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ABSTRACT

Several improvements have been made to COBRA-IIIC/MIT. All of the improvements, except for one, have been made in response to the recommendations of past research. The improvements are included in a new version of the code as new modeling options. The new modeling options overcome limitations and disadvantages of old modeling options. The improvements are as follows:

1. Addition of a new fuel pin conduction model which includes temperature dependent properties and burn-up dependent gap heat transfer coefficient.

2. Addition of a new heat transfer package which covers a broad range of flow regimes and contains more consistent logic.

3. Addition of a quality dependent mixing model for two-phase flow.

4. Addition of new correlations for BWR, CHFR and CPR calculation.

5. Addition of new options for calculating transverse momentum coupling parameters use for the single pass method.

The improvements have been tested individually and during application of the improved code to transient PWR and BWR test cases. Testing mainly involved comparison of the predictions of different modeling options and in some instances, comparison of predictions with experimental measurements. MDNBR, MCPR and MCHFR predictions showed only small sensitivities to the fuel rod and heat transfer modeling options used for the test cases analyzed. Differences in predictions of the old and new heat transfer models resulted in different clad temperature predictions. Clad temperature varies more smoothly in the axial direction when the new heat transfer model is used. The new heat transfer model predictions vary smoothly from one time step to the next with changing coolant conditions. Discontinuous change in old heat transfer model predictions caused failure of the flow solution to converge during transient BWR analysis. Fuel rod surface heat flux predictions of the old and new fuel rod models were close even though fuel rod temperature predictions showed some differences. The new mixing model did not improve subchannel flow and enthalpy predictions for BWR conditions. However, some improvement was seen in predictions for sub-cooled conditions. The CISE-4 MCPR predictions were in agreement with experimental CHF measurements. Hench-Levy MCHFR predictions were conservative for the CHF test cases. The new transverse momentum parameters had no significant effect on steady state hot channel predictions of the single-pass method.

ACKNOWLEDGEMENTS

Lothar Wolf deserves recognition as the person whose ideas and efforts brought this research into being. He shaped the general scope of this project at the planning stage to fill specific research needs which became apparent during previous research with which he was involved. Dr. Wolf and Prof. Neil Todreas are both to be thanked for the many useful ideas which they provided during the course of this research. Information provided by Chong Chiu of Combustion Engineering regarding the approach to transverse momentum modeling was also appreciated.

We gratefully acknowlege the financial support, ideas, and test case information provided by the sponsors of this research under the MIT Energy Laboratory's Electric Utility Program.

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I. INTRODUCTION

Thermal-hydraulic analysis of light water reactor (LWR) cores is usually performed using a computer code. Thermal-hydrualic analysis calculates parameters such as temperature, density, or departure from nucleate boiling ratio (DNBR). "Subchannel codes" may be used for this analysis. "Subchannel codes" represent the geometry of a core using coolant and fuel rod nodes. There are a number of "subchannel codes," one of which is COBRA-IIIC/MIT.

COBRA-IIIC/MIT research has continued since its initial development in 1976 (Ref. 1). Past COBRA-IIIC/MIT research efforts have followed two paths. One path is concerned with the development and assessment of the bundle-wide analysis tool, MEKIN/T.H., which is based on COBRA-IIIC/MIT and is the thermal-hydraulic part of the three-dimensional core-wide kinetics code, MEKIN.

The second path was concerned with COBRA-IIIC/MIT. Early efforts along this path focussed on development of the single-pass analysis method, whereby an entire PWR core is analyzed in one stage using a fine mesh in a zone surrounding subchannels with higher radial peaking factors, and a coarser mesh outside this zone. More recent efforts along this second path compared COBRA-IIIC/MIT predictions with predictions of other codes and experimental data. Past research along the two paths has indicated several areas for COBRA-IIIC/MIT improvement.

Several improvements have been made to COBRA-IIIC/MIT. All of the improvements, except for one, have been made in response to recommendations of past research. The improvements are included in a new version of the codes as new modeling options. The new modeling options overcome limitations and disadvantages of old modeling options.

First, past research will be reviewed to provide an understanding of why COBRA-IIIC/MIT has been improved. Secondly, individual improvements will be described. Then, results of tesing individual improvements and application of the improved COBRA-IIIC/MIT version to transient test cases will be presented. Lastly, data input for the new version will be described.

II. REVIEW OF PAST RESEARCH

A. Overview

Since completion of the initial development of COBRA-IIIC/MIT in 1976 (Ref. 1), work on the code has continued at MIT under both EPRI and individual utility sponsorship. This work has proceeded along two paths. One path is concerned with the development and assessment of the bundle-wide analysis tool, MEKIN/T.H., which is based on COBRA-IIIC/MIT and is the thermal-hydraulic part of the three-dimensional core-wide kinetics code, MEKIN. The other path is concerned with development and improvement of the single-pass, mixed-lattice version of COBRA-IIIC/MIT. Although their goals are somewhat different, the two paths have complemented each other to some extent. Therefore, research work along both paths has been reviewed. A summary of this work is provided in Table II-1. The following discussion is separated into a discussion of work done prior to Fall 1977 (Ref. 1-11) and work done betweeen Fall 1977 and Fall 1978 (Ref. 12).

B. Work Completed Prior to Fall 1978

Rodack (Ref. 2) used MEKIN/T.H. to study Reactivity Insertion Accident (RIA) type transients in PWRs and related topics, including the sensitivity of thermal-hydraulic predictions to several parameters. His results indicate the importance of considering the spatial and temporal variation of the gap heat transfer coefficient, h_{gap}, in order to accurately calculate steady state fuel rod temperature distributions and transient surface heat fluxes. The effects of the temperature-dependence of fuel material properties and the quality-dependence of turbulent mixing parameter β, were also evaluated and shown to be significant.

The sensitivity study performed by Emami (Ref. 3) related to both MEKIN and COBRA-IIIC/MIT development but used COBRA-IIIC/MIT rather than MEKIN/T.H.. This study considered steady state conditions for both PWR and BWR systems. Overall thermal results were not significantly affected by wide ranges

TABLE II-1

Summary of Past Research

Emphasis on MEKIN	Emphasis on COBRA-IIIC/MIT	System PWR	System BWR	Operation S.S.	Operation Transient	Code Used	Information/Results	Reference
+	-	+	-	-	+	MEKIN/T.H.	PWR-RIA study, sensitivity study of T-H input parameters on fuel temperatures and coolant density, void fraction. List of most important parameters.	(2)
+	+	+	+	+	-	COBRA-IIIC/MIT	Sensitivity of COBRA solution to user input parameters and user selected correlations.	(3)
-	+	+	-	-	+	COBRA-IIIC/MIT	Lumped and mixed lattice approach (single pass method).	(4,7)
-	+	+	-	-	+	COBRA-IIIC/MIT	Verification of the single pass method in transients, discussion of experimental verification of COBRA.	(5,7)
-	+	+	-	+	-	COBRA-IIIC/MIT	Transport coefficients to improve results of lumped, mixed lattice approach.	(6,7)
-	+	+	-	+	-	COBRA-IIIC/MIT	Senisitivity of COBRA solution to user input parameters.	(8)
+	+	+	-	+	+	COBRA-IIIC/MIT	Development of a new solution method based on pressure field, convergence studies.	(9,10)
+	+	+	+	+	+	-	Study of different fuel pin models.	(11)
-	+	+	+	+	+	COBRA-IIIC/MIT & IV-I	Assessment and comparison/similar results except for clad temperature predictions.	(12)

Key: + yes
- no

of values used for the transverse momentum parameters, s/ℓ and K_{ij}, except for cases of large inlet flow upset of blockage. Variation of the turbulent mixing parameter, β, greatly affected flow and enthalpy predictions under two-phase conditions typical of BWR's.

Work described in Refs. 4-8 was concerned with COBRA-IIIC/MIT development. The major portion of this reasearch was directed toward the development of a single-pass method, a method whereby an entire core is analyzed in only one stage using a fine mesh in a zone surrounding sub-channels with higher radial peaking factors, and a coarser mesh outside this zone. The parameter primarily concentrated on during this development was DNBR, since it was considered to be the most important parameter for licensing purposes. The research by Moreno (Ref. 4) and Liu (Ref. 5) provided the basis for justification of the method developed for steady-state and transient analyses as compared to the multi-pass (chain) methods used by reactor vendors. Chiu (Ref. 6) examined the applicability of two-dimensional transport coefficients to improve the lumped energy transfer models. Transverse momentum coupling parameters were investigated and found to have negligible effect for steady state conditions considered. All these research efforts are summarized in Ref. 7, which together with Refs. 5 and 8 comprised the state-of-the-art of the single-pass method and status of COBRA-IIIC/MIT development as of September 1977. The major conclusion from this work is that the simplified (single-pass) method yields accurate DNBR predictions, consistent multi-stage methods for PWRs under steady state and some transient conditions.

The research done by Masterson (Refs. 9 & 10) developed more efficient methods for solving the set of conservation equations of COBRA-IIIC/MIT. The COBRA-IIIP/MIT code was the result of his effort. COBRA-IIIP/MIT is numerically more efficient by allowing the use of iterative solution methods for sets of linear equations. COBRA-IIIP/MIT solves for the pressure distributions at individual axial levels, rather than crossflows. COBRA-IIIP/MIT generates converged crossflow distributions for decreasing axial mesh sizes, unlike COBRA-IIIC/MIT.

Finally it should be pointed out that recommendations to investigate fuel rod modeling given by Rodack (Ref. 2) have been followed to some extent by Mehrabian (Ref. 11) who compared various fuel pin models.

C. Work Completed Between Fall 1977 and Fall 1978

Between Fall 1977 and Fall 1978, research work was conducted by Kelly (Ref. 12) to evaluate the applicability of COBRA-IIIC/MIT for the thermal-hydraulic analysis of various Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) cases of interest to utility engineers. The evaluation was made by comparing predictions of COBRA-IIIC/MIT with predictions of COBRA-IV-I and experimental data. During the investigation, COBRA-IIIC/MIT was modified to eliminate various inconsistencies and failures.

Application and testing of COBRA-IIIC/MIT during this project included the following:

1) BWR Bundle Analysis
   a. Steady-State
   b. Pressurization Transient
2) PWR Analysis
   a. Severe Power Transients
   b. Loss of Flow Transients
3) Comparisons with Experimental Data
   a. Maine Yankee Exit Temperature Comparison
   b. B&W Inter-bundle Crossflow Experiment
   c. EIR Flow Blockage Experiment

The cases analyzed and results obtained are summarized in Table II-2. Conclusions made on the basis of these results were as follows:

1) Improvements are needed in both the heat transfer logic and the procedure for calculating the rod-to-coolant heat transfer coefficient.

2) As a result of the modifications made, it is now possible to use COBRA-IIIC/MIT to analyze a BWR core on a bundle-wide basis for tansient condtions and to analyze a PWR

<u>Table II-2</u>

<u>Summary of Cases Analyzed and Results from Ref. 11</u>

Case		Steady state or transient initial conditions				Levy sub-cooled Boiling Model Used	Results
		G ($Mlb/hr-ft^2$)	P (psia)	T (°F)	q" ($MBtu/hr-ft^2$)		
BWR	Inlet Flow Sensitivity	1.25 1.25 1.25 1.25	1035 1035 1035 1035	527 527 527 514	0.152 0.152 0.152 0.152	yes yes no yes	Inlet flow shows some sensitivity to many perimeters
	Steady State Comparisons	1.25 1.25 1.25	1035 1035 1035	527 527 514	0.152 0.152 0.152	yes no yes	COBRA-IIIC/MIT and COBRA-IV-I clad temperature predictions different
	Pressurization Transient	1.25 1.25	1035 1035	527 527	0.152 0.152	yes no	Using Levy model improves predictions. Code modifications made are described in Ref. 11, pages 54-68
PWR	Severe Power Transient	2.48 2.48 2.48 0.25	2100 2100 2100 2100	635 635 635 635	10. 10. 10. 1000.	yes yes no no	COBRA-IIIC/MIT and COBRA-IV-I predictions nearly the same except for clad temperature. Levy model fixed to prevent oscillations as described in Ref. 11, pages 95-103
	Loss of Flow Transient	2.48 2.48 2.48 2.48	2100 2100 2100 2100	541 541 541 570	0.1695 0.30 0.1695 0.30	yes yes yes yes	COBRA-IIIC/MIT and COBRA-IV-I predictions nearly the same except for clad temperature
	Maine Yankee Exit Temp. Comparison	2.48	2100	532	0.173	no	Exit temperature predictions of COBRA-IIIC/MIT and COBRA-IV-I in good agreement with data
B&R Crossflow Experiment		---	near atmospheric	ambient	0.0	no	COBRA-IIIC/MIT and COBRA-IV-I crossflow predictions sensitive to axial nodalization; aside from this, predictions in good agreement with data
EIR Flow Blockage Experiment		---	near atmospheric	ambient	0.0	no	Predictions in fairly good agreement with data. COBRA-IV-I gave better predictions by modeling variation of flow area directly

transient using small time steps. However, the crossflow solution is sensitive to axial mesh size.

3) Despite the difficulties with the heat transfer calculation, COBRA-IIIC/MIT appears to provide adequate PWR DNBR predictions. However, the ccde does not contain the logic or correlations needed to calculate BWR Critical Power Ratio (CPR).

These conclusions are each discussed in the following paragraphs and some examples of underlying calculationsal results are provided.

The need for improvement of the COBRA-IIIC/MIT rod-to-coolant heat transfer model became apparent from the comparison of COBRA-IIIC/MIT predictions with those of COBRA-IV-I. The inconsistency of the two code predictions is clearly shown in Figure II-1, which is a graph of steady state temperature vs. axial position for a BWR bundle analysis case. As shown in the figure, the clad temperature predicted by COBRA-IIIC/MIT varies discontinuously in the axial direction near the inlet and is significantly different from the COBRA-IV-I predictions. As discussed in Ref. 12, this difference is caused by differences in the heat transfer logic and energy equations used in the two codes in the subcooled boiling regime, with COBRA-IIIC/MIT being the least accurate.

Application of COBRA-IIIC/MIT to BWR and PWR transient analysis cases indicated that the code had not previously been adequately tested for such cases. One problem encountered was an oscillatory behavior of mass flow rate predictions during iteration, as shown in Figure II-2. This figure shows the variation of mass flow rate with iteration number at the point where boiling starts during analysis of PWR power transient. The oscillatory behavior was eliminated by a correction which prevented the quality from oscillating unrealistically between positive and negative values once it becomes positive in a particular node. Elimination of this and similar problems subsequently allowed COBRA-IIIC/MIT to analyze and make reasonable predictions for several PWR and BWR transients, as mentioned in Table II-2.

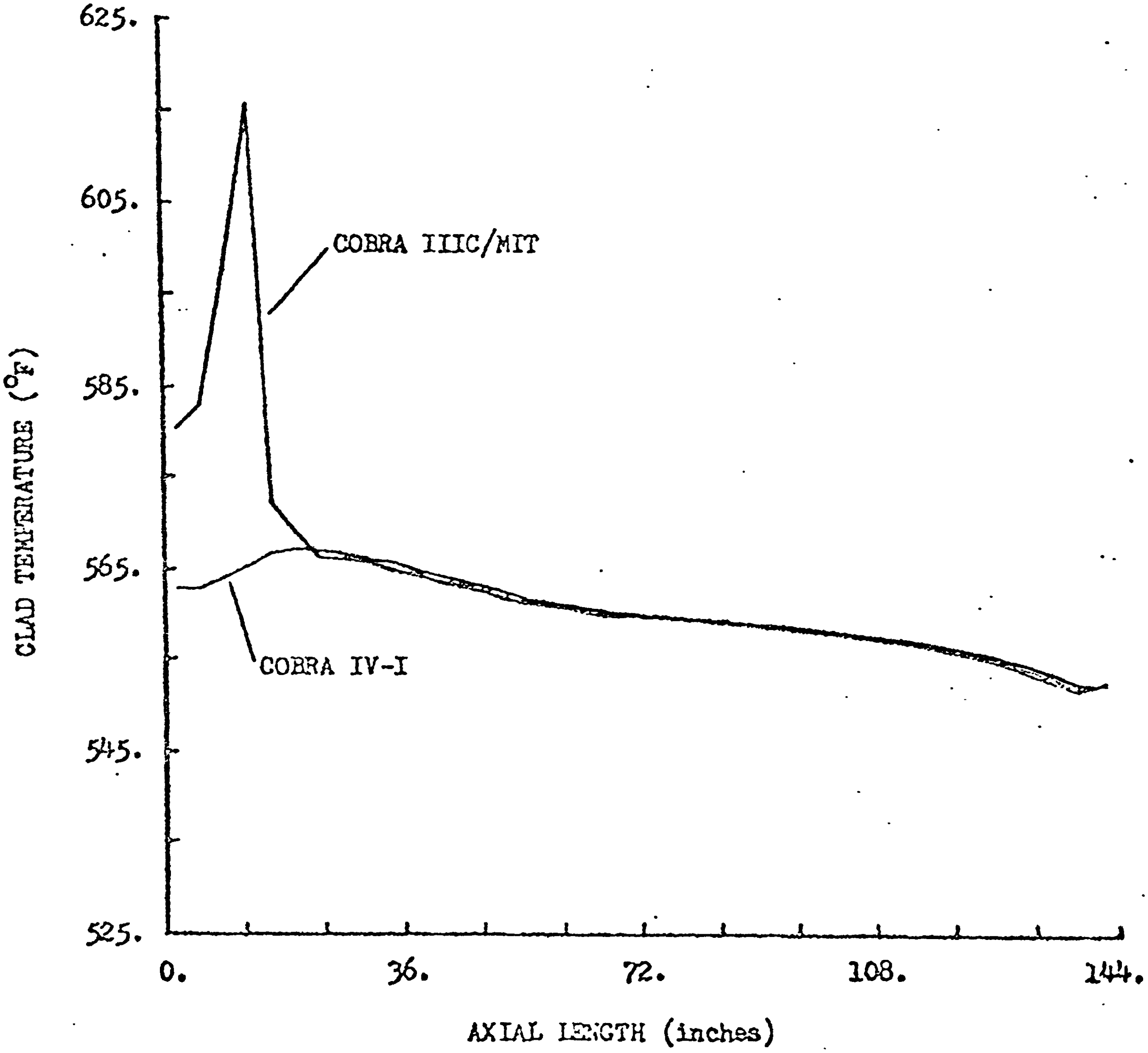


Figure II-1 (FIGURE 2.7 of Ref. 12)
CLAD TEMPERATURE VERSUS AXIAL LENGTH
RESULTS FOR STEADY STATE BWR CASE

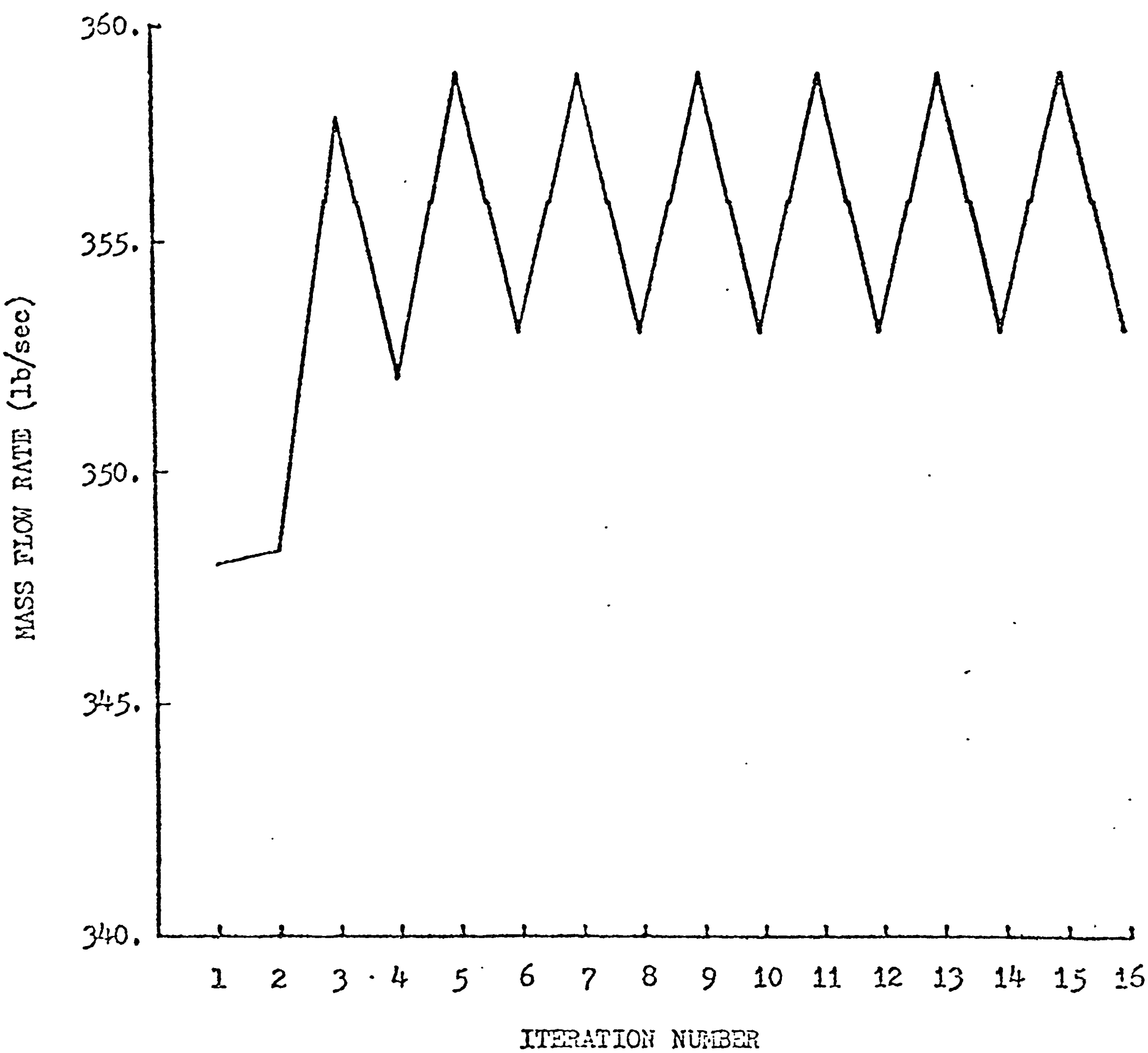


Figure II-2 (Fig. 3.4 of Ref. 12)

Mass Flow Rate Versus Iteration Number at
Initiation of Boiling for PWR Severe Power Transient Case

Sensitivity of the crossflow solutions of both COBRA-IIIC/MIT and COBRA-IV-I to axial nodalization was encountered during analysis of the B&W crossflow experiment. The B&W isothermal test apparatus is shown in Figure II-3. The apparatus contains two bundles, separated above and below a common mixing length by divider plates. The flow control valves were adjusted to give the two bundles different flow rates; thus, inlet flow upset conditions were simulated. Sensitivity of crossflow predictions can be seen in Figs. II-4 and II-5. Figure II-4 shows COBRA-IIIC/MIT crossflow predictions of experimental results inferred from pressure measurements. Both COBRA-IIIC/MIT predictions use six channels to represent the experiment. One set of COBRA predictions uses 20 axial nodes and the other uses 36. The predictions show significant differences. Figure II-5 contains a pair of COBRA-IV-I crossflow predictions similar to those of COBRA-IIIC/MIT in Figure II-4. The differences between the predictions of COBRA-IV-I when the number of axial nodes change from 20 to 36 is dramatic. The crossflow solutions of both COBRA-IIIC/MIT and COBRA-IV-I failed to converge when 72 axial nodes were used. Figure II-6 shows the consistent set of results obtained for 20, 36, and 72 axial nodes when THERMIT, (Ref. 13) a code with greater capabilities than either COBRA-IIIC/MIT or COBRA-IV-I, was used. THERMIT contains the complete Navier-Stokes equations for momentum transport in all three directions, thereby avoiding any of the simplifications in the transverse momentum equations which are common for COBRA-IIIC/MIT and COBRA-IV-I.

Finally, despite the need for improvements in the COBRA-IIIC/MIT heat transfer logic and the procedure for calculating the rod-to-coolant heat transfer coefficient, the code appears to provide adequate PWR DNBR predictions. As dicussed in Ref. 12, with the exception of clad temperature predictions, COBRA-IIIC/MIT and COBRA-IV-I predictions were in good agreement with each other and experimental measurements; and the DNBR was not affected by the clad temperature discrepancies. However, COBRA-IIIC/MIT does not contain the logic or correlations needed to calculate Critical Power Ratio (CPR), a figure-of-merit for BWR thermal margin.

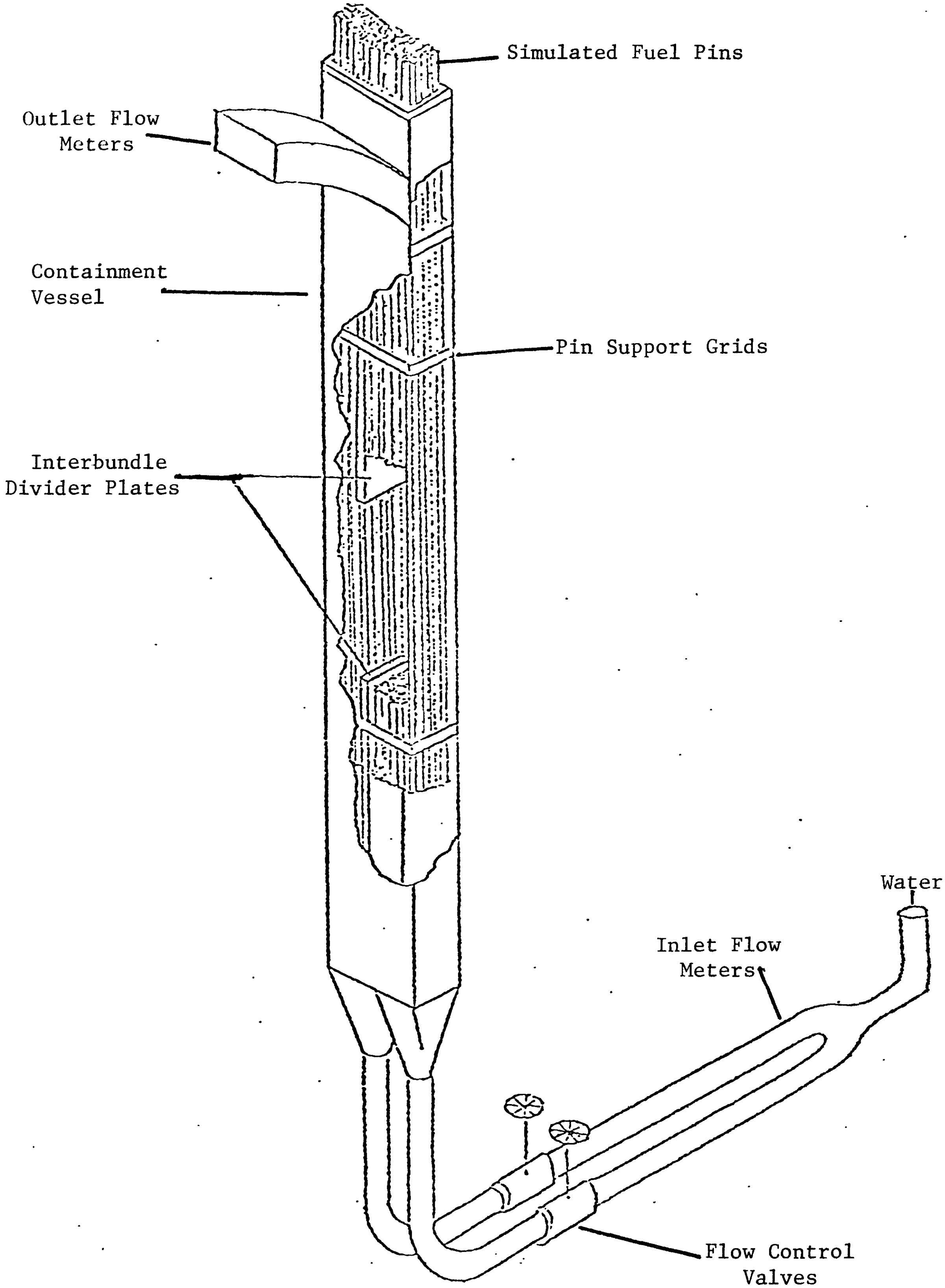


Figure II-3 (Fig. 5.2 of Ref. 12)

Schematic of B&W Apparatus

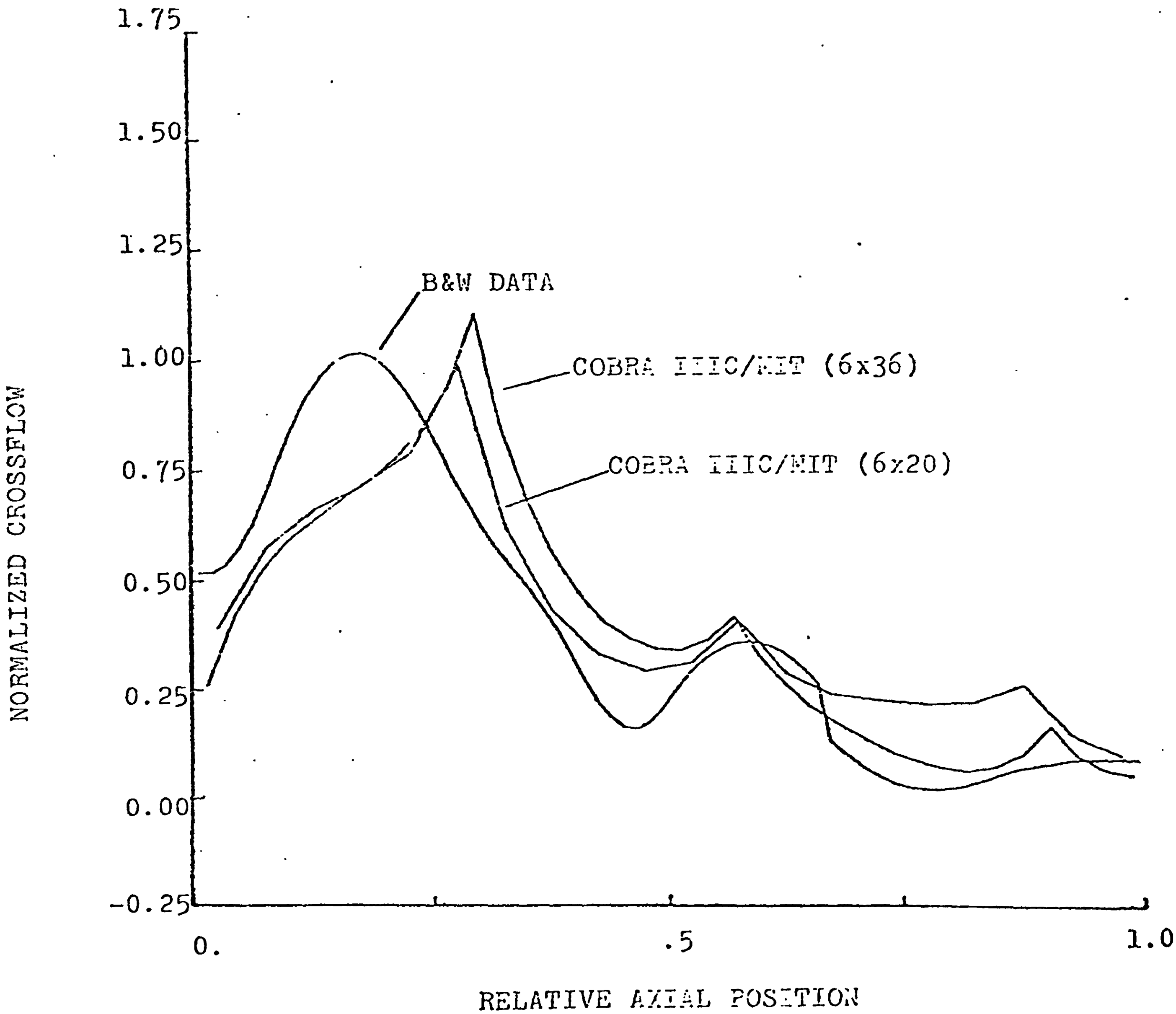


Figure II-4 (FIGURE 3.18 of Ref. 11)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
COBRA-IIIC/MIT RESULTS FOR B&W CROSSFLOW EXPERIMENT

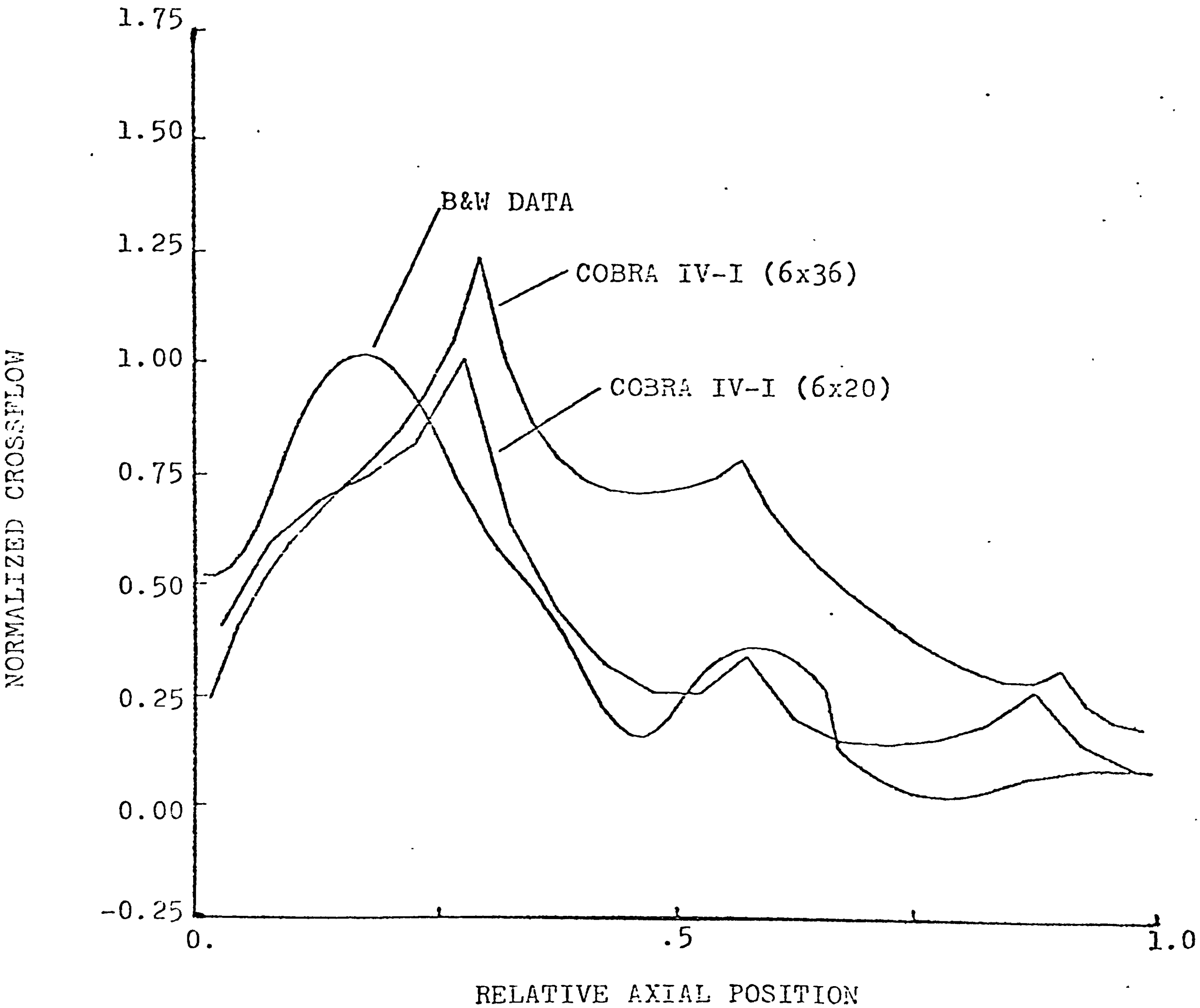


Figure II-5 (FIGURE 3.19 of Ref. 12)

NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
COBRA-IV-I RESULTS FOR B&W CROSSFLOW EXPERIMENT

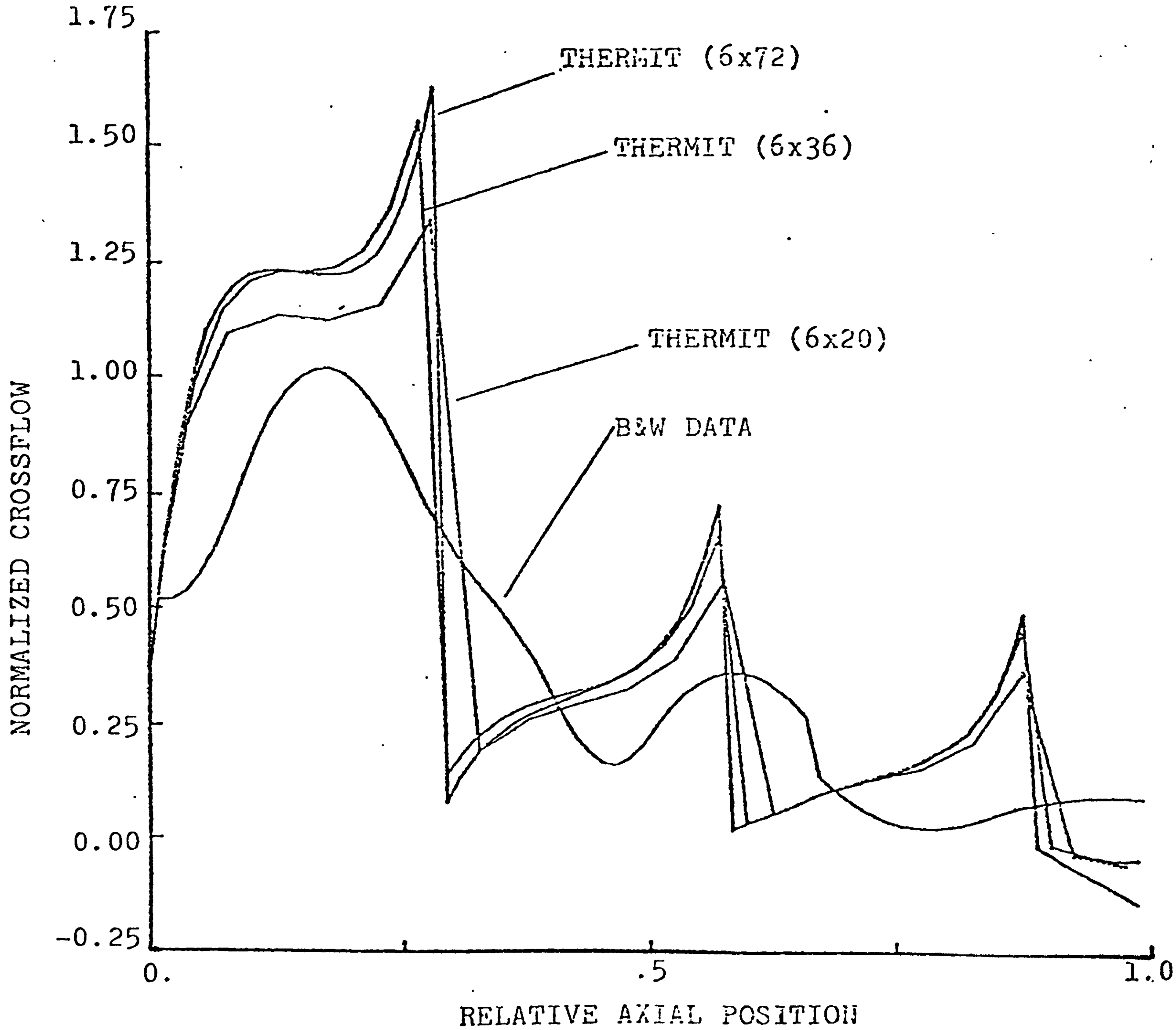


Figure II-6 (FIGURE 3.20 of Ref. 12)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
THERMIT RESULTS FOR B&W CROSSFLOW EXPERIMENT (Ref. App. H)

D. Summary of Major Conclusions Leading to Present Research

The major conclusions from past research that have led to the research described in this report can be summarized as follows:

1) A new fuel rod model containing temperature-dependent properties and considering spatial and temporal variation of the gap heat transfer coefficient should be added.

2) The heat transfer model of COBRA-IIIC/MIT has poor logic which causes unrealistic discontinuities in its predictions.

3) In the two phase region, flow and enthalpy predictions are sensitive to the turbulent mixing parameter, β, which varies greatly with respect to quality.

4) The simplified (single-pass) method yields accurate DNBR predictions, consistent with multi-stage methods for PWRs under steady-state and some transient conditions. However, COBRA-IIIC/MIT does not have the logic or correlations needed to calculate BWR CPR.

5a) Transverse momentum coupling parameters are of negligible importance for steady state (near-normal) conditions.

5b) Overal thermal results are not dependent on the crossflow parameters s/ℓ and K_{ij}, except for cases of large inlet flow upset or blockage.

6) Crossflow predictions are sensitive to axial nodalization.

III. CODE IMPROVEMENTS

A. Introduction

Several improvements have been made to COBRA-IIIC/MIT. The improvements are briefly described in Table III-1. The need for improvements a through d was seen during past research. Improvements a through d correspond to conclusions 1 through 4 given in Section II.D. Improvement e is the result of a suggestion by Prof. J. Weisman (Ref. 14). Conclusions 5a and 5b of Section II.D are related to the technical issue behind improvement e. The improvements are options of the improved version of COBRA-IIIC/MIT. Code changes made during implementation of improvements are described in Appendix A. Improvements will be individually described in the following sections.

B. New Fuel Rod Model

A new fuel rod model has been added to COBRA-IIIC/MIT. This model is based on the MATPRO model developed at INEL (Ref. 15) and eliminates the following disadvantages of the old COBRA-IIIC/MIT fuel rod model:

1) Fuel and cladding properties were assumed to be independent of temperature.

2) A single value of the fuel-clad gap heat transfer coefficient, h_{gap}, was used for the entire reactor core.

3) Gap and clad conductivity were lumped into single node.

4) Gap thickness was assumed to be zero.

The need for considering the temperature dependence of fuel rod properties is indicated by results of past research, as discussed in Section II. These results (Ref. 2) showed that transient thermal-hydraulic predictions are especially sensitive to fuel thermal conductivity and heat capacity and fuel-to-clad gap heat transfer coefficient. The temperature variation of fuel conductivity and heat capacity is shown in Figures III-1 and III-2, respectively.

TABLE III-1

COBRA-IIIC/MIT IMPROVEMENTS

IMPROVEMENT	PREVIOUS STATUS	DESCRIPTION OF IMPROVEMENT	ADVANTAGES/DISADVANTAGES
a) New Fuel Rod Model	No temperature dependence, constant value of fuel-clad gap heat transfer coefficient used for entire core	New model with temperature dependent properties, higher numerical accuracy and burnup-dependent fuel-clad gap heat transfer coefficient	Better modeling, higher accuracy improved heat transfer prediction/ slightly increased computation time
b) New Rod-to-Coolant Heat Transfer Model	Inconsistent logic causes poor clad temperature predictions	New heat transfer model with greater capabilities in the high quality regime and more consistent logic	Improved heat transfer predictions/ Increased computation time
c) New Mixing Model	Cannot account for quality dependence	Added option enabling use of quality dependent mixing model	Improved capability for BWR subchannel analysis/Slightly increased computation time
d) Critical Power Ratio (CPR) and Critical Heat Flux Ratio (CHFR) Calculation Options	No CPR or CHFR calculation options available for BWR analysis	Added options calculate CPR and CHFR	CPR and CHFR can be calculated/No disadvantage expected
e) New Transverse Momentum Coupling Parameters for the Single-Pass Method	Only one value of s/ℓ and K used for all gap interconnections of a case	s/ℓ and K are, in effect, varied from one gap interconnection to another by coupling parameters	May slightly improve accuracy of predictions under some conditions/Extra input preparation effort, no axial variation of coupling parameters

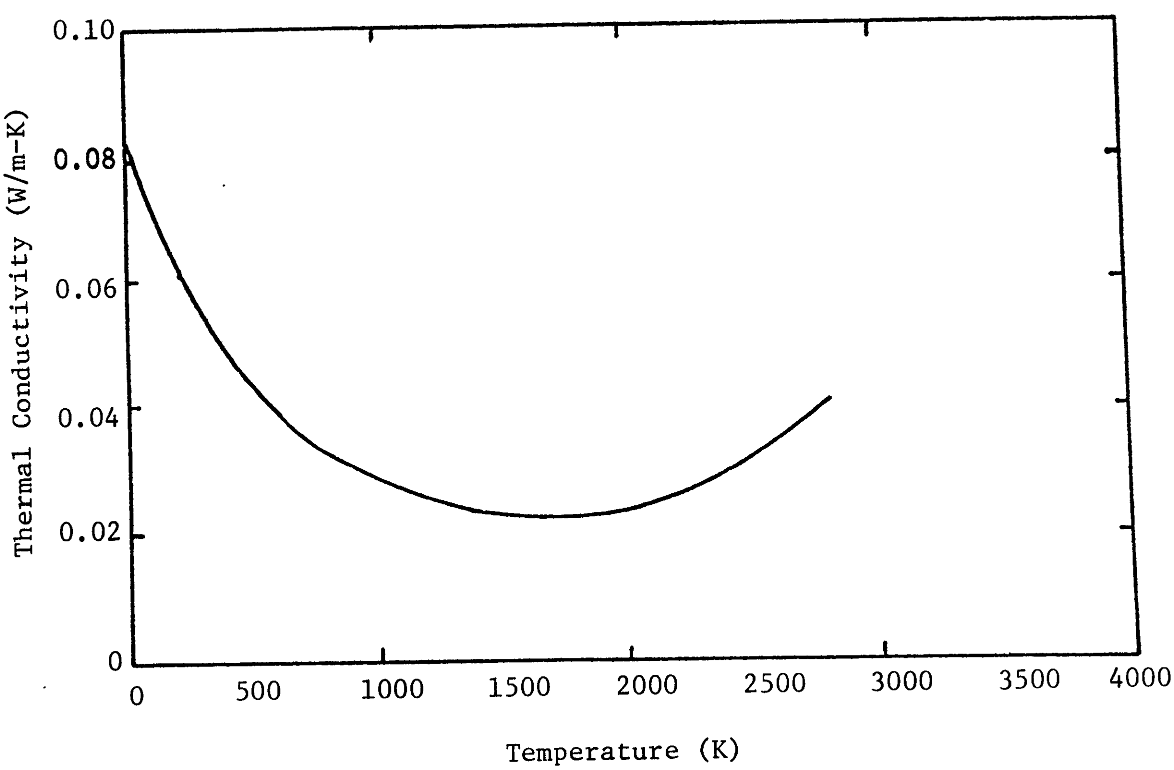


Figure III-1 (Based on Fig. A-2.1 of Ref. 15)

Thermal Conductivity of UO_2

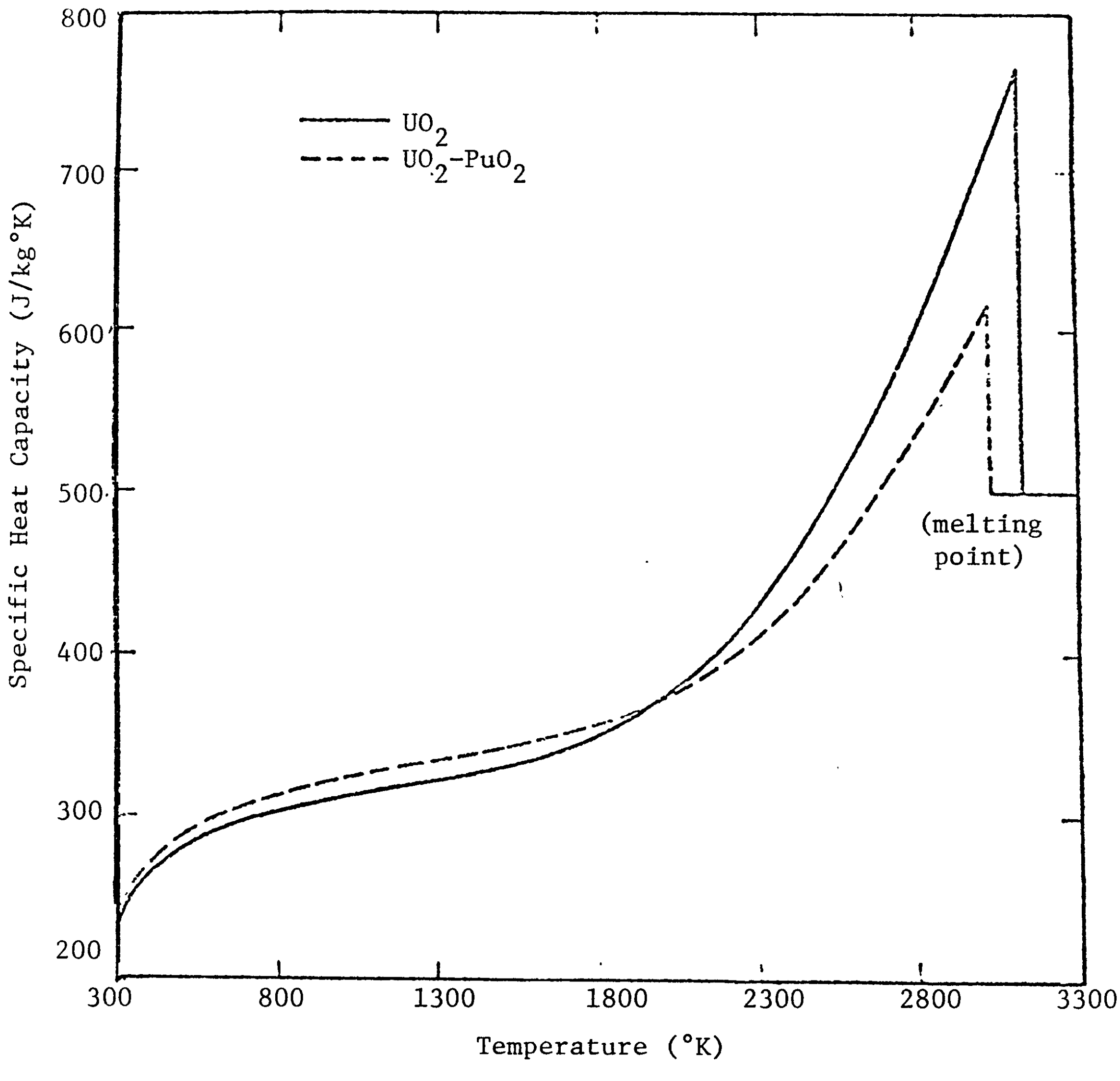


Figure III-2 (Fig. A-1.1 of Ref. 15)

Specific Heat Capacity of UO_2 and UO_2-$P_{\mu}O_2$

The methods used by the new fuel rod model to represent temperature dependent properties and h_{gap} are described in Appendix B. The old and new fuel rod model is called by subroutine HEAT and used in the calculation of fuel rod temperatures and surface heat fluxes as described in Appendix C.

C. New Rod-to-Coolant Heat Transfer Model

A new heat transfer model based on the BEEST (Ref. 16) package has been added to COBRA-IIIC/MIT. The new model has greater capabilities and better heat transfer logic than the model previously used. The old heat transfer model was limited to pre-CHF conditions and used questionable logic to switch from forced convection to nucleate boiling heat transfer. Void fraction rather than wall temperature determines when the switch is made.

The new model can construct a complete boiling curve, such as the one shown in Figure III-3, for each space and time step. The boiling curve shown has positive slope up to point A, where critical heat flux occurs. Between point A and B is a transition boiling region. Point B is at the metastable film boiling temperature. The curve continues to the right from B in the film boiling region. The new model constructs portions of the curve only as they are needed in order to avoid unnecessary computation.

The new heat transfer model has two options. The first option is to consider only pre-CHF conditions. This option bypasses calculations which are made to check if CHF has been exceeded. The second option is to consider pre- and post-CHF conditions. If the first options is used for a case which includes post-CHF conditions, pre-CHF correlations will be mistakenly used for post-CHF conditions. One may be able to detect this error by noticing a CHFR, CPR, or DNBR prediction which is less than unity.

The new heat transfer model is further described in Appendix D. The equations and data bases of the pre-CHF correlations used in the old and new heat transfer models are given in Appendix E. The new heat transfer model is similar to the COBRA-IV-I heat transfer model in that it constructs a complete boiling curve. The COBRA-IV heat transfer model is briefly described in Appendix F for purposes of comparison.

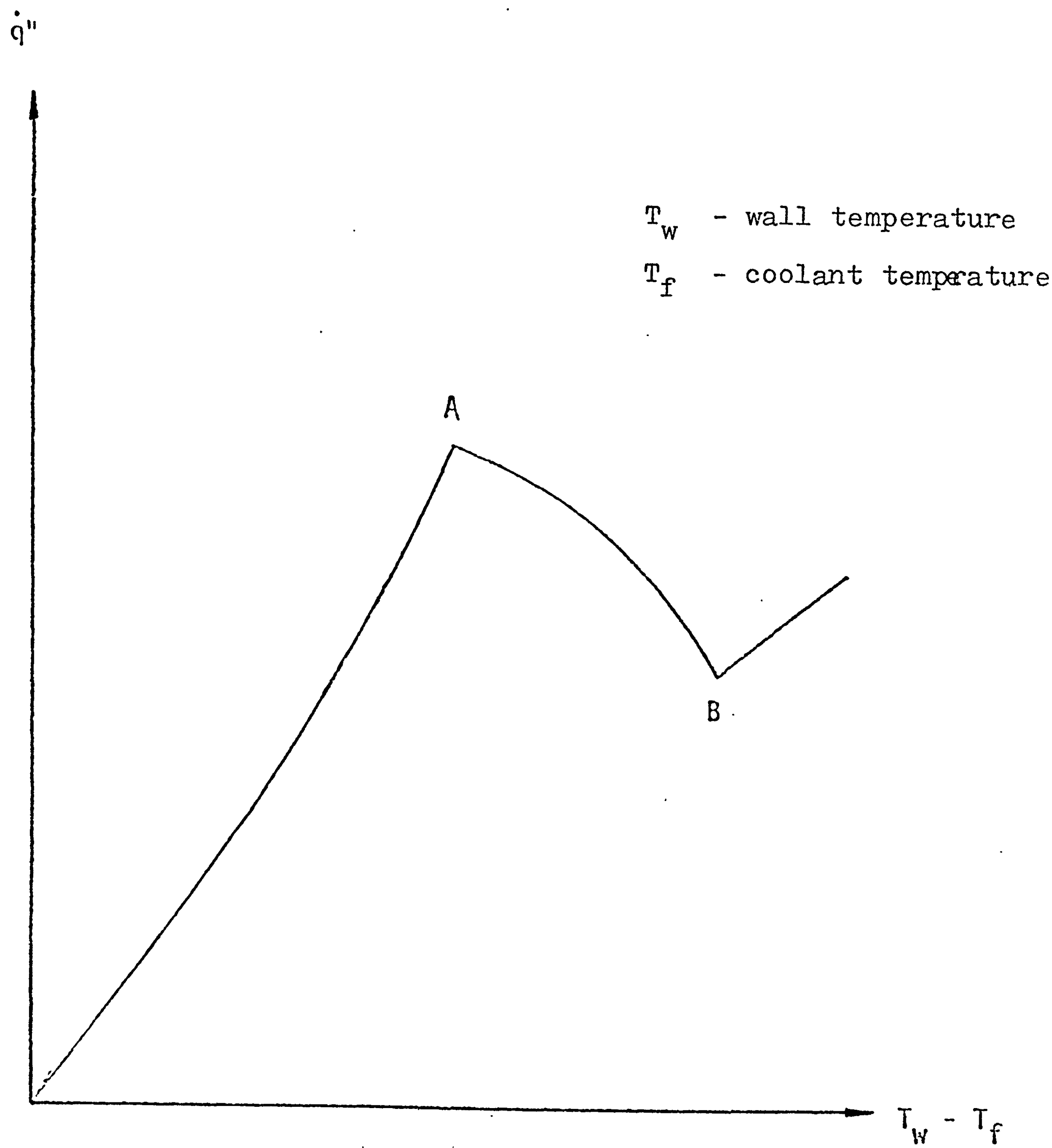


Figure III-3

A Typical Boiling Curve of New Heat Transfer Model

D. New Mixing Model

1. Description of Model

The Beus quality dependent mixing model (Ref. 17) has been added as an option to COBRA-IIIC/MIT to enable the user to better predict turbulent mixing for two-phase flow in rod bundles. The model assumes existence of two mixing regions corresponding to the bubbly-slug and annular flow regimes. The region is determined by x, G, P, and geometry (s/D_h). Figures III-4 and III-5 represent typical curves showing the variation of mixing with quality and pressure in these two mixing regions. The equations describing the model are contained in Appendix G.

The model has been constructed from the data which were taken within the following ranges:

System Pressure*	$50 \leqslant P \leqslant 775$	psia
Mass Velocity	$7.3\times10^4 \leqslant G \leqslant 3\times10^6$	lb/hr-ft^2
Quality	$0 \leqslant x \leqslant .80$	
Gap Width	$0.2 \leqslant s \leqslant .10$	in.

E. New Correlations for Critical Power Ratio (CPR) and Critical Heat Flux Ratio (CHFR) Calculation

Correlations have been added to the code to enable it to calculate CPR and CHFR. The new correlations and associated logic are described in the following subsections and Appendix H.

1. Critical Power Ratio (CPR) Correlation

a. Introduction

A common measure for thermal margin is the Critical Heat Flux Ratio (CHFR) which is defined as the ratio of CHF given by a correlation for a given set of local conditions to the local heat flux. Under BWR conditions this "local condition hypothesis" is not generally applicable. Thus, GE has adopted Critical Power Ratio (CPR) to replace CHFR as the figure of merit for evaluating BWR thermal margin as part of the GE Thermal Analysis Basis (GETAB). CPR is defined as the ratio of critical bundle power to operating bundle power. The GETAB design procedure uses the GEXL correlation

*It should be noted that the pressure range of interest for BWR's (and PWR's) exceeds the range of data upon which the Beus model is based. Thus, use of the model for analysis of reactor conditions assumes that it accounts for the pressure dependence sufficiently well to allow extrapolation to higher pressures.

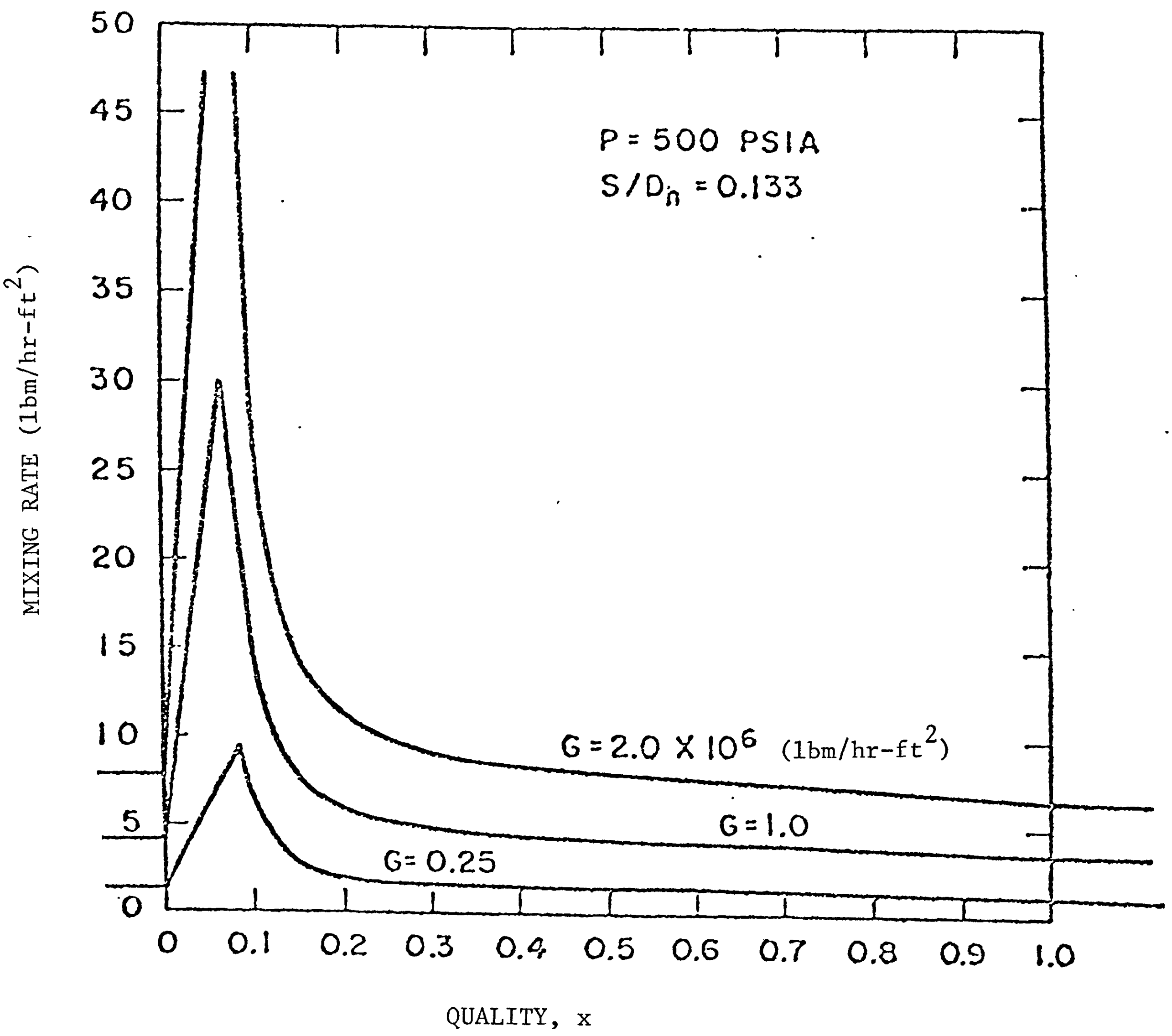


Figure III-4 (Fig. 8 of Ref. 16)

Mixing Rate Variation with Quality

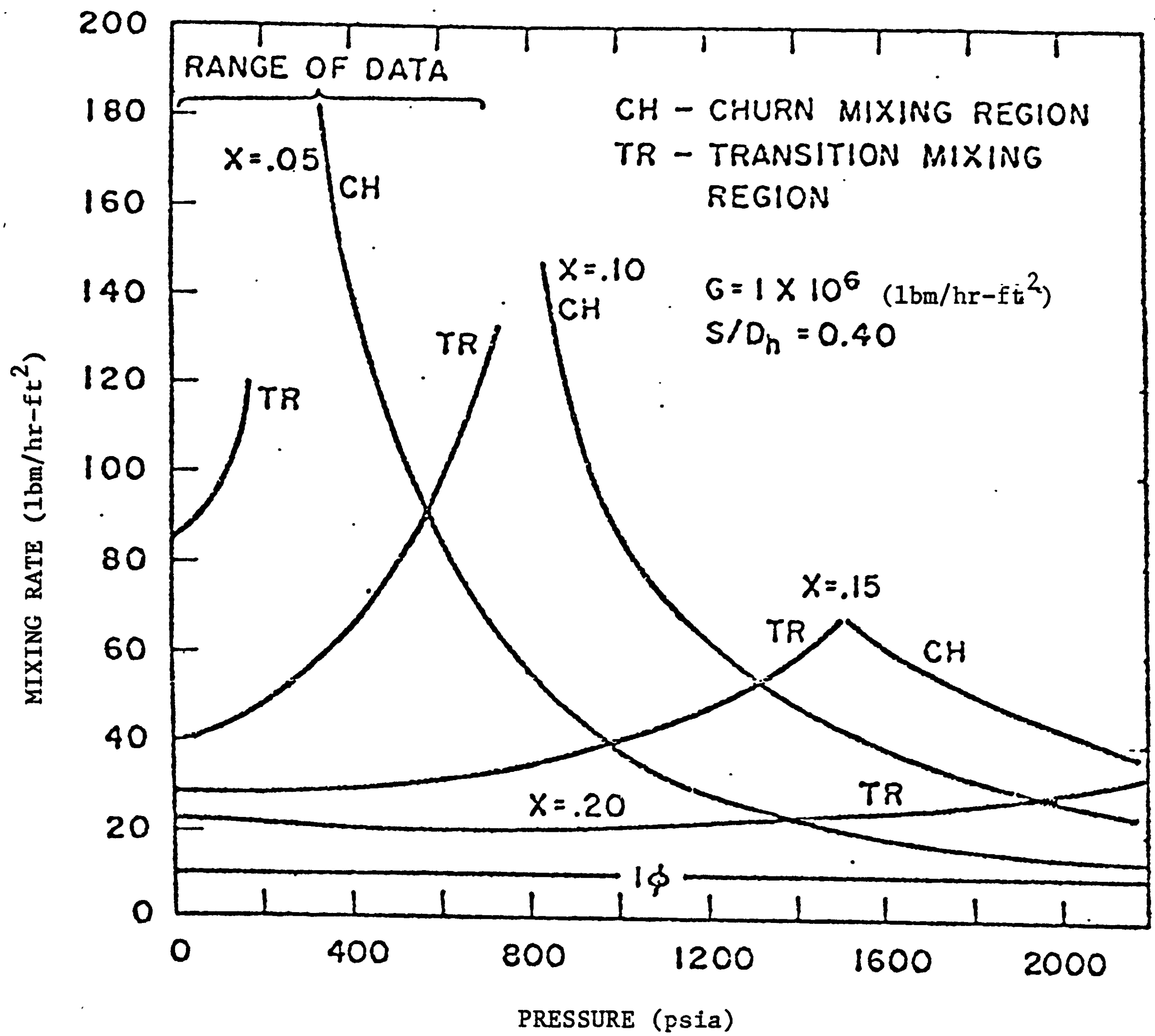


Figure III-5 (Fig. 9 of Ref. 16)

Mixing Rate Variation with Pressure

(Ref. 18) as part of a statistical treatment of the required thermal margin. The GEXL correlation is a critical quality-boiling length approach. This approach lends itself automatically to the CPR concept as a figure-of-merit for evaluating thermal margin.

The correlation, expressed in its most general form, is:

$$X_C = X_C(L_B, D_Q, G, L, P, R)$$

where:

X_C = bundle average critical quality;

L_B = boiling length;

D_Q = thermal diameter (i.e., four times the ratio of total flow area to total rod perimeter);

L = heated length;

P = system pressure;

R = a parameter which characterizes the local peaking pattern with respect to the most limiting rod; and

G = mass flux.

The parameter R, in addition to being a function of the local peaking pattern, is also dependent on lattice dimensions and on the grid spacer configuration. In effect, R, takes into account the details of the flow and enthalpy distribution which are ordinarily only accounted for by a detailed subchannel analysis.

The range of conditions over which the GEXL correlation is considered to be valid:

Pressure:	800 to 1400 psia
Mass Flux:	0.10×10^6 to 1.25×10^6 lb/hr-ft^2
Inlet Subooling:	0 to 100 BTU/lb.

As shown in Figure III-6, the heat balance curve which touches the GEXL correlation determines the critical power. The calculation of critical power involves an iterative procedure. The critical power curve is associated with a minimum critical power ratio (MCPR) of one which reduces the critical quality difference, $\langle \Delta X_e \rangle_c$, as shown in the figure to zero.

In order to comply as much as possible with the new BWR design procedure, the CISE-4 critical quality-boiling length correlation has been added to COBRA-IIIC/MIT. The CISE-4 correlation,

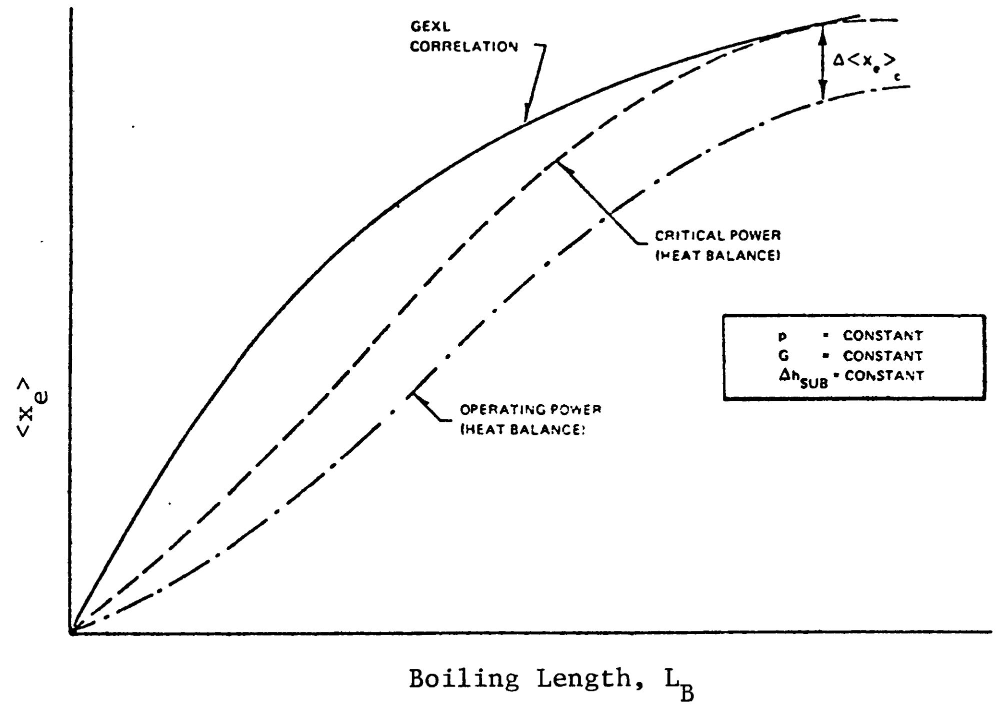


Figure III-6 (Fig. 4-40 of Ref. 19)

Graphic Display of GEXL Correlation and BWR Heat Balance Curves

(Refs. 20 and 21), the starting point of GE's own development, was introduced by Bertoletti, et. al. The CISE-type approach uses critical quality versus boiling length. Boiling length is the length over which bulk boiling occurs. Figure III-7 shows the boiling boundary, λ, the critical boiling length, L_{Bc}, and critical quality, $\langle x_e \rangle_c$. Data from experiments with uniform and non-uniform axial heat flux profiles are collapsed onto curves of $\langle x_e \rangle_c$ vs. L_{Bc} as shown in Figure III-8.

b. CISE-4 Correlation

CISE-4 is a modified version of the earlier CISE-3 correlation (Ref. 20 & 21). The modification extends the range of the correlation's applicability to lower flow rates. The CISE-4 correlation is intended for analysis using rod-centered subchannels rather than coolant-centered subchannels, such as COBRA uses. The use of CISE-4 correlations for coolant-centered subchannels is though to be permissable, however, for analysis of central bundle subchannels.

The general functional form of the correlation is:

$$\langle x_e \rangle_c = \frac{D_h}{D_e} \frac{a(P,G) L_{B_c}}{[L_{B_c} + b(P,G,D_e)]} \qquad \text{(Eqn. III-1)}$$

In COBRA-IIIC/MIT, the critical power ratio (CPR) prediction is based on a heat balance, which yields the following equation:

$$CPR \simeq 1 + \frac{\langle x_e(L_{B_c}) \rangle_c - \langle x_e(L_{B_c}) \rangle}{\langle x_e(L_{B_c}) \rangle + \dfrac{h_f - h_{in}}{h_{fg}}} \qquad \text{(Eqn. III-2)}$$

Equation (III-2) is appoximate in that it assumes that the distribution of coolant flow among channels does not change with power level. This assumption is fairly accurate in the general vicinity of critical power. The accuracy is sufficient for iteration on power until CPR=1.

*Ref. page H-9 of Appendix H for definition of nomenclature used in this section.

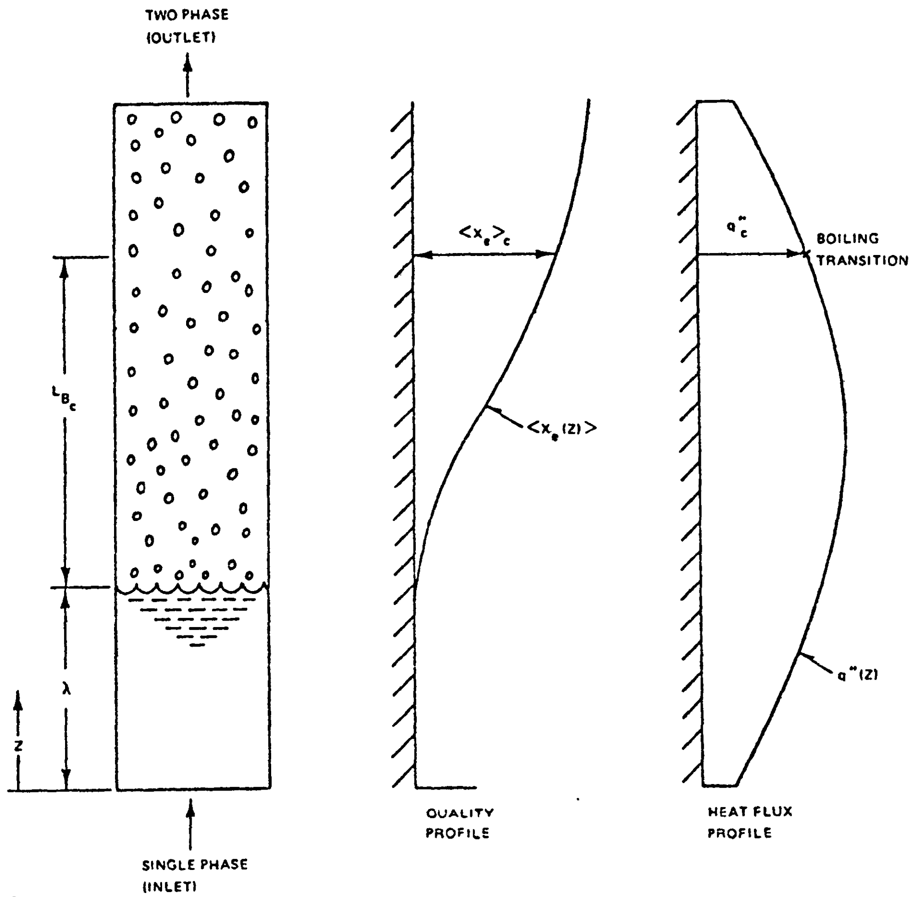


Figure III-7 (Fig. 4-27 of Ref.19)

Scehmatic Showing Relationship

Between L_{Bc}, $<x_e>_c$ and the Boiling Transition

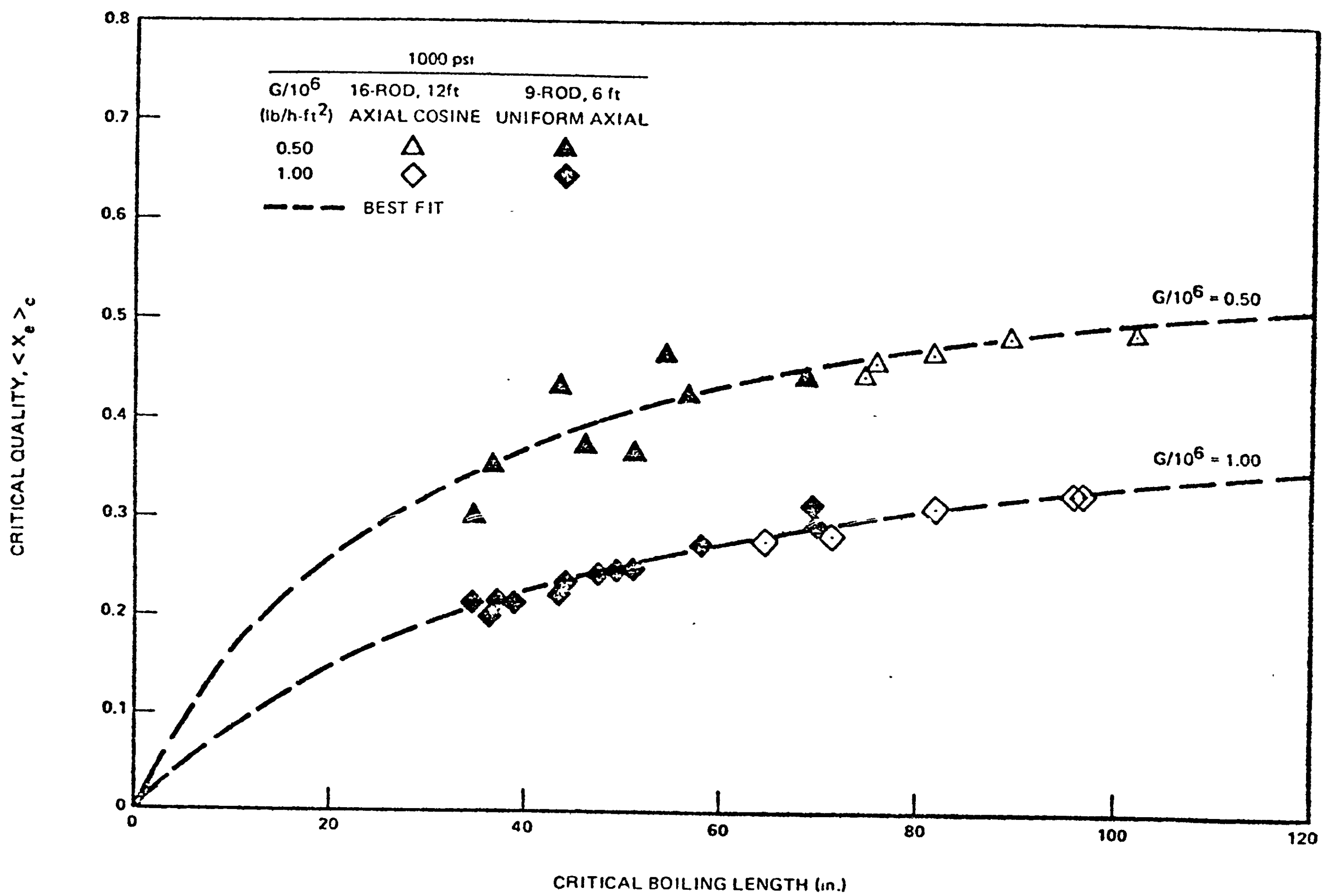


Figure III-8 (Fig. 4-31 of Ref. 19)

GE Nine-rod and Sixteen-rod Critical Quality
Versus Boiling Length Curves

2. Hench-Levy CHF Correlation

The Hench-Levy correlation (Ref. 22) uses limit lines to define a lower envelope to the CHF data. Hench-Levy limit lines are shown in Figure III-9. The limit line approach is conservative in that it predicts CHF at a power level below the power level at which the experimental data indicates it would actually occur. Because it does not account for non-uniform axial heat flux effects, however, it does not accurately predict the axial CHF location. Also, under some conditions, it can conservatively predict the power levels at which CHF occurs while non-conservatively predicting the local CHF at the critical power. An example of this paradox is given in Figure III-10.

3. Biasi/Void-CHF Correlation

The Biasi/Void-CHF correlation was initially provided in the new heat transfer model for the CHF calculation required in order to construct a boiling curve. This calculation is also an additional option for CHFR calculation.

The Biasi/Void-CHF correlation is actually a combination of the Biasi (Ref. 23) and Void-CHF (Ref. 24) correlations. The combination was developed for calculation of local CHF during transients. Simplicity and applicability to a wide range of coolant conditions were high priorities. CHF prediction accuracy was a lesser priority.

The form of the Biasi/Void-CHF correlation is:

$$(q''_{CHF})_{Biasi} = f(D_e, G, P, x) \qquad \text{(Eqn. III-3)}$$

$$(q_{CHF})_{Void\text{-}CHF} = f(\alpha, \sigma, \rho_f, \rho_g, H_{fg}) \qquad \text{(Eqn. III-4)}$$

where,

Eqn. (III-3) is used for $G \geq G_1$;

A linear interpolation between Eqn. (III-3) and (III-4) is used for $G_0 < G < G_1$;

Eqn. (III-4) is used for $G \leq G_0$.

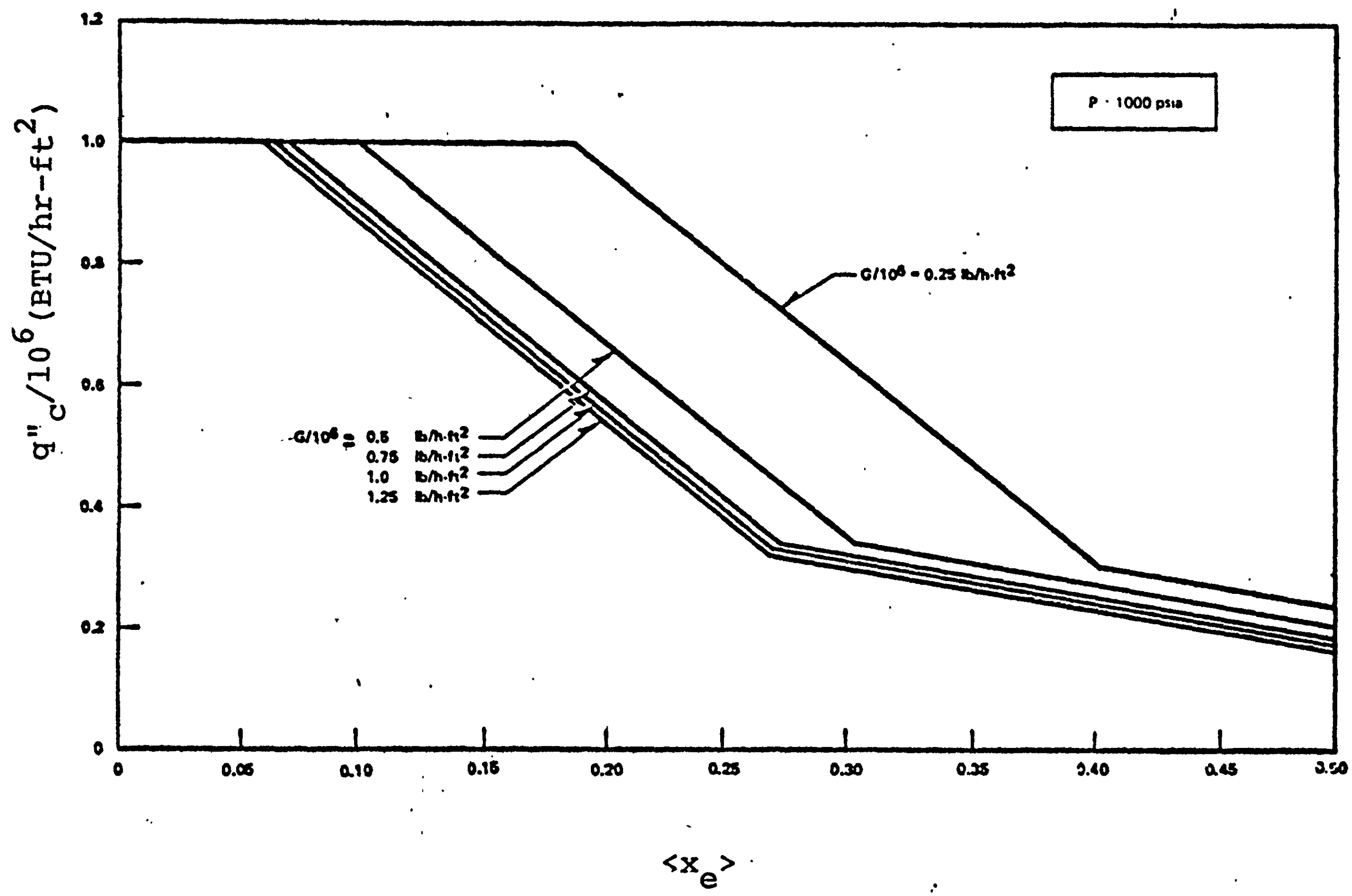


Figure III-9

Hench-Levy Limit Lines
(Ref. 18)

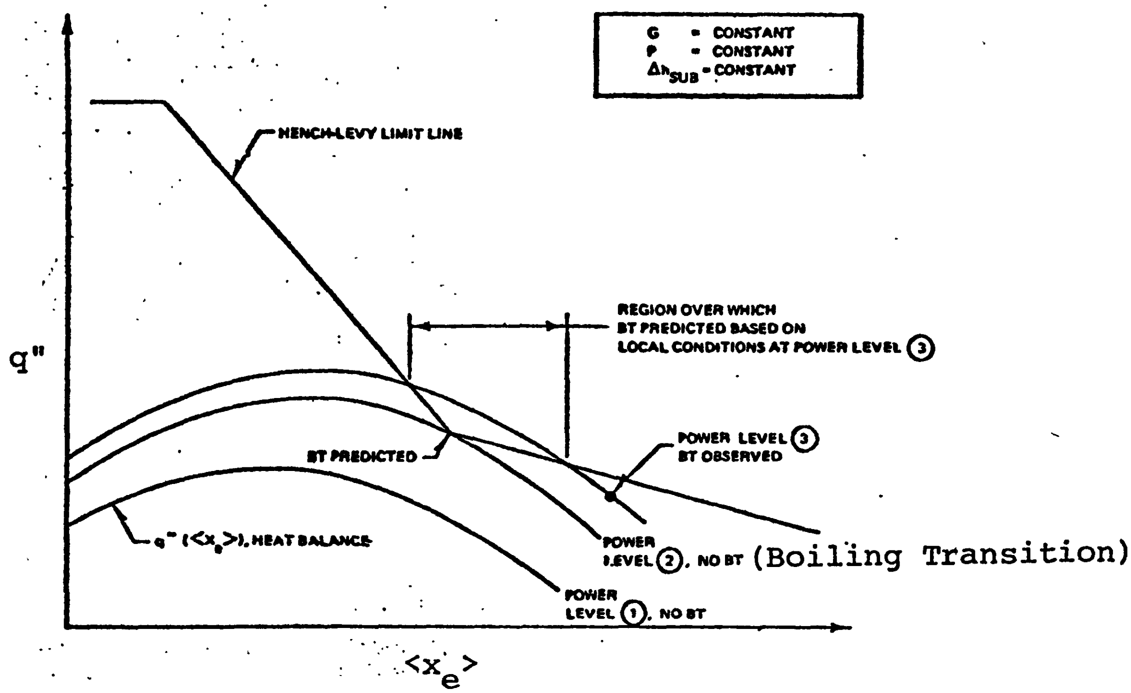


Figure III-10

Experimentally Observed Trend in CHF Data Compared to the Hench-Levy Limit Line

(Ref. 19)

Ref. Appendix H for a more detailed description of the correlation, including information concerning its range of applicability.

