TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

400 Chestnut Street Tower II

January 20, 1983

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Denton:

In the Matter of the	)	Docket Nos. 50-259
Tennessee Valley Authority	)	50-260
		50-296

By letter from D. B. Vassallo to H. G. Parris dated December 30, 1982, we received an NRC request for additional information concerning TVA Topical Report, "BWR Transient Analysis Model Utilizing the RETRAN Program," TVA-TR81-01. Enclosed is our response to that request.

It is requested that your staff complete their review as expeditiously as possible. Our rapid response indicates the urgency of our need for final NRC approval. Any further delays in NRC approval beyond the requested date of November 1, 1982 will likely result in schedular complications for TVA.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Licensing

Subscribed and sworn to before
me this 20 day of January 1983.

Patt A. Gibson
Notary Public

My Commission Expires 7/29/86

Enclosure
cc: See page 2

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Mr. Harold R. Denton January 20, 198

cc (Enclosure):
U.S. Nuclear Regulatory Commission
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Mr. R. J. Clark
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ENCLOSURE
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
BROWNS FERRY RETRAN
CPR METHODOLOGY (TVA-TR81-01)

Q1. Since the RETRAN system transient analysis provides time-dependent boundary conditions for the RETRAN hot channel CPR calculation, how is the interface between the system analysis and hot channel CPR calculation accomplished? Is a separate RETRAN hot channel CPR calculation performed after the whole system transient analysis is completed? Provide a detailed description on how this is done.

A1. Figure 1 shows a schematic of the data flow for a transient critical power ratio calculation using the TVA methods. The complete system level calculation for an event is first performed (block 1) and a data file (labeled 'A') is produced (termed a data 'tape' in the RETRAN User's Manual). This file is of standard RETRAN format containing all of the T/H and neutronic solution results and can be utilized for restart calculations or, as in this case, to provide time-dependent boundary conditions to a RETRAN hot-channel analysis (block 2). For licensing calculations an approved generic design axial power distribution is always employed in the hot channel calculation.

The hot-channel level analysis also generates a data file (labeled 'B'). The data file produced by the hot channel analysis is read by the RETRAN 'REEDIT' option which produces a specially formatted output file (labeled 'C') containing the time variation of the junction flows and enthalpies in the hot bundle as well as the system pressure and associated enthalpies of saturated liquid and vapor.

The data file (termed an 'AUXILIARY DATA FILE' in the RETRAN User's Manual) produced by REEDIT and user input constants are all that are required to utilize the GEXL correlation to evaluate the transient CPR. The CPR evaluation is performed by a small auxiliary program TCP (block 4). The program TCPYA01 (reference 1) is functionally identical to the TVA TCP program from which it was derived and reference 1 describes the methods employed in TCP and shows comparisons to transient boiling transition tests.

The results of the TCP calculation are the initial channel minimum CPR (ICPR), the minimum CPR during the event (MCPR) and the maximum decrease in CPR (ΔCPR=ICPR-MCPR). The initial power in the hot channel calculation is selected such that the MCPR is approximately equal to the 'safety limit' CPR (SLCPR) of 1.07. Sensitivity studies have shown that a change of 0.1 in ICPR generally results in less than a 0.02 change in ΔCPR so that the transient ΔCPR can be accurately evaluated if the ICPR is selected such that the MCPR is within 0.02 of the SLCPR. Normally, previous calculations allow the required initial hot channel power to be estimated closely enough that by running two hot channel cases differing by approximately 0.04 in ICPR, one of the cases will have an MCPR within 0.02 of the SLCPR. If this is not the case, the two results can be used to estimate a new hot channel power with the required MCPR and the hot channel-REEDIT-TCP calculation repeated. This procedure is utilized for each different fuel type (e.g., 8x8R, P8x8R) in the reactor core.

Each of the blocks on figure 1 represents a separate program execution and can be performed separately. However, the normal practice is to perform the calculations as successive steps in a single computer job.

