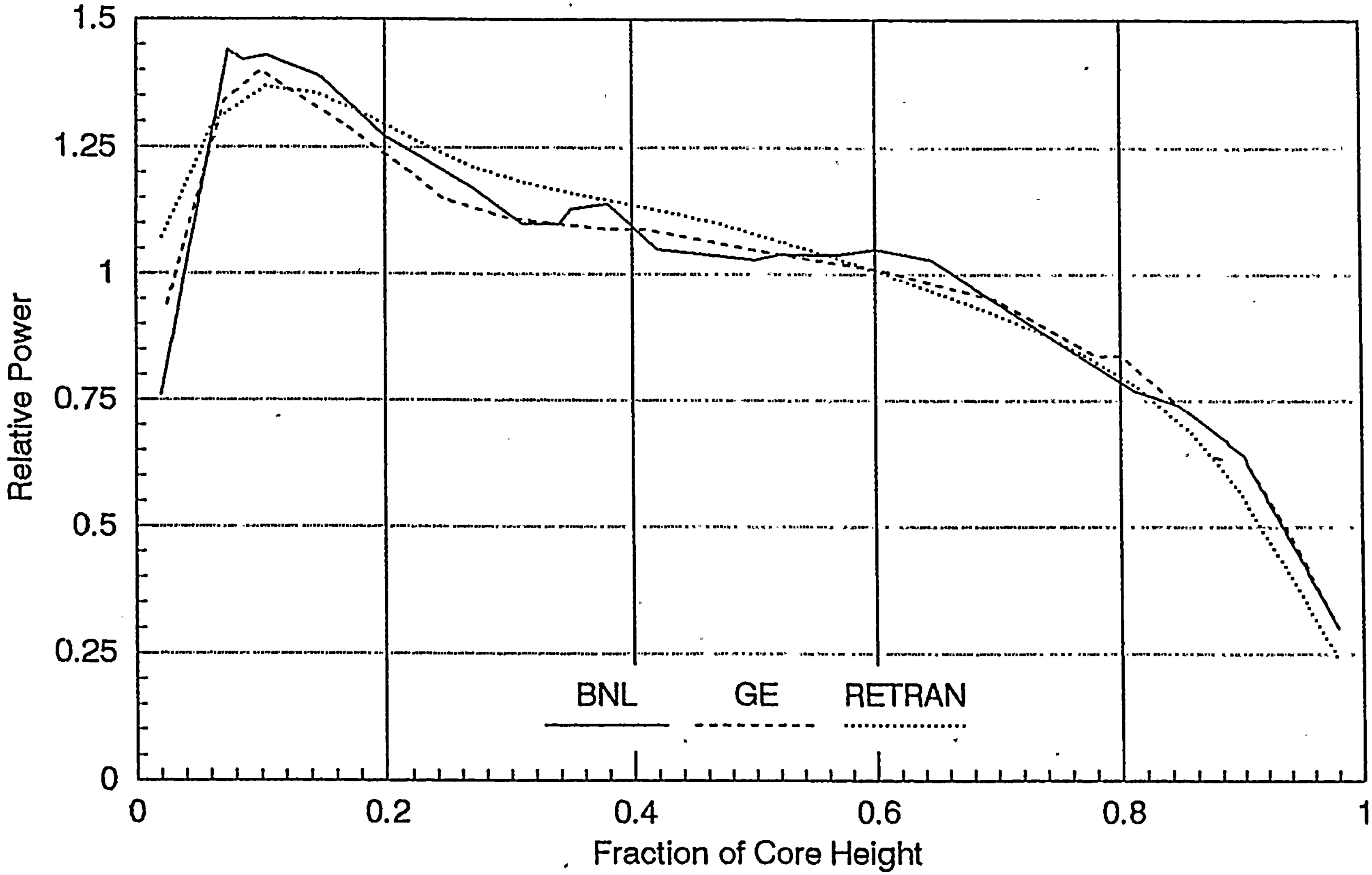

FIGURE 3.2
LBT INITIAL AXIAL HEAT FLUX DISTRIBUTION

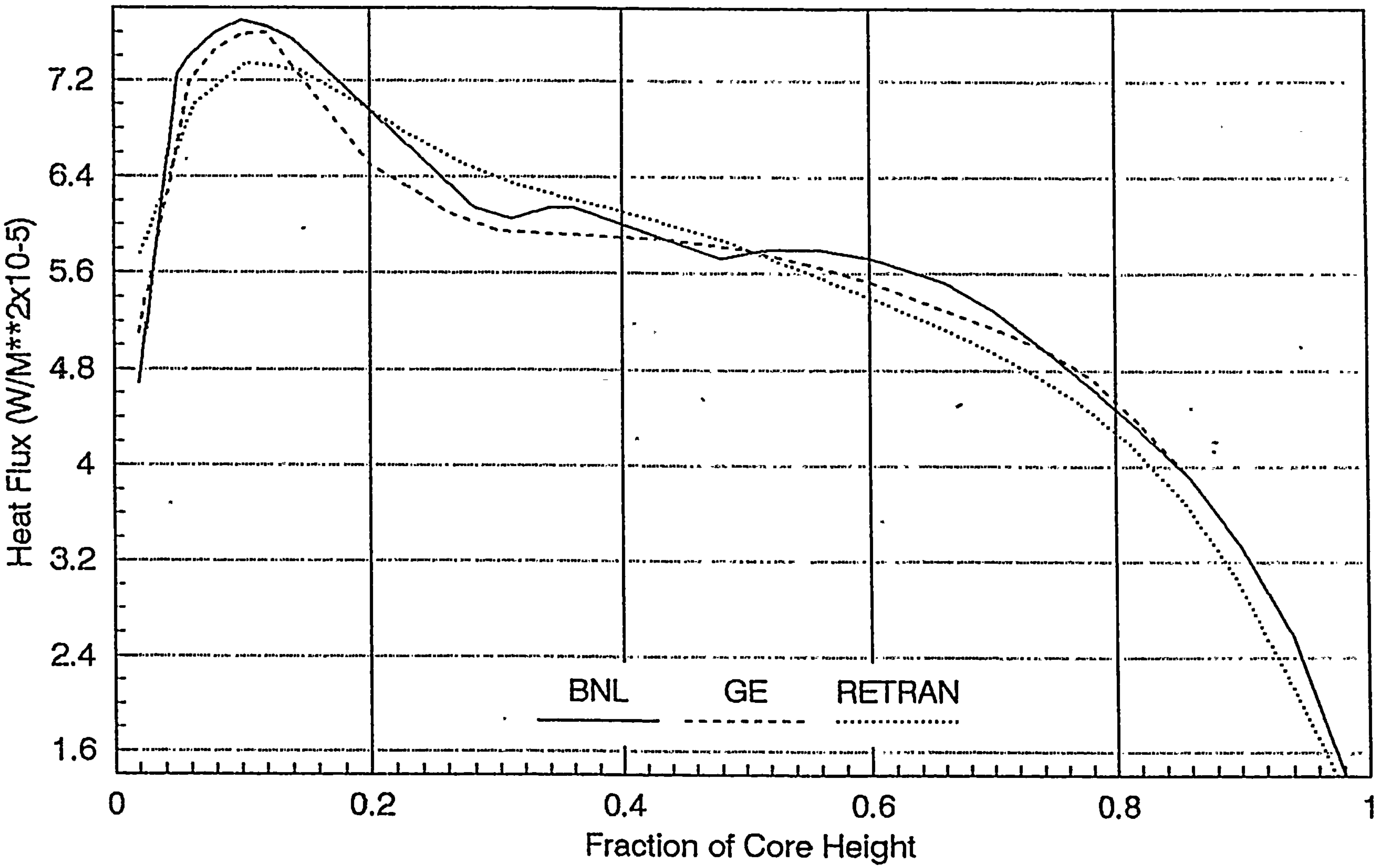