4. Summary of the Correlations Provided in the Improved Version of COBRA-IIIC/MIT

Appendix H provides a summary of the correlation provided in COBRA-IIIC/MIT for calculation of CHFR and CPR. Also included are the W-3 and B&W-2 DNBR correlations. This summary provides references, equations and range of data base for each correlation.

F. New Transverse Momentum Coupling Options for the Single-Pass Method

1. Background

Weisman (Ref. 14) has suggested that the transverse momentum parameters used in COBRA-IIIC/MIT, s/ℓ and K, should be modified when the code is used for analysis cases involving interconnected regions of different size.* This suggestion has also been made by Chiu (Ref. 11). The old COBRA-IIIC/MIT approach is compared with the modified approaches suggested by Weisman and Chiu in Appendix I. COBRA-IIIC/MIT has been modified to provide the option of using the Weisman and Chiu approaches in addition to the old COBRA approach for transverse momentum modeling.

2. Description of Code Modification

The old equations for transverse momentum [Eqns. (I-1) and (I-2) of Appendix I] are changed to the following:

$$\frac{\partial}{\partial t}[W_{ij}] + \frac{\partial(u^*W_{ij})}{\partial x} = (f_{s\ell})_{ij}\,\frac{s}{\ell}(P_i - P_j) - F_{ij} \qquad \text{(Eqn. III-5)}$$

$$F_{ij} = \frac{K|W_{ij}|W_{ij}}{2(S_{ij})^2\rho^*}\,\frac{s}{\ell}(f_{s\ell k})_{ij} \qquad \text{(Eqn. III-6)}$$

*Such cases are encountered when using the single-pass method for core thermal-hydraulic analysis (Ref. 12).

For the Weisman approach,

$$(f_{s\ell})_{ij} = \left(\frac{N_g}{N_r}\right)_{ij} \qquad \text{(Eqn. III-7)}$$

$$(f_{s\ell k})_{ij} = (N_g)_{ij} \qquad \text{(Eqn. III-8)}$$

For the Chiu approach,

$$(f_{s\ell})_{ij} = \frac{(N_g)_{ij}}{(N_o)_{ij}} \qquad \text{(Eqn. III-9)}$$

$$(f_{s\ell k})_{ij} = (N_g)_{ij} \qquad \text{(Eqn. III-10)}$$

When a user does not select the new transverse momentum option, the $f_{s\ell}$ and $f_{s\ell k}$ factors are set to unity.

IV. TESTING AND APPLICATION

A. Introduction

Most of the new COBRA-IIIC/MIT options have been tested either individually or by application of the improved version of the code to transient test cases. The new fuel rod, heat transfer, and mixing models have been individually tested. The new correlations for CPR and CHFR and the transverse momentum parameters have also been individually tested. The improved version has been applied to PWR and BWR transient test cases. New options which have not been tested are post-CHF rod-to-coolant heat transfer and Biasi/Void-CHF CHFR predictions. Section IV.B will cover individual testing of new COBRA-IIIC/MIT options. Section IV.C will cover application of the improved version to transient test cases.

B. Individual Testing of New Models

1. Testing of New Fuel Rod Model

The new fuel rod model has been tested using steady state and transient test cases. Some test cases were run to test the solution method for numerical stability and energy conservation. Further tests compare predictions of new fuel rod model options with predictions of the old fuel rod model. The following sub-sectins describe the tests and the results obtained.

a. Steady State Predictions

Predictions of the old and new fuel rod models are compared for the case of constant fuel and clad properties and gap conductance. The results are shown in Figure IV-1 which gives the radial fuel rod temperature dsitributions for the two cases. Data used by the fuel rod models is also given in the figure. The difference between the predictions is in the clad and gap regions. The old fuel rod model lumps the clad and gap regions together while the new fuel rod model considers them as seperate regions.

The new fuel rod model was also individually tested by calculating a steady state temperature distribution for one axial node of a fuel rod. The heat generation rate, coolant tempera-

Data

Fluid temperature	532°F
Rod-to-coolant heat transfer coefficient	4751 BTU/hrft^2°F
Rod surface heat flux	0.2076 $\frac{\text{MBTU}}{\text{hr-ft}^2}$
Gap heat transfer coefficient	600 BTU/hr ft^2°F

Properties	Fuel	Clad
conductivity	1.4	8.8 BTU/hr-ft°F
density	650	410 lb/ft^3
specific heat	.08	.078 BTU/lb°F

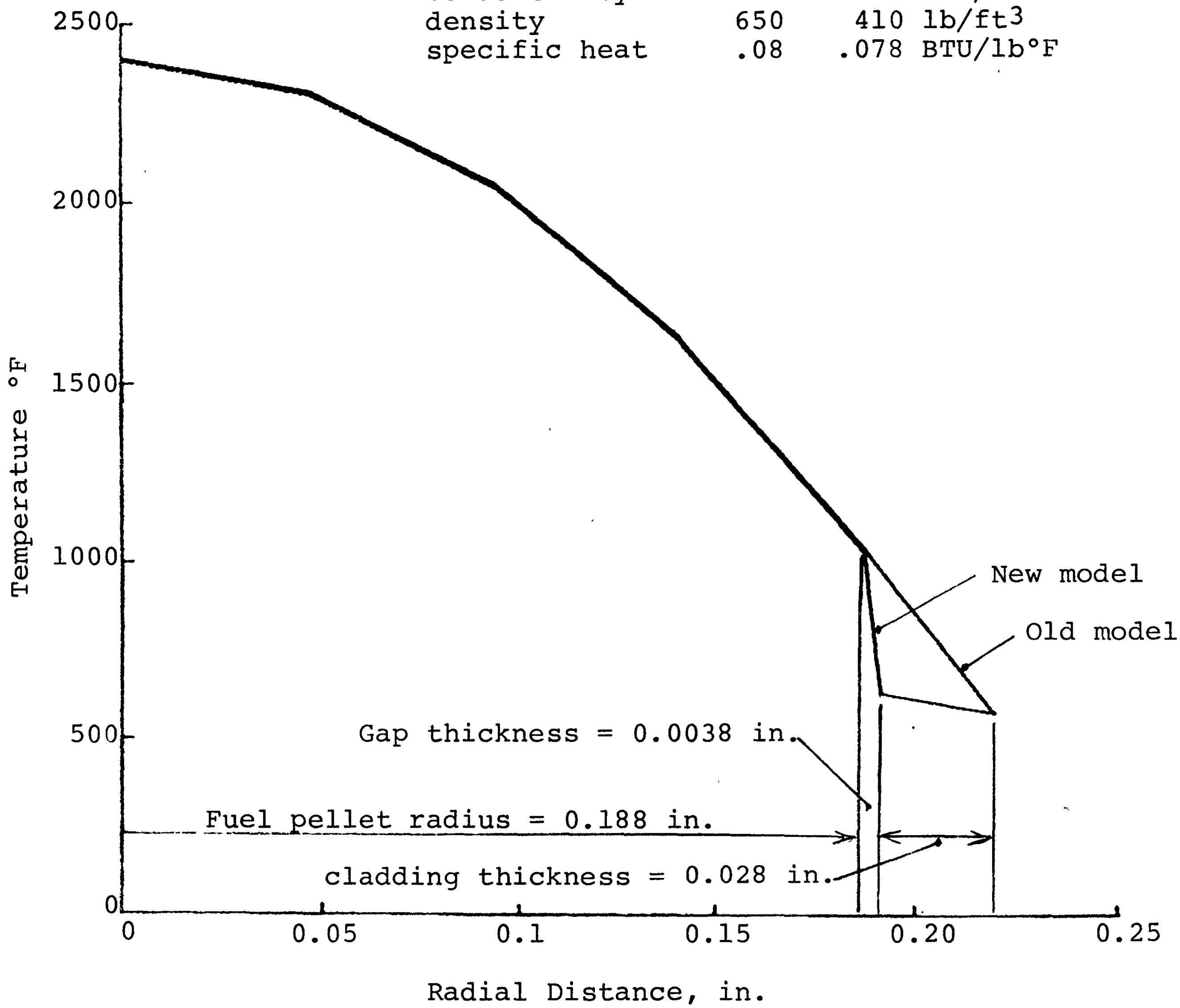


Figure IV-1

Predictions of Old and New Fuel Rod Models Using Constant Properties and h_{gap} Option ture, and rod-to-coolant heat transfer coefficient were held constant. The nodalization scheme used was four radial fuel nodes, one gap node, and one clad node, for a total of six radial fuel rod nodes. Steady state temperature predictions were obtained using the three options of the new model. These are:

1) Constant properties, user input values of fuel and clad properties and gap conductance, h_{gap}.
2) Fuel and clad properties calculated, user input value of h_{gap}.
3) All properties calculated.

The results of these predictions are shown in Figure IV-2. The three temperature profiles shown have similar shapes. The radial position of the gap region is marked by a sharp temperature drop near r=0.15 in. One effect of temperture dependent properties can be seen in the difference between the temperature profile predicted using the constant properties option and the other two profiles predicted using calculated fuel and clad properties. In the fuel region, which extends from r=0. to r=0.15 in., the negative slope magnitude of the profile predicted by the constant properties option is exceeded by the slopes of profiles predicted by the other two options as radius goes from 0. to 0.15 in. This observed difference is due to decreasing calculated thermal conductivity of the fuel with decreasing temperature (increasing radius).

b. Transient Predictions

The new fuel rod model was further tested by calculating transient temperature distributions for one axial node of a fuel rod. The coolant temperature and rod-to-coolant heat transfer coefficient were held constant. The nodalization schemes used thirteen radial fuel nodes, one gap node, and three clad nodes, or seventeen radial fuel rod nodes in all. Temperature distributions were obtained using two options, all properties calculated and all properties constant. At time zero, with temperatures at steady state as shown in Figure IV-3, the heat generation rate was assumed to undergo a step increase by a factor of

Fuel Rod Radius	.22 in.
Fluid temperature	640 °F
Rod-to-coolant heat transfer coefficient	6000 Btu/hr-ft^2-°F
Linear heat generation rate	5.8 Kw/ft

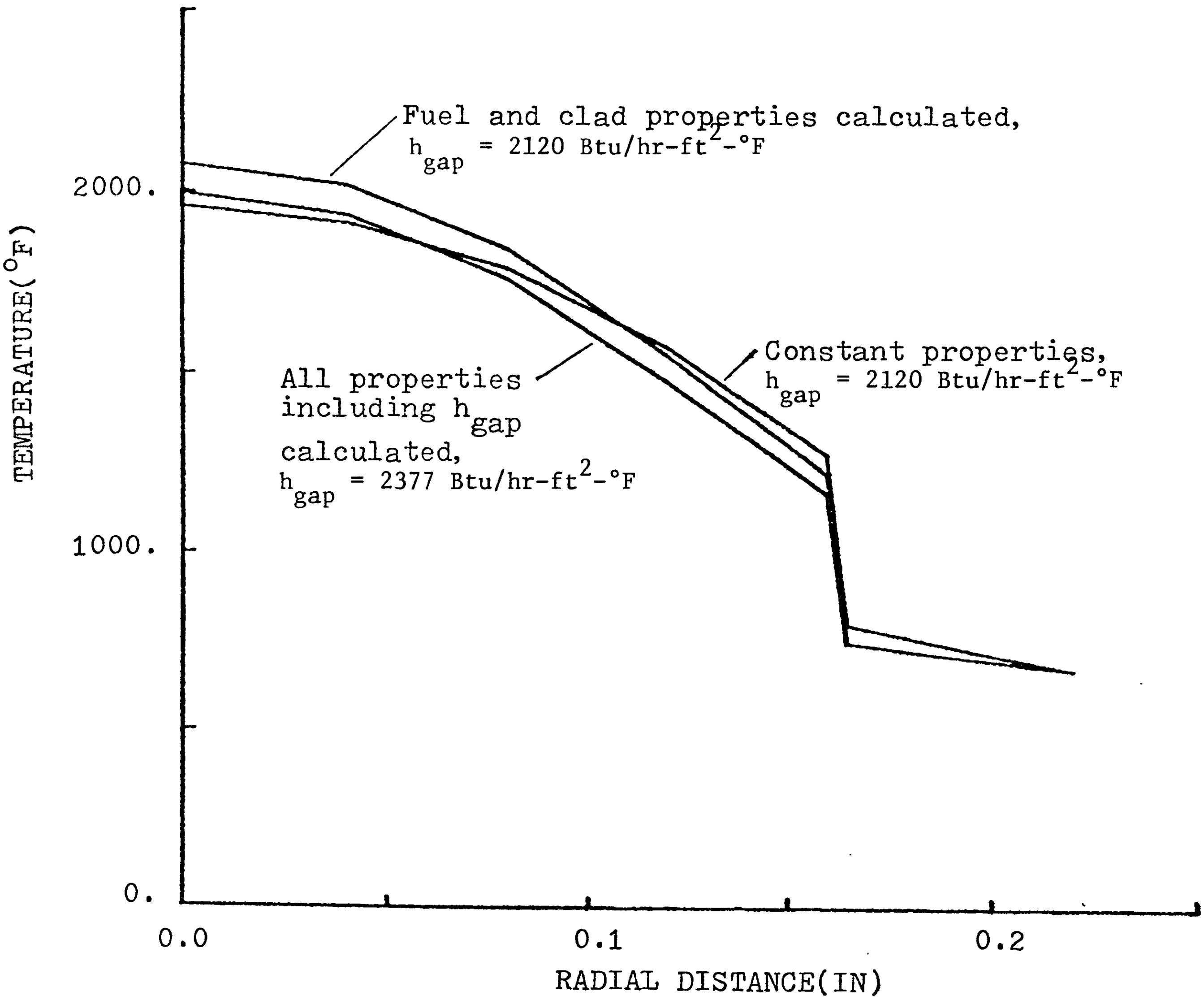


Figure IV-2

Predictions of the Three Options
of New Fuel Rod Model

Constant h_{gap} = 8000. W/m^2-k

Calculated h_{gap} = 3020. at t=0

Calculated h_{gap} = 4110. at t=∞

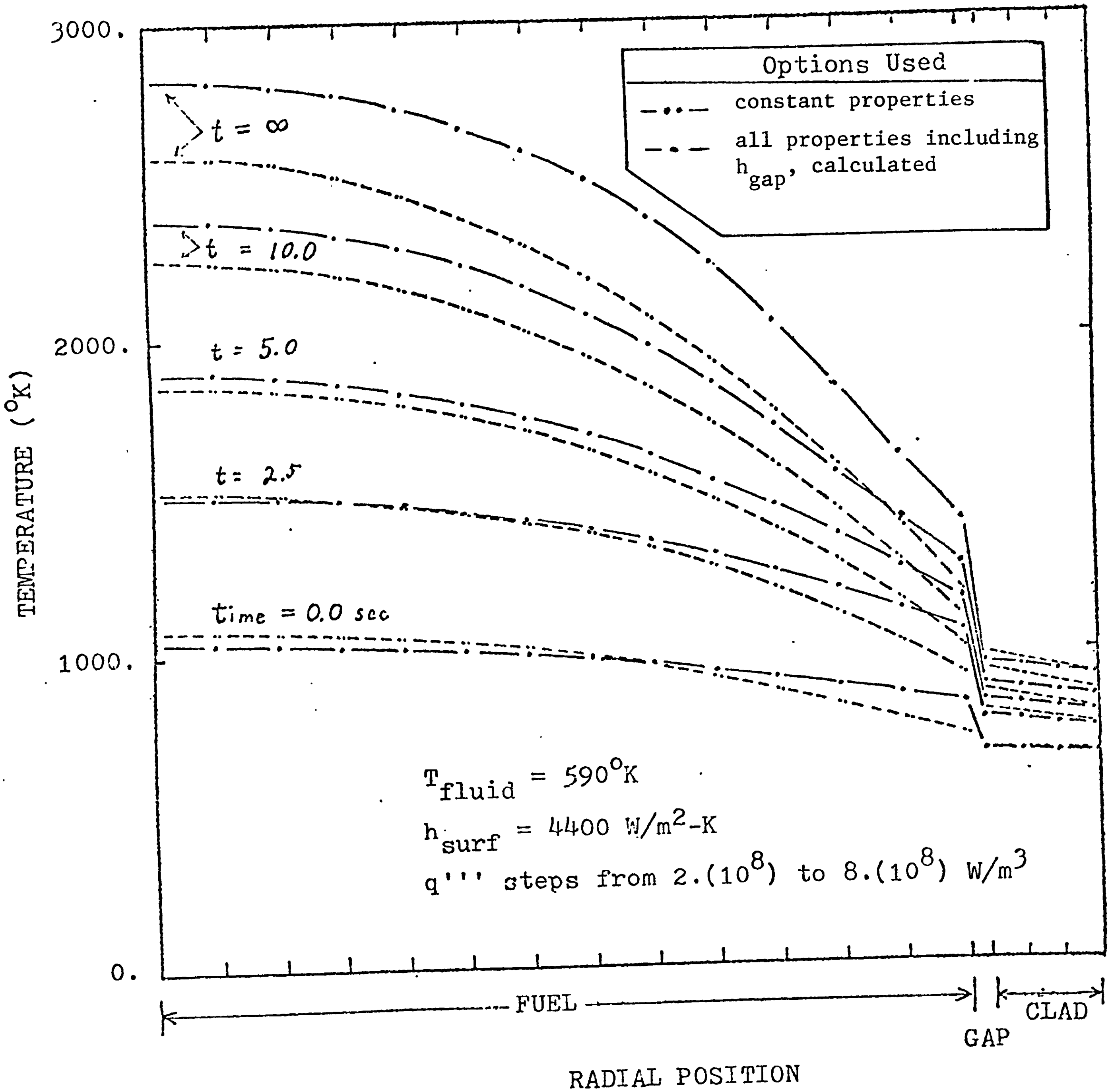


Figure IV-3

Transient Predictions for Two Options
of the New Fuel Rod Model

four. Eventually the temperature profiles reached a new steady state. One of the differences between the two sets of steady state predictions is seen in the change of centerline temperature predictions. At time zero the centerline temperature obtained using calculated properties is less than the value obtained using constant properties. At the new steady state ($t=\infty$) the centerline temperature prediction based on constant properties less than the value predicted using calculated properties and h_{gap}.

2. Testing of New Rod-to-Coolant Heat Transfer Model

The pre-CHF part of the new rod-to-coolant heat transfer model was tested by running two test cases using the old and new heat transfer models. Both steady state and transient conditions were considered.

a. Steady State Predictions

Steady state predictions were obtained for a case which consisted of three BWR channels with different radial peaking factors. Predictions for coolant parameters such as enthalpy and density were nearly the same for both the old and new models. Wall temperature predictions showed differences as great as 40°F in the hot channel as can be seen in Figure IV-4. The wall temperature predictions of the new model vary more smoothly than those of the old. The coolant temperature reaches a plateau near the inlet, indicating the axial position where voiding occurs. The old heat transfer model uses voiding to switch from a forced convection to a nucleate boiling heat transfer correlation. This switch causes the sharp discontinuity in clad temperature predictions based on the old model, as shown in Figure IV-4 and also earlier in Figure II-1. In spite of the large differences in wall temperature predictions of the old and new heat transfer models shown in Figure IV-4, the MDNBR predictions are nearly identical.

b. Transient Predictions

A transient case was analyzed which considered adjacent PWR channels. These channels were assumed to be initially at nearly zero power and then subjected to a short burst of power sufficient to cause some voiding. This case was run previously as part of the comparison of COBRA-IIIC/MIT and COBRA-IV-I described in Ref. 12.

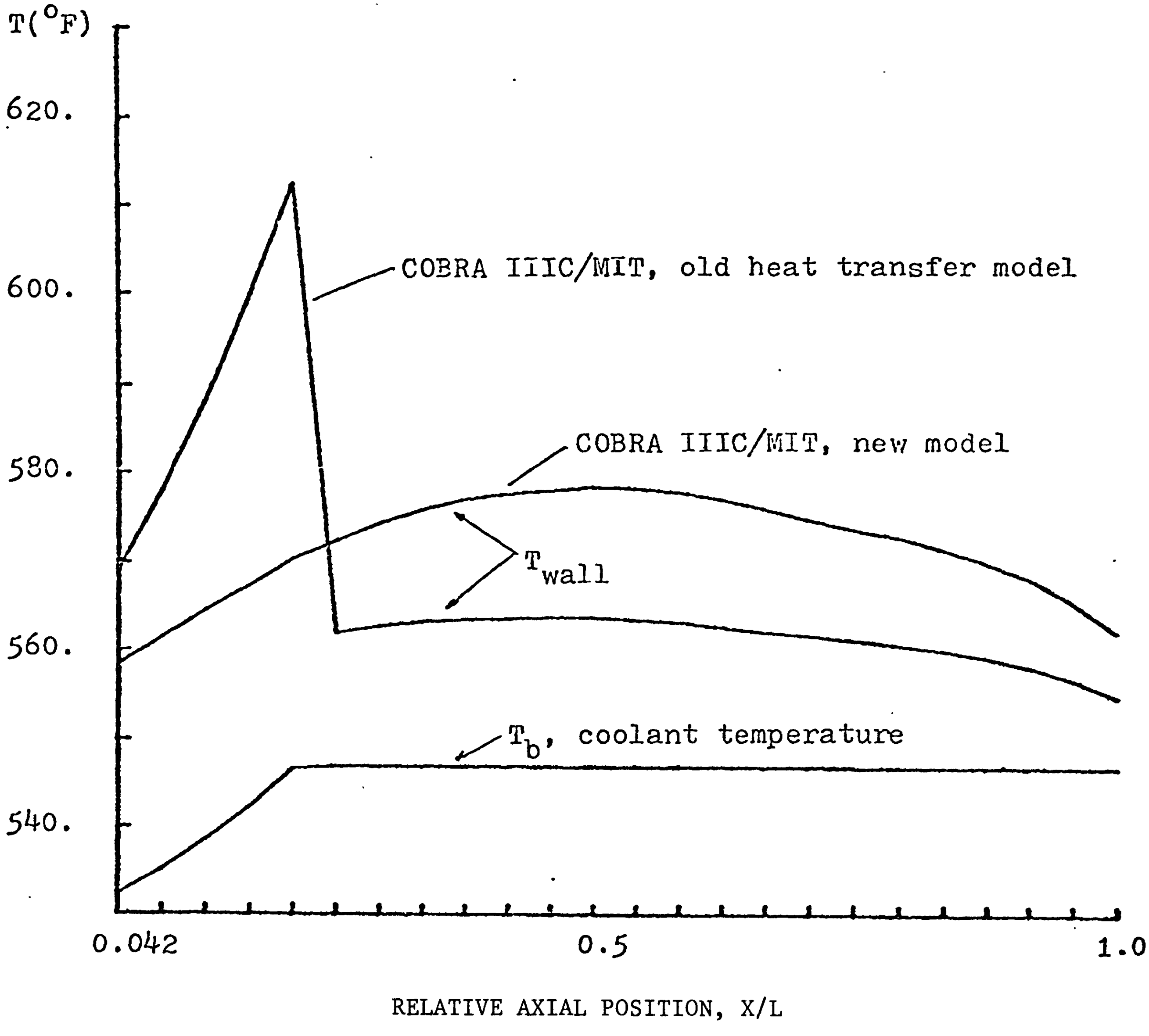


Figure IV-4

Axial Temperature Profiles for Steady State
BWR Hot Channel Calculation

The case was rerun using the new heat transfer model of COBRA-IIIC/MIT. The channel pressure drop predictions are shown as a function of time in Figure IV-5. The COBRA-IIIC/MIT results using the new heat transfer model show a much lower pressure drop spike before t=0.2 sec. than the results using the old heat transfer model. The difference in behavior between the old and new heat transfer models is due to the discontinuity of the old heat transfer model predictions when voiding occurs. The pressure drop predictions of the new COBRA-IIIC/MIT heat transfer model are similar to those of COBRA-IV-I, which also uses an advanced heat transfer package capable of constructing a complete boiling curve. The heat transfer model of COBRA-IV-I is described in Appendix F.

c. Conclusions

Testing of the new rod-to-coolant heat transfer model led to the following conclusions:

1) Heat transfer predictions of the new model vary smoothly as heat transfer changes from forced convection to the nucleate boiling heat transfer regime.

2) Clad temperature predictions showed differences which were explainable from differences in the heat transfer correlations and logic used.

3) Minimum Departure from Nucleate Boiling Ratio (MDNBR) predictions were nearly the same.

4) Predictions of coolant parameters such as density, enthalpy, and pressure drop were the same for both models in steady state.

3. Testing of New Mixing Model

The new mixing model was tested by comparing COBRA-IIIC/MIT predictions with data from the GE 9-Rod Mixng Tests and the Columbia 16-Rod Mixing Tests (Ref. 26). COBRA-IIIC/MIT predictions for the test cases were obtained using the new mixing model and β=0.02. Predictions using the two models for mixing are compared to experimental data in the following subsections.

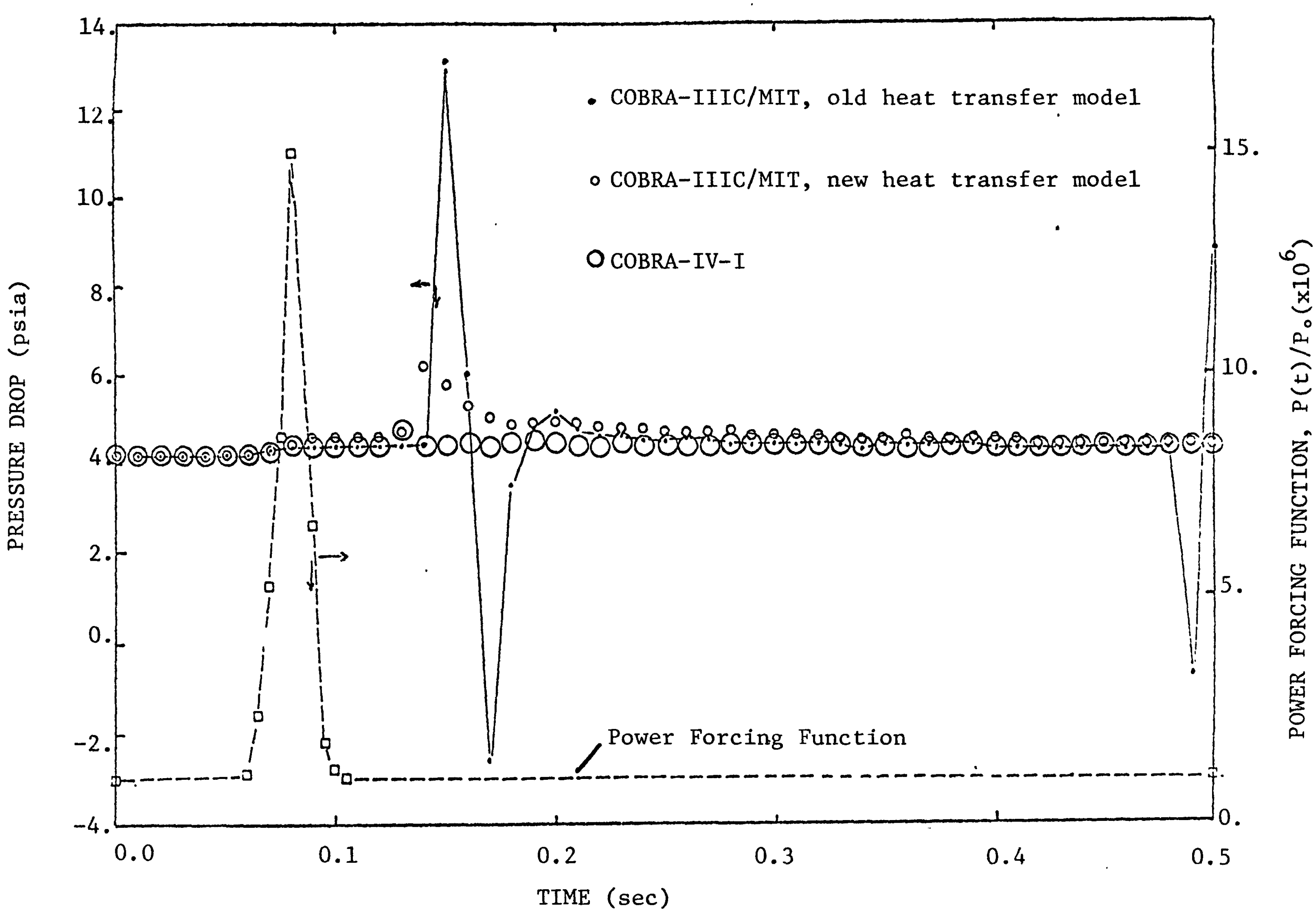


Figure IV-5
Channel Pressure Drop vs. Time

a. Comparison with GE 9-Rod Mixing Tests

1) Description of Tests

The GE 9-rod mixng tests were carried out for a range of conditions typical of operating BWRs. The experiments were performed using water. The test section was an electrically heated 3x3 rod bundle. Pressure and enthalpy measurements were made for corner, side and interior subchannels. The geometry, test conditions and measurement locations are shown in Figure IV-6. Nine test cases were anlayzed with COBRA-IIIC/MIT using the old and new mixing models. The analysis was done for one-fourth of an assembly, assuming quarter-assembly symmetry. The cases analyzed are listed in Table IV-1.

2) Comparison of COBRA-IIIC/MIT Predictions with Test Cases

Four isothermal test cases (1B, 1C, 1D and 1E) were analyzed with COBRA-IIIC/MIT. Axial friction pressures drop predictions for the isothermal test cases were made to agree with the experimental measurements by adjusting the single-phase friction factor correlation. The usual form for the correlation, given below, was used.

$$f = a(Re)^b \qquad \text{(Eqn. IV-1)}$$

The "b" coefficient was given the smooth-tube friction correlation value of -0.2. The "a" coefficient was adjusted to a value of 0.286 to make predictions agree with experiment. Comparisons of the resulting predicted and experimental pressure drops are shown in Table IV-2. COBRA exit mass flow distribution predictions are compared with experimental data in Figure IV-7. Each curve in the figure is based on three calculated values of data points. These are the values of the normalized mass flux for the corner, side and center subchannels. The COBRA predictions for each subchannel are within 1% of one another for all four isothermal cases. The COBRA predictions are within the spread of data in the corner subchannel and near the spread of data in the side and corner subchannels.

Figure IV-6

GE 9-Rod Mixing Tests
Geometry, Test Conditions and Measurement Locations (Ref. 25)

Number of Rods	9
Rod Diameter	.570 inch
Radius of Corner Subchannel	.420 inch
Rod Rod Clearance	.168 inch
Rod Wall Clearance	.135 inch
Hydraulic Diameter	.474 inch
Heated Length	72 inch
Pressure	1000 psia
Average Bundle Mass Flux	0.48 to 1.970 Mlbm/hr-ft^2
Average Heat Flux	0.225 to 0.675 MBtu/hr-ft^2
Inlet Subcooling	29.1 to 504.6 Btu/lbm

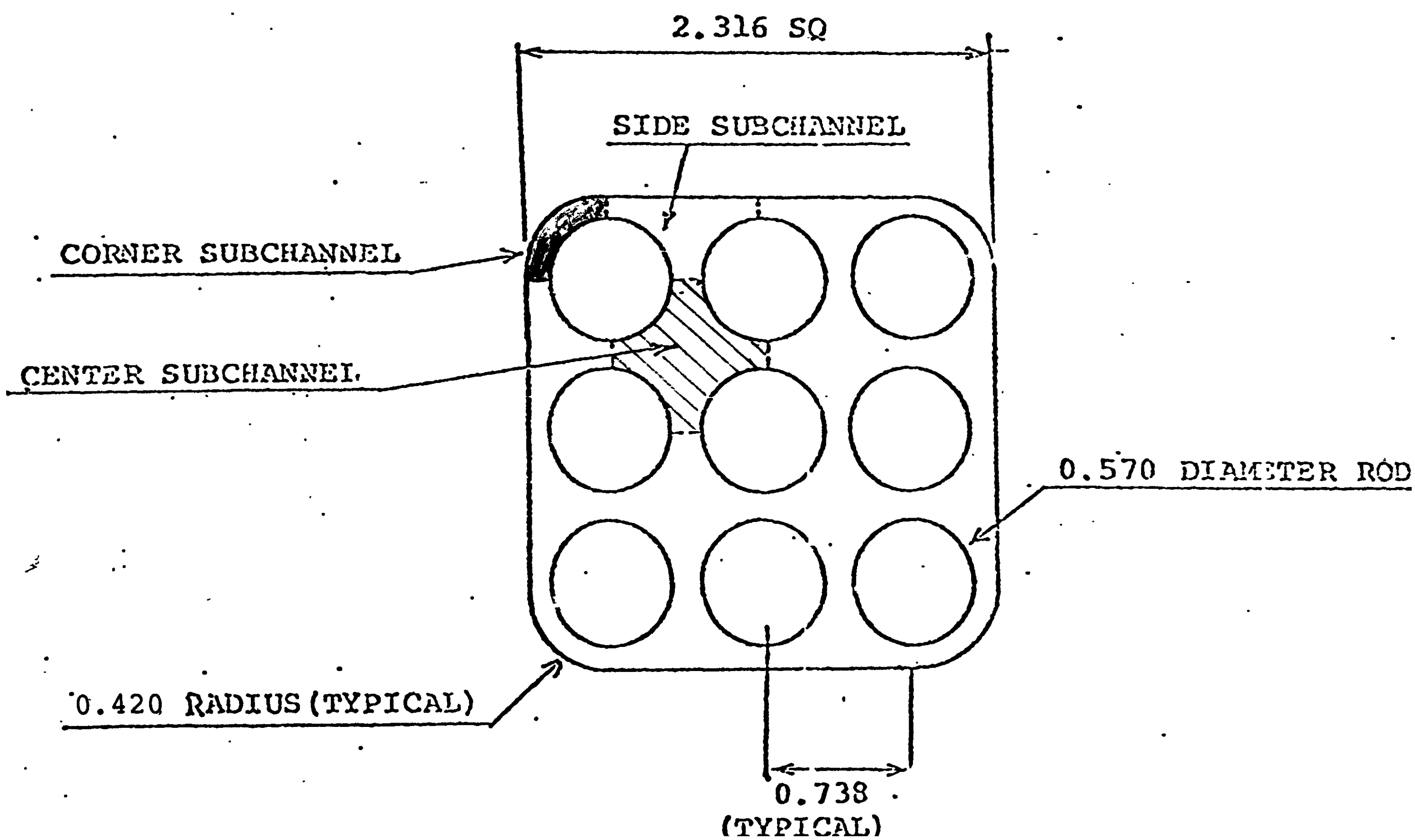


Table IV-1

GE 9-Rod Mixing Test Cases Analyzed

Test Case Number	Mass Flux (Mlb/hr ft^2)	Average Heat Flux (MBTU/hr ft^2)	Power Distribution	Inlet Subcooling (BTU/lb)	Average Exit Quality	Boiling Length L_B/L
1B	0.48	0.0	-	504.6	0.	0.00
1C	0.99	0.0	-	504.6	0.	0.00
1D	1.51	0.0	-	504.6	0.	0.00
1E	1.97	0.0	-	504.6	0.	0.00
2G1	1.070	0.675	uniform	225.9	0.038	0.10
2G2	1.080	0.675	uniform	189.8	0.090	0.24
2G3	1.070	0.675	uniform	146.7	0.160	0.41

Range of Data Base for Beus Correlation
(Ref. 4)

System Pressure	$50 \leq P \leq 775$	psia
Mass Flux	$.073 \leq G \leq 3.$	Mlb/hr ft^2
Quality	$-0.2 \leq X \leq .80$	
Gap Width Between Subchannels	$.02 \leq S \leq .10$	in.

Table IV-2

Measured and Predicted Axial Friction Pressure Drop

Test Case	(ΔP_f) measured (psia)	(ΔP_f) predicted* (psia)
1B	0.2128	0.21
1C	0.7130	0.75
1D	1.596	1.60
1E	2.540	2.58
1D (re-peated)	1.610	1.60

*Frictional pressure drop with COBRA-IIIC/MIT using the single-phase friction correlation $f = a(Re)^{-0.2}$ with $a = 0.286$.

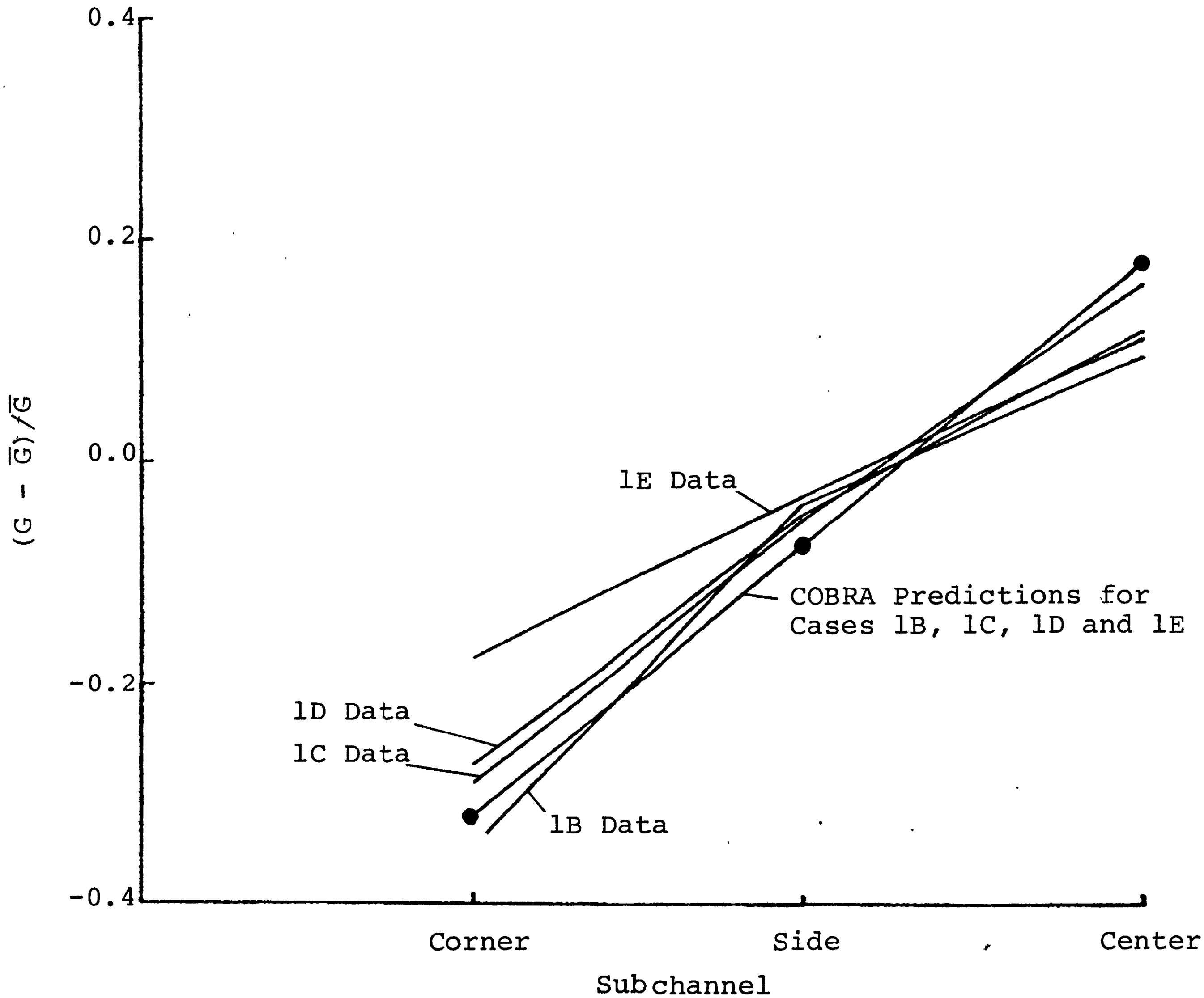


Figure IV-7

GE Mixing Test Cases 1B, 1C, 1D and 1E
Normalized Exit Mass Flux Distributions

Three adiabatic test cases (2G1, 2G2 and 2G3) were analyzed with COBRA-IIIC/MIT using the old and new mixing models. The analyses with the old model used β=0.02 (the standard value of β in COBRA-IIIC/MIT's input). The new mixing model is the Beus model. COBRA exit mass flux and enthalpy predictions are compared to data in Figures IV-8 through IV-11 and IV-13 through IV-15.

Figures IV-8 through IV-10 compare predicted and measured enthalpy distributions. Enthalpy becomes increasingly over-predicted as exit quality increases, going from case 2G1 to 2G2 and on to case 2G3. The enthalpy distribution predictions using β=0.02 are essentially the same for all three cases.

Beus and β=0.02 enthalpy predictions differ because the Beus model predicts less mixing: thus, the Beus model is similar to using a β less than 0.02. However, the Beus predictions do follow the quality dependence of the model's mixing predictions. (i.e. increasing mixing rate at low quality and then decreasing mixing rate at high quality). This can be seen by comparing Figure IV-11, where corner subchannel enthalpy predictions and data are compared for cases 2G1, 2G2 and 2G3 with Figure IV-12.

Figure IV-11 includes predictions of a temporary modification of the Beus mixing model, whereby the single-phase component of Beus mixing, W_L, is predicted using β=0.02. This change affects the mixing predictions from subcooled conditions up to the beginning of the transition mixing region shown in Figure IV-12. Mixing rate predictions in the transition region are unaffected by the modification. Comparisons of Figures IV-9 and IV-11 show that the normalized corner channel enthalpy distribution prediction calculated using β=0.02, changes little as quality increases.

In going from an exit quality of 0.038 to 0.16, the Beus corner subchannel enthalpy prediction falls and rises. The behavior is due to the increased turbulent interchange of enthalpy from the corner subchannel for case 2G2, where exit quality is 9%. For a given geometry, mass flow rate and pressure, Beus mixing predictions are a function of quality, as shown in Figure IV-12. The mixing rate starts at a single-phase liquid value and icnreases to a maximum value as quality increases. Then, mixing rate decrease asymptotically to a single-phase vapor value at high qualities. For cases 2G1, 2G2 and 2G3,

$\overline{G} = 1.07$ Mlb/hr ft^2

$q'' = 0.675$ MBTU/hr ft^2

$\overline{X}_{exit} = 0.038$

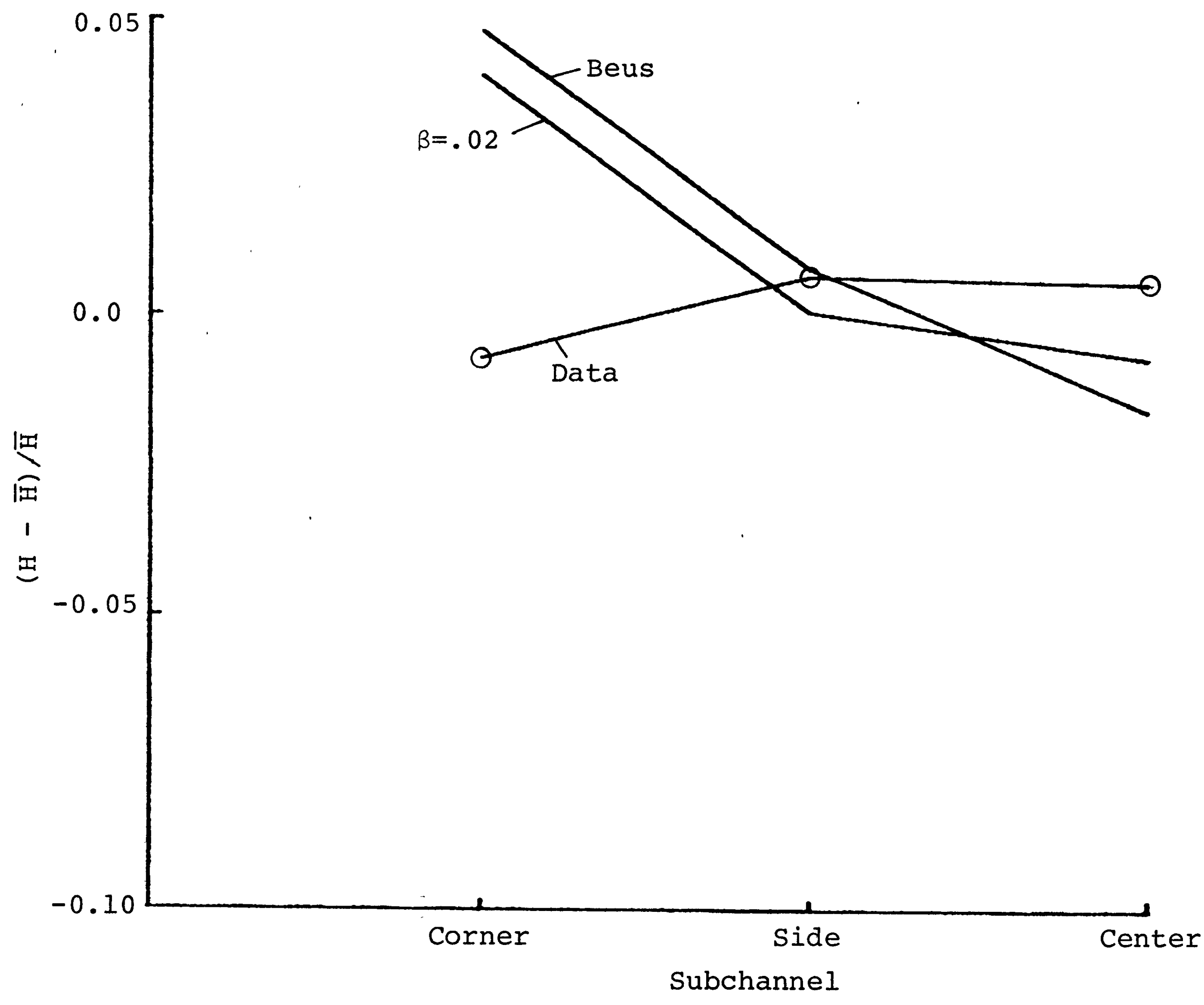


Figure IV-8

GE Mixing Test Case 2G1
Normalized Exit Enthalpy Distribution

$\overline{G} = 1.08$ Mlb/hr ft^2
$q'' = 0.675$ MBTU/hr ft^2
$\overline{X}_{exit} = 0.09$

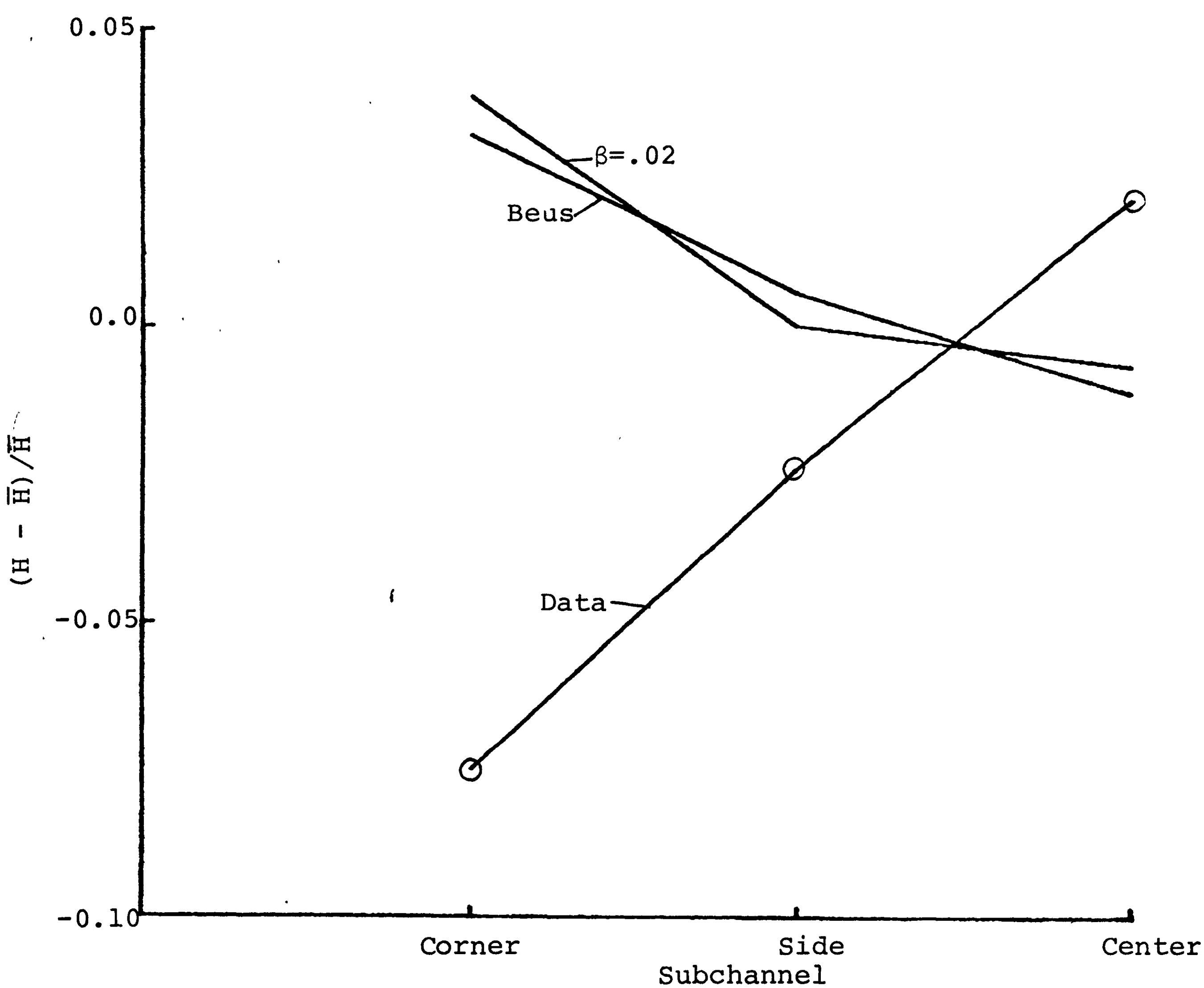


Figure IV-9

GE Mixing Test Case 2G2
Normalized Exit Enthalpy Distribution

$\overline{G}$ = 1.07 Mlb/hr ft^2

q" = 0.675 MBTU/hr ft^2

$\overline{X}_{exit}$ = 0.16

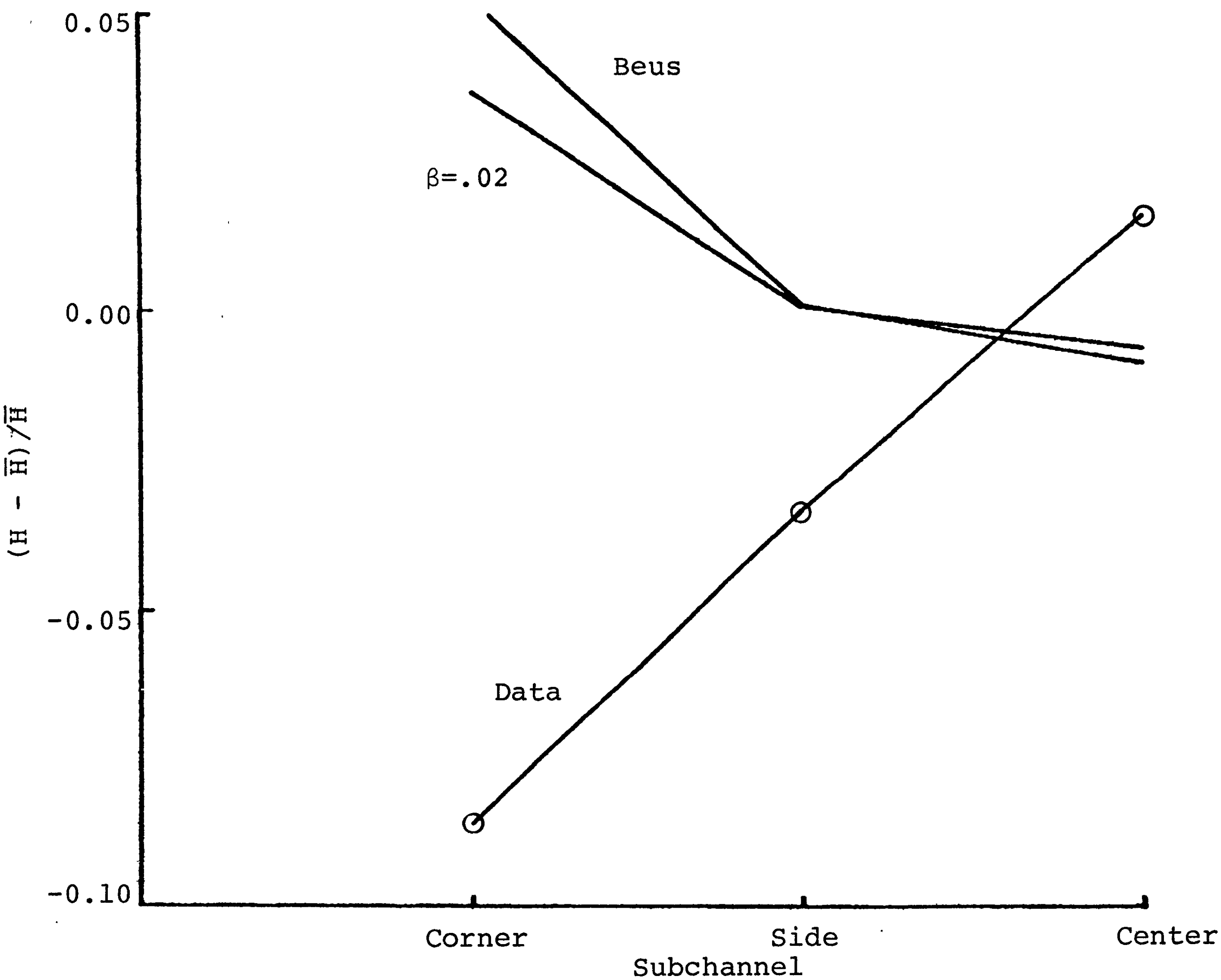


Figure IV-10

GE Test Case 2G3
Normalized Exit Enthalpy Distribution

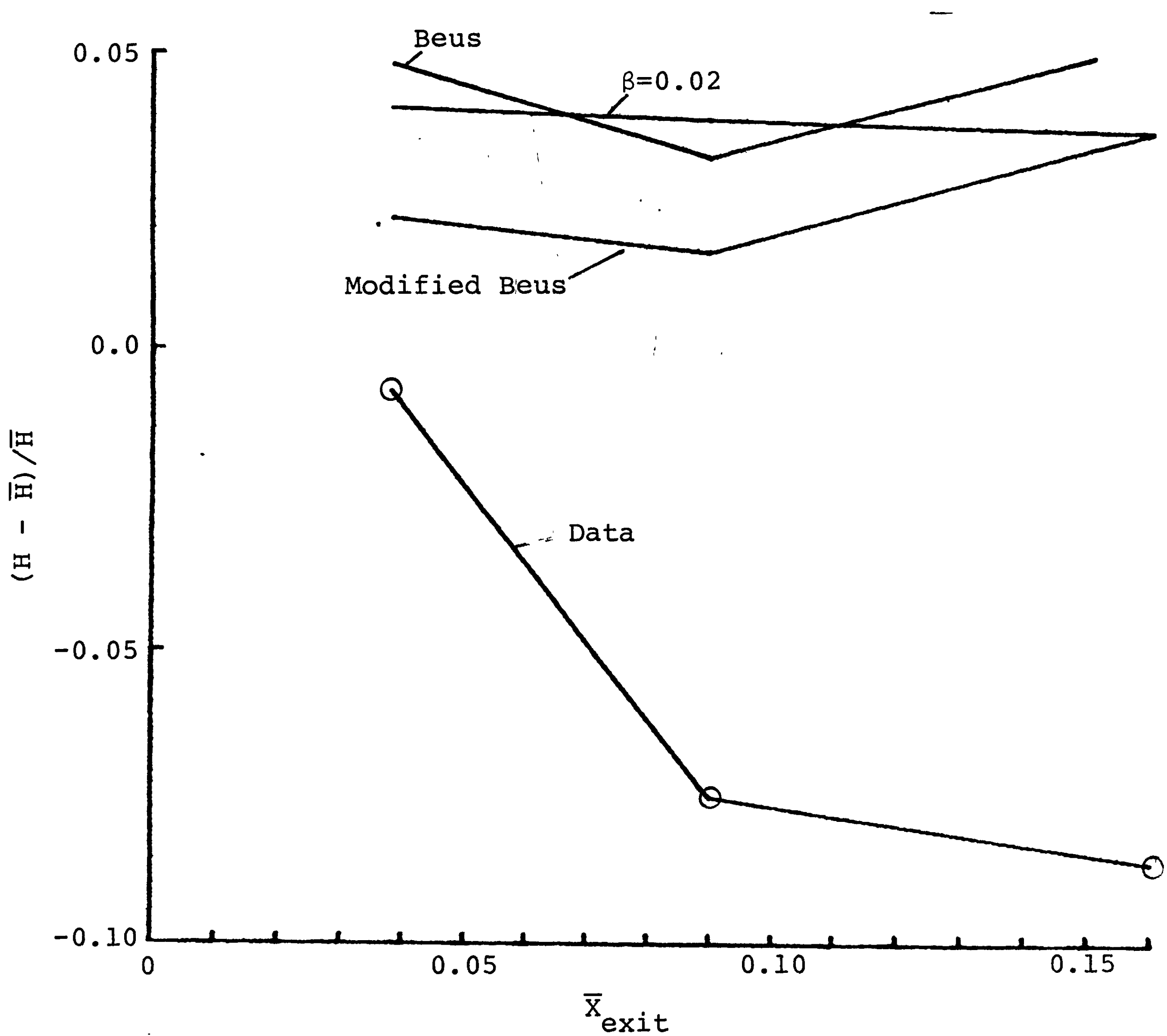


Figure IV-11

GE Test Cases 2G1, 2G2 and 2G3
Normalized Corner Channel Enthalpy vs. Exit Quality

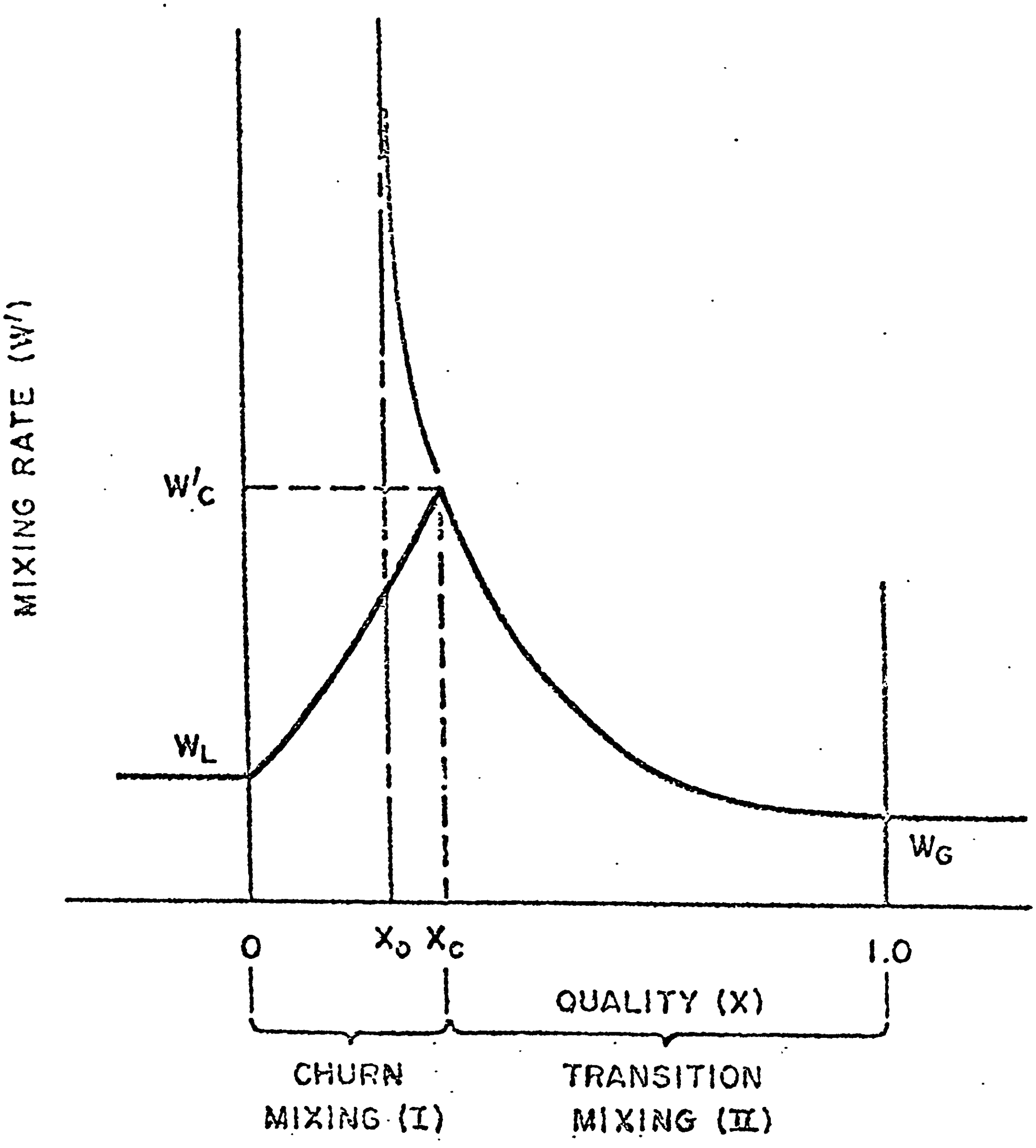


Figure IV-12

Plot of Mixing Model Showing Variation with Quality
(Fig. E.1 of Ref.17)

$\overline{G}$ = 1.07 Mlb/hr ft^2

q" = 0.675 MBTU/hr ft^2

$\overline{X}_{exit}$ = 0.038

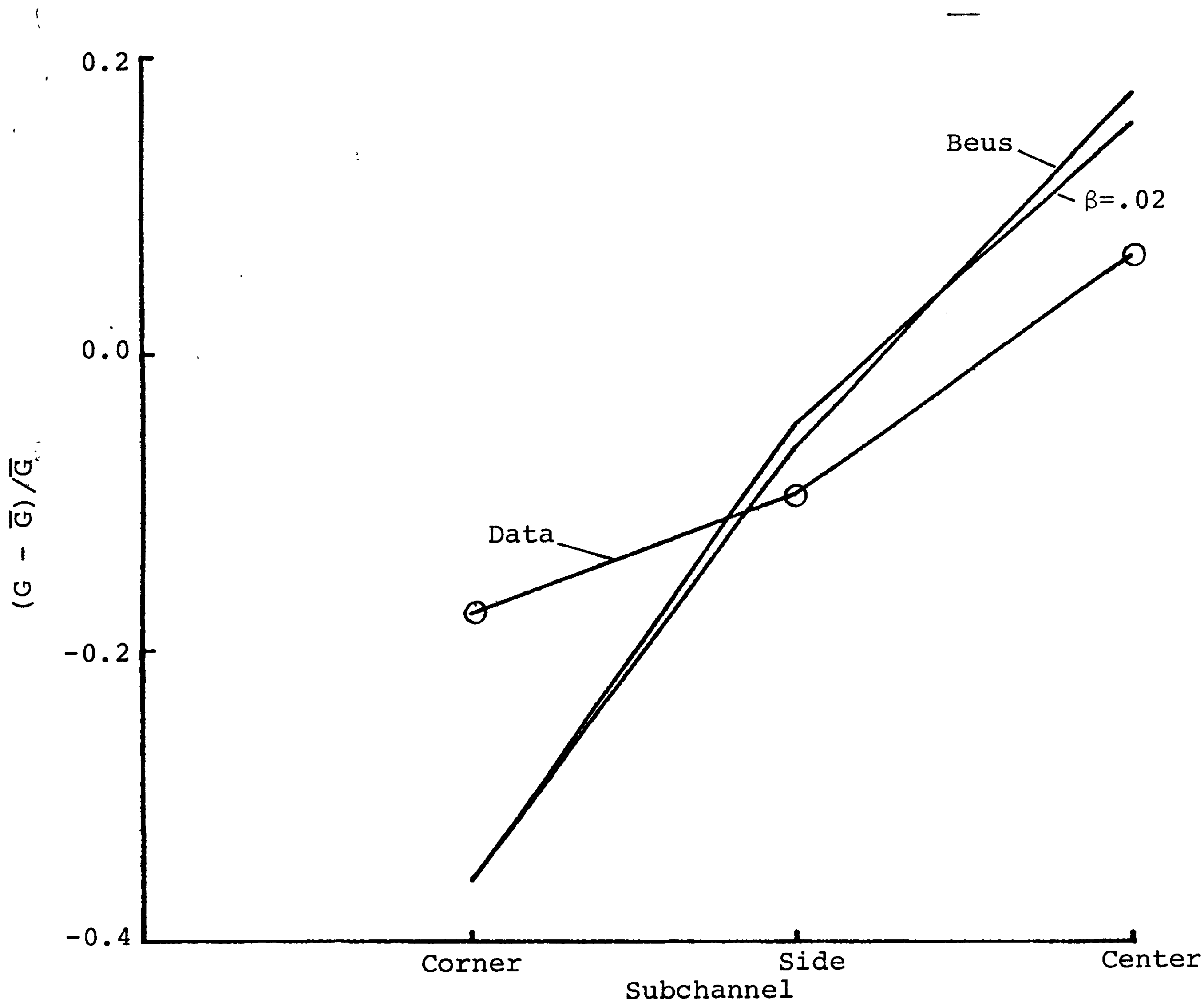


Figure IV-13

GE Mixing Test Case 2G1
Normalized Exit Mass Flux Distribution

$\overline{G}$ = 1.08 Mlb/hr ft^2

q" = 0.675 MBTU/hr ft^2

$\overline{X}_{exit}$ = 0.09

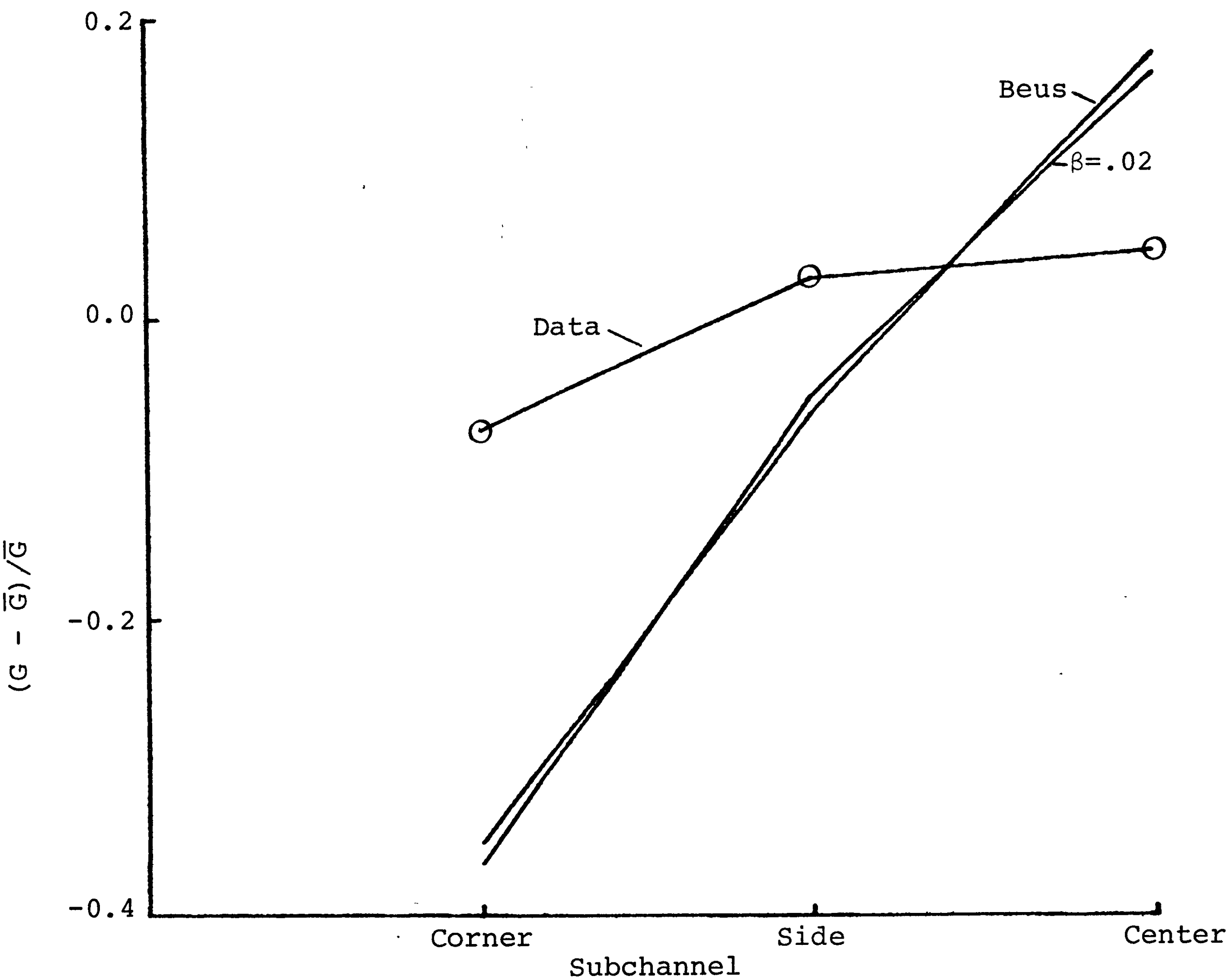


Figure IV-14

GE Mixing Test Case 2G2
Normalized Exit Mass Flux Distribution

$\overline{G} = 1.07$ Mlb/hr ft^2

$q'' = 0.675$ MBTU/hr ft^2

$\overline{X}_{exit} = 0.16$

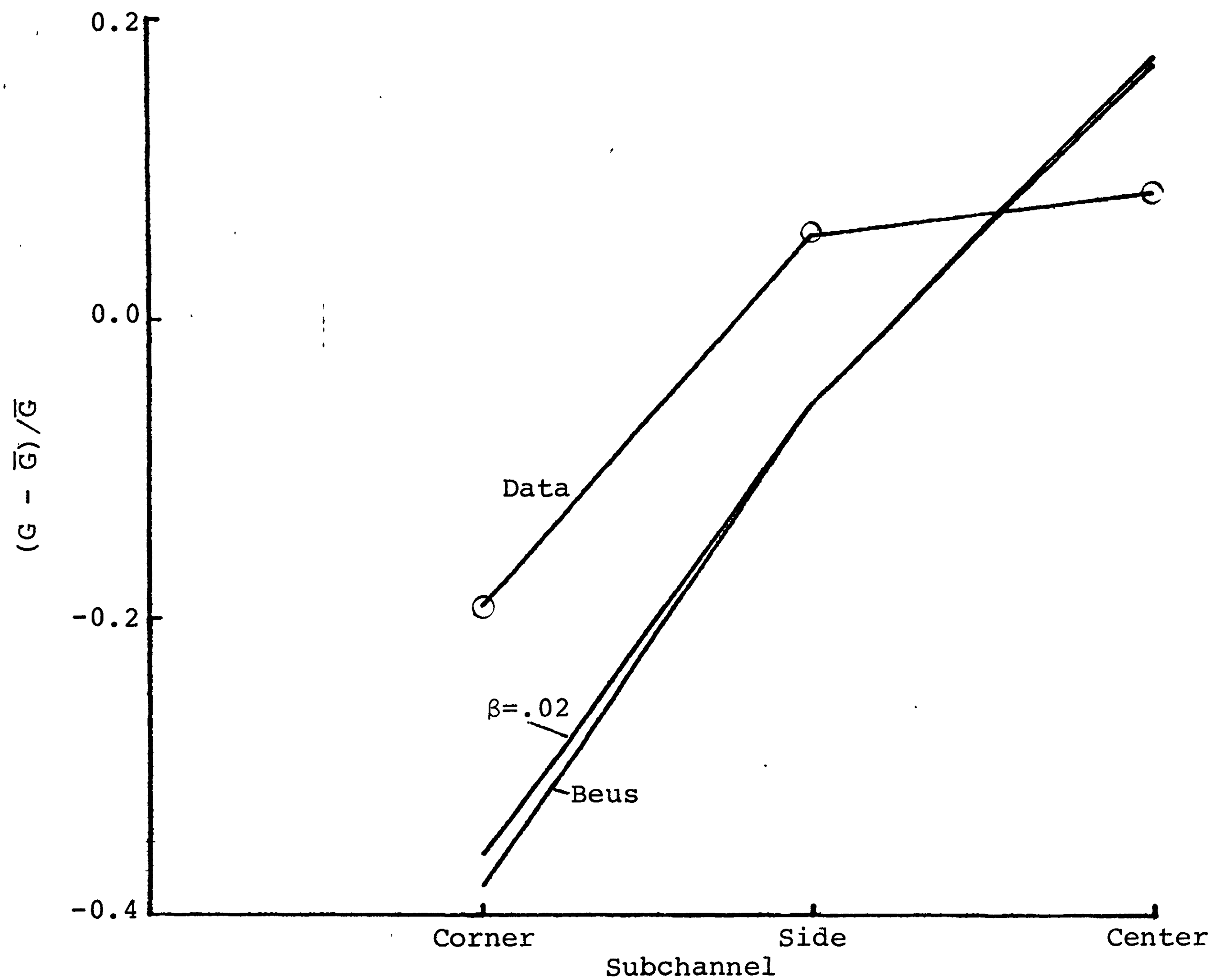


Figure IV-15

GE Mixing Test Case 2G3
Normalized Exit Mass Flux Distribution

X_c, the quality at which the peak mixing rate occurs, is about 10%. The normalized enthalpy predictions of the modified Beus model start lower, closer to the data than the other predictions and rise to meet the β=0.02 predictions of 16% quality.

Figures IV-13 through IV-15 compare predicted and measured mass flux distributions. The effect of mixing rate on mass flow distribution is a second order effect. The general trends of predictions and data are similar. Mass flux was underpredicted in the corner subchannel and overpredicted in the center subchannel. Mass flux in the side subchannel is underpredicted for two of the three cases. The Beus and β=0.02 mass flux distribution trends show little difference.

In conclusion, enthalpy distribution is predicted differently than data. Enthalpy is over predicted in the corner subchannel and under predicted in the center channel. Use of the Beus mixing model to predict two phase mixing does not make much difference for the BWR test conditions considered in these comparisons. A void-drift model or other similar approach is probably needed to account for the observed tendency of vapor to move toward the center of the bundle under such conditions.

b. Comparison with Columbia 16-Rod Mixing Tests

1) Description of Tests

The Columbia 16-rod mixing tests were carried out for both subcooled and boiling conditions using an electrically heated 4x4 bundle of typical PWR fuel geometry. Simultaneous measurements of water flow and enthalpy were made at the exits of two interior subchannels. The power profile was uniform in the axial direction but varied radially so as to provide a power tilt. The geometry, test conditions and measurement locations are shown in Figure IV-16.

2) Comparison of COBRA-IIIC/MIT Predictions with Test Data

Nine test cases were analyzed with COBRA-IIIC/MIT using the old and new mixing models. The analyses were made for one-half of an assembly, assuming half-assembly symmetry. The cases analyzed are listed in Table IV-3. COBRA-IIIC/MIT predictions for channel 5 and 11 exit mass flux and enthalpy are compared with experimental measurements for cases 22, 25, 27, 29 and 30 in Figures IV-17 through IV-20.

Figure IV-16

Columbia 16-Rod Mixing Tests
Geometry, Test Conditions and Measurement Locations
(Ref. 26)

Rod Outside Diameter	0.422 in.
Rod Pitch	0.555 in.
Rod to Wall Spacing	0.143 in.
Total Flow Area	0.02389 ft^2
Radial Heat Flux	
Hot Rods (H)	100%
Cold Rods (C)	86%
Heated Length	60 in.
Pressure	500 and 1200 psia
Average Bundle Mass Flux	1×10^6; 2×10^6; 3×10^6 lbm/hr ft^2
Inlet Temperature	172°F to 484°F
Average Heat Flux	0.384×10^6; 0.56×10^6; 0.967×10^6 BTU/hr ft^2
Traverse Heating Ratio	Colder/Hotter: 0.86 Colder/Average: 1.02 Hotter/Average: 1.08

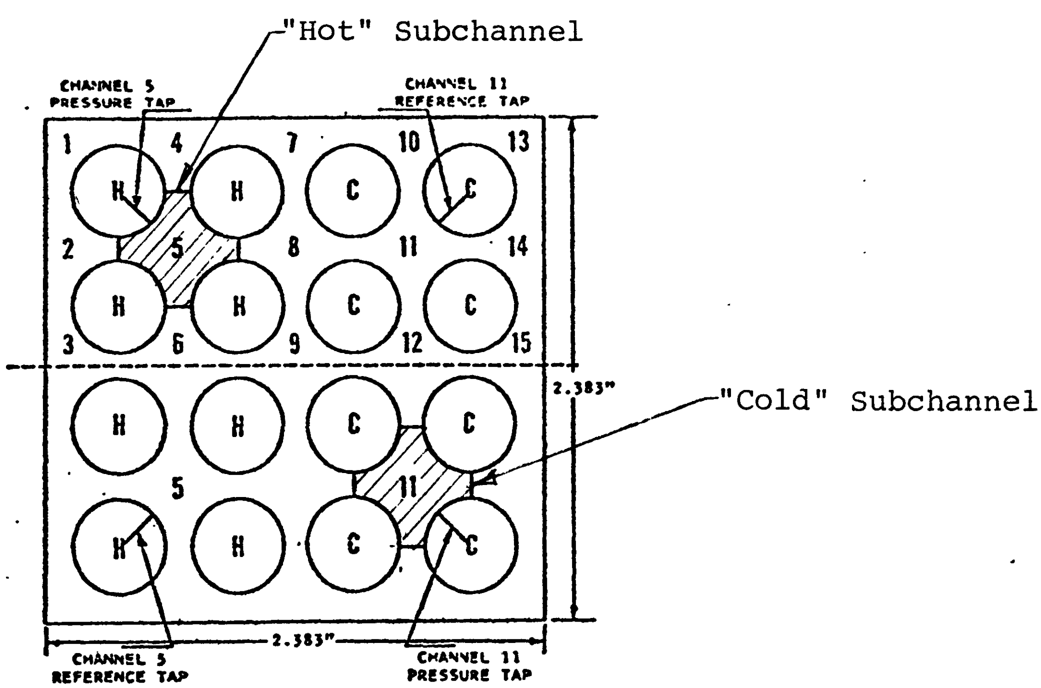


Table IV-3

Columbia 16-Rod Mixing Test Case Analyzed

System Pressure, P = 1200 psia for all cases listed.