Q2. How are the initial and transient hot channel flow rates determined?

A2. The RETRAN hot channel model is initialized to a desired ICPR by specifying the bundle power and flow. Hot channel thermal-hydraulic characteristics (power vs ICPR, flow vs power) are determined using the FIBWR computer code (reference 2) to model the reload core configuration. The bundle power and the corresponding bundle flow that produce the desired ICPR are used to initialize the RETRAN hot channel model.

The transient hot channel flow is calculated by the RETRAN model. The normalized power and upper and lower plenum conditions (essentially time dependent core pressure drop) calculated by the RETRAN system model are applied as boundary conditions on the hot channel model.

Q3. In the hot channel CPR calculation, the critical power which results in onset of boiling transition is determined by an iterative process. Provide a step-by-step description as to how the power iteration is done. During the power iteration, how is the hot channel flow rate determined since the two-phase pressure drop will be greatly affected by the power level change? Justify your method of the hot channel flow determination during iteration.

A3. A step-by-step description of the TCP calculation is presented in reference 1. The hot channel flow rates (for each axial level) at each point in time are taken as the values calculated by the RETRAN hot channel analysis and are not modified during the CPR (i.e., power) iteration. The CPR iteration only scales the hot bundle enthalpy rise to match the quality to the GEXL critical quality (this also causes the boiling boundary to be adjusted). This definition of CPR implies that it is a measure of the bundle power margin to boiling transition <u>provided</u> the bundle flow, axial power distribution, inlet enthalpy, and system pressure do not change with bundle power. This definition of CPR is consistent with the procedure defined for use with GEXL in reference 3 for static calculations. During transients, the only quantity of interest is minimum CPR and if the hot channel initial conditions are selected such that the minimum CPR is 1.0, then no change is made to any of the hot channel thermal-hydraulic data during the iteration regardless of the definition of CPR. The safety limit CPR is used instead of 1.0 for the minimum transient CPR to account for uncertainties in the GEXL correlation and in the methods used to monitor CPR during operation. Thus, the techniques used to perform the CPR iteration in TCP do not affect the values of interest (i.e., minimum CPR and maximum ΔCPR).

Q4. In the use of the GEXL critical quality boiling length correlation for the critical power calculation, the boiling boundary must be determined. Since the boiling boundary varies with channel flow rate, power input and power shape, how is the boiling boundary determined during power iterative process? Are there any shortcomings in your method of calculating boiling boundary?

A4. The determination of the boiling length during the CPR iteration is described in reference 1. As discussed in response to question 3, the channel flows and bundle axial power shape are not changed during the CPR iteration. The boiling length required for the GEXL correlation is based on homogeneous equilibrium thermal-hydraulic conditions at each axial plane in the hot channel (i.e., no subcooled boiling). Thus, the requirement for its accurate evaluation is a reliable calculation of the total energy added to the fluid at each axial level. This is a relatively easy calculation and the adequacy of the RETRAN evaluations was tested by comparisons to transient CPR tests in reference 1.

Q5. Since the RETRAN code was primarily designed for reactor system transient analyses, in using the RETRAN code for hot channel CPR calculation do you make any modifications to the code? How is the power iterative procedure done? Is it done external to the RETRAN code?

A5. RETRAN is intended to be a general one-dimensional transient thermal-hydraulics code and has been extensively used for analyses other than reactor system transients. No modifications have been made to the code for the hot channel analyses as this capability was planned from RETRAN's inception. The GEXL correlation is not directly incorporated into RETRAN but into the auxiliary program TCP as discussed in response to question 1.

Q6. There are many options and constitutive correlations in the RETRAN code with regard to two-phase flow characteristics, such as void fraction, two-phase pressure drop calculations, etc. Are there any differences in the use of these options and correlations between the RETRAN system analysis and hot channel analysis? Provide a list of options to be used in the system transient and hot channel calculations for thermal-hydraulic design analyses.