FIGURE 3.3
LBT INITIAL VOID DISTRIBUTION

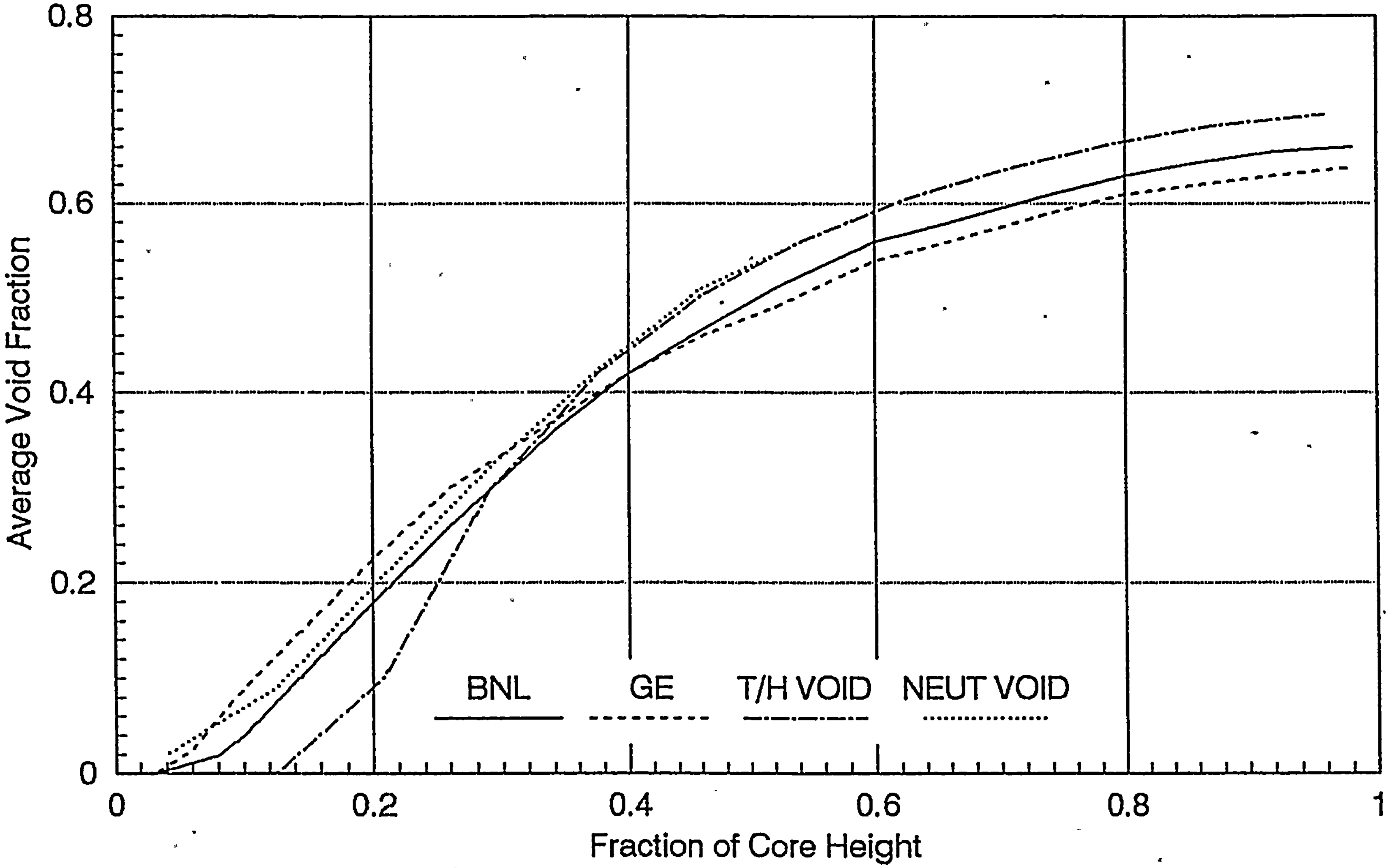

FIGURE 3.4
LBT INITIAL FUEL