Test Case Number	Mass Flux (Mlb/hr ft^2)	Average Heat Flux (MBTU/hr ft^2)	Power Distribution	Subcooling BTU/lb	Average Exit Quality	Boiling Length Fraction, L_B/L
22	1.01	0.38	non-uniform	-400.	-0.424	0.00
25	1.01	0.38	non-uniform	-268.	-0.209	0.00
27	1.03	0.38	non-uniform	-217.	-0.132	0.00
29	1.00	0.38	non-uniform	-152.	-0.015	0.00
30	0.99	0.38	non-uniform	-124.	0.036	0.15
35	1.50	0.58	non-uniform	-301.	-0.317	0.00
39	1.50	0.58	non-uniform	-173.	-0.110	0.00
42	1.49	0.58	non-uniform	-137.	-0.051	0.00
90	1.48	0.58	non-uniform	-88.	0.028	0.16

Range of Data Base for Beus Correlation
(Ref. 4)

System Pressure	$50 \leq P \leq 775$	psia
Mass Flux	$.073 \leq G \leq 3.$	Mlb/hr ft^2
Quality	$-0.2 \leq X \leq .80$	
Gap Width Between Subchannels	$.02 \leq S \leq .10$	in.

$$\overline{G} = 1. \ \frac{\text{Mlb}}{\text{hr ft}^2}$$

$$q'' = 0.38 \ \frac{\text{MBTU}}{\text{hr ft}^2}$$

$$P = 1200 \text{ psia}$$

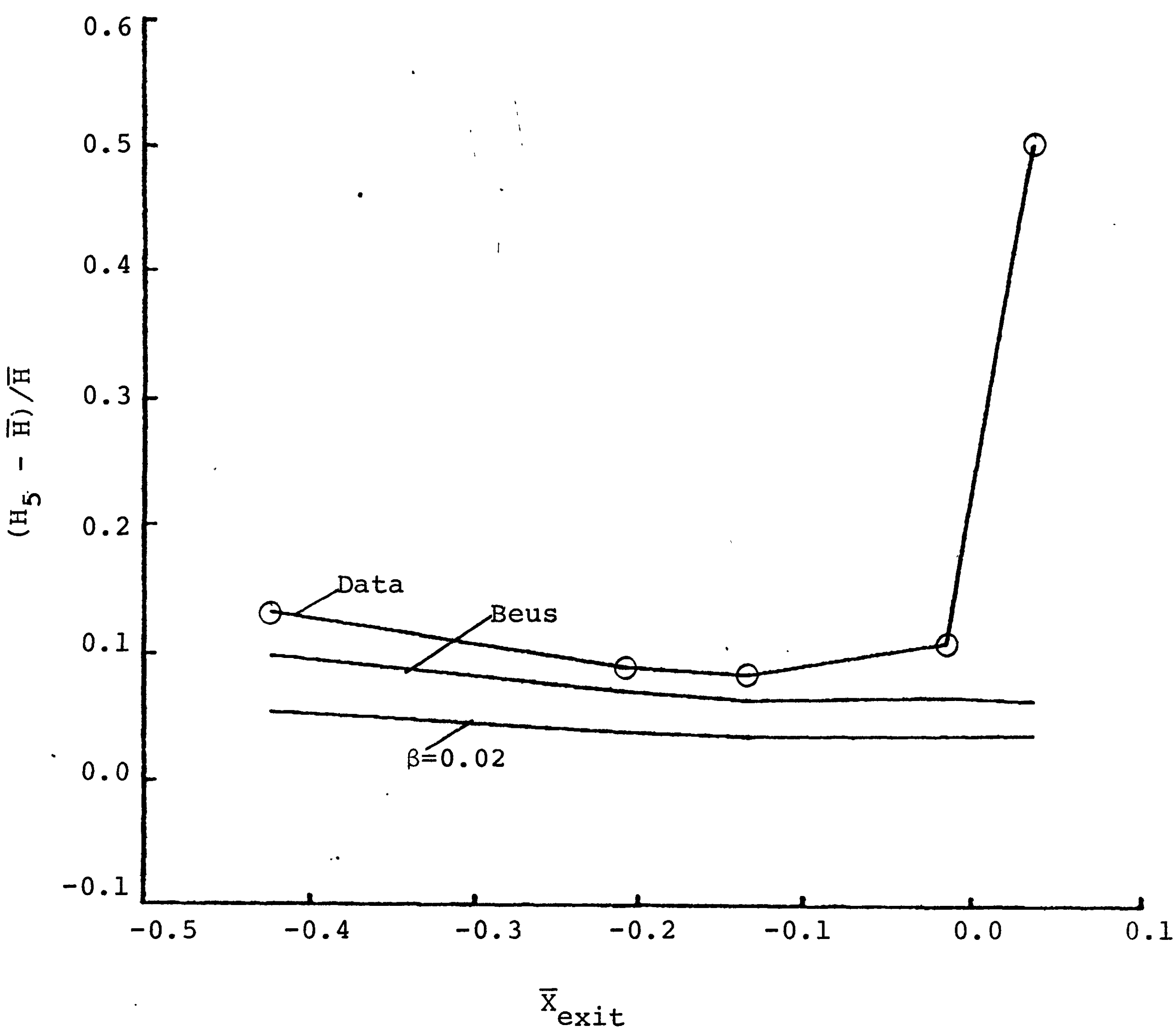


Figure IV-17

<u>Columbia Test Cases 22, 25, 27, 29 and 30</u>
<u>Normalized Channel 5 Exit Enthalpy vs. Quality</u>

$$G = 1. \frac{Mlb}{hr\ ft^2}$$

$$q'' = 0.38 \frac{MBTU}{hr\ ft^2}$$

$$P = 1200\ psia$$

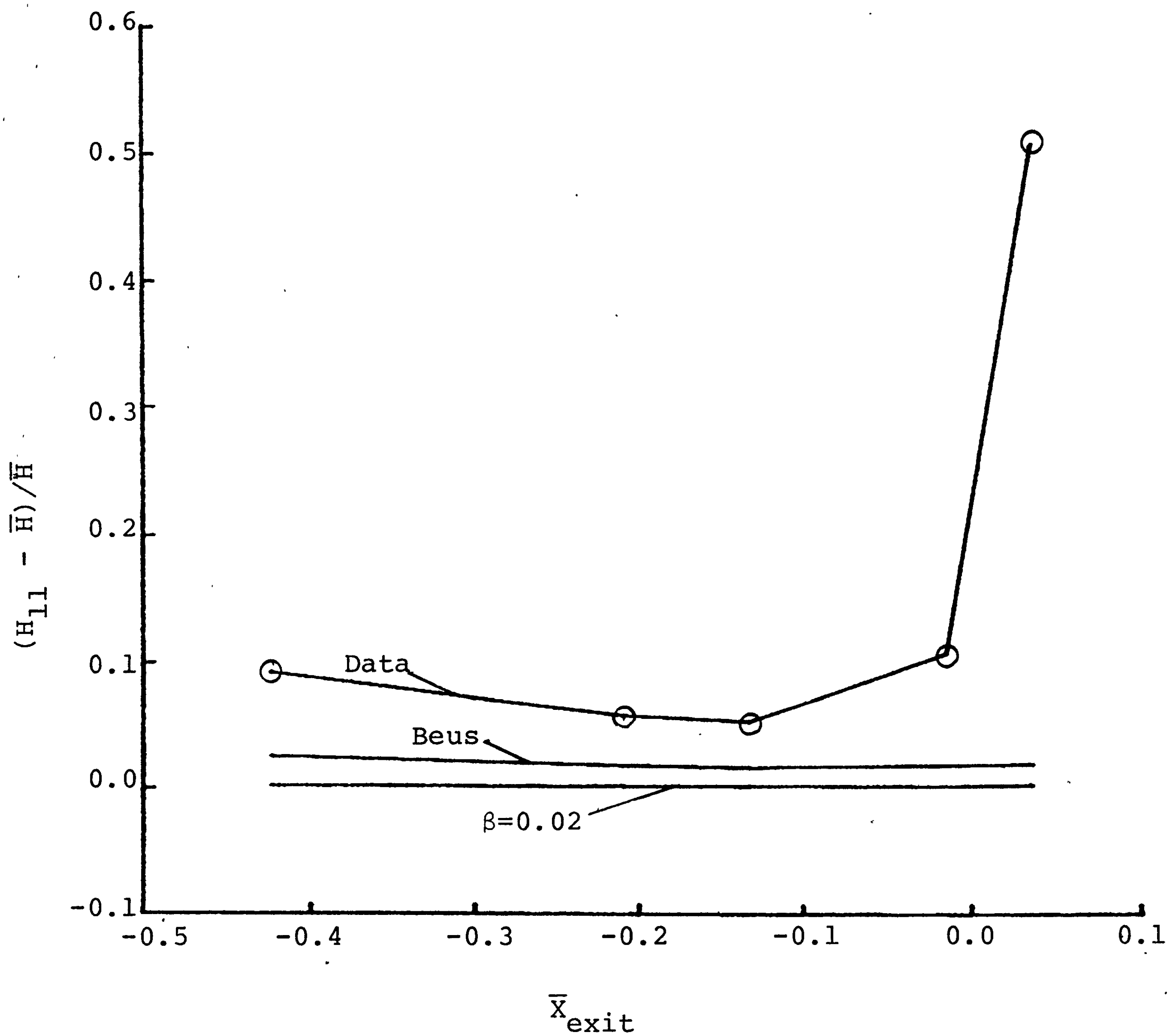


Figure IV-18

<u>Columbia Test Cases 22, 25, 27, 29 and 30</u>
<u>Normalized Channel 11 Exit Enthalpy vs. Quality</u>

$$G = 1. \frac{\text{Mlb}}{\text{hr ft}^2}$$

$$q'' = 0.38 \frac{\text{MBTU}}{\text{hr ft}^2}$$

$$P = 1200. \text{ psia}$$

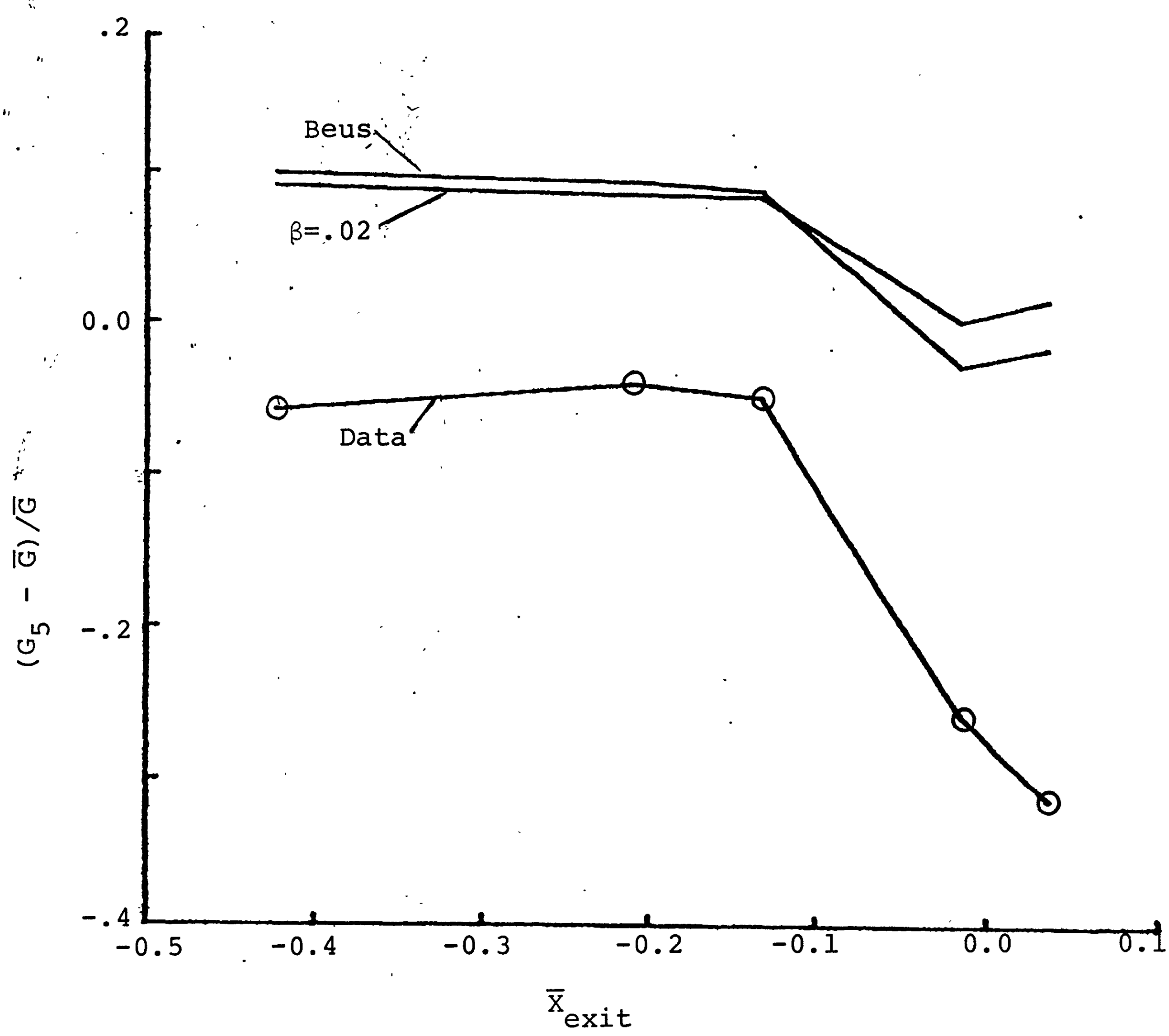


Figure IV-19

Columbia Test Cases 22, 25, 27, 29 and 30
Normalized Channel 5 Exit Mass Flux vs. Quality

$$\overline{G} = 1. \frac{Mlb}{hr\ ft^2}$$

$$q'' = 0.38 \frac{MBTU}{hr\ ft^2}$$

$$P = 1200.\ psia$$

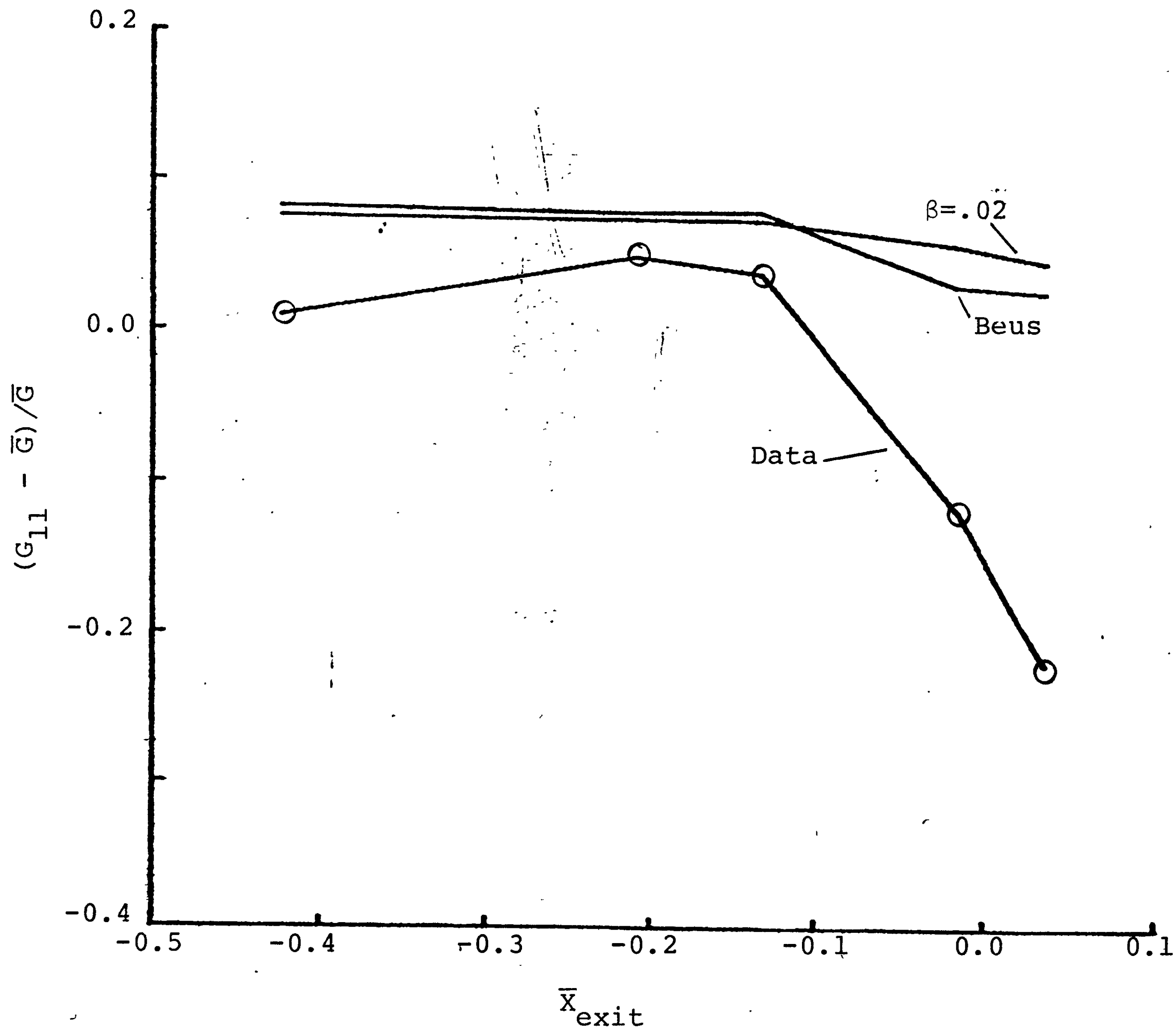


Figure IV-20

Columbia Test Cases 22, 25, 27, 29 and 30
Normalized Channel 11 Exit Mass Flux vs. Quality

Normalized exit enthalpy as a function of average exit quality is shown for channels 5 and 11 in Figures IV-17 and IV-18, respectively. The data shows higher than average enthalpy in channels 5 and 11. Beus predicts a higher than average enthalpy but less than the data. The β=0.02 enthalpy predictions are less than the Beus predictions because β=0.02 predicts greater mixing than the Beus model. The sharp normalized enthalpy increase in channels 5 and 11 as exit quality increases in the vicinity of saturated liquid conditions is not reflected in the predictions.

Normalized exit mass flux is shown as a function of average exit quality for channels 5 and 11 in Figures IV-19 and IV-20, respectively. The data shows a general decline of normalized mass flux in channels 5 and 11 as exit quality increase above -0.1. The predictions are similar for each channel, as expected, since the effect on mass flux distribution is a second order effect, especially in the single-phase liquid flow regime. Mass flux was overpredicted in channels 5 and 11.

Data and predictions for higher mass and heat flux case 35, 39, 42 and 90 show behavior similar to data and predictions discussed for cases 22, 25, 27, 29 and 30. However, predictions were closer to data, especially the Beus predictions. Channel 5 and 11 exit enthalpies were closer to bundle average values. The results for cases 35, 39, 42 and 90 are shown in Figures IV-21 through IV-24.

In summary, predictions are closer to data for subcooled conditions typical of PWR's operating under normal condition. Data trends for boiling conditions typical of BWR's are not well predicted, however. The Beus predictions are closer to data than β=0.02 predictions. Enthalpy is predicted closer to data than mass flux. The data for high mass and heat flux cases are more closely predicted.

4. Testing of New Correlations for Critical Power Ratio and Critical Heat Flux Ratio

The CISE-4 correlation for CPR and Hench-Levy correlation for CHFR were tested using the GE 9-Rod CHF Tests (Ref. 27). The Biasi/Void-CHF correlation for CHFR has not been tested. CPR and CHFR predictions were obtained for conditions under which CHF was experimentally found to occur.

$\overline{G} = 1.5 \ \frac{Mlb}{hr\ ft^2}$

$q'' = .58 \ \frac{MBTU}{hr\ ft^2}$

$P = 1200$ psia

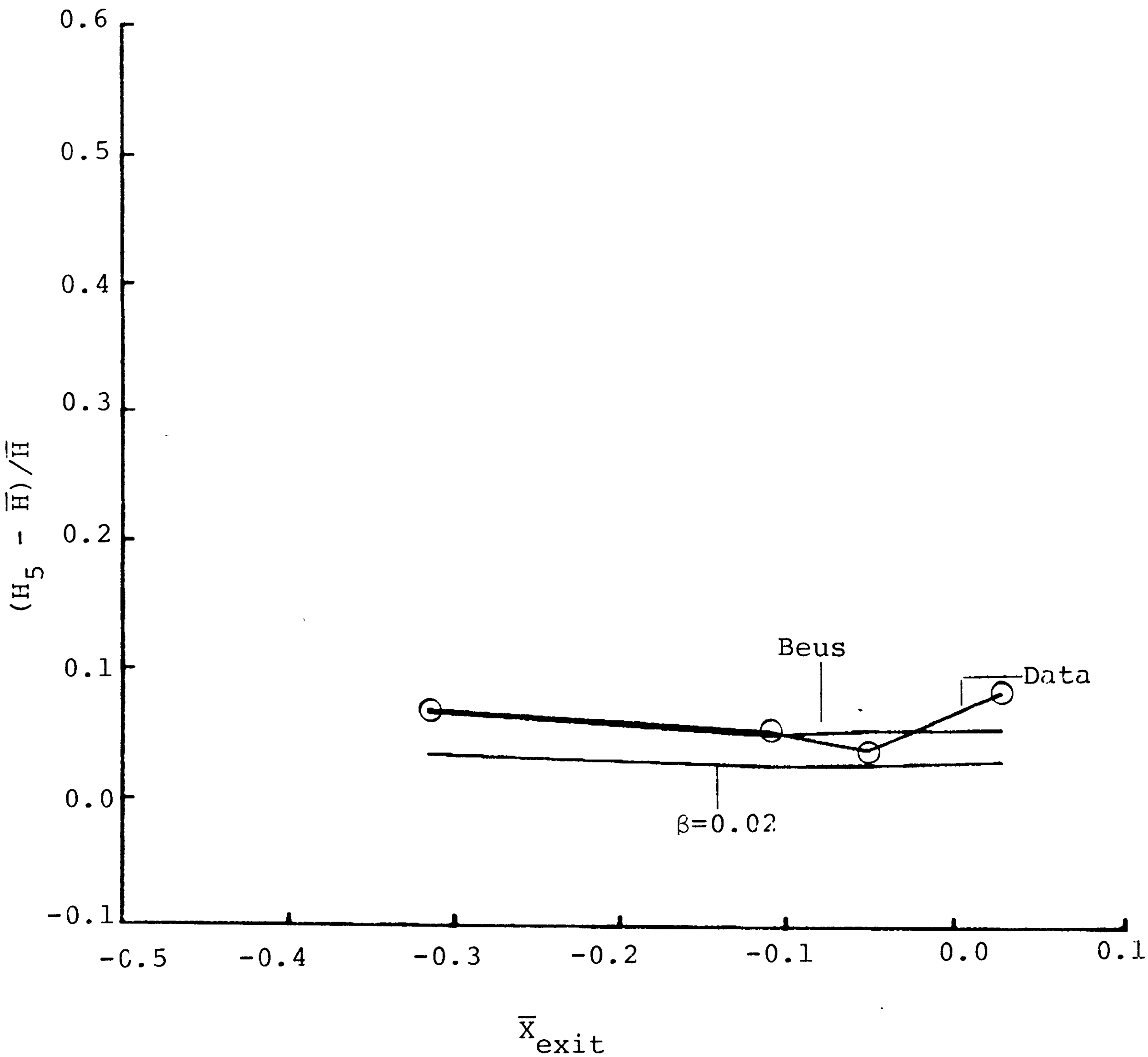


Figure IV-21

Columbia Test Cases 35, 39, 42, and 90
Normalized Channel 5 Exit Enthalpy vs. Quality

$$\overline{G} = 1.5 \frac{Mlb}{hr\ ft^2}$$

$$q'' = .58 \frac{MBTU}{hr\ ft^2}$$

$$P = 1200 \text{ psia}$$

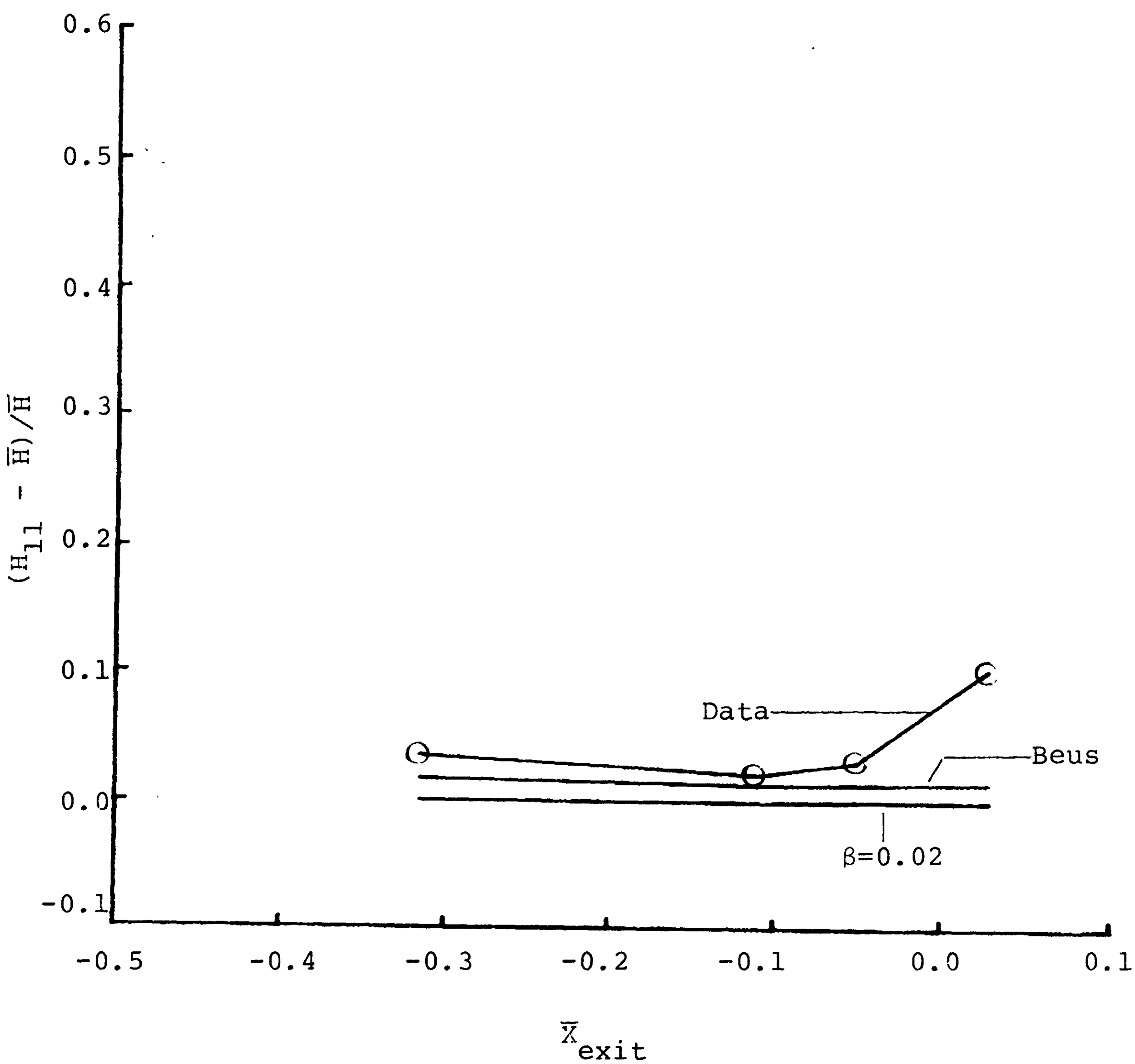


Figure IV-22

Columbia Test Cases 35, 39, 42, and 90
Normalized Channel 11 Exit Enthalpy vs. Quality

$$\overline{G} = 1.5 \ \frac{\text{Mlb}}{\text{hr ft}^2}$$

$$q'' = 0.58 \ \frac{\text{MBTU}}{\text{hr ft}^2}$$

$$P = 1200 \text{ psia}$$

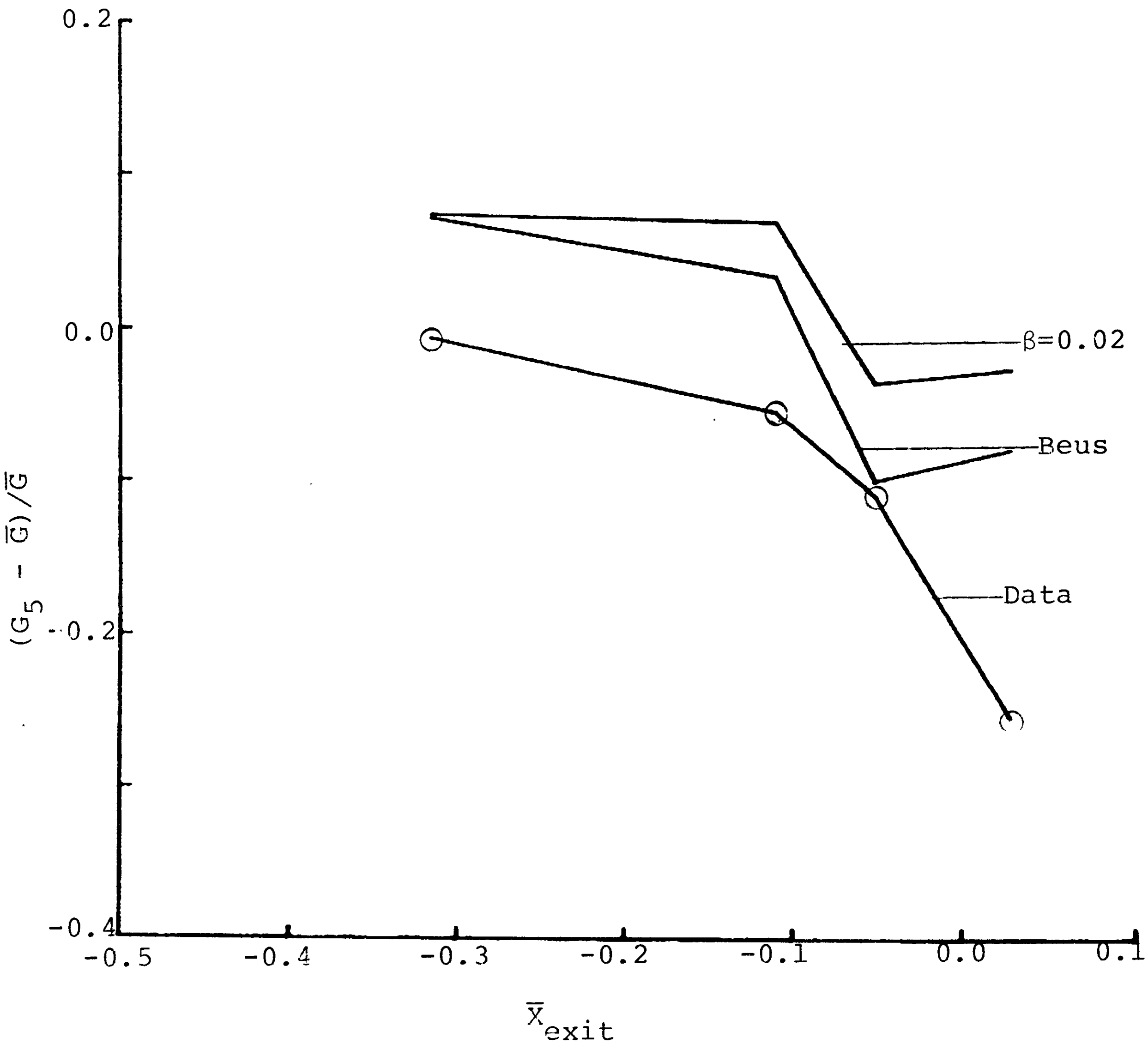


Figure IV-23

Columbia Test Cases 35, 39, 42, and 90
Normalized Channel 5 Exit Mass Flux vs. Quality

$$\overline{G} = 1.5 \frac{\text{Mlb}}{\text{hr ft}^2}$$

$$q'' = 0.58 \frac{\text{MBTU}}{\text{hr ft}^2}$$

$$P = 1200 \text{ psia}$$

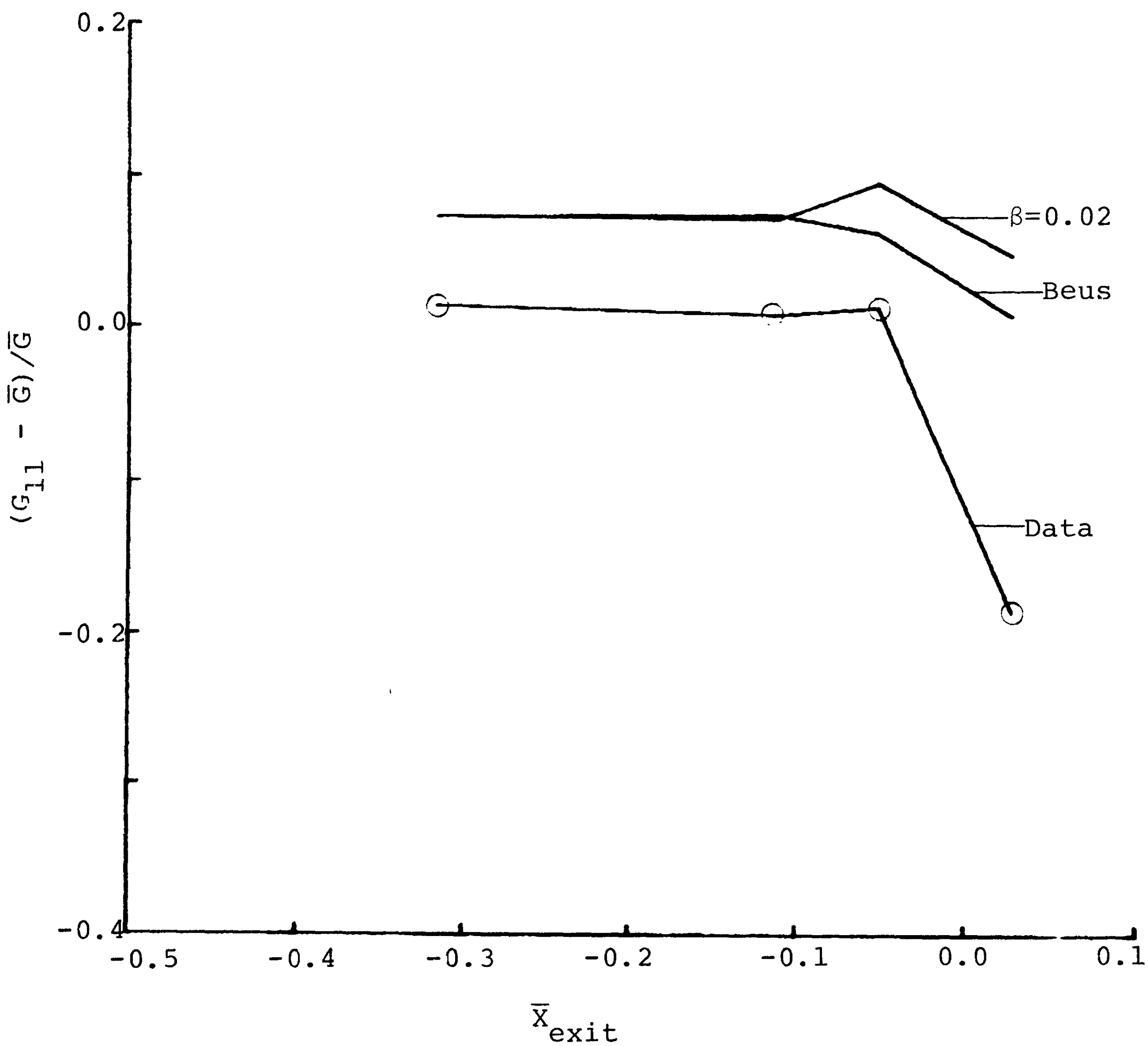


Figure IV-24

Columbia Test Cases 35, 39, 42, and 90
Normalized Channel 11 Exit Mass Flux vs. Quality

a. Description of GE 9-Rod CHF Tests

The GE 9-Rod CHF tests were carried out using the bundle geometry and test conditions shown in Figure IV-25. The five test channels shown in Figure IV-26 were used. The test channels all had the same grid type spacers and rods. Surface heat flux was uniform axially and radially. The test channels had different heated length and spacer-locations.

b. Comparison of COBRA-IIIC/MIT Predictions with Data

Channel 3 and 4 test cases listed in Table IV-4 were analyzed using COBRA. CISE-4 critical power ratio (CPR) and Hench-Levy CHFR predictions were obtained. CISE-4 was developed for rod-centered subchannel analysis. Coolant-centered subchannel analysis, the type COBRA performs, is less suitable for CISE-4 than analyzing the 9-rod bundle as a single channel. However, COBRA subchannel analysis is appropriate for use with the Hench-Levy CHFR correlation.

For comparison purposes, CISE-4 CPR and Hench-Levy CHFR predictions were obtained using the single channel and subchannel analysis methods for test cases 266 and 268. Predictions using the two analysis methods are compared in Table IV-5. The CISE-4 and Hench-Levy predictions are less conservative using single channel analysis. In order to show how the least conservative method compares with the experimental data, single channel analysis was used to analyze the rest of the test cases analyzed.

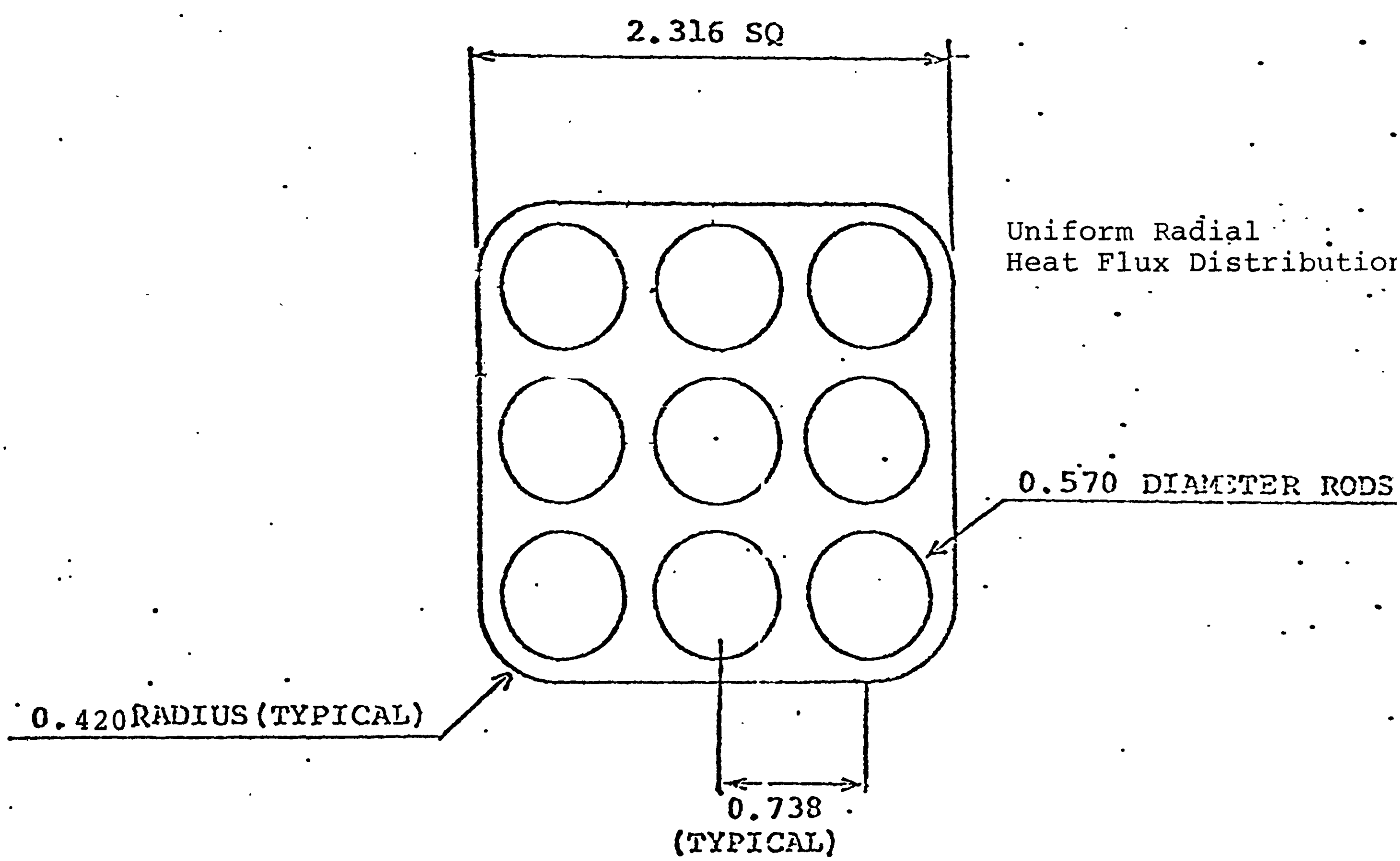
Single channel analysis MCPR and MCHFR predictions for test channels 3 and 4 are given in Table IV-4. All the Hench-Levy MCHFR predictions are conservative. The CISE-4 MCPR predictions are not nearly as conservative as the Hench-Levy MCHFR predictions. The MCPR predictions are slightly non-conservative for one of six channel 3 cases and three of four channel 4 cases. MCPR is overpredicted by less than 3% and underpredicted by less than 20%. Hench-Levy underpredicts MCHFR by 13 to 55%.

Figure IV-27 compares critical power data and prediction versus inlet coolant subcooling. All the CHF predictions fall below the data. The CISE-4 predictions are within 7% of the critical power data for the cases shown. Figure IV-28 compares

Figure IV-25

GE 9-Rod CHF Tests
Geometry and Test Conditions (Ref. 27)

Number of Rods	9
Rod Diameter	.570 inch
Radius of Corner Subchannel	.420 inch
Rod Rod Clearance	.168 inch
Rod Wall Clearance	.135 inch
Hydraulic Diameter	.474 inch
Heated Length	72 inch
Pressure	800 to 1000 psia
Average Bundle Mass Flow	0.5 to 1.25 $mlb_m/hr\ ft^2$
Inlet Subcooling	35 to 200 BTU/lb



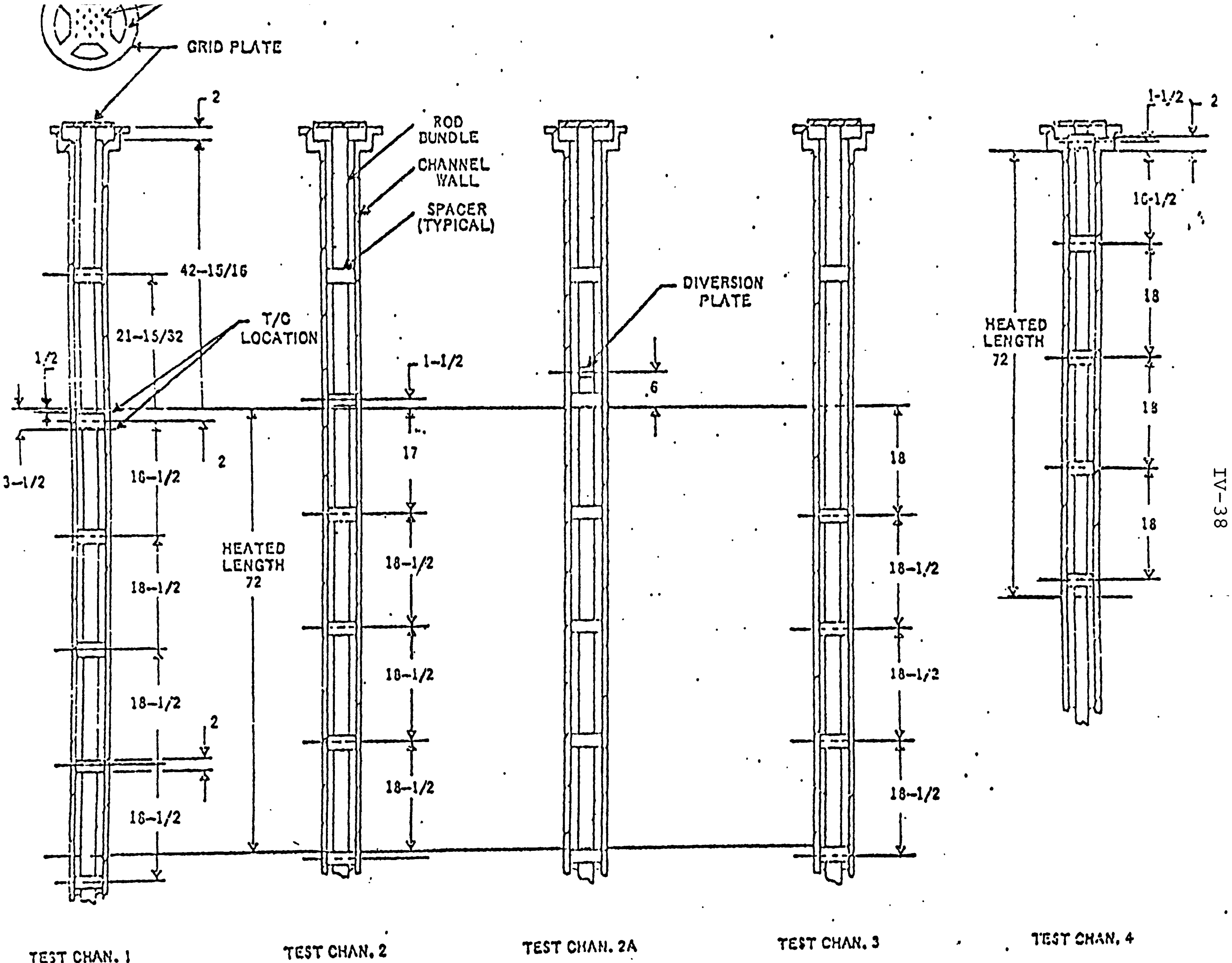


Figure IV-26

Schematic View of Test Channels, Showing Axial Position of Heated Length and Grid-Type Spacers (Ref. 27)

Table IV-4

9-Rod GE-CHF Experiments Analyzed and Single Channel Analysis Predictions

Test Channel Case	Test Case No.	p(psia)	Moss Flux (Mlb/hr ft^2)	Inlet Subcooling (BTU/lb)	q" (MBTU/hr ft^2)	COBRA Single Channel Analysis Predictions	
						CISE-4 MCPR	Hench-Levy MCHFR
3	266	1005.	1.008	7.1	0.510	0.9320	0.6017
	268	1015.	1.004	96.5	0.633	0.9950	0.6665
	270	1000.	1.000	191.8	0.785	0.9936	0.7662
	279	1000.	0.500	70.7	0.474	0.8634	0.4622
	286	997.	0.249	42.0	0.289	0.8028	0.4528
	296	1000.	1.248	12.8	0.522	1.0198	0.8130
4	301	1019.	1.051	29.4	.518	1.0013	0.6849
	302	1007.	1.075	54.6	0.560	1.0074	0.7685
	303	1018.	1.134	110.2	0.665	1.0289	0.8659
	320	1027.	0.306	197.4	0.410	0.9170	0.5098

Note: Ranges of data base for CISE-4 and Hench-Levy correlations are given in Table H-2 of Appendix H.

Table IV-5

Comparison of MCPR and MCHFR Predictions Using Single Channel and Subchannel Analysis

Test Case No.	Analysis Method	CISE-4 MCPR	Hench-Levy MCHFR
266	Single channel	0.9320	0.6017
	Subchannel	0.7657	0.5955
268	Single channel	0.9950	0.6665
	Subchannel	0.9126	0.6241

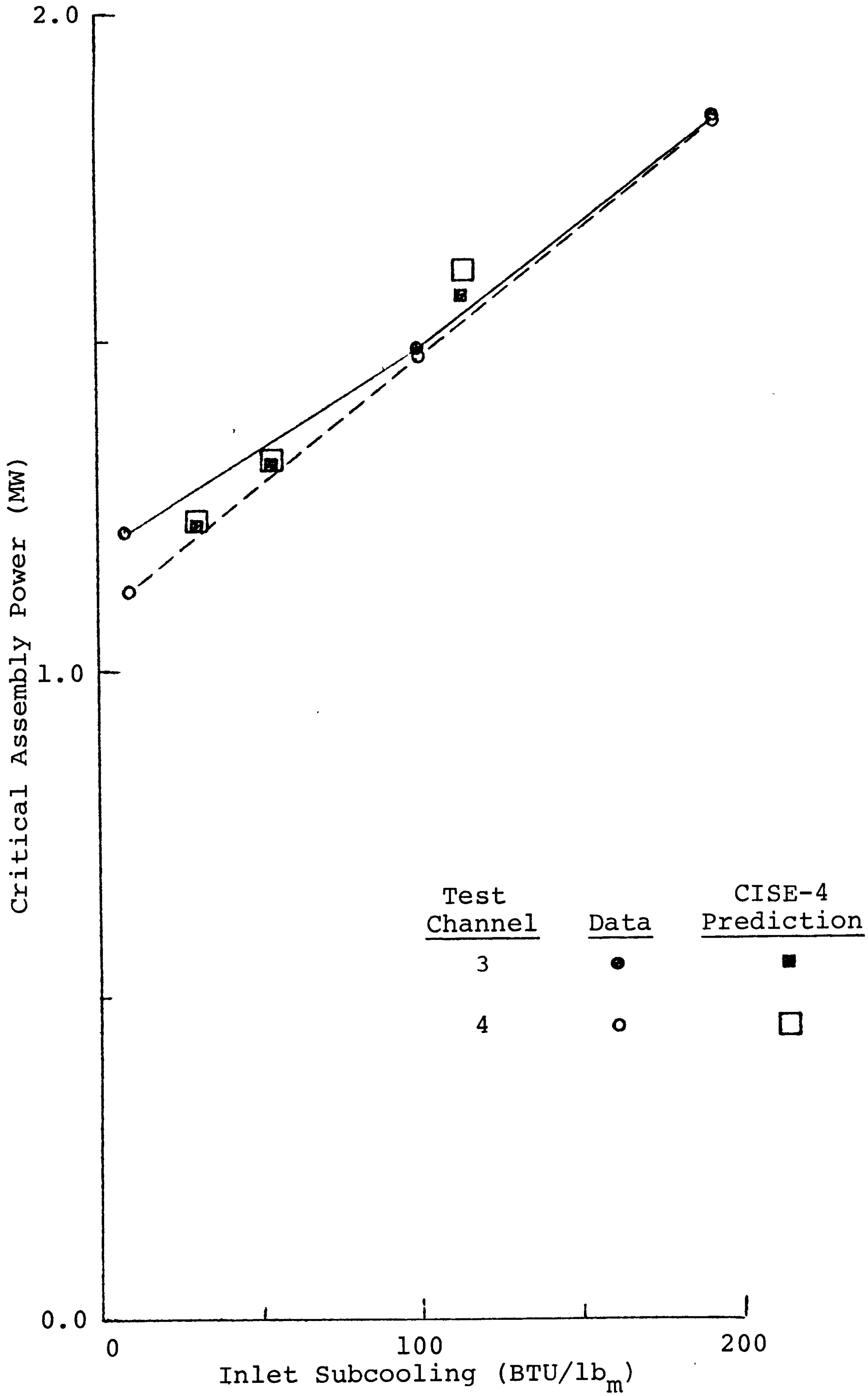


Figure IV-27

GE 9-Rod CHF Tests
Critical Assembly Power vs. Inlet Subcooling

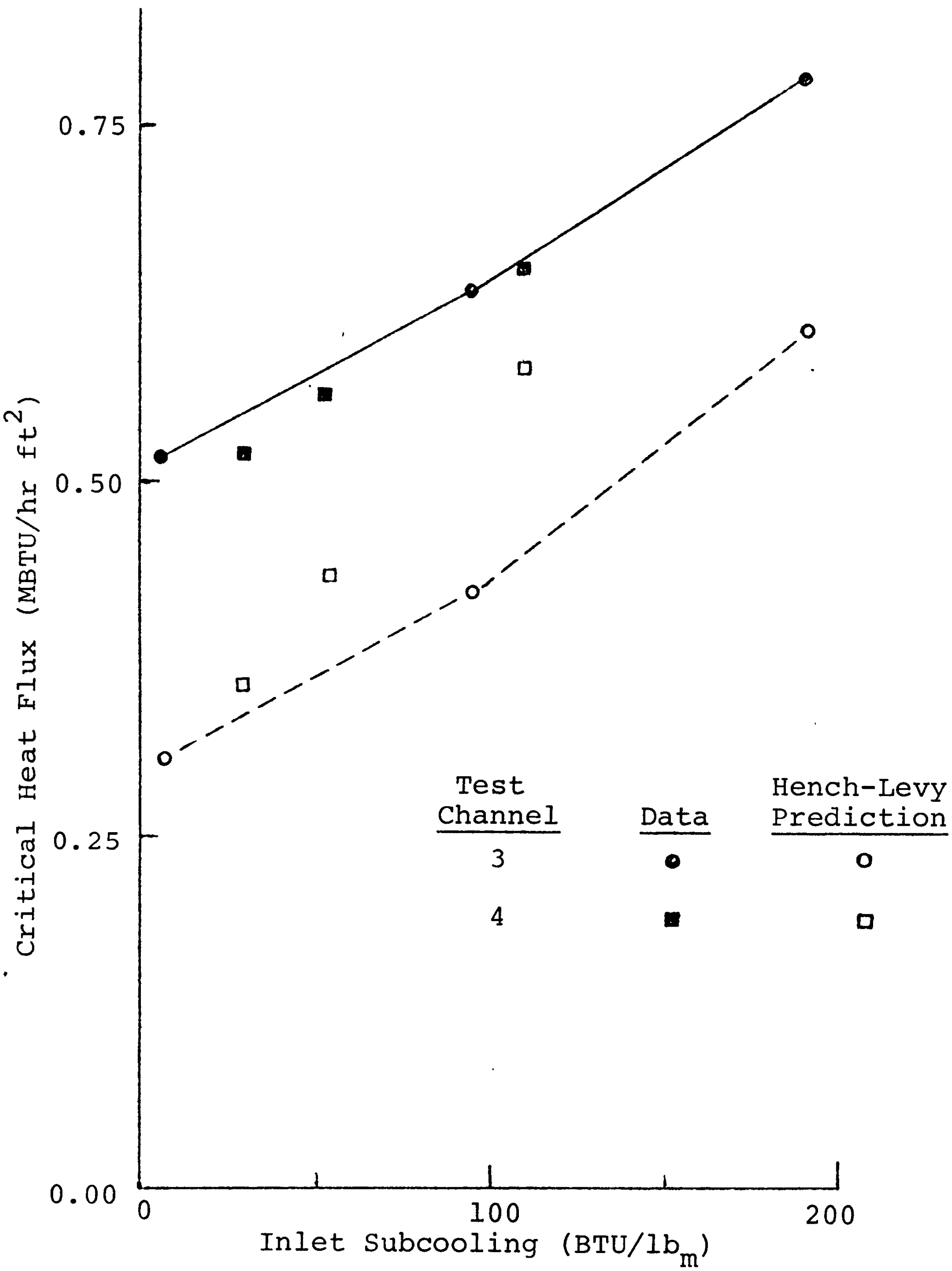


Figure IV-28

GE 9-Rod CHF Tests
Critical Heat Flux vs. Inlet Subcooling

CHF data and Hench-Levy predictions. The Hench-Levy predictions are within 40% of the CHF data for the cases shown.

CISE 4 closesly predicts critical power ratio. The less conservatism of the CISE-4 predictions in comparison to those of Hench-Levy can be understood in terms of the intended purpose of each. CISE-4 was developed to predict critical heat flux in accordance to experimental data. Hench-Levy was developed for design purposes rather than accurate CHF prediction; thus, it tends to underpredict critical heat flux.

5. Testing of One of the Two New Transverse Momentum Options for Single-Pass Method

One of the two new transverse momentum options was tested by comparing predictions obtained using this option with predictions obtained using the "standard" option. The new option tested was the "Weisman" option. The test case used was a single-pass analysis of a PWR core.

The 1/8 section of the PWR core shown in Figure IV-29 was modeled using the layout shown in Figure IV-30. Geometric and thermal-hydraulic data used is given in Appendix J. Rod 12 was the hot rod and channel 9 was the "hot" subchannel where MDNBR for each axial level occurs. Figure IV-31 shows the top-peaked axial heat flux profile used to make predictions. Analysis results are shown in Figures IV-32 through IV-36.

Predictions for the hot subchannel (channel 9) were nearly the same for the two analysis approaches. Figure IV-32 shows enthalpy as a function of axial position in the hot subchannel. The predictions of the two approaches are essentially the same. Predictions of net crossflow out of the hot subchannel are also nearly the same, as shown in Figure IV-33. MDNBR predictions of the two approaches lie on top of one another, as shown in Figure IV-34.

The axial crossflow distributions showed some change for gaps connecting the fine mesh region to the coarse mesh region. Figuve IV-35 shows the axial crossflow predictions of the two analysis methods for the gap connecting channels 7 and 11. The profile shapes are different; however, the net crossflow, represented by the area under each curve, appears to be similar.

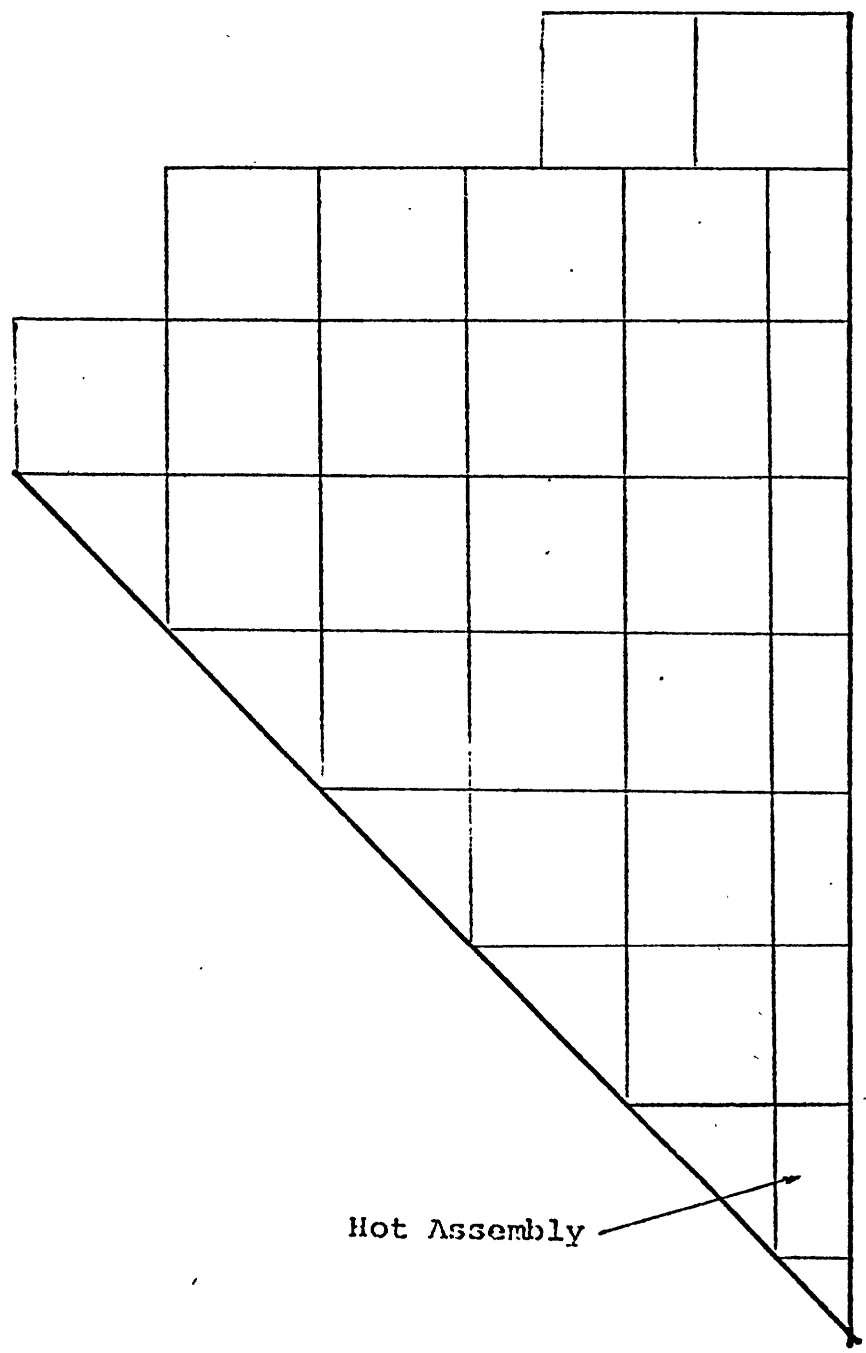
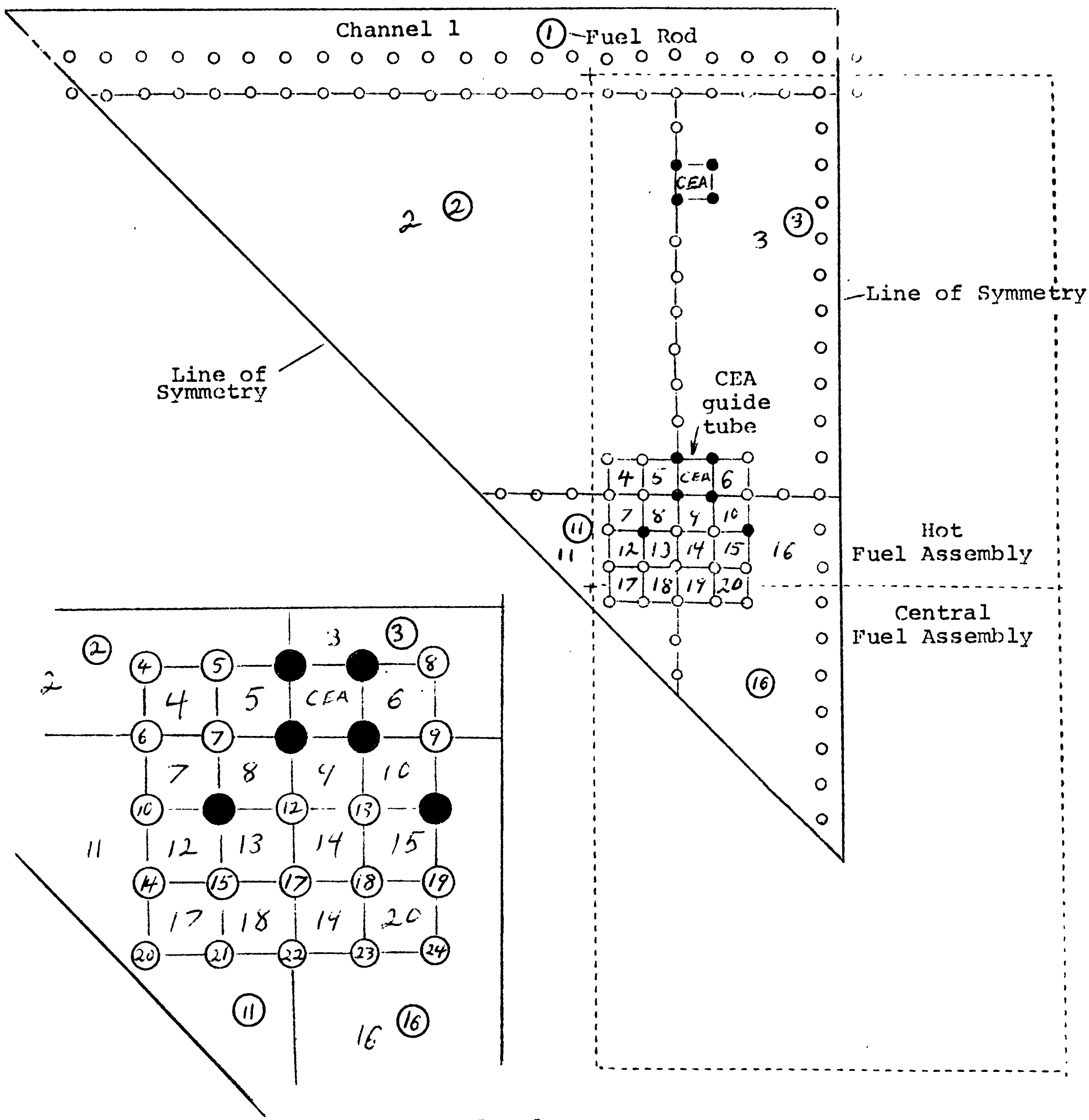


Figure IV-29

1/8 Section of PWR Core Used for Test Case



Note: Rod 12 is the hot rod and channel 9 is the hot subchannel

Figure IV-30

Layout Used for 1/8 Core Single-Pass Case

Note: Ref. Appendix J for other
thermal hydraulic data used.

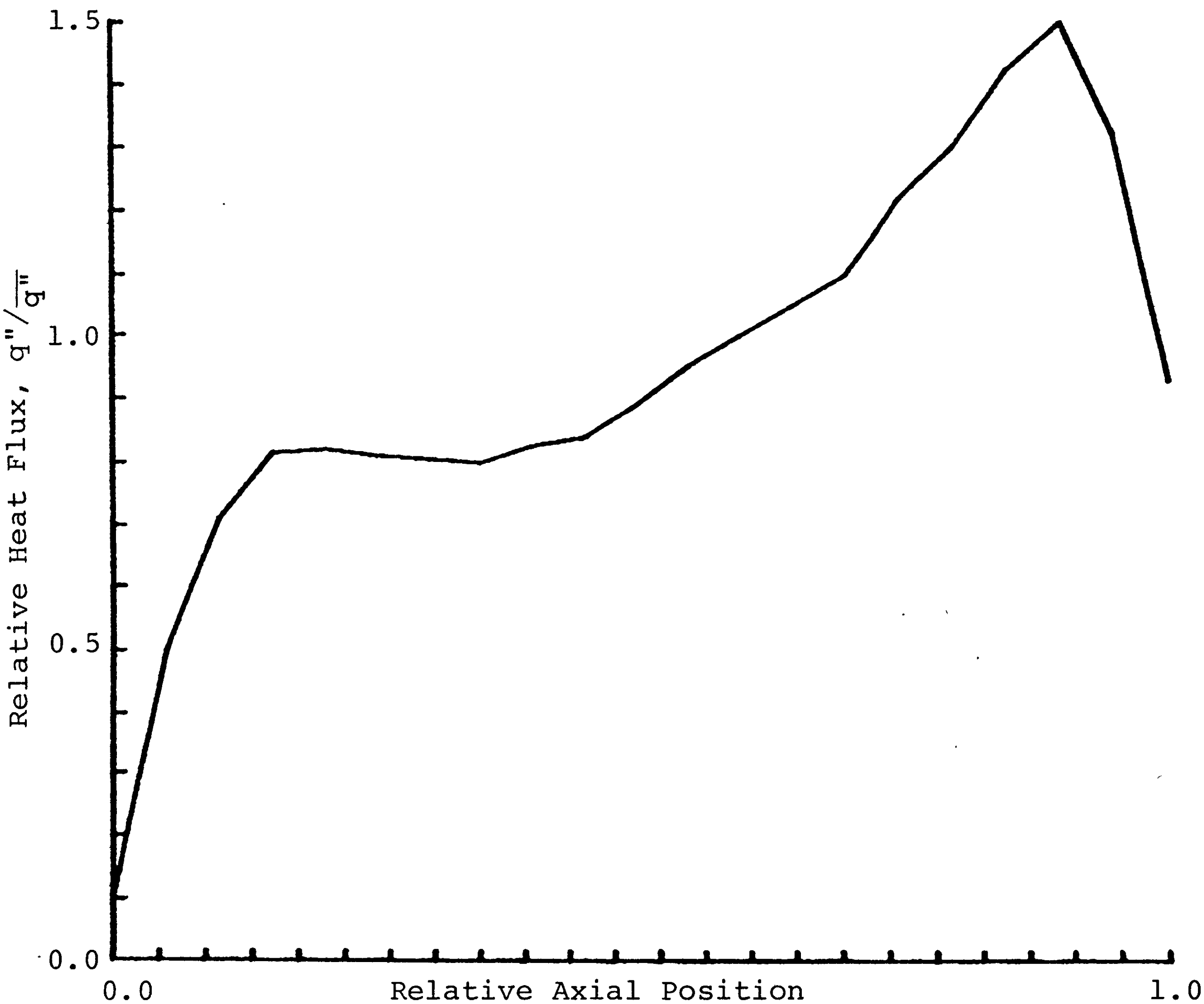


Figure IV-31

Top-Peaked Axial Heat Flux Profile
Used for 1/8 Core Single-Pass Analysis

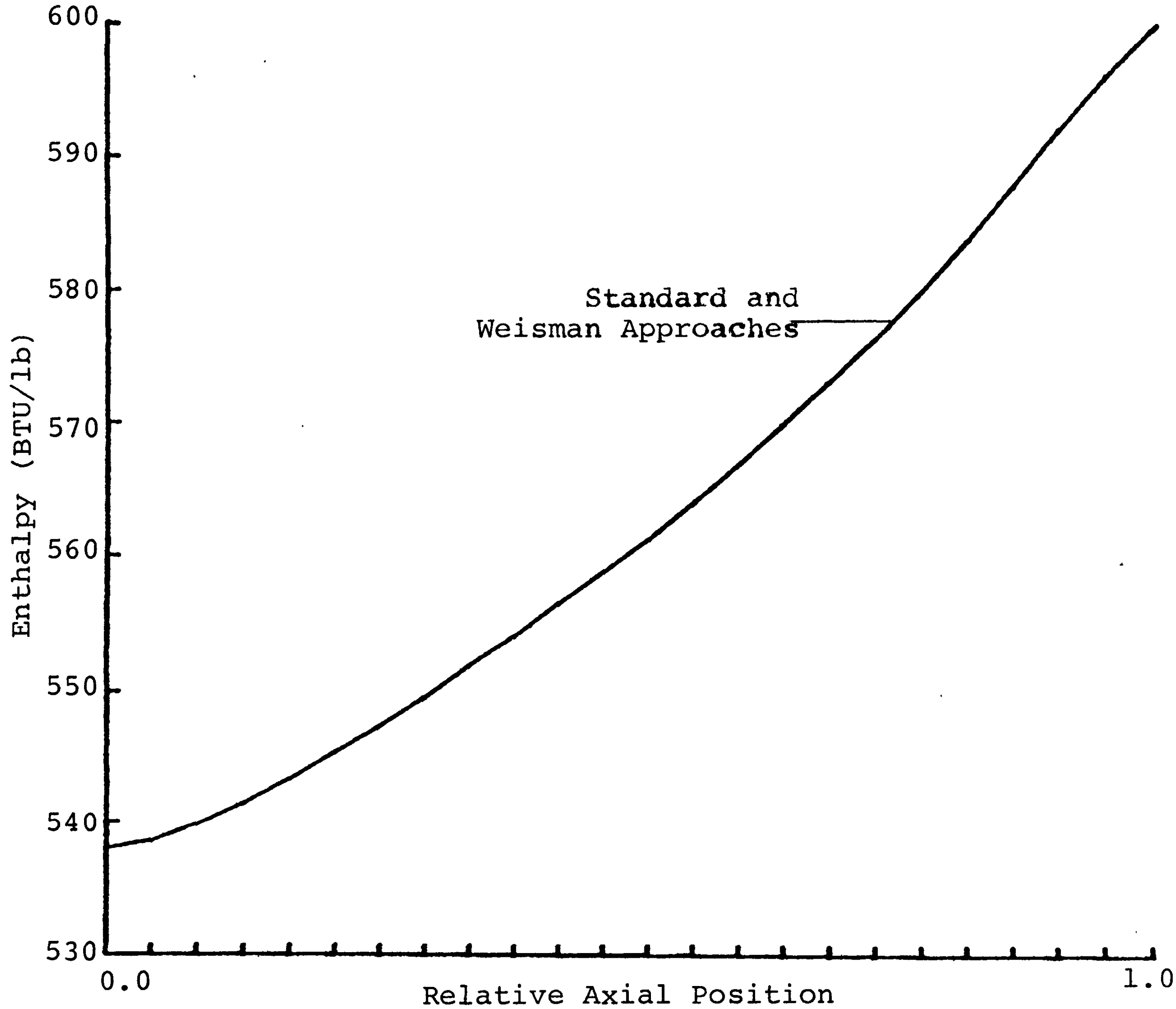


Figure IV-32

1/8 Core Single-Pass Analysis Case

Enthalpy in Channel 9 (Hot Subchannel)
vs. Relative Axial Position

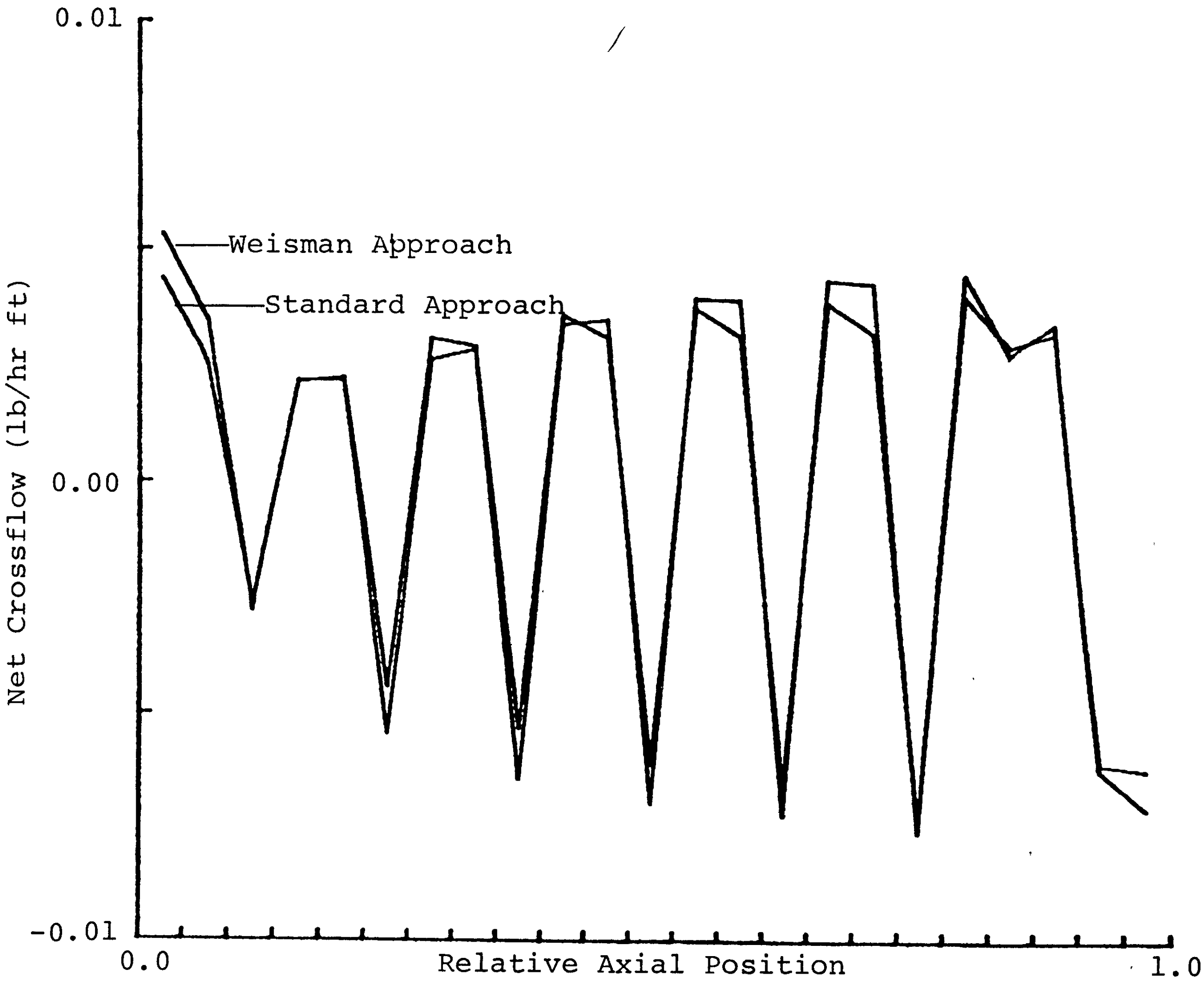


Figure IV-33

1/8 Core Single-Pass Analysis Case

Net Crossflow Out of Channel 9 (Hot Subchannel) vs. Relative Axial Position

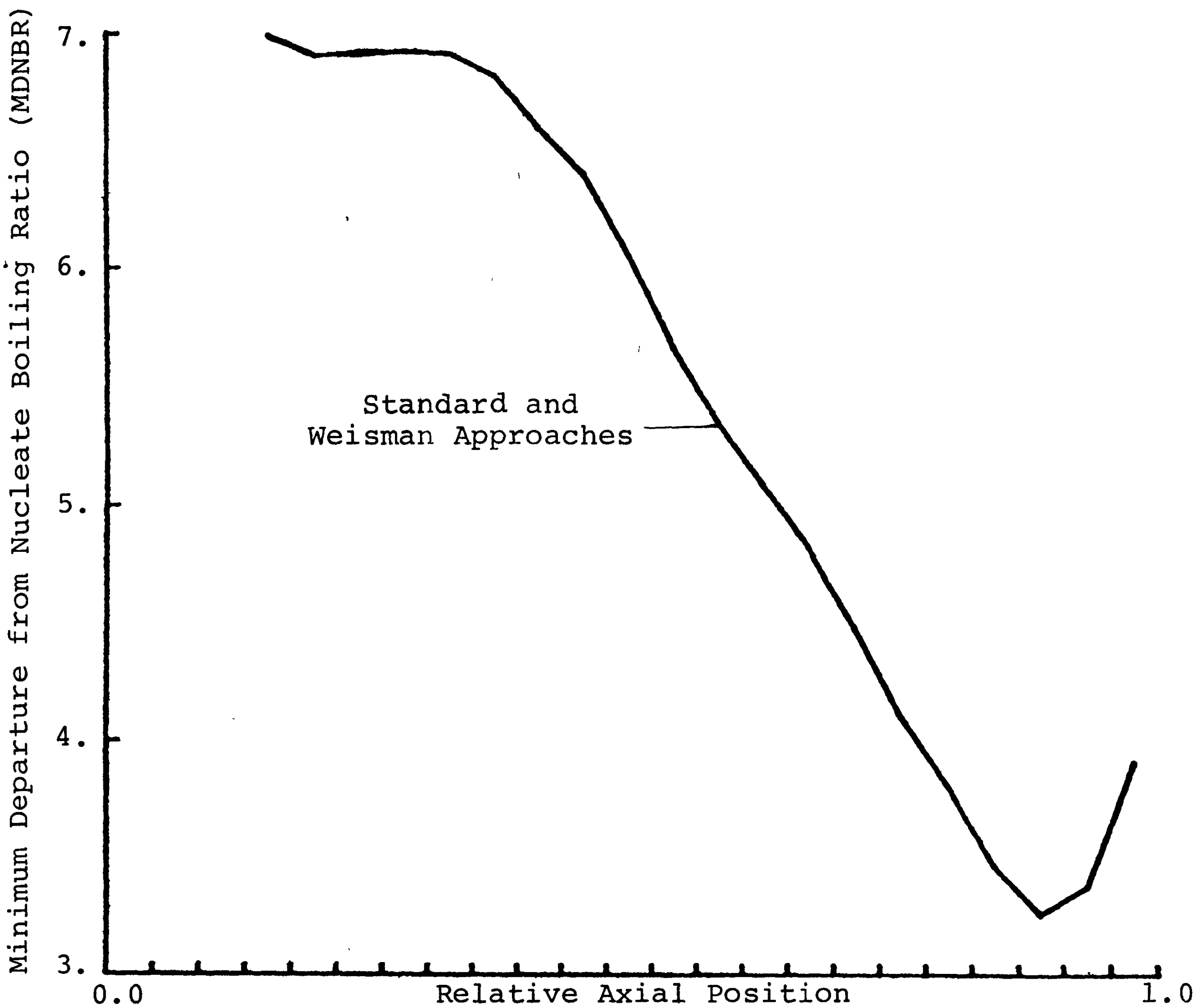


Figure IV-34

1/8 Core Single-Pass Analysis Case

MDNBR vs. Axial Position

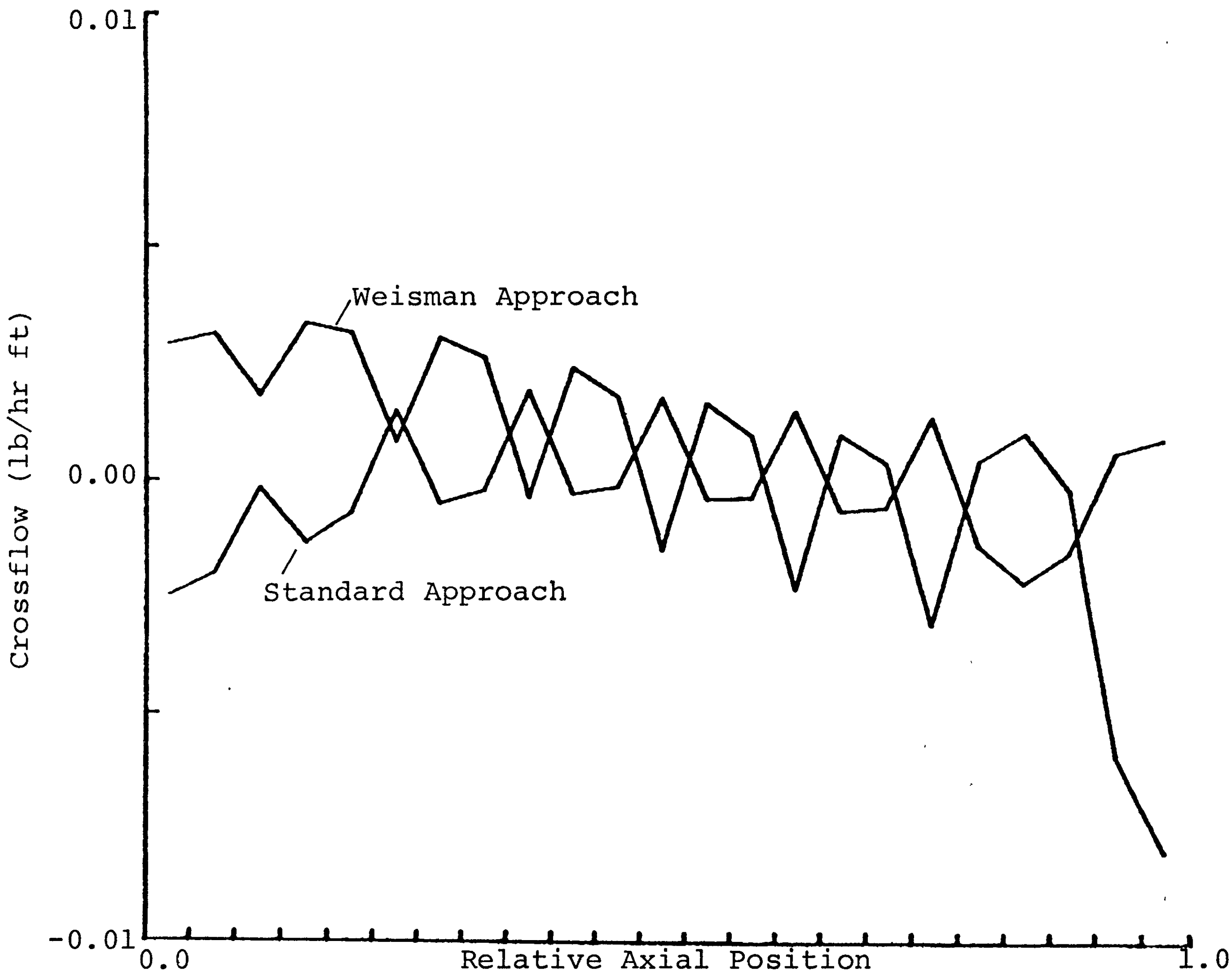


Figure IV-35

1/8 Core Single-Pass Analysis Case

Crossflow from Channel 7 to 11 vs. Relative Axial Position

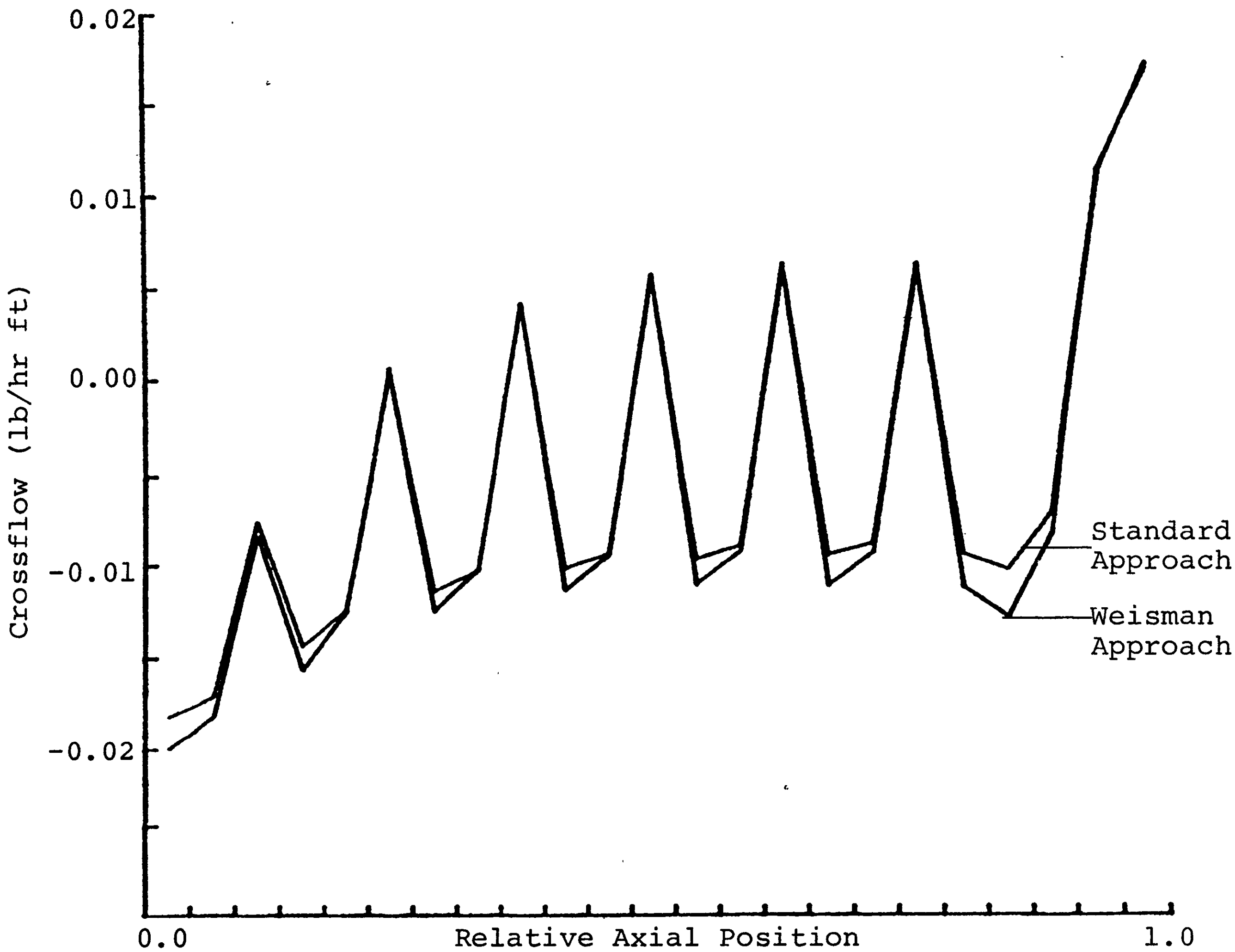


Figure IV-36

1/8 Core Single-Pass Analysis Case

Crossflow from Channel 7 to 8 vs. Relative Axial Position

The difference in axial crossflow profiles is much less for the gap connecting fine mesh regions 7 and 8, as Figure IV-36 shows.

Thus, for the case analyzed, the standard and Weisman approaches* give nearly the same results for crossflow and enthalpy distribution; and MDNBR predictions are the same. It is possible that the two appraoches might not give the same results for more off normal conditions such as a case involving flow blockage, for example. In this case, however, it may be questionable whether COBRA-IIIC/MIT should be used for the analysis.

C. Application to Transient Test Cases

COBRA-IIIC/MIT has been tested by application to transient test cases. A PWR loss of flow transient and BWR turbine trip transient were analyzed using both new and old modeling options.

1. PWR Transient Test Case - Loss of Flow Transient

a. Description of Loss of Flow Transient

The PWR transient test case is a postulated loss of coolant accident for the Maine Yankee reactor (Ref. 28 & 29). In this accident, all three primary coolant pumps lose electrical power during full power operation. Flow coasts down, causing a low flow reactor trip signal. Control element assemblies (CEAs) are assumed to fall into the core three seconds after initiation of flow coastdown. The minimum value of DNBR occurs between three and four seconds after initiation of flow coastdown.

b. Description of Modeling

The loss of flow transient was analyzed using single-pass COBRA-IIIC/MIT analysis. A 1/8 section of the Maine Yankee core was modeled using the layout shown schematically in Figure IV-37. Rods 5 and 15 are the hot rods. MDNBR is predicted to occur on either rod 5 or 15 during the transient.

---

*The "standard" approach used the old transverse momentum option ($f_{s\ell}$ and $f_{s\ell k}$ equal to unity). The "Weisman approach used coupling factors as defined by Eqns. (III-7) and (III-8).

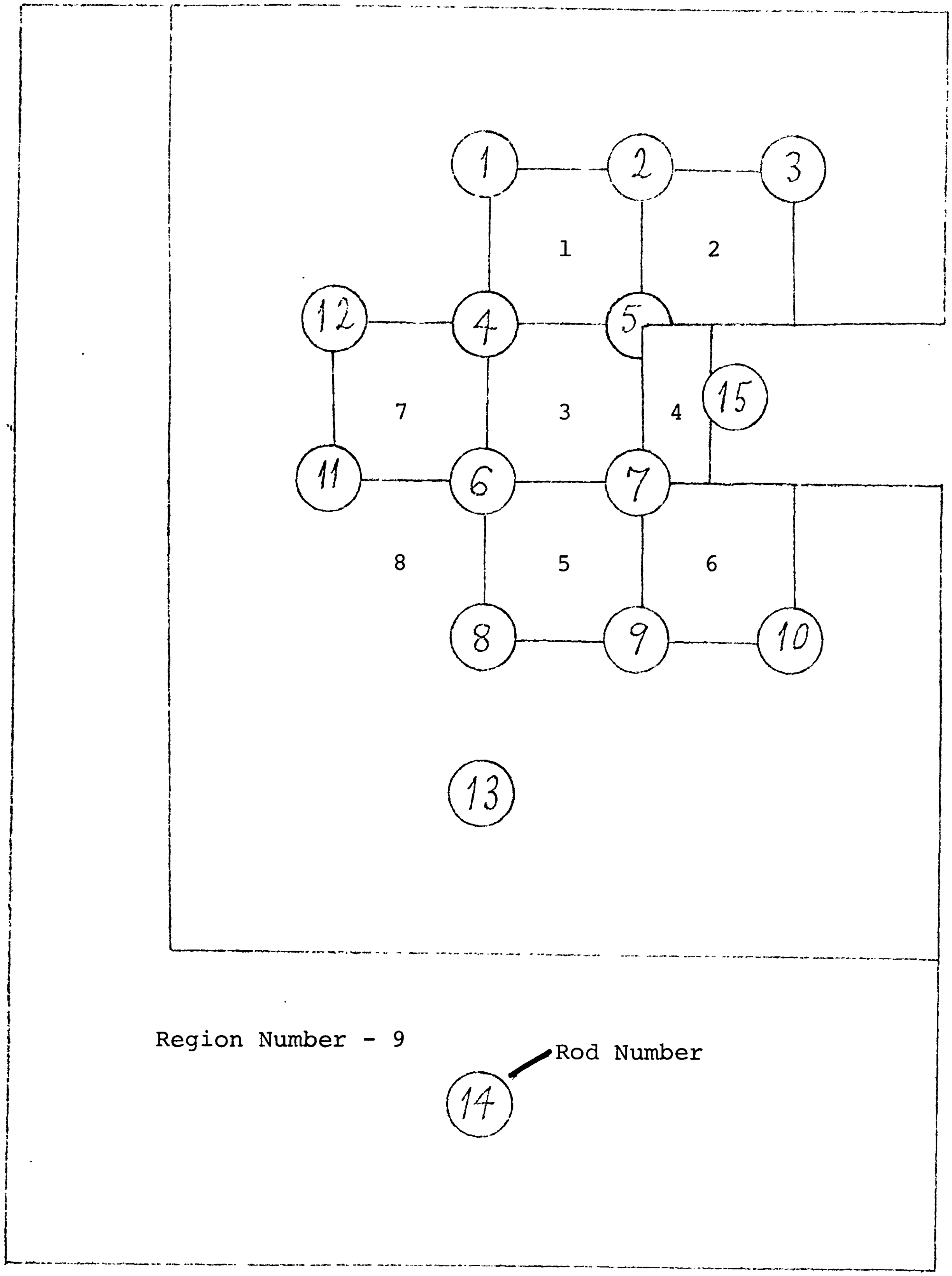


Figure IV-37

Schematic of Layout Used for Loss of Flow Analysis

Fine radial nodalization (subchannel size coolant and nodes) is used in the vicinity of rods 5 and 15. Coarser radial nodalization is used outside the fine mesh region. Regions one to eight represent one 14x14 fuel rod assembly. Region nine represents the remaining assemblies in the 1/8 section of core.