A6. The two-phase constitutive correlation options used in the RETRAN system and hot channel analyses are listed below. The same correlations are used in both analyses.

Void Fraction	- Algebraic Slip
Two-phase Friction Multiplier	- Baroczy
Friction Factor	- Fanning

The local loss coefficients input to RETRAN were determined such that the steady-state relationship between power and flow predicted by RETRAN agreed with a more detailed thermal-hydraulic code. This procedure is discussed in section 2.3.5 of TVA-TR81-01.

Q7. Have you performed any sensitivity study on the effect of these options on CPR? What are the results?

A7. The sensitivity of ΔCPR/ICPR to the void fraction correlation was investigated by performing a hot channel analysis using the homogeneous equilibrium model (HEM) instead of the algebraic slip model used in the base case (the same system analysis was used to drive both hot channel analyses). For the GLRWOB transient, the ΔCPR/ICPR increased by 0.0025 with the use of the HEM void model. Sensitivity studies indicate that the ΔCPR/ICPR is relatively insensitive to the pressure drop distribution (maintaining the same plenum-to-plenum pressure drop) in the hot channel model. The combined sensitivity of the system and hot channel to core pressure drop is discussed in section 7.1.2.2 of TVA-TR81-01.

Q8. Section 2.2.4 of TVA-TR81-01 states that 'the use of a constant axially uniform gap conductance results in a conservative overprediction of CPR/ICPR (is it ΔCPR/ICPR?) for pressurization transients.' Section 4.4.1 states that 'a gap conductance of 1000 Btu/hr-ft²-°F was used in the analyses.' How is this 1000 Btu/hr-ft²-°F obtained? Is this value to be used in your thermal-hydraulic design analyses? Since gap conductance varies with fuel burnup, power level and transients, is the 1000 Btu/hr-ft²-°F a bounding value for all fuel cycles, all transients and power levels? If not, justify the use of this value.

A8. The statement in section 2.2.4 refers to the core-wide gap conductance used in the system level analysis and is correct when the Δ symbol is inserted. The statement in section 4.4.1 refers to the value of hot channel gap conductance utilized to infer the change in CPR during the Peach Bottom turbine trip tests and is a reasonable estimate for the limiting 8x8 fuel design. Because ΔCPR increases with increasing hot channel gap conductance, the maximum value expected over the exposure range of interest is used in the licensing analysis. The generic hot channel gap conductance used are:

GE 8x8 Fuel	-	1160 Btu/hr-ft²-°F
GE 8x8R Fuel	-	975 Btu/hr-ft²-°F
GE P8x8R Fuel	-	1287 Btu/hr-ft²-°F

The gap conductance values are representative of an assembly continuously operated at the MAPLHGR limits and were obtained from analyses performed with the COMETHE program (reference 4).

The core-wide gap conductance used in licensing basis system level analyses is evaluated for each reload core and state point analyzed. The value of 606 Btu/hr-ft²-°F utilized for the core-wide gap conductance in the analyses presented in chapter 6 of TVA-TR81-01 is representative of reload cores consisting of pressurized 8x8R fuel (for 105 percent NBR power at end of cycle).

Q9. Have you performed any sensitivity study on the effect of the value of gap conductance on CPR for various transients? What are the results?

A9. A sensitivity study performed for the GLRWOB transient in chapter 6 of TVA -TR81-01 indicates that a 20 percent increase in hot channel gap conductance (1287 to 1544 Btu/hr-ft²-°F) resulted in an increase of 0.0085 in ΔCPR/ICPR. Further increases in gap conductance lead to proportionately smaller changes in ΔCPR/ICPR as the heat transfer to the coolant becomes limited by the fuel pellet time constant.

Q10. Have you performed any sensitivity study on the effect of axial nodalization and transient time step size on CPR? What are the results?