TEMPERATURE DISTRIBUTION

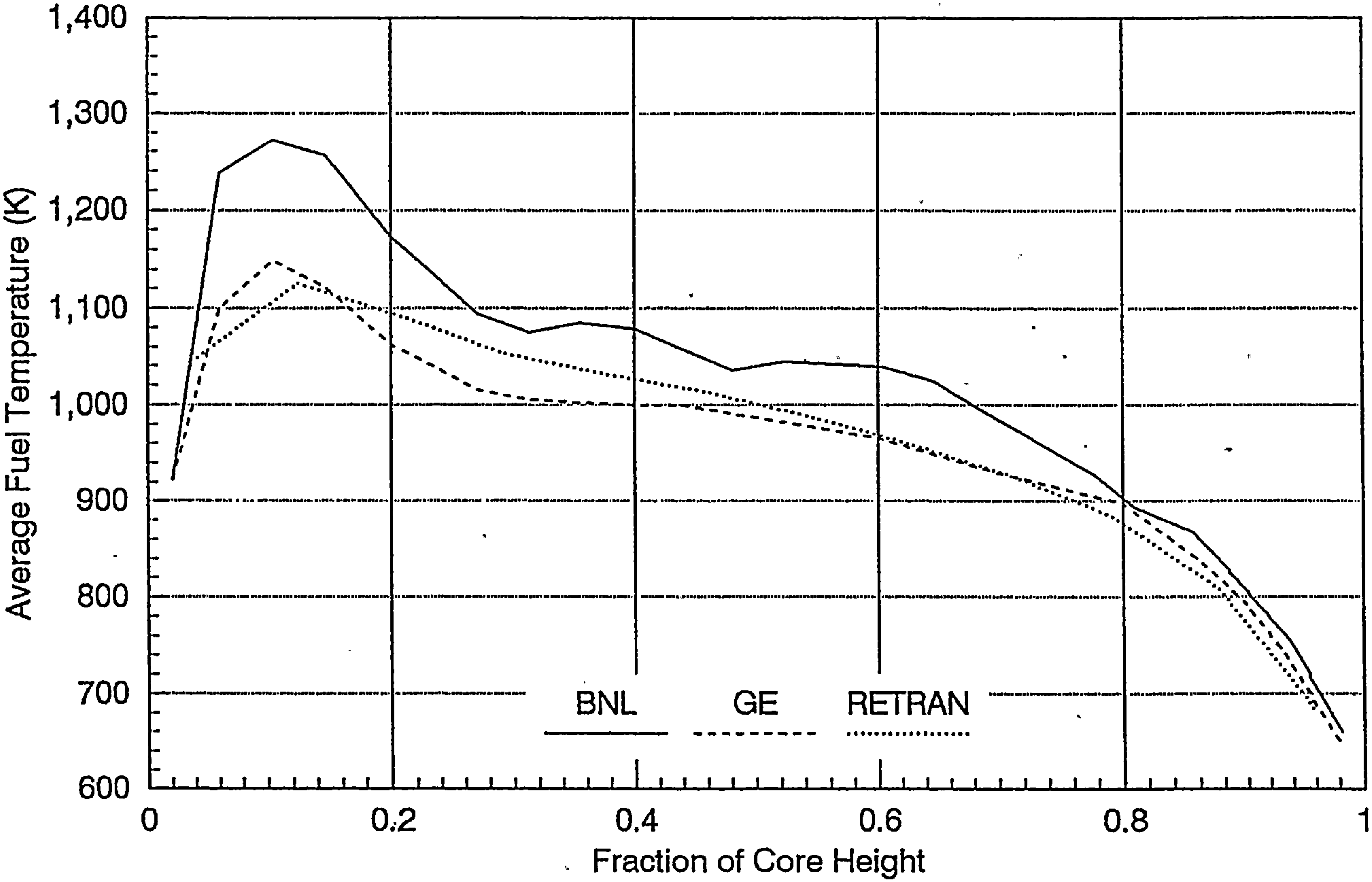

FIGURE 3.5
LBT CORE AVERAGE VOID FRACTION