Four COBRA-IIIC/MIT analyses were made using various modeling options as indicated in Table IV-6. Transient forcing functions used by the analyses are shown in Figure IV-38. The core inlet flow forcing function is based on plant data. The heat flux and power level forcing functions are based on predictions of the CHIC-KIN code (Ref. 28). Heat flux was used as a forcing function for analysis cases which did not use a fuel rod model. Power level was used as a forcing function for analysis cases which used a fuel rod model. The loss of flow transient was analyzed for five seconds using a time step size of 0.25 sec. for all cases. Channels were divided axially into twenty nodes. Predictions were printed once every two time steps. COBRA-IIIC/MIT input for the loss of flow transient in secribed in Appendix K.

c. Analysis of Results

The predictions of the four analysis cases were similar. MDNBR predictions were nearly the same. The largest dissimilarities in predictions were due to differences between the old and new rod-to-coolant heat transfer models. Clad surface temperature predictions of the two heat transfer models showed differences.

Since DNBR is usually the limiting parameter for a loss of flow accident, comparison of analysis case predictions will begin with this parameter. Predicted MDNBR is shown as a function of time for the four analysis cases in Figure IV-39. The predictions are close. The maximum difference between MDNBR predictions is less that 5%. The MDNBR predictions show the same trend. MDNBR decreases as flow coasts down and power is constant in the time range from 0. to 3. seconds. Reactor shutdown initiates at three sec. while flow coastdown continues. MDNBR predictions reach their minimum values near 3.5 sec. and increase

Table IV-6

Models Used for Loss of Flow Analysis Cases

Analysis Case Number	Fuel Rod Model	Fuel & Clad Material Properties	Heat Transfer Model
1	none	none	none
2	old	constant	old
3	new	temperature-dependent	new
4	old	constant	new

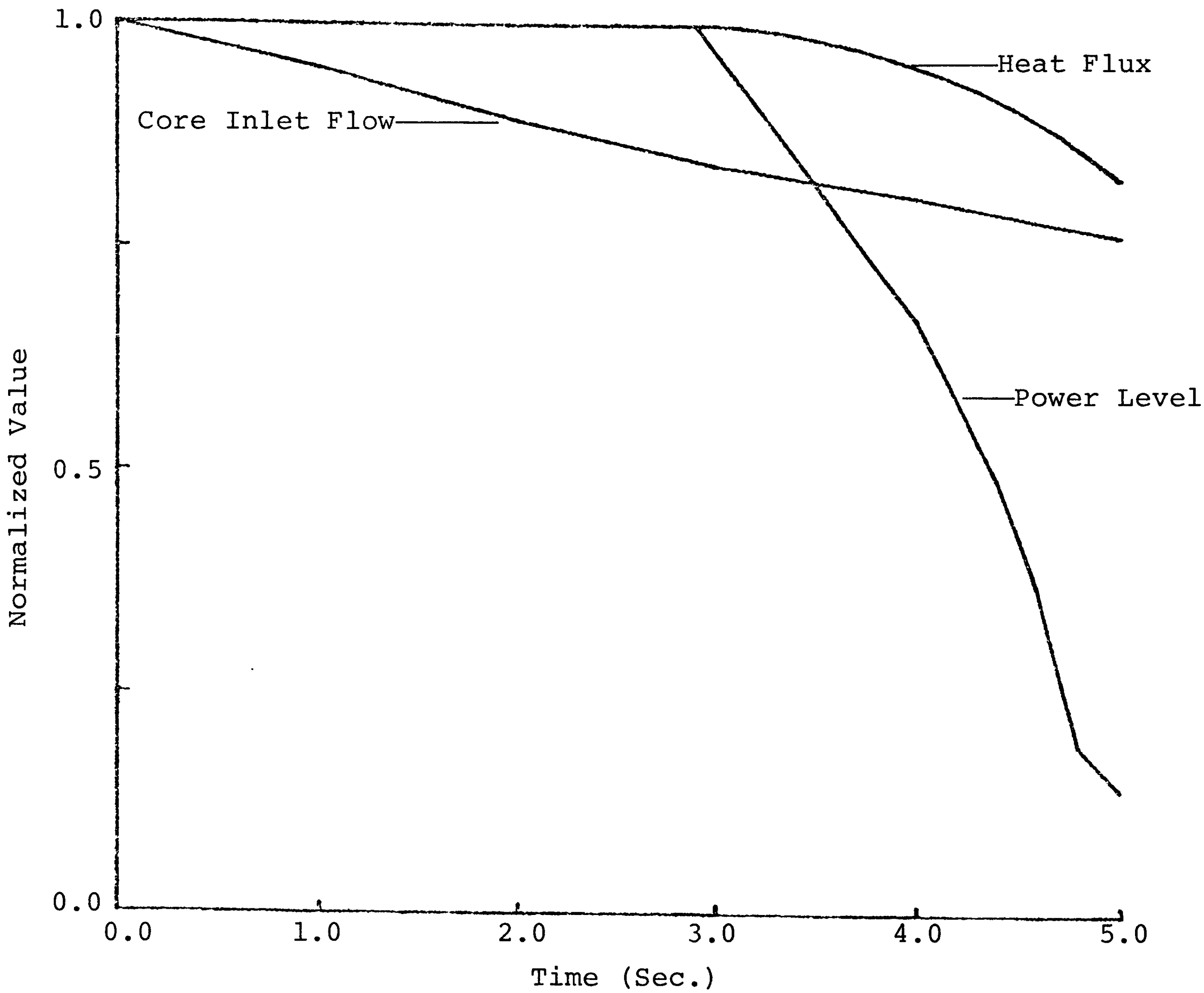


Figure IV-38

Transient Forcing Functions
PWR Loss of Flow Transient Test Case

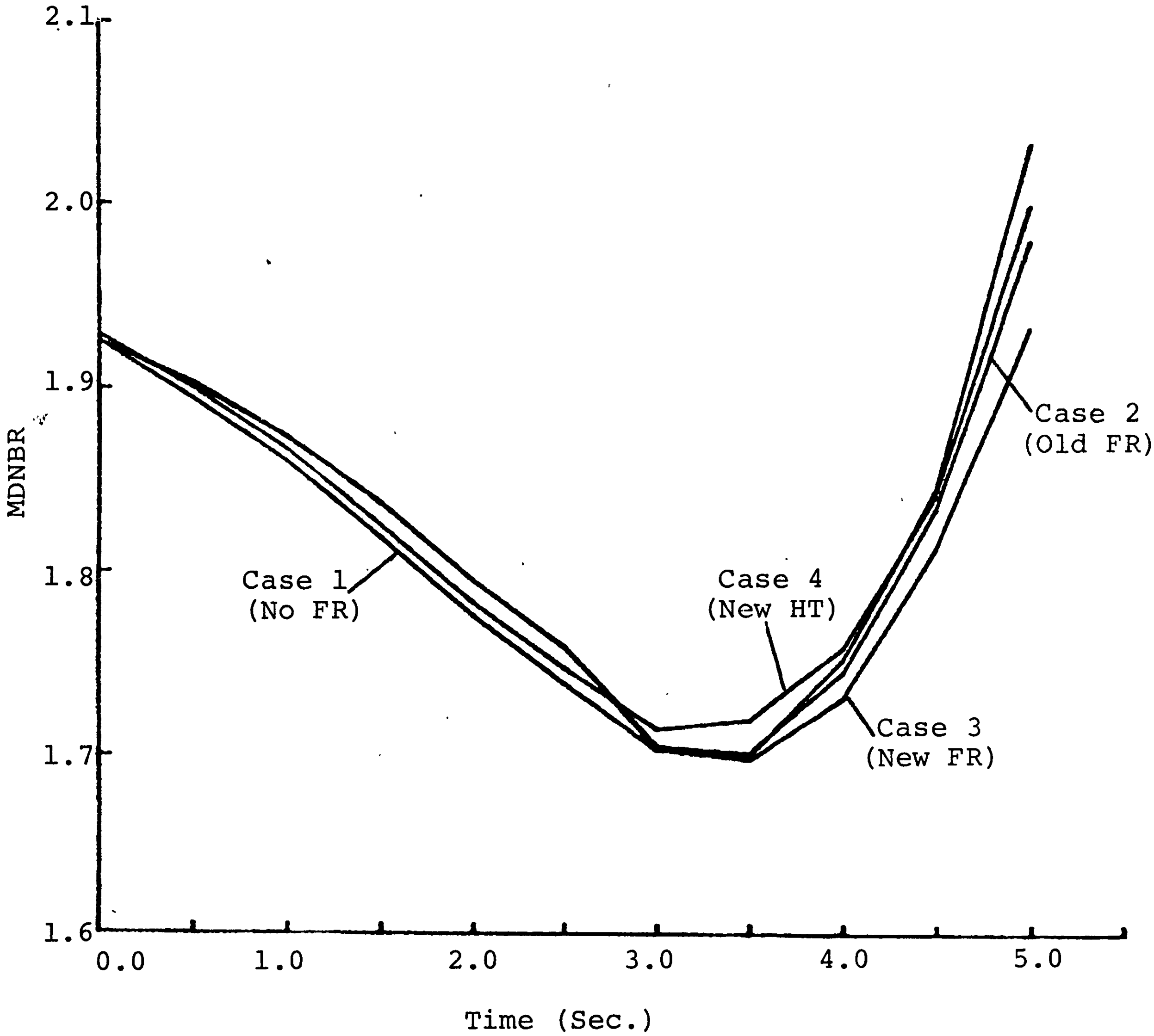


Figure IV-39

Predicted MDNBR vs. Time
PWR Loss of Flow Transient Test Case

as time continues to 5.0 seconds. The minimum values of MDNBR predicted during the loss of flow transient are within the 1% of each other.

DNBR predictions depend largely on heat flux predictions. The close agreement between MDNBR predictions was due to agreement between heat flux predictions of the analysis cases. Maximum predicted heat flux is shown as a function of time in Figure IV-40. The predicted maximum heat flux is nearly constant up to 3.0 seconds. Maximum heat flux falls in the time range from three to five seconds. The predicted maximum heat fluxes are within 5% of each other during the transient. The closeness of maximum heat flux predictions indicate a general similarity of heat flux predictions.

Heat flux predictions will be further compared by considering rod 15 axial heat flux profiles. Rod 15 is selected for comparison because it is predicted to be the location of MDNBR for a large portion of the transient. In Analysis Cases 1, 2, and 3 predictions, the location of MDNBR shifts temporarily from rod 15 (facing channel 4) to rod 5 (facing channel 3), due to voiding in channel 3. Almost no voiding occurs in channel 4. Analysis Case 4 predicts that MDNBR is located on rod 15 through the transient. Figure IV-41 shows exit void fraction of channel 3 as a function of time. Exit void fraction peaks at 3.5 seconds. The void fraction predictions of Analysis Case 4 are less than those of other cases. This may account for the fact that the location of MDNBR remains on rod 15 throughout the transient in the predictions of Analysis Case 4.

Heat flux profiles of rod 15 are compared in Figure IV-42 and IV-43. Figure IV-42 shows axial heat flux profiles at 0.0 and 2.5 seconds. The profiles of all cases are exactly the same at 0.0 seconds and nearly the same at 2.5 seconds. Figure IV-43 shows axial heat flux profiles at 0.0 and 5.0 seconds. The profiles at 5.0 seconds are close. A comparison of Figures IV-42 and IV-43 will show a larger change in heat flux between 2.5 and 5 seconds.

Although heat flux predictions of the analysis cases were close, differences between the old and new rod-to-coolant heat transfer models caused differences in clad surfact temperature

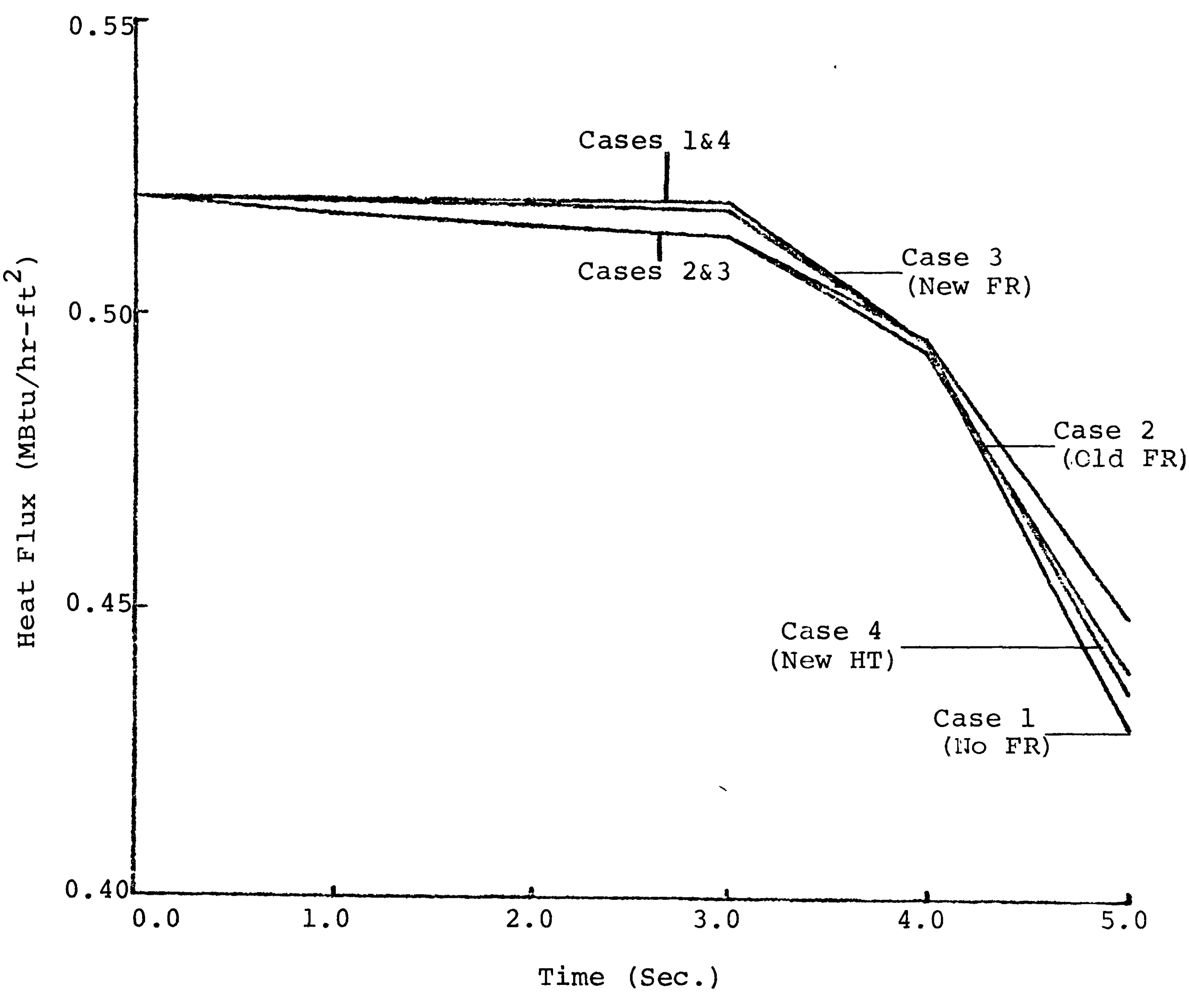


Figure IV-40

Maximum Heat Flux vs. Time
PWR Loss of Flow Transient Test Case

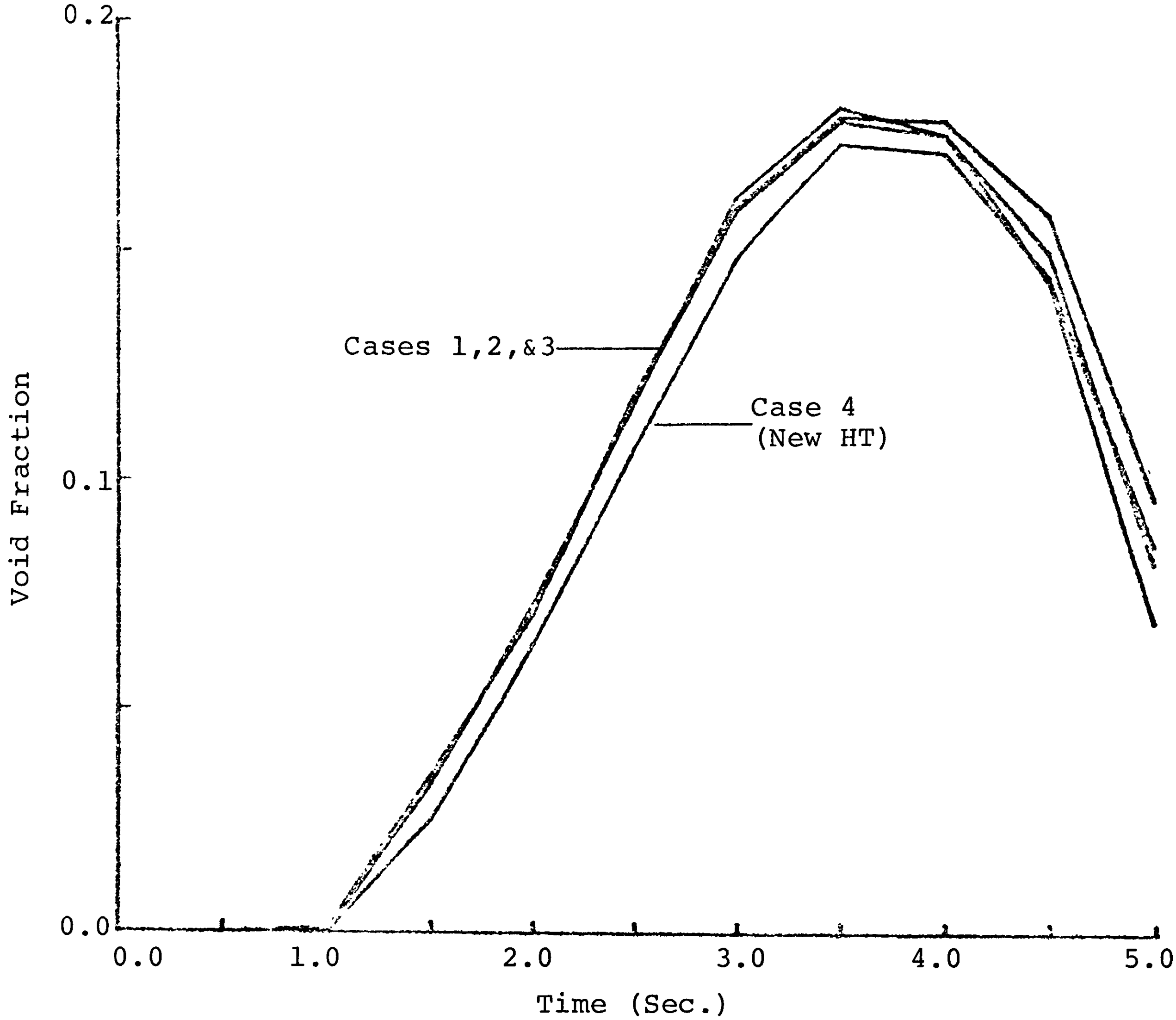


Figure IV-41

Exit Void Fraction vs. Time
Channel 3
PWR Loss of Flow Transient Test Case

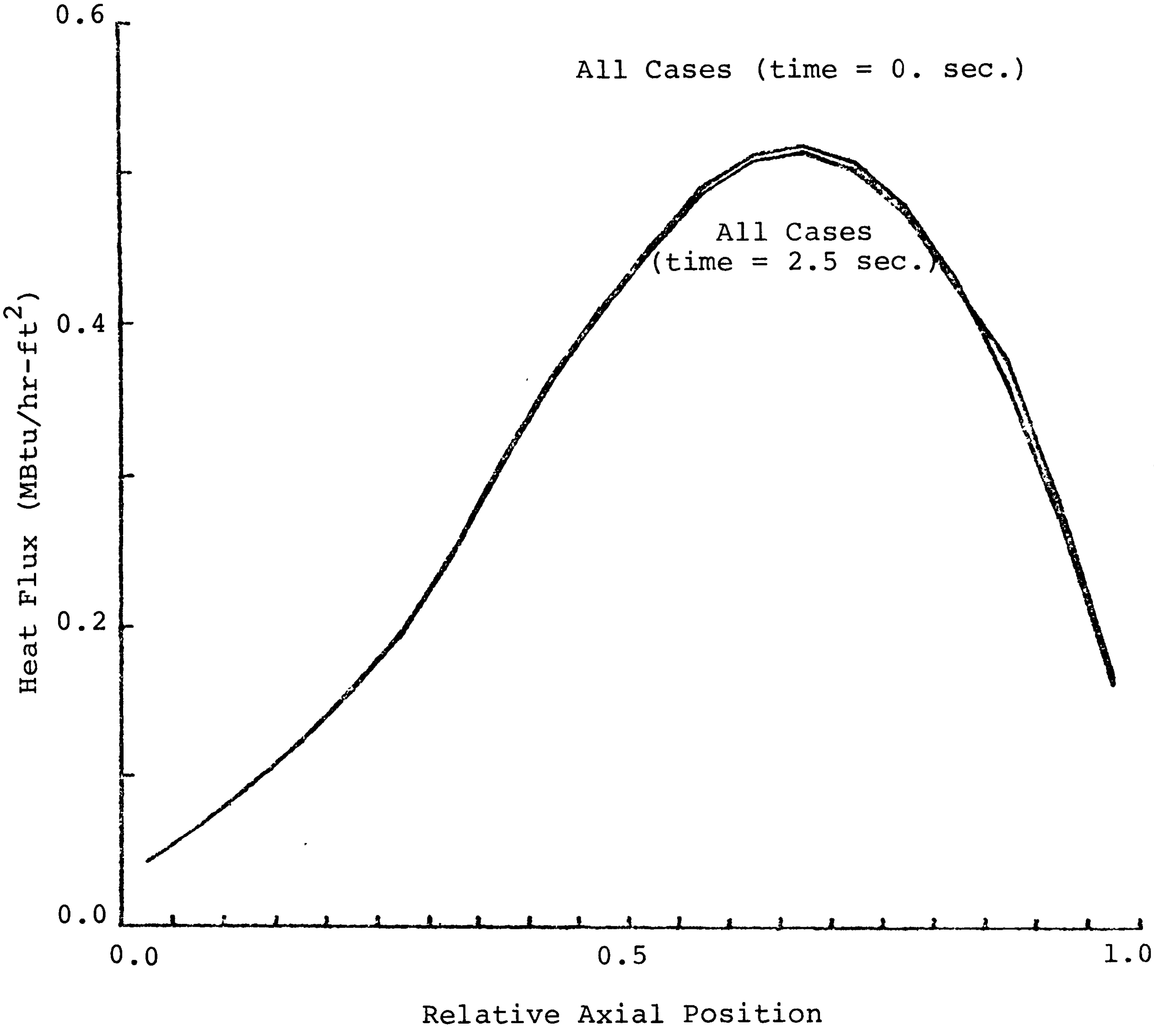


Figure IV-42

Axial Heat Flux Profile

Rod 15

PWR Loss of Flow Transient Test Case

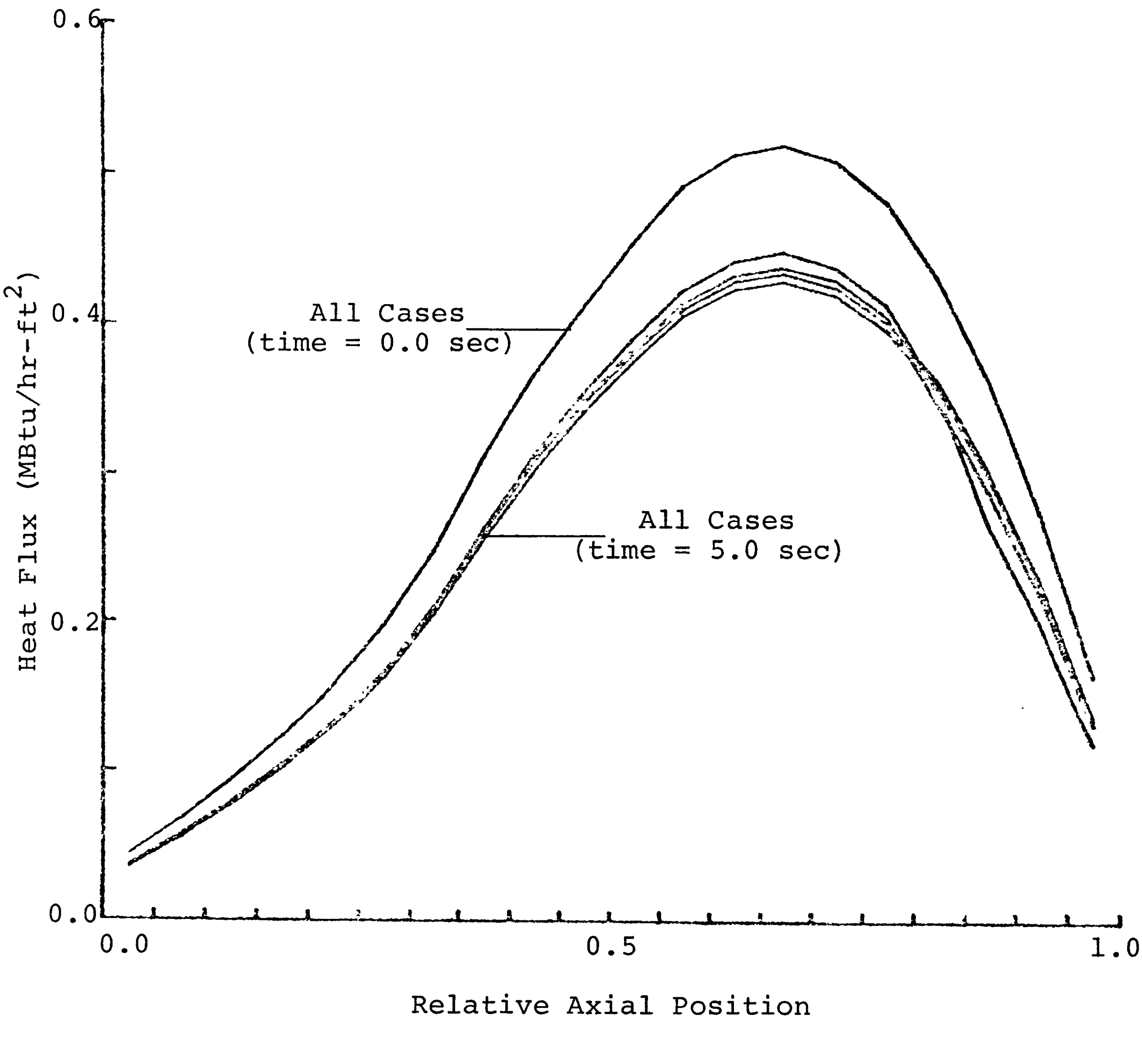


Figure IV-43

Axial Heat Flux Profile
Rod 15
PWR Loss of Flow Transient Test Case

predictions. Figures IV-44, IV-45 and IV-46 contain axial clad surface temperature profiles for rod 15. Clad temperature profiles at 0.0 seconds are shown in Figure IV-44. In the top half of rod 15, clad temperature predictions of Analysis Cases 2 and 3, which use the old heat transfer model rise well above the saturation temperature. Clad temperature predictions of case 4, which uses the new heat transfer model do not rise as far above the saturation temperature. Higher wall temperature represents slightly larger stored heat. Differences in the heat transfer logic contained in the two heat transfer models is the major cause of the large differences in clad temperature predictions.

The old heat transfer model switches from forced convection to nucleate boiling heat transfer when void fraction is greater than 0. The new heat transfer model switches from forced convection to nucleate boiling heat transfer when wall temperature is greater than saturation temperature. Figure IV-45 shows Analysis Case 2 clad temperature profiles at 0., 2.5, and 5 seconds. The profile has an irregular shape at 2.5 seconds. Increased void fraction when time is near 2.5 seconds causes a sudden change in rod-to-coolant heat transfer since Analysis Case 1 uses the old heat transfer model. The sudden change in heat transfer produces the irregular clad temperature profile. Similar clad temperature behavior was seen in Analysis Case 3 prediction which also used the old heat model. Figure IV-46 shows Analysis Case 4 axial clad temperature profile predictions. These predictions of the new heat transfer model show only small changes in time and none of the discontinuities apparent in the predictions of the old heat transfer model.

d. Summary

The loss of flow transient was analyzed by four analysis cases which all used the one-pass method. One analysis case did not use a fuel rod model. The other three cases used old and new fuel rod and heat transfer models. MDNBR and heat flux predictions of the analysis cases were close. Clad temperature predictions differed according to the rod-to-coolant heat transfer model used.

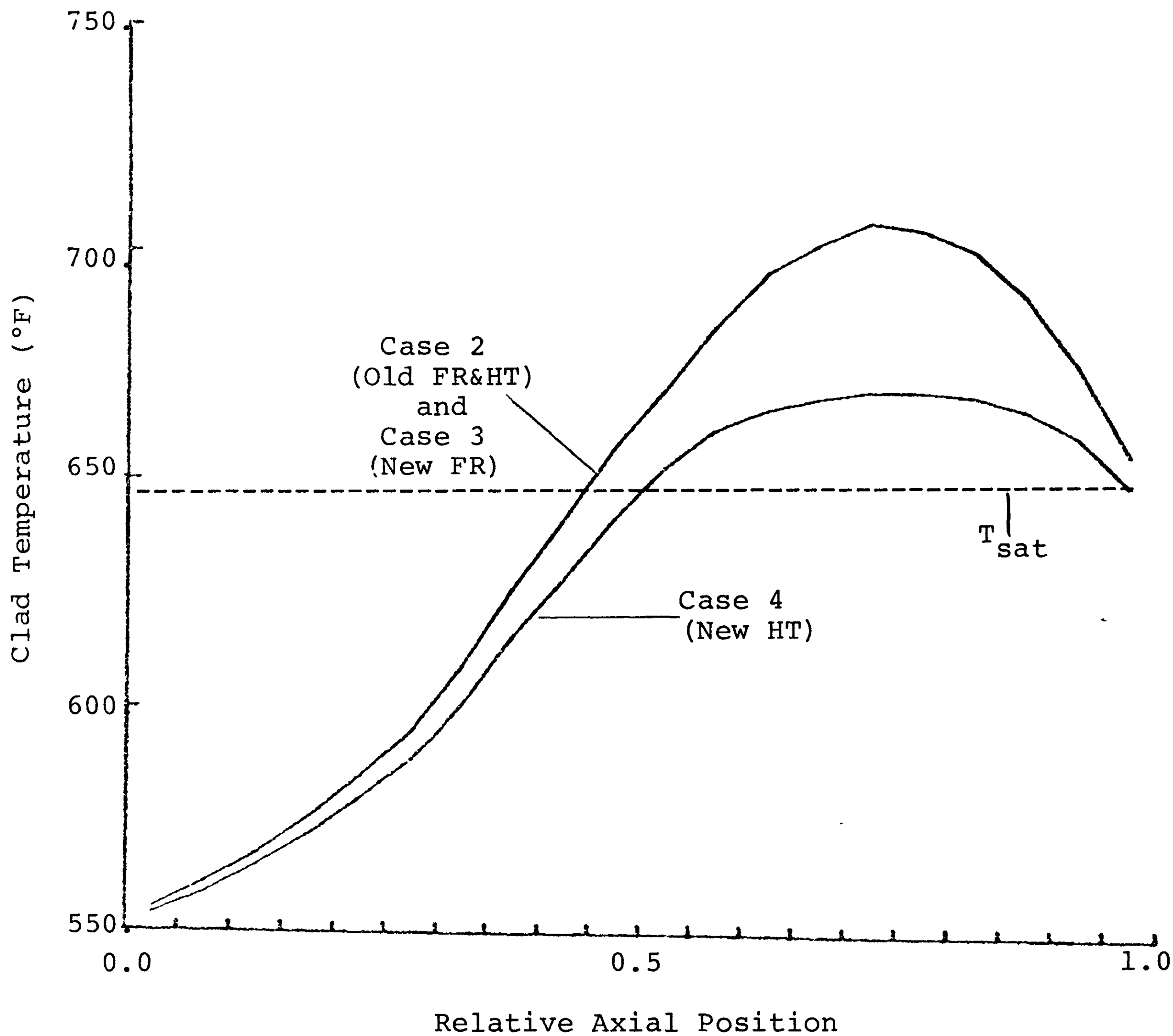


Figure IV-44

Axial Clad Temperature Profile

Rod 15, Time = 0

PWR Loss of Flow Transient Test Case

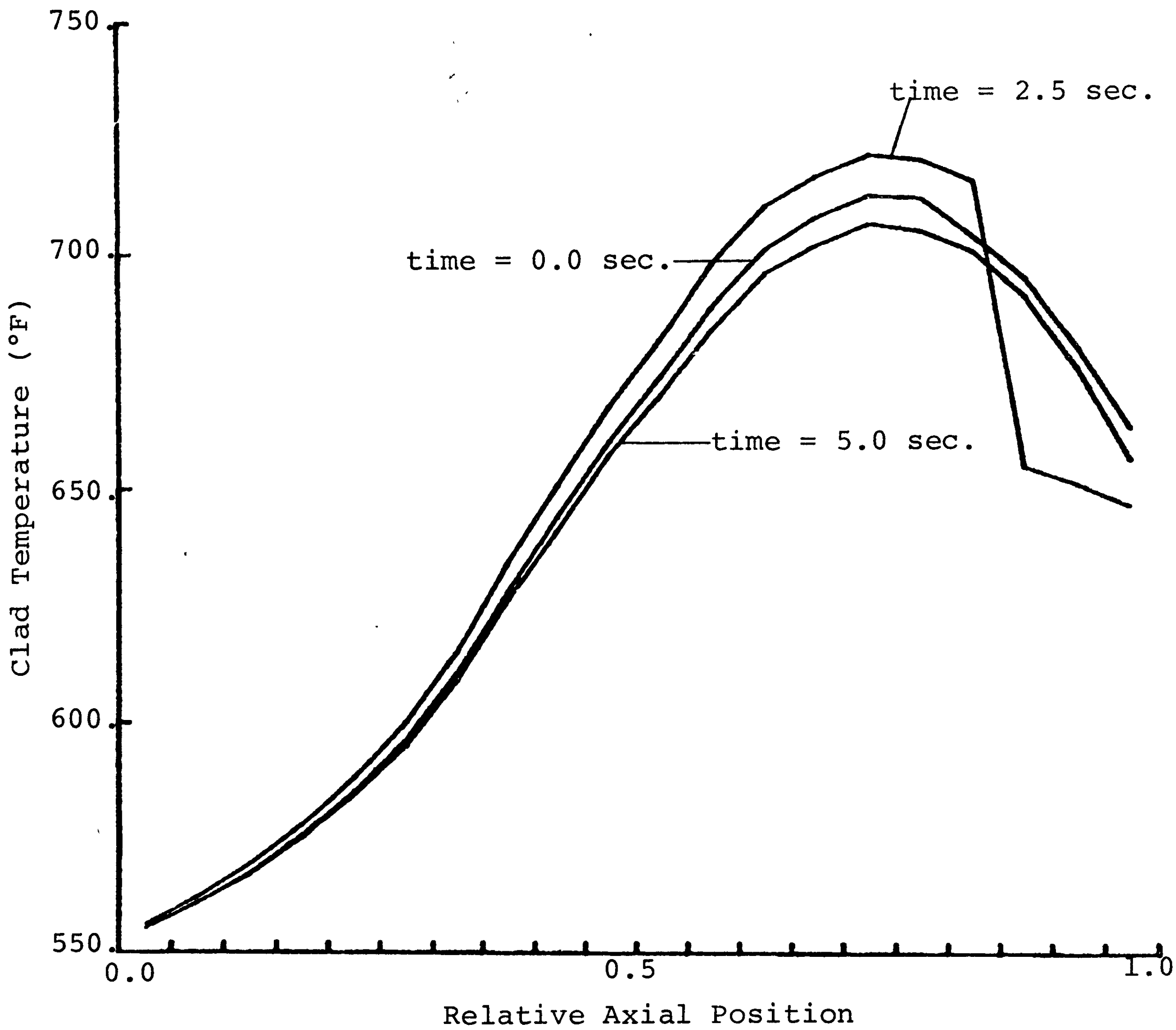


Figure IV-45

Axial Clad Temperature Profile

Rod 15

Analysis Case 2 (Old FR&HT)

PWR Loss of Flow Transient Test Case

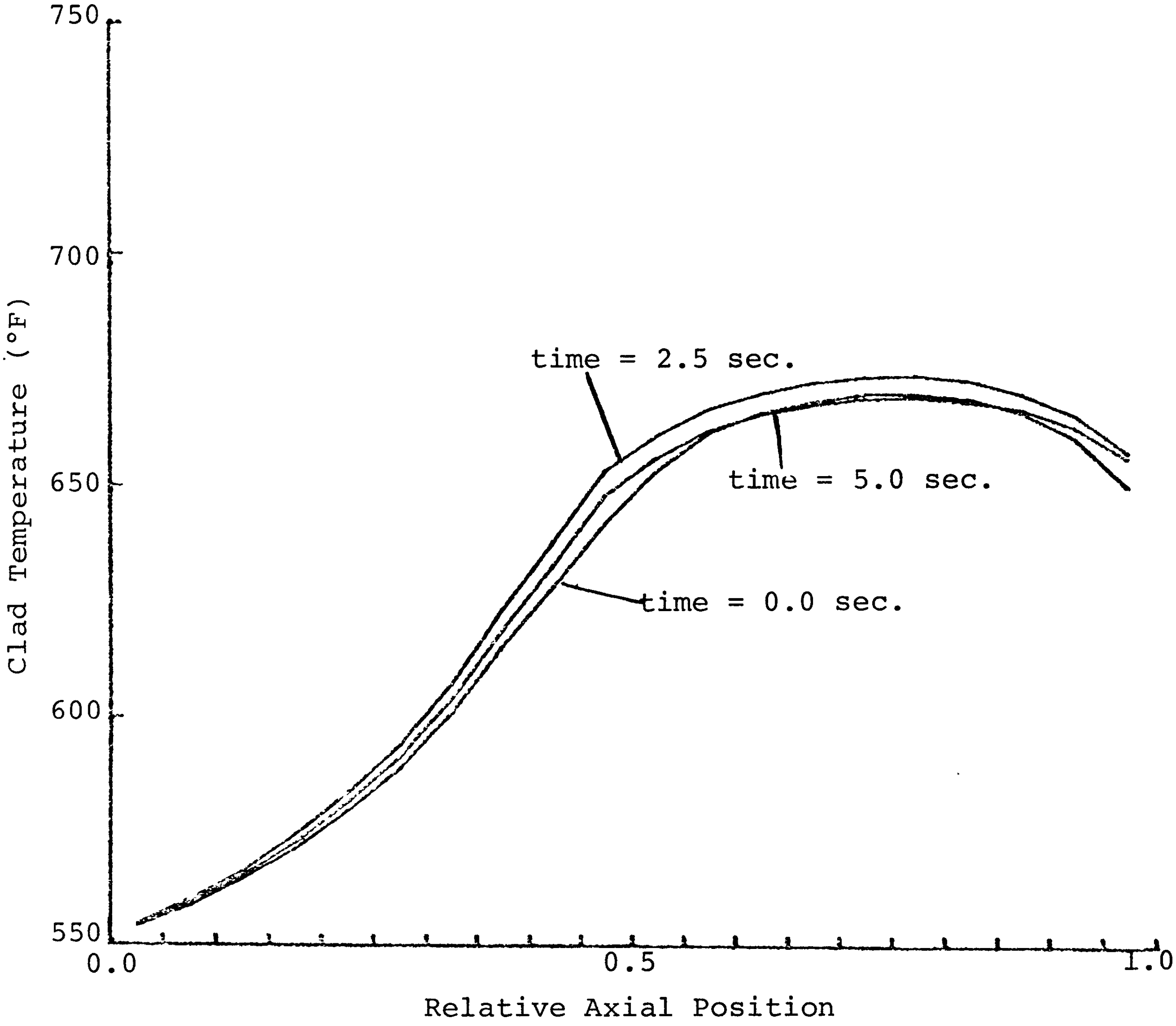


Figure IV-46

Axial Clad Temperature Profile
Rod 15
Analysis Case 4 (New HT)
PWR Loss of Flow Transient Test Case

2. BWR Transient Test Case - Turbine Trip Without Bypass

a. Description of Turbine Trip Transient

The BWR transient test case is a postulated turbine trip without bypass transient for the Shoreham reactor. Failure of the turbine bypass system to operate would result in an increase in system pressure and cause the power level to reach 231% of the initial steady state value. The power level increase is caused by void reactivity feedback. Increasing pressure decreases the amount of voids in the core. Power level increases due to void reactivity feedback. The transient forcing functions for power level, system reference pressure and core inlet flow are shown in Figure IV-47.

b. Description of Modeling

The turbine trip transient was analyzed using two channels to represent the central hot and central average assemblies of the Shoreham Nuclear Power Station Unit One (SNPS-1) reactor. Data from the SNPS-1 FSAR (Ref. 30) was used in the analysis. Four COBRA-IIIC/MIT analyses were made using fuel rod and rod-to-coolant heat transfer model options as listed in the Table IV-7. Transient forcing functions used by the analyses are contained in Figure IV-47. The transient was anlayzed for 2.5 seconds using 0.05 second time steps. The two channels were divided axially into twenty nodes. Predictions were printed once every five time steps. COBRA-IIIC/MIT input for the turbine trip transient is described in Appendix L.

c. Analysis Case Predictions

Examination of analysis case predictions will begin with MCPR and MCHFR predictions. MCPR and MCHFR predictions are useful for comparison of modeling option predictions. However, the applicability of the CPR and CHFR correlations to transient conditions and assemblies represented by single channels is uncertain. The CISE-4 MCPR correlation was developed for rod-centered subchannels. Althougth the MCPR and MCHFR predictions may be unreliable, they are based on calculated predictions of COBRA-IIIC/MIT models and can indicate differences in these predictions.

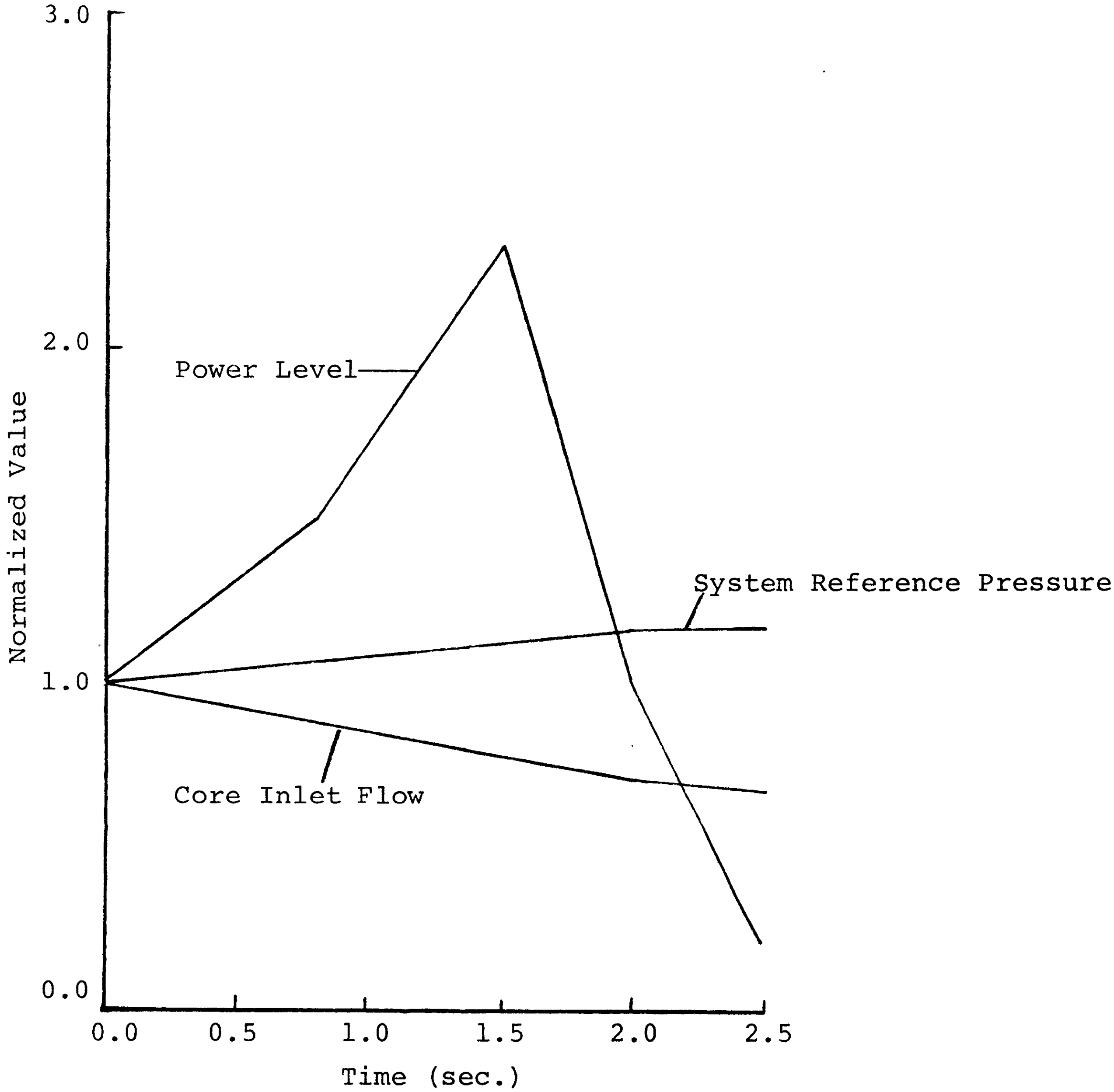


Figure IV-47

Transient Forcing Functions
BWR Turbine Trip Transient Test Case

Table IV-7

Models Used for Turbine Trip Analysis Cases

Analysis Case Number	Fuel Rod Model	Fuel & Clad Material Properties	Heat Transfer Model
1	old	constant	old
2	new	temp.-dependent	old
3	old	constant	new
4	new	temp.-dependent	new

Analysis case predictions of MCPR version time are contained in Figure IV-48. MCPR predictions are within 3% of one another. Analysis Case 3 predictions are lowest. Analysis Case 1 MCPR predictions end at 2.0 seconds. The Case 1 flow solution failed to converge one time step after 2.0 seconds. This problem will be discussed later. The predictions shown a general downward trend which appears to level off near 2.5 seconds. The lowest MCPR value is 1.017.

MCHFR predictions are shown in Figure IV-49. MCHFR predictions are within 6% of one another. Analysis Case 3 predictions are lowest. The minimum predicted MCHFR value, 1.060 occurs at 2.25 seconds. MCHFR predictions at 2.5 seconds are larger than at 2.25 seconds.

The Analysis Case 1 flow solution failed to converge at 2.05 seconds, one time step after 2.0 seconds, as mentioned earlier. None of the other analysis cases had this problem. Instability of the solution is caused by coupling between the heat transfer and hydraulic calculations. Symptoms of a stability problem appear in Analysis Case 1 predictions near 2.0 seconds. Flow rate predictions in channel 2 at 1.75 and 2.0 seconds are shown in Figures IV-50 and IV-51, respectively. Flow rate predictions are close and follow the same smooth trend at 1.75 seconds. Flow rate predictions of Analysis Case 1 and 4 are not as smooth at 2.0 seconds. Analysis Case 1 shows much larger variations in flow rate than the other cases at 2.0 seconds.

Rod 2 axial heat flux profiles at 0.0 and 2.0 seconds are shown in Figure IV-52. Rod 2 is located in channel 2. All analysis cases start with the same heat flux profiles. Heat flux profiles are close to each other at 2.0 seconds except for the sharp dip of Analysis Case 1 predictions.

The sharp dip is caused by large changes in rod-to-coolant heat transfer predictions of the old heat transfer model which accompany diminishing void fractions. Axial void fraction profiles in channel 2 are shown in Figures IV-53 and IV-54. Void fraction profiles at 0.0 and 2.0 seconds are shown in Figure IV-52. All analysis cases start with the same void fraction

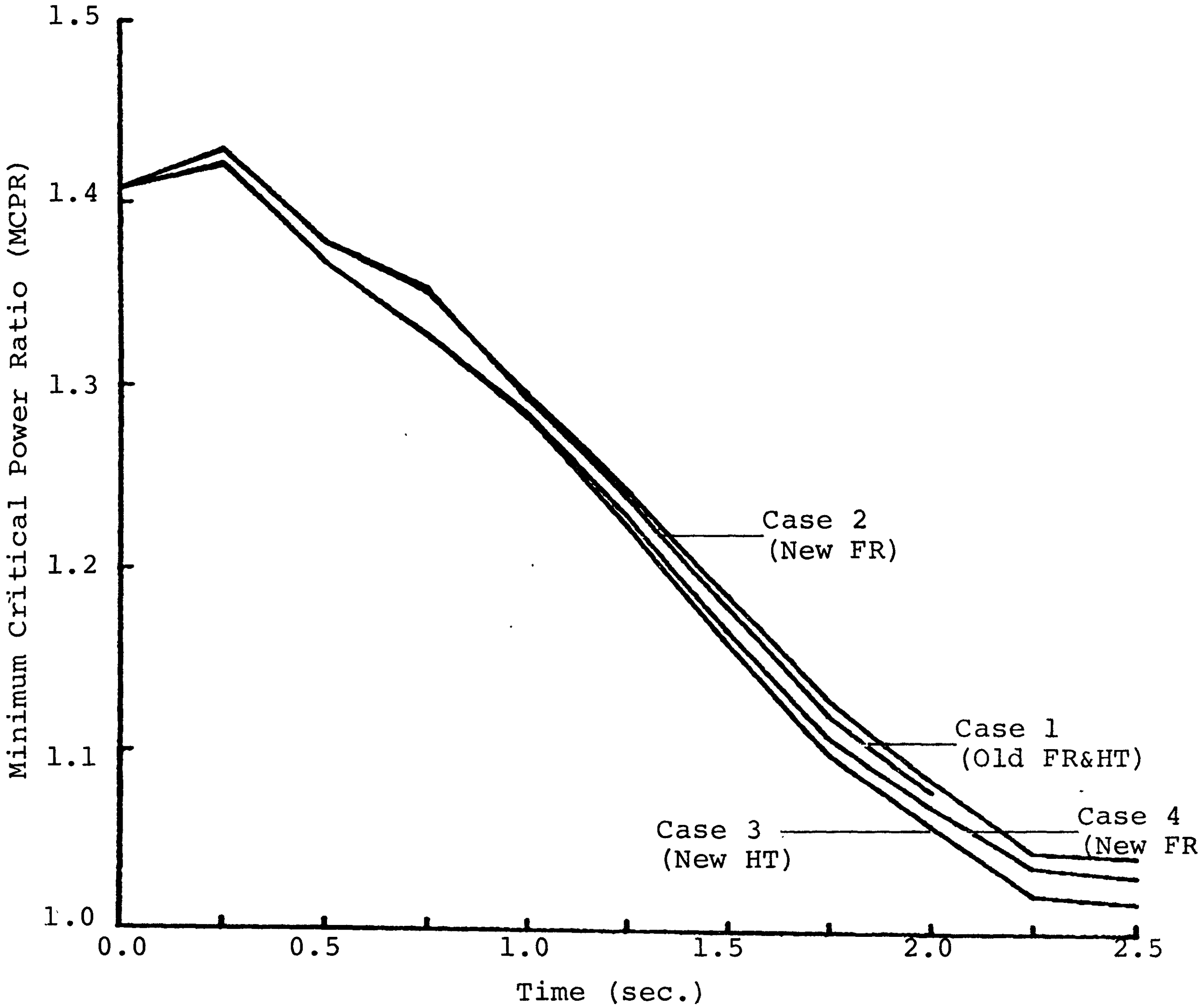


Figure IV-48

CISE-4 MCPR vs. Time
BWR Turbine Trip Transient Test Case

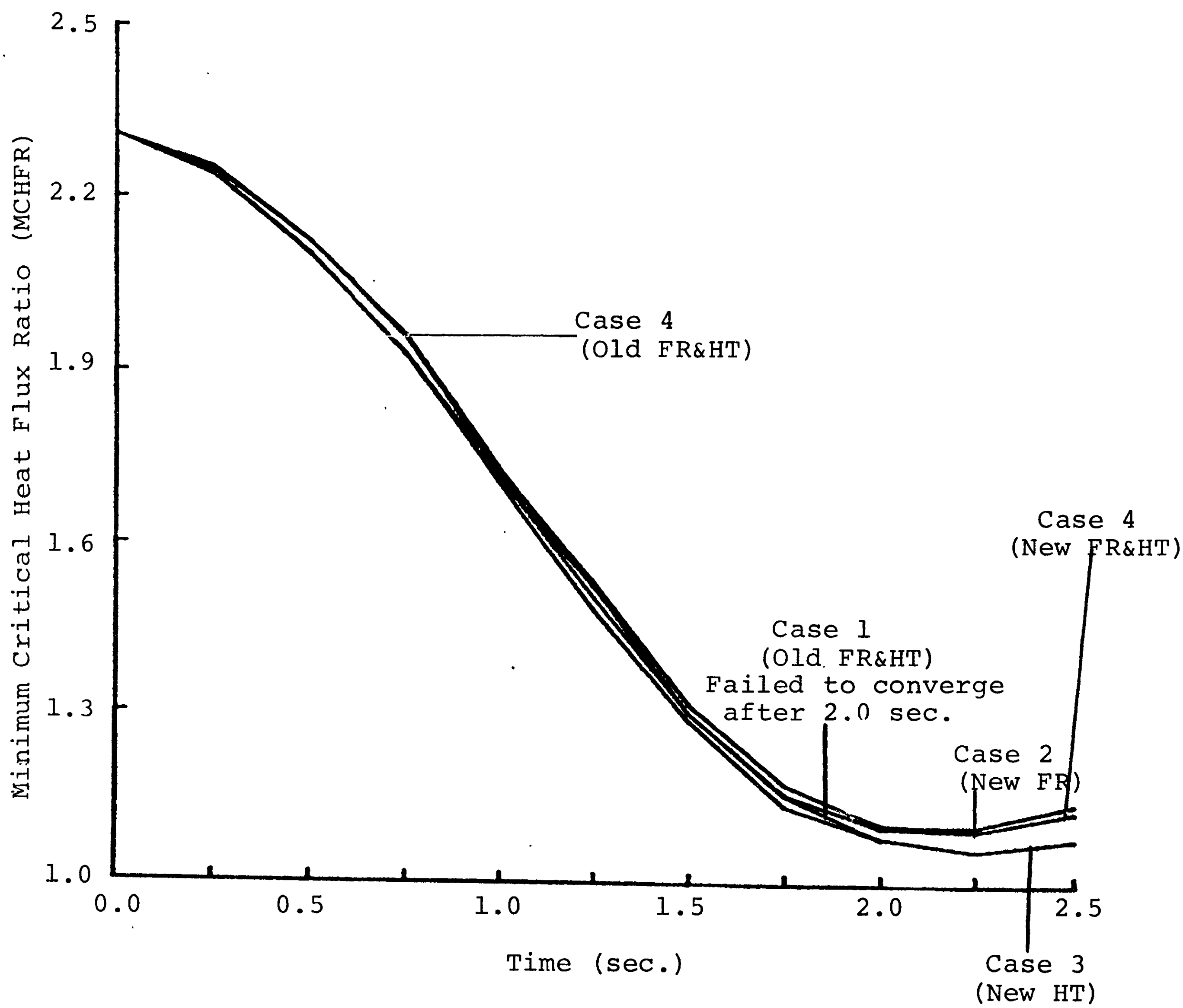


Figure IV-49

Hench-Levy MCHFR vs. Time
BWR Turbine Trip Transient Test Case

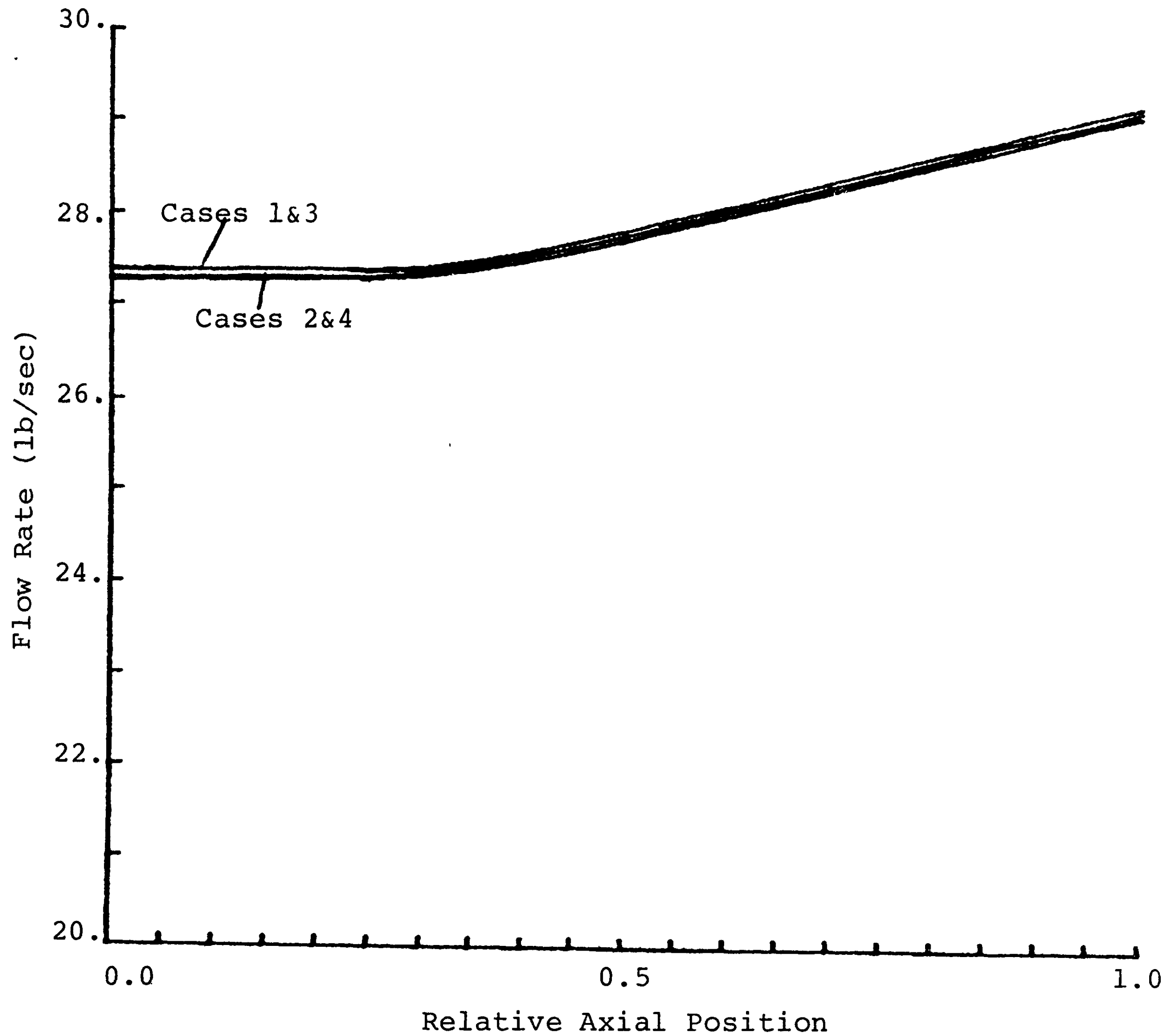


Figure IV-50

Flow Rate vs. Axial Position
Channel 2, time = 1.75
BWR Turbine Trip Transient Test Case

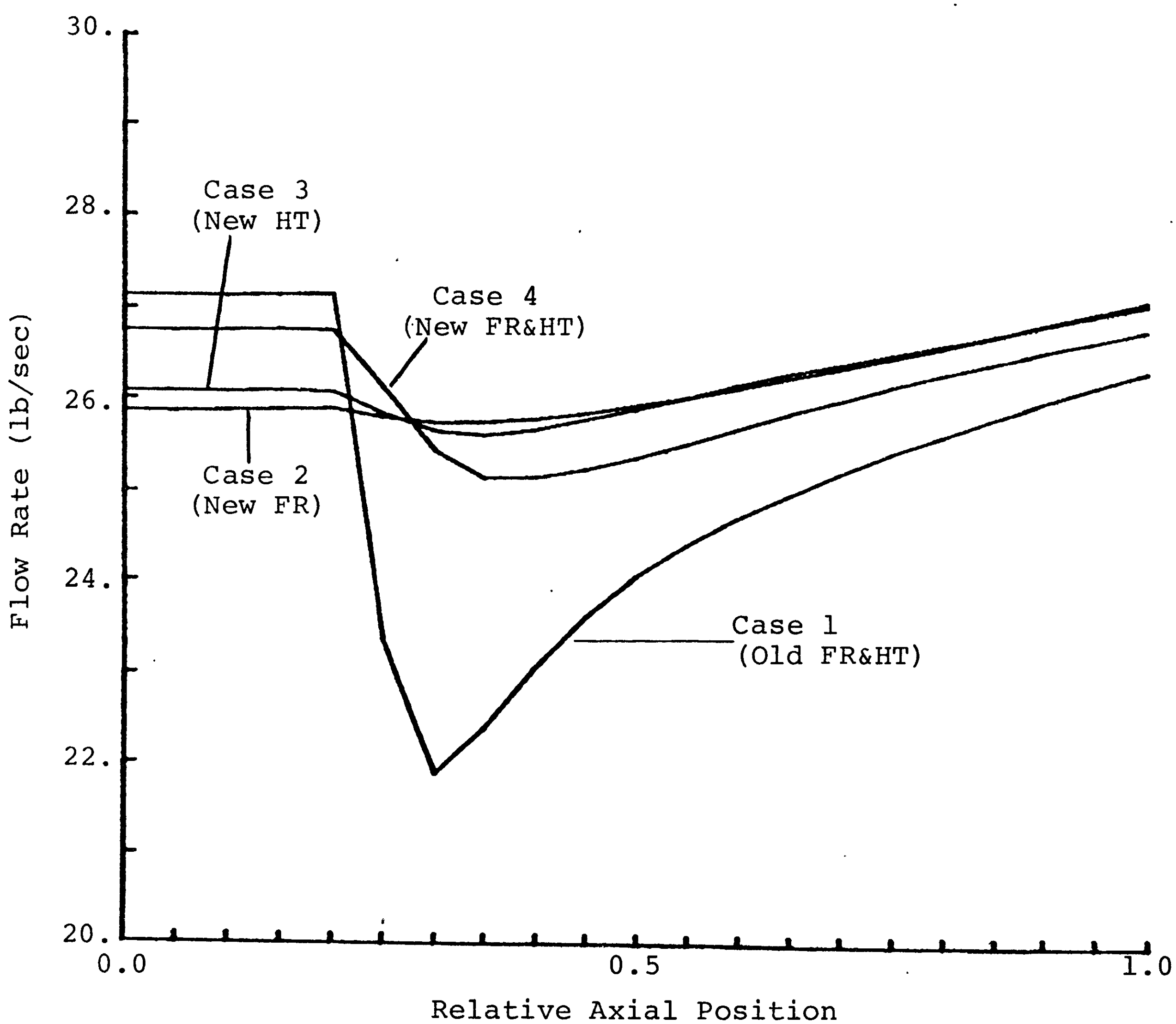


Figure IV-51

Flow Rate vs. Axial Position
Channel 2, time = 2.0 sec.
BWR Turbine Trip Transient Test Case

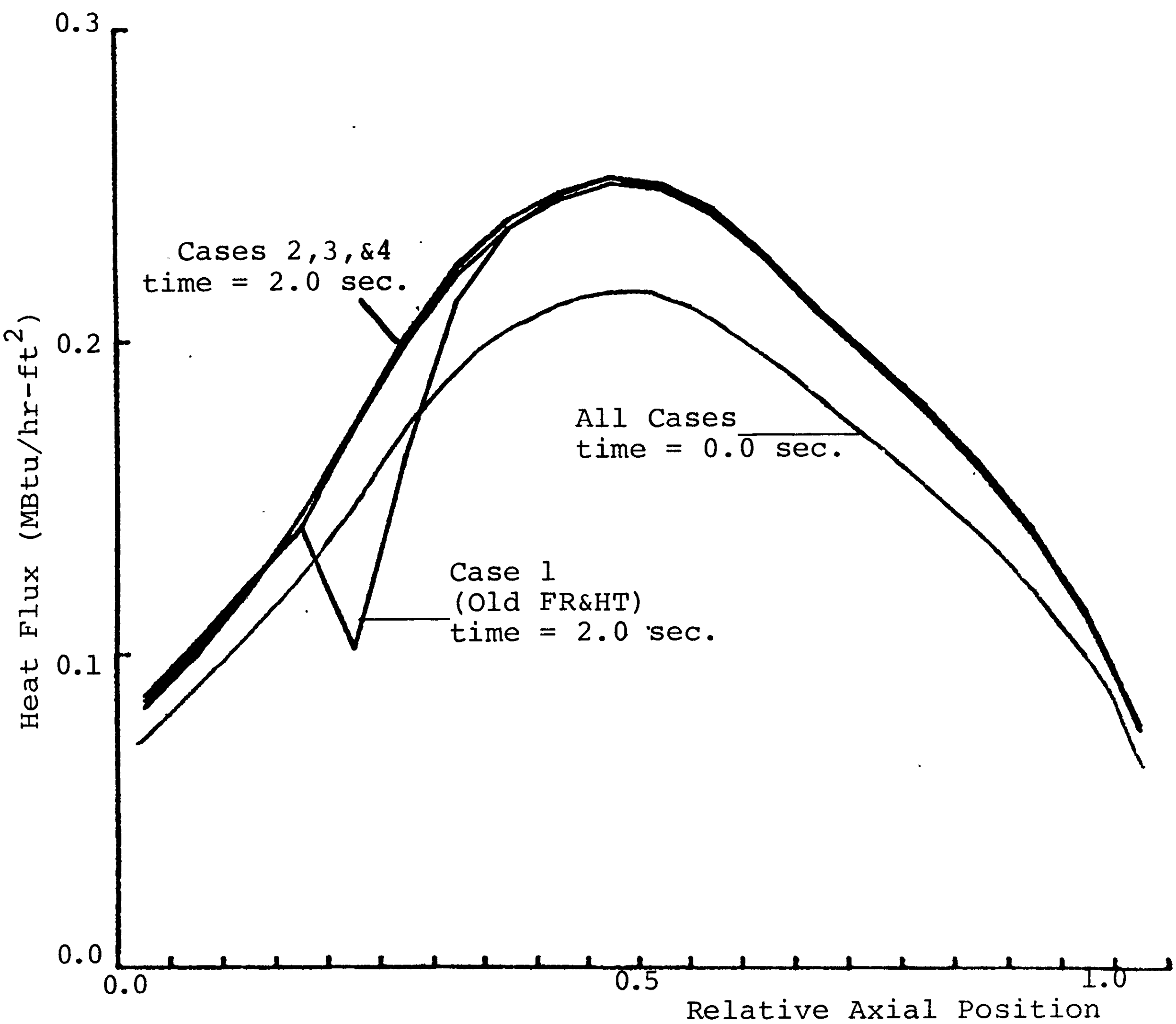


Figure IV-52

Axial Heat Flux Profile
Rod 2
BWR Turbine Trip Transient Test Case

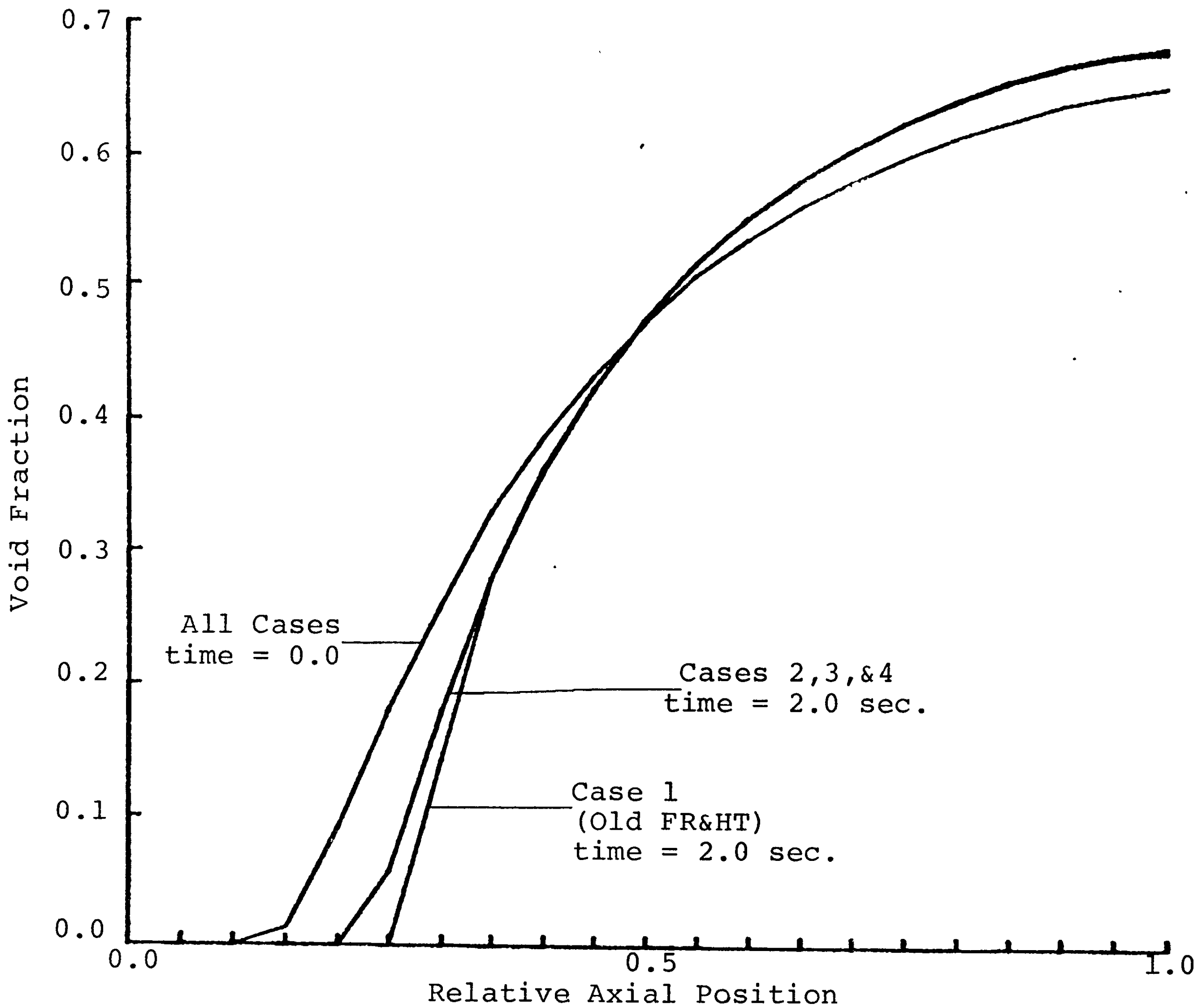


Figure IV-53

Axial Void Fraction Profile

Channel 2

BWR Turbine Trip Transient Test Case

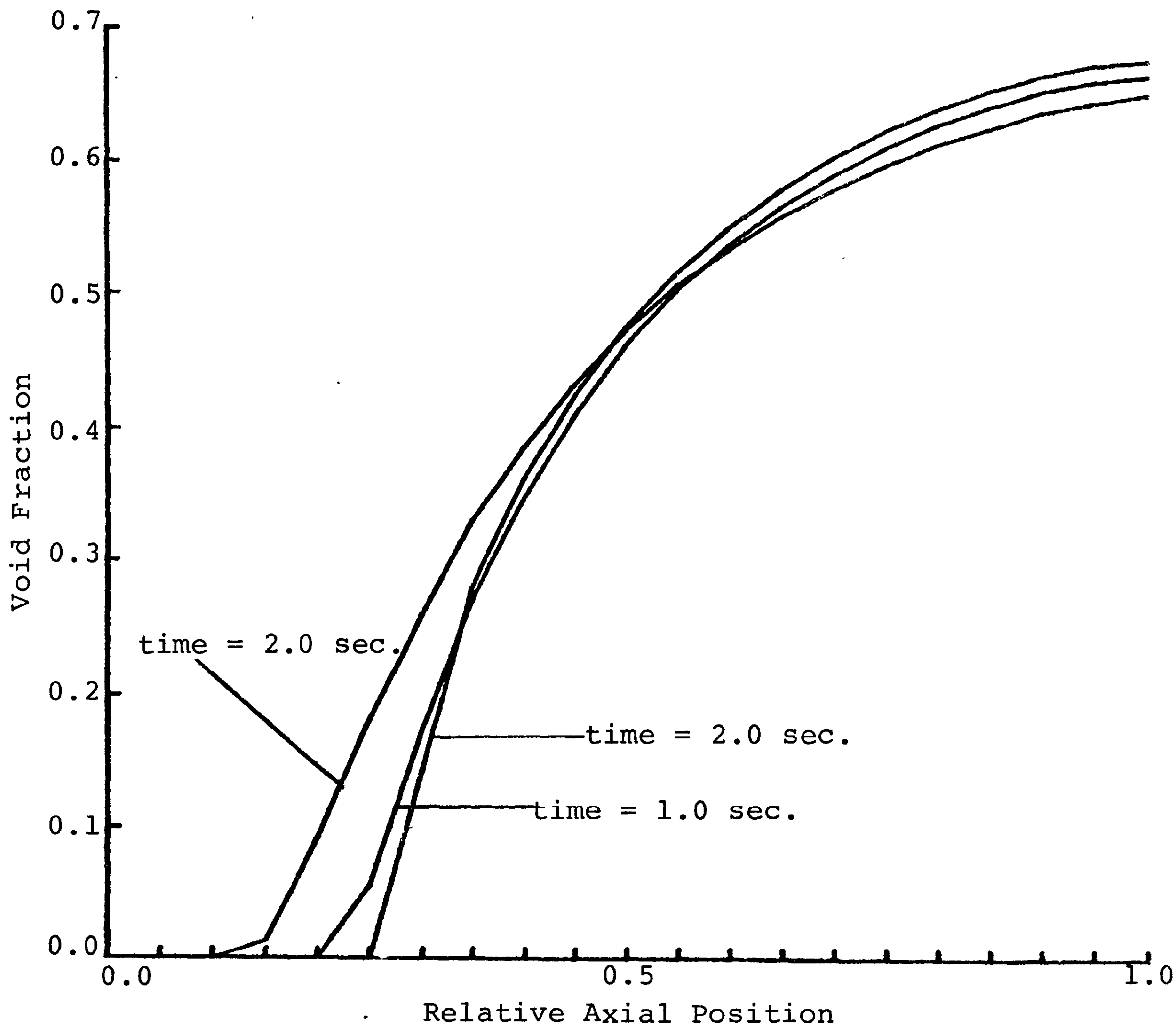


Figure IV-54

Axial Void Fraction Profile

Channel 2

Analysis Case 1 (Old FR&HT)

BWR Turbine Trip Transient Test Case

profile. Void fractions go to zero at lower axial positions due to pressure increases. Analysis Case 1 predictions at 2.0 seconds indicate that void fractions have become zero at three axial nodes. (Each tic represents one axial node.) Analysis Cases 2, 3, and 4 predictions at 2.0 seconds indicate that void fractions have become zero at two axial nodes. Decrease in void fractions at lower axial levels of channel 2 as time passes can be seen in Analysis Case 1 predictions shown in Figure IV-54. Axial clad surface temperature profiles show the effects of rod-to-coolant heat transfer models. Rod 2 axial clad temperature predictions are shown in Figures IV-55, IV-56 and IV-57. Clad temperature profiles at 0.0 seconds are shown in Figure IV-55. Analysis Cases 1 and 2 predict one profile using the old heat transfer model. Saturation temperature at 0.0 seconds is also shown in the figure. Clad temperature profiles are similar in shape to their initial profiles. The clad temperatures are higher than they were initially. Analysis Case 1 temperature profiles at 1.75 and 2.0 seconds are shown in Figure IV-57. The profile shows a change in shape due to rapid changes in rod-to-coolant heat transfer predictions of the old heat transfer model which occur when void fraction becomes zero at any axial node.

Fuel pellet temperature predictions of the old and new fuel rod models showed differences due mainly to differences in fuel pellet conductivity. The old model uses a constant value for fuel pellet conductivity. The new fuel rod model calculates fuel pellet conductivity as a function of temperature. The constant value for fuel pellet conductivity given to the old fuel rod model is too high for locations where fuel temperatures were highest. Fuel temperature predictions of the old and new fuel rod models are in better agreement at locations where fuel rod temperatures are not the highest.

Radial fuel pellet temperature distributions predicted by the old and new fuel rod models at 0.0 seconds are shown in Figure IV-58 for two fuel nodes of rod 1, the hot rod. Predictions for axial fuel nodes 5 and 10 are shown. Axial fuel node 5 is between the core inlet and midplane. The fuel pellet is

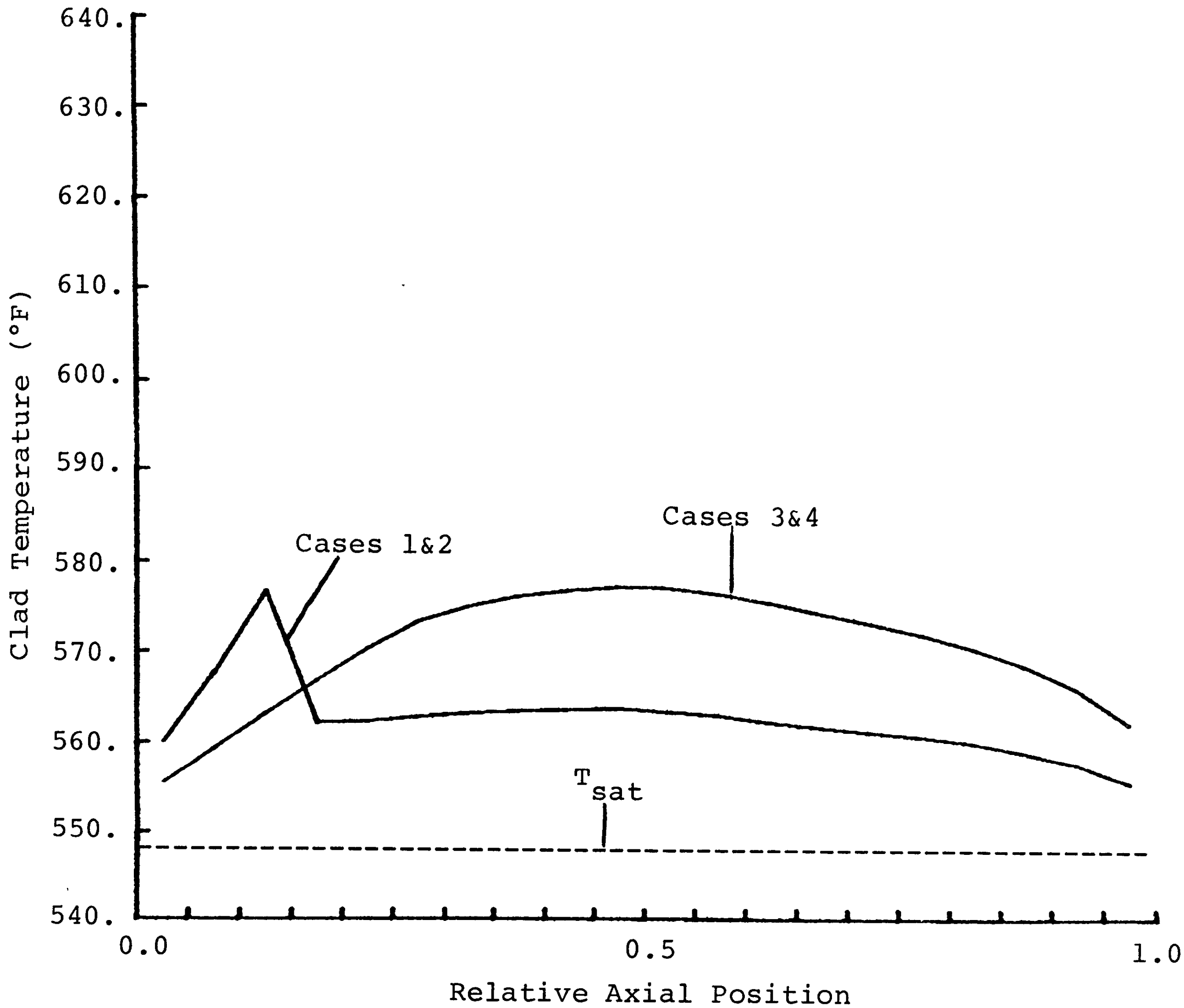


Figure IV-55

Axial Clad Temperature Profile

Rod 2, time = 0.0 sec.

BWR Turbine Trip Transient Test Case

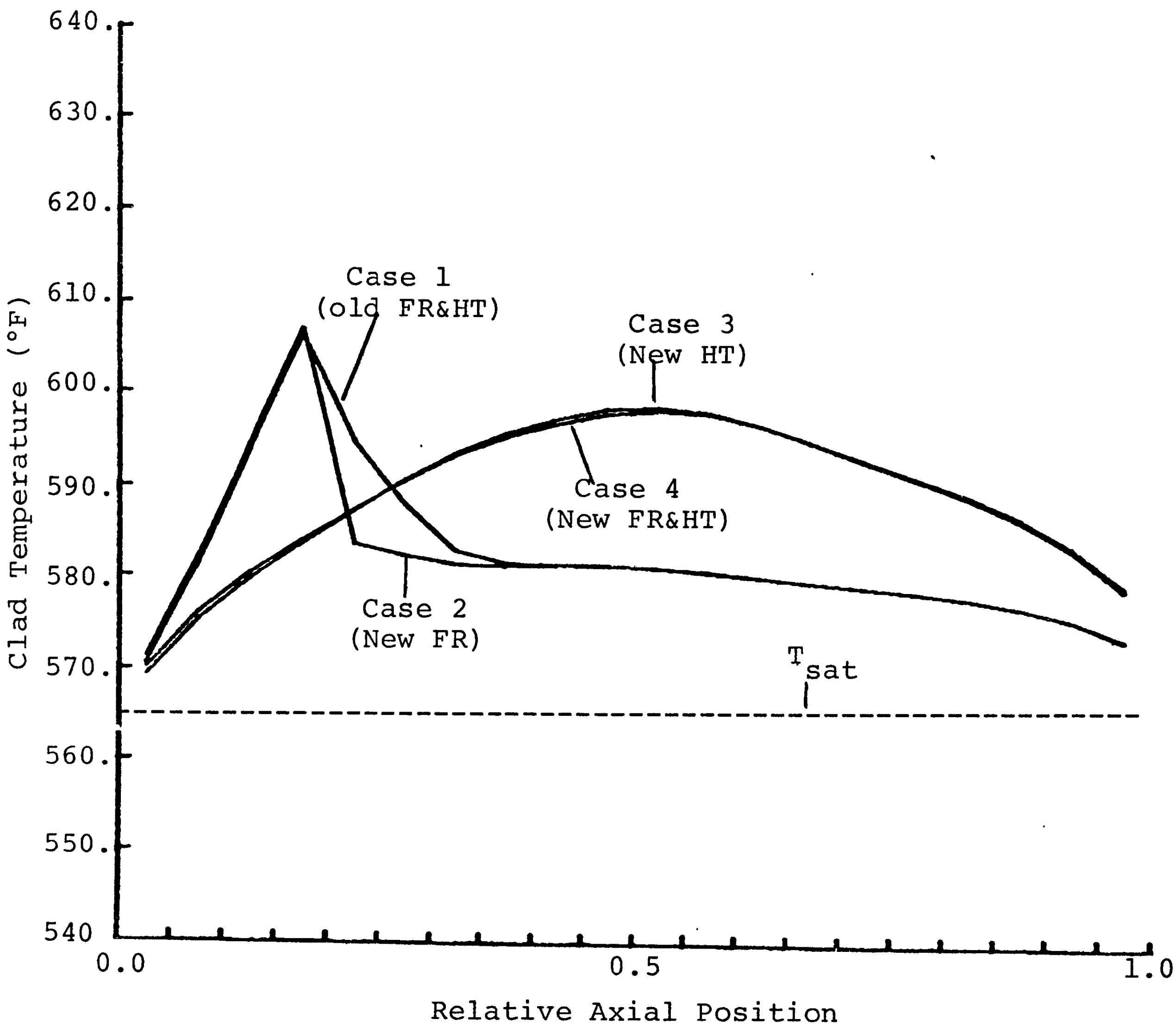


Figure IV-56

Axial Clad Temperature Profile

Rod 2, time = 2.0 sec.