A10. The use of 12 active fuel nodes in the hot channel model (compared to the standard 24) for the GLRWOE analyses presented in chapters 6 and 7 of TVA-TR81-01 resulted in an 0.002 increase in ΔCPR/ICPR. For the same event, reduction of the maximum hot channel time step size during the limiting portion of the event from 0.005 seconds to 0.0025 seconds resulted in no changes in results.

Q11. For the RETRAN hot channel modeling qualification, have you performed any benchmark comparison of the RETRAN CPR predictions against any steady-state and transient test data other than the three Peach Bottom turbine trip data listed in table 4-12 of TVA-TR81-01? Please list the results of comparison.

A11. Reference 1 contains a comparison of the RETRAN-TCP methodology to transient CPR tests. The applicability of the work in reference 1 to the TVA analysis methodology was confirmed by repeating six of the flow decay transients with TVA codes and hot channel models. The results of these tests are shown in table 1 and the consistency of TVA and YAEC results confirm the applicability of reference 1 results for TVA methods.

Because the thermal-hydraulic equations for steady-state conditions reduce to a simple enthalpy balance, steady-state tests confirm little other than correct implementation of the GEXL correlation. TVA has performed several tests to confirm that the GEXL correlation is correctly coded. A sample of these tests is shown in table 2 which shows TVA calculations compared to General Electric results for various bundle designs. These data points represent transient initial conditions from several Browns Ferry reload licensing submittals. Due to the limited number of digits specified for the data in the reload licensing submittals agreement can only be expected to within 0.01 on CPR and is obtained for all cases.