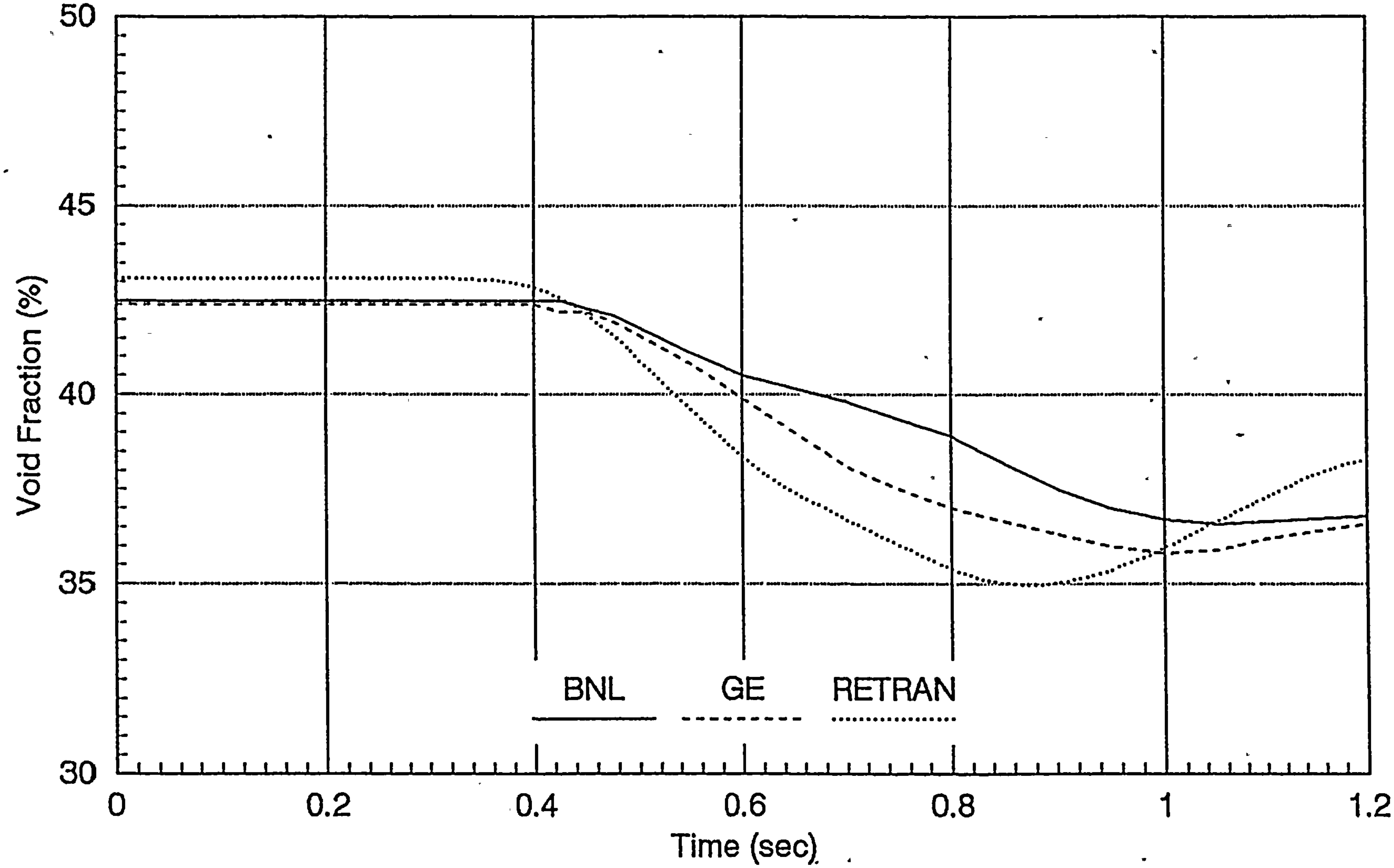

FIGURE 3.6
LBT CORE MIDPLANE PRESSURE

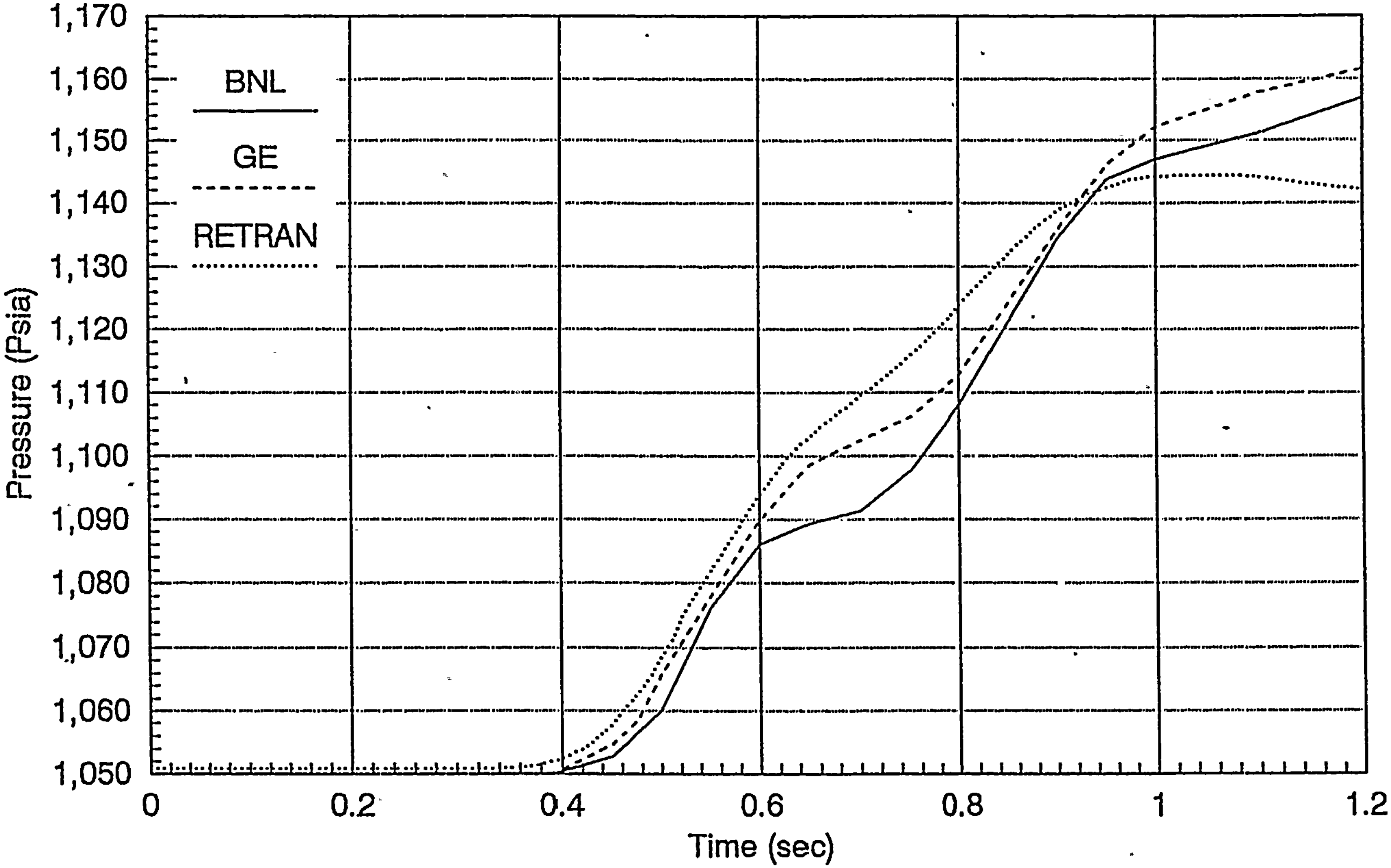

FIGURE 3.7
LBT TOTAL CORE FLOW