BWR Turbine Trip Transient Test Case

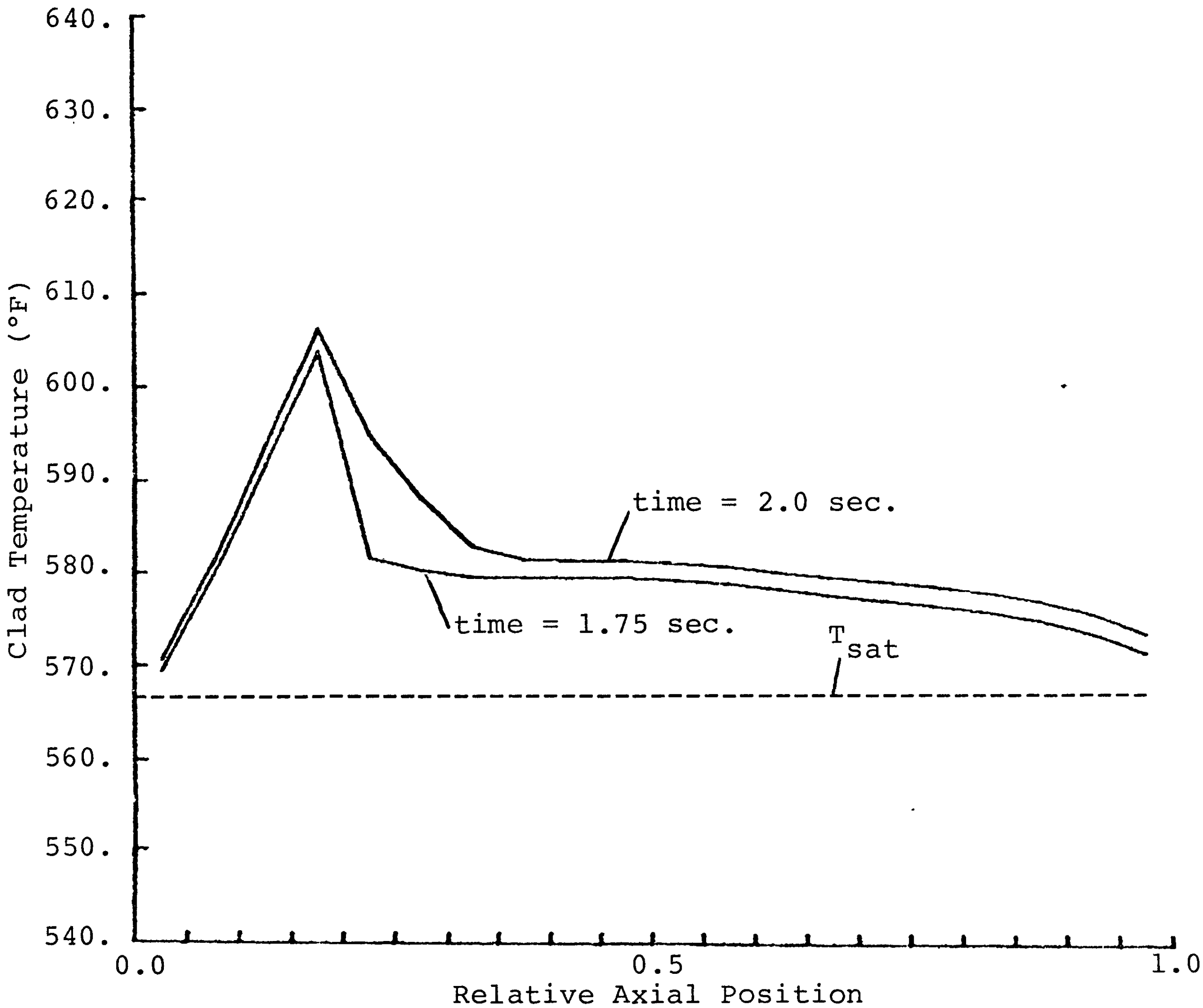


Figure IV-57

Axial Clad Temperature Profile

Rod 2

Analysis Case 1 (Old FR&HT)

BWR Turbine Trip Transient Test Case

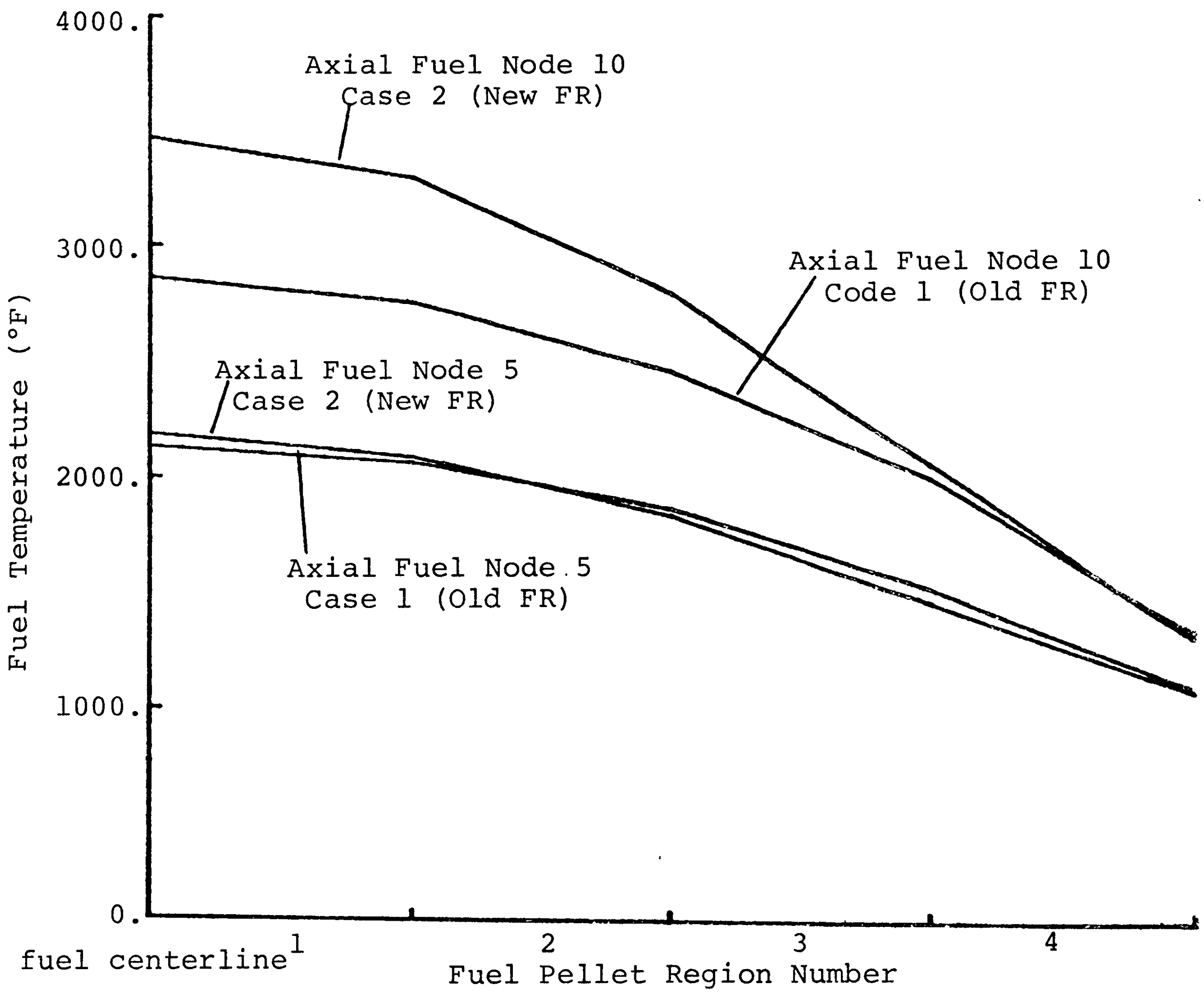


Figure IV-58

Radial Fuel Pellet Temperature Distribution

Rod 1, Time = 0.0 sec.

BWR Turbine Trip Transient Test Case

divided radially into four regions. Fuel centerline temperature predictions are at the left edge of the Figure IV-58 graph. Fuel pellet surface temperature predictions at the right edge are nearly the same for both axial fuel ndoes. The old and new fuel rod model predictions are close for axial fuel node 5. The predictions are much farther apart for axial node 10, where fuel temperatures are higher than node 5. Higher temperatures are predicted by the new fuel rod model because fuel conductivity is calculated to be lower than the constant value used by the old fuel rod model.

Fuel centerline temperature predictions indicated that the constant fuel conductivity value used by the old fuel rod model was better for fuel at lower temperatures. Figures IV-59 and IV-60 show centerline temperature predictions of the old and new fuel rod models for rods 1 and 2 at 0.0 seconds. Centerline temperature predictions for rod 1 are shown in Figure IV-59. Predictions are farther apart in the vicinity of the core midplane. Centerline temperature predictions for rod 2 are shown in Figure IV-60. Rod 2 has a lower radial power factor than rod 1. Predictions of the old and new fuel rod models are closer together for this rod because fuel temperatures are lower.

The differences in predictions indicate a general shortcoming of the old fuel rod model. It can only use constant fuel rod properties. This limits the old fuel rod model to one value for a parameter such as fuel pellet conductivity, which is actually a function of space and time.

d. Summary

The turbine trip without bypass transient was analyzed using four combinations of old and new COBRA-IIIC/MIT rod-to-coolant heat transfers and fuel rod models. Predictions for MCPR and MCHFR were close. Analysis Case 1, which used the old heat transfer and fuel rod models, had a convergence failure at 2.05 seconds. Coupling of the heat transfer and hydraulic calculations allowed sudden changes in heat transfer to cause instability in the flow solution. Analysis Cases 2, 3, and 4, which used the new heat transfer and/or new fuel rod model, did not have flow convergence problems. Differences

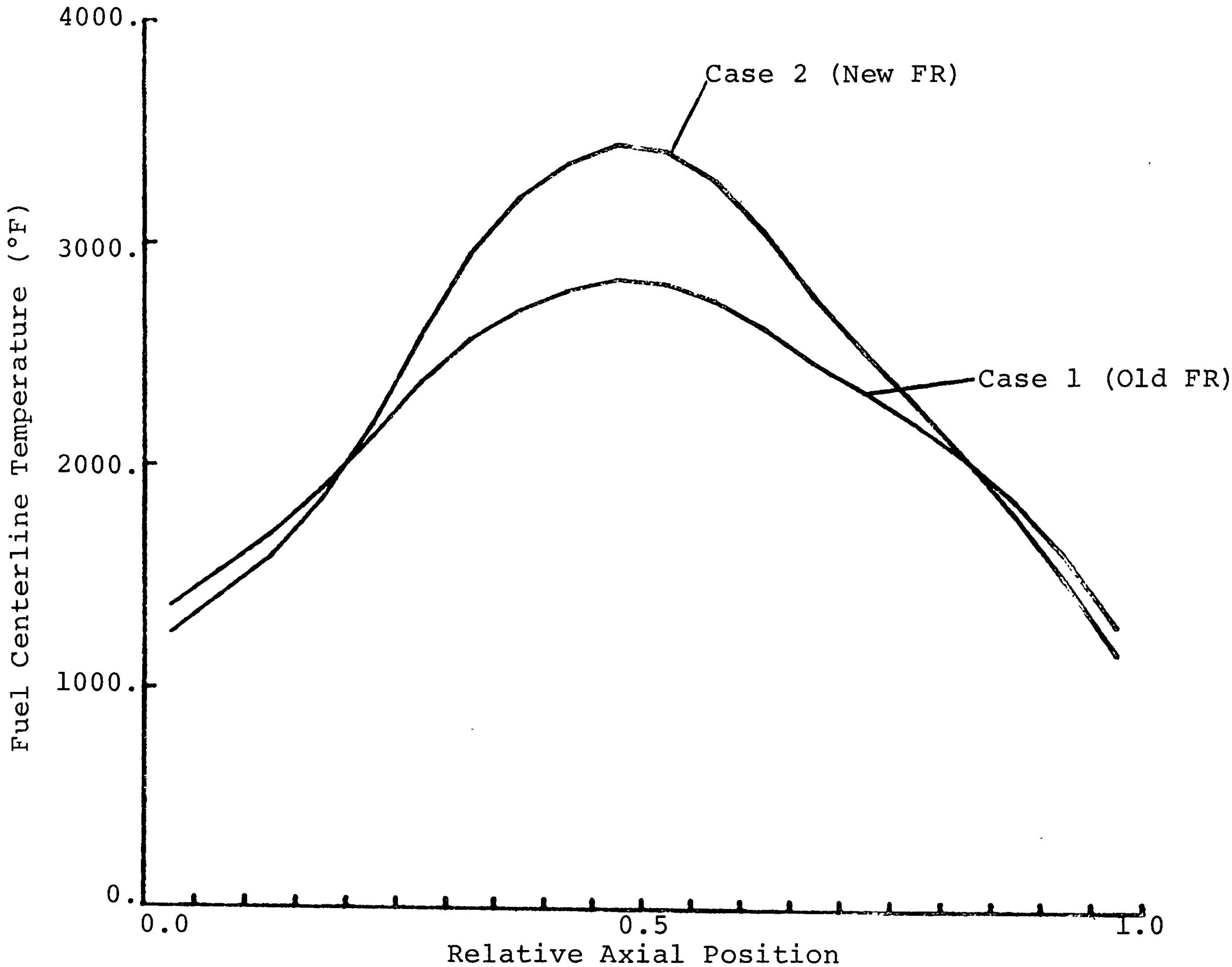


Figure IV-59

Centerline Temperature vs. Axial Position

Rod 1, Time = 0.0 sec.

BWR Turbine Trip Transient Test Case

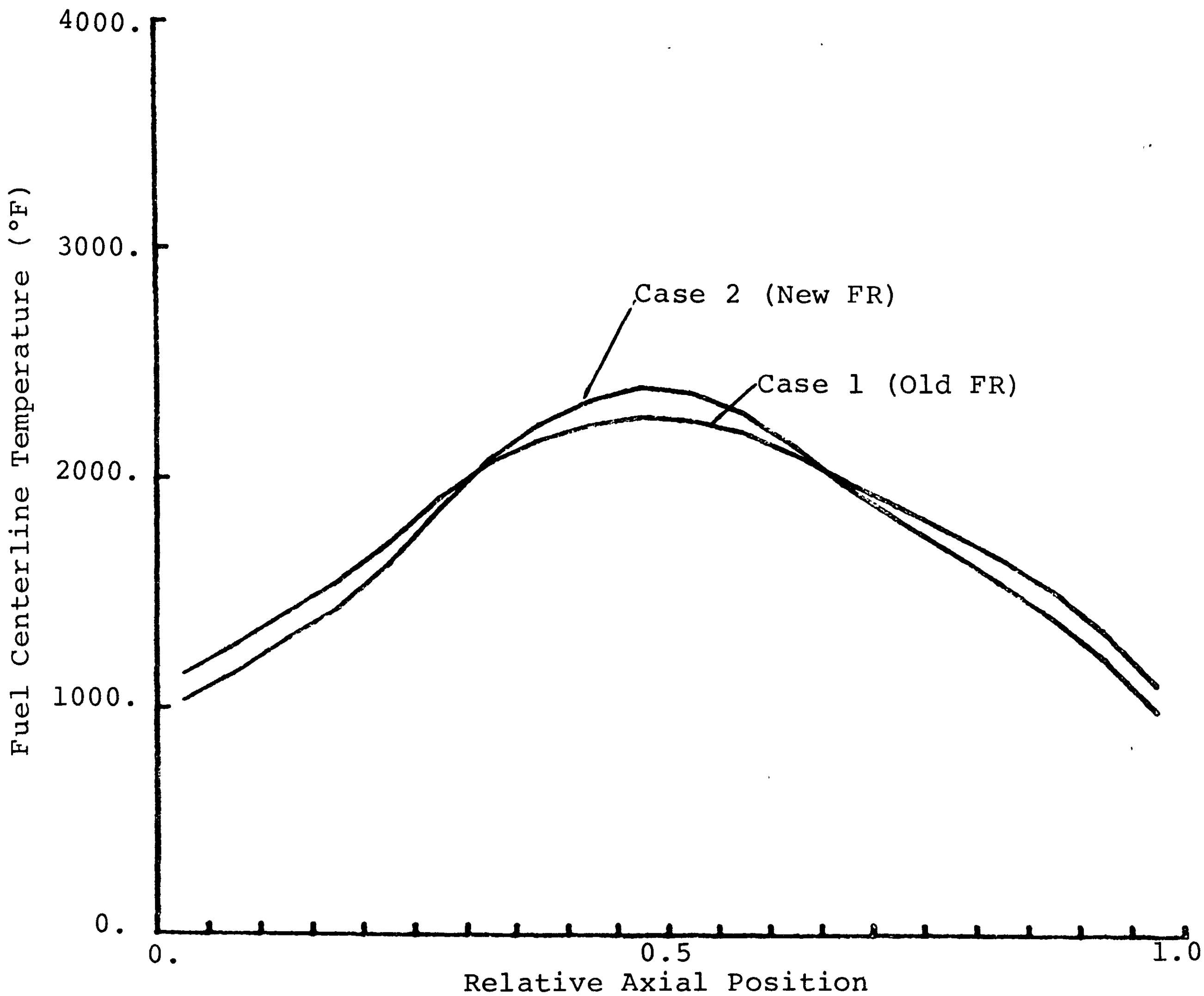


Figure IV-60

Centerline Temperature vs. Axial Position
Rod 2, Time - 0.0 sec.
BWR Turbine Trip Transient Test Case

exist between the predictions of the old fuel rod model, using constant fuel and clad properties, and the new fuel rod model, using temperature-dependent fuel and clad properties.

D. Summary of Testing and Application Results

The results of testing and application are summarized as follows:

- MDNBR, MCPR, and MCHFR predictions were nearly the same for each case, even though various modeling options were used.
- Rod-to-coolant heat transfer predictions of the new heat transfer model vary smoothly in space and time. Discontinuous changes in predictions of the old heat transfer model can cause code failures during transient analysis of BWRs.
- Differences in fuel rod temperature predictions of the old and new fuel rod models made only small differences in fuel rod surface heat flux predictions.
- The new mixing model does not appear to significantly improve subchannel flow and enthalpy predictions for BWR conditions. A better physical model such as the drift flux model (Ref. 45) is needed rather than only an improved mixing model, in order to predict the void drift experimentation observed in BWR subchannels.
- CISE-4 MCPR predictions are consistant with a best-estimate approach. Hench-Levy MCHFR predictions are conservative.
- Use of the Weisman transverse momentum option has no significant effect on steady state hot channel predictions of the single-pass method.

V. DATA INPUT FOR THE IMPROVED VERSION OF COBRA-IIIC/MIT

The improved version of COBRA-IIIC/MIT has new calculation options that may be selected for use by input data. The three input data methods of COBRA-IIIC/MIT have been revised to allow use of new calculation options. Table V-1 gives the new options that may be selected by each input method.

The "New INPUT DATA Presentation" is the recommended input data method. It allows use of all new options and is convenient and well-documented. A limited selection of new options is available when either of the other two input methods is selected. Table V-1 also gives the IPILE options allowed by each of the three input methods. IPILE is a calculation option indicator. The value given for IPILE by input data determines the type of calculation performed. Table V-2 gives the features and uses of the different IPILE options. Old input data card decks may be expected to perform the same calculations when used by the improved version as they performed using COBRA-IIIC/MIT before improvement. Revisions of the input data methods have been made with the intent to have old card decks select old options when they are used with the improved version of COBRA-IIIC/MIT. There are ways for old card decks to mistakenly select new calculation options even though they selected old calculation options when used with an unimproved version of COBRA-IIIC/MIT. Although it is unlikely that old card decks will select new options, output should be checked to see that old options are selected when old decks are used with the improved version. A card-by-card description for each of the three input data methods is contained in Appendix M. Sample input and COBRA-IIIC/MIT output is included in Appendix O to facilitate understanding of data input for the improved version of COBRA-IIIC/MIT.

Table V-1

Input Data Methods for Improved Version of COBRA-IIIC/MIT

Input Data Method	New Options Allowed	IPILE Options Allowed	Reference of Description for Input Data Method
Input Data Representation Based on that of COBRA-IIIC	New mixing model. Calculation of CPR using CISE correlation. Calculation of CHFR using Hench-Levy correlation.	IPILE = 0	App. 10 of Ref. 1
Simplified COBRA-IIIC Input Data Presentation to be Used for Assembly-to-Assembly Analysis of LWR	Same as above.	IPILE = 1 or 2	App. 11 of Ref. 1
New INPUT DATA Presentation	All new options available. New fuel rod, rod-to-coolant, heat transfer, and mixing models. Calculation of CPR using CISE. Calculation of CHFR using Hench-Levy or Biasi/Void-CHF. Transverse momentum coupling parameters may be used.	IPILE = 0,1 or 2	App. 12 of Ref. 1

Table V-2

Features and Uses of IPILE Options

IPILE Option	Features	Uses
IPILE = 0	Gaps of various sizes may be used to interconnect coolant channels	Single-pass analysis Assembly-to-assembly analysis Subchannel-to-subchannel analysis
IPILE = 1	Gaps connecting coolant channels expected to be same size, except for channels split by "half-boundaries"	Assembly-to-assembly PWR analysis Subchannel-to-subchannel analysis
IPILE = 2	No interconnection between channels	Assembly-to-assembly BWR analysis

VI. SUMMARY

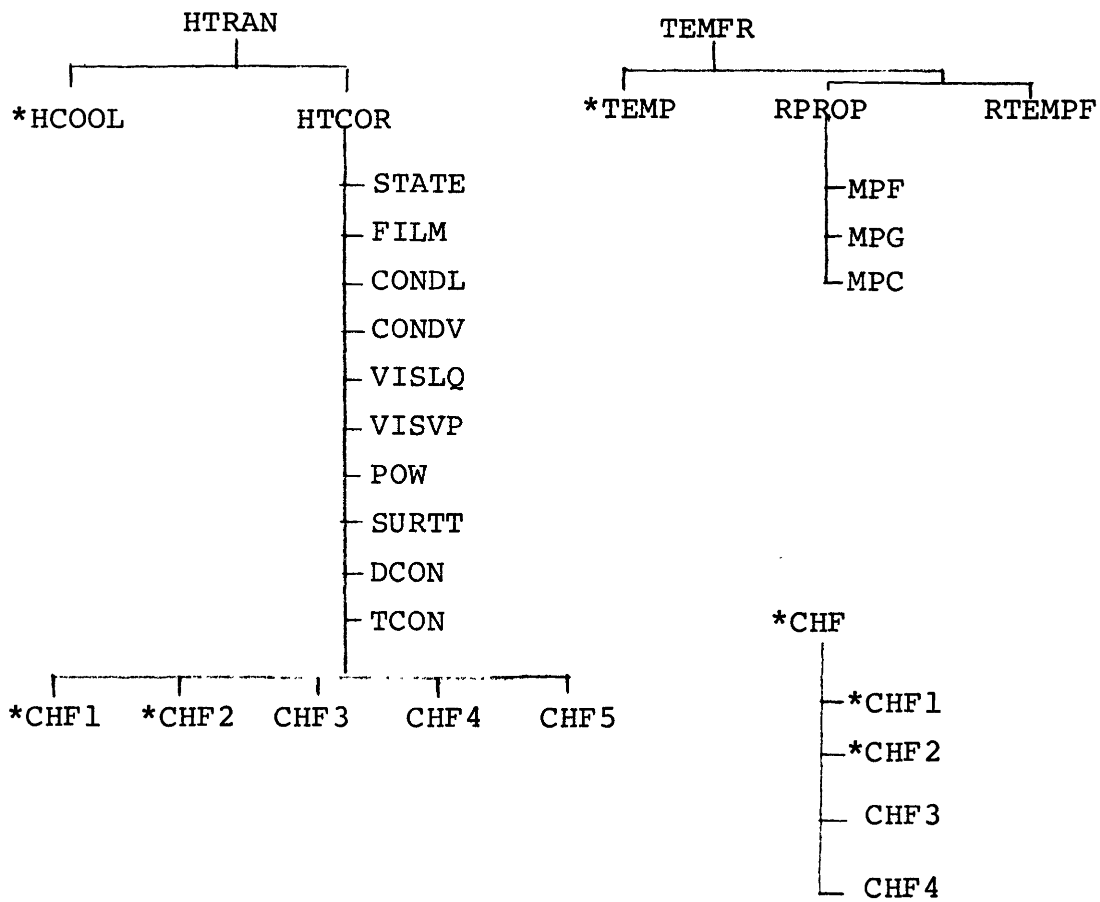
Past research has indicated areas for improvement of COBRA-IIIC/MIT. The code has been improved by the addition of new options. New fuel rod, rod-to-coolant heat transfer, and mixing modeling options are now available. New critical power ratio and critical heat flux ratio calculation options and transverse momentum coupling parameters are also available in the improved COBRA-IIIC/MIT version.

The improvements have been tested individually and during application of the improved code to transient test cases. Testing mainly involved comparison of the predictions of different modeling options and in some instances, comparison of predictions with experimental measurements. The testing results provide an assessment of COBRA-IIIC/MIT capabilities in general, as well as the capabilities of individual options. Major testing results will be briefly discussed. MDNBR, MCPR and MCHFR predictions showed only small sensitivities to the fuel rod and heat transfer modeling options used for the test cases analyzed. Differences in predictions of the old and new heat transfer models resulted in different clad temperature predictions. Clad temperature varies more smoothly from one time step to the next with changing coolant conditions. Discontinuous change in old heat transfer model predictions caused failure of the flow solution to converge during transient BWR analysis. Fuel rod surface heat flux predictions of the old and new fuel rod models were close even though fuel rod temperature predictions showed some differences. The new mixing model did not improve subchannel flow and enthalpy predictions for BWR conditions. However, some improvement was seen in predictions for subcooled conditions. The CISE-4 MCPR predictions were in agreement with experimental CHF measurements. Hench-Levy MCHFR predictions were conservative for the CHF test cases. The new transverse momentum parameters had no significant effect on steady state hot channel predictions of the single-pass method.

APPENDIX A

COBRA-IIIC/MIT Code Modifications

The COBRA-IIIC/MIT code has been modified during implementation of improvements. New subroutines have been added and old ones modified. Major new subroutines are contained within the subroutine structure shown in Figure A-1. New subroutines are described in Table A-1. Modifications of old subroutines are described in Table A-2. Subroutines are listed in the tables according to the order in which the subroutines appear in the listing of the improved version of COBRA-IIIC/MIT given in Appendix N.



Note: * indicates old subroutines.

Figure A-1

New COBRA-IIIC/MIT Subroutine Structure

Table A-1

New Subroutines

Subroutine (or Function)	Description
CHF3	calculation of critical heat flux using the Hench-Levy correlation
CHF4	calculation of critical power ratio using the CISE-4 correlation
HTRAN	oversees old and new rod-to-coolant heat transfer models
STATE	evaluates thermodynamics equations of state and their derivatives
TEMFR	oversees old and new fuel rod model calculations
INITRC	Initializes variables and arrays for new fuel rod model. Called by CALC before calculation of steady state.
RTEMPF	solves radial rod heat conduction for new fuel rod model
RPROP	finds fuel rod material and gap properties for new fuel rod model
MPF	material properties of fuel
MPG	gap conductance
MPC	material properties of clad
HTCOR	calculates rod-to-coolant heat transfer coefficient for new heat transfer model
FILM	calculates film boiling heat transfer coefficients for new heat transfer model
CHF5	calculation of critical heat flux using Biasi/CHF-Void correlation
POW	A function which evaluates a**b. It may be replaced by a fast, engineering accuracy exponentiation routine.
CONDL	liquid thermal conductivity
CONDV	steam thermal conductivity

Table A-1 (cont.)

Subtoutine (or Function)	Description
VISLQ	liquid water viscosity
VISVP	steam viscosity
TCON	converts temperature from F to K
DCON	converts density from lb/ft**3 to kg/m**3
SURTT	surface tension of water

Table A-2

Modifications of Old Subroutines

Subroutine	
BAROC	COMMON COSAVE added to save CORAB array
CALC	Call to INITRC added. COMMONS LINK4, PPSV, REFP, and TIMEST added.
CURVE	COMMON INDSAV added to save index
INPRIN	New models indicated in printout. COMMONS FRDATA and LINK4 added.
EXPRIN	Type of CHF calculation indicated in printout.
MIX	New mixing model calculational option added.
PROP	Fuel rod surface temperature used to determine start of nucleate boiling and wall viscosity when rod-to-coolant heat transfer model is used. COMMON LINK4 added.
CARDS4	MC added to argument list. NK set to zero if IPILE=2.
CHAN	Modified to read in and print information regarding new models. COMMON FRDATA, GAPFAC, ITPSV, and LINK4 added.
CHF	Modified to call CHF3 and CHF4. CHF predictions made by CHF5 are obtained from the CHSAVE array. COMMON CHFSV added.
DIVERT	New transverse momentum parameters used in equations. COMMON GAPFAC added.
INDAT	Prints new model information. Fuel rod and rod-to-coolant heat transfer model indicators are initialized as zero. Elements of FACSL and FACSLK arrays are set to one. COMMON LINK4 added.
MODEL	IPILE added to argument list. Mixing model options are made available.
CORE	KS=1 and KMAX=80000 since DATA array set in MAIN program.
HEAT	Calls HTRAN rather than HCOOL. Calls TEMFR rather than TEMP. Iteration loop added. COMMON LINK4 and TIMEST added.
SEPRAT	COMMON REFP added.
VOID	COMMON PPSV added.

APPENDIX B

Methods Used by New Fuel Rod Model

B.1 Fuel and Cladding Material Properties

Calculation of fuel and cladding material properties is based on the MATPRO model (Ref. 15). The MATPRO model contains good fits to experimental data for fuel and clad material properties. However, some of the fits were formulated in terms of expressions which, although physically derived, were time consuming to compute. Therefore, the expressions were examined to find satisfactory fits which could be rapidly evaluated by a digital computer.

Cubic polynomials were developed to fit the temperature dependence of fuel ρc_p within 2 percent over temperature from 300°K to 3000°K. The thermal conductivity of fuel was fit by a quadratic polynomial within 10 percent over 400°K to 2500°K. In each case there are separate, slightly different fits for uranium oxide and mixed oxide fuels.

Temperature-dependent clad material properties are also given by simple expressions in the new fuel rod model. The MATPRO model for thermal conductivity of Zircaloy is already a simple polynomial fit, and was taken over unchanged. The value of ρc_p has been approximated by a linear fit from 300°K to 1190°K; this fit is within 5 percent of the data given in Ref. 13. (Clad temperatures would normally be far below 1190°K.) At 1190°K Zircaloy undergoes a transition fitted in the new model by two linear fits making a sharp, inverted vee corresponding to data in Ref. 15; above 1254°K, where the transition ends, few data are available, and a constant value is assumed as is recommended in Ref. 15.

B.2 Fuel-to-Clad Gap Heat Transfer Coefficient

The new fuel rod model calculates time-space behavior of gap conductance h_{gap}, using the MATPRO cracked-pellet model. This model calculates

$$h_{gap} = h_{cond} + h_{contact} + h_{rad} + h_{press}$$

where the four components on the right hand side represent, respectively, the effects of: thermal conductivity of the gas mixture of the gap; partial fuel-clad contact, supposed to change with burnup due to fuel pellet cracking and relocation; radiation heat transfer across the gap; and fuel pressing against clad if the gap is closed due to excessive fuel expansion. The gap heat transfer model has been added to COBRA-IIIC/MIT in a subroutine named MPG.

The four components of gap conductance will be briefly discussed. The first, gap gas conductivity, is computed in subroutine MPG by calculating a theoretical mixture conductivity for a mixture of four noble gases, helium, argon, krypton, and xenon. The presence of air and water vapor is neglected. The conductivity of helium is modified to represent the effect of a small gap on the statistical thermodynamics assumptions involved. The partial fuel-clad contact contribution is from the cracked-pellet model developed at INEL (Ref. 15); it involves a function of fuel burnup calculated once on the basis of input to MPG at the beginning of COBRA-IIIC/MIT calculations. The radiation heat transfer is based on standard formulas depending on the fuel and clad emissivities. The closed gap component is added on when the user-input gap width is less than the mean fuel-clad surface roughness; it takes the form $h_{press} = CP_f^n$, where C, P_f (the fuel contact pressure against the clad), and the exponent n are user-specified input. The user-input dimensions are hot dimensions and are not recalculated to account for thermal expansion.

APPENDIX C

Description of Options and Logic Associated with Subroutine HEAT

Subroutine HEAT calculates the heat addition per unit length q'(I,J) for coolant nodes at axial position J of all channels I, from 1 to NCHANL. HEAT is called once for each axial level during the axial iteration scheme of COBRA-IIIC/MIT. HEAT may be used with or without a fuel rod model. When HEAT is used without a fuel rod model, the effect of heat capacity is ignored.

When a fuel rod model is used, the sequence of operations is as shown in Figure C-1. HEAT calculates fuel rod temperatures by first calling subroutine HTRAN to calculate a rod-to-coolant heat transfer coefficient. Then HEAT calls either subroutine TEMP (old fuel rod model) or subroutine TEMFR (new fuel rod model) to solve for the fuel rod temperature distribution. The calculation of rod-to-coolant heat transfer coefficient and the calculation of fuel rod temperatures have several options, as shown in Table C-1.

Subroutine HEAT has an inner iteration scheme to determine each steady state temperature distribution. This scheme is used at each axial level and for each pass through the reactor when either the temperature dependent property option or the new heat transfer model is used. The iteration is done either 50 times or until the centerline fuel temperature changes by less than an amount EPSF, which is user specified. If convergence is not reached in 50 iterations, the COBRA calculations are stopped and an error message is given.

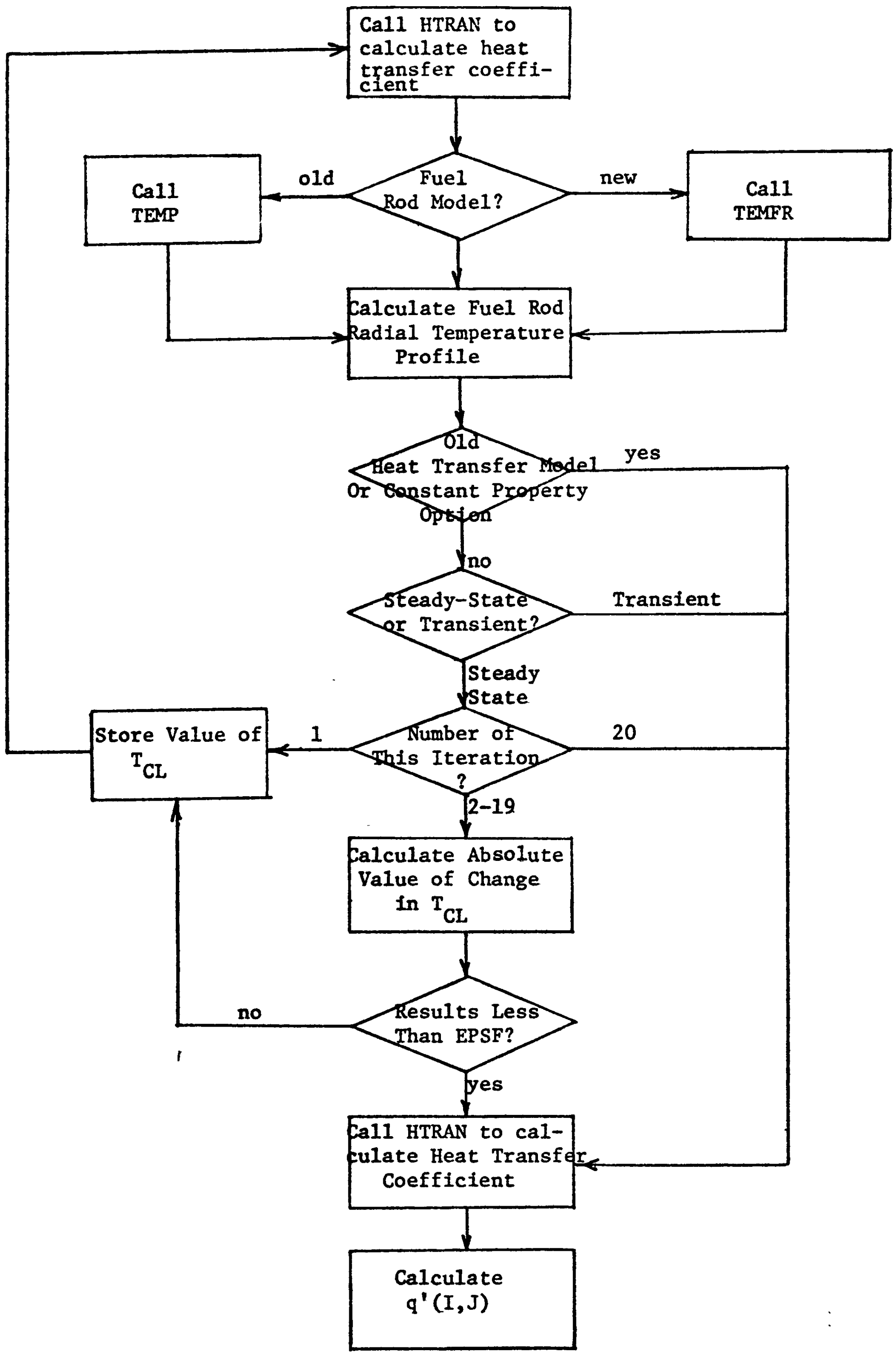


Figure C-1

Flow Diagram of Logic Used in Subroutine HEAT When a Fuel Rod Model is Used

Table C-1

Available Options for Calculation of Heat Transfer Coefficient and Fuel Rod Temperatures

Option Indicator			Calculational Model Used		
IFRM	IPROP	IHTM	Fuel Rod Model	Property Option	Heat Transfer Model
0	0	0	Old	Constant properties, user input values of fuel and cladding properties and h_{gap}.	Old
		1			New, pre-CHF only
		2			New,pre and post-CHF
1	0	0	New	Constant properties, user input values of fuel and cladding properties and h_{gap}.	Old
		1			New, pre-CHF only
		2			New,pre and post CHF
1	1	0	New	Fuel and cladding properties calculated, user input value of h_{gap}.	Old
		1			New, pre-CHF only
		2			New,pre and post CHF
1	2	0	New	Fuel and cladding properties and h_{gap} calculated	Old
		1			New, pre-CHF only
		2			New,pre and post CHF

Note

Inner iteration on fuel rod temperature is used for all options except those which involve use of the constant property option (IPROP=0) and the old heat transfer model (IHTM=0).

APPENDIX D

New Heat Transfer Model

The new heat transfer model calculates the rod-to-coolant heat transfer coefficient in subroutine HTRAN which is called by subroutine HEAT. The new heat transfer model is based on the BEEST package (Ref. 16). HTRAN calculates the heat transfer coefficient in two steps. First, it determines the heat transfer regime. Then, the correlation appropriate to the regime is used to calculate a heat transfer coefficient. The input to HTRAN is clad outer surface temperature and coolant temperature, pressure, velocity and void fraction. The heat transfer logic is given in Figure D-1. Correlations used by the new model are listed in Table D-1. The variable "IHTR" is a heat transfer regime indicator. "IHTM" is the heat transfer model indicator. IHTM equals either one or two when the new heat transfer model is used. If IHTM equals one, the new heat transfer model uses correlation and logic for pre-CHF conditions. When the IHTM equals two, the correlations and logic for pre- and post-CHF conditions are used.

Subroutine HTRAN computes fuel-to-fluid heat transfer coefficient using the following subroutines:

- STATE - calculates fluid properties as a function of temperature and pressures
- FILM - film boiling heat transfer coefficient
- CONDL - thermal conductivity of liquid water
- CONDV - thermal conductivity of dry steam
- VISLQ - viscosity of saturated liquid water
- MPC - thermal conductivity of cladding
- SURTTEN - surface tension of liquid water
- CHF1, CHF2, CHF3, CHF4, or CHF5 - determines critical heat flux when IHTM = 2.

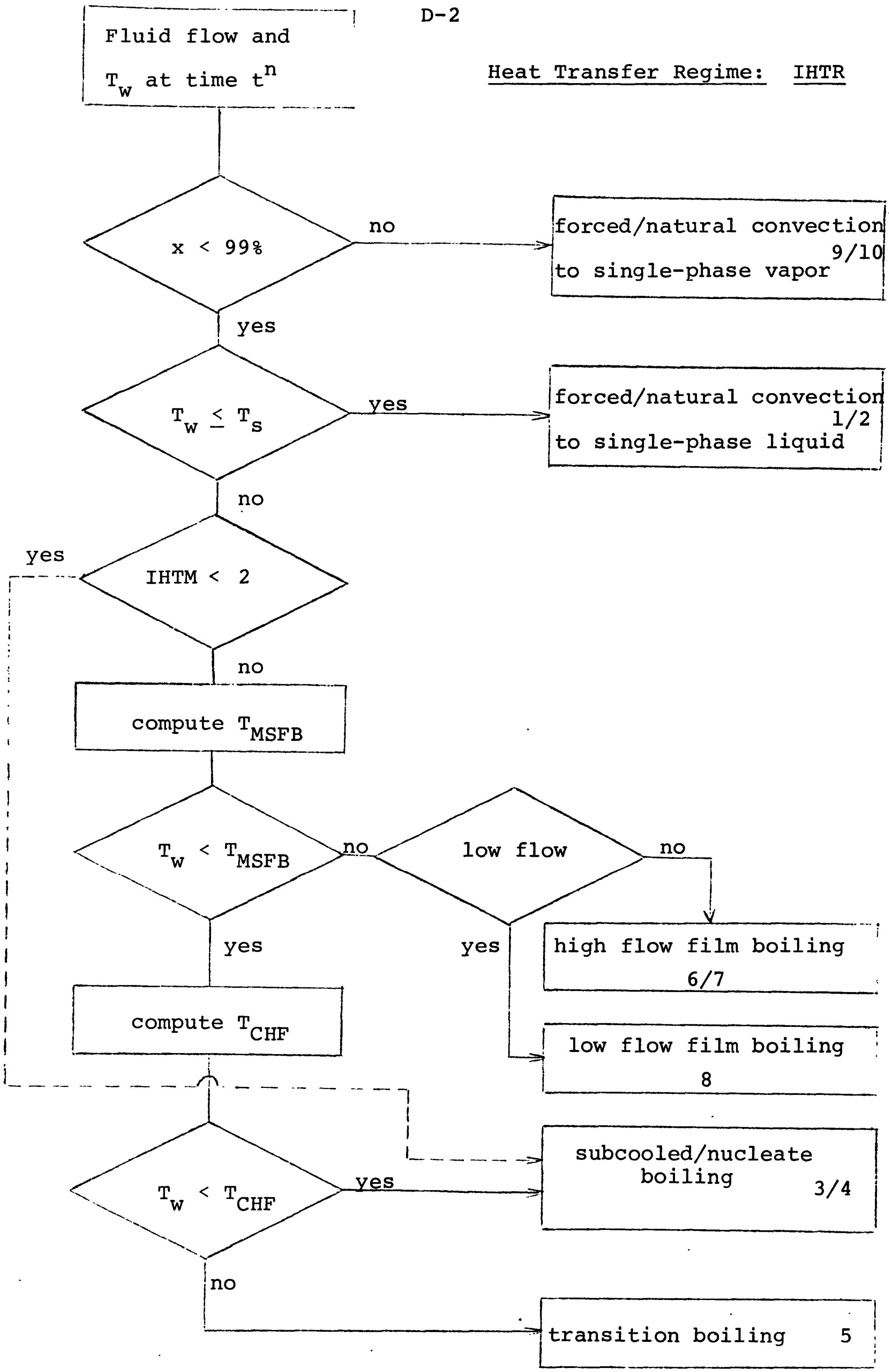

Fluid flow and
T_w at time t^n
Heat Transfer Regime: IHTR
x < 99%
no
forced/natural convection
9/10
to single-phase vapor
yes
T_w ≤ T_s
yes
forced/natural convection
1/2
to single-phase liquid
no
yes
IHTM < 2
no
compute T_MSFB
T_w < T_MSFB
no
low flow
no
high flow film boiling
6/7
yes
yes
compute T_CHF
low flow film boiling
8
subcooled/nucleate
boiling
3/4
T_w < T_CHF
yes
no
transition boiling 5

Figure D-1

Table D-1

Heat Transfer Summary

IHTR	Regime	Correlation
1	forced convection to single-phase liquid	Sieder-Tate
2	natural convection to single-phase liquid	McAdams
3	subcooled boiling	Chen
4	nucleate boiling	Chen
5	transition	Interpolation between q_{CHF} and q_{MSFB}
6	high P, high G film boiling	Groeneveld
7	low P, high G film boiling	modified Dittus-Boelter
8	low G film boiling	modified Bromley plus either McAdams vapor or high flow film boiling
9	forced convection to single-phase vapor	Sieder-Tate
10	natural convection to single-phase vapor	McAdams

APPENDIX E

Summary of Pre-CHF Correlations Used in Old and New Heat Transfer Models

The pre-CHF heat transfer correlations used in the old and new mdoels are summarized in Tables E-1 and E-2. Table E-1 lists the correlations used. Table E-2 gives references, equations and range of data base for each correlation.

Table E-1

Pre-CHF Correlations Used in the Old and New Heat Transfer Models

Regime	Correlation Used and Selection Criterion	
	New Model	Old Model
Forced convection to single phase liquid	Sieder Tate Forced convection $x < 99\%$ $T_w \leq T_s$	Thom modified Dittus-Boelter $x \leq 0$ (Levy model not used) $x < x_d$ (Levy model used)
Natural convection to single phase liquid	McAdams Natural convection $x < 99\%$ $T_w \leq T_s$	Not considered
Local boiling or bulk boiling	Chen $x < 99\%$ $T_s < T_w < T_{MSFB}$	Thom modified Jens-Lottes $x > 0$ (Levy model not used) $x \geq x_d$ (Levy model used)

*See list of nomenclature on page E-5.

Table E-2

Summary of Pre-CHF Correlations
Used in New and Old Heat Transfer Models

Correlation	Ref.	Equation	Range of Data Base
Sieder Tate	31	$h = 0.023\frac{k}{D}Re^{0.8}Pr^{0.33}(\mu/\mu_w)^{0.14}$ Fluid properties at bulk fluid temperature, except μ_w at T_w $Re = \frac{GD}{\mu} \quad Pr = \frac{\mu C_p}{k}$	Flow of water through tubes $10^2 < Re < 10^5$
McAdams	32	$h = 0.13k[Gr \cdot Pr]^{0.33}$ Fluid properties should be at fluid film temperature $G_r = \frac{\rho^2 g\beta(T_w - T)}{\mu^2}$	$10^9 < Gr \cdot Pr < 10^{12}$
Chen Note: This eqn. is in SI units. All other eqns. in Table are in English units.	33	$q'' = h_{FC}(T_w - T_f) + h_{NB}(T_w - T_s)$ $h_{FC} = 0.023\frac{k_f}{D}Re_f^{0.8}Pr_f^{0.4}F$ $h_{NB} = 0.00122S\left[\frac{k_f C_{p_f}}{\sigma}\right]^{0.5}Pr_f^{-0.29}$ $* \rho_f^{0.25}(P_w - P)^{0.75}$ $* \left[\frac{C_{p_f}(T_w - T_s)\rho_f}{h_{fg}\rho_g}\right]^{0.24}$	Based on upflow and downflow through heated tubes and annuli. Originally developed for bulk boiling and two phase forced convective regimes. Extension to subcooled boiling regimes has produced satisfactory results (Ref. 3). P: 8 - 505 psia $V_{f,in}$: 0.2 - 14.8 ft/sec x: 0 - 71% q": .03 - 0.76 $\frac{MBTU}{hr\text{-}ft^2}$

Table E-2 (cont.)

Correlation	Ref.	Equation	Range of Data Base
(Chen cont.)		$F = \begin{cases} 1 \text{ for } X_{tt}^{-1} \leq 0.1 \\ 2.35(X_{tt}^{-1} + 0.213)^{0.736} \\ \quad \text{for } X_{tt}^{-1} > 0.1 \end{cases}$ $X_{tt}^{-1} = [x/(1 - x)]^{0.9}(\rho_f/\rho_g)^{0.5}$ $* \ (\mu_g/\mu_f)^{0.1}$ $S = \begin{cases} [1 + 0.12Re_{TP}^{1.14}]^{-1.0} \\ \quad \text{for } Re_{TP} < 32.5 \\ [1 + 0.42Re_{TP}^{0.78}]^{-1.0} \\ \quad \text{for } 32.5 \leq Re_{TP} \leq 70 \\ 0.1 \text{ for } Re_{TP} > 70 \end{cases}$ $Re_{TP} = 10^{-4}F^{1.25}(1 - \alpha)(Re)_f$	
Thom modified Dittus-Boelter and Jens-Lottes	34	$h = 0.134\frac{k}{D}Re^{0.65}Pr^{0.4}$ for forced convection to liquid $T_w = T_{sat} + \frac{0.072(q")^{0.5}}{e^{P/1260}}$ $h = \frac{T_w - T_b}{q"}$ for local boiling	Based on upflow through heated tubes and annuli. Developed as a forced convective and subcooled boiling correlation. $P = 750$ to 2000 psia $V_{f,in} = 5$ to 20 ft/sec $q" = 0$ to $0.5\frac{MBTU}{hr\text{-}ft^2}$

Nomenclature for Tables E-1 and E-2

Symbols

C_p	heat capacity	BTU/lb_m°F
D	diameter	ft
g	gravitational acceleration	ft/hr^2
G	mass flow rate	lb_m/ft^2hr
Gr	Grashof number $\left(\frac{\rho^2 g\beta[T_w - T]}{\mu^2}\right)$	-
h	heat transfer coefficient	BTU/hr ft^2°F
h_{fg}	latent heat of vaporization	BTU/lb
k	thermal conductivity	BTU/hr ft°F
P	pressure	psia
Pr	Prandtl number ($= \mu c_p/k$)	-
q"	heat flux	BTU/hr ft^2
Re	Reynolds number ($= GD_h/\mu$)	-
T	temperature	°F
V	velocity	ft/sec
x	quality	-
x_d	quality at which bubble departure starts according to Levy model	-
X_{tt}	Martinelli parameter	-
α	void fraction	-
β	thermal expansion coefficient	$°F^{-1}$
μ	viscosity	lb_m/ft hr
ρ	density	lb_m/ft^3
σ	surface tension	lb_f/ft

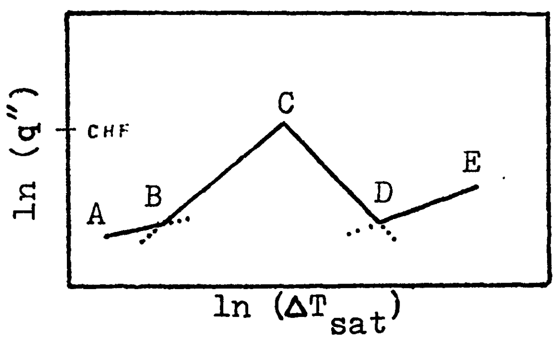
Subscripts

b	bulk fluid
f	liquid phase
s	saturation
g	vapor phase
w	wall
FC	forced convection
in	inlet
MSFB	minimum stable film boiling
NB	nucleate boiling
TP	two phase

APPENDIX F

The COBRA-IV-I Heat Transfer Model

The COBRA-IV-I heat transfer model contains the capability to construct a complete boiling curve, as shown in the figure below, for each space and time step of the problem.



A-B forced convection

B-C subcooled and nucleate boiling, and forced convection vaporization

C-D transition boiling and transition pool boiling

D-E film boiling, low-pressure film boiling and pool film boiling

The heat transfer model contains the following correlations:

1. Dittus-Boelter
2. Thom (nucleate boiling heat transfer)
3. Schrock and Grossman
4. McDonough, Millich, and King
5. Groeneveld
6. Dougall and Rohsenow
7. Berenson

APPENDIX G

Beus Mixing Model

The Beus mixing model (Ref. 17) considers two regions on a plot mixing rate versus quality as shown in Figure G-1. The low quality region is referred to as the churn mixing region and corresponds to the bubbly slug flow regime, as shown in Figure G-2. The high quality region is referred to as the transition mixing region and corresponds to the annular flow regime. The two regions are divided by a location of peak mixing at which quality, x, equals x_c.

In the churn mixing region, the mixing model is based on a physical model which assumes that mixing is due to displacements of fluid between subchannels caused by movement of vapor slugs with respect to cocurrently flowing liquid. In this region, the experimental data studied by Beus indicates tha the mixing rate increases steadily with quality and is given by the following equation*:

$$W' = W_S + \beta_1 [\frac{AG}{D_h}] \frac{\rho_\ell}{\rho_g} [\frac{\gamma - 1}{\gamma}] x$$

where the slip ratio, γ, is obtained from the Smith correlation (Ref. 35). W_L and β_1 are calculated using the following equations:

$$W_L = 0.0035 \mu_\ell Re_\ell^{.9}$$

$$\beta_1 = 0.04 [\frac{S}{D_h}]^\lambda , \lambda = 1.5 .$$

The quality at which peak mixing occurs, and where transition mixing begins, x_c is determined by the following equation:

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*nomenclature is defined at the end of this appendix.

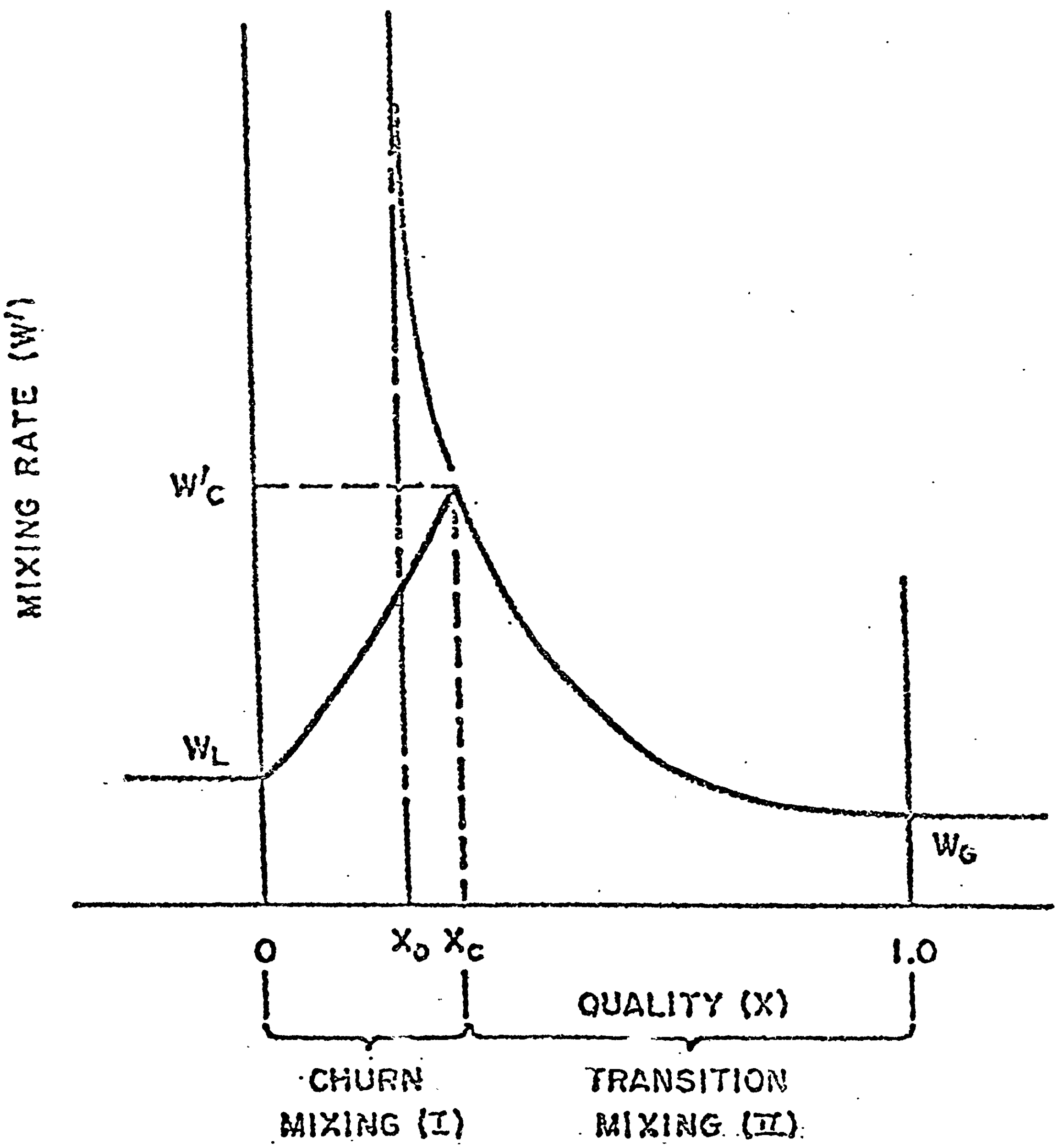

Figure G.1 (Fig. 4 of Ref. 17)

Plot of Mixing Model Showing Variation with Quality

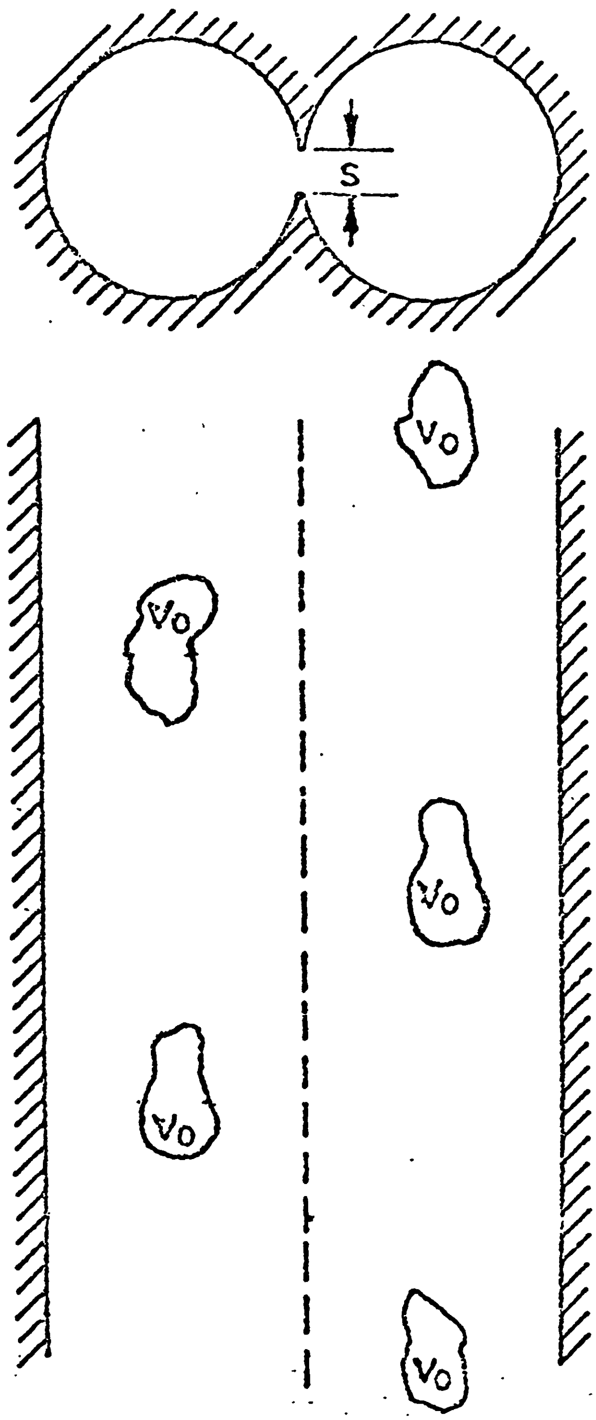

Figure G-2 (Based on Figure 2 of Ref. 17)

Idealized Subchannel Configuration

$$x_c = \frac{\frac{A_1}{G}[g\rho_\ell D_h(\rho_\ell - \rho_g)]^{1/2}}{[\frac{\rho_\ell}{\rho_g}]^{1/2} + A_2}$$

where,

$A_1 = 0.4$

$A_2 = 0.6.$

In the transition mixing region, the data studied by Beus indicated a smooth decline of mixing rate from the peak value to a constant value at high quality, W_G, as shown in Figure G-1. The Beus model constructs a hyperbolic curve to approximate the equation:

$$W'_{II} = W_G + [W'_c - W_G] \left[\frac{1 - \frac{x_o}{x_c}}{\frac{x}{x_c} - \frac{x_o}{x_c}} \right]$$

where,

$W'_c = W'_I[x_c]$

$W_G = .0035\mu_g Re_g^{.9}$

and

$$\frac{x_o}{x_c} = .57Re^{.0417} .$$

The values of β_1, x_o/x_c, W_L and W_G were obtained by least square fits to the studied data.

Nomenclature

A = subchannel flow area (ft^2)

D_h = hydraulic diameter (ft)

G = mass flux ($lbm/hr\text{-}ft^2$)

L = channel length (ft)

T = temperature (°F)

W = mixing rate (lbm/hr-ft)

μ = viscosity (lbm/hr-ft)

ρ = density ($lbm/hr\text{-}ft^3$)

x = quality

$Re_\ell = (G \cdot D_h)/\mu_\ell$

$Re_g = (G \cdot D_h)/\mu_g$

APPENDIX H

Summary of Correlations Provided for Calculation of DNBR, CHFR and CPR

The correlations now provided in COBRA-IIIC/MIT for calculation of DNBR, CHFR and CPR are summarized in Tables H-1 and H-2. Table H-1 lists the correlations provided. Table H-2 gives references, equations and range of data base for each correlation.

Table H-1

Correlations Provided for Calculation of DNBR, CHFR and CPR

Option Indicator (NCHF)	Correlation	Quantity Calculated		
		DNBR	CHFR	CPR
1	B&W-2	✓		
2	W-3	✓		
3	Hench-Levy		✓	
4	CISE-4			✓
5	Biasi/Void-CHF		✓	

Notes:

1. The new heat transfer model requires a CHF calculation in order to consider post-CHF heat transfer. Any of the correlations listed above can be used for this calculation. (Ref. discussion in Section II.B.1)

2. The W-3 correlation requires calculation of the start of local boiling. When the old heat transfer model is being used, the Thom modifed Jens-Lottes correlation is used (Ref. Table B.2 of Appendix B). When the new heat transfer model is being used, the start of local boiling is determined by $T_W > T_S$.

Table H-2

Summary of Correlations Provided for Calculation of DNBR, CHFR and CPR*

Correlation	Ref.	Equation	Range of Data Base
B&W-2	36	$\frac{q''_{CHF,EU}}{10^6}$ $= \{(1.155 - 0.407D_e)[0.37 * 10^8$ $* (0.591G/10^6)^{[0.83+0.685(p/10^3-2)]}$ $- 0.1521GX_{CHF}H_{fg}]\}/\{12.71$ $* (3.054G/10^6)^{[0.712+0.2073(p/10^3-2)]}\}$ where $q''_{CHF,EU}$ is in BTU $hr^{-1}ft^{-2}$	p = 2000 to 2400 psia $G = 0.75 * 10^6$ to $4.0 * 10^6 lb\ hr^{-1}ft^{-2}$ D_e = 0.2 to 0.5 in. X_{exit} = -0.03 to 0.20 L = 72 in. Geometry = rod bundles 72 in. long having 15 in. grid span
	37	$F_c = \frac{q''_{CHF,EU}}{q''_{CHF,NU}}$ $= \frac{1.025C\int_0^{\ell_{CHF}} q''(z)\exp[-C(\ell_{CHF} - z)]dZ}{q''_{loc} * [1 - \exp(-C(\ell_{CHF,EU})]}$ where ℓ is measured from the channel inlet $C = \frac{0.249(1 - X_{CHF})^{7.82}}{(G/10^6)^{0.457}}$	p = 2000 to 2400 psia $G = 1 * 10^6$ t0 $3.5 * 10^6 lb\ hr^{-1}ft^{-2}$ D_e = 0.2 to 0.5 in. X_{exit} = 0.02 to 0.25

*See list of nomenclature on page C-9.

Correlation	Ref.	Equation	Range of Data Base
W-3	38	$\frac{q''_{crit,EU}}{10^6} = \{(2.02 - 0.0004302p)$ $+ (0.1722 - 0.0000984p)$ $* \exp[(18.177 - 0.004129p)X]\}$ $* [(0.1484 - 1.596X$ $+ 0.1729X\|X\|)(G/10^6) + 1.037]$ $* (1.157 - 0.869X)[0.2664$ $+ 0.8357\exp(-3.151D_e)][0.8258$ $+ 0.000794(H_{sat} - H_{in})]$ where $q''_{CHF,EU}$ is in BTU $hr^{-1}ft^{-2}$.	p = 1000 to 2400 psia $G = 1.0 * 10^6$ to $5.0 * 10^6$ lb $hr^{-1}ft^{-2}$ D_e = 0.2 to 0.7 X_{loc} = -0.25 to +0.15 L = 10 to 144 in. $\frac{\text{Heated perimeter}}{\text{Wetted perimeter}}$ = 0.88 to 1.00 Geometries = circular tube, rectangular channel, and bare rod bundle
	39	Non-unform flux shape factor: $F_c = \frac{q''_{DNB,EU}}{q''_{CHF,NU}} = \frac{C}{q''_{crit,NU}(1 - e^{-C\ell_{crit}})}$ $* \int_0^{\ell_{crit}} q''(z)e^{-C(\ell_{crit}-z)}dz$ where ℓ is measured from start of local boiling. $C = 0.15\frac{(1 - X_{crit})^{4.31}}{(G/10^6)^{0.478}}$ in.$^{-1}$	p = 1000 to 2400 psia $G = 1.0 * 10^6$ to $3.0 * 10^6$ lb $hr^{-1}ft^{-2}$ D_e = 0.2 to 0.7 in. $X_{exit} \leq 0.15$ L = 10 to 144 in.

Table H-2 (cont.)

Correlation	Ref.	Equation	Range of Data Base
W-3 (cont.)	40	Spacer-grid effect $F_S = \frac{q''_{crit,spacer}}{q''_{crit,bare\ rod\ bundle}}$ $F_S = 1.0 + 0.03(\frac{G}{10^6})(\frac{TDC}{0.019})^{0.35}$ where TDC is thermal diffusion coefficient denoting the mixing caused by the spacer. Further, TDC = $\varepsilon/(Va)$, where ε is the eddy diffusivity, V is the axial velocity, and a is the gap between two adjacent fuel rods.	rod bundles 8 to 14 ft. long
	41	$\frac{CHF_{cold\ wall}}{CHF_{W-3,D_h}} = 1.0 - Ru\Big[13.76 - 1.372e^{1.78X} - 4.732 * (\frac{G}{10^6})^{-0.0535} - 0.0619 * (\frac{P}{10^3})^{0.14} - 8.509D_h^{0.107}\Big]$ where, Ru = $1 - (D_e/D_h)$ and D_e and D_h are the equivalent diameters based on wetted and heated perimeters, respectively.	$X_{DNB} \leq 0.10$ $1.0 \leq G/10^6 lb\ hr^{-1} ft^{-2} \leq 5.0$ L $\geq$ 10 in. Gap $\geq$ 0.10 in.
Hench-Levy	19	$(q''_c/10^6) = F_P \frac{BTU}{hr\text{-}ft^2}$ for $(\langle x_e \rangle) \leq 0.273 - 0.212\ TANH^2(3G/10^6)$	P = 600 to 1450 psia G = $0.2 * 10^6$ to $1.6 * 10^6$ lb/h-ft^2 D_e = 0.324 to 0.485 in. rod to rod and rod to wall spacings greater than 0.060 in.

Table 4-2 (cont.)

Correlation	Ref.	Equation	Range of Data Base
Hench-Levy (cont.)		$(q''_c/10^6) = F_p[1.9 - 3.3 \langle x_e \rangle - 0.7 \text{ TANH}^2 * (3G/10^6)]$, BTU $hr^{-1}ft^{-2}$ for $0.273 - 0.212 \text{ TANH}^2 (3G/10^6) \leq (\langle x_e \rangle) \leq 0.5 - 0.269 \text{ TANH}^2 (3G/10^6) + 0.0346 * \text{TANH}^2 (\frac{2G}{10^6})$ $(q''_c/10^6) = F_p[0.6 - 0.7 \langle x_e \rangle - 0.09 * \text{TANH}^2 (2G/10^6)]$, BTU $hr^{-1}ft^{-2}$ for $(\langle x_e \rangle) \geq 0.5 - 0.269 \text{ TANH}^2 (3G/10^6) + 0.0346 \text{ TANH}^2 (\frac{2G}{10^6})$ where $F_p = [1.1 - 0.1(\frac{P - 600}{400})^{1.25}]$	
CISE-4	21	$\langle x_e \rangle_c = \frac{D_h}{D_e}[a \frac{L_{B_c}}{L_{B_c} + b}]$ where $a = \frac{1}{1 + 0.20(1 - P/P_{CR})^{-3} a/10^6}$ for $G < G^*$	P = 720 to 1000 psia G = 0.8 to 3.0 x 10^6 lb $hr^{-1}ft^{-2}$ L = 30 to 144 in. Rod O.D. = 0.40 to 0.78 No. rods = 7 to 37

Table H-2 (cont.)

Correlation	Ref.	Equation	Range of Data Base
CISE-4 (cont.)		and $a = \frac{1 - P/P_{CR}}{(1.35G/10^6)^{1/3}}$ for $G > G^*$ where $G^* = 2.5 * 10^6(1 - P/P_{CR})^3$ and $b = 168(P_{CR}/P - 1)^{0.4}G/10^6 D_e^{1.4}$	
Biasi/Void-CHF	16	For $\lvert G \rvert \geq 10^6$ lb hr^{-1}ft^{-2} use the highest of the values of q''_{CHF} given by the following equations: 1) $q''_{CHF} = 2.633(10^7)(30.48D)^{-n}G^{-1/6} * [4.412F(p)G^{-1/6} - x]$ 2) $q''_{CHF} = 1.181(10^9)H(p)(30.48D)^{-n} * G^{-0.6}(1.0 - x)$ where $F(p) = 0.7249 + 0.00683p \exp(-0.0021p)$ $H(p) = -1.159 + 0.01029p \exp(-0.00131p) + 130.4p(2103 + p^2)^{-1}$ $n = \begin{cases} 0.4 \text{ for } D \geq 0.0328 \text{ ft.} \\ 0.6 \text{ for } D < 0.0328 \text{ ft} \end{cases}$	Eqns. 1&2 are based on the Biasi correlation (Ref.23). The range of data for this correlation is: P = 39 to 2058 psia $G/10^6$ = 0.074 to 4.4 lb hr^{-1}ft^{-2} D = 0.01 to 0.12 ft. L = 0.66 to 19.7 ft. $X = (\frac{1}{1 + \rho_f/\rho_g})$ to 1.0 Note: Data base is for water in flow through vertical, uniformly heated tubes. The correlation is principally a dryout correlation and consequently is not expected to work well for low qualities and low flows. Eqn. 3 is based on the Void-CHF correlation (Ref.24). This correlation contains the physically based pool boiling CHF relationship of Zuber (Ref 42) Data base covers low flow upflow, downflow and counter-current flow conditions in Freon. Extension to water is justified on the basis of the proven wide range of applicability of the Zuber correlation.

Correlation	Ref.	Equation	Range of Data Base
Biasi/Void-CHF (cont.)		For $10^6 > \lvert G \rvert > 2 * 10^4$ lb hr^{-1}ft^{-2} use a linear interpolation between the value obtained for q''_{CHF} at $G = 10^6$ and the value obtained by the following equation at $G = 2 * 10^4$: 3) $q''_{CHF} = (1 - \alpha)0.9\pi 24^{-1} H_{fg}\rho_g^{0.5} * [g g_c \sigma(\rho_f - \rho_g)]^{0.25}$ For $2 * 10^4 \geq \lvert G \rvert \geq 0$ use Eqn. 3 with void fraction calculated for $G = +2 * 10^4$. Exception: For $P \geq 1200$ psia and $x \geq 0.5$, use Eqns. 1 and 2 for $\lvert G \rvert \geq 2 * 10^5$ lbs hr^{-1}ft^{-2}. Use linear interpolation between Eqns. 1 and 2 at $G = 2 * 10^5$ and Eqn. 3 at $G = 2 * 10^4$.	

Nomenclature for Table H.2

a	Gap between two adjacent fuel rods	ft
C	Function of G and X_{CHF} or X_{crit}	ft^{-1}
CHF	Critical heat flux	BTU $hr^{-1}ft^{-2}$
D	Diameter of tube	ft
D_e	Equivalent diameter based on wetted perimeter	ft
D_h	Equivalent diameter based on heated perimeter	ft
F_c	Flux shape factor	-
F_P	Function of P	-
F_S	Spacer grid factor	-
G	Mass velocity	lb $hr^{-1}ft^{-2}$
g	Acceleration of gravity	ft/sec^2
g_c	Conversion factor	ft/sec^2
H	Enthalpy	BTU/lb
H_{fg}	Latent heat of evaporation	BTU/lb
L	Length of heated channel	ft
L_B	Boiling length	ft
L_{BC}	Critical boiling length	ft
ℓ_{CHF}	Distance from start of local boiling to CHF location (W-3)	ft
ℓ_{crit}	Distance from channel inlet to critical heat flux location (B&W-2)	ft
$\ell_{CHF,EU}$	Distance from start of local boiling to CHF location for equivalent uniform heat flux condition (W-3)	ft
p	Pressure	psia

p_c	Critical pressure	psia
q'', q''_{crit}, q''_c	Critical heat flux	BTU $hr^{-1}ft^{-2}$
$q''_{crit,EU}$, $q''_{CHF,EU}$, $q''_{DNB,EU}$	Critical heat flux for equivalent uniform heat flux	BTU $hr^{-1}ft^{-2}$
$q''_{crit,NU}$, $q''_{CHF,NU}$	Critical heat flux for non-uniform heat flux distribution	BTU $hr^{-1}ft^{-2}$
q''_{loc}	Local heat flux	BTU $hr^{-1}ft^{-2}$
v	velocity	ft/hr
$\langle x_e \rangle$	Bundle average quality	-
$\langle x_e \rangle_c$	Bundle average critical quality	-
x_{CHF}, x_{DNB}	Quality at the critical heat flux location	-
X_{exit}	Quality of channel exit	-
x_{loc}	Local quality	-
Z	Axial length	ft
α	Void fraction	-
ε	Eddy diffusivity or Reynolds flux	ft^2/hr
ρ_f	Density of saturated liquid	lb_m/ft^3
ρ_g	Density of saturated vapor	lb_m/ft^3
σ	Surface tension	lb/ft

APPENDIX I

Description of the Three Transverse Momentum Options Provided in COBRA-IIIC/MIT

1. The Old COBRA-IIIC/MIT Approach

The old COBRA approach (Ref. 43) is based on conserving transverse momentum in a control volume for the gap between two subchannels as shown in Figure I-1. By conservation of momentum, the following equation is obtained:

$$\frac{\partial}{\partial t}[W_{ij}] + \frac{\partial(u^*W_{ij})}{\partial x} = \frac{s}{\ell}(P_i - P_j) - F_{ij} \quad \text{(Eqn. I-1)}$$

where

$$F_{ij} = \frac{K|W_{ij}|W_{ij}}{2(S_{ij})^2\rho^*}\frac{s}{\ell} \quad \text{(Eqn. I-2)}$$

and

W_{ij} = diversion crossflow between subchannels i and j (lb_m/hr ft)

u^* = effective velocity carried by diversion crossflow (ft/sec)

x = axial distance (ft)

s = width of gap between rods (ft)

ℓ = effective length of connection between subchannels (ft)

P_i = pressure in channel i (lb_f/ft^2)

P_j = pressure in channel j (lb_f/ft^2)

K = crossflow resistance coefficient (dimensionless)

S_{ij} = total gap width connecting channels i and j (S_{ij}=s for subchannel analysis) [ft]

ρ^* = density of the diversion crossflow (lb_m/ft^3)

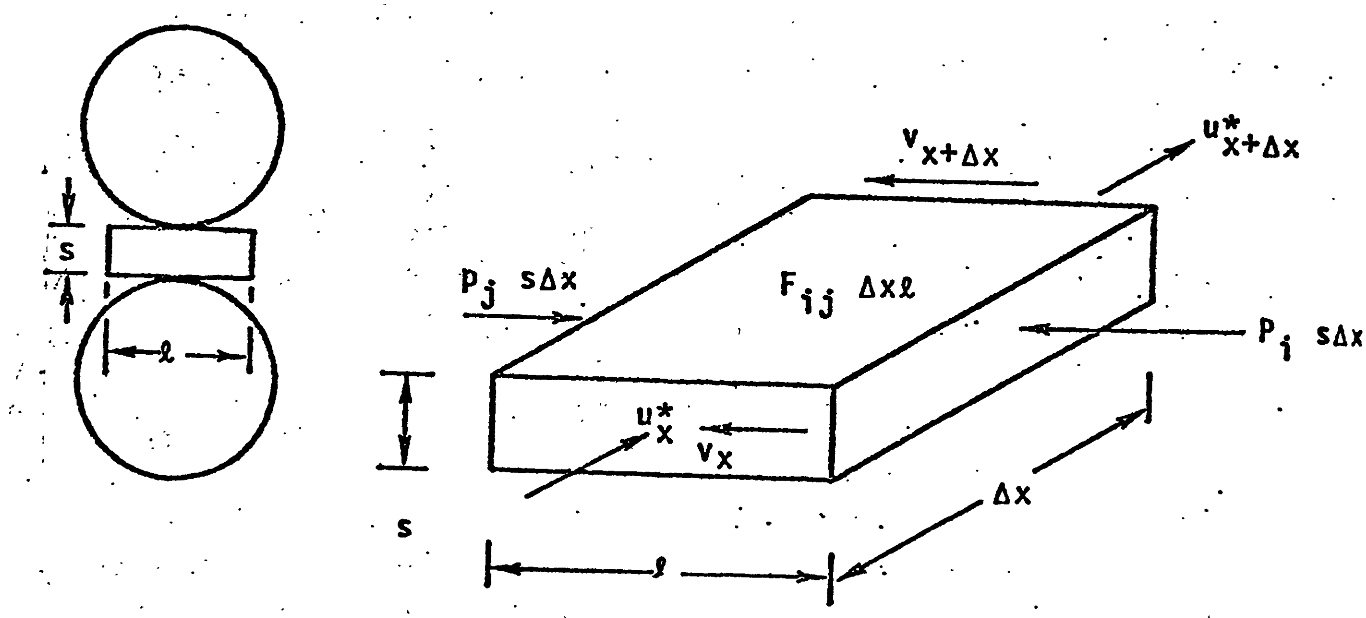

Figure I-1

COBRA Transverse Momentum Control Volume

2. The Weisman Approach

The Weisman approach (Ref. 14) casts the transverse momentum equation in a more general form, allowing interconnection of different-sized channels.

$$\frac{\partial}{\partial t}[W_{ij}] + \frac{\partial(u^* W_{ij})}{\partial x} = (\frac{S}{L})_{ij}(P_i - P_j) - F_{ij} \quad \text{(Eqn. I-3)}$$

where

$$F_{ij} = \frac{K|W_{ij}|W_{ij}}{2(S_{ij})^2 \rho^*} (\frac{S}{L})_{ij}(N_r)_{ij} \quad \text{(Eqn. I-4)}$$

and

$$S_{ij} = (N_g)_{ij} s \quad \text{(Eqn. I-5)}$$

$$L_{ij} = (N_r)_{ij} \ell \quad \text{(Eqn. I-6)}$$

where

$(N_g)_{ij}$ = number of gaps through which flow between channels i and j takes place

(N_r) = number of rods between centers of channels i and j .

For subchannel or bundle-to-bundle analysis, $N_g = N_r$ for all flow region interconnections. Thus, the Weisman approach reduces to the old COBRA approach for such analyses. Figure I-2 shows two interconnected regions of different size, a situation where the Weisman approach applies.

3. The Chiu Approach

The Chiu approach (Ref. 44) differs from the Weisman approach in the control volume used. Chiu uses the interaction of the adjacent rows of subchannels of two regions to represent the interaction between two regions, as shown in Figure I-3. This approach uses the following transverse momentum equation.

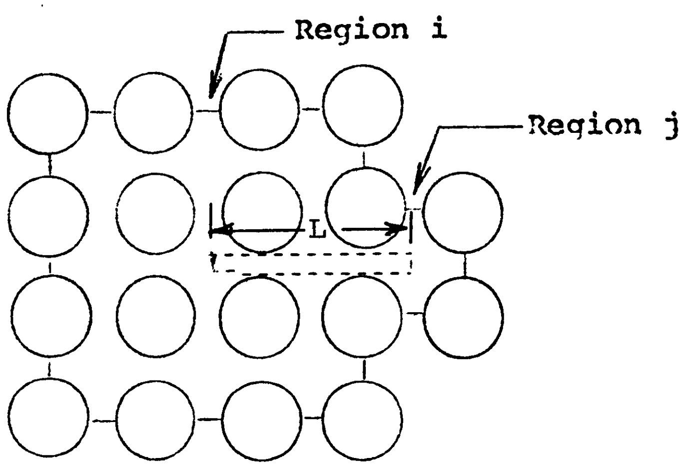

Figure I-2

Transverse Momentum Control Volume for Weisman Approach

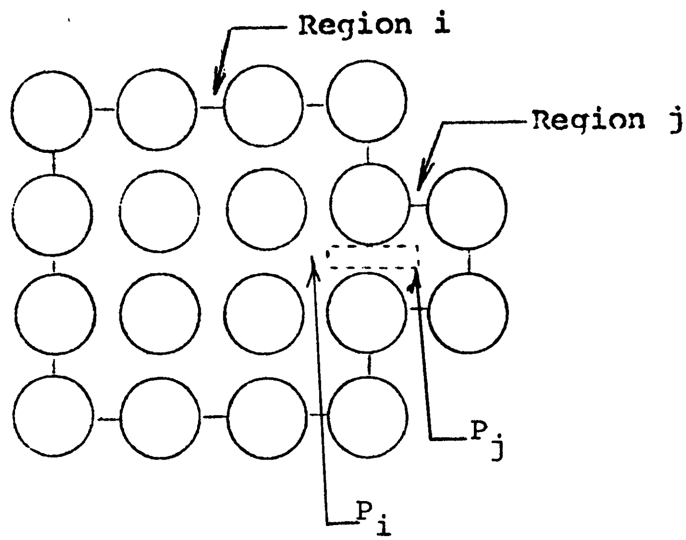

Figure I-3

Transverse Momentum Control Volume for Chiu Approach

$$\frac{\partial}{\partial t}[W_{ij}] + \frac{\partial(u^*W_{ij})}{\partial x} = \frac{S_{ij}}{\ell}\,\frac{(P_i - P_j)}{(N_p)_{ij}} - F_{ij} \qquad \text{(Eqn.I-7)}$$

where

$$F_{ij} = \frac{K|W_{ij}|W_{ij}}{2(S_{ij})^2\rho^*}\,\frac{S_{ij}}{\ell} \qquad \text{(Eqn.I-8)}$$

and

$$(N_p)_{ij} = \frac{(P_i - P_j)}{(p_i - p_j)} \qquad \text{(Eqn.I-9)}$$

where

$(N_p)_{ij}$ = the pressure transport coefficient for subchannels adjacent to the boundary between subchannels i and j.

p_i = pressure in interacting subchannel(s) of channel i adjacent to gap interconnection ij (lb_f/ft^2).

p_j = pressure in interacting subchannel(s) of channel j adjacent to gap interconnection ij (lb_f/ft^2).

During the development of the single-pass method (Ref. 12), use of the pressure transport coefficient was found to have little effect upon COBRA-IIIC/MIT enthalpy predictions, especially in comparison to changes resulting from use of an enthalpy transport coefficient in COBRA's energy equation. Both pressure and enthalpy transport coefficients were found to be unnecessary for single-pass MDNBR analysis under conditions without strong crossflow.

APPENDIX J

Data Used for 1/8 Core Single-Pass Analysis Case (Ref. Section IV.B Part 5)

Operating Conditions

System reference pressure	2100 psia
Average mass flux	2.48 Mlb/hr ft^2
Average heat flux	0.1695 MBTU/hr ft^2
Inlet coolant temperature	541°F

Geometry

The 20 channel layout shown in Figure IV-30 is used for the analysis. The channels are 136.7 inches in length. The fuel rod pitch is 0.58 inches.

Grid Spacer Data

Nine grid spacers are modeled in each channel. The relative axial locations and associated drag coefficient are given below.

x/L	Drag Coefficient
0.0	1.105
0.090	.461
0.228	.461
0.366	.461
0.504	.461
0.642	.461
0.780	.461
0.918	.461
1.0	1.015

Power Distribution Data

A total of 24 fuel rods are modeled (Ref. Figure II-6 of Section II.E). The radial power factors used are listed below.