FIGURE 1

TVA TRANSIENT CPR EVALUATIONS
DATA FLOW CHART

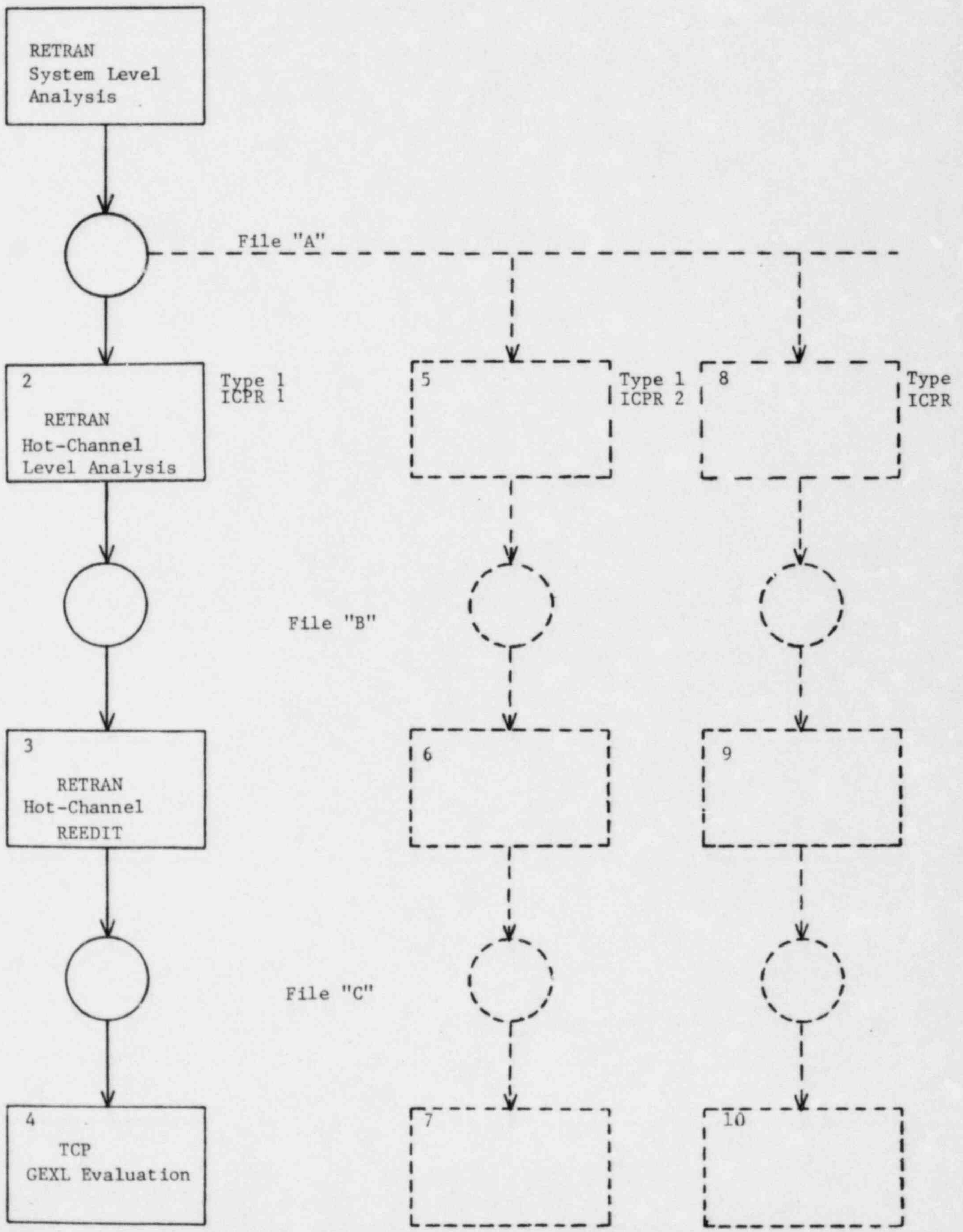

TABLE 1 TVA-YANKEE ATOMIC-ATLAS COMPARISON FOR FLOW DECAY TRANSIENTS

		TVA				YANKEE ATOMIC			
Run #	Exp. Time to BT (Sec)	Initial CPR	Time to BT	Min. CPR	Time	Initial CPR	Time to BT	Min. CPR	Time
102	2.44	1.276	2.67			1.28	2.65		
106	3.08	1.455	3.09			1.45	2.80		
108	3.92	1.289	3.84			1.29	3.75		
110	5.24	1.442	5.07			1.44	5.10		
112	6.24	1.547		1.017	8.20	1.55		1.02	7.95
114	4.48	1.291	4.62			1.29	4.25		

TABLE 2 TVA-GE TRANSIENT INITIAL CONDITION CPR COMPARISONS

Case No.	Bundle Type	Power (MW)	Flow (KLB/HR)	GE ICPR	TVA ICPR	Difference
1	7x7	5.576	118.6	1.25	1.26	+0.01
2	7x7	5.323	120.4	1.31	1.32	+0.01
3	7x7	5.280	120.7	1.33	1.33	-
4	8x8	5.656	110.0	1.32	1.32	-
5	8x8	5.360	112.2	1.39	1.39	-
6	8x8	5.276	112.8	1.42	1.42	-
7	8x8	5.913	107.2	1.25	1.25	-
8	8x8R	6.571	108.0	1.25	1.24	-0.01
9	8x8R	6.495	108.4	1.26	1.26	-

References

1. YAEC-1299P, 'Methods for the Analysis of Boiling Water Reactors, Transient Critical Power Ratio Analysis,' Yankee Atomic Electric Company, March 30, 1982, reviewed by NRC and found acceptable, SER issued under docket number 50-271 (cited with permission).

2. A. F. Ansari, R. R. Gay, and B. J. Gitnick, 'FIBWR - A Steady-state Core Flow Distribution Code for Boiling Water Reactors,' EPRI-NP-1923, July 1981.

3. NEDE-24273 (Proprietary), 'GEXL Correlation Application to TVA Browns Ferry Nuclear Power Station,' General Electric Company, July 1980.

4. BN-7509, 'COMETHE IIIJ, A Computer Code for Predicting Mechanical and Thermal Behavior of a Fuel Pin,' Belgonucleaire S. A., Broxelle.