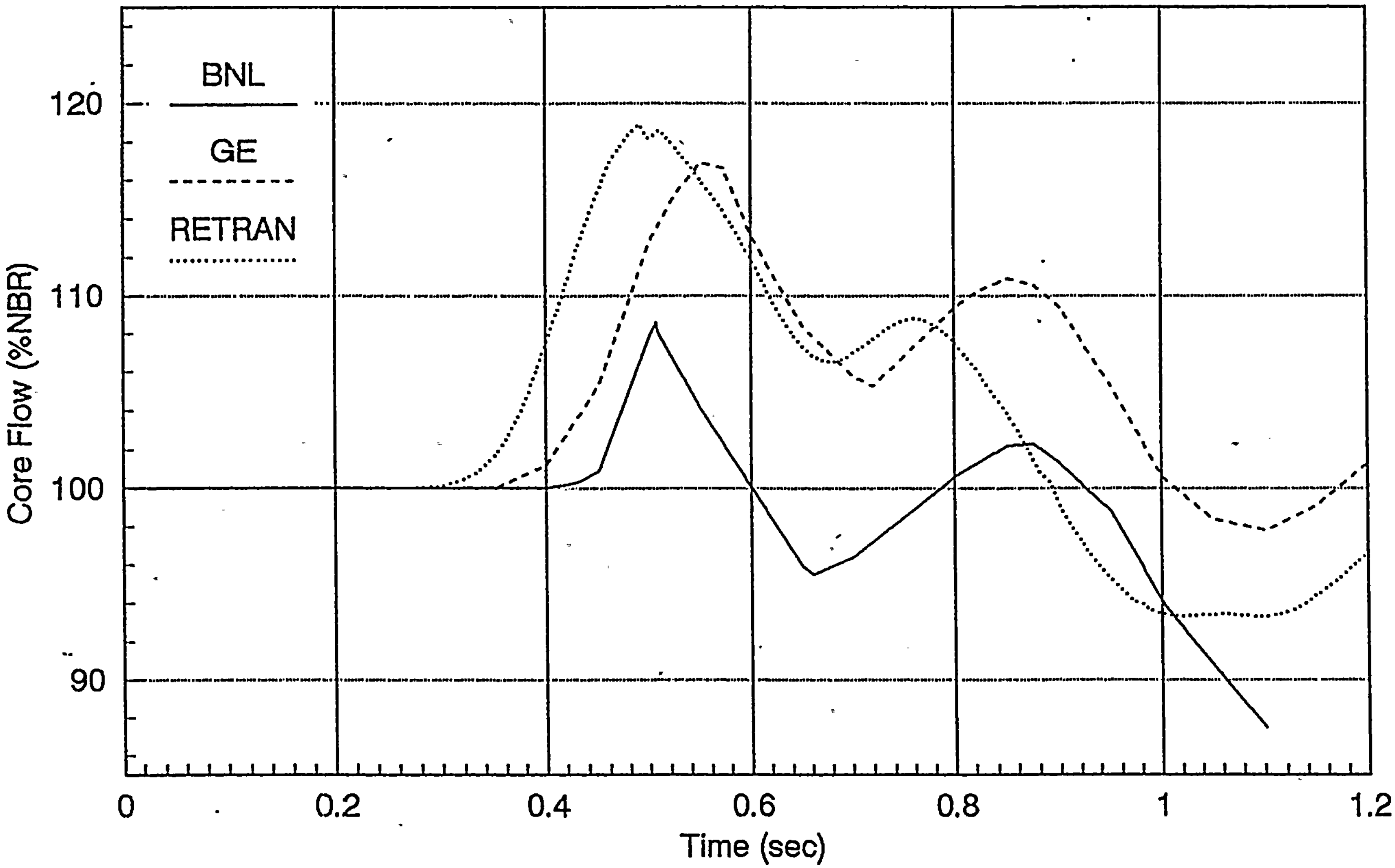

FIGURE 3.8
LBT CORE POWER

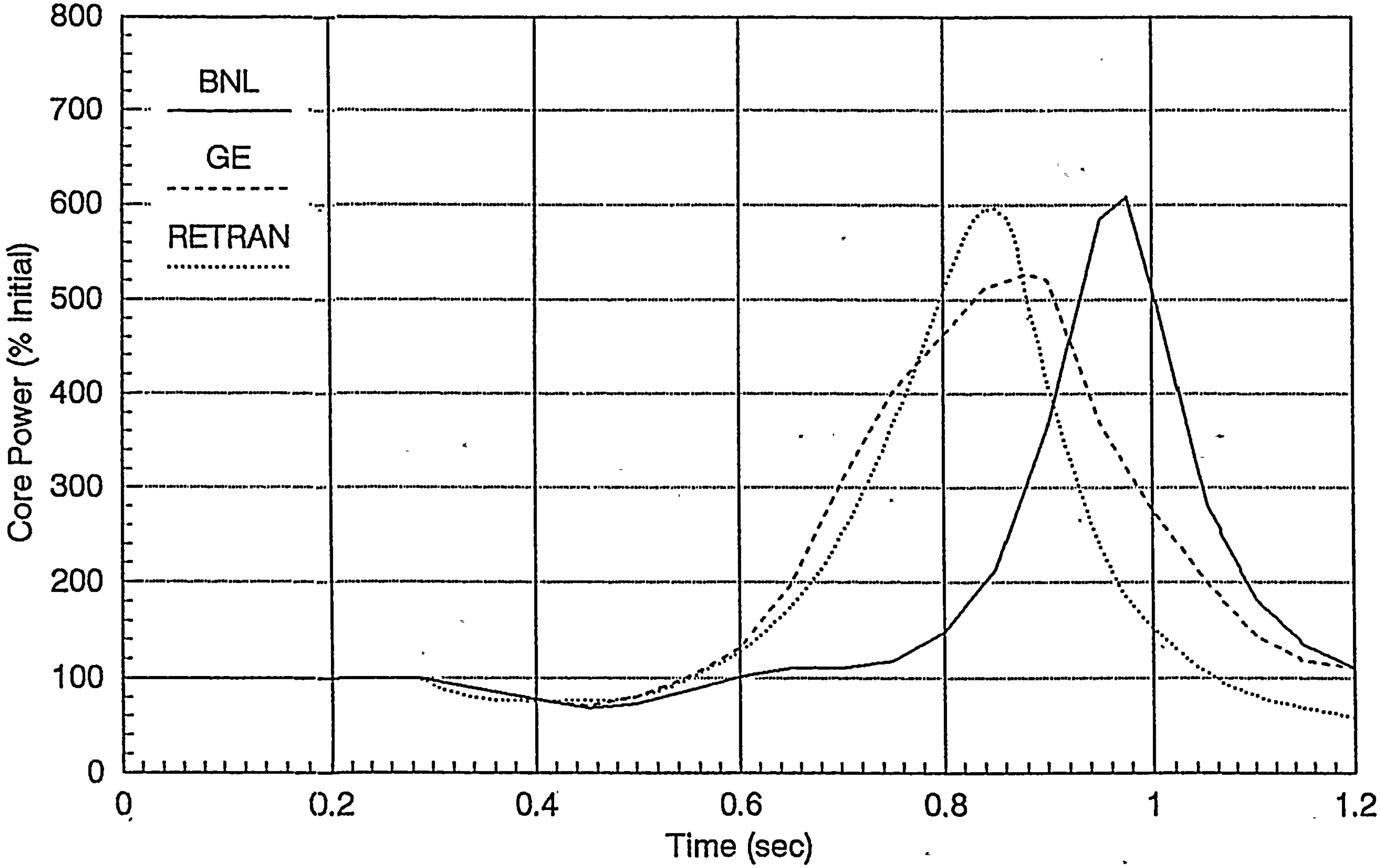

FIGURE 3.9