Rod Number	Radial Power Factor
1	0.9976
2	1.120
3	1.25
4	1.273
5	1.352
6	1.280
7	1.365
8	1.330
9	1.334
10	1.273
11	1.116
12	1.40
13	1.353
14	1.249
15	1.273
16	1.119
17	1.30
18	1.29
19	1.251
20	1.130
21	1.130
22	1.135
23	1.140
24	1.140

Each rod has the dimensions and consists of the same physical properties. These data are:

Fuel Diameter - 0.3765 in.
Clad O.D. - 0.44 in.
Clad Thickness - 0.028 in.
Fuel Density - 650. lb/ft^3
Fuel Thermal Conductivity - 1.4 BTU/hr ft°F
Fuel Specific Heat - 0.08 BTU/lb°F
Clad Density - 410. lb/ft^3

Clad Thermal Conductivity - 8.8 BTU/hr ft°F
Clad Specific Heat - 0.078 BTU/lb°F
Fuel-Clad Gap Conductance - 600. BTU/hr ft^2°F

The axial power distribution used is shown in Figure II-7 (Ref. Section II.E).

Thermal Hydraulic Parameters

The following values were used for various other thermal hydraulic parameters.

Single Phase Friction - $f = 0.184\ Re^{-0.2}$
Two-Phase Friction - Homogeneous Model
Two-Phase Slip - Equal to 1
Subcooled Void Fraction - Levy Model
Mixing β - 0.02
K factor - 0.5
s/ℓ factor - 0.5

APPENDIX K

PWR Transient Test Case Data

Nine channels were used to represent the Maine Yankee core for the three pump loss of flow transient analyzed with COBRA-IIIC/MIT.

Operating Conditions

The following operating conditions were used:

a) System Pressure - 2200. psia
b) Average Inlet Mass Flux - 2.29×10^6 lb/hr-ft^2
c) Average Heat Flux - 0.1821×10^6 Btu/hr-ft^2
d) Inlet Coolant Temperature - 546. °F

Dimension of Channels

Channel	Flow Area(in^2)	Wetted Perimeter(in)	Heated Perimeter(in
1, 3, 5, &7	0.1843	1.382	1.382
2 & 6	0.2309	1.695	1.178
4	0.0918	0.9083	0.5496
8	33.00	251.0	210.1
9	895.80	6813.0	6107.0

Channel Length = 136.7 in.

Channel Numbering Map

0	8	8	8	8	8
0	2	1	0	8	8
6	4	3	5	5	8
8	0	7	0	6	8
8	8	8	8	8	8
9	9	9	9	9	9

Gap Boundary Data

1-2	0.140
1-3	0.140
1-8	0.280
2-4	0.1396
2-8	0.2796
3-4	0.140
3-5	0.140
3-7	0.140
4-6	0.1396
5-6	0.140
5-8	0.280
6-8	0.2796
7-8	0.420
8-9	7.280

Power Distribution

The axial power distribution used is shown in Figure K-1. Fifteen fuel rods were modeled using the radial power factors given in Table K-1.

Fuel Rod Modeling

Fuel pin geometry is as follows:

Fuel Pellet Diameter - 0.44 in

Clad O.D. - 0.3675 in

Clad Thickness - 0.028 in

Some cases used constant and others used temperature-dependent fuel and clad properties. Constant fuel and clad properties used were:

Fuel Density - 650 lb/ft^3

Fuel Thermal Conductivity - 1.5 Btu/hr-ft-°F

Fuel Specific Heat - 0.08 Btu/lb-°F

Clad Density - 410 lb/ft^3

Clad Thermal Conductivity - 8.8 Btu/hr-ft-°F

Clad Specific Heat - 0.078 Btu/lb-°F

Fuel-Clad Gap Heat Transfer Coefficient - 600 Btu/hr-ft^2-°F

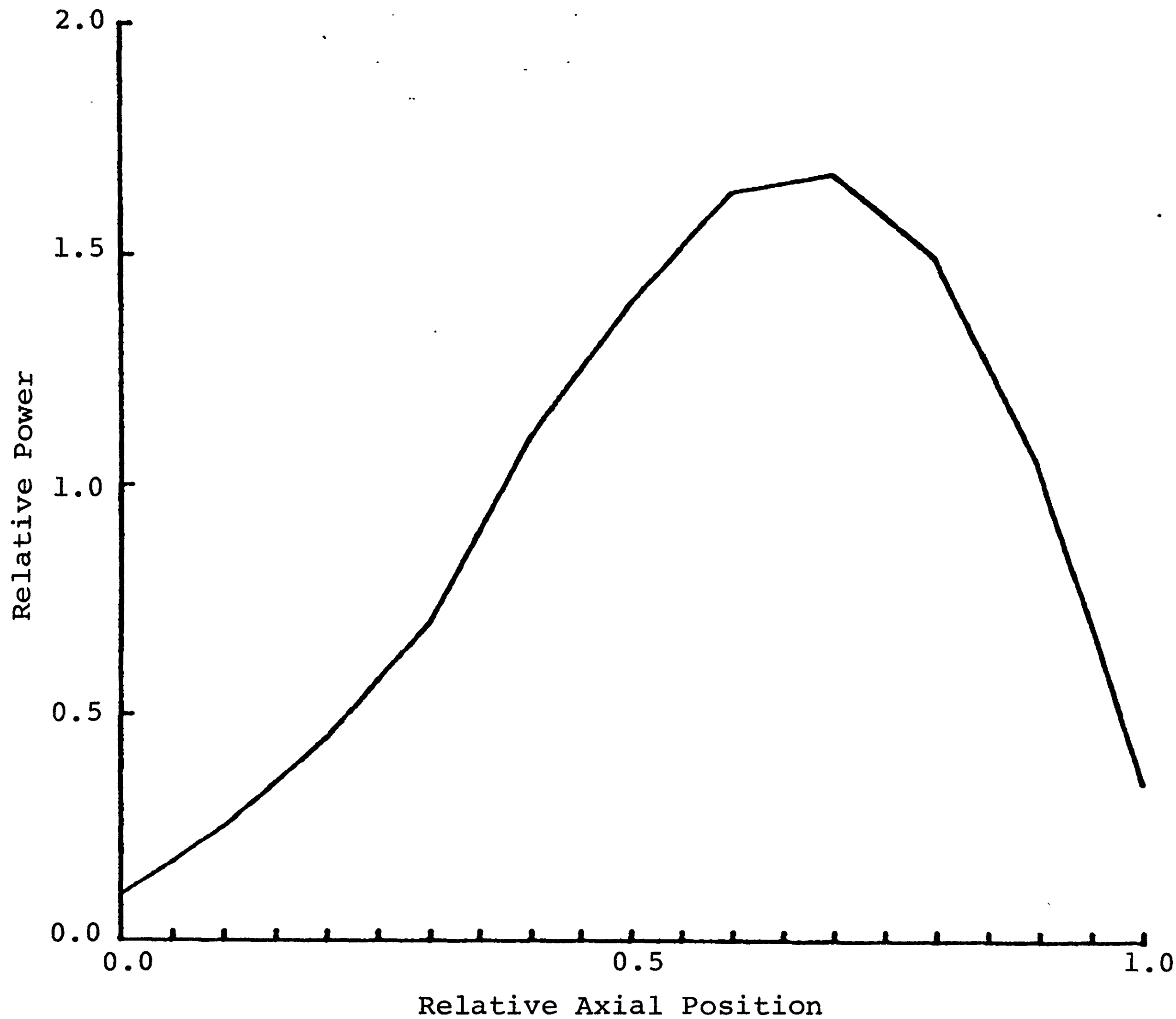

Figure K-1

Axial Power Distribution
Loss of Flow Transient

Table K-1

Radial Power Factors Used for PWR Transient Test Case

Rod	Radial Power Factor	Fraction of Power(Channel)			
1	1.475	.2564(1)	.7692(8)		
2	1.475	.2564(1)	.2564(2)	.5128(8)	
3	1.475	.3089(2)	.7166(8)		
4	1.475	.2564(1)	.2867(3)	.2564(7)	.2564(8)
5	1.611	.2442(1)	.2942(2)	.2730(3)	
6	1.475	.2867(3)	.2564(5)	.2564(7)	.2564(8)
7	1.475	.2867(3)	.2039(4)	.2564(5)	.3089(6)
8	1.475	.2564(5)	.7692(8)		
9	1.475	.2564(5)	.2564(6)	.5128(8)	
10	1.475	.3089(6)	.7166(8)		
11	1.475	.2564(7)	.7692(8)		
12	1.475	.2564(7)	.7692(8)		
13	1.264	168.2(8)			
14	0.9495	4716.(9)			
15	1.711	.1943(4)			

Spacer Friction Data

Nine grid spacers were modeled in each channel. The relative locations and associated drag coefficients are given in Table K-2.

Thermal-Hydraulic Models

The following thermal-hydraulic models were used for all cases:

Single-Phase Friction - $f = 0.184\ R_e^{-0.2}$

Two-Phase Friction - Homgeneous Model

Two-Phase Slip - Equal to 1

Subcooled Void Fraction - Levy Model

Mixing - $\beta = 0.0062 (\frac{D}{s}) R_e^{-0.10}$

k factor - 0.5

Transverse Friction Factor, k - 0.5

s/ℓ Factor - 0.5

Rod-to-coolant heat transfer was calculated using old model in some cases and new model for pre-CHF conditions in other cases.

Transient Forcing Functions

Transient forcing functions assumed are shown in Figure IV-30. Average inlet flow rate was specified for all cases. Average heat flux was specified for cases which used no fuel rod model. Average power level was specified for cases which used a fuel rod model.

Time Step Size

A time step size of 0.25 sec. was used for all cases.

Table K-2

Grid Spacer Data for PWR Transient Test Case

x/L	Drag Coefficient
0.0050	1.105
0.0877	0.4605
0.2194	0.4605
0.3511	0.4605
0.4828	0.4605
0.6144	0.4605
0.7461	0.4605
0.8778	0.4605
0.995	1.015

Appendix L

BWR Transient Test Case Data

Shoreham Used to Represent the Turbine Trip Without Bypass Transient*

Description of Input Used for COBRA-IIIC/MIT Analysis

Two channels were considered. One represented a "central hot" assembly and the other, a "central average" assembly. Both assemblies were 8x8. The channels were divided into twenty axial nodes.

Operating Conditions

The following operating conditions are used in all cases:

a) System Pressure - 1031 psia

b) Average Inlet Mass Flux - 1.10×10^6 lb/hr-ft^2

c) Average Heat Flux - 0.1512×10^6 Btu/hr-ft^2

Dimensions of Channels

Two channels are used in each of the cases. The dimensions of both channels are as follows:

a) Flow Area - 15.82 in^2

b) Wetted Perimeter - 118.25 in

c) Heated Perimeter - 94.08 in

d) Channel Length - 150.0 in

Power Distribution

The axial power distribution used in all cases is given in Figure L-1. Channel 1, used to represent a hot central assembly, has the radial peaking factor 1.4. Channel 2, used to represent an average central assembly, has the radial peaking factor of 1.04.

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*Ref. discussion in section IV.C.2

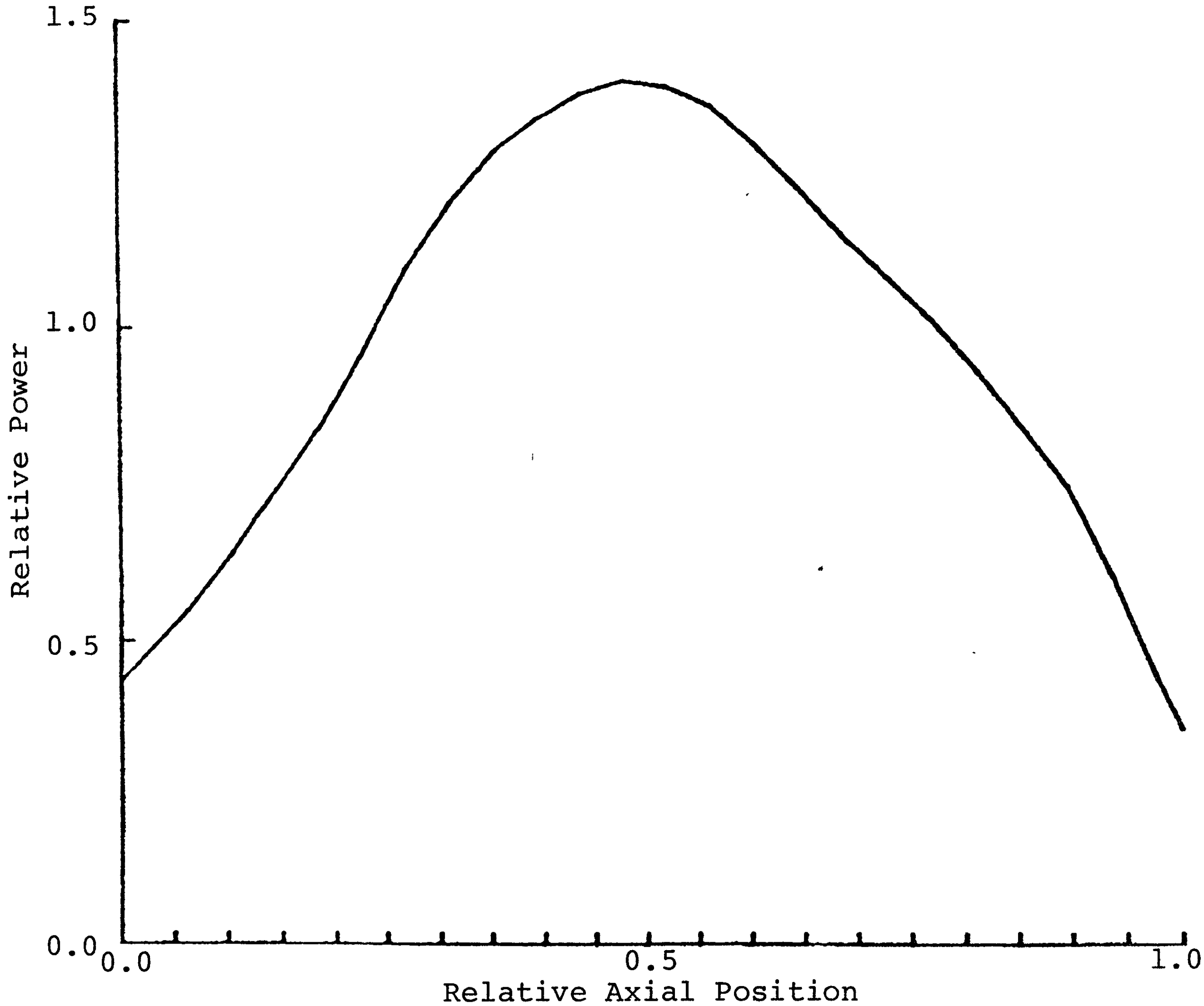

Figure L-1

Axial Power Distribution
Turbine Trip Transient

Fuel Rod Modeling

Fuel pin geometry is as follows:

Fuel Pellet Diameter - 0.410 in

Clad O.D. - 0.483 in

Clad Thickness - 0.032 in

Cases were run with constant properties in some instances and temperature-dependent properties in others. The constant physical property used are as follows:

Fuel Density - 640.0 lb/ft^3

Fuel Thermal Conductivity - 2.0 Btu/lb-ft-°F

Clad Specific Heat - 0.08 Btu/lb-°F

Clad Density - 405.0 lb/ft^3

Clad Thermal Conductivity - 8.8 Btu/hr-ft-°F

Clad Specific Heat - 0.076 Btu/lb-°F

Fuel-clad Gap Conductance - 500 Btu/hr-ft^2-°F

Rod to Coolant Heat Transfer Modeling

Some cases were analyzed using the old heat transfer model while others were analyzed using the new heat transfer model.

Spacer Data

Nine grid spacers are used to represent seven actual grid spacers, orificed fuel supports, and upper tie plates. Grid locations and coefficients for the two channels are as follows:

Axial Location (x/L)	Grid Type	Grid Coefficient Channel 1	Channel 2
0.01	1	33.0	33.0
0.714	2	1.0	1.0
0.2143	2	1.0	1.0
9.3571	2	1.0	1.0
0.5000	2	1.0	1.0
0.6429	2	1.0	1.0
0.7857	2	1.0	1.0
0.9289	2	1.0	1.0
0.9900	3	10.0	19.0

Thermal Hydraulic Models

The following thermal-hydraulic models are used for all cases:

Single-Phase Friction - $f = 0.184\ Re^{-0.2}$

Two-Phase Friction - Baroczy Model

Subcooled Void Fraction - Levy Model

Two-Phase Slip - Smith Model

Rod-to-coolant heat transfer calculated using old model in some cases and new model for pre-CHF conditions in other cases.

Transient Forcing Functions

Average heat flux, average inlet flow rate, and system reference power were varied as a function of time as is shown in Figure IV-39.

APPENDIX M

Input Data Methods for the Improved Version of COBRA-IIIC/MIT

The improved version of COBRA-IIIC/MIT has three methods for data input, as discussed in Section V. This appendix gives a card-by-card description of input for each of the three input data types. "Input Data Presentation Based on that of COBRA-IIIC/MIT" is described on pp. M-2 to M-21. "Simplified COBRA-IIIC/MIT Input Data Presentation to Be Used for Assembly to Assembly Analysis of LWR" is described on pp. M-22 to M-56. "New INPUT DATA Presentation" is described on pp. M-57 to M-121. This last methods is the recommended method.

Input Data Presentation Based on that of COBRA-IIIC
(APPENDIX 10 of Ref. 1)

Card(s)	Type C1	Problem Array Size
Required to be present:		Always
FORTRAN READ list:		MC MG MN MR MX
FORTRAN FORMAT:		10I5
Read from Subroutine:		INDAT

Variable	Columns	Format	Description	CG
MC	1-5	I5	> No. of channels (NCHANL) in problem. NCHANL is set from NTHBOX on cards C5-C7, or in the original COBRA format, in Card Group 4.	--
MG	6-10	I5	> No. of gap interconnections[NK] between channels in problem. If this is not know, MG=2*MC is usually adequate but should be checked later. For a BWR, MG may be given as zero, when it is reset to 1 in CORE.	--
MN	11-15	I5	> No. of fuel nodal points in problem. This should be > (NODESF+1) on Card T1. If MN is given as zero, it is reset to 1 in CORE.	--
MR	16-20	I5	> No. of rods (NROD) in problem. For PWR and BWR, NROD=NCHANL, hence MR may be given=MC.	--
MX	21-25	I5	> No. of axial stations in problem. It may be given as NDX (Card C11) as it is increased by 1 immediately after reading in.	--

Notes:

(1) MC to MX are used to set the array sizes in the dynamic storage, hence they should be set too big rather than too small.

(2) Note that MC to MX are given in alphabetical order.

(3) The maximum problem size is limited to 30,000 words by the dimension of the DATA array given in the MAIN program and the value of KMAX given in the CORE subroutine. Users can alter this limit with appropriate changes in their source programs.

Revised by J. Loomis
May 1980

Card(s) Type	C2	Maximum Running Time
Required to be present		Always
FORTRAN READ list:		MAXT
FORTRAN FORMAT:		I5, 6E12.6
Read from Subroutine:		INDAT

Variable	Columns	Format	Description	CG
MAXT	1-5	I5	Maximum Running Time, Nominal value is 2000.	CONTROL

THE INPUT FOR A CASE REQUIRES A CASE CONTROL CARD FOLLOWED WITH UP TO 12 GROUPS OF INPUT INFORMATION. EACH OF THE 12 CARD GROUPS HAS A GROUP CONTROL CARD THAT IDENTIFIES THE GROUP NUMBER AND THE OPTIONS AVAILABLE FOR THAT GROUP.

GO TO THE CARD GROUP SPECIFIED BY NGROUP, IF THE DATA OF A CARD GROUP THE SAME AS THE PREVIOUS CASE, THEN THAT CARD GROUP AND ITS CONTROL MAY BE OMITTED.

Card C3	
Cards (s) Type C3	Case Control Card
Required to be present	Always
FORTRAN READ list	IPILE, KASE, J1, TEXT
FORTRAN FORMAT	I1, I4, I5, 17A4
Read from subroutines	INDAT

Variables	Format	Columns	Description
IPILE	I1	1	= 0
KASE	I4	2 - 5	Run identification number. If > 0, calculation continue If ≤ 0, calculation stops.
J1	I5	6 - 10	Printing option for standard COBRA output - as in COBRA III-C. = 1 print entire output = 2 print only operation conditions
TEXT	I7A4	11 - 78	Alphanumeric information to identify case

Card Group 1	Always
Required to be present	NGROUP N1
FORTRAN READ list	I5, I5
FORTRAN FORMAT	INDAT
Read from subroutine	

Variable	Columns	Format	Description
NGROUP	1-5	I-5	= 1 (to select Card Group 1)
N_1	6-10	I-5	≤ 0 : calculate physical properties from polynomials > 1 : the physical properties are given in the next N1 Cards as in the original COBRA.

Physical Properties

Required to be present	when N1(in Card Group 1) ≤ 0
FORTRAN READ list	N PH P2 N1
FORTRAN FORMAT	I5 F10.3 F10.3 I5
READ from subroutine	CARDS 1

Variable	Format	Columns		Description
N	I5	1-5	= 1:	PH defined as lowest pressure encountered in problem.
			= 2:	PH defined as lowest enthalpy encountered in problem
PH	F10.3	6-15		Lowest pressure (psia) if N1 = 1 or lowest enthalpy (Btu/lb) if N1 = 2.
P2	F10.3	16-25		Highest pressure (psia) encountered in problem.
N1	I5	26-30		Number of pressure steps generated by polynomial (maximum 30)

Notes:

The lowest pressure encountered in the problem is defined as that at which the lowest enthalpy would be the saturation value. For example, at 1000 psia the saturation enthalpy is 543 Btu/lb. At an inlet subcooling of 100 Btu/lb, the enthalpy would be 443 Btu/lb and this would be the saturation value at a pressure of about 470 psia. Thus, one would require physical property data over the range 470 (or less) psia to 1000 psia in order to include data which covered the enthalpy range.

To avoid translating the lowest enthalpy to pressure, the option of giving the enthalpy is included. The program translates this value to a pressure which is safely below that required using the expression

$$p = 6h^3 (h-1.35) / (h - 0.35)$$

when p = calculated pressure (psia), h = 0.01H, H = enthalpy (Btu/lb).

The values of p, so calculated, are given below and it may be seen that they are all less than P_{sat}, the tabled value of pressure corresponding to H.

H(Btu/lb)	181.2	300	400	500	600	700
p(psia)	11	101	279	589	1067	1749
P_{sat}(psia)	15	103	319	745	1409	2236

In the original COBRA, the physical properties are read from cards into the arrays (PP(L), TT(L), etc., L = 1, N1). In the new version, the values of (PP(L), TT(L), etc., L = 1, N1) are generated within a Do Loop from 1 to N1 from the physical property polynomials. With the arrays set, the subsequent use of the values is the same in both versions of the code. Note: NPROP is set to N1 for storage of the size of the arrays.

	Physical Properties
Required to be present:	When N1 (in Card Group 1) > 0
Read from Subroutine	CARDS 1

READ IN N1 CARDS OF FLUID PROPERTY DATA.
EACH CARD CONTAINS -- SATURATION PRESSURE (PSIA), TEMPERATURE(DEG-F)

LIQUID SPECIFIC VOLUME (CU-FT/LB), VAPOR SPECIFIC VOLUME (CU-FT/LB)
LIQUID ENTHALPY(BTU/LB), VAPOR ENTHALPY(BTU/LB), LIQUID VISCOSITY

(LB/FT-HR), LIQUID THERMAL CONDUCTIVITY(BTU/HR-FT-F) AND SURFACE TENSION(LB/FT), FORMAT(E5.2,F5.1,7F10.0). N1 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER MP.

THIS PROPERTY TABLE MUST HAVE PRESSURE HIGHER THAN OPERATING PRESS. AND LIQUID ENTHALPY LOWER THAN THE BUNDLE INLET ENTHALPY.

CARD GROUP 2, FLOW CORRELATIONS

READ IN UP TO FOUR SETS OF FRICTION FACTOR CORRELATION CONSTANTS THAT CORRESPOND TO THE SUBCHANNEL TYPES, FORMAT(12F5.3).

N1 IS THE SUBCOOLED VOID CORRELATION OPTION. N1=0, NO SUBCOOLED VOIDS. N1=1, LEVY SUBCOOLED VOID CORRELATION.

N2 IS THE BULK VOID CORRELATION OPTION. N2=0, HOMOGENEOUS MODEL. N2 = 1, MODIFIED ARMAND MODEL. N2 =5, READ IN SLIP RATIO, FORMAT (5X,E10.5). N2=6, READ IN THE NUMBER OF TERMS AND COEFFICIENTS FOR UP TO A SIXTH ORDER POLYNOMIAL FUNCTION OF STEAM QUALITY, FORMAT (I5,7E10.5).

N3 IS THE TWO-PHASE FRICTION GRADIENT MULTIPLIER OPTION. N3=0, HOMOGENEOUS. N3=1, ARMAND. N3=5, READ IN NUMBER OF TERMS AND COEFFICIENTS FOR UP TO A SIXTH ORDER POLYNOMIAL FUNCTION OF QUALITY FORMAT(I5,7E10.5).

N4 IS AN OPTION TO INCLUDE A WALL VISCOSITY CORRECTION TO THE FRICTION FACTOR. IF N4=1, IT IS INCLUDED, OTHERWISE IT IS NOT.

CARD GROUP 3, AXIAL HEAT FLUX TABLE

READ IN N1 PAIR OF DATA FOR THE TABLE. EACH PAIR CONSISTS OF THE RELATIVE POSITION (X/L) AND THE CORRESPONDING RELATIVE HEAT FLUX (LOCAL FLUX/AVERAGE FLUX). EACH CARD ACCEPTS UP TO SIX PAIR OF DATA, FORMAT(12F5.3). N1 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER MP.

CARD GROUP 4, SUBCHANNEL LAYOUT AND DIMENSIONS

READ IN N1 CARDS OF SUBCHANNEL DATA CORRESPONDING TO THOSE SUBCHANNEL FOR WHICH DATA ARE BEING SUPPLIED. N2 IS THE TOTAL NUMBER OF SUBCHANNELS. FOR EACH OF THE N1 CARDS, READ IN THE SUBCHANNEL TYPE NUMBER (IF BLANK, IT IS ASSUMMED TYPE 1), SUBCHANNEL IDENTIFICATION NUMBER, NOMINAL FLOW AREA(SQ-IN.), WETTED PERIMETER (IN.), HEATED PERIMETER(IN.) AND UP TO FOUR SETS OF ADJACENT SUBCHANNEL CONNECTING INFORMATION, FORMAT(I1,I4,3E5.2,4(I5,2E5.2)). EACH SET OF CONNECTING INFORMATION INCLUDES THE ADJACENT SUBCHANNEL NUMBER (NEGATIVE IF A LINE OF SYMMETRY SPLITS A GAP AT A BOUNDARY), NOMINAL GAP SPACING AND CENTROID-TO-CENTROID DISTANCE(IN.). IF SUBCHANNELS ARE INPUT IN ASCENDING ORDER, THEN ONLY HIGHER NUMBER SUBCHANNELS NEED TO BE IDENTIFIED AS CONNECTIONS. CENTROID DISTANCES ARE NOT REQUIRED IF THEY ARE NOT USED IN THE MIXING CORRELATIONS. N2 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER MC.

CARD GROUP 5, SUBCHANNEL AREA VARIATION TABLE

IF THERE ARE NO AREA VARIATIONS, OMIT THIS CARD GROUP.

READ N2 VALUES OF RELATIVE LOCATION(X/L) WHERE AREA FACTORS ARE GIVEN FORMAT(12F5.3). N2 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER ML.

READ N1 SETS OF AREA VARIATION FACTORS (LOCAL AREA/NOMINAL AREA). EACH SET CONSISTS OF SUBCHANNEL NUMBER AND N2 AREA VARIATION FACTORS, FORMAT(I5/(12F5.3)). N1 IS LIMITED BY THE PARAMETER MA. IF N1 IS ZERO, AREA VARIATIONS ARE DELETED FOR SUCCEEDING CASES.

N3 IS THE NUMBER OF ITERATIONS FOR INSERTING AREA VARATIONS. IF N3 IS ZERO OR BLANK, N3 IS SET EQUAL TO 1.

CARD GROUP 6, GAP SPACING VARIATION TABLE

IF THERE ARE NO GAP VARIATIONS, OMIT THIS CARE GROUP.

READ N2 VALUES OF THE RELATIVE LOCATION(X/L) WHERE GAP FACTORS ARE GIVEN, FORMAT(12F5.3). N2 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER ML.

READ N1 SETS OF GAP SPACING FACTORS(LOCAL GAP/NOMINAL GAP). EACH SET CONSISTS OF THE ADJACENT SUBCHANNEL NUMBERS FOR THE GAP N2 GAP VARIATION FACTORS, FORMAT(2I5/(12F5.3)). N1 IS LIMITED BY PARAMETER MS. IF N1 IS ZERO, GAP VARIATIONS ARE DELETED FOR SUCCEEDING CASES.

CARD GROUP 7, SPACER DATA

IF N1=1, WIRE WRAP FORCED DIVERSION CROSSFLOW MIXING IS INCLUDED, OTHERWISE, IT IS OMITTED.

READ ONE CARD CONTAINING THE WIRE WRAP PITCH (IN.), PIN DIAMETER AND WIRE DIAMETER (IN.), FORMAT (8E10.5).

IF N1=1, N5 IS AN OPTION TO SAVE OR USE A PREVIOUSLY COMPUTED CROSSFLOW SOLUTION. THE FLOW CONDITION MUST NOT CHANGE FOR THESE CASES NOR THE BASIC PROBLEM SETUP. THIS OPTION WOULD NORMALLY BE USED FOR CASES INVOLVING CHANGES IN POWER OR MIXING FOR NONBOILING PROBLEMS.

N5=0, CROSSFLOW SOLUTION IS COMPUTED FOR EACH CASE.

N5=1, USE FIRST CASE SOLUTION FOR ALL SUCCEEDING CASES.

N5=2, WRITE SOLUTION TO TAPE AND USE FOR SUCCEEDING CASES.

N5=3, READ SOLUTION FROM TAPE AND USE FOR SUCCEEDING CASES.

FOR EACH GAP, READ A CARD CONTAINING THE GAP NUMBER, THE EFFECTIVE FRACTION OF A PITCH FOR FORCING CROSSFLOW AND UP TO SIX RELATIVE PITCH LENGTHS IDENTIFYING THE LOCATION OF WRAPS CROSSING THROUGH A GAP USING A POSITIVE VALUE FOR WRAPS CROSSING FROM I TO J AND A NEGATIVE VALUE FOR CROSSINGS FROM J TO I WHERE I IS LESS THAN J. THE GAP NUMBERS ARE ASSIGNED IN THE ORDER THAT SUBCHANNEL PAIRS ARE IDENTIFIED IN CARD GROUP 4.

READ IN THE NUMBER OF WRAPS CONTAINED IN EACH SUBCHANNEL AT THE START OF THE BUNDLE IN ASCENDING SUBCHANNEL ORDER, FORMAT(10I5). USE ENOUGH CARDS TO SPECIFY ENTIRE WRAP INVENTORY.

IF N1=2, SPACER PRESSURE LOSSES AND FORCED FLOW DIVERSION ARE INCLUDED OTHERWISE, THEY ARE OMITTED.
N2 IS THE TOTAL NUMBER OF SPACER LOCATIONS.
N3 IS THE NUMBER OF SPACER TYPES.
N4 IS THE NUMBER OF ITERATIONS TO INSERT LOSS COEFFICIENTS OR THE WIREWRAP MIXING. IF N4 IS BLANK OR ZERO, ONE IS USED.

READ N2 RELATIVE LOCATIONS(X/L) WHERE SPACERS ARE LOCATED AND THE TYPE OF SPACER AT THAT LOCATION, FORMAT(6(F5.2,I5)).

READ N3 SETS OF DATA CORRESPONDING TO EACH SPACER TYPE. EACH SET CONSISTS OF A CARD FOR EVERY SUBCHANNEL. ON EACH CARD IS THE SUBCH NUMBER, SPACER LOSS COEFFICIENT, CONNECTION NUMBER OF GAP THROUGH WHICH FLOW IS FORCED, AND FRACTION OF FLOW DIVERTED, FORMAT(2(I5,E5.0)) IF THE CONNECTION NUMBER IS ZERO AND THE FLOW FRACTION IS ZERO, THEN THERE IS NO FORCED FLOW DIVERSION. THE FORCED CROSSFLOW HAS THE SAME SIGN AS THE FORCED FLOW FRACTION.

CARD GROUP 8, ROD LAYOUT, DIMENSIONS AND POWER FACTORS

READ IN N1 CARDS OF ROD LAYOUT DATA CORRESPONDING TO THOSE RODS FOR WHICH DATA ARE BEING SUPPLIED. N2 IS THE TOTAL NUMBER OF RODS. FOR EACH OF THE N1 CARDS, READ THE ROD TYPE, NUMBER, DIA.(IN.), RELATIVE ROD POWER (ROD POWER/AVERAGE ROD POWER) AND UP TO SIX SETS DATA FOR ROD-TO-SUBCHANNEL CONNECTIONS, FORMAT [I1, I4, IE5.2, 6(I5, E5.0)] NUMBER AND FRACTION OF THE ROD POWER TO THAT SUBCHANNEL. THE NUMBER OF FUEL ROD TYPES ARE PRESENTLY LIMITED TO 2. N=1 INDICATES ROD FUEL. N=2 INDICATES PLATE FUEL. IN EACH CASE FOR PLATE FUEL THE ROD DIAMETER (ABOVE) IS THE PLATE THICKNESS AND THE FRACTION OF POWER TO A CHANNEL IS THE FRACTION OF THE CIRCUMFERENCE REQUIRED TO SPECIFY THE PLATE WIDTH FACING THE SUBCHANNEL.

N2 IS LIMITED BY THE PARAMETER MR.

N3 IS THE NUMBER OF RADIAL FUEL NODES INCLUDING THE CLADDING.

N4 IS THE TOTAL NUMBER OF FUEL TYPES.

FOR EACH FUEL TYPE, READ IN ON ONE CARD, THE THERMAL CONDUCTIVITY (B/HR-FT-F), SPECIFIC HEAT (B/LB-F), DENSITY (LB/FT3), AND PELLET DIAMETER (IN.) FOR THE FUEL, AND THE SAME FOR THE CLADDING EXCEPT FOR THICKNESS (I AND THE GAP COEFFICIENT (B/HR-FT]-F). THESE ARE ASSUMED CONSTANT. N5 IS AN OPTION TO SELECT A CRITICAL HEAT FLUX CORRELATION. IF N5=0, NO CHF CALCULATIONS ARE PERFORMED. IF N5=1, THE BAW-2 CORRELATION IS USED. IF N5=2, THE W-3 CORRELATION IS USED AND THE USER SHOULD VALIDATE THE TDC VALUE IN SUBROUTINE CHF. IF N5=3, THE HENCH-LEVY CORRELATION IS USED. IF N5=4, THE CISE-4 CORRELATION IS USED. OTHER CORRELATIONS OPTIONS CAN BE EASILY PROVIDED BY USERS.

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May 1980

CARD GROUP 9, CALCULATION VARIABLES

READ IN DIVERSION CROSSFLOW RESISTANCE FACTOR, TURBULENT MOMENTUM FACTOR, BUNDLE LENGTH(IN.), POSITION FROM VERTICAL(DEGREES), NUMBER OF AXIAL NODES, NUMBER OF TIME STEPS, TOTAL TRANSIENT TIME(SECONDS) MAXIMUM NUMBER OF ITERATIONS, ALLOWABLE FRACTION ERROR IN FLOW FORMAT CONVERGENCE AND TRANSVERSE MOMENTUM PARAMETER(S/L), FORMAT(4E5.2,2I5,E5.2,I5,4E5.2). IF THE NUMBER OF ITERATIONS, ALLOWABLE ERROR AND MOMENTUM PARAMETER ARE BLANK OR ZERO, THE PROGRAM USES 20., 1.E-3, AND .5, RESPECTIVELY.

N1 IS AN OPTION GIVING THE SPATIAL PRINTING INCREMENT. IF N1=1, STEP IS PRINTED. IF N2=2, EVERY OTHER STEP IS PRINTED, ETC. IF ZERO OR BLANK, THE PROGRAM SETS N1=1.

N2 IS AN OPTION GIVING THE TIME PRINTING INCREMENT AND IS SET UP SAME AS N1 ABOVE.

N3 IS A DEBUG PRINT OPTION. IF N3=0, NO DEBUG INFORMATION IS PRINT IF N3=1 A DEBUG PRINT IS MADE FOR EACH STEP OF THE CALCULATION. IT CAN GENERATE A LOT OF PAPER SO IT IS NOT NORMALLY USED.

CARD GROUP 10, TURBULENT MIXING CORRELATIONS

N1 IS THE OPTION FOR SUBCOOLED MIXING CORRELATIONS. FOR ANY N1<4 READ IN THE CONSTANTS A AND B, FORMAT(2F5.3). THE OPTIONS ARE --

N1=0, W/GS=A

N1=1, W/GS=A*RE**B

N1=2, W/GD=A*RE**B

N1=3, W/GS=D/ZIJ*A*RE**B

N1=4, NEW (BEUS) MIXING MODEL IS USED

NOTE THAT BETA = W/GS WHERE W IS THE TURBULENT CROSSFLOW.

N2 IS THE OPTION FOR TWO-PHASE MIXING. IF N2=1, TWO-PHASE MIXING IS THE SAME AS FOR SUBCOOLED CONDITIONS. IF N2 IS GREATER THAN ONE READ IN N2 PAIR OF DATA FOR A TABLE OF TWO-PHASE MIXING DATA. EACH PAIR CONSISTS OF THE STEAM QUALITY AND THE CORRESPONDING VALUE OF BETA. N2 IS LIMITED BY THE PARAMETER MP.

N3 IS THE OPTION FOR THERMAL CONDUCTION MIXING. IF N3=0, NO THERMA CONDUCTION. IF N3=1, READ IN THE THERMAL CONDUCTION GEOMETRY FACTOR FORMAT (F5.3).

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May 1980

CARD GROUP 11, OPERATING CONDITIONS

READ IN THE OPERATING PRESSURE(PSIA), INLET ENTHALPY(BTU/LB) OR INLET TEMPERATURE(DEG-F), MASS VELOCITY(M-LB/HR-SQ-FT) AND AVERAGE HEAT FLUX(M-BTU/HR-SQ-FT). (6F10.0)

N1 IS THE INLET ENTHALPY OPTION. IF N1=0, INLET ENTHALPY IS GIVEN. IF N1=1, INLET TEMPERATURE IS GIVEN. IF N1=2, READ IN THE INDIVIDUAL SUBCHANNEL INLET ENTHALPIES, FORMAT(12E5.0). IF N1=3, READ IN THE INDIVIDUAL SUBCHANNEL INLET TEMPERATURES, FORMAT(12E5.

N2 IS THE INLET FLOW DISTRIBUTION OPTION. IF N2=0, THE SUBCHANNELS ARE GIVEN THE SAME MASS VELOCITY. IF N2=1, THE INLET FLOW IS DIVID TO GIVE EQUAL PRESSURE GRADIENT IN THE SUBCHANNELS. IF N2=2, READ MASS VELOCITY FACTORS FOR EACH SUBCHANNEL, FORMAT(12E5.0).

N3, N4, N5 and N6 ARE OPTIONS FOR TRANSIENT FORCING FUNCTIONS. IF ANY OF THESE OPTION NUMBERS ARE ZERO OR BLANK, THE CORRESPONDING FORCING DATA IS NOT READ AND IS EXCLUDED FROM THE CALCULATIONS. EACH OF THESE NUMBERS GIVE THE NUMBER OF PAIRS OF TABULAR DATA TO BE RE FOR EACH FUNCTION. ALL DATA ARE READ AS PAIRS OF TIME(SECONDS) AND RELATIVE VALUE, FORMAT(12E5.0).

N3 IS THE OPTION FOR REFERENCE PRESSURE VERSUS TIME.
N4 IS THE OPTION FOR INLET ENTHALPY OR TEMPERATURE AS A FUNCTION OF TIME DEPENDING ON THE OPTION FOR INLET ENTHALPY OR TEMPERATURE.
N5 IS THE OPTION FOR INLET FLOW VERSUS TIME.
N6 IS THE OPTION FOR HEAT FLUX VERSUS TIME.

CARD GROUP 12, OUTPUT DISPLAY OPTIONS

N1 IS AN OPTION FOR PRINTING ANSWERS.

N1=0, PRINT SUBCHANNEL DATA ONLY.

N1=1, PRINT SUBCHANNEL DATA AND CROSSFLOWS.

N1=2, PRINT SUBCHANNEL DATA AND FUEL TEMPERATURES.

N1=3, PRINT SUBCHANNEL DATA, CROSSFLOWS AND FUEL TEMPERATURES.

N2 IS AN OPTION FOR SUBCHANNEL DATA PRINTOUT. IF N2=0, ALL SUBCHANNEL DATA ARE PRINTED. IF IT IS CALLED FOR BY N1. FOR N2 GREATER THAN Z READ IN THE SUBCHANNEL NUMBERS FOR WHICH RESULTS ARE TO BE PRINTED FORMAT(36I2).

N3 IS AN OPTION FOR FUEL TEMPERATURE PRINTOUT. IF N3=0, DATA FOR ALL RODS ARE PRINTED IF CALLED FOR BY N1. FOR N3 GREATER THAN ZERO, READ IN N3 ROD NUMBERS FOR WHICH TEMPERATURES ARE TO BE PRINTED, FORMAT(36I2). IF CHF DATA IS CALLED FOR BY INPUT OPTION IT IS PRINTED FOR EACH SELECTED ROD PLUS A SUMMARY TO IDENTIFY THE ROD AND CHANNEL WITH THE MINIMUM CHF RATIO.

N4 IS AN OPTION FOR FUEL NODE PRINTOUT. IF N4=0, TEMPERATURES ARE PRINTED FOR EVERY NODE. FOR N4 GREATER THAN ZERO, READ IN N4 NODE NUMBERS TO BE PRINTED, FORMAT(36I2).

TO START A CALCULATION, READ A BLANK GROUP CONTROL CARD.

TO STOP THE CALCULATIONS, AFTER FINISHING A CASE, READ A BLANK CASE

* * * * END OF INPUT INSTRUCTIONS * * * *

UNITS - ALL COMPUTATIONS ARE DONE USING FT, LB, SEC, BTU AND DEG-F. UNIT CHANGES FOR INPUT AND OUTPUT ARE DONE IN THE PROGRAM.

Simplified COBRA-IIIC Input Data Presentation to be used for Assembly to Assembly Analysis of LWR (APPENDIX 11 of Ref. 1)

Card(s)	Type C1	Problem Array Size
Required to be present:		Always
FORTRAN READ list:		MC MG MN MR MX
FORTRAN FORMAT:		10I5
Read from Subroutine:		INDAT

Variable	Columns	Format	Description	CG
MC	1-5	I5	> No. of channels (NCHANL) in problem. NCHANL is set from NTHBOX on cards C5-C7, or in the original COBRA format, in Card Group 4.	--
MG	6-10	I5	> No. of gap interconnections[NK] between channels in problem. If this is not know, MG=2*MC is usually adequate but should be checked later. For a BWR, MG may be given as zero, when it is reset to 1 in CORE.	--
MN	11-15	I5	> No. of fuel nodal points in problem. This should be > (NODESF+1) on Card T1. If MN is given as zero, it is reset to 1 in CORE.	--
MR	16-20	I5	> No. of rods (NROD) in problem. For PWR and BWR, NROD=NCHANL, hence MR may be given=MC.	--
MX	21-25	I5	> No. of axial stations in problem. It may be given as NDX (Card C11) as it is increased by 1 immediately after reading in.	--

Notes:

(1) MC to MX are used to set the array sizes in the dynamic storage, hence they should be set too big rather than too small.

(2) Note that MC to MX are given in alphabetical order.

(3) The maximum problem size is limited to 30,000 words by the dimension of the DATA array given in the MAIN program and the value of KMAX given in the CORE subroutine. Users can alter this limit with appropriate changes in their source programs.

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May 1980

Card(s) Type	C2	Maximum Running Time
Required to be present		Always
FORTRAN READ list:		MAXT
FORTRAN FORMAT:		I5, 6E12.6
Read from Subroutine:		INDAT

Variable	Columns	Format	Description	CG
MAXT	1-5	I5	Maximum Running Time, Nominal value is 2000.	CONTROL

THE INPUT FOR A CASE REQUIRES A CASE CONTROL CARD FOLLOWED WITH UP TO 12 GROUPS OF INPUT INFORMATION. EACH OF THE 12 CARD GROUPS HAS GROUP CONTROL CARD THAT IDENTIFIES THE GROUP NUMBER AND THE OPTIONS AVAILABLE FO THAT GROUP.

GO TO THE CARD GROUP SPECIFIED BY NGROUP. IF THE DATA OF A CARD GROU THE SAME AS THE PREVIOUS CASE, THEN THAT CARD GROUP AND ITS CONTROL MAY BE OMITTED.

Card(s) Type C3	Case Control Card
Required to be present	Always
FORTRAN READ list	1PILE, KASE, J1 TEXT
FORTRAN FORMAT:	I1, I4, I5, 17A4
Read from subroutine	INDAT

Variable	Column	Format	Description:
1PILE	1	I1	= 1: for PWR, with interconnected channels. = 2: for BWR, with separated channels.
KASE			as in Appendix 10
J1			as in Appendix 10
TEXT			as in Appendix 10

Card Group 1

Required to be present	Always
FORTRAN READ list	NGROUP N1
FORTRAN FORMAT	I5, I5
Read from Subroutine	INDAT

Variable	Columns	Format	Description
NGROUP	1-5	I5	= 1 (to select Card Group 1)
N1	6-10	I5	$\leq$ 0: Calculate physical properties from polynomials. > 1: the physical properties are given in the next N1 Cards as in the original COBRA.

Physical Properties

Required to be present	When N1(in Card Group 1) $\leq$ 0
FORTRAN READ List	N PH P2 N1
FORTRAN FORMAT	I5 F10.3 F10.3 I5
READ from subroutine	Cards 1

Variable	Columns	Format	Description
N	1-5	I5	= 1: PH defined as lowest pressure encountered in problem, = 2: PH defined as lowest enthalpy encountered in problem
PH	6-15	F10.3	Lowest pressure (psia if N1 = 1 or lowest enthalpy (Btu/lb) if N1 = 2
P2	16-25	F10.3	Highest pressure (psia) encountered in problem
N1	26-30	I5	Number of pressure steps generated by polynomial (maximum 30).

The lowest pressure encountered in the problem is defined as that at which the lowest enthalpy would be the saturation value. For example, at 1000 psia the saturation enthalpy is 543 Btu/lb. At an inlet subcooling of 100 Btu/lb, the enthalpy would be 443 Btu/lb and this would be the saturation value at a pressure of about 470 psia. Thus, one would require physical property data over the range 470 (or less) psia to 1000 psia in order to include data which covered the enthalpy range.

To avoid translating the lowest enthalpy to pressure, the option of giving the enthalpy is included. The program translates this value to a pressure which is safely below that required using the expression

$$p = 6h^3(h - 1.35) / (h - 0.35)$$

when p = calculated pressure (psia), h = 0.01H, H = enthalphy (Btu/lb).

The values of p, so calculated, are given below and it may be seen that they are all less than P_{sat}, the tabled value of pressure corresponding to H.

H(Btu/lb)	181.2	300	400	500	600	700
p(psia)	11	101	279	589	1067	1749
P_{sat}(psia)	15	103	319	745	1409	2236

In the original COBRA, the physical properties are read from cards into the arrays (PP(L), TT(L), etc., L = 1, N1). In the new version, the values of (PP(L), TT(L), etc., L = 1, N1) are generated within a Do Loop from 1 to N1 from the physical property polynomials. With the arrays set, the subsequent use of the values is the same in both versions of the code. Note: NPROP is set to N1 for storage of the size of the arrays.

Physical Properties

Required to be present | When N1 (in the card group 1) > 0

READ IN N1 CARDS OF FLUID PROPERTY DATA.
EACH CARD CONTAINS -- SATURATION PRESSURE (PSIA), TEMPERATURE(DEG-F
LIQUID SPECIFIC VOLUME(CU-FT/LB), VAPOR SPECIFIC VOLUME(CU-FT/LB),
LIQUID ENTHALPY(BTU/LB), VAPOR ENTHALPY(BTU/LB), LIQUID VISCOSITY
(LB/FT-HR), LIQUID THERMAL CONDUCTIVITY(BTU/HR-FT-F) AND SURFACE
TENSION(LB/FT), FORMAT(E5.2,F5.1,7F10.0). N1 MUST BE GREATER THAN
ONE BUT NOT GREATER THAN THE PARAMETER MP.

THIS PROPERTY TABLE MUST HAVE PRESSURE HIGHER THAN OPERATING PRESS.
AND LIQUID ENTHALPY LOWER THAN THE BUNDLE INLET ENTHALPY.

CARD GROUP 2, FLOW CORRELATIONS

READ IN UP TO FOUR SETS OF FRICTION FACTOR CORRELATION CONSTANTS THAT CORRESPOND TO THE SUBCHANNEL TYPES, FORMAT(12F5.3).

N1 IS THE SUBCOOLED VOID CORRELATION OPTION. N1=0, NO SUBCOOLED VOIDS. N1=1, LEVY SUBCOOLED VOID CORRELATION.

N2 IS THE BULK VOID CORRELATION OPTION. N2=0, HOMOGENEOUS MODEL. N2 = 1, MODIFIED ARMAND MODEL. N2=5, READ IN SLIP RATIO, FORMAT (5X,E10.5). N2=6, READ IN THE NUMBER OF TERMS AND COEFFICIENTS FOR UP TO A SIXTH ORDER POLYNOMIAL FUNCTION OF STEAM QUALITY, FORMAT (I5,7E10.5).

N3 IS THE TWO-PHASE FRICTION GRADIENT MULTIPLIER OPTION. N3=0, HOMOGENEOUS. N3=1, ARMAND. N3=5, READ IN NUMBER OF TERMS AND COEFFICIENTS FOR UP TO A SIXTH ORDER POLYNOMIAL FUNCTION OF QUALIT FORMAT(I5,7E10.5).

N4 IS AN OPTION TO INCLUDE A WALL VISCOSITY CORRECTION TO THE FRICTION FACTOR. IF N4=1, IT IS INCLUDED, OTHERWISE IT IS NOT.

CARD GROUP 3, AXIAL HEAT FLUX TABLE

READ IN N1 PAIR OF DATA FOR THE TABLE. EACH PAIR CONSISTS OF THE RELATIVE POSITION(X/L) AND THE CORRESPONDING RELATIVE HEAT FLUX (Local flux/AVERAGE FLUX), EACH CARD ACCEPTS UP TO SIX PAIR OF DATA, FORMAT(12F5.3). N1 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER MP.

Card Group 4	(Channel Data) Card (1)
Required to be present	when IPILE=1 or 2
FORTRAN READ list	NGROUP
FORTRAN FORMAT	I5
READ from subroutine	INDAT

Variable	Columns	Description
NGROUP	1-5	= 4 (To select Card Group 4)

NOTE: Once this card is read in the new subroutine CARDS 4 is entered for the remaining Read statements and Data processing of this Card Group 4.

Card (2)	
Required to be present:	when NGROUP = 4
FORTRAN READ list:	N1, N2, NGRID, NGRIDT, NODESF, NFUELT, NCHF, IMAP, ITEXT
FORTRAN FORMAT:	9I4
Read from subroutine;	CARDS4

Variable	Columns	
N1	1-4	Number of channel types [(max 15) see below]
N2	5-8	Total number of channels in problem
NGRID	9-12	Number of grid positions
NGRIDT	13-16	Number of types of grid
NODESF	17-20	Number of radial nodes on the fuel for center temperature calculation
NFUELT	21-24	Number of fuel types
NCHF	25-28	= 0 for no CHF calculations = 1 for B&W2 CHF correlation = 2 for W-3 correlation = 3 for Hench-Levy correlations = 4 for CISE-4 correlation
IMAP	29-32	= 1 to 4 to indicate method of presenting gap interconnection data [see Cards (9) below]
ITEXT	33-36	number of cards to be read in next which will be printed out as a message. If ITEXT=0, no message cards are read in

Note:

Channels are defined as being all of the same type if they have the same geometry, rod dimensions and grids and only differ in their power. More precisely, Cards (4) and (5) given later which define the geometry and grids must apply to all channels of the same type. In, for example, 1/4-core symmetry data, 1/4, 1/2 and whole channels would be different types.

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	Card (3)
Required to be present	when ITEXT > 0
FORTRAN READ list	TEXT
FORTRAN FORMAT	20A4
Read from Subroutine	CARDS4

Variable	Columns	Description
TEXT	1-80	The array TEXT (20) is read and immediately printed in a DO loop from 1 to ITEXT. It is envisaged that a map of the channel numbering system could be printed as an aide-memory in a large problem.

	Card (4)
Required to be present	Always (being NGROUP=4)
FORTRAN READ list	N,I,FRAC, AC(I), PW(I), PH(I) GAPS(I,1), DIST(I,1), DR(I), PHI(I,1), M
FORTRAN FORMAT	I1, I4, 8E9.3, I2
READ from subroutine	CARDS4

Variable	Columns	Description
N	1	Selector for friction factor expression. If N=0 reset to 1.
I	2 - 5	Any channel number, preferably the first of the channel type being described.
FRAC	6-14	Factor by which AC, PW, PH should be multiplied. Thus for 1/4 channel, one may give FRAC = 0.25 and AC, PW, PH the same as for a whole channel.
AC	15-23	Channel flow area (in^2)
PW	24-32	Channel wetted perimeter (in)
PH	33-41	Channel heated perimeter (in)
GAPS	42-50	Boundary gap dimensions (in)
DIST	51-59	Centroid-to-centroid channel distance (in). This is only required for a particular mixing correlation and may normally be given as zero.
DR	60-68	Rod diameter (in)
PHI	69-77	Number of rods in channel
M	78-79	Fuel type: = 1 for rod, = 2 for plate, Reset to 1 if M = 0

Card (5)

Required to be present	If NGRID > 0
FORTRAN READ list	(CD (I.L), L=1, NGRIDT), (FXF(L), L=1, NGRIDT)
FORTRAN FORMAT	16 E5.3
Read from subroutine	CARDS4

Variable	columns	Descriptions
CD		Spacer loss coefficients
FXF		Fraction of axial flow forced across each boundary. It is not expected that this would be used in reactor problems hence nominal value = 0.0

If N1 (Card (2)) is greater than one, cards describing channel and grid for channel type 2 will be given now, after these cards, the ones describing channel type 3 will be inputed and so on until the completion of the N1 channel types.

	Card (6)
Required to be present	Always
FORTRAN READ list	(Radial (I), I=1, NROD)
FORTRAN FORMAT	16 E5.3
Read from subroutine	CARDS4

Variable	Columns	Description
RADIAL	1-70	Radial power factor for rod I which is located in channel I. This is defined as the ratio of the rod power to that of the reactor average power.

Notes:

a) NROD is the total number of rods, having set to NCHANL (total number of channels) which was itself set to N2 (Card (2)).

b) If all rods have the same power, RADIAL (1) alone may be given and is set negative. THis triggers setting (RADIAL (I); I=1, NROD) = 1.0

	Card (7)
Required to be present	If NGRID > 0
FORTRAN READ list	(GRIDXL(L), IGRID(I), (I=1, NGRID)
FORTRAN FORMAT	8(E5.3, I5)
Read from subroutine	CARDS4

Variable	Columns	Description
GRIDXL		Relative location (z/L) where grids are located
IGRID		Type of grid at GRIDXL

	Card (3)
Required to be present	If N1 (Card(2) > 1
FORTRAN READ list	JB(I)
FORTRAN FORMAT	20I4
Read from subroutine	CARDS4

Variable	Columns	Description
JB	1-80	List of channels of Type 2

Notes:

The first set given is the list of channel numbers in Type 2. The list is terminated by reading in a zero (or a blank space). Hence, if the last channel number comes at the end of a card, a blank card must follow in order to give the terminating zero. It is safer to make a habit of punching a final zero. Following Type 2, card(s) are read in for those channels in Type 3, then Type 4 etc. up to N1 Types.

Note that since the channel numbers for Type 1 are not read in, it is more economical to select Type 1 as that with the majority of channels.

An internal consistency check is made when reading in JB(I). If a set includes the channel number (I in Card (4)) for Type 1 or does not include that given for its own type in Card (4), an appropriate message is printed and the run terminated.

If N1 = 1, the JB cards above are not given.

Card (9a)

Required to be present	only if IPILE = 1 (If IPILE = 2) BWR case, no cards are given sinc the channels are not connected) a IMAP = 1 (Card (2))
FORTRAN READ list	ICROSS, IDOWN
FORTRAN FORMAT	2I4
Read from subroutine	CARDS4

Variable	Columns	Description
ICROS	1-4	} see notes below
IDOWN	5-8	

NOTES

This option is only possible to use when the pattern of channel is rectangular. If this is the case, ICROSS is the number of columns and IDOWN the number of rows. For example, in the case represented in figure 1, ICROSS should be 4 and IDOWN 3. The maximum value for IDOWN and ICROSS is 20. The channels are sequentially numbered by the computer and the channel boundaries set in the IK, JK arrays; the oreder is that used to illustrate the case of IMAP = 4 (Card (9d)).

1	2	3	4
5	6	7	8
9	10	11	12

Figure 1.

Rectangular Matrix of Channels

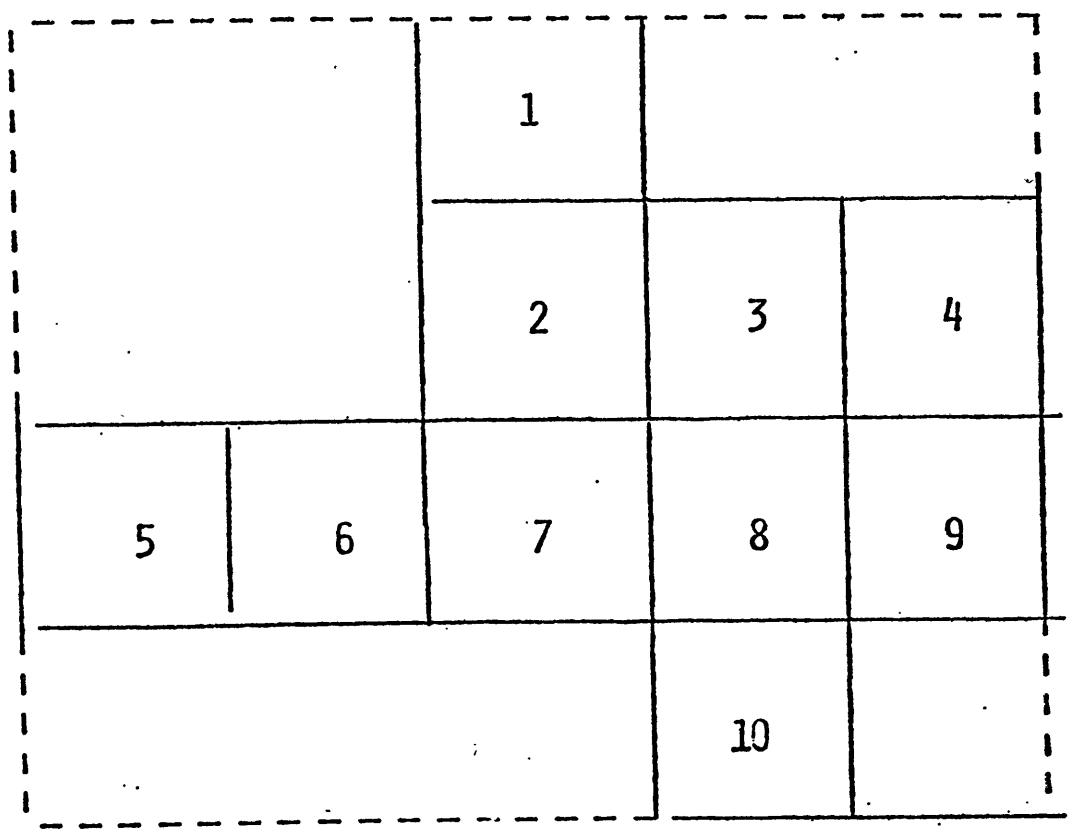

FIGURE 2
Irregular Pattern of Channels

	Card (9b)
Required to be present	Where IPILE = 1 and IMAP = 2
FORTRAN READ List	ISTART IEND
FORTRAN FORMAT	2I4
Read from subroutine	CARDS4

Variable	Columns	Description
ISTART	1-4	First channel in each row
IEND	5-8	Last channel in each row

Notes:

One of these cards should be given for each row. Note that this method could not be used if there were an insert blank channel in any row; for this case use IMAP = 3. The maximum value of IEND is 20 and the maximum number of rows is also 20. If less than 20 rows are to be given, a blank card (or one with two zero) should be given after the last row.

The computer numbers the channels and the boundaries sequentially as illustrated in Figures 1 and 2.

Examples follow:

For Figure 1 the following cards should be inputed:

ISTART	IEND
1	4
1	4
1	4
0	0

For Figure 2 the following cards should be inputed:

ISTART	IEND
3	3
3	5
1	5
4	4
0	0

	Card (9c)
Required to be present	When IPILE = 1 and IMAP = 3
FORTRAN READ list	(MAAP(L), L= 1,20)
FORTRAN FORMAT	20 I4
Read from subroutine	CARDS4

Variable	Columns	Description
MAAP	1-80	The number of the channels making up a row

Notes:

One of these cards should be inputed for each row (maximum 20 rows). The value of MAAP represents the channel number with a zero indicating no channel. If less than 20 cards are to be used, the last should be all zeros (i.e., a blank card). The set of cards represents a map of the channel numbering system, which is thus under the control of the user. The boundary ordering is done by the computer.

Examples:

For pattern described in figure 1

1	2	3	4
5	6	7	8
9	10	11	12
0	0	0	0

For pattern described in figure 2

0	0	1		
0	0	2	3	4
5	6	7	8	9
0	0	0	10	
0				

	Card (9d)
Required to be present	When IPILE = 1 and IMAP = 4
FORTRAN READ list	(IK(L), JK(L), L = 1,NK)
FORTRAN FORMAT	20 I4
Read from subroutine	CARDS4

Variable	Columns	Description
IK		} See notes below
JK		

Notes:

IK, JK are the channel pairs defining each boundary in turn; NK = number of boundaries specified. The set of numbers are read in, 20 to a card, continuing on as many cards as necessary. They are terminated by a zero; if the final channel number is at the end of a card, the zero must be given on the next card. (Note, the value of NK is not known at the time of reading in IK, JK; it is set to the number of pairs read in). Thus, with IMAP = 4, both channel and boundary numbering are under the control of the user. When listing the subchannel pairs, it is preferable to give the lower number first; this saves the computer reversing the order.

Card (9d)

Examples 1

For case in figure 2:

1 2 2 3 3 4 2 7 3 8 4 9 5 6 6 7 7 8 8 9

8 10 0 0

For Case in figure 1:

1 2 2 3 3 4 1 5 2 6 3 7 4 8 5 6 6 7 7

5 9 6 10 7 11 8 12 9 10 10 11 11 12 0 0

Card (10)

Required to be present	When IPILE = 1
FORTRAN Read list	JB(L), L = 1,
FORTRAN FORMAT	20 I4
Read from Subroutine	CARDS4

Variable	Columns	Description
JB	1-80	List the identification number of the channels making up each "half-boundary", i.e. the boundaries that are split by a line of symmetry.

Notes:

Always terminate with a zero. If there are no half boundaries, give a single card with a zero. The parameter FACTOR(K) is set to 1.0 for full boundaries and 0.5 for "half-boundaries".

	Card (11)
Required to be present	When NODESF > 0
FORTRAN READ list	(K FUEL(I), CFUEL(I), RFUEL(I), DFUEL(I), KCLAD(I), CCLAD(I), RCLAD(I), TCLAD(I), HGAP(I), I=1, NFUELT)
FORTRAN FORMAT	16E5.3
Read from subroutine	CARDS4

Variable	Columns	Description
KFUEL	1-5	Fuel thermal conduction ($\frac{BTU}{hrft\ °F}$)
CFUEL	6-10	Fuel specific heat $\frac{BTU}{lb\ °F}$
RFUEL	11-15	Fuel Density (lb/ft^3)
DFUEL	16-20	Pellet Diameter (in)
KCLAD	21-25	Cladding thermal conduction $\frac{BTU}{hrft\ °F}$
CLAD	26-30	Cladding specific heat $\frac{BTU}{lb\ °F}$
RCLAD	31-35	Cladding density (lb/ft^3)
TCLAD	36-40	Cladding thickness (in)
HGAP	41-45	Fuel-cladding heat transfer coefficient (BTU/ft^{2}hr°F)

CARD GROUPS 5, 6, 9, 10, 11 AND 12 ARE READ IN BY SUBROUTINE INDAT WITH THE FOLLOWING FORMAT:

CARD GROUP 5, SUBCHANNEL AREA VARIATION TABLE

IF THERE ARE NO AREA VARIATIONS, OMIT THIS CARD GROUP.

READ N2 VALUES OF RELATIVE LOCATION(X/L) WHERE AREA FACTORS ARE GIVEN FORMAT (12F5.3). N2 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER ML.

READ N1 SETS OF AREA VARATION FACTORS(LOCAL AREA/NOMINAL AREA). EACH SET CONSISTS OF SUBCHANNEL NUMBER AND N2 AREA VARIATION FACTORS, FORMAT(I5/(12F5.3)). N1 IS LIMITED BY THE PARAMETER MA. IF N1 IS ZERO, AREA VARIATIONS ARE DELETED FOR SUCCEEDING CASES.

N3 IS THE NUMBER OF ITERATIONS FOR INSERTING AREA VARATIONS. IF N3 IS ZERO OR BLANK, N3 IS SET EQUAL TO 1.

CARD GROUP 6, CAP SPACING VARIATION TABLE

IF THERE ARE NO GAP VARIATIONS, OMIT THIS CARD GROUP.

READ N2 VALUES OF THE RELATIVE LOCATION(X/L) WHERE GAP FACTORS ARE GIVEN, FORMAT(12F5.3). N2 MUST BE GREATER THAN ONE BUT NOT GREATER THAN THE PARAMETER ML.

READ N1 SETS OF GAP SPACING FACTORS(LOCAL GAP/NOMINAL GAP). EACH SET CONSISTS OF THE ADJACENT SUBCHANNEL NUMBERS FOR THE GAP N2 GAP VARIATION FACTORS, FORMAT(2I5/(12F5.3)). N1 IS LIMITED BY THE PARAMETER MS. IF N1 IS ZERO, GAP VARIATIONS ARE DELETED FOR SUCEED \SES.

CARD GROUP 9, CALCULATION VARIABLES

READ IN DIVERSION CROSSFLOW RESISTANCE FACTOR, TURBULENT MOMENTUM FACTOR, BUNDLE LENGTH(IN.), POSITION FROM VERTICAL(DEGREES), NUMBER OF AXIAL NODES, NUMBER OF TIME STEPS, TOTAL TRANSIENT TIME(SECONDS) MAXIMUM NUMBER OF ITERATIONS, ALLOWABLE FRACTION ERROR IN FLOW FORM CONVERGENCE AND TRANSVERSE MOMENTUM PARAMETERS(S/L), FORMAT(4E5.2, 2I5, E5.2, I5, 4E5.2). IF THE NUMBER OF ITERATIONS, ALLOWABLE ERROR AND MOMENTUM PARAMETER ARE BLANK OR ZERO, THE PROGRAM USES 20., 1.E-3, AND .5, RESPECTIVELY.

N1 IS AN OPTION GIVING THE SPATIAL PRINTING INCREMENT. IF N1=1, EVERY STEP IS PRINTED. IF N2=2, EVERY OTHER STEP IS PRINTED, ETC. IF N IS ZERO OR BLANK, THE PROGRAM SETS N1=1.

N2 IS AN OPTION GIVING THE TIME PRINTING INCREMENT AND IS SET UP THE SAME AS N1 ABOVE.

N3 IS A DEBUG PRINT OPTION. IF N3=0, NO DEBUG INFORMATION IS PRINTED IF N3=1, A DEBUG PRINT IS MADE FOR EACH STEP OF THE CALCULATION. IT CAN GENERATE A LOT OF PAPER SO IT IS NOT NORMALLY USED.

CARD GROUP 10, TURBULENT MIXING CORRELATIONS

N1 IS THE OPTION FOR SUBCOOLED MIXING CORRELATIONS. FOR N1<4 READ IN THE CONSTANTS A AND B, FORMAT(2F5.3).

THE OPTIONS ARE --

N1=0, W/GS=A

N1=2, W/GS=A*RE**B

N1=2, W/GD=A*RE**B

N1=3, W/GS=D/AIJ*A*RE**B

N1=4, NEW (BUES) MIXING MODEL IS USED

NOTE THAT BETA = W/GS WHERE W IS THE TURBULENT CROSSFLOW.

N2 IS THE OPTION FOR TWO-PHASE MIXING. IF N2=1, TWO-PHASE MIXING IS THE SAME AS FOR SUBCOOLED CONDITIONS. IF N2 IS GREATER THAN ONE READ IN N2 PAIR OF DATA FOR A TABLE OF TWO-PHASE MIXING DATA. EACH PAIR CONSISTS OF THE STEAM QUALITY AND THE CORRESPONDING VALUE OF BETA. N2 IS LIMITED BY THE PARAMETER MP.

N3 IS THE OPTION FOR THERMAL CONDUCTION MIXING. IF N3=0, NO THERMAL CONDUCTION. IF N3=1, READ IN THE THERMAL CONDUCTION GEOMETRY FACTOR FORMAT (F5.3).

CARD GROUP 11, OPERATING CONDITIONS

READ IN THE OPERATING PRESSURE (PSIA), INLET ENTHALPY (BTU/LB) OR INLET TEMPERATURE (DEG-F), MASS VELOCITY (M-LB/HR-SQ-FT) AND AVERAGE HEAT FLUX (M-BTU/HR-SQ-FT). (6F10.0)

N1 IS THE INLET ENTHALPY OPTION. IF N1=0, INLET ENTHALPY IS GIVEN. IF N1=1, INLET TEMPERATURE IS GIVEN. IF NL=2, READ IN THE INDIVIDUAL SUBCHANNEL INLET ENTHALPIES, FORMAT (12F5.0). IF N1=3, READ IN THE INDIVIDUAL SUBCHANNEL INLET TEMPERATURES, FORMAT (12E5.0).

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N2 IS THE INLET FLOW DISTRIBUTION OPTION. IF N2=0, THE SUBCHANNELS ARE GIVEN THE SAME MASS VELOCITY. IF N2=1, THE INLET FLOW IS DIVIDED TO GIVE EQUAL PRESSURE GRADIENT IN THE SUBCHANNELS. IF N2=2, READ MASS VELOCITY FACTORS FOR EACH SUBCHANNEL, FORMAT(12E.50).

N3, N4, N5 and N6 ARE OPTIONS FOR TRANSIENT FORCING FUNCTIONS. IF ANY OF THESE OPTION NUMBERS ARE ZERO OR BLANK, THE CORRESPONDING FORCING DATA IS NOT READ AND IS EXCLUDE FROM THE CALCULATIONS. EACH OF THESE NUMBERS GIVE THE NUMBER OF PAIRS OF TABULAR DATA TO BE READ FOR EACH FUNCTION. ALL DATA ARE READ AS PAIRS OF TIME (SECONDS) AND RELATIVE VALUE, FORMAT (12E5.0).

N3 IS THE OPTION FOR REFERENCE PRESSURE VERSUS TIME.
N4 IS THE OPTION FOR INLET ENTHALPY OR TEMPERATURE AS A FUNCTION OF TIME DEPENDING ON THE OPTION FOR INLET ENTHALPY OR TEMPERATURE.
N5 IS THE OPTION FOR INLET FLOW VERSUS TIME.
N6 IS THE OPTION FOR HEAT FLUX VERSUS TIME.

CARD GROUP 12, OUTPUT DISPLAY OPTIONS

N1 IS AN OPTION FOR PRINTING ANSWERS.
N1=0, PRINT SUBCHANNEL DATA ONLY.
N1=1, PRINT SUBCHANNEL DATA ANC CROSSFLOWS.
N1=2, PRINT SUBCHANNEL DATA AND FUEL TEMPERATURES.
N1=3, PRINT SUBCHANNEL DATA, CROSSFLOWS AND FUEL TEMPERATURES.

N2 IS AN OPTION FOR SUBCHANNEL DATA PRINTOUT. IF N2=0, ALL SUBCHAN DATA ARE PRINTED. IF IT IS CALLED FOR BY N1. FOR N2 GREATER THAN Z READ IN THE SUBCHANNEL NUMBERS FOR WHICH RESULTS ARE TO BE PRINTED FORMAT(36I2).

N3 IS AN OPTION FOR FUEL TEMPERATURE PRINTOUT. IF N3=0, DATA FOR ALL RODS ARE PRINTED IF CALLED FOR BY N1. FOR N3 GREATER THAN ZERO, READ IN N3 ROD NUMBERS FOR WHICH TEMPERATURES ARE TO BE PRINTED, FORMAT(36I2). IF CHF DATA IS CALLED FOR BY INPUT OPTION IT IS PRINTED FOR EACH SELECTED ROD PLUS A SUMMARY TO IDENTIFY THE ROD AND CHANNEL WITH THE MINIMUM CHF RATIO.

N4 IS AN OPTION FOR FUEL NODE PRINTOUT. IF N4=0, TEMPERATURES ARE PRINTED FOR EVERY NODE. FOR N4 GREATER THAN ZERO, READ IN N4 NODE NUMBERS TO BE PRINTED, FORMAT(36I2).

TO START A CALCULATION, READ A BLANK GROUP CONTROL CARD.

TO STOP THE CALCULATIONS, AFTER FINISHING A CASE, READ A BLANK CASE

**** END OF INPUT INSTRUCTIONS ****

UNITS - ALL COMPUTATIONS ARE DONE USING FT, LB, SEC, BUT AND DEG-F. UNIT CHANGES FOR INPUT AND OUTPUT ARE DONE IN THE PROGRAM.

New INPUT DATA Presentation
(APPENDIX 12 of Ref. 1)

Card(s) Type C1	Problem Array Size
Required to be present:	Always
FORTRAN READ list:	MC MG MN MR MX
FORTRAN FORMAT:	10I5
Read from Subroutine:	INDAT

Variable	Columns	Format	Description	CG
MC	1-5	I5	$\geq$ No. of channels (NCHANL) in problem. NCHANL is set from NTHBOX on cards C5-C7, or in the original COBRA format, in Card Group 4.	--
MG	6-10	I5	$\geq$ No. of gap interconnections[NK] between channels in problem. If this is not know, MG=2*MC is usually adequate but should be checked later. For a BWR, MG may be given as zero, when it is reset to 1 in CORE.	--
MN	11-15	I5	$\geq$ No. of fuel nodal points in problem. This should be > (NODESF+1) on Card T1. If MN is given as zero, it is reset to 1 in CORE.	--
MR	16-20	I5	$\geq$ No. of rods (NROD) in problem. For PWR and BWR, NROD=NCHANL, hence MR may be given=MC.	--
MX	21-25	I5	$\geq$ No. of axial stations in problem. It may be given as NDX (Card C11) as it is increased by 1 immediately after reading in.	--

Notes:

(1) MC to MX are used to set the array sizes in the dynamic storage, hence they should be set too big rather than too small.

(2) Note that MC to MX are given in alphabetical order.

(3) The maximum problem size is limited to 30,000 words by the dimension of the DATA array given in the MAIN program and the value of KMAX given in the CORE subroutine. Users can alter this limit with appropriate changes in their source programs.

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Card(s) Type	C2	Maximum Running Time
Required to be present		Always
FORTRAN READ list:		MAXT
FORTRAN FORMAT:		I5, 6E12.6
Read from Subroutine:		INDAT

Variable	Columns	Format	Description	CG
MAXT	1-5	I5	Maximum Running Time, Nominal value is 2000.	CONTROL

Card(s) Type C3	Case Control Card
Required to be present	Always
FORTRAN READ list:	IPILE KASE J1 TEXT
FORTRAN FORMAT:	I1, I4, I5, 17A4
Read from Subroutine:	INDAT

Variable	Columns	Format	Description	CG
IPILE	1	II	= 0 for simplified method = 1 for PWR = 2 for BWR The value is unimportant if Card Group 20 is selected since it is overwritten on card T1.	CONTROL
KASE	2-5	I4	Run Identification Number -- as in COBRA IIIC. If > 0, calculation continues; if ≤ , calculation stops.	
J1	6-10	I5	Printing option for standard COBRA output--as in COBRA IIIC. = 0 print only new input = 1 print entire input = 2 print only operating conditions This option is only effective if NOPRIN = 0, i.e., N1 = 0 on card C4	
TEXT	11-78		Alphanumeric information to identify Case.	

Card(s) Type C4	Select Card Group 20
Required to be present	Always
FORTRAN READ list:	NGROUP N1 N2 N3 N4 N5 N6
FORTRAN FORMAT:	7I5
Read from Subroutine:	INDAT

Variable	Columns	Format	Description	CG
NGROUP	1-5	I5	= 20	
N1	6-10	I5	Printing trigger, NOPRIN, set to N1. N1=0, standard COBRA IIIC printing obtained as well as as "new" printout. N1=1, standard COBRA printing suppressed.	CONTROL
N2-N6	11-35	I5	Leave blank	

Notes:

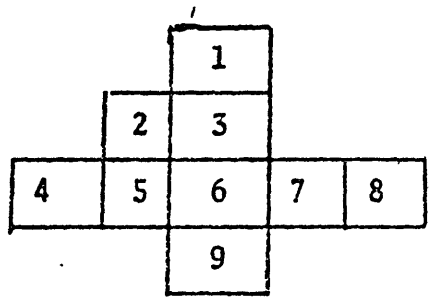
(1) If NGROUP = 0, this acts as a trigger to stop reading Input Data and to start the hydraulic calculation (.e.g., after card T30).

Card(s) Type C5	Channel Map parameter
Required to be present	Always
FORTRAN READ list:	IMAP ND1X ND2X
FORTRAN FORMAT:	14I5
Read from Subroutine:	CARD20

Variable	Columns	Format	Description	CG
IMAP	1-5	I5	Selects method of reading channel into array NTHBOX (ND1X, ND2X). IMAP=1, 2 or 3	--
ND1X	6-10	I5	Size of array NTHBOX, maximum values of each are 25.	--
ND2X	11-15	I5		--

If IMAP =	1	2	3
Go to Card	C8	C6	C7

The channel numbering system is contained in the array NTHBOX (ND1X, ND2X) with a zero for each non-channel. The array is later used to define the interaction between adjacent channels. Thus a channel map:



would be represented in NTHBOX (5, 4) as

0	0	1	0	0
0	2	3	0	0
4	5	6	7	8
0	0	9	0	0

If IMAP=1, there are assumed to be ND1X * ND2X channels numbered sequentially along each row, and column by column, to give a rectangular matrix. Thus IMAP=1, ND1X=4, ND2X=3 gives a channel map:

1	2	3	4
5	6	7	8
9	10	11	12

For IMAP=2, 3 more complicated channel maps may be specified.

Card(s) Type	C6	Channel Map
Required to be present		Only if IMAP=2
FORTRAN READ list:		ISTART IFIN
FORTRAN FORMAT:		14I5 ND2X Cards of this type read.
Read from Subroutine:		CARD20

Variable	Columns	Format	Description	CG
ISTART	1-5	I5	see below	--
IFIN	6-10	I5	" "	--

A total of ND2X cards of this type are read sequentially, one for each row of the channel map. Each card gives the start and finish of the row. For example, ISTART=3, IFIN=6 would imply a row 0 0 (N+1) (N+2) (N+3) (N+4) 0 0 etc. where channel N was the last channel in the previous row.

For IMAP=2, ND1X=7, ND2X=4, cards

3 3
3 6
1 7
2 2

would represent a channel map

		1				
		2	3	4	5	
6	7	8	9	10	11	12
	13					

Card(s) Type C7	Channel Map
Required to be present	Only if IMAP=3
FORTRAN READ list:	((NTHBOX (ND1, ND2), ND1=1, ND1X), ND2=1, ND2X)
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	CARD20

Variable	Columns	Format	Description	CG
NTHBOX	1-70	14I5	Channel identification number	--

If ND1X>14, the remaining numbers (i.e., 15-ND1X) are read on a comtinuation card. Note ND1X must not exceed 25. Each row of NTHBOX must start on a new card.

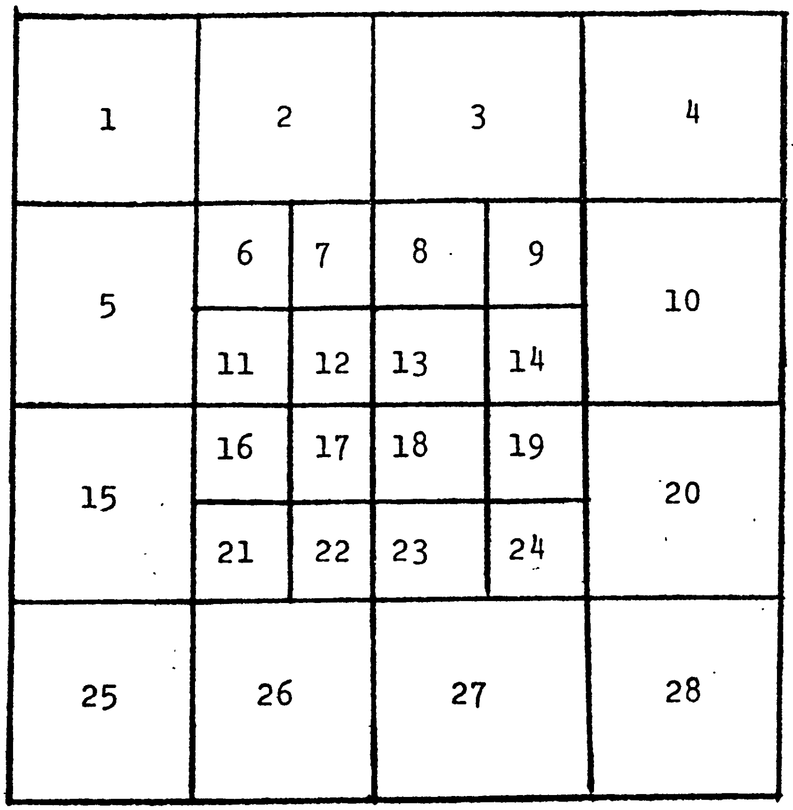
For IMAP=3, ND1X=7, ND2X=4, cards

```
0    0    1
0    0    2    3    4    5
6    7    8    9   10   11 12
0   13
```

would give the same channel map as that illustrating IMAP=2 (see card C6).

IMAP=3 could be used, either to specify a particular numbering system or when there are two channels in the same row separated by a "zero."

In the simplified method, (i.e. IPILE=0) cases as the one represented below may be required to be used. To input this kind of array only IMAP=3 is adequate. The cards needed are illustrated in the figure below.



IMAP=3, ND1X=6, ND2X=6 and

1	2	2	3	3	4
5	6	7	8	9	10
5	11	12	13	14	10
15	16	17	18	19	20
15	21	22	23	24	20
25	26	26	27	27	28

Card(s) Type	C8 Heat Flux
Required to be present	Always
FORTRAN READ list:	N1 AFLUX
FORTRAN FORMAT:	(I5, 13E5.0)
Read from Subroutine:	CARD20

Variable	Columns	Format	Description	CG
N1	1-5	I5	N1=0; trigger to read average nodal fuel powers after rest of data (Cards C12-14). NAX set to 0, IQP3 set to 0. N1=1; trigger to read average nodal fuel and coolant powers after rest of data (Cards 12-14). NAX set to 0, IQP3 set to 1. N1≥2; number of axial points at which heat flux profile will be given on following card C9. Maximum value of N1=30. NAX set to N1, IQP3 set to 2.	
AFLUX	6-10	E5.0	Reactor average heat flux in MBtu/ft^2h/. If N1=0 or 1, the value of AFLUX is irrelevant and may be given as zero.	11

Card(s) Type C9	Heat Flux Profile
Required to be present	Only if N1 on Card C8≥2
FORTRAN READ list:	(Y(I), AXIAL (I), I=1, N1)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	READIN/CARD20

Variable	Columns	Format	Description	CG
Y	1-70	E5.0	Normalised axial position along channel (x/L); $0 \leq Y \leq 1.0$	3
AXIAL	1-70	E5.0	Relative heat flux (local/average) corresponding to Y.	3

Card(s) Type	C10	Rod Power Factors
Required to be present		Only required if N1 on Card C8≥2
FORTRAN READ list:		(RADIAL (I), I=1, NCHANL)
FORTRAN FORMAT:		(14E5.0)
Read from Subroutine:		READIN/CARD20

Variable	Columns	Format	Description	CG
RADIAL	1-70	14E5.0	Relative Rod Power (local/average)	8

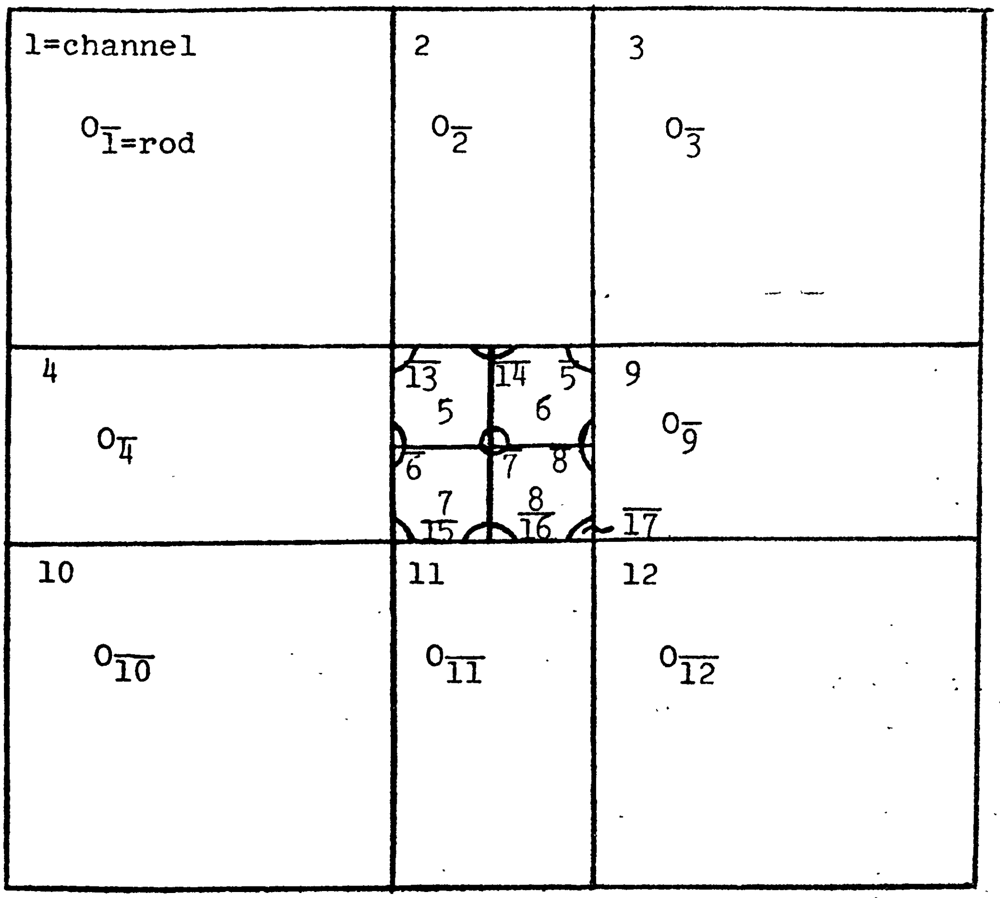
NCHANL = No. of channels in problem (≤MC in Card C1). It is set to the highest value of the channel map array NTHBOX -- see cards C5-C7.

Note

In the simplified method (IPILE≠0) some subchannels are lumped together to create one channel, while others are treated as individual subchannels (see figure below). For those every channel can be visualized as having only one rod that generates the whole power of the channel. In order to reduce the Input Data the power given to such a channel for its rod is specified here, while rods that share their power with several channels, will be described in Card T5a.

This system of entering the Data, reduces the cards required in the old presentation (do not forget that more than 150 channels can be used and only a few of them will be real subchannels) and only introduce the restriction that the lumped channels need to have the same identification number as its rod.

The following example clarifies all these points:



For this case, card C10 should have the actual relative rod power for channels 1, 2, 3, 4, zero for 5, 6, 7, 8 and the actual values for 9, 10, 11, and 12.

The power given to channels 5, 6, 7 and 8 from rods $\overline{13}$, $\overline{14}$, $\overline{5}$, $\overline{6}$, $\overline{7}$, $\overline{8}$, $\overline{15}$, $\overline{16}$, and $\overline{17}$ will be specified later in card T5a.

Card(s) Type	C11 Miscellaneous data
Required to be present	Always
FORTRAN READ list:	Z NDX NDT TTIME
FORTRAN FORMAT:	(E5.0, 2I5, 10E5.0)
Read from Subroutine:	CARD20

Variable	Columns	Format	Description	CG
Z	1-5	E5.0	Channel length (in.)	9
NDX	6-10	I5	Number of axial intervals	9
NDT	11-15	I5	Number of time steps NDT=0; steady state only NDT>0; steady state + transient	9
TTIME	16-20	E5.0	Total duration of transient (sec) The length of each time step is set to TTIME/NDT.	9

Card Type T1	Channel Indicators
Required to be present:	Always
FORTRAN READ list:	IPILE NCTYP NGRID NGRIDT NODESF NFXF IFRM IHTM IPROP
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
IPILE	1-5	I5	Iteration trigger=0 for simplified method=1 for PWR, =2 for BWR	
NCTYP	6-10	I5	No. of channel types to be read in; controls reading of cards T2-T4	--
NGRID	11-15	I5	No. of grid positions (maximum=10)	7
NGRIDT	16-20	I5	No. of grid types for each channel (maximum=5)	7
NODESF	21-25	I5	No. of fuel nodes	8
NFXF	26-30	I5	No. of "forced flow" types. Not in use; leave blank	--
IFRM	31-35	I5	Indicator for fuel rod model If IFRM=0, old model is used If IFRM=1, new model is used	--
IHTM	36-40	I5	Indicator for rod-to-coolant heat transfer model. If IHTM=0, old model ised used. If IHTM=1, new model for pre-CHF conditions is used. If IHTM=2, new model for pre- and post-CHF conditions is used.	--
IPROP	41-45	I5	Indicator for new fuel rod properties(used when IFRM=1). IPROP=0, constant fuel and clad properties, h_{gap}(gap conductance) constant. IPROP=1, temp-dep. fuel and clad, h_{gap} constant. IPROP=2, temp-dep. fuel and clad, h_{gap} calculated	--

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Card Type Tla	
Required to be present:	When NODESF>0 and either IFRM=1 or IHTM>0
FORTRAN READ list:	EPSF
FORTRAN FORMAT:	(E8.0)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
EPSF	1-8	E8.0	Fuel rod temperature convergence criterion. If EPSF is given as zero, it is set to the default value 10^{-2}.	--

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May 1980

Card(s) Type T2	Channel Data for Type I
Required to be present	Always
FORTRAN READ list:	N J FRAC GAP HNR DR A B C D
FORTRAN FORMAT:	(2I5, 8E5.0)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
N	1-5	I5	Friction Indicator to select friction factor for channel (seeT10). Nominal value=1, maximum=4.	4
J	6-10	I5	Indicator to define A, B, C, D below (=1 or 2)	--
FRAC	11-15	E5.0	Amount by which channel area, wetted and heated perimeters and number of heated rods are to be multiplied (see below).	--
GAP	16-20	E5.0	Effective rod gap for interconnection between channels (in.). If IPILE=0 this may be given as zero.	4
HNR	21-25	E5.0	No. of heated rods in fuel assembly.	8
DR	26-30	E5.0	Diameter of heated rods (in.)	8
If J=1:				
A	31-35	E5.0	Channel Flow Area (in^2)	4
B	36-40	E5.0	Channel Wetted perimeter (in.)	4
C	41-45	E5.0	Channel heated perimeter (in.)	4
D	46-50	E5.0	Not used--leave blank	--
If J=2:				
A	31-35	E5.0	No. of unheated (e.g., control) rods	--
B	36-40	E5.0	Diameter of unheated rods (in.)	--
C	41-45	E5.0	Width of square assembly (in.)	--
D	46-50	E5.0	Radius of channel corners (in.)	--

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Notes

(1) In COBRA IIIC, individual cards are read for each channel and rod. For PWR and BWR smeared assemblies, considerable simplification is possible because (a) there is a one-to-one correspondence between channels and rods, hence the data may be given together, and (b) many channels have identical geometries, hence one may give a typical geometry and specify to which channels it applies.

(2) Channels are of the same type if they are described by the same data on cards T2, T3.

(3) Cards T2, T3, T4 are read sequentially in a DO Loop I=1, NCTYP. Channels making up Types 2, NCTYP are specified on card T4. The unspecified channels are taken to be of Type 1, hence for economy, Type 1 should be defined as that which contains the majority of the channels.

(4) The channel area and perimeters may either be given directly (J=1) or calculated from the dimensions of the assembly (J=2).

(5) These parameters are multiplied by FRAC. Thus, if a line of symmetry divides a channel so that it is a half-channel, the data for a whole channel may be given and FRAC set to 0.5. Alternatively, data for a single channel may be given and FRAC

set to (say) 4.0 to obtain the parameters for a smeared group of 4 channels. If FRAC is given as zero, it is reset to 1.0.

(6) GAP is the "effective" gap between assemblies. For no internal resistance to mixing within an assembly, GAP could be considered to be the gap between individual rods * the number of gaps. This would be reduced according to the internal resistance model used.

(7) Next card read is:

NCTYP=1	NGRID > 0	Card T 5
	NGRID = 0	Card T 5a
NCTYP>1; I=1 (i.e., first type)		
	NGRID > 0	Card T3
	NGRID = 0	Card T2 for I=2
NCTYP>1: I>1 (i.e., subsequent types)		
	NGRID > 0	Card T3
	NGRID = 0	Card T4

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Card(s) Type T3	Grid Data for Channel Type I
Required to be present	Only if NGRID>0
FORTRAN READ list:	(CDG(L),L=1, NGRIDT)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
CDG	1-70	14E5.0	Single phase grid coefficient for each grid type.	7

Card(s) Type T4	Channels making up Type I
Required to be present	Only if I>1
FORTRAN READ list:	(JB(L), L=1, N)
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
JB	1-70	I5	Channel Identification Number for Type I	--

Notes:

(1) The channels of Type I are listed on one or more cards. A complete card is read and the numbers up to the first zero are taken as the relevant channels. The zero (or blank) must be given since it acts as a trigger, hence if the last channel number is at the end of a card, a blank card must follow to supply the terminating zero.

(2) Next card read is:

I = NCTYP	Card T5
I < NCTYP	Card T2

Card(s) Type T5	Grid Positions
Required to be present	Only if NGRID>0
FORTRAN READ list:	(GRIDXL(I), IGRID(I), I=1, NGRID)
FORTRAN FORMAT:	(7(E5.0, I5))
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
GRIDXL	1-70	E5.0	Fractional distance up channel (x/L) at which each grid is situated, i.e., $0 \leq GRIDXL \leq 1.0$	7
IGRID	1-70	I5	Grid Type; the coefficients for each type of grid were read by T3.	7

Card(s) Type T5a	Indicators
Required to be present:	only if IPILE=0
FORTRAN READ list:	NN11, NN22, NN33, NN44, ITMP
FORTRAN FORMAT:	(4I5)
Read from Subroutine:	CHAN

Variables	Columns	Format	Description	CG
NN11	1-5	I5	Cards of rod layout data to be read	8
NN22	5-10	I5	Total number of rods	8
NN33	10-15	I5	Number of radial fuel nodes including the cladding	8
NN44	15-20	I5	Total number of fuel types	8
ITMP	21-25	I5	Transverse momentum coupling parameter indicator. Parameters read by card(s) T7a if ITMP=1. No parameters read if ITMP=0.	--

Note:

(1) NN44 should equal 1 if IRFM=1 (on T1) because the new fuel rod model only considers cylindrical geometry.

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Card(s) Type	T5b	Rod layout information
Required to be present:		only if IPILE=0 and NN11 > 0
FORTRAN READ list:		N, I, DR(I), RADIA(I), (LR(I,L), PHI(I,L), L=1,6)
FORTRAN FORMAT		(I1, I4, 2E5.0,6(I3,E7.0))
Read from Subroutine:		CHAN

Variables	Columns	Format	Description
N	1	I1	Fuel rod type (1)
I	2-5	I4	Identification number of the rod
DR(I)	6-10	E5.0	Rod diameter (in)
RADIA(I)	11-15	E5.0	Relative rod power (rod power/average rod powe
LR(I,L)		I3	Adjacent channel number
PHI(I,L)		E7.0	Fraction of the rod power to that channel

Then one card for every rod considered is required.

(1) N=1 indicates rod fuel

N=2 indicates plate fuel

(2) This block is repeated 6 times (L=1,6)

Card(s) Type T6	Fuel temperature data
Required to be present	Only if NODESF>0
FORTRAN READ list:	KF(I), CF(I), RF(I), DF(I), KC(I), CC(I), C(I), TC(I), HG(I), I=(1,NN44)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
KF	1-5	E5.0	Fuel thermal conductivity (Btu/hr ft °F)	8
CF	6-10	E5.0	Fuel specific heat (Btu/lb °F)	8
RF	11-15	E5.0	Fuel density (lb/ft^3)	8
DF	16-20	E5.0	Pellet diameter (inch)	8
KC	21-25	E5.0	Clad thermal conductivity (Btu/hr ft °F)	8
CC	26-30	E5.0	Clad specific heat (Btu/lb °F)	8
RC	31-35	E5.0	Clad density (lb/ft^3)	8
TC	36-40	E5.0	Clad thickness (inch)	8
HG	41-45	E5.0	Fuel-to-clad heat transfer coefficient ($Btu/ft^2 hr$ °F)	8

Note:

(1) Fuel temperature data must be given even when IPROP>0

Note added by J. Loomis
May 1980

Card Type T6a	
Required to be present:	When NODESF>0 and IFRM=1
FORTRAN READ list:	NCF, NCC, THG
FORTRAN FORMAT:	(2I5, 8E5.0)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
NCF	1-5	I5	Number of radial clad cells	--
NCC	6-10	I5	Number of radial fuel cells	--
THG	11-15	I5	Gap thickness(in)	--

Added by J. Loomis
May 1980

Card Type T6b	
Required to be present:	When NODESF>0 and IFRM=1 and IPROP>0
FOTRAN READ list:	FTD, FPUO2
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
FTD	1-5	E5.0	Fraction of theoretical density of fuel	--
EPUO2	6-10	E5.0	PUO2 content, volume fraction	--

Added by J. Loomis
May 1980

Card Type	T6c
Required to be present:	When NODESF>0, IFRM=1, and IPROP=2
FORTRAN READ list:	BURN, CPR, EXPR, FPRESS, GRGH, GMIX, PGAS
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
BURN	1-5	E5.0	Burnup, MWD/MTU	--
CPR	6-10	E5.0	Coefficient of fuel pressure on clad for gap conductance model	--
EXPR	11-15	E5.0	Exponent for fuel pressure on clad	--
FPRESS	16-20	E5.0	Fuel pressure on clad for gap conductance model (psia)	--
GRGH	21-25	E5.0	RMS of fuel and clad roughness(in) GRG set equal to $1.6x10^{-5}$ in. if GRGH given as 0.	--
GMIX(1)	26-30	E5.0	Mole fraction of helium	--
GMIX(2)	31-35	E5.0	Mole fraction of argon	--
GMIX(3)	36-40	E5.0	Mole fraction of krypton	--
GMIX(4)	46-45	E5.0	Mole fraction of zenon	--
PGAS	46-50	E5.0	Pressure of gas mixture in gap (psia)	--

Note: The four elements of GMIX must sum to 1.0.

Added by J. Loomis
May 1980

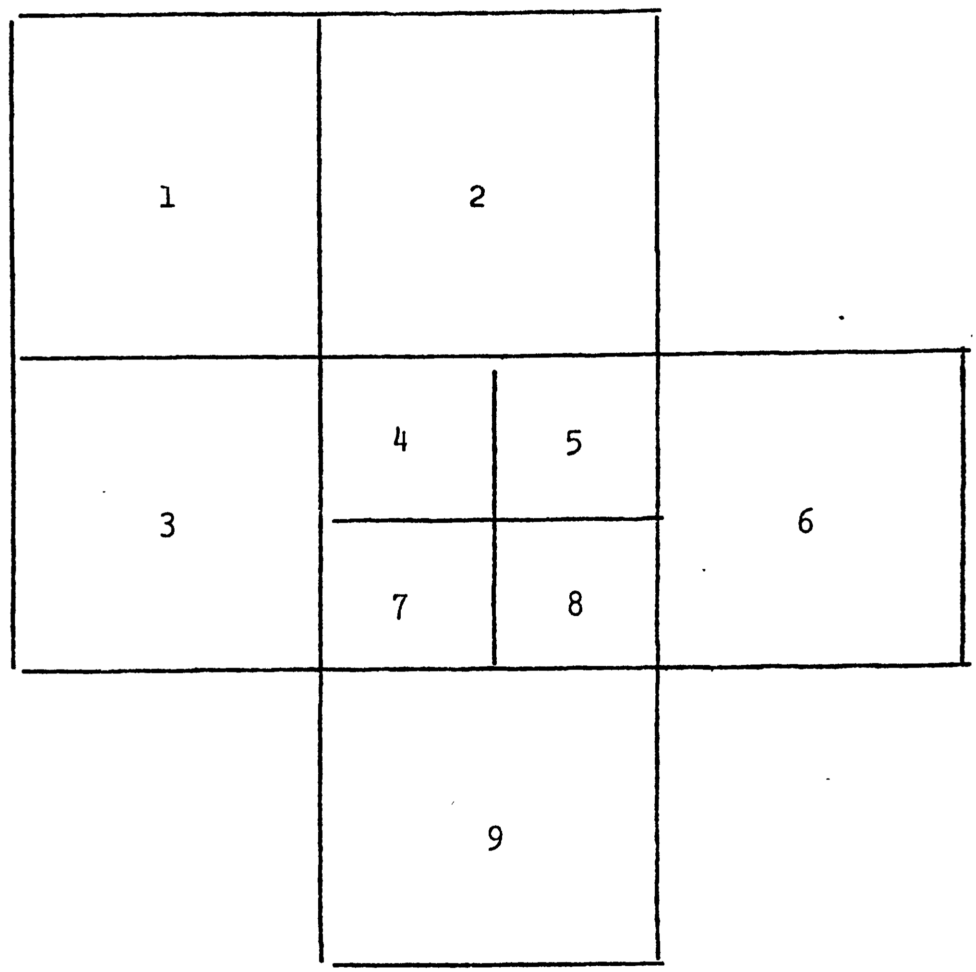
Card(s) Type T6d	Effective rod gap for interconnection between channels (in)
Required to be present:	Only if IPILE=0
FORMAT READ list:	(GAPREC(I),I=1,NK) where NK is the total number of gap interconnections
FORTRAN FORMAT:	14E5.0
Read from Subroutine:	CHAN

Variable	Columns	Description
GAPREC	1-70	Effective rod gap for interconnection between channels (in)

Notes

In order to give to each boundary its gap these gaps should be inputed in the same order as the boundaries are established. Then a few words are required to know how the boundaries are established.

For the following case the boundaries are established for the code as follows:



Boundary number

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Pair of channels making up each boundary

1-2 1-3 2-4 2-5 3-4 4-5 5-6 4-7 5-8 3-7 7-8 8-6 7-9 8-

and in general the boundaries are established by going from left to right in each row and from top to bottom between two consecutive rows.

Card(s) Type	T7	Transverse Momentum Coupling Parameters
Required to be present:		When IPILE=0 and ITMP(on card T5a)=1
FORTRAN READ list:		(FACSL(I), FACSLK(I), I=1,NK)
FORTRAN FORMAT:		(14E5.0)
Read from subroutine:		CHAN

Variable	Columns	Format	Description	CG
FACSL(I)		E5.0	Coupling parameter for gap I. May be set equal to the ratio of the number of inter-rod gaps at the boundary between the two regions separated by gap I, divided by the number of rows of rods separating the centroids of the two interconnected regions.	--
FACSLK(I)		E5.0	Second type of coupling parameter. May be set equal to the number of inter-rod gaps at the boundary of the two regions separated by gap I.	--

Note: The suggestions given in the above descriptions are for use of the "Weisman approach" for transverse momentum modeling which is discussed in Section III.F. FACSL corresponds to $(N_g/N_r)_{ij}$ and FACSLK corresponds to $(N_r)_{ij}$. The transverse momentum parameters could, alternatively, be used for the "Chiu appraoch."

Added by J. Loomis
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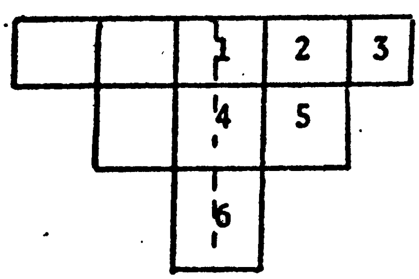
Card(s) Type T7a	PWR "Half-Boundaries"
Required to be present	Only if IPILE=1
FORTRAN READ list:	(II(L), JJ(L), L=1, N) where II(N)=0
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	CHAN

Variable	Columns	Format	Description	CG
II	1-70	I5	II(L), JJ(L) are the channel identification numbers which define the Lth "half-boundary."	--
JJ	1-70	I5		--

Notes:

(1) A "half-boundary" is one cut by a line of symmetry. In the example below the channel pairs defining the half-boundaries are 1 and 4, 4 and 6.



(2) The list of "half-boundaries" is terminated by a zero. If the list finishes at the end of a card, a blank card should follow to provide the zero-trigger.

(3) If there are no half-boundaries, give a blank card.

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Card(s) Type T8	Hydraulic Model Indicators
Required to be present	Always
FORTRAN READ list:	N1 N2 N3 N4 N5 N6 N7 N8 N9
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
N1	1-5	I5	Mixing Indicator	--
N2	6-10	I5	Single Phase Friction Indicator	--
N3	11-15	I5	Two Phase Friction Indicator	--
N4	16-20	I5	Void Indicator	--
N5	21-25	I5	Inlet Flow Indicator	--
N6	26-30	I5	Parameter Indicator	--
N7	31-35	I5	Iteration Indicator	--
N8	36-40	I5	Physical Property Indicator	--
N9	41-45	I5	Coupling parameter in the mixing term of the energy equation	--

Notes:

(1) If all N1-N9 given as zero (i.e., blank card) a preset hydraulic model is obtained and the next card read is T20. If any are given positive, the appropriate part of the model may be changed by giving extra card(s).

(2) The preset model is defined in the card-descriptions following for the appropriate Indicator=0.

(3) N9 = 0 means that no coupling parameter will be used.

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Card(s) Type	T9	Mixing Model
Required to be present:		Only if N1 (on T8) > 0 and N1 < 3
FORTRAN READ list:		ABETA BBETA
FORTRAN FORMAT:		(14E5.0)
Read from subroutine:		MODEL

Variable	Columns	Format	Description	CG
ABETA	1-5	E5.0	β= W/(G*S)=ABETA*(RE**BBETA) if N1=1 W/(G*D)=ABETA*(RE**BBETA) if N1=2 The new mixing model is used if N1=3	10
BBETA	6-10	E5.0		

Notes:

(1) If N1=0, then ABETA=0.02, BBETA=0.0, and W/(G*S)=ABETA*(RE**BBETA)

(2) Thermal conduction between channels is suppressed for all N1.

(3) The new mixing model is described in Section III.D.

(4) W is the mixing rate
RE is an average Reynolds number for the gap
S is the gap width
D is an average hydraulic diameter

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Card(s) Type T10	Single Phase Friction Model
Required to be present	Only if N2(on T8) > 0
FORTRAN READ list:	NVISCW, (A(J), B(J), C(J), J=1, 4)
FORTRAN FORMAT:	(I5, 13E5.0)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
NVISCW	1-5	I5	=1, if the wall viscosity correction to the single phase friction factor is required. =0, if not required.	2
A	6-65	E5.0	The single phase friction factor is calculated as A*(RE**B)+C, where RE=Reynolds Number.	2
B	6-65	E5.0		
C	6-65	E5.0		

Notes:

(1) The friction factor defined by A(J), B(J), C(J) is applied to those channels with that value of J on card T2. If all channels have the same friction factor, J is given as 1 on card T2 for all channel types and only A(1), B(1), C(1) given on card T10.

(2) If N2=0, NVISC is set to 0 and the smooth tube friction factor is used, i.e., A=0.184, B= -0.2 and C=0.0 for all J=1,4.

Card(s) Type T11	Two Phase Friction Model
Required to be present	Only if N3 (on T8)>0
FORTRAN READ list:	J4
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
J4	1-5	I5	Two phase friction correlation trigger	2

J4=0 Homogeneous Theory
=1 Armand
=2 Baroczy
=3,4 Not in use
=5 Polynomial in quality

Note:

If N3=0, J4 is set to 0.

Card(s) Type T12	Two phase friction polynomial
Required to be present	Only if J4 (on T11) = 5
FORTRAN READ list:	NF (AF(L), L=1, NF)
FORTRAN FOPMAT:	(I5, 13E5.0)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
NF	1-5	I5	No. of terms in polynomial (max=7)	2
AF	6-40	E5.0	Polynomial coefficients	2

Notes:

(1) The two phase friction multiplier is calculated as

$$\sum_{\gamma=1}^{\gamma=NF} (AF(\gamma) X^{\gamma-1})$$

where X = quality $(0 \leq X \leq 1)$

Card(s) Type T13	Void Fraction Model
Required to be present	Only if N4 (on T8) > 0
FORTRAN READ list:	J2 J3
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
J2	1-5	I5	Subcooled Void Indicator	2
J3	6-10	I5	Slip Ratio Indicator	2

J2=0 no subcooled void
=1 Levy subcooled void correlation

J3=0 Slip Ratio=1
=1 Armand Slip Ratio Correlation
=2 Smith Slip Ratio Correlation
=3,4 Not in use
=5 Slip ratio given (T14)
=6 Void fraction as a polynomial in quality (T14)

Note:

If N4=0, J2 and J3 are both set to 0.

Card(s) Type T14	Slip Ratio
Required to be present	Only if J3(on T13)=5 or 6
FORTRAN READ list:	NV (AV(L), L=1, NV)
FORTRAN FORMAT:	(I5, 13E5.0)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
NV	1-5	I5	No. of terms in polynomial (≤ 7)	2
AV	6-40	E5.0	Polynomial coefficients	2

A polynomial $\sum_{r=1}^{r=NV} (AV(r)X)$ is calculated where X=quality ($0 \leq X \leq 1$).

For J3=5, NV should be set to 1 and only one value of AV read in. The slip ratio is taken as AV(1).

For J3=6, up to 7 values of AV may be read in and the void fraction is calculated as a polynomial in X, namely:

$$\sum_{r=1}^{r=NV} (AV(r)X^{r-1})$$

Card(s) Type T15	Inlet Flow Model
Required to be present	Only if N5 (on T8) > 0
FORTRAN READ list:	IG
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
IG	1-5	I5	Inlet Flow Indicator	11

IG = 0 Inlet mass velocity same for all channels

IG = 1 Inlet mass velocities for channels calculated to give same inlet pressure gradient

IG = 2 Inlet mass velocities given (on T16)

Note

(1) If N5 = 0, IG set to 0.

Card(s) Type T16	Inlet Flow Distribution
Required to be present	Only if IG (on T15) = 2
FORTRAN READ list:	(GR(I), I=1, NCHANL)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	READIN/MODEL

Variable	Columns	Format	Description	CG
GR	1-70	E5.0	Inlet Mass Velocity Ratio (local/ average) for all NCHANL channels	11

Card(s) Type T17	Parameters
Required to be present:	Only if N6 (on T8)>0
FORTRAN READ list:	NCHF KIJ FTM SL THETA
FORTRAN FORMAT:	(I5, 13E5.0)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
NCHF	1-5	I5	Critical Heat Flux Correlation dicator. (1)	8
KIJ	6-10	E5.0	Cross-Flow Resistance Coefficient, k.	9
FTM	11-15	E5.0	Turbulent Momentum Factor, f_t.	9
SL	16-20	E5.0	Transverse Momentum Factor, S/L	9
THETA	21-25	E5.0	Inclination of channel to vertical (degrees).	9

(1) If NCHF=0 no CHF calculations are performed

If NCHF=1 the BAW-2 correlations is used

If NCHF=2 the W-3 correlation is used

If NCHF=3 the Hench-Levy correlation is used

If NCHF=4 the CISE-4 correlation is used

If NCHF=5 the Biasi/Void-CHF correlation is used

Note:

(1) If N6=0; NCHF set to 0, KIJ to 0.5, FTM to 0.0, SL to 0.5 and THETA to 0.0 (i.e. vertical).

(2) If NCHF=5 then IHTM must equal 2 on card T1.

Revised by J. Loomis
May 1980

Card(s) Type T18	Convergence Criteria
Required to be present	Only if N7 (on T8) > 0
FORTRAN READ list:	NTRIES FERROR
FORTRAN FORMAT:	(I5, 13 E5.0)
Read from Subroutine:	MODEL

Variable	Columns	Format	Description	CG
NTRIES	1-5	I5	Maximum permissable number of hydraulic iterations	9
FERROR	6-10	E5.0	Flow convergence criterion	9

Note

(1) If N7=0, NTRIES set to 20 and FERROR to 0.001.

Card(s) Type	T19	Physical Properties
Required to be present		Only if N8 (on T8) > 0
FORTRAN READ list:		NPROP N PH P2
FORTRAN FORMAT:		(2I5, 2E5.0)
Read from Subroutine:		MODEL

Variable	Columns	Format	Description	CG
NPROP	1-5	I5	No. of pressure points in physical property table for interpolating between (Minimum=2, Maximum=30).	1
N	6-10	I5	= 1 or 2 (see PH below)	--
PH	11-15	E5.0	N=1, PH=lowest pressure (psia) in problem. N=2, PH=lowest enthalpy (Btu/lb) in problem, from which the lowest pressure is calculated (see below).	--
P2	16-20	E5.0	Highest pressure in problem (psia)	--

Notes

(1) From this card, a table containing NPROP equi-spaced values of pressure from P1 (see below) to P2 is constructed giving relevant physical properties--calculated from polynomial expressions--at each pressure. Physical properties at intermediate pressures are found by linear interpolation.

(2) It is important that the table spans the physical property range of the problem. For example, with inlet subcooling, the inlet en-enthalpy would correspond to a pressure lower than the reference value; the pressure would be that at which the enthalpy was the saturation value. Hence the first pressure in the table should be lower than the value corresponding to the lowest steady state or transient enthalpy encountered, so that the other physical properties at that enthalpy may be properly interpolated. If N=1, PH is given as P1, the lowest pressure in the problem and if N=2, as the lowest enthalpy--the lowest pressure P1 is then calculated from PH.

(3) If N8=0, NPROP is set to 30 and P1, P2 calculated by the computer.

Revised by J.Liu
May 23, 1977

Card(s) Type T19a	Coupling parameters
Required to be present	Only if N9 (on T8) > 0
FORTRAN READ list:	(ENEH(K), K=1,NK) where NK=total number of boundaries
FORTRAN FORMAT:	14E5.0
Read from Subroutine:	MODEL

Variable	Columns	Format	Description
ENEH	1-70	E5.0	Coupling parameter introduce in the mixing term of the energy conservation equation.

Note: The order in which these coupling parameters should be entered is the same as the one described in card T6d for interconnection between channels.

Card(s) Type T20	Steady State Operating Conditions
Required to be present	Always
FORTRAN READ list:	IH HIN GIN PEXIT
FORTRAN FORMAT:	(I5, 13E5.0
Read from Subroutine:	OPERA

Variable	Columns	Format	Description	CG
IH	1-5	I5	Inlet Enthalpy Indicator	11
HIN	6-10	E5.0	IH=0: Inlet Enthalpy (Btu/lb) IH=1: Inlet Temperature (°F) IH=2,3: HIN not used, set to zero (see T21)	11
GIN	11-15	E5.0	Average Inlet Mass Velocity (Mlb/ft^{2}hr)	11
PEXIT	16-20	E5.0	System pressure (psia)	11

Card(s) Type T21	Inlet Enthalpy Distribution
Required to be present	Only if IH = 2 or 3
FORTRAN READ list:	(A(I), I=1, NCHANL)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	READIN/OPERA

Variable	Columns	Format	Description	CG
A	1-70	E5.0	IH=2: Inlet enthalpies for each channel (Btu/lb)	11
			IH=3: Inlet temperatures for each channel (°F)	

Card(s) Type T22	Transient Indicators
Required to be present	Always
FORTRAN READ list:	NP NH NG NQ
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	OPERA

Variable	Columns	Format	Description	CG
NP	1-5	I5	No. of points at which pressure transient forcing function will be given (T23). Maximum=30	11
NH	6-10	I5	As NP but inlet enthalpy (T24). Maximum=30	11
NG	11-15	I5	As NP but inlet flow (T25). Maximum=30	11
NQ	16-20	I5	As NP but channel power (T25a). Maximum=30	11

Notes

(1) NQ is only given in COBRA but not in MEKIN (leave NQ blank) as in MEKIN, the transient channel power is obtained from the Neutronics.

(2) If only steady state calculations are required, T22 may be a blank card.

Card(s) Type T23	Pressure Transient Forcing Function
Required to be present	Only if NP>1 (T22)
FORTRAN READ list:	(YP(I), FP(I), I=1, NP)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	READIN/OPERA

Variable	Columns	Format	Description	CG
YP	1-70	E5.0	Time (seconds)	11
FP	1-70	E5.0	Ratio of transient to steady state pressure at time YP	11

Notes

(1) YP(1), FP(1) should be given as 0.0 and 1.0 respectively.

(2) The value of FP at a time intermediate between two values of YP is found by linear interpolation.

Card(s) Type T24	Inlet Enthalpy Transient Forcing Function
Required to be present	Only if NH>1 (T22)
FORTRAN READ list:	(YH(I), FH(I), I=1, NH)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	READIN/OPERA

Variable	Columns	Format	Description	CG
YH	1-70	E5.0	Time (seconds)	11
FH	1-70	E5.0	Ratio of transient to steady state enthalpy or temperature (depending on IH--card T20) at time Y.H.	11

Notes

(1) As for card T23, but YH, FH instead of YP, FP.

Card(s) Type T25	Inlet Flow Transient Forcing Function
Required to be present	Only if NG > 1 (T22)
FORTRAN READ list:	(YG(I), FG(I), I=1, NG)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	READIN/OPERA

Variable	Columns	Format	Description	CG
YG	1-70	E5.0	Time (seconds)	11
FG	1-70	E5.0	Ratio of transient to steady state average mass velocity at time YG	11

Notes

(1) As for card T23, but YG, FG instead of YP, FP.

Card(s) Type T25a	Inlet Power Transient Forcing Function
Required to be present	Only if NQ > 1 (T22) and IQP3=2 (C8)
FORTRAN READ list:	(YQ(I), FQ(I), I=1, NQ)
FORTRAN FORMAT:	(14E5.0)
Read from Subroutine:	READIN/OPERA

Variable	Columns	Format	Description	CG
YQ	1-70	E5.0	Time (seconds)	11
FQ	1-70	E5.0	Ratio of transient to steady state channel power at time YQ	11

Notes

(1) As for card T23, but YP, FQ instead of YP, FP.

Card(s) Type T26	"Debug" Option
Required to be present	Always
FORTRAN READ list:	KDEBUG
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	TABLES

Variable	Columns	Format	Description	CG
KDEBUG	1-5	I5	"Debug" option =0: normal--no test printing =1: "debug"--with test printing	9

Card(s) Type T27	Output Printing
Required to be present	Always
FORTRAN READ list:	NSKIPX NSKIPT NOUT NPCHAN NPROD NPNODE
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	TABLES

Variable	Columns	Format	Description	CG
NSKIPX	1-5	I5	Axial print option =0 or 1: every axial step printed >1 : each (NSKIPX)th step printed	9
NSKIPT	6-10	I5	Time step option As for NSKIPX but time (not axial) steps	9
NOUT	11-15	I5	=0: print channel results only =1: channel + cross flow tables =2: channel + fuel temperature tables =3: channel + cross flow + fuel temperature tables	12
NPCHAN	16-20	I5	=0: all channels printed ≥1: read in NPCHAN channels to be printed	12
NPROD	21-25	I5	As for NPCHAN but rods instead of channels	12
NPNODE	26-30	I5	As for NPCHAN but radial fuel nodes instead of channels	12

Card(s) Type T28	Channels to be printed
Required to be present	Only if NPCHAN (T27) $\geq$ 1
FORTRAN READ list:	(PRINTC(I), I=1, NPCHAN)
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	TABLES

Variable	Columns	Format	Description	CG
PRINTC	1-70	I5	Identification Number of channels to be printed.	12

Card(s) Type T29	Rods to be printed
Required to be present	Only if NPROD (T27) $\geq$ 1
FORTRAN READ list:	(PRINTR(I), I=1, NPROD)
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	TABLES

Variable	Columns	Format	Description	CG
PRINTR	1-70	I5	Identification Number of rods to be printed.	12

Card(s) Type T30	Fuel nodes to be printed
Required to be present	Only if NPNODE (T27) ≥ 1
FORTRAN READ list:	(PRINTN(I), I=1, NPNODE)
FORTRAN FORMAT:	(14I5)
Read from Subroutine:	TABLES

Variable	Columns	Format	Description	CG
PRINTN	1-70	I5	Radial fuel nodes to be printed 1=rod center, (NODESF + 1)=outer clad surface	12

Card(s) Type C4	End Input Data, start calculation
Required to be present	Always
FORTRAN READ list:	BLANK CARD
FORTRAN FORMAT:	
Read from Subroutine:	INDAT

Variable	Columns	Format	Description	CG
				CONTROL

Note:

At this point in the calculation, control returns to reading Card C4. If NGROUP = 1-12, more Input Data are read in the original COBRA format, these later data overwriting what has already been read in. If NGROUP = 0, calculation starts.

Card(s) Type	C12	Nodal Power Multiplier
Required to be present		Only if IQP3 (C8) = 0 or 1.
FORTRAN READ list:		ZM
FORTRAN FORMAT:		(8E10.0)
Read from Subroutine:		QPR3

Variable	Columns	Format	Description	CG
ZM	1-10	E10.0	Nodal Power Multiplier	--

ZM= -2.0: Reset to 1000.0/3.6 (MBtu/hr to Btu/s)

ZM= -1.0: Reset to 3413.0/3.6 (MW to Btu/s)

ZM> 0.0: ZM unchanged

The nodal powers given on cards C13, C14 are all multiplied by ZM. This allows, for example, units to be converted.

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May 23, 1977

Card(s) Type C13	Fuel Nodal Powers
Required to be present	Only if IQP3 (C8) = 0 or 1
FORTRAN READ list:	((QF(I,J), J=1, NDX), I=1, NCHANL)
FORTRAN FORMAT:	(8E10.0)
Read from Subroutine:	QPR3

Variable	Columns	Format	Description	CG
QF	1-80	8E10.0	Average Fuel Nodal Power for Channel I, axial interval J to (J+1)	--

The power for each channel I (I=1, NCHANL) is read in turn. Each channel-set, i.e., J=1, NDX, starts on a new card, continuing onto the next card if NDX > 8. The units of QF in the calculation are Btu/sec. They may be read in those units (when ZM=1.0 on C12) or converted using ZM. NDX is read on card C11.

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Card(s) Type C14	Coolant Nodal Powers
Required to be present	Only if IQP3 (C8) = 1
FORTRAN READ list:	((QC(I,J), J=1, NDX), I=1, NCHANL)
FORTRAN FORMAT:	(8E10.0)
Read from Subroutine:	QPR3

Variable	Columns	Format	Description	CG
QC(I,J)	1-80	8E10.0	Average Nodal Power deposited in Coolant for channel I, axial interval J to J+1.	--

As for card C13, but QC instead of QF.

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Card(s) Type C13	Transient Fuel Nodal Power
Required to be present	Only if IQP3 = 0 or 1 and NDT > 1
FORTRAN READ list:	((QF(I,J), J=1, NDX), I=1, NCHANL)
FORTRAN FORMAT:	(8E10.0)
Read from Subroutine:	QPR3

Variable	Columns	Format	Description	CG
			Cards C13 and (if IQP3=1) C14 are read for the first transient time step, then both sets of cards for the next time step, etc. until data for all time steps have been given.	--

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Card(s) Type	C14	Transient Coolant Nodal Power
Required to be present		Only if IQP3= 1 and NDT > 1
FORTRAN READ list:		((QC(I,J), J=1, NDX), I=1, NCHANL)
FORTRAN FORMAT:		(8E10.0)
Read from Subroutine:		QPR3

Variable	Columns	Format	Description	CG

See last card, "transient" C13.

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Card(s) Type C3	Next case or End
Required to be present	Always
FORTRAN READ list:	IPILE KASE J1 TEXT
FORTRAN FORMAT:	(I1, I4, I5, 17A4)
Read from Subroutine:	INDAT

Variable	Columns	Format	Description	CG
	See earlier C3			

Note

At the end of the calculation, control returns again to the read statement for card C3.

If KASE > 0; the next case is read.

If KASE = 0 (e.g., a blank card), calculation stops.

APPENDIX N

Listing of the Improved Version of COBRA-IIIC/MIT

```
C  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
C  *  *  *  *  *  COBRA-IIIC/MIT  *  *  *  *  *
C  *  *  *  *  * 1980 MIT VERSION *  *  *  *  *
C  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
C
C  UNITS - ALL COMPUTATIONS ARE DONE USING FT, LB, SEC, BTU AND DEG-F,
CC  EXCEPT FOR SOME ASSOCIATED WITH NEW FUEL ROD AND HEAT TRANSFER MODEL
C
C  UNIT CHANGES FOR INPUT AND OUTPUT ARE DONE IN THE PROGRAM.
C
CC
CC   KMAX IN SUBROUTINE CORE EQUALS
CC   LENGTH OF DATA ARRAY GIVEN BELOW
CC
      COMMON DATA(80000)
      INIT = 1
  2   CALL INDAT(INIT,NOPRIN)
      IF(NOPRIN.EQ.0)  CALL INPRIN
      CALL CALC
      INIT = 2
      GO TO 2
      END
      SUBROUTINE AREA(J)
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30). TCLAD(2). UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
```

```
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH    ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF ,$QC    ,$QF    ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO   ,$RHOOL,$SP    ,$T    ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V     ,$VISC ,$VISCW,$VP    ,$VPA  ,
     A   $W    ,$WOLD ,$WP    ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
      EQUIVALENCE (NCHAN,NCHANL)
C
C
      DIMENSION  AFAC(10), GFAC(10)
C
C  CALCULATE CHANNEL AREA IF REQUIRED.
      DO 5 I=1,NCHANL
      DATA($A    +I)=DATA($AN    +I)
 5    DATA($DHYD +I)=DATA($DHYDN+I)
      DO 6 K=1,NK
 6    DATA($GAP  +K)=DATA($GAPN +K)
      IF(NAXL.EQ.0) GO TO 101
      DO 100 I=1,NCHANL
      JJ=IDAT($IDARE+I)
      IF(JJ.LT.1) GO TO 100
      DO 10 K=1,NAXL
   10 AFAC(K) = AFACT(JJ,K)
      CALL CURVE(FF,(DATA($X+J)/Z),AFAC,AXL,NAXL,IERROR,1)
      IF(IERROR.GT.1) GO TO 1000
      IF(DT.LT.100.) GO TO 20
      DUMY = FLOAT(ITERAT)/FLOAT(NARAMP)
      IF(DUMY.GT.1.) DUMY = 1.
      IF(FF.LE.0.) GO TO 1000
      FF = 1.-(1.-FF)*DUMY
 20   DATA($A    +I)=DATA($AN    +I)*FF
      DATA($DHYD +I)=DATA($DHYDN+I)*FF
  100 CONTINUE
  101 IF(J6.NE.1) GO TO 110
C  MODIFY AREA AND HYDRAULIC DIAMETER FOR WIRE WRAPS IN SUBCHANNELS.
      DO 102 I=1,NCHANL
      DATA($A+I)=DATA($A+I)-FLOAT(IDAT($NWRAP+I))*PI*THICK**2*0.25
 102  DATA($DHYD+I)=4.*DATA($A+I)/(DATA($PERIM+I)+FLOAT(IDAT($NWRAP+I))*
     1    PI*THICK)
C
C  CALCULATE GAP SPACING IF REQUIRED.
  110 IF(NGXL.EQ.0) GO TO 210
      DO 200 K=1,NK
      L=IDAT($IDGAP+K)
      IF(L.LT.1) GO TO 200
      DO 120 I=1,NGXL
  120 GFAC(I) = GFACT(L,I)
      CALL CURVE(FF,(DATA($X+J)/Z),GFAC,GAPXL,NGXL,IERROR,1)
      IF(IERROR.GT.1) GO TO 1000
      IF(FF.LE.0.) GO TO 1000
      DATA($GAP  +K)=DATA($GAPN +K)*FF
```

```
  200 CONTINUE
  210 RETURN
 1000 IERROR = 9
      RETURN
      END
      SUBROUTINE BAROC(IPART,P,Q,GWV,FMULT,PPI)
C
      COMMON/COSAVE/CORAB
C
C
      DIMENSION A1(4),A2(4),CORAB(14,7),COEF(12,8),DAT(12,5,5),X(5)
     1,        GG(7),QQ(14),PP(8),ZNN(3,6)
      DATA I3/6/
      DATA ZNN/1.2621,0.6749,0.073,1.9551,1.0043,0.1097,1.4985,0.8408,
     10.0971,0.7965,0.5531,0.0673,0.771,0.5638,0.0713,0.4838,0.4793,
     20.0657/
      DATA PP/0.0001,0.001,0.004,0.01,0.03,0.1,0.3,1.0/
      DATA GG/0.0,0.25,0.5,1.0,2.0,3.0,1000.0/
      DATA QQ/0.0,0.001,0.01,0.035,0.05,0.075,0.1,0.15,0.2,
     10.3,0.4,0.6,0.8,1.0/
      DATA COEF/2.2,9.2,26.5,47.0,99.0,163.0,376.0,630.0,1300.0,2050.0,
     1 4300.0,6600.0,
     2 2.15,8.8,22.8,34.2,48.2,70.0,108.0,148.0,240.0,330.0,538.0,760.0,
     3 2.08,7.8,16.3,22.8,29.0,36.0,49.5,63.0,86.0,110.0,155.0,203.0,
     4 1.59,4.8,9.6,12.4,16.0,20.0,27.0,33.5,43.5,53.0,69.0,85.0,
     5 1.12,1.81,3.45,4.7,6.1,7.9,11.0,13.2,17.3,21.2,26.0,30.0,
     6 1.04,1.22,1.78,2.05,2.5,2.8,3.6,4.2,5.5,6.5,8.0,9.1,
     7 1.01,1.06,1.26,1.36,1.5,1.59,1.77,1.93,2.25,2.48,2.86,3.2,12*1.0/
      DATA DAT/1.669,1.669,1.626,1.6,1.59,1.58,1.58,1.58,1.534,
     1 1.492,1.362,1.178,
     2 1.16,1.158,1.059,1.0,1.21,1.42,1.42,1.42,1.324,1.234,1.139,1.103,
     31.22,1.307,1.355,1.384,1.502,1.36,1.36,1.36,1.33,1.34,1.162,1.086,
     4 1.11,1.166,1.42,1.572,1.695,1.818,1.818,1.818,1.619,1.445,
     5 1.204,1.07,12*1.0,
     6 1.3,1.33,1.311,1.3,1.3,1.3,1.304,1.308,1.284,1.26,1.2,1.1,
     71.13,1.25,1.17,1.12,1.148,1.276,1.256,1.236,1.195,1.153,1.11,1.07,
     8 1.1,1.15,1.15,1.214,1.21,1.219,1.223,1.24,1.235,1.23,1.13,1.084,
     9 1.078,1.086,1.232,1.32,1.334,1.460,1.472,1.596,1.457,
     A 1.318,1.164,1.061,12*1.0,60*1.0,
     B0.75,0.74,0.749,0.754,0.752,0.75,0.736,0.722,0.746,0.77,0.82,0.91,
     C 0.864,0.66,0.676,0.686,0.704,0.721,0.746,0.75,0.788,0.806,0.86,
     D 0.932,0.905,0.88,0.829,0.798,0.805,0.812,0.788,0.764,0.73,
     E 0.696,0.705,0.82,
     F 0.97,0.912,0.817,0.76,0.73,0.7,0.665,0.63,0.602,0.574,0.574,0.7,
     G 12*1.0,0.63,0.61,0.625,0.634,0.634,0.634,0.606,0.598,0.624,0.65,
     H.718,.836,.78,.484,.501,.512,.551,.59,.605,.62,.667,.714,.782,.88,
     I.865,.81,.741,.7,.701,.702,.673,.643,.593,.542,.542,.69,.937,.884,
     J .769,.7,.671,.642,.587,.540,.493,.454,.454,.58,12*1.0/
      DATA A2/0.220112,-0.299745,0.440706,-0.325823/
      DATA A1/2.46896E-04,1.95508E-01,-3.14163E-02,2.64363E-01/
      DATA X/-8.25483,-5.572754,-2.8647,-1.619488,0.0/
C
      ZLINE(XA,YA,XC,YC,XB)=((YA-YC)*XB+(YC*XA-YA*XC))/(XA-XC)
      ZRECT(X1,X2,Y1,Y2,Z11,Z12,Z21,Z22,XX,YY) =
     1 ( (Y2-YY)*(Z11*(X2-XX) + Z21*(XX-X1))
```

```
     2 - (Y1-YY)*(Z12*(X2-XX) + Z22*(XX-X1)) )
     3 /((Y1-Y2)*(X1-X2))
C
C      ZLINE IS VALUE OF YB AT XB, INTERPOLATED LINEARLY BETWEEN (XA,YA)
C      AND (XC,YC)
C      ZRECT IS VALUE OF Z AT (XX,YY), LINEARLY INTERPOLATED BETWEEN Z11
C      AT (X1,Y1), Z12 AT (X1,Y2), Z21 AT (X2,Y1) AND Z22 AT (X2,Y2)
C      IPART = 1,  ENTER WITH PRESSURE AND SET ARRAY CORAB
C      IPART = 2,  ENTER WITH MASS VELOCITY AND QUALITY, INTERPOLATE
C      IN CORAB TO OBTAIN MULTIPLIER.
C
       IF (IPART.EQ.2) GO TO 41
C      SET PHYSICAL PROPERTY INDEX FROM PRESSURE.
       IF((P.LT.11.429).OR.(P.GT.3204.0)) WRITE(I3,1001) P
       IF(P.GT.1429.5) GO TO 8
       YY=A1(4)
       DO 2 I=1,3
       L=4-I
     2 YY=YY*P/3204+A1(L)
       PX = YY
       GO TO 12
     8 CONTINUE
       YY=A2(4)
       DO 10 I=1,3
       L=4-I
    10 YY=YY*P/3204+A2(L)
       PX = YY*P/(3204-P+YY*P)
    12 PPI = ALOG(PX)
    13 CONTINUE
       IMAX=14
       IF(PX.LT.PP(1)) PX = PP(1)
       J=1
    14 IF(PX.LE.PP(J)) GO TO 16
       J=J+1
       GO TO 14
C
C      SET MULTIPLIER AT G = 1.0
    16 DO 22 I=1,IMAX
       IF(I.EQ.1) CORAB(1,4)=1.0
       IF(I.EQ.IMAX) CORAB(IMAX,4)=1.0/PX
       IF((I.EQ.1).OR.(I.EQ.IMAX)) GO TO 22
       M=I-1
       IF(J.GT.2) GO TO 15
       WV=ZLINE(ALOG(PP(1)),ALOG(COEF(M,1)),ALOG(PP(2)),ALOG(COEF(M,2)),
      1PPI)
       CORAB(I,4)=EXP(WV)
       GO TO 22
    15 IF(I.GE.8) GO TO 17
       IF((J.LT.4).OR.(J.GT.5)) GO TO 17
       ZN=EXP(ZNN(1,M)+ZNN(2,M)*PPI+ZNN(3,M)*PPI*PPI)
       GO TO 19
    17 IF (J.LE.7) GO TO 18
       WV = ZLINE(ALOG(PP(7)),ALOG(COEF(M,7)), 0.0,0.0,PPI)
       CORAB(I,4)=EXP(WV)
       GO TO 22
```

```
   18 IF(J.EQ.1) J=2
      ZN1 = ALOG((COEF(M,J-1) - 1.0 + QQ(I))*PP(J-1))/ALOG(QQ(I))
      ZN2 = ALOG((COEF(M,J  ) - 1.0 + QQ(I))*PP(J  ))/ALOG(QQ(I))
      ZN = ZLINE(ALOG(PP(J-1)),ALOG(ZN1),ALOG(PP(J)),ALOG(ZN2),PPI)
      ZN = EXP(ZN)
   19 CORAB(I,4) = 1.0 - QQ(I) + (QQ(I)**ZN)/PX
   22 CONTINUE
C
C     SET CORAB MATRIX USING MASS VELOCITY CORRECTION FACTOR.
      IND1=1.0
      BIT=0.15
   30 IF(PPI.LT.X(IND1+1)) GO TO 32
      IND1=IND1+1
      GO TO 30
   32 IND2=0.0
      DO 34 K=2,4
   34 IF((PPI.GT.(X(K)-BIT)).AND.(PPI.LT.(X(K)+BIT))) IND2=K
      DO 38 I=1,IMAX
      N=I-1
      DO 38 J=1,7
      IF((I.EQ.1).AND.(J.LT.7)) GO TO 35
      IF((I.EQ.IMAX).AND.(J.LT.7)) GO TO 35
      M=J-1
      IF(J.EQ.1) M=J
      IF(J.EQ.7) GO TO 37
      YY=ZLINE(X(IND1),DAT(N,IND1,M),X(IND1+1),DAT(N,IND1+1,M
     1),PPI)
      IF(IND2.EQ.0.0) GO TO 36
      X1=X(IND2)-BIT
      X2=X(IND2)+BIT
      Y1=ZLINE(X(IND2-1),DAT(N,IND2-1,M),X(IND2),DAT(N,IND2,M),X1)
      Y2=ZLINE(X(IND2),DAT(N,IND2,M),X(IND2+1),DAT(N,IND2+1,M),X2)
      YY=0.5*(ZLINE(X1,Y1,X2,Y2,PPI)+YY)
      GO TO 36
   35 YY=1.0
   36 CORAB(I,J)=YY*CORAB(I,4)
      GO TO 38
   37 CORAB(I,J)=1.0
   38 CONTINUE
      RETURN
C
C     INTERPOLATE IN CORAB ARRAY TO FIND MULTIPLIER.
   41 G=GWV*1.0E-06
      IF(G.GE.1000.0)G = 1000.0
      IND1=1
   42 IF(Q.LE.QQ(IND1)) GO TO 44
      IND1=IND1+1
      GO TO 42
   44 CONTINUE
      IND2=1
   46 IF(G.LT.GG(IND2)) GO TO 48
      IND2=IND2+1
      GO TO 46
   48 G2=GG(IND2)
      G1=GG(IND2-1)
```

```
      G3=G                                                              COB02760
      IF(G.LE.1.0) GO TO 50                                             COB02770
      G1=1.0/G1                                                         COB02780
      G2=1.0/G2                                                         COB02790
      G3=1.0/G3                                                         COB02800
   50 CONTINUE                                                          COB02810
C                                                                       COB02820
      Z11 = CORAB(IND1-1,IND2-1)                                        COB02830
      Z12 = CORAB(IND1-1,IND2  )                                        COB02840
      Z21 = CORAB(IND1  ,IND2-1)                                        COB02850
      Z22 = CORAB(IND1  ,IND2  )                                        COB02860
      X1 = QQ(IND1-1)                                                   COB02870
      X2 = QQ(IND1  )                                                   COB02880
      XX = Q                                                            COB02890
      FMULT = ZRECT(X1,X2,G1,G2,Z11,Z12,Z21,Z22,XX,G3)                  COB02900
      PPI=ALOG10(EXP(PPI))                                              COB02910
      RETURN                                                            COB02920
C                                                                       COB02930
 1001 FORMAT('  PRESSURE = ', 1PE15.4, ' OUTSIDE VALID RANGE OF 11.43 TOCOB02940
     1 3204 PSIA')                                                      COB02950
      END                                                               COB02960
      FUNCTION BVOID(I,J)                                               COB02970
C  BVOID CALCULATES THE BULK VOID FRACTION GIVEN A QUALITY.             COB02980
C                                                                       COB02990
C                                                                       COB03000
      IMPLICIT INTEGER ($)                                              COB03010
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB03020
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB03030
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB03040
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB03050
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB03060
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB03070
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB03080
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB03090
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB03100
C                                                                       COB03110
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB03120
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB03130
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB03140
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB03150
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB03160
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB03170
C                                                                       COB03180
C                                                                       COB03190
      LOGICAL  GRID                                                     COB03200
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB03210
C                                                                       COB03220
C                                                                       COB03230
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB03240
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB03250
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB03260
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB03270
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB03280
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB03290
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB03300
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     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE.$NWRAP.$NWRPS,$P     .$PERIM,$PH    ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF ,$QC    ,$QF    ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V     ,$VISC ,$VISCW,$VP    ,$VPA  ,
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X     ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
      XP=DATA($QUAL+I)
      BVOID = 0.
      IF(XP.LE.0.) RETURN
      DATA($ALPHA+I)=0.
      IF(J3.EQ.0) DATA($ALPHA+I)=XP*VG/((1.-XP)*VF+XP*VG)
      IF(J3.EQ.1)DATA($ALPHA+I)=(0.833+.167*XP)*XP*VG/((1.-XP)*VF+XP*VG)
      IF (J3.EQ.2) GO TO 85
      IF(J3.EQ.5) DATA($ALPHA+I)=XP*VG/((1.-XP)*VF*AV(1)+XP*VG)
      IF(J3.NE.6) GO TO 90
                  DATA($ALPHA+I)=AV(1)
      XX=DATA($QUAL+I)
      DO 80 K=2,NV
      DATA($ALPHA+I)=DATA($ALPHA+I)+AV(K)*XX
 80   XX             =DATA($QUAL+I)*XX
      GO TO 90
C     SMITH SLIP CORRELATION
  85  SLP = 0.4 + 0.6*((0.4+XP*(VG/VF-0.4))/(0.4+0.6*XP))**0.5
      DATA($ALPHA+I) = XP*VG/(SLP*(1.0-XP)*VF+XP*VG)
 90    BVOID         =DATA($ALPHA+I)
      RETURN
      END
      SUBROUTINE CALC
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
```

```
      LOGICAL  GRID                                                     COB03860
      REAL.    KIJ, KF, KKF, KCLAD, KFUEL                               COB03870
C                                                                       COB03880
C                                                                       COB03890
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB03900
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B     ,COB03910
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB03920
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB03930
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB03940
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB03950
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB03960
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB03970
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB03980
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB03990
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB04000
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A  ,$$B   ,$XPOLD  COB04010
C                                                                       COB04020
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                 COB04030
C                                                                       COB04040
      COMMON /TIMEST/ NT                                                COB04050
C                                                                       COB04060
C                                                                       COB04070
      COMMON /REFP/ PO                                                  COB04080
C                                                                       COB04090
      COMMON /PPSV/ PPI                                                 COB04100
C                                                                       COB04110
C                                                                       COB04120
      COMMON  DATA(1)                                                   COB04130
      LOGICAL LDAT(1)                                                   COB04140
      INTEGER IDAT(1)                                                   COB04150
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB04160
      EQUIVALENCE  (NCHAN,NCHANL)                                       COB04170
C                                                                       COB04180
C                                                                       COB04190
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),  COB04200
     1 JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),COB04210
     2 YQ(30)                                                           COB04220
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB04230
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB04240
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB04250
      COMMON/TSAVER/TSTART                                              COB04260
      INTEGER   SIGNAL(18)                                              COB04270
      DATA SIGNAL /4HMAIN,4HDIFF,4HDVRT,4HMIX ,                         COB04280
     14HSCHM,4HFORC,4HVOID,4HSPLT,4HAREA,4HCURV,4HPROP,                 COB04290
     24HDCOM,4HSOLV,4HHEAT,4HTEMP,4HHCOL,4HGAUS,4HCIJ /                 COB04300
C     HYDRAULIC CONTROL ( COBRA CARDS MAIN0360-MAIN1820 AND 2340 - 2410)COB04310
C                                                                       COB04320
C  START SUBCHANNEL FLOW AND ENTHALPY CALCULATIONS.                     COB04330
  400 KT = NSKIPT                                                       COB04340
      IPILE = J7                                                        COB04350
      DT = SAVEDT                                                       COB04360
      DO 401 J=1,NDXP1                                                  COB04370
  401 DATA($X+J)=DX*FLOAT(J-1)                                          COB04380
      NDTP1 = NDT+1                                                     COB04390
      CALL PRNTIM (0)                                                   COB04400
```

```
CC
CC  TIMING IS EXPECTED TO RETURN CPU TIME
CC  (IN HUNDREDTHS OF A SECOND) AS AN INTEGER
CC
      CALL TIMING(ICPU)
      TSTART=FLOAT(ICPU)/100.
CC
CC INITIALIZE FUEL ROD VARIABLES IF NEW FUEL ROD MODEL USED
CC
      IF (IFRM.EQ.0) GO TO 409
      CALL INITRC
C
C     START TRANSIENT DO LOOP
  409 DO 500 NT=1,NDTP1
      CALL PRNTIM (1)
      IERROR = 0
      IF (IQP3.GT.1) GO TO 710
      CALL QPR3(NCHANL,     KASE,TEXT,DATE,TIME,DATA($X+1))
  710 CONTINUE
      DT = SAVEDT
      IF(NT.EQ.1) DT = 1.E+10
      ETIME = DT*FLOAT(NT-1)
C  ESTABLISH CHANNEL BOUNDARY CONDITIONS AND FORCING FUNCTION VALUES.
C
C     SET TRANSIENT PRESSURE
      DUMY = 1.
      IF(NP.GT.1)
     1CALL CURVE (DUMY,ETIME,FP,YP,NP,IERROR,1)
      IF(IERROR.GT.1) GO TO 505
      PREF = DUMY*PEXIT
      CALL PROP(1,1)
      IF(IERROR.GT.1) GO TO 505
C
C     SET TRANSIENT INLET ENTHALPY
      DUMY = 1.
      IF(NH.GT.1)
     1CALL CURVE (DUMY,ETIME,FH,YH,NH,IERROR,1)
      IF(IERROR.GT.1) GO TO 505
      DO 402 I=1,NCHANL
      DATA($HOLD+I)=DATA($H   +I)
      DATA($H   +I)=DATA($HINLE+I)*DUMY
      IF(IN.EQ.1 .OR. IN.EQ.3)
     1CALL CURVE(DATA($H+I),DATA($TINLE+I)*DUMY,HHF,TT,NPROP,IERROR,1)
  402 CONTINUE
C
C     SET TRANSIENT INLET FLOW
      DUMY = 1.
      IF(NG.GT.1)
     1 CALL CURVE(DUMY,ETIME,FG,YG,NG,IERROR,1)
      IF(IERROR.GT.1) GO TO 505
      IF ( (IPILE.EQ.2) .AND. (NT.GT.1) ) GO TO 404
C     STEADY STATE AND PWR.
      DO 403 I=1,NCHANL
      DATA($FOLD+I)=DATA($F+I)
  403 DATA($F   +I)=DATA($FINLE+I)*DUMY
```

```
      GO TO 407
C     BWR.  UPDATE INLET FLOW FOR DUMY AND LAST TRANSIENT.
  404 SUMSS = 0.0
      SUMTR = 0.0
      DO 405 I=1,NCHANL
      SUMSS = SUMSS + DATA($FINLE+I)
  405 SUMTR = SUMTR + DATA($F+I)
      WV = DUMY*SUMSS/SUMTR
      DO 406 I=1,NCHANL
      DATA($FOLD+I)=DATA($F+I)
  406 DATA($F+I) = WV*DATA($F+I)
  407 CONTINUE
C
C     SET TRANSIENT POWER
      DUMY = 1.
      IF(NQ.GT.1)
     1CALL CURVE (DUMY,ETIME,FQ,YQ,NQ,IERROR,1)
      IF(IERROR.GT.1) GO TO 505
      POWER = DUMY
C
C     SET BAROCZY PRESSURE DROP ARRAY
      IF (J4.EQ.2) CALL BAROC(1,PREF,0.0,0.0,RUB,PPI)
C
C  BEGIN ITERATION TO OBTAIN SOLUTION.
      DO 430 NN=1,NTRIES
      CALL PRNTIM (2)
      DO 410 I=1,NCHANL
 410  IDAT($NWRAP+I)=IDAT($NWRPS+I)
      ITERAT = NN
      CALL SCHEME(JUMP,DATA($AAA+1))
      CALL PRNTIM (6)
      IF(IERROR.GT.1) GO TO 440
      CALL TIMING(ICPU)
      MTIME=IFIX(FLOAT(ICPU)/100.-TSTART)
      IF(MTIME.LT.MAXT) GO TO 429
      WRITE(I3,102)
      GO TO 440
  429 IF(JUMP.LT.1 .OR. JUMP.GT.3) GO TO 505
      GO TO (430,440,440),JUMP
  430 CONTINUE
      WRITE(I3,22) NTRIES
      IERROR = 1
C
C  SET CONDITIONS FOR NEXT TIME STEP
  440 IF(JUMP.EQ.3) GO TO 441
      CALL PRNTIM (7)
      IF(NJUMP.GT.0) JUMP = 3
      IF(NJUMP.NE.2) GO TO 441
      REWIND I8
      WRITE(I8) ((DATA($W+I+MG*(J-1)),I=1,MG),J=1,MX),
     1           ((DATA($P+I+MC*(J-1)),I=1,MC),J=1,MX),
     2         ((DATA($RHO+I+MC*(J-1)),I=1,MC),J=1,MX),
     3         ((DATA($F   +I+MC*(J-1)),I=1,MC),J=1,MX)
      END FILE I8
      REWIND I8
```

```
  441 DO 445 J=1,NDXP1
      DO 443 K=1,NK
      DATA($WOLD+K+MG*(J-1))=
     1DATA($W    +K+MG*(J-1))
  443 CONTINUE
      DO 444 I=1,NCHANL
      DATA($FOLD +I+MC*(J-1))=DATA($F     +I+MC*(J-1))
      DATA($HOLD +I+MC*(J-1))=DATA($H     +I+MC*(J-1))
      DATA($RHOOL+I+MC*(J-1))=DATA($RHO   +I+MC*(J-1))
  444 CONTINUE
  445 CONTINUE
      CALL EXPRIN
      IF(KT.GE.NSKIPT) KT=0
      IF(ISAVE.GT.0) GO TO 505
      IF(IERROR.GT.0) GO TO 505
  500 CONTINUE
      CALL PRNTIM (8)
C
C  END OF PROBLEM,  LOOK FOR NEW CASE
      GO TO 990
  505 WRITE(I3,55) SIGNAL(IERROR)
      WRITE(I3,55) SIGNAL(ISAVE)
  990 RETURN
C
   22 FORMAT (23H0FAILURE INTEGRATION IN,I4,17H ITERATIONS AT X=
     1,F8.4,2I10)
   55 FORMAT (10H ERROR IN ,A6,'  **  CALCULATION FOR THIS CASE STOPPED'
     1)
  102 FORMAT(///' * * * ABNORMAL EXIT THROUGH MAXIMUM TIME * * *'//)
      END
      SUBROUTINE CARDS1(PP,TT,VVF,VVG,HHF,HHG,UUF,KKF,SSIGMA,N1,I2)
      DIMENSION  PP(1),TT(1),VVF(1),VVG(1),HHF(1),HHG(1),UUF(1),KKF(1),
     1    SSIGMA(1)
      REAL KKF
C
      I2=5
C  MEKIN NEW  PHYS PROP FROM CARDS OR POLYNOMIALS
      IF (N1.LE.0) GO TO 6
      READ(I2,4) (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HHG(I),UUF(I),
     1 KKF(I),SSIGMA(I),I=1,N1)
    4 FORMAT(E5.2,F5.1,7F10.0)
      RETURN
C
C   P2 TO BE HIGHER THAN OPERATING PRESSURE
C   N=1,PH TO BE LOWER THAN P FOR H-IN
C   N=2,PH TO BE LOWER THAN H-IN.
C   N1=NUMBER OF PRESSURE INTERPOLATION STEPS
    6 READ(I2,8) N,PH,P2,N1
    8 FORMAT(I5,2F10.3,I5)
      P1=PH
      IF(N.EQ.1) GO TO 10
      P1=10.0
      IF(PH.LT.161.3) GO TO 10
      H=0.01*PH
      P1=6.0*H*H*H*(H-1.35)/(H-0.35)
```

```
   10 IF(N1.LT.3) N1=3                                                   COB06060
      A=(P2-P1)/(N1-1)                                                   COB06070
      DO 12 I=1,N1                                                       COB06080
      P=P1+(I-1.0)*A                                                     COB06090
      PP(I)=P                                                            COB06100
      TT(I)=SATTEM(P)                                                    COB06110
      RL=ROLIQ(P)                                                        COB06120
      VVF(I)=1.0/RL                                                      COB06130
      RG=ROVAP(P)                                                        COB06140
      VVG(I)=1.0/RG                                                      COB06150
      H=HLIQ(P)                                                          COB06160
      HHF(I)=H                                                           COB06170
      HHG(I)=HVAP(P)                                                     COB06180
      CALL HAPROP(P,H,CP,UUF(I),KKF(I))                                  COB06190
      CALL SURTEN(P,RL,RG,SSIGMA(I))                                     COB06200
   12 CONTINUE                                                           COB06210
      RETURN                                                             COB06220
      END                                                                COB06230
      SUBROUTINE CARD20(NOPRIN)                                          COB06240
C                                                                        COB06250
C                                                                        COB06260
      IMPLICIT INTEGER ($)                                               COB06270
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB06280
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB06290
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB06300
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB06310
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB06320
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB06330
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB06340
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB06350
     8   UF    ,VF    ,VFG   ,VG    ,Z                                   COB06360
C                                                                        COB06370
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB06380
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB06390
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB06400
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB06410
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB06420
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB06430
C                                                                        COB06440
C                                                                        COB06450
      LOGICAL  GRID                                                      COB06460
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                COB06470
C                                                                        COB06480
C                                                                        COB06490
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB06500
     1           $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB06510
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB06520
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB06530
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB06540
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB06550
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB06560
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB06570
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB06580
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB06590
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB06600
```

```
     A    $W    ,$WOLD ,$WP    ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ
      DIMENSION NTHBOX(25,25)
      DIMENSION CARD(20)
C
C     SIMULATE NEUTRONIC INPUT TO MEKIN ITHO
C
      WRITE (I3,1010)
      DO 2 ND1 = 1,20
      DO 2 ND2 = 1,20
    2 NTHBOX(ND1,ND2) = 0
      NTHBXX = 0
      READ (I2,1001) CARD, IMAP, ND1X, ND2X
      WRITE (I3,1011) CARD
      IF ( (ND1X.LE.25) .AND. ( ND2X.LE.25) ) GO TO 4
      WRITE (I3,1012) ND1X,ND2X
      STOP
C
    4 IF (IMAP-2) 6,10,14
C     IMAP = 1.    RECTANGULAR MATRIX
    6 DO 8 ND2 = 1,ND2X
      DO 8 ND1 = 1,ND1X
      NTHBXX = NTHBXX+1
    8 NTHBOX(ND1,ND2) = NTHBXX
      GO TO 18
C
C     IMAP = 2.    GIVE START AND END OF EACH ROW.
   10 DO 12 ND2=1,ND2X
      READ (I2,1001) CARD, ISTART, IFIN
      WRITE (I3,1013) ND2, CARD
      DO 12 ND1=1,ND1X
      IF ( (ND1.LT.ISTART) .OR. (ND1.GT.IFIN) ) GO TO 12
      NTHBXX = NTHBXX+1
      NTHBOX(ND1,ND2) = NTHBXX
   12 CONTINUE
      GO TO 18
C
C     IMAP = 3.    READ NTHBOX
   14 MAXRD = 14
      MP1 = MAXRD+1
      MORE = ND1X - MAXRD
      DO 16 ND2 = 1,ND2X
      READ (I2,1001) CARD, (NTHBOX(ND1,ND2),ND1=1,MAXRD)
      WRITE (I3,1014) ND2, CARD
      IF (MORE.LE.0) GO TO 15
      READ (I2,1001) CARD, (NTHBOX(ND1,ND2),ND1=MP1,ND1X)
```

```
      WRITE (I3,1014) ND2, CARD
   15 DO 16 ND1=1,ND1X
      IF (NTHBOX(ND1,ND2).GT.NTHBXX) NTHBXX=NTHBOX(ND1,ND2)
   16 CONTINUE
C
C     READ HEAT FLUX PARAMETERS.
   18 READ (I2,1003) CARD, N1, AFLUX
      WRITE (I3,1015) CARD
      IF (N1.GT.1) GO TO 22
      IQP3 = N1
      DO 20 I=1,NTHBXX
   20 DATA($RADIA+I) = 1.0
      GO TO 24
   22 NAX = N1
      CALL READIN(8,NAX,Y,AXIAL,CARD,2)
      CALL READIN(9,NTHBXX,DATA($RADIA+1),CARD,CARD,1)
C
   24 READ (I2,1004) CARD,Z, NDX, NDT, TTIME
      WRITE (I3,1016) CARD
C
      CALL ITHO(NTHBOX,NTHBXX,ND1X,ND2X)
      IF (NOPRIN.EQ.0) CALL TIDY
      CALL PRECAL
      RETURN
C
 1001 FORMAT(20A4, T1, 14I5)
 1003 FORMAT(20A4, T1, I5, 13E5.0)
 1004 FORMAT(20A4, T1, E5.0, 2I5, 10E5.0)
 1010 FORMAT(1H1, 42X, 'COBRA INPUT DATA', /, 43X,
     1 '----------------', //, '  NB. DATA READ FROM CARD20 WOULD BE REA
     2D OR SET WITH THE NEUTRONICS DATA IN MEKIN', ///, '  CARD IMAGES',
     3 /, 2X, '---- ------', /, 32X, '0....*....1....*....2....*....3...
     4.*....4....*....5....*....6....*....7....*....8')
 1011 FORMAT('  IMAP ND1X ND2X', 14X, '***', 20A4, '*** CARD20')
 1012 FORMAT('  INPUT DATA ERROR IN CARD20. ND1X, ND2X = ', 2I5,
     1 ' IE GREATER THAN 25 FOR EACH ALLOWED')
 1013 FORMAT('  ND2=',I3, ' ISTART IFIN', 9X, '***', 20A4, '*** CARD20')
 1014 FORMAT('  ND2=', I3, ' NTHBOX', 14X, '***', 20A4, '*** CARD20')
 1015 FORMAT('  NAX AFLUX', 19X, '***', 20A4, '*** CARD20')
 1016 FORMAT('  Z NDX NDT TTIME', 13X, '***', 20A4, '*** CARD20')
C
      END
      FUNCTION CHF1(N,I,J)
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
```

```
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
C  BAW-2 CHF CORRELATION
      DATA A0, B0,A1,A2,A3,A4,A5,A6,A7,A8,A9 / 1.15509, 4.8844,
     1 0.3702E+8, 2.1289E-3, 0.83040, 0.68479E-3, 4.5756E+4, 1.0996E-2,
     2 0.71186, 0.20729E-3, 547.49/
      REAL KD
      DATA  A21,A22,A23,KD /  2.9840, 7.82293, 0.45758, 1.02508 /
      QA=DATA($A +I)
      QP=DATA($PERIM+I)
      QF=DATA($F+I+MC*(J-1))
      QH=DATA($H+I+MC*(J-1))
      RAT=QF/QA
      DE=4.*QA/QP
      XX=(QH-HF)/HFG
      CHF1=(A0-B0*DE)*(A1*(A2*RAT)**(A3+A4*(PREF-2000.))
     1    -A9*RAT*XX*HFG)/(A5*(A6*RAT)**(A7+A8*(PREF-2000.)))
C  AXIAL FLUX CORRECTION FACTOR
      FAXIAL = 1.
      IF(J.EQ.1) GO TO 10
      C=A21*(1.-XX)**A22/(RAT*.0036)**A23
      SUM = 0.
      JS = 2
      DO 5 JJ=JS,J
  5   SUM=SUM+DATA($FLUX+N+MR*(JJ-1))*(EXP(C*DATA($X+JJ))-
```

```
     1                                   EXP(C*DATA($X+JJ-1)))
      FAXIAL=SUM*EXP(-C*DATA($X+J))/DATA($FLUX+N+MR*(J-1))/
     1     (1.-EXP(-C*(DATA($X+J)-DATA($X+JS-1)))))*KD
   10 CHF1 = CHF1/FAXIAL
      RETURN
      END
      FUNCTION CIJ(K,J)
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE
C   MAJOR SUBROUTINES OF COBRA-IIIC.
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
      GGG=DATA($GAP+K)
      IF(GGG.LE.0.0)  GO TO 1000
```

```
      II=IDAT($IK+K)
      JJ=IDAT($JK+K)
                                          RSTAR=DATA($RHO+II+MC*(J-1))
      IF(DATA($W+K+MG*(J-1)).LT.0.0) RSTAR=DATA($RHO+JJ+MC*(J-1))
      WMIN=ABS(DATA($W+K+MG*(J-1)))
      IF(WMIN.LT..001) WMIN = .001
      CIJ=KIJ*WMIN*0.5/GC/RSTAR/GGG/GGG
      CIJ=CIJ/DATA($FACTO+K)**2
      RETURN
 1000 IERROR = 18
      RETURN
      END
      SUBROUTINE CURVE (FX,X,F,Y,N,J,ISAVE)
      DIMENSION F(30), Y(30)
C
C   FX - QUANTITY TO BE FOUND
C    X - INDEPENDENT VARIABLE
C    F - INPUT ARRAY FOR THE ORDINATE(MONOTONIC WITH Y)
C    Y - INPUT ARRAY FOR THE ABCISSA (MONOTONIC INCREASE)
C    N - NUMBER OF F(I) OR Y(I) VALUES
C    J - ERROR SIGNAL, J=10
C
C   THE INDEX I IS SAVED IN COMMON INDSAV
C
      COMMON/INDSAV/I
C
       DATA I3/6/
C
    1 FORMAT(49H TABULAR LOOKUP FAILED IN SUBROUTINE CURVE, FX = E12.6,
     1 6H    X = E12.6 / (10E12.4))
      IF(ISAVE.LT.1 .OR. ISAVE.GT.2) GO TO 70
      GO TO (10,50),ISAVE
   10 DO 20 I=1,N
      IF(X-Y(I)) 30,15,20
   15 IF(I.EQ.N) GO TO 40
   20 CONTINUE
      GO TO 60
   30 IF(I.EQ.1) GO TO 60
   40 B = (X-Y(I-1))/(Y(I)-Y(I-1))
   50 FX = F(I-1) + B*(F(I)-F(I-1))
      RETURN
   60 WRITE(I3,1) FX,X,(F(I),Y(I),I=1,N)
   70 J = 10
      RETURN
      END
      SUBROUTINE DECOMP (NN,IERROR,LMAX,MID,UL,X,B,NK)
      DIMENSION UL(NK,1),X(1),B(1)
C
C     SIMPLIFIED VERSION OF DECOMP WITH NO PIVOTING.
C     STORE DIAGONAL BAND OF AAA MATRIX.   POSITION (K,L) IN SQUARE
C     ARRAY BECOMES (K,(MID-K+L) ) IN NEW ARRAY.
C
      N = NN
      IF(N.EQ.1) RETURN
C
```

```
      DATA I3/6/                                                        COB09360
      NM1 = N-1                                                         COB09370
      DO 17  K = 1,NM1                                                  COB09380
      PIVOT = UL(K ,MID)                                                COB09390
      KP1 = K+1                                                         COB09400
      LIMIT = MINO(N,(K+MID-1) )                                        COB09410
      DO 16 I = KP1,LIMIT                                               COB09420
      KK = MID+K-I                                                      COB09430
      EM = -UL(I,KK)/PIVOT                                              COB09440
      UL(I,KK) = -EM                                                    COB09450
      IF (EM) 20,16,20                                                  COB09460
   20 DO 21 J=KP1,LIMIT                                                 COB09470
      JI = MID-I+J                                                      COB09480
      JK = MID-K+J                                                      COB09490
   21 UL(I,JI) = UL(I,JI) + EM*UL(K,JK)                                 COB09500
   16 CONTINUE                                                          COB09510
   17 CONTINUE                                                          COB09520
C                                                                       COB09530
      IF (UL(N,MID)) 19,18,19                                           COB09540
   18 WRITE(I3,112)                                                     COB09550
  100 WRITE(I3,113) ((UL(K,L),L=1,NN),K=1,NN)                           COB09560
  113 FORMAT(/E14.8)                                                    COB09570
  112 FORMAT(54H0SINGULAR MATRIX IN DECOMPOSE.  ZERO DIVIDE IN SOLVE.  )COB09580
      IERROR = 12                                                       COB09590
   19 RETURN                                                            COB09600
      END                                                               COB09610
      SUBROUTINE DOY(A)                                                 COB09620
      DIMENSION A(2),DATIM(5)                                           COB09630
      CALL WHEN(DATIM)                                                  COB09640
      A(1)=DATIM(1)                                                     COB09650
      A(2)=DATIM(2)                                                     COB09660
      RETURN                                                            COB09670
      END                                                               COB09680
      SUBROUTINE EXPRIN                                                 COB09690
C                                                                       COB09700
C                                                                       COB09710
      IMPLICIT INTEGER ($)                                              COB09720
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB09730
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB09740
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB09750
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB09760
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB09770
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB09780
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB09790
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB09800
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB09810
C                                                                       COB09820
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB09830
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB09840
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB09850
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB09860
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB09870
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB09880
C                                                                       COB09890
C                                                                       COB09900
```

```
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA     ,MC     ,MG     ,MN     ,MR     ,MS     ,MX     ,
     1         $$$    ,$A     ,$AAA   ,$AC    ,$ALPHA,$AN    ,$ANSWE,$B     ,
     1   $CCHAN,$CD   ,$CHFR ,$CON   ,$COND ,$CP    ,$D     ,$DC    ,$DFDX  ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST  ,$DPDX ,$DPK   ,$DUR   ,$DR    ,$F     ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX  ,$FMULT,$FOLD  ,$FSP   ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H     ,$HFILM,$HINLE,$HOLD  ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL ,$JK   ,$LC    ,$LENGT,$LOCA  ,$LR    ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH    ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF  ,$QC    ,$QF    ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD  ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V     ,$VISC ,$VISCW,$VP    ,$VPA   ,
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X     ,$XCROS,$$A   ,$$B    ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
      EQUIVALENCE (NCHAN,NCHANL)
C
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),
     1 JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),
     2 YQ(30)
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ
      DIMENSION CHFCOR(5),CHFLBL(5)
      DATA CHFCOR /4HBAW2,4HW-3 ,4HH-L ,4HC-4 ,4HB-VC/
      DATA CHFLBL /4HDNBR,4HDNBR,4HCHFR,4HCPR ,4HCHFR/
       DATA H1,H2,H3,H4,H5 / 1H(, 1H,, 1H), 4H  W(, 4H)WP( /
      DATA H6, H7, H8 /1HW, 1HX, 2HT( /
C     PRINT OUTPUT (COBRA CARDS MAIN1822 - MAIN2331)
      ISAVE = IERROR
      IERROR = 0
      IF(NCHF.GT.0 .AND. ISAVE.EQ.0) CALL CHF(3,NDXP1)
      KT = KT+1
      IF(KT.LT.NSKIPT) GO TO 500
      CALL TOD(TIME)
C
C  PRINT RESULTS
      IF(ETIME.GT.0.) GO TO 457
C  COMPUTE MASS AND ENERGY BALANCE
      FLOIN = 0.
      FLOOUT = 0.
      ENGIN = 0.
      ENGOUT = 0.
      NDXP1 = NDX+1
      DO 448 I=1,NCHANL
      FLOIN =FLOIN +DATA($F    +I)
      FLOOUT=FLOOUT+DATA($F    +I+MC*(NDXP1-1))
      ENGIN =ENGIN +DATA($F    +I)*DATA($H+I)
```

```
 448  ENGOUT=ENGOUT+DATA($F    +I+MC*(NDXP1-1))*
     1                DATA($H    +I+MC*(NDXP1-1))
      FLOERR = FLOOUT - FLOIN
      ENGADD = AFLUX*Z*PHTOT/.0036
      ENGERR =  ENGOUT - ENGIN - ENGADD
      WRITE(I3,99) KASE,TEXT,DATE,TIME,FLOIN,ENGIN,FLOOUT,ENGADD,FLOERR,
     1ENGOUT,ENGERR
C  PREPARE CHANNEL EXIT SUMMARY
      J = NDXP1
      DO 450 I=1,NCHANL
      OUTPUT(1) = TF
      IF(DATA($H+I+MC*(J-1)).LT.HF)  CALL CURVE(OUTPUT(1),
     1   DATA($H+I+MC*(J-1)),TT,HHF,NPROP,IERROR,1)
      OUTPUT(2)=(DATA($H+I+MC*(J-1))-HF)/HFG
      IF(OUTPUT(2).LT.0.) OUTPUT(2) = 0.
      OUTPUT(3)=(RHOF-DATA($RHO+I+MC*(J-1)))/(RHOF-RHOG)
      IF(OUTPUT(3).LT.0.) OUTPUT(3) = 0.
      OUTPUT(4)=DATA($F+I+MC*(J-1))/DATA($AN+I)*.0036
      WRITE(I3,100) I,DATA($H+I+MC*(J-1)),OUTPUT(1),DATA($RHO+I+
     1    MC*(J-1)),OUTPUT(2),OUTPUT(3),          DATA($F  +I+MC*(J-1)),
     2    OUTPUT(4)
  450 CONTINUE
      IF(IERROR.GT.1) GO TO 505
C  COMPUTE BUNDLE AVERAGED RESULTS
  452 WRITE(I3,25) KASE,TEXT,DATE,TIME
      WRITE(I3,101)
      WRITE(I3,82)
      DO 456 J=1,NDXP1,NSKIPX
      SAVE1 = 0.
      SAVE2 = 0.
      SAVE3 = 0.
      SAVE4 = 0.
      DO 454 I=1,NCHANL
      SAVE1=SAVE1+DATA($P+I+MC*(J-1))*DATA($AN+I)
      SAVE2=SAVE2+DATA($H+I+MC*(J-1))*DATA($F+I+MC*(J-1))
      SAVE3=SAVE3+DATA($F+I+MC*(J-1))
 454  SAVE4=SAVE4+DATA($RHO+I+MC*(J-1))*DATA($AN+I)
      OUTPUT(1)=DATA($X+J)*12.
      OUTPUT(2) = SAVE1/ATOTAL/144.
      OUTPUT(3) = SAVE2/SAVE3
      OUTPUT(4) = TF
      IF(OUTPUT(3).LT.HF) CALL CURVE(OUTPUT(4),OUTPUT(3),TT,HHF,NPROP,
     1 IERROR,1)
      IF(IERROR.GT.1) GO TO 505
      OUTPUT(5) = SAVE4/ATOTAL
      OUTPUT(6) = 0.
      IF(OUTPUT(3).GT.HF) OUTPUT(6) = (OUTPUT(3)-HF)/HFG
      OUTPUT(7) = 0.
      IF(OUTPUT(5).LT.RHOF) OUTPUT(7) = (RHOF-OUTPUT(5))/(RHOF-RHOG)
      OUTPUT(8) = SAVE3
      OUTPUT(9) = SAVE3/ATOTAL*.0036
      WRITE(I3,81) (OUTPUT(II),II=1,9)
  456 CONTINUE
      IF(IERROR.GT.1) GO TO 505
C  PRINT CHANNEL AND ROD RESULTS AS DEFINED BY OUTPUT OPTIONS
```

```
  457 DO 460 JJ=1,NPCHAN
      I=IDAT($PRNTC+JJ)
      WRITE(I3,25) KASE, TEXT, DATE, TIME
      WRITE(I3,80) ETIME,I
      WRITE(I3,82)
      DO 458 J=1,NDXP1,NSKIPX
      OUTPUT(1)=DATA($X+J)*12.
      OUTPUT(3)=DATA($H+I+MC*(J-1))
      OUTPUT(2)=DATA($P+I+MC*(J-1))/144.
      OUTPUT(4) = TF
      IF(        DATA($H+I+MC*(J-1)).LT.HF)CALL CURVE(OUTPUT(4),
     1           DATA($H+I+MC*(J-1)),TT,HHF,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 505
      OUTPUT(5)=DATA($RHO+I+MC*(J-1))
      OUTPUT(6) = 0.
      IF(DATA($H+I+MC*(J-1)).GT.HF)  OUTPUT(6)=(
     1   DATA($H+I+MC*(J-1))-HF)/HFG
      OUTPUT(7) = 0.
      IF(DATA($RHO+I+MC*(J-1)).LT.RHOF)  OUTPUT(7)=(RHOF-
     1   DATA($RHO+I+MC*(J-1)))/(RHOF-RHOG)
      OUTPUT(8)=DATA($F+I+MC*(J-1))
      OUTPUT(9)=DATA($F+I+MC*(J-1))/DATA($AN+I)*.0036
      WRITE(I3,81) (OUTPUT(II),II=1,9)
  458 CONTINUE
  460 CONTINUE
      IF(NOUT.LT.1) GO TO 499
      IF(NOUT.EQ.2) GO TO 470
      DO 465 M=1,NK,10
      MM = M+9
      IF(NK.LE.MM) MM=NK
      WRITE(I3,31)KASE,TEXT,DATE,TIME,H7,(H6,H1,IDAT($IK+K),H2,IDAT($JK+
     1   K),H3,K=M,MM)
      DO 465 J=1,NDXP1,NSKIPX
      XDUMY=DATA($X+J)*12.
      WRITE(I3,30) XDUMY,(DATA($W+K+MG*(J-1)),K=M,MM)
  465 CONTINUE
      IF(NOUT.EQ.1) GO TO 499
  470 IF(NPROD.LT.1) GO TO 4990
      DO 485 NN=1,NPROD
      N=IDAT($PRNTR+NN)
      NDUMY=IDAT($IDFUE+N)
      II=1
      IF(NCHF.GT.0) II=NCHF
      WRITE(I3,94) KASE, TEXT, DATE, TIME, ETIME, N, NDUMY,CHFLBL(II),
     1    (H8,IDAT($PRNTN+I),H3,I=1,NPNODE)
      DO 483 J=1,NDXP1,NSKIPX
      XDUMY=DATA($X+J)*12.
      DO 480 II=1,NPNODE
      I=IDAT($PRNTN+II)
  480 DATA($TDUMY+II)=
     1            DATA($TROD+I+MN*(N-1+MR*(J-1)))
      DFLUX=DATA($FLUX+N+MR*(J-1))*.0036
      IF(IDAT($CCHAN+N+MR*(J-1)).EQ.0)  DATA($CHFR+N+MR*(J-1))=0.
      IF(NODESF.GT.1) WRITE(I3,95) XDUMY,DFLUX,DATA($CHFR+N+MR*(J-1)),
     1    IDAT($CCHAN+N+MR*(J-1)),(DATA($TDUMY+I),I=1,NPNODE)
```

```
      IF(NODESF.LT.1) WRITE(I3,95) XDUMY,DFLUX,DATA($CHFR+N+MR*(J-1)),
     1    IDAT($CCHAN+N+MR*(J-1))
  483 CONTINUE
  485 CONTINUE
 4990 IF(NCHF.LT.1) GO TO 499
      WRITE(I3,96)  KASE,TEXT,DATE,TIME,ETIME,CHFCOR(NCHF),CHFLBL(NCHF)
      DO 4995 J=1,NDXP1,NSKIPX
      XDUMY=DATA($X+J)*12.
      N=    IDAT($MCFRR+J)
      DFLUX = 0.
      IF(N.NE.0)  DFLUX=DATA($FLUX+N+MR*(J-1))*.0036
      IF(N.EQ.0)  DATA($MCHFR+J)=0.
      WRITE(I3,97) XDUMY,DFLUX,DATA($MCHFR+J),IDAT($MCFRR+J),
     1                                     IDAT($MCFRC+J)
 4995 CONTINUE
  499  WRITE(I3,75) ITERAT
  500 CONTINUE
  505 CONTINUE
      RETURN
C
   25 FORMAT(17H1CHANNEL RESULTS   /
     1  5H CASEI5,5X17A4,  9H   DATE   2A4,7H TIME    2A4,A1/)
   30 FORMAT(F7.1,10F10.5)
   31 FORMAT (68H1DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J),
     1 (LB/SEC-FT).
     1    // 5H CASEI5 , 5X, 17A4,
     29H   DATE  2A4,7H  TIME  2A4,A1 ///
     3 5X,A1,2X,10(2X,A1,A1,I2,A1,I2,A1))
   75 FORMAT (// 14H ITERATIONS =   I4)
   80 FORMAT(8H TIME =  F8.5,  9H SECONDS
     1  20H    DATA FOR CHANNEL   I3/)
   81 FORMAT(F6.1,F12.2,2F12.2,F10.2,2F9.3,F11.4,F12.4)
   82 FORMAT (' DISTANCE    DELTA-P    ENTHALPY   TEMPERATURE DENSITY
     1EQUIL    VOID        FLOW     MASS FLUX'/ '  (IN.)       (PSI)      (
     1BTU/LB)     (DEG-F)    (LB/CU-FT) QUALITY FRACTION    (LB/SEC) (MLB/H
     1R-FT2)')
   94 FORMAT(5H1CASEI5,5X17A4,9H   DATE   2A4,7H TIME    2A4,A1//
     1  8H TIME =  F8.5,9H SECONDS
     2 28H    TEMPERATURE DATA FOR ROD  I3,
     3 12H,  FUEL TYPE  I2//
     4 ' DISTANCE   FLUX        ',A4,'  CHANNEL                TEMP',
     5  'ERATURE(F)'/,22H  (IN.)  (MBTU/HR-FT2)   13X,10(4X,A2,I2,A1))
   95 FORMAT(F8.1,F9.4,F9.3,I4,5X,10(F9.1))
   96 FORMAT(5H1CASEI5,5X17A4,9H   DATE   2A4,7H TIME    2A4,A1//
     1 8H TIME =  F8.5,9H SECONDS  //
     2A7,  ' CRITICAL HEAT FLUX SUMMARY'/
     3 ' DISTANCE   FLUX   M',A4,'     ROD    CHANNEL')
   97 FORMAT(F8.1,2F8.3,2I8)
   99 FORMAT('1CHANNEL EXIT SUMMARY RESULTS'/
     1  5H CASEI5,5X17A4,  9H   DATE   2A4,7H TIME    2A4,A1//
     2' MASS BALANCE - -        ',17X,
     410X,'ENERGY BALANCE - -         ',/
     3,'     MASS FLOW IN       ',E12.5,' LB/SEC',
     410X,'    FLOW ENERGY IN       ',E12.5,' BTU/SEC',/
     3'     MASS FLOW OUT      ',E12.5,' LB/SEC',
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     410X,'    ENERGY ADDFD         ',E12.5,' BTU/SEC',/
     3'     MASS FLOW ERROR  ',E12.5,' LB/SEC',
     410X,'    FLOW ENERGY OUT      ',E12.5,' BTU/SEC',/
     449X,'    ENERGY ERROR         ',E12.5,' BTU/SEC',//
     7' CHANNEL ENTHALPY TEMPERATURE DENSITY   EQUIL     VOID     FLOW
     8  MASS FLUX'/
     9'  (NO.) (BTU/LB)  (DEG-F)    (LB/FT3) QUALITY  FRACTION  (LB/SEC)
     1 (MLB/HR-FT2)')
  100 FORMAT(I6,2F10.2,F10.2,2F9.3,F10.4,F12.4)
  101 FORMAT(' BUNDLE AVERAGED RESULTS'/)
      END
      SUBROUTINE FIZPRP(IPART,NPROP)
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
      REAL KKF
C
C     IPART = 1, SET PHYSICAL PROPERTIES
C     IPART = 2, PRINT PHYSICAL PROPERTIES
C     CODING SAME AS FOR COBRA
C
      IF (IPART.EQ.2) GO TO 10
C     ENTER WITH NPROP PMAX (=PP(1)) PMIN (=PP(2)) SET IN OPERA OR MODEL
      P1 = PP(1)
      P2 = PP(2)
    6 A = (P2-P1)/FLOAT(NPROP-1)
      DO 8 I=1,NPROP
      P=P1+(I-1.0)*A
      PP(I)=P
      TT(I)=SATTEM(P)
      RL=ROLIQ(P)
      VVF(I)=1.0/RL
      RG=ROVAP(P)
      VVG(I)=1.0/RG
      H=HLIQ(P)
      HHF(I)=H
      HHG(I)=HVAP(P)
      CALL HAPROP(P,H,CP,UUF(I),KKF(I))
      CALL SURTEN(P,RL,RG,SSIGMA(I))
    8 CONTINUE
      RETURN
C
   10 WRITE (6,1003)
      WRITE (6,1004) (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HHG(I),UUF(I),
     1 KKF(I),SSIGMA(I),I=1,NPROP)
      RETURN
C
 1003 FORMAT(////, '  PHYSICAL PROPERTIES', /, 2X,'-------- ----------',
     1 //, 4X, 'P', 9X, 'T', 8X, 'VF', 8X, 'VG', 8X, 'HF', 8X, 'HG',
     2 7X, 'VISC', 8X, 'KF', 6X, 'SIGMA', /)
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 1004 FORMAT(F8.1, F10.2, F8.5. F12.5. 2F10.2, 3F10.5)                 COB12660
      END                                                                COB12670
      SUBROUTINE FORCE(J)                                                COB12680
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THECOB12690
C   MAJOR SUBROUTINES OF COBRA-IIIC.                                     COB12700
C                                                                        COB12710
C                                                                        COB12720
      IMPLICIT INTEGER ($)                                               COB12730
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB12740
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB12750
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB12760
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB12770
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB12780
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB12790
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB12800
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB12810
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB12820
C                                                                        COB12830
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB12840
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB12850
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB12860
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB12870
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB12880
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB12890
C                                                                        COB12900
C                                                                        COB12910
      LOGICAL  GRID                                                      COB12920
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                COB12930
C                                                                        COB12940
C                                                                        COB12950
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB12960
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB12970
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB12980
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB12990
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB13000
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB13010
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB13020
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB13030
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB13040
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB13050
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB13060
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB13070
C                                                                        COB13080
      COMMON  DATA(1)                                                    COB13090
      LOGICAL LDAT(1)                                                    COB13100
      INTEGER IDAT(1)                                                    COB13110
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                             COB13120
C                                                                        COB13130
C                                                                        COB13140
      NKK = NK                                                           COB13150
      DO 10 K=1,NKK                                                      COB13160
      LDAT($FDIV+K)= .FALSE.                                             COB13170
   10 CONTINUE                                                           COB13180
      IF(J6.EQ.0) RETURN                                                 COB13190
      JM1 = J-1                                                          COB13200
```