LBT CORE HEAT FLUX

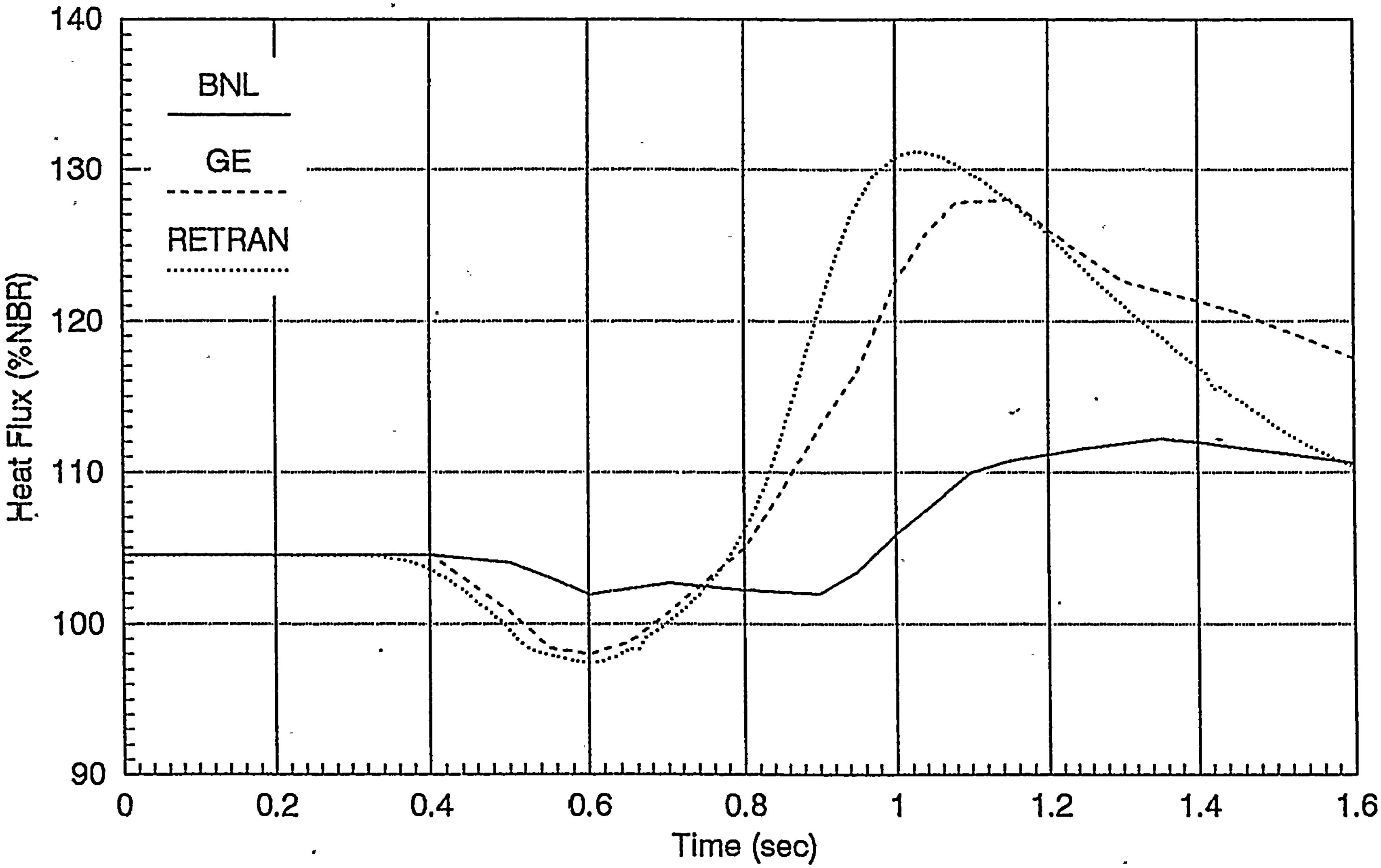

FIGURE 3.10
LBT CORE AVERAGE FUEL TEMPERATURE

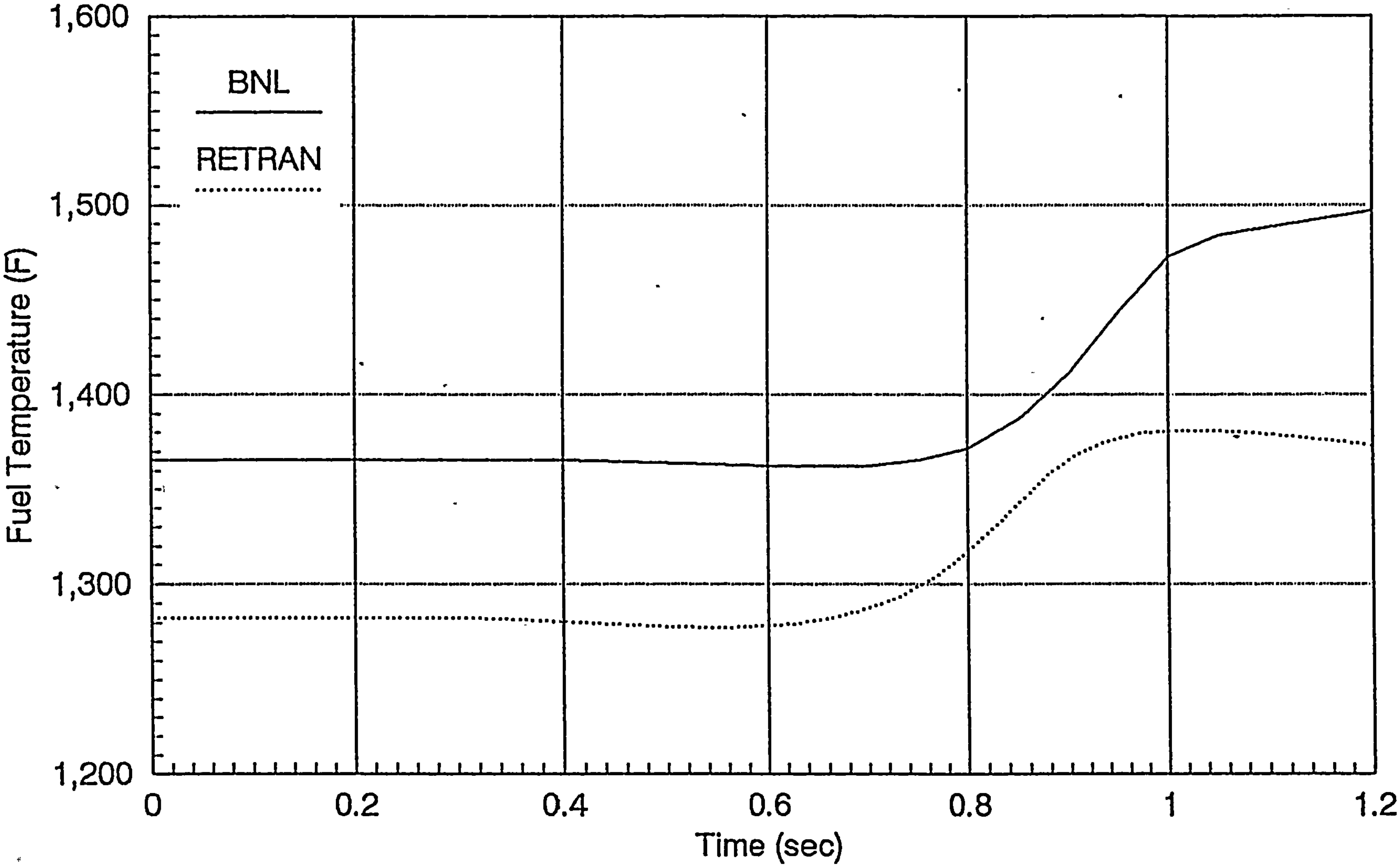

FIGURE 3.11
LBT HEAT FLUX DISTRIBUTION AT 0.8 SEC

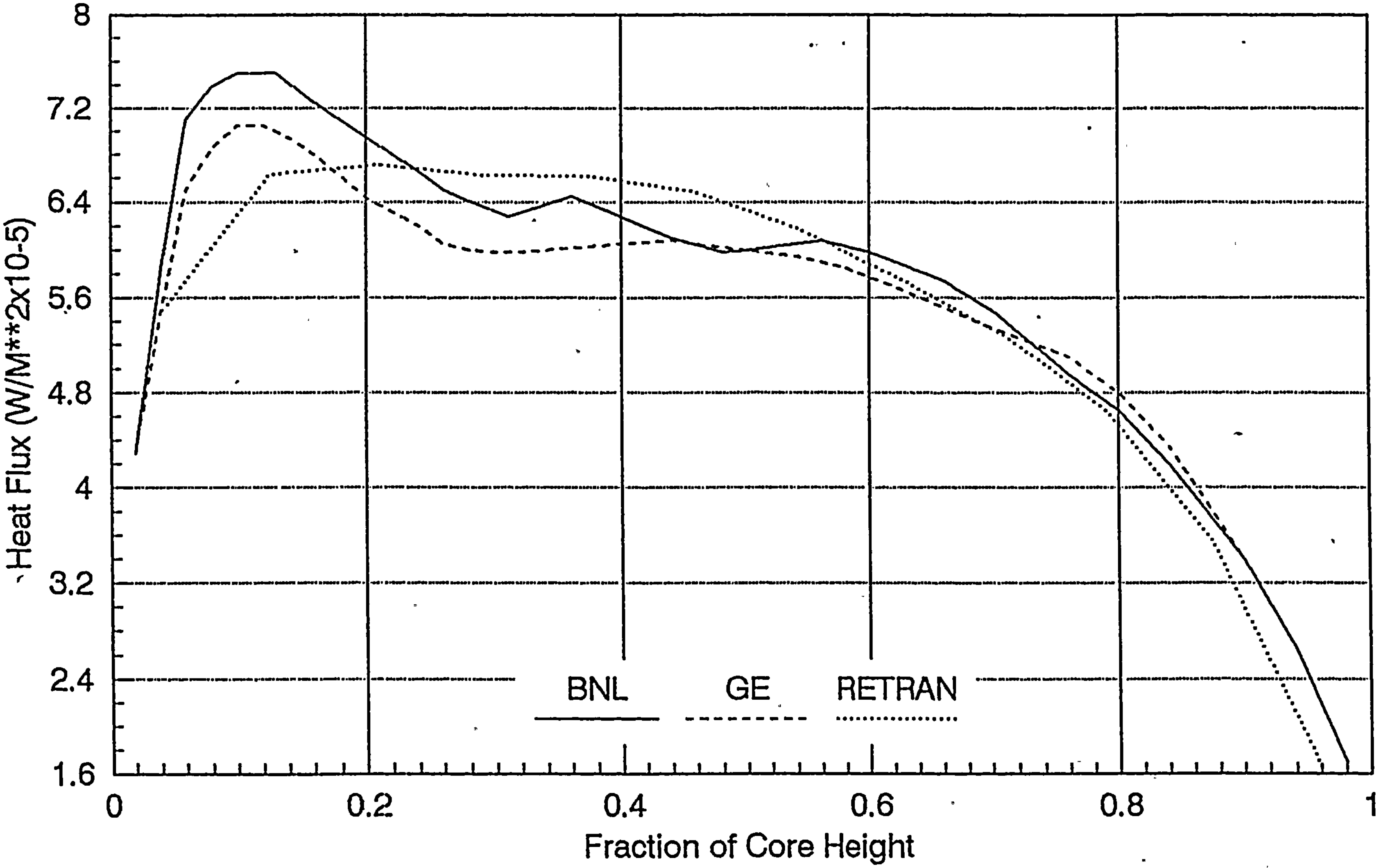

FIGURE 3.12
LBT HEAT FLUX DISTRIBUTION AT 1.2 SEC

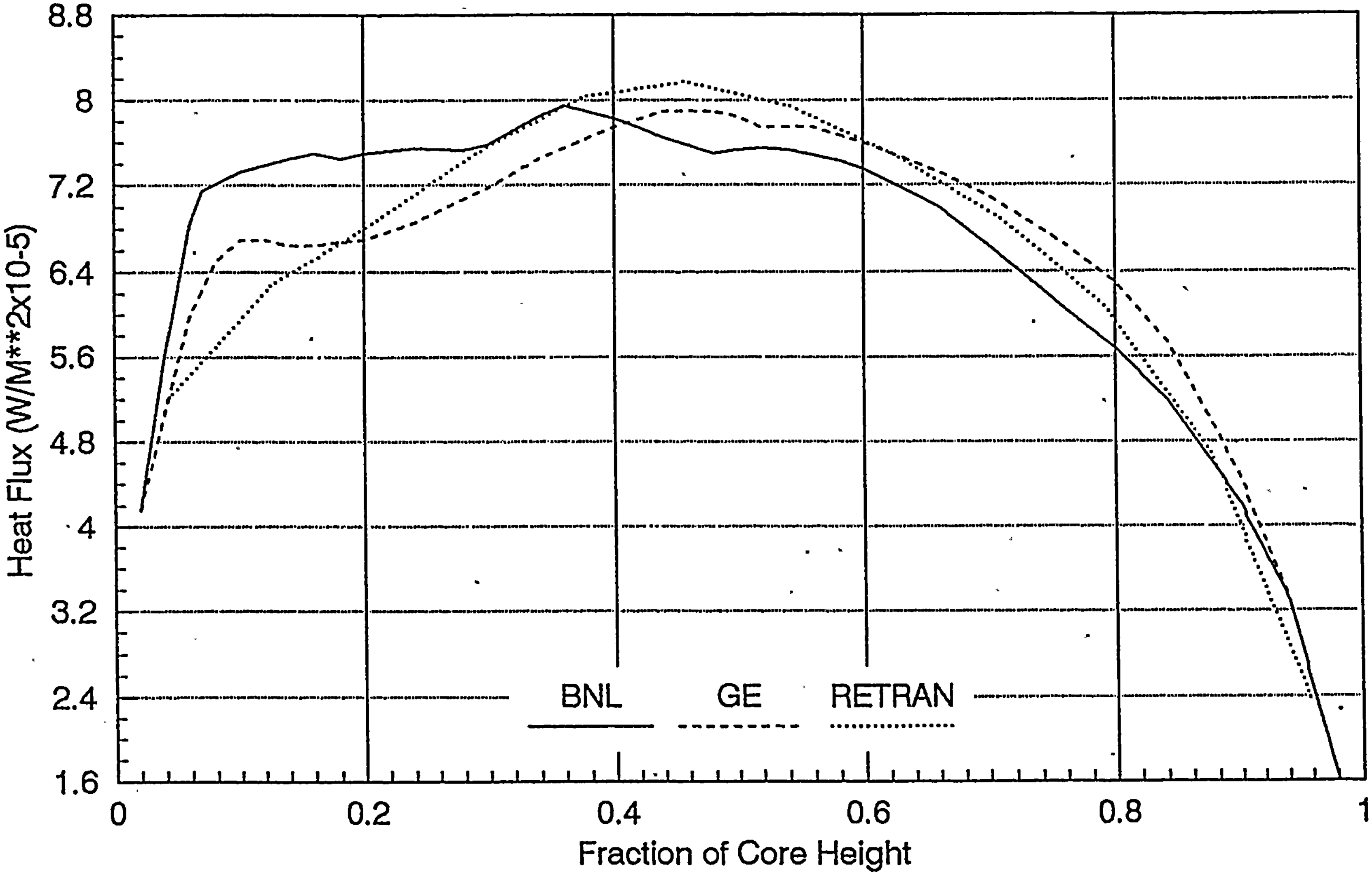

FIGURE 3.13
LBT TOTAL CORE REACTIVITY