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      GO TO (100,200),J6
C  FORCED DIVERSION CROSSFLOW FROM WIRE WRAPS
  100 IF(PITCH.LE.0.) GO TO 1000
      NN = Z/PITCH
      NN = NN+1
      DO 115 K=1,NN
      IF(DATA($X+J).LE.PITCH*FLOAT(K))  GO TO 118
  115 CONTINUE
  118 PL = K-1
C  PL IS THE PITCH LENGTH CONTAINING X(J).
C  FIND THE WRAP CROSSINGS IN DX.
      DO 130 K=1,NK
      II=IDAT($IK+K)
      JJ=IDAT($JK+K)
      DO 130 L=1,6
      IF(DATA($XCROS+K+MG*(L-1)))  119,130,119
 119  XC = (ABS(DATA($XCROS+K+MG*(L-1)))+PL)*PITCH
      IF(XC.GT.DATA($X+J).OR.
     1   XC.LE.DATA($X+JM1))  GO TO 130
      LDAT($FDIV+K) = .TRUE.
C  ADD AND SUBSTRACT WIRE WRAPS FROM SUBCHANNEL AT EACH WRAP CROSSING.
      IF(DATA($XCROS+K+MG*(L-1)))  120,130,121
 120  IDAT($NWRAP+II)=IDAT($NWRAP+II)+1
      IDAT($NWRAP+JJ)=IDAT($NWRAP+JJ)-1
      GO TO 123
 121  IDAT($NWRAP+II)=IDAT($NWRAP+II)-1
      IDAT($NWRAP+JJ)=IDAT($NWRAP+JJ)+1
  123 IF(NRAMP.LE.0) GO TO 1000
      DUMY = FLOAT(ITERAT)/FLOAT(NRAMP)
      IF(DUMY.GT.1.) DUMY = 1.
      DATA($W+K+MG*(J-1))=DATA($GAP+K)*PI*(DIA+THICK)*DATA($DUR+K)/DX
     1     *DUMY
      IF(DATA($XCROS+K+MG*(L-1)))  124,130,125
 124  DATA($W+K+MG*(J-1))=-DATA($W+K+MG*(J-1))*DATA($F+JJ+MC*(J-1))/
     1DATA($A+JJ)
      DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($FACTO+K)
      GO TO 130
 125  DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($F+II+MC*(J-1))/
     1DATA($A+II)
      DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($FACTO+K)
  130 CONTINUE
      RETURN
  200 IF(.NOT.GRID) RETURN
      DO 230 K=1,NKK
      IF(ABS(DATA($FXFLO+K+MG*(NGTYPE-1))).LT.1.0E-10)  GO TO 230
C  ZERO FORCED FLOW FRACTION DOES NOT BLOCK THE NATURAL DIVERSION CROSSF
      II=IDAT($IK+K)
      JJ=IDAT($JK+K)
      LDAT($FDIV+K)=.TRUE.
      IF(NRAMP.LE.0) GO TO 1000
      DUMY = FLOAT(ITERAT)/FLOAT(NRAMP)
      IF(DUMY.GT.1.) DUMY = 1.
      DUMY=DUMY*DATA($FXFLO+K+MG*(NGTYPE-1))/DX
      IF(DUMY.GT.0.)  DATA($W+K+MG*(J-1))=DUMY*DATA($F+II+MC*(J-1))
      IF(DUMY.LT.0.)  DATA($W+K+MG*(J-1))=DUMY*DATA($F+JJ+MC*(J-1))
```

```
      DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($FACTO+K)            COB13760
  230 CONTINUE                                                          COB13770
      RETURN                                                            COB13780
 1000 IERROR = 6                                                        COB13790
      RETURN                                                            COB13800
      END                                                               COB13810
      SUBROUTINE GAUSS (N,M,A,B,T)                                      COB13820
C     SUBROUTINE SOLVES TRIDIAGONAL MATRIX BY GAUSS ELIMINATION         COB13830
      DIMENSION  A(3,1),B(1),T(1)                                       COB13840
      MM         = M-1                                                  COB13850
      DO  10 K = N,MM                                                   COB13860
      AK         = A(1,K+1)/A(2,K)                                      COB13870
      A(2,K+1) = A(2,K+1)-A(3,K)*AK                                     COB13880
   10 B(K+1)     = B(K+1)-B(K)*AK                                       COB13890
      T(M)       = B(M)/A(2,M)                                          COB13900
      DO  20 K = N,MM                                                   COB13910
      L          = MM-K+N                                               COB13920
   20 T(L)       = (B(L)-A(3,L)*T(L+1))/A(2,L)                          COB13930
      RETURN                                                            COB13940
      END                                                               COB13950
      SUBROUTINE HAPROP(P,H,CP,XMU,XK)                                  COB13960
C   MEKIN NEW.      AUGUST  1974                                        COB13970
      X=0.001*H                                                         COB13980
      X3=X*X*X                                                          COB13990
      CP=0.864+1.66*X-7.0*X*X+10.6*X3-7.0*X*X3                          COB14000
      CP=1.0/CP                                                         COB14010
      XMU=0.008+118.0/H                                                 COB14020
      IF(H-90.0)1,2,2                                                   COB14030
1     XMU=0.008+118.0/(H+0.25*(90.0-H))                                 COB14040
2     X=X-0.25                                                          COB14050
      XK=0.47-0.45*X-0.072/EXP(6.25*X)                                  COB14060
      RETURN                                                            COB14070
      END                                                               COB14080
      FUNCTION HCOOL(N,I,JJ)                                            COB14090
C  COMPUTES THE HEAT TRANSFER COEFFICIENT FOR ROD N FACING SUBCHANNEL I COB14100
C  AT AXIAL LOCATION J.                                                 COB14110
C     USING THOM/JENS/LOTTES SUBCOOLED BOILING HEAT TRANSFER COEFF.     COB14120
C     PROC.I.M.E. VOL 180, PART 3C, PAGES 226-246 (1965-6)              COB14130
C     HCOOL CALC BY FWD DIFFERENCING, IE FROM CONDITIONS IN LAST INTVL. COB14140
C     JJ = J-1 WHEN CALLED FROM HEAT   AND J FROM PROP.                 COB14150
C                                                                       COB14160
C                                                                       COB14170
      IMPLICIT INTEGER ($)                                              COB14180
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB14190
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB14200
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB14210
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB14220
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB14230
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB14240
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB14250
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB14260
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB14270
C                                                                       COB14280
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB14290
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB14300
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     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2). HHF(30), HHG(30),
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON   DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
      IF (N+1) 6,4,2
    2 IF (DATA($QUAL+I).GT.0.0) GO TO 6
C     SINGLE PHASE AND ENTRY FROM PROP (N=-1)
    4 RE=DATA($F+I+MC*(JJ-1))/DATA($A+I)*DATA($DHYD+I)/DATA($VISC+I)
      IF(RE.LT.2000.) RE = 2000.
      PR=DATA($CP+I)*DATA($VISC+I)/DATA($CON+I)
C     HCOOL         =0.023*DATA($CON+I)/DATA($DHYD+I)*RE**.8*PR**.4
      HCOOL      = 0.134*DATA($CON+I)/DATA($DHYD+I)*RE**.65*PR**.4
      RETURN
C
C     TWO PHASE AND ENTRY FROM PROP(N=-2)
    6 FI = 3600.0*DATA($QPRIM+I)/DATA($HPERI+I)
      IF(FI.LT.0.) FI=ABS(FI)
      DTSAT = 0.072*(FI**0.5)*EXP(-PREF/1260.0)
      IF (N.GE.0) GO TO 8
      HCOOL = DTSAT
      RETURN
    8 DTTOT = DTSAT + TF - DATA($T+I)
      HCOOL = FI/(3600.0*DTTOT)
      RETURN
      END
      FUNCTION HLIQ(P)
C  MEKIN NEW.      AUGUST  1974
      U=ALOG(P)
      IF(P.LE.265.0) GO TO 2
      U=U-7.0
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```
      HLIQ=((((((-0.58728711D00*U+0.11490811D01)*U+0.74153448D01)*U       COB14860
     1+0.10801090D02)*U+0.13891584D02)*U+0.37492429D02)*U                 COB14870
     2+0.16078158D03)*U+0.55715337D03                                     COB14880
      RETURN                                                              COB14890
 2    HLIQ=(((((((((-0.4771D-04*U+0.84618D-03)*U-0.533926D-02)*U          COB14900
     1+0.12037370D-01)*U+0.908507D-02)*U-0.6628012D-01)*U                 COB14910
     2+0.41031089D-01)*U+0.28766511D-00)*U+0.22225855D01)*U               COB14920
     3+0.33320422D02)*U+0.69795537D02                                     COB14930
      RETURN                                                              COB14940
      END                                                                 COB14950
      FUNCTION HVAP(P)                                                    COB14960
C   MEKIN NEW.      AUGUST  1974                                          COB14970
      U=ALOG(P)                                                           COB14980
      IF(P.LE.450.0) GO TO 2                                              COB14990
      U=U-7.0                                                             COB15000
      HVAP=(((((0.37170416D01*U-0.91118126D01)*U-0.2444781D02)*U          COB15010
     1-0.27217176D02)*U-0.44206896D02)*U-0.46351642D02)*U                 COB15020
     2+0.11876082D04                                                      COB15030
      RETURN                                                              COB15040
 2    HVAP=((((((-0.3674D-04*U-0.5862D-03)*U+0.43507598D-02)*U            COB15050
     1-0.14535040D-01)*U+0.22775919D-01)*U                                COB15060
     2+0.85550917D0)*U+0.14228318D02)*U+0.11059625D04                     COB15070
      RETURN                                                              COB15080
      END                                                                 COB15090
      SUBROUTINE INPRIN                                                   COB15100
C                                                                         COB15110
C                                                                         COB15120
      IMPLICIT INTEGER ($)                                                COB15130
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX     ,COB15140
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF     ,COB15150
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2     ,COB15160
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,        COB15170
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF     ,COB15180
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP  ,COB15190
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF   ,COB15200
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK  ,COB15210
     8   UF    ,VF    ,VFG   ,VG    ,Z                                   COB15220
C                                                                         COB15230
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),      COB15240
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),     COB15250
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),   COB15260
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),        COB15270
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),         COB15280
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                       COB15290
C                                                                         COB15300
C                                                                         COB15310
      LOGICAL  GRID                                                       COB15320
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                 COB15330
C                                                                         COB15340
C                                                                         COB15350
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX     ,COB15360
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B     ,COB15370
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX  ,COB15380
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F     ,COB15390
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB15400
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     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB15410
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB15420
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB15430
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB15440
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB15450
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB15460
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD  COB15470
C                                                                       COB15480
      COMMON  DATA(1)                                                   COB15490
      LOGICAL LDAT(1)                                                   COB15500
      INTEGER IDAT(1)                                                   COB15510
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB15520
      EQUIVALENCE (NCHAN,NCHANL)                                        COB15530
C                                                                       COB15540
      LOGICAL PRINT                                                     COB15550
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),  COB15560
     1 JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),COB15570
     2 YQ(30)                                                           COB15580
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB15590
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB15600
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB15610
C                                                                       COB15620
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                 COB15630
C                                                                       COB15640
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,      COB15650
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG                            COB15660
C                                                                       COB15670
       DATA H1,H2,H3,H4,H5 / 1H(, 1H,, 1H), 4H  W(, 4H)WP( /            COB15680
      DATA H6, H7, H8 /1HW, 1HX, 2HT( /                                 COB15690
C     PRINT INPUT DATA (COBRA CARDS MAIN8840 - MAIN0350)                COB15700
C  SET UP VARIABLES FOR OUTPUT PRINTOUT                                 COB15710
C                                                                       COB15720
  250 DO 251  I=1,NCHANL                                                COB15730
      DATA($A    +I)=DATA($AN   +I)                                     COB15740
  251 DATA($DHYD +I)=DATA($DHYDN+I)                                     COB15750
      DO 252 K=1,NK                                                     COB15760
  252 DATA($GAP  +K)=DATA($GAPN +K)                                     COB15770
      IF(NPCHAN.GT.0) GO TO 257                                         COB15780
      NPCHAN = NCHANL                                                   COB15790
      DO 256 I=1,NCHANL                                                 COB15800
  256 IDAT($PRNTC+I)=I                                                  COB15810
  257 IF(NPROD.GT.0) GO TO 259                                          COB15820
      NPROD = NROD                                                      COB15830
      DO 258 N=1,NROD                                                   COB15840
  258 IDAT($PRNTR+N)=N                                                  COB15850
  259 IF(NPNODE.GT.0) GO TO 261                                         COB15860
      NN = NODESF+1                                                     COB15870
      NPNODE = NN                                                       COB15880
      DO 260 I=1,NN                                                     COB15890
  260 IDAT($PRNTN+I)=I                                                  COB15900
C                                                                       COB15910
C  OUTPUT OF INPUT DATA                                                 COB15920
C                                                                       COB15930
  261 IF(.NOT.PRINT(1)) GO TO 265                                       COB15940
      WRITE(I3,13)  (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HHG(I),UUF(I),    COB15950
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```
     1KKF(I),SSIGMA(I),I=1,NPROP)
 265 IF(.NOT.PRINT(2)) GO TO 270
     WRITE(I3,28)
     DO 266 J=1,4
     IF(AA(J).GT.0. .OR. CC(J).GT.0.) WRITE(I3,29)  J,AA(J),BB(J),CC(J)
 266 CONTINUE
     IF(NVISCW.EQ.0) WRITE(I3,61)
     IF(NVISCW.EQ.1) WRITE(I3,62)
     WRITE (I3,44)
     IF(J2.EQ.0) WRITE(I3,45)
     IF(J2.EQ.1) WRITE(I3,46)
     IF(J3.EQ.0) WRITE(I3,47)
     IF(J3.EQ.1) WRITE(I3,48)
     IF(J3.EQ.5) WRITE(I3,49) AV(1)
     IF(J3.EQ.6) WRITE(I3,57) NV,(AV(I),I=1,NV)
     IF(J4.EQ.0) WRITE(I3,58)
     IF(J4.EQ.1) WRITE(I3,59)
     IF(J4.EQ.5) WRITE(I3,60) NF,(AF(I),I=1,NF)
 270 IF(.NOT.PRINT(3)) GO TO 275
     WRITE(I3,6) (Y(I),AXIAL(I),I=1,NAX)
 275 IF(.NOT.PRINT(4)) GO TO 280
     WRITE(I3,12)
     DO 277 I=1,NCHANL
     IF((DATA($AC+I).LT.9.99).AND.
    1   (DATA($PW+I).LT.9.99))  GO TO 276
     WRITE(I3,1003)  I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),
    1    DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),
    2    DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)
     GO TO 277
 276 WRITE(I3,1004)  I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),
    1    DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),
    2    DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)
 277 CONTINUE
 280 IF(NAXL  .LT.1) GO TO 285
     IF(.NOT.PRINT(5)) GO TO 285
     N=1
     NN=10
     DO 284 LL=1,4
     IF(NN.GT.NAFACT) NN = NAFACT
     WRITE (I3,19) (H1,NCH(J),H3,J=N,NN)
     DO 283 I=1,NAXL
 283 WRITE(I3,38) AXL(I), (AFACT(J,I),J=N,NN)
     N=N+10
     NN=NN+10
     IF(N.GE.NAFACT) GO TO 285
 284 CONTINUE
 285 IF(NGXL .LT.1) GO TO 290
     IF(.NOT.PRINT(6)) GO TO 290
     N = 1
     NN= 10
     DO 289 LL = 1,6
     IF(NN.GT.NGAPS) NN=NGAPS
     DO 286 M=N,NN
     K = NGAP(M)
     IM(M)=IDAT($IK+K)
```

```
 286  JM(M)=IDAT($JK+K)                                              COB16510
      WRITE (I3,20) (H1,IM(M),H2,JM(M),H3,M=N,NN)                    COB16520
      DO 287 L=1,NGXL                                                COB16530
 287  WRITE (I3,38)  GAPXL(L),(GFACT(M,L),M=N,NN)                    COB16540
      N=N+10                                                         COB16550
      NN=NN+10                                                       COB16560
      IF(N.GE.NGAPS) GO TO 290                                       COB16570
 289  CONTINUE                                                       COB16580
 290  IF(.NOT.PRINT(7)) GO TO 300                                    COB16590
      IF(J6.EQ.0) GO TO 300                                          COB16600
      IF(J6.GT.1) GO TO 296                                          COB16610
      PITCH = PITCH*12.                                              COB16620
      DIA = DIA*12.                                                  COB16630
      THICK = THICK*12.                                              COB16640
      WRITE(I3,69) PITCH, THICK,DIA                                  COB16650
      PITCH = PITCH/12.                                              COB16660
      DIA = DIA/12.                                                  COB16670
      THICK = THICK/12.                                              COB16680
      WRITE(I3,70)  (K,H1,IDAT($IK+K),H2,IDAT($JK+K),H3,DATA($DUR+K), COB16690
     1    (DATA($XCROS+K+MG*(L-1)),L=1,6),K=1,NK)                    COB16700
      WRITE(I3,74) (IDAT($NWRAP+I),I=1,NCHANL)                       COB16710
      GO TO 300                                                      COB16720
 296  WRITE(I3,71) (IGRID(I),I=1,NGRID)                              COB16730
      WRITE(I3,72) (GRIDXL(I),I=1,NGRID)                             COB16740
      DO 297 L=1,NGRIDT                                              COB16750
 297  WRITE(I3,73)  L,(I,DATA($CD+I+MC*(L-1)),I=1,NCHANL)            COB16760
      DO 299 I=1,NGRIDT                                              COB16770
      II = 0                                                         COB16780
      DO 298 K=1,NK                                                  COB16790
      IF(ABS(DATA($FXFLO+K+MG*(I-1))).GT.0)  II=1                    COB16800
 298  CONTINUE                                                       COB16810
      IF(II.EQ.0) GO TO 299                                          COB16820
      WRITE(I3,76) I,(KK,H1,IDAT($IK+KK),H2,IDAT($JK+KK),H3,         COB16830
     1    DATA($FXFLO+KK+MG*(I-1)),KK=1,NK)                          COB16840
 299  CONTINUE                                                       COB16850
 300  IF(.NOT.PRINT(8)) GO TO 305                                    COB16860
      WRITE(I3,15) (I,IDAT($IDFUE+I),DATA($DR+I),                    COB16870
     1                                DATA($RADIA+I),(DATA($PHI+I+MR*COB16880
     1    (L-1)),IDAT($LR+I+MR*(L-1)),L=1,6),I=1,NROD)               COB16890
      IF(NODESF.LT.1) GO TO 305                                      COB16900
       DO 301 I = 1,NFUELT                                           COB16910
       KFUEL(I) = KFUEL(I)*3600.                                     COB16920
       KCLAD(I) = KCLAD(I)*3600.                                     COB16930
       DFUEL(I) = DFUEL(I)*12.                                       COB16940
       TCLAD(I) = TCLAD(I)*12.                                       COB16950
       HGAP(I) = HGAP(I)*3600.                                       COB16960
 301   CONTINUE                                                      COB16970
      WRITE(I3,77) NODESF                                            COB16980
      WRITE(I3,78) (J,KFUEL(J),CFUEL(J),RFUEL(J),DFUEL(J),KCLAD(J),  COB16990
     1 CCLAD(J),RCLAD(J),TCLAD(J),HGAP(J),J=1,NFUELT)                COB17000
       DO 302 I = 1,NFUELT                                           COB17010
      KFUEL(I) = KFUEL(I)/3600.                                      COB17020
      KCLAD(I) = KCLAD(I)/3600.                                      COB17030
       DFUEL(I) = DFUEL(I)/12.                                       COB17040
      TCLAD(I) = TCLAD(I)/12.                                        COB17050
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      HGAP(I) = HGAP(I)/3600.
  302  CONTINUE
  305 IF(.NOT.PRINT(9)) GO TO 310
      WRITE(I3,18) KIJ,FTM,SL,ZZ,THETA,NDX,DXX,NDT,TTIME,DT,NTRIES,
     1 FERROR
  310 IF(IFRM.EQ.0.AND.IHTM.EQ.0) GO TO 307
      WRITE(I3,17) EPSF
  307 IF(.NOT.PRINT(10))GO TO 315
      WRITE(I3,35)
      IF(NSCBC.LT.1) WRITE(I3, 32) ABETA
      IF(NSCBC.EQ.1) WRITE(I3, 33) ABETA, BBETA
      IF(NSCBC.EQ.2) WRITE(I3, 34) ABETA, BBETA
      IF(NSCBC.EQ.3) WRITE(I3,39) ABETA, BBETA
      IF (NSCBC.EQ.4) WRITE(I3,41)
      IF(NBBC-1) 311,311,312
  311 IF (NSCBC.NE.4) WRITE(I3,36)
      GO TO 314
  312 WRITE (I3,37) (XQUAL(I),BX(I),I=1,NBBC)
  314 IF(J5.EQ.1) WRITE(I3,65) GK
  315 IF(.NOT.PRINT(11)) GO TO 318
      WRITE(I3,21) PEXIT,HIN,GIN,TIN,AFLUX
      IF(IN.EQ.0) WRITE(I3,87)
      IF(IN.EQ.1) WRITE(I3,88)
      IF(IN.EQ.2) WRITE(I3,89)
      IF(IN.EQ.3) WRITE(I3,90)
      IF(IG.EQ.0) WRITE(I3,91)
      IF(IG.EQ.1) WRITE(I3,92)
      IF(IG.EQ.2) WRITE(I3,93)
      IF(NP.GT.1) WRITE(I3,83) (YP(I),FP(I),I=1,NP)
      IF(NH.GT.1) WRITE(I3,84) (YH(I),FH(I),I=1,NH)
      IF(NG.GT.1) WRITE(I3,85) (YG(I),FG(I),I=1,NG)
      IF(NQ.GT.1) WRITE(I3,86) (YQ(I),FQ(I),I=1,NQ)
  318 IF(KDEBUG) 400,400,319
 319  WRITE(I3,50)   ((IDAT($LC+I+MC*(L-1)),I=1,NCHANL),L=1,4)
      WRITE(I3,50)    (IDAT($IK+K),IDAT($JK+K),K=1,NK)
      WRITE(I3,51)   (DATA($FACTO+K),K=1,NK)
      WRITE(I3,50) ((IDAT($LR+NR+MR*(L-1)),NR=1,NROD),L=1,6)
      WRITE(I3,51) ((DATA($PWRF+I+MC*(NR-1)),NR=1,NROD),I=1,NCHANL)
      WRITE(I3,51)   (DATA($D+NR)               ,NR=1,NROD),
     1               (DATA($RADIA+NR)           ,NR=1,NROD)
  400 CONTINUE
      RETURN
C
    6 FORMAT (23H0HEAT FLUX DISTRIBUTION  /23H  X/L     RELATIVE FLUX /
     1(F7.3,F12.3))
   12 FORMAT(22H0SUBCHANNEL INPUT DATA  /
     1109H CHANNEL   TYPE   AREA   WETTED   HEATED   HYDRAULIC    (ADJ
     2ACENT CHANNEL NO., SPACING, CENTROID DISTANCE)         /
     3 55H   NO.           (SQ-IN) PERIM.    PERIM.    DIAMETER       /
     4 25X,                   30H (IN)       (IN)       (IN)         /)
   13 FORMAT(22H0FLUID PROPERTY TABLE ,/,
     1 60H     P          T        VF         VG          HF        HG
     1 30H  VISC.       KF       SIGMA    ,/,
     1 (F8.1,F10.2,F8.5,F12.5,2F10.2,3F10.5))
   15 FORMAT(15H0ROD INPUT DATA  /   96H   ROD  TYPE  DIA  RADIAL POWER
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     1    FRACTION OF POWER TO ADJACENT CHANNELS (ADJ. CHANNEL NO.)    / COB17610
     2 30H   NO.  NO.     (IN)    FACTOR    /(2I5,F8.4,F9.4,F11.4,1H(I2,  COB17620
     11H)F9.4,1H(I2,1H)F9.4,1H(I2,1H)F9.4,1H(I2,1H)F9.4,1H(I2,1H)F9.4,    COB17630
     11H(I2,1H)))                                                          COB17640
  17 FORMAT(/,'  FUEL ROD TEMP. CONVERGENCE CRITERIA = ',E10.5//)          COB17650
  18 FORMAT (23H0CALCULATION PARAMETERS /                                  COB17660
     2 28H   CROSSFLOW RESISTANCE,KIJ F8.3/                                COB17670
     4 28H   MOMENTUM TURBULENT FACTORF8.4  /                              COB17680
     3 28H   PARAMETER, (S/L)         F8.3/                                COB17690
     4 28H   CHANNEL LENGTH           F8.2,8H INCHES /                     COB17700
     4 28H   CHANNEL ORIENTATION      F8.1,8H DEGREES/                     COB17710
     5 28H   NUMBER OF AXIAL NODES    I8/                                  COB17720
     6 28H   NODE LENGTH              F8.3,7H INCHES /                     COB17730
     7 28H   NUMBER OF TIME STEPS     I8/                                  COB17740
     8 28H   TOTAL TRANSIENT TIME     F8.3,8H SECONDS/                     COB17750
     X 28H   TIME STEP                F8.4,8H SECONDS/                     COB17760
     1 28H   ALLOWABLE ITERATIONS     I8/                                  COB17770
     2 28H   FLOW CONVERGENCE FACTOR   E10.5/)                             COB17780
  19 FORMAT (50H0 X/L    AREA VARIATION FACTORS FOR SUBCHANNEL (I) /       COB17790
     1  7X,10(3X,A1,I2,A1,1X))                                             COB17800
  20 FORMAT (69H0 X/L    GAP SPACING VARIATION FACTORS FOR ADJACENT SUBCOB17810
     1CHANNELS (I,J) / 7X,10(1X,A1,I2,A1,I2,A1))                           COB17820
  21 FORMAT (22H0OPERATING CONDITIONS  /                                   COB17830
     1 25H   SYSTEM PRESSURE    =  ,F8.1,5H PSIA /                         COB17840
     2 25H   INLET ENTHALPY     =  ,F8.1,7H BTU/LB /                       COB17850
     3 25H   AVG. MASS VELOCITY =  ,F8.3,21H MILLION LB/(HR-SQFT) /        COB17860
     2 25H   INLET TEMPERATURE  =         ,F8.1,10H DEGREES F /            COB17870
     4 25H   AVG. HEAT FLUX     =  ,F8.6,22H MILLION BTU/(HR-SQFT)  )      COB17880
  28 FORMAT (/29H FRICTION FACTOR CORRELATION    )                         COB17890
  29 FORMAT ( 16H    CHANNEL TYPE I3,11H   FRICT = F5.3,6H*RE**(F5.3,      COB17900
     14H) +  F6.4   )                                                      COB17910
  32 FORMAT(31H     SUBCOOLED MIXING,   BETA = F6.4)                       COB17920
  33 FORMAT(31H     SUBCOOLED MIXING,   BETA = F6.4,6H*RE**(F6.4,1H))      COB17930
  34 FORMAT(31H     SUBCOOLED MIXING,   BETA = F6.4,12H*(D/S)*RE**(F6.4,COB17940
     1 1H))                                                                COB17950
  35 FORMAT(20H0MIXING CORRELATIONS )                                      COB17960
  36 FORMAT(54H     BOILING MIXING, BETA IS ASSUMMED SAME AS SUBCOOLED) COB17970
  37 FORMAT(55H     BOILING MIXING, BETA IS A FUNCTION OF STEAM QUALITY/COB17980
     1          25H          X         BETA(X)  / (F12.3,F13.6))           COB17990
  38 FORMAT  (F6.3,10F8.3)                                                 COB18000
  39 FORMAT(31H     SUBCOOLED MIXING,   BETA = F6.4,12H*(D/L)*RE**(F6.4,COB18010
     1 1H))                                                                COB18020
  41 FORMAT(1H ,' NEW(BEUS) MIXING MODEL USED')                            COB18030
  44 FORMAT( /  28H TWO-PHASE FLOW CORRELATIONS  )                         COB18040
  45 FORMAT(     33H    NO SUBCOOLED VOID CORRELATION  )                   COB18050
  46 FORMAT(     35H    LEVY SUBCOOLED VOID CORRELATION)                   COB18060
  47 FORMAT(     31H    HOMOGENEOUS BULK VOID MODEL)                       COB18070
  48 FORMAT(     41H    MODIFIED ARMAND BULK VOID CORRELATION )            COB18080
  49 FORMAT(     50H    HOMOGENEOUS BULK VOID MODEL WITH SLIP RATIO OF,    COB18090
     1 F6.2 )                                                              COB18100
  50 FORMAT(2015)                                                          COB18110
  51 FORMAT (8E12.3)                                                       COB18120
  57 FORMAT(     33H    BULK VOID FRACTION GIVEN AS A I2,56H TERM POLYNOCOB18130
     1MIAL FUNCTION OF QUALITY WITH COFFICIENTS OF/ 10X,7E10.4)            COB18140
  58 FORMAT(     41H    HOMOGENEOUS MODEL FRICTION MULTIPLIER )            COB18150
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   59 FORMAT(    30H    ARMAND FRICTION MULTIPLIER)                       COB18160
   60 FORMAT(    34H    FRICTION MULTIPLIER GIVEN AS A I2,57H TERM POLYNCOB18170
     1OMIAL FUNCTION OF QUALITY WITH COEFFICIENTS OF/ 10X,7E10.4)         COB18180
   61 FORMAT(65H    WALL VISCOCITY CORRECTION TO FRICTION FACTOR IS NOT  COB18190
     1INCLUDED     )                                                      COB18200
   62 FORMAT(65H    WALL VISCOSITY CORRECTION TO FRICTION FACTOR IS INCLCOB18210
     1UDED          )                                                     COB18220
   65 FORMAT(42H    CONDUCTION MIXING,  GEOMETRY FACTOR = F6.4)           COB18230
   69 FORMAT ( /62H WIRE WRAP SPACER DATA FOR FORCED DIVERSION CROSSFLOWCOB18240
     1 MIXING    //20H    WRAP PITCH     = F6.1,7H INCHES /               COB18250
     2              20H    WRAP THICKNESS = F6.4,7H INCHES /              COB18260
     3              20H    PIN DIAMETER   = F6.4,7H INCHES //)            COB18270
   70 FORMAT (23H    WRAP CROSSING DATA /                                 COB18280
     1   60H        GAP   SUBCHANNEL   MIXING           RELATIVE LOCATION COB18290
     2 / 60H        NO.   PAIR NO.    PARAMETER        OF WRAP CROSSINGS COB18300
     3 /(I10,4X,A1,I2,A1,I2,A1,F11.4,6F10.4))                             COB18310
   71 FORMAT( /12H SPACER DATA / 20H    SPACER TYPE NO.   ,10I6 )         COB18320
   72 FORMAT(  21H    LOCATION (X/L)     ,10F6.3)                         COB18330
   73 FORMAT (15H0   SPACER TYPE I2 /                                     COB18340
     1 62H      CHANNEL DRAG   CHANNEL DRAG   CHANNEL DRAG   CHANNEL DRAGCOB18350
     2/64H        NO.   COEFF.   NO.   COEFF.   NO.   COEFF.   NO.   COEFCOB18360
     3F.   /(3X,4(I6,F9.3)))                                              COB18370
   74 FORMAT (46H    INITIAL WRAP INVENTORY FOR EACH SUBCHANNEL /(10I5))COB18380
   76 FORMAT (43H0   FLOW DIVERSION FACTORS FOR SPACER TYPE  ,I2,/,      COB18390
     1   5X,46HGAP  CHANNEL FRACTION    GAP  CHANNEL FRACTION  ,/,        COB18400
     2   5X,46HNO.   PAIR   DIVERTED    NO.   PAIR   DIVERTED  ,/,        COB18410
     3  (2(5X,I3,1X,A1,I2,A1,I2,A1,F9.4)))                                COB18420
   77 FORMAT(39H THERMAL PROPERTIES FOR FUEL MATERIAL                     COB18430
     1 I8,18H RADIAL FUEL NODES  /                                        COB18440
     1 37H                         FUEL PROPERTIES ,25X,15HCLAD PROPERTIES,COB18450
     2 /,50H    TYPE    COND.    SP. HEAT   DENSITY   DIA.                COB18460
     3           50H  COND.    SP. HEAT   DENSITY  THICK.   GAP COND. /   COB18470
     4 49H      NO. (B/HR-FT-F) (B/LB-F)   (LB/FT3)  (IN.)                COB18480
     5          52H(B/HR-FT-F) (B/LB-F)   (LB/FT3)  (IN.)  (B/HR-FT2-F))COB18490
   78 FORMAT(I7,2X,F7.2,F11.4,F11.1,F9.4,2X,F7.2,F11.4,F11.1,F9.4,2X,     COB18500
     1 F9.2)                                                              COB18510
   83 FORMAT (33H    FORCING FUNCTION FOR PRESSURE /                      COB18520
     1          23H      TIME      PRESSURE /                             COB18530
     2          23H     (SEC)      FACTOR  /  (F10.4,F13.4))              COB18540
   84 FORMAT (38H    FORCING FUNCTION FOR INLET ENTHALPY/                 COB18550
     1          26H      TIME  INLET ENTHALPY          /                  COB18560
     2          23H     (SEC)      FACTOR    /  (F10.4,F13.4))            COB18570
   85 FORMAT (38H    FORCING FUNCTION FOR INLET FLOW       /              COB18580
     1          28H      TIME  INLET FLOW              /                  COB18590
     2          23H     (SEC)      FACTOR    /  (F10.4,F13.4))            COB18600
   86 FORMAT (38H    FORCING FUNCTION FOR HEAT FLUX       /               COB18610
     1          38H      TIME   HEAT FLUX              /                  COB18620
     2          23H     (SEC)      FACTOR    /  (F10.4,F13.4))            COB18630
   87 FORMAT(30H    UNIFORM INLET ENTHALPY         )                      COB18640
   88 FORMAT(35H    UNIFORM INLET TEMPERATURE           )                 COB18650
   89 FORMAT(45H    INDIVIDUAL SUBCHANNEL ENTHALPY SPECIFIED      )       COB18660
   90 FORMAT(50H    INDIVIDUAL SUBCHANNEL TEMPERATURE SPECIFIED        )  COB18670
   91 FORMAT(35H    UNIFCRM INLET MASS VELOCITY            )              COB18680
   92 FORMAT(50H    FLOWS SPLIT TO GIVE EQUAL PRESSURE GRADIENT        )  COB18690
   93 FORMAT(45H    INDIVIDUAL SUBCHANNEL FLOWS SPECIFIED         )       COB18700
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 1003 FORMAT(I5,I7,4F10.4,4X,4(1H(I3,1H,F5.3,1H,F5.3,1H)))
 1004 FORMAT(I5,I7,4F10.6,4X,4(1H(I3,1H,F5.3,1H,F5.3,1H)))
      END
      SUBROUTINE ITHO(NTHBOX,NTHBXX,ND1X,ND2X)
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
      DIMENSION NTHBOX(25,25)
      DIMENSION CARD(20)
C
C     CONTROL FOR THERMAL-HYDRAULIC INPUT DATA
C
C     WRITE (I3,1001)
C     WRITE(I3,1002)
      CALL CHAN(1,NTHBOX,NTHBXX,ND1X,ND2X,CARD)
      CALL MODEL(1,CARD,IPILE)
      CALL OPERA(1,CARD)
      CALL FIZPRP(1,NPROP)
      CALL TABLES(CARD)
      WRITE(I3,1002)
      CALL CORE3
      IF (IERROR.EQ.0) GO TO 2
      WRITE (I3,1004)
      RETURN
C
    2 CONTINUE
      WRITE (I3,1003)
      CALL OPERA(2,CARD)
      CALL CHAN(2,NTHBOX,NTHBXX,ND1X,ND2X,CARD)
      CALL MODEL(2,CARD,IPILE)
      CALL FIZPRP(2,NPROP)
      RETURN
C
 1001 FORMAT(1H1, 42X, 'THERMAL - HYDRAULIC INPUT DATA', /, 43X,
     1 '------------------------------', ////, '  CARD IMAGES', /, 2X,
     2 '---- ------')
 1002 FORMAT(32X, '0....*....1....*....2....*....3....*....4....*....5..
     1..*....6....*....7....*....8')
 1003 FORMAT(1H1, 42X, 'PROCESSED INPUT DATA', /, 43X,
     1 '--------------------', /, '  * = SET IN NEUTRONICS (CARD20)',
     2 ///)
 1004 FORMAT('  ERROR SIGNAL IN ITHO')
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      END                                                               COB19260
      SUBROUTINE MIX(J)                                                 COB19270
C                                                                       COB19280
C                                                                       COB19290
      IMPLICIT INTEGER ($)                                              COB19300
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB19310
     1  ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB19320
     2  HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB19330
     3  J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB19340
     4  NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB19350
     5  NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB19360
     6  NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB19370
     7  QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB19380
     8  UF    ,VF    ,VFG   ,VG    ,Z                                   COB19390
C                                                                       COB19400
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB19410
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB19420
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB19430
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB19440
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB19450
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB19460
C                                                                       COB19470
C                                                                       COB19480
      LOGICAL  GRID                                                     COB19490
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB19500
C                                                                       COB19510
C                                                                       COB19520
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB19530
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB19540
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB19550
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB19560
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB19570
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB19580
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB19590
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB19600
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB19610
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB19620
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB19630
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB19640
C                                                                       COB19650
      COMMON  DATA(1)                                                   COB19660
      LOGICAL LDAT(1)                                                   COB19670
      INTEGER IDAT(1)                                                   COB19680
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB19690
C                                                                       COB19700
C                                                                       COB19710
      NKK = NK                                                          COB19720
      DO 240 K=1,NKK                                                    COB19730
      DATA($COND+K)=0.                                                  COB19740
      II=IDAT($IK+K)                                                    COB19750
      JJ=IDAT($JK+K)                                                    COB19760
      ABAR=DATA($A+II)+DATA($A+JJ)                                      COB19770
      FBAR=DATA($F+II+MC*(J-1))+DATA($F+JJ+MC*(J-1))                    COB19780
      PBAR=DATA($PERIM+II)+DATA($PERIM+JJ)                              COB19790
      QBAR=DATA($QUAL +II)+DATA($QUAL +JJ)                              COB19800
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      VBAR=DATA($VISC +II)+DATA($VISC +JJ)
      DAVG=4.*ABAR/PBAR
      GAVG=FBAR/ABAR
      XAVG = 0.
      IF(AMAX1(DATA($QUAL+II),DATA($QUAL+JJ)).GT.0.) XAVG=0.5*QBAR
      IF(XAVG.GT.0..AND.NBBC.GE.2) GO TO 80
      UAVG=0.5*VBAR
      IF(NSCBC.GE.1) RE =  GAVG*DAVG/UAVG
      IF(NSCBC.EQ.0) DATA($WP+K)=DATA($GAP+K)*GAVG*ABETA
      IF(NSCBC.EQ.1) DATA($WP+K)=DATA($GAP+K)*GAVG*ABETA*RE**BBETA
      IF(NSCBC.EQ.2) DATA($WP+K)=DAVG        *GAVG*ABETA*RE**BBETA
      IF(NSCBC.EQ.3.AND.DATA($LENGT+K).LE.0.)  GO TO 1000
      IF(NSCBC.EQ.3) DATA($WP+K)=DATA($GAP+K)/DATA($LENGT+K)*DAVG*GAVG
     1    *ABETA*RE**BBETA
      IF(NSCBC.EQ.4) GO TO 50
      DATA($WP+K)=DATA($WP+K)*DATA($FACTO+K)
      GO TO 100
CC    BEUS MIXING MODEL USED WHEN NSCBC=4
   50 WL=0.0035*UAVG*RE**0.9
      ARBAR=ABAR*0.5
      B1=0.04*(DATA($GAP+K)/DAVG)**1.5
      XC=(0.4/GAVG*SQRT(32.2*RHOF*DAVG*(RHOF-RHOG))+0.6)/(SQRT(RHOF
     1  /RHOG)+0.6)
CC    SLIP RATIO, GAM, BASED ON SMITH CORRELATION
      GAM=1.
      IF(XAVG.LE.0.) GO TO 52
      ALP=1./(1.+0.4*RHOG/RHOF*(1./XAVG-1.)+(1.-0.4)*RHOG/RHOF*(1.
     1  /XAVG-1.)*SQRT((RHOF/RHOG+0.4*(1./XAVG-1.))/(1.+0.4*(1./XAVG
     2  -1.))))
      GAM=XAVG/(1.-XAVG)*(1.-ALP)/ALP*RHOF/RHOG
      IF(XAVG.GT.XC) GO TO 55
   52 DATA($WP+K)=WL+B1*ARBAR*GAVG/DAVG*RHOF/RHOG*(GAM-1.)/GAM*XAVG
      GO TO 100
   55 XOXC=0.57*RE**0.0417
      TK=0.5556*(TF+459.67)
      VISCG=0.672*VISVP(TK)
      WG=0.0035*VISCG*(GAVG*GAM*DAVG/VISCG)**0.9
      WC=WL+B1*ARBAR*GAVG/DAVG*RHOF/RHOG*(GAM-1.)/GAM*XC
      DATA($WP+K)=(WG+(WC-WG)*((1.-XOXC)/(XAVG/XC-XOXC)))*DATA($FACTO+K)
      GO TO 100
   80 CALL CURVE (XBETA,XAVG,BX,XQUAL,NBBC,IERROR,1)
      IF(IERROR.GT.1) GO TO 1000
      DATA($WP+K)=          GAVG*DAVG*XBETA *DATA($FACTO+K)
  100 IF(J5.EQ.0) GO TO 240
      CAVG=0.5*(DATA($CON+II)+DATA($CON+JJ))
      IF(DATA($LENGT+K).LE.0.0)  GO TO 1000
      DATA($COND+K)=CAVG*DATA($GAP+K)/DATA($LENGT+K)*GK*DATA($FACTO+K)
  240 CONTINUE
      RETURN
 1000 IERROR = 4
      RETURN
      END
      SUBROUTINE OPERA(IPART,CARD)
C
C
```

```
      IMPLICIT INTEGER ($)                                              COB20360
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB20370
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB20380
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB20390
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB20400
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB20410
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB20420
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB20430
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB20440
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB20450
C                                                                       COB20460
C                                                                       COB20470
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB20480
     1   AXL(10), B5(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB20490
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB20500
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB20510
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB20520
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB20530
C                                                                       COB20540
C                                                                       COB20550
      LOGICAL  GRID                                                     COB20560
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB20570
C                                                                       COB20580
C                                                                       COB20590
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB20600
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB20610
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB20620
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB20630
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB20640
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB20650
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB20660
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB20670
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB20680
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB20690
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB20700
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB20710
C                                                                       COB20720
      COMMON  DATA(1)                                                   COB20730
      LOGICAL LDAT(1)                                                   COB20740
      INTEGER IDAT(1)                                                   COB20750
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB20760
C                                                                       COB20770
C                                                                       COB20780
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),  COB20790
     1 JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),COB20800
     2 YQ(30)                                                           COB20810
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB20820
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB20830
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB20840
      DIMENSION CARD(20)                                                COB20850
C                                                                       COB20860
C     IPART=1  READ OPERATING CONDITIONS                                COB20870
C     IPART=2  PRINT OPERATING CONDITIONS                               COB20880
C     COBRA AND MEKIN SAME CODING EXCEPT IMEKIN = 0                     COB20890
C                                                                       COB20900
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      IMEKIN = 0                                                        COB20910
      IF(IPART.EQ.2) GO TO 10                                           COB20920
      READ (I2,1001) CARD, IN, HIN, GIN, PEXIT                          COB20930
      WRITE(I3,1011) CARD                                               COB20940
      IF ( (NDX.LE.0) .OR. (Z.LE.0.0) ) GO TO 30                        COB20950
      PREF = PEXIT                                                      COB20960
      IF(IN.LT.2) GO TO 2                                               COB20970
      IF(IN.EQ.2) CALL READIN(2,NCHANL,DATA($HINLE+1),CARD,CARD,1)      COB20980
      IF(IN.EQ.3) CALL READIN(3,NCHANL,DATA($HINLE+1),CARD,CARD,1)      COB20990
    2 READ(I2,1002) CARD,NP,NH,NG,NQ                                    COB21000
      WRITE(I3,1012) CARD                                               COB21010
      IF (NP.GT.1) CALL READIN(4,NP,YP,FP,CARD,2)                       COB21020
      IF (NH.GT.1) CALL READIN(5,NH,YH,FH,CARD,2)                       COB21030
      IF (NG.GT.1) CALL READIN(6,NG,YG,FG,CARD,2)                       COB21040
      IF (NQ.GT.1) CALL READIN(7,NQ,YQ,FQ,CARD,2)                       COB21050
      IF (NPROP.GT.0) GO TO 9                                           COB21060
C     SET MAX AND MIN PRESSURES FOR PHYSICAL PROPERTIES IN FIZPRP.      COB21070
      ZMIN = 1.0                                                        COB21080
      IF (NH.LE.1) GO TO 4                                              COB21090
      DO 3 I=1,NH                                                       COB21100
      IF (FH(I).LT.ZMIN) ZMIN = FH(I)                                   COB21110
    3 CONTINUE                                                          COB21120
    4 WV = HIN                                                          COB21130
      IF (IN.LT.2) GO TO 6                                              COB21140
      WV = 1000.0                                                       COB21150
      DO 5 I=1,NCHANL                                                   COB21160
      IF (DATA($HINLE+I).LT.WV) WV=DATA($HINLE+I)                       COB21170
    5 CONTINUE                                                          COB21180
C     WV CORRESPONDS TO MIN HIN OR TIN AT STEADY STATE                  COB21190
    6 R = 0.01*WV*ZMIN                                                  COB21200
      IF (R.LT.4.5) R = R*(1.0-0.1*(4.5-R))                             COB21210
C     SET PP(1) TO PRESSURE LOWER THAN MIN IN PROBLEM FOR FIZPRP        COB21220
      PP(1) = 10.0                                                      COB21230
      IF (R.GT.2.0) PP(1) = 6.0*R*R*R*(R-1.35)/(R-0.35)                 COB21240
      ZMAX = 1.0                                                        COB21250
      IF (NP.LE.1) GO TO 8                                              COB21260
      ZMIN = 1.0E06                                                     COB21270
      DO 7 I=1,NP                                                       COB21280
      IF (FP(I).GT.ZMAX) ZMAX = FP(I)                                   COB21290
      IF (FP(I).LT.ZMIN) ZMIN = FP(I)                                   COB21300
    7 CONTINUE                                                          COB21310
      IF (ZMIN*PREF.LT.PP(1)) PP(1) = ZMIN*PREF                         COB21320
C     SET PP(2) TO HIGHEST PRESSURE DURING TRANSIENT                    COB21330
    8 PP(2) = ZMAX*PREF + 0.01                                          COB21340
      NPROP = 30                                                        COB21350
    9 CONTINUE                                                          COB21360
C                                                                       COB21370
C     SET TTIME AND NDT FOR MEKIN ONLY                                  COB21380
      IF (IMEKIN.EQ.0) RETURN                                           COB21390
      TTIME = 1.0                                                       COB21400
      NDT = 1                                                           COB21410
      IF ((NP+NH+NG+NQ).LE.0) NDT=0                                     COB21420
      RETURN                                                            COB21430
C                                                                       COB21440
   10 WRITE (I3,1020) PEXIT,GIN                                         COB21450
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C     SET HINLET = H OR T ACCORDING TO IN                               COB21460
      IF (IN-1) 12,14,20                                                COB21470
   12 WRITE (I3,1021) IN,HIN                                            COB21480
      GO TO 16                                                          COB21490
   14 WRITE (I3,1022) IN,HIN                                            COB21500
   16 DO 18 I=1,NCHANL                                                  COB21510
   18 DATA($HINLE+I) = HIN                                              COB21520
      GO TO 22                                                          COB21530
   20 IF (IN.EQ.2) WRITE (I3,1023) IN,(I,DATA($HINLE+I),I=1,NCHANL)     COB21540
      IF (IN.EQ.3) WRITE (I3,1024) IN,(I,DATA($HINLE+I),I=1,NCHANL)     COB21550
   22 WRITE (I3,1025) Z,NDX                                             COB21560
      Z = Z/12.0                                                        COB21570
      IF (NDT.GT.0) GO TO 24                                            COB21580
      WRITE (I3,1026)                                                   COB21590
      GO TO 26                                                          COB21600
   24 IF (IMEKIN.EQ.0) WRITE (I3,1027) NDT,TTIME                        COB21610
      IF (NP.GT.1) WRITE(I3,1028) (YP(I),FP(I),I=1,NP)                  COB21620
      IF (NH.GT.1) WRITE(I3,1029) (YH(I),FH(I),I=1,NH)                  COB21630
      IF (NG.GT.1) WRITE(I3,1030) (YG(I),FG(I),I=1,NG)                  COB21640
      IF (NQ.GT.1) WRITE(I3,1031) (YQ(I),FQ(I),I=1,NQ)                  COB21650
   26 RETURN                                                            COB21660
   30 WRITE (I3,1040)                                                   COB21670
      STOP                                                              COB21680
C                                                                       COB21690
 1001 FORMAT(20A4, T1, I5, 13E5.0)                                      COB21700
 1002 FORMAT(20A4, T1, 14I5)                                            COB21710
C                                                                       COB21720
 1011 FORMAT('  IN H(OR T)IN GIN PEXIT', 6X, '***', 20A4, '*** OPERA')  COB21730
 1012 FORMAT('  TRANS INDIC FOR P H G Q',5X, '***', 20A4, '*** OPERA')  COB21740
C                                                                       COB21750
 1020 FORMAT(43X, 'OPERATING CONDITIONS', /, 43X,                       COB21760
     1 '--------------------', //, '  PRESSURE', 20X, '(PSIA)', 9X, '=',COB21770
     2 F10.2, /, '  AV. INLET MASS VELOCITY', 5X, '(MLB/SQFT.HR)', 2X,  COB21780
     3 '=', F12.4)                                                      COB21790
 1021 FORMAT('  IN=', I2, '  INLET ENTHALPY',   7X, '(BTU/LB)', 7X, '=',COB21800
     1 F11.3)                                                           COB21810
 1022 FORMAT('  IN=', I2, '  INLET TEMPERATURE',4X, '(DEG F)', 8X, '=', COB21820
     1 F11.3)                                                           COB21830
 1023 FORMAT('  IN=', I2, '  INLET ENTHALPIES', 5X, '(BTU/LB)', 7X, '=',COB21840
     1/(5X,6(I5,5X,F10.3)/))                                            COB21850
 1024 FORMAT('  IN=', I2, '  INLET TEMPERATURES',3X, '(DEG F)', 8X, '=',COB21860
     1/(5X,6(I5,5X,F10.3)/))                                            COB21870
 1025 FORMAT(' *CHANNEL LENGTH', 14X, '(IN)', 11X, '=', F10.2, /,       COB21880
     1 ' *NO. OF AXIAL INTERVALS', 21X, '=', I7)                        COB21890
 1026 FORMAT('  NO TRANSIENT CALCULATION')                              COB21900
 1027 FORMAT(' *NO. OF TIME STEPS', 26X, '=', I7, /,                    COB21910
     1 ' *TOTAL TIME OF TRANSIENT', 5X, '(SEC)', 10X, '=', F10.2)       COB21920
 1028 FORMAT (/, 33H   FORCING FUNCTION FOR PRESSURE /                  COB21930
     1          23H      TIME      PRESSURE /                           COB21940
     2          23H     (SEC)      FACTOR   /  (F10.4,F13.4))           COB21950
 1029 FORMAT  (/, 38H   FORCING FUNCTION FOR INLET ENTHALPY/            COB21960
     1          28H      TIME  INLET ENTHALPY          /                COB21970
     2          23H     (SEC)      FACTOR   /  (F10.4,F13.4))           COB21980
 1030 FORMAT  (/,38H   FORCING FUNCTION FOR INLET FLOW    /             COB21990
     1          28H      TIME  INLET FLOW              /                COB22000
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    2         23H     (SEC)      FACTOR   /  (F10.4,F13.4))
 1031 FORMAT (/, 38H   FORCING FUNCTION FOR HEAT FLUX     /
    1         38H     TIME   HEAT FLUX            /
    2         23H     (SEC)      FACTOR   /  (F10.4,F13.4))
 1040 FORMAT('  INPUT DATA ERROR. NDX OR Z .LT.0.  STOP (OPERA)')
      END
      SUBROUTINE PRECAL
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE   (DATA(1),IDAT(1),LDAT(1))
C
C
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ
C
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C     PREPARE TO START CALCULATION (IN CALC)                            COB22560
      CALL PROP(1,1)                                                    COB22570
      IF (IERROR.GT.0) GO TO 20                                         COB22580
      NDXP1 = NDX + 1                                                   COB22590
      DX = Z/FLOAT(NDX)                                                 COB22600
      DXX = DX*12.0                                                     COB22610
      DT = 0.0                                                          COB22620
      IF ( (NDT.GT.0) .AND. (TTIME.LE.0.0) ) NDT=0                      COB22630
      IF (NDT.GT.0) DT = TTIME/FLOAT(NDT)                               COB22640
      SAVEDT = DT                                                       COB22650
C     SET HINLET                                                        COB22660
      HIN = DATA($HINLE+1)                                              COB22670
      IF ( (IN.EQ.0) .OR. (IN.EQ.2) ) GO TO 10                          COB22680
      IF (IN.GE.3) GO TO 6                                              COB22690
      TIN = HIN                                                         COB22700
      CALL CURVE(HIN,TIN,HHF,TT,NPROP,IERROR,1)                         COB22710
      IF (IERROR.GT.0) GO TO 20                                         COB22720
      DO 4 I=1,NCHANL                                                   COB22730
      DATA($TINLE+I) = TIN                                              COB22740
    4 DATA($HINLE+I) = HIN                                              COB22750
      GO TO 10                                                          COB22760
    6 DO 8 I=1,NCHANL                                                   COB22770
      DATA($TINLE+I) = DATA($HINLE+I)                                   COB22780
      CALL CURVE(DATA($HINLE+I),DATA($TINLE+I),HHF,TT,NPROP,IERROR,1)   COB22790
      IF (IERROR.GT.0) GO TO 20                                         COB22800
    8 CONTINUE                                                          COB22810
C     SET FINLET                                                        COB22820
   10 WV = GIN/0.0036                                                   COB22830
      FLO = WV*ATOTAL                                                   COB22840
      WV1 = 1.0                                                         COB22850
      DO 12 I=1,NCHANL                                                  COB22860
      IF (IG.EQ.2) WV1 = DATA($FINLE+I)                                 COB22870
   12 DATA($FINLE+I) = WV*WV1*DATA($AN+I)                               COB22880
      IF (IG.EQ.1) CALL SPLIT                                           COB22890
      RETURN                                                            COB22900
   20 WRITE (I3,1001)                                                   COB22910
      RETURN                                                            COB22920
C                                                                       COB22930
 1001 FORMAT('  PRECAL    ERROR SIGNAL AFTER CALLING CURVE OR PROP')     COB22940
      END                                                               COB22950
      SUBROUTINE PROP(IPART,J)                                          COB22960
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THECOB22970
C   MAJOR SUBROUTINES OF COBRA-IIIC.                                    COB22980
C                                                                       COB22990
C                                                                       COB23000
      IMPLICIT INTEGER ($)                                              COB23010
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB23020
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB23030
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB23040
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB23050
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB23060
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB23070
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB23080
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB23090
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB23100
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C                                                                        COB23110
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB23120
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB23130
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB23140
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB23150
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB23160
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB23170
C                                                                        COB23180
C                                                                        COB23190
      LOGICAL  GRID                                                      COB23200
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                COB23210
C                                                                        COB23220
C                                                                        COB23230
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB23240
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB23250
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB23260
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB23270
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB23280
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB23290
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB23300
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB23310
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB23320
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB23330
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB23340
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A  ,$$B  ,$XPOLD   COB23350
C                                                                        COB23360
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                  COB23370
C                                                                        COB23380
      COMMON  DATA(1)                                                    COB23390
      LOGICAL LDAT(1)                                                    COB23400
      INTEGER IDAT(1)                                                    COB23410
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                             COB23420
C                                                                        COB23430
      EQUIVALENCE (NCHAN,NCHANL)                                         COB23440
C                                                                        COB23450
    1 FORMAT('  PROP.  REYNOLDS NO. IN CHAN ', I3, ' J = ', I3,          COB23460
     1 ' IS TOO LOW. RE = ', 1PE10.3, 5X, 'F, VISC = ', 2E15.4)          COB23470
    5 FORMAT(60H FAILURE OF SUBROUTINE PROP, PRESSURE TOO LOW FOR TABLE  COB23480
     1P =     E12.5 /(10E10.4))                                          COB23490
    6 FORMAT(61H FAILURE OF SUBROUTINE PROP, PRESSURE TOO HIGH FOR TABLE COB23500
     1 P =     E12.5 /(10E10.4))                                         COB23510
    7 FORMAT(40H TABLE LOOKUP FAILED IN SUBROUTINE PROP   )              COB23520
      NPROP = NPROP                                                      COB23530
      IF(IPART.LT.1 .OR. IPART.GT.2) GO TO 1001                          COB23540
      GO TO  (9,100),IPART                                               COB23550
C                                                                        COB23560
C     PART 1, CALCULATION OF SATURATATED PROPERTIES                      COB23570
    9 DO 10  I=1,NPROP                                                   COB23580
      IF(PREF.LT.PP(I)) GO TO 20                                         COB23590
   10 CONTINUE                                                           COB23600
      GO TO 200                                                          COB23610
   20 IF(I.GT.1) GO TO 40                                                COB23620
      GO TO 210                                                          COB23630
   40 VALUE = (PREF-PP(I-1))/(PP(I)-PP(I-1))                             COB23640
      HF     =    HHF(I-1) + VALUE*(    HHF(I)-    HHF(I-1))             COB23650
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```
      HG    =    HHG(I-1) + VALUE*(   HHG(I)-   HHG(I-1))
      VF    =    VVF(I-1) + VALUE*(   VVF(I)-   VVF(I-1))
      VG    =    VVG(I-1) + VALUE*(   VVG(I)-   VVG(I-1))
      UF    =    UUF(I-1) + VALUE*(   UUF(I)-   UUF(I-1))
      TF    =     TT(I-1) + VALUE*(    TT(I)-    TT(I-1))
      KF    =    KKF(I-1) + VALUE*(   KKF(I)-   KKF(I-1))
      SIGMA = SSIGMA(I-1) + VALUE*(SSIGMA(I)-SSIGMA(I-1))
      HFG = HG-HF
      VFG = VG-VF
      RHOG = 1./VG
      RHOF = 1./VF
      RETURN
C
C  PART 2, CALCULATE LIQUID PROPERTIES AND PARAMETERS
  100 NCHAN = NCHANL
      IF(J.GT.1) GO TO 102
      DO 101 I=1,NCHAN
  101 IDAT($JBOIL+I)=0
  102 DO 150 I=1,NCHAN
      DATA($VISCW+I)=UF
      DATA($VISC +I)=UF
      DATA($T    +I)=TF
      DATA($CON  +I)=KF
      DATA($V    +I)=VF
      HH=DATA($H+I+MC*(J-1))
      IF(HH.GT.HF) GO TO 105
      CALL CURVE(DATA($VISC+I),HH,UUF,HHF,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 1000
      CALL CURVE(DATA($V   +I),HH,VVF,HHF,NPROP,IERROR,2)
      CALL CURVE(DATA($T   +I),HH,TT ,HHF,NPROP,IERROR,2)
      CALL CURVE(DATA($CON +I),HH,KKF,HHF,NPROP,IERROR,2)
  105 TM=DATA($T    +I)-1.
      CALL CURVE (HM,TM,HHF,TT,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 1000
      DATA($CP+I)=HH-HM
      IF(HH.GT.HF)  DATA($CP+I)=HF-HM
      DATA($VISC +I)=DATA($VISC +I)/3600.
      DATA($CON  +I)=DATA($CON  +I)/3600.
      RE=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($DHYD+I)/DATA($VISC+I)
      IF(RE.LT.0.) WRITE(I3,1) I,J,RE,DATA($F+I+MC*(J-1)),DATA($VISC+I)
      IF(RE.LT.2000.) RE = 2000.
      PR=DATA($CP+I)*DATA($VISC+I)/DATA($CON+I)
      IF(DATA($H+I+MC*(J-1)).GT.HF.AND.IDAT($JBOIL+I).NE.0)
     1    GO TO 120
      IF(IHTM.NE.0.AND.J.NE.1) GO TO 108
C     DATA($HFILM+I)=0.023*DATA($CON+I)/DATA($DHYD+I)*RE**.8*PR**.4
      DATA($HFILM+I) = HCOOL(-1,I,J)
      DTWALL=DATA($QPRIM+I)/DATA($HPERI+I)/DATA($HFILM+I)
C  DETERMINE THE START OF NUCLEATE BOILING
      IF(IDAT($JBOIL+I).GT.0)    GO TO 106
      IF(DATA($QPRIM+I).LT.0.0)  GO TO 106
C     TLBOIL=TF-DTWALL+60.*EXP(-PREF/900.)*(DATA($QPRIM+I)/
      TLBOIL=TF-DTWALL+ HCOOL(-2,I,J)
      IF(DATA($T+I).GE.TLBOIL.AND.NCHF.NE.4) IDAT($JBOIL+I)=J
      IF(NCHF.EQ.4.AND.DATA($H+I+MC*(J-1)).GE.HF) IDAT($JBOIL+I)=J
```

```
  106 TWALL=DATA($T+I)+DTWALL                                        COB24210
      GO TO 110                                                      COB24220
C                                                                    COB24230
  108 SAVE=0.                                                        COB24240
      SUM=0.                                                         COB24250
      DO 109 NN=1,NROD                                               COB24260
      DUMY=DATA($PWRF+I+MC*(NN-1))                                   COB24270
      IF(DUMY.LE.0.) GO TO 109                                       COB24280
      SUM=SUM+DUMY*DATA($TROD+NODESF+1+MN*(NN-1+MR*(J-1)))           COB24290
      SAVE=SAVE+DATA($PWRF+I+MC*(NN-1))                              COB24300
  109 CONTINUE                                                       COB24310
      IF(SAVE.EQ.0.) GO TO 120                                       COB24320
      TWALL=SUM/SAVE                                                 COB24330
      IF(IDAT($JBOIL+I).NE.0) GO TO 112                              COB24340
      IF(TWALL.GE.TF.AND.NCHF.NE.4) IDAT($JBOIL+I)=J                 COB24350
      IF(DATA($H+I+MC*(J-1)).GE.HF.AND.NCHF.EQ.4) IDAT($JBOIL+I)=J   COB24360
CC                                                                   COB24370
  110 CONTINUE                                                       COB24380
  112 IF(TWALL.LT.TF) CALL CURVE(DATA($VISCW+I),TWALL,UUF,TT,NPROP,  COB24390
     1     IERROR,1)                                                 COB24400
      IF(IERROR.GT.1) GO TO 1000                                     COB24410
 120  L=IDAT($NTYPE+I)                                               COB24420
      DATA($FSP+I)=AA(L)*RE**BB(L)+CC(L)                             COB24430
      DATA($VISCW+I)=DATA($VISCW+I)/3600.                            COB24440
      IF(NVISCW.EQ.1)                                                COB24450
     1DATA($FSP+I)=DATA($FSP+I)*(1.+DATA($HPERI+I)/DATA($PERIM+I)*   COB24460
     2    ((DATA($VISCW+I)/DATA($VISC+I))**0.6-1.0))                 COB24470
  150 CONTINUE                                                       COB24480
      RETURN                                                         COB24490
  200 WRITE(I3,6) PREF,PP                                            COB24500
      GO TO 1001                                                     COB24510
  210 WRITE(I3,5) PREF,PP                                            COB24520
      GO TO 1001                                                     COB24530
 1000 WRITE(I3,7)                                                    COB24540
 1001 IERROR = 11                                                    COB24550
      RETURN                                                         COB24560
      END                                                            COB24570
      SUBROUTINE QPR3(NCHANL,   IKASE,TEXT,DATE,TIME,X)              COB24580
C                                                                    COB24590
C                                                                    COB24600
      IMPLICIT INTEGER ($)                                           COB24610
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB24620
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB24630
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB24640
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB24650
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB24660
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB24670
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB24680
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB24690
     8   UF    ,VF    ,VFG   ,VG    ,Z                                 COB24700
C                                                                    COB24710
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),  COB24720
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), COB24730
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB24740
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),    COB24750
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      4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),         COB24760
      5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                        COB24770
C                                                                           COB24780
C                                                                           COB24790
      LOGICAL  GRID                                                         COB24800
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                   COB24810
C                                                                           COB24820
C                                                                           COB24830
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB24840
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB24850
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB24860
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB24870
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB24880
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB24890
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB24900
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB24910
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB24920
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB24930
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB24940
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD  COB24950
C                                                                           COB24960
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,      COB24970
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,      COB24980
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ                 COB24990
      COMMON  DATA(1)                                                       COB25000
      LOGICAL LDAT(1)                                                       COB25010
      INTEGER IDAT(1)                                                       COB25020
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                                COB25030
C                                                                           COB25040
C                                                                           COB25050
      DIMENSION  JB(10),TEXT(17),DATE(2),TIME(3),X(1)                       COB25060
C                                                                           COB25070
      READ (I2,700) ZM                                                      COB25080
      WRITE (I3,1000) ZM                                                    COB25090
      IF (ZM.GE.0.0) GO TO 505                                              COB25100
      IF (ZM.LT.-1.01) GO TO 500                                            COB25110
      ZM = 3413.0/3.6                                                       COB25120
      GO TO 505                                                             COB25130
  500 ZM = 1000.0/3.6                                                       COB25140
  505 WRITE (I3,1001) ZM                                                    COB25150
      NDXP1=NDX+1                                                           COB25160
      DO 601 I=1,NCHANL                                                     COB25170
 601  READ(I2,700)  (DATA($QF+I+MC*(J-1)),J=2,NDXP1)                        COB25180
      IF(IQP3.EQ.0) GO TO 705                                               COB25190
      DO 602 I=1,NCHANL                                                     COB25200
 602  READ(I2,700)  (DATA($QC+I+MC*(J-1)),J=2,NDXP1)                        COB25210
  705 CONTINUE                                                              COB25220
C                                                                           COB25230
C     PRINT INPUT FUEL NODAL POWERS                                         COB25240
      WRITE(I3,650)                                                         COB25250
      DO 621 I=1,NCHANL,10                                                  COB25260
      DO 5 K=1,10                                                           COB25270
    5 JB(K)=I+K-1                                                           COB25280
      II=I+9                                                                COB25290
      IF(NCHANL.LE.II) II=NCHANL                                            COB25300
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      L=II-I+1                                                          COB25310
      WRITE(I3,655) (JB(K),K=1,L)                                       COB25320
      DO 621 J=1,NDX                                                    COB25330
      WRITE(I3,30) J    ,(DATA($QF+K+MC*(J  )),K=I,II)                  COB25340
  621 CONTINUE                                                          COB25350
C                                                                       COB25360
C     MULTIPLY FUEL POWERS BY ZM                                        COB25370
      SUMF = 0.0                                                        COB25380
      DO 630 I=1,NCHANL                                                 COB25390
      DATA($RADIA+I) = 0.0                                              COB25400
      DO 630 J=2,NDXP1                                                  COB25410
      DATA($QF+I+MC*(J-1))=DATA($QF+I+MC*(J-1))*ZM                      COB25420
      DATA($RADIA+I) = DATA($RADIA+I) + DATA($QF+I+MC*(J-1))            COB25430
  630 SUMF = SUMF + DATA($QF+I+MC*(J-1))                                COB25440
      SUMC = 0.0                                                        COB25450
      IF(IQP3.EQ.0) GO TO 645                                           COB25460
C                                                                       COB25470
C     PRINT INPUT COOLANT NODAL POWERS                                  COB25480
      WRITE(I3,660)                                                     COB25490
      DO 622 I=1,NCHANL,10                                              COB25500
      DO 6 K=1,10                                                       COB25510
    6 JB(K)=I+K-1                                                       COB25520
      II=I+9                                                            COB25530
      IF(NCHANL.LE.II) II=NCHANL                                        COB25540
      L=II-I+1                                                          COB25550
      WRITE(I3,655) (JB(K),K=1,L)                                       COB25560
      DO 622 J=1,NDX                                                    COB25570
      WRITE(I3,30) J    ,(DATA($QC+K+MC*(J  )),K=I,II)                  COB25580
  622 CONTINUE                                                          COB25590
C                                                                       COB25600
C     MULTIPLY COOLANT POWERS BY ZM                                     COB25610
      DO 640 I=1,NCHANL                                                 COB25620
      DO 640 J=2,NDXP1                                                  COB25630
      DATA($QC+I+MC*(J-1))=DATA($QC+I+MC*(J-1))*ZM                      COB25640
      DATA($RADIA+I) = DATA($RADIA+I) + DATA($QC+I+MC*(J-1))            COB25650
  640 SUMC = SUMC + DATA($QC+I+MC*(J-1))                                COB25660
C                                                                       COB25670
C     PRINT FUEL AND COOLANT SUMMED POWERS.                             COB25680
  645 SUMT = SUMF+SUMC                                                  COB25690
      WV = FLOAT(NCHANL)/SUMT                                           COB25700
      DO 647 I=1,NCHANL                                                 COB25710
  647 DATA($RADIA+I) = DATA($RADIA+I)*WV                                COB25720
      WRITE (I3,1004) (DATA($RADIA+I),I=1,NCHANL)                       COB25730
      WV = 3.6/3413.0                                                   COB25740
      SUMF1 = WV*SUMF                                                   COB25750
      SUMC1 = WV*SUMC                                                   COB25760
      SUMT1 = WV*SUMT                                                   COB25770
      SUMF = 0.001*SUMF                                                 COB25780
      SUMC = 0.001*SUMC                                                 COB25790
      SUMT = 0.001*SUMT                                                 COB25800
      WRITE (I3,1002) SUMF1,SUMF, SUMC1,SUMC, SUMT1,SUMT                COB25810
      AFLUX = SUMT1*3.413/(PHTOT*Z)                                     COB25820
      WRITE(I3,1003) AFLUX                                              COB25830
      RETURN                                                            COB25840
C                                                                       COB25850
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   30 FORMAT(I5, 2X, 10F10.5)
  650 FORMAT( //,'  HEAT GENERATION IN    FUEL')
  655 FORMAT(//, '  NODE  ROD', I4, I9, 8I10, /)
  660 FORMAT( //,'  HEAT GENERATION IN COOLANT')
  700 FORMAT(8E10.0)
 1000 FORMAT(1H1,      ' READ NODAL POWERS IN SUBROUTINE QPR3 AND MULTIPLY
     1 GIVEN VALUES BELOW BY ZM', //, '  ZM GIVEN AS', F10.4, 7X,
     2 '(.GE.0.0  USED AS MULTIPLIER TO CONVERT TO BTU/SEC)', /, 30X,
     3 '(.EQ.-1.0 TO CONVERT MW TO BTU/SEC)', /, 30X,
     4 '(.EQ.-2.0 TO CONVERT MBTU/HR TO BTU/SEC)' )
 1001 FORMAT(/, '  ZM TAKEN TO BE ', F11.5)
 1002 FORMAT(/, '  POWER IN FUEL    = ',  F9.2, ' MW  IE ', F9.2,
     1 ' KBTU/SEC', /, 8X, 'IN COOLANT = ', F9.2 , ' MW  IE ', F9.2,
     2 ' KBTU/SEC', /, 8X, 'TOTAL      = ', F9.2,  ' MW  IE ', F9.2,
     3 ' KBTU/SEC')
 1003 FORMAT(/, '  AVERAGE HEAT FLUX = ', F10.4, ' MBTU/SQFT.HR')
 1004 FORMAT(//, '  RADIAL POWER FACTORS FOR EACH CHANNEL', /,
     1 (6X, 10F10.4, 22X) )
      END
      SUBROUTINE READIN(IVAR,N,A,B,CARD,M)
      DIMENSION A(1),B(1),CARD(20)
C
C     READ AND PRINT CARD IMAGES.
C     IVAR IDENTIFIES A, B AND THUS PRINTING
C     IF M=1, READ (A(I),I=1,N).     M=2, READ (A(I),B(I),I=1,N)  16E5.0
C
      IDI = 14/M
      IVMAX = 9
      DO 20 I=1,N,IDI
      II = I + IDI-1
      IF (II.GT.N) II=N
      IF (M.EQ.1) READ (5,1000) CARD, (A(L),L=I,II)
      IF (M.EQ.2) READ (5,1000) CARD, (A(L),B(L),L=I,II)
      IF (I.GT.1) GO TO 11
      IF ( (IVAR.LT.1) .OR. (IVAR.GT.IVMAX) ) GO TO 30
      GO TO (1,2,3,4,5,6,7,8,9), IVAR
    1 WRITE (6,1001) CARD
      GO TO 20
    2 WRITE (6,1002) CARD
      GO TO 20
    3 WRITE (6,1003) CARD
      GO TO 20
    4 WRITE (6,1004) CARD
      GO TO 20
    5 WRITE (6,1005) CARD
      GO TO 20
    6 WRITE (6,1006) CARD
      GO TO 20
    7 WRITE (6,1007) CARD
      GO TO 20
    8 WRITE (6,1008) CARD
      GO TO 20
    9 WRITE (6,1009) CARD
      GO TO 20
   11 WRITE (6,1011) CARD
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 20  CONTINUE                                                            COB26410
     RETURN                                                              COB26420
 30  WRITE (6,1030) IVAR,IVMAX,CARD                                      COB26430
     RETURN                                                              COB26440
C                                                                        COB26450
1000 FORMAT(20A4, T1, 14E5.0)                                            COB26460
1001 FORMAT('  INLET FLOW SPLIT', 12X, '***',20A4,'*** READIN (MODEL)')COB26470
1002 FORMAT('  INLET ENTHALPIES', 12X,'***',20A4, '*** READIN (OPERA)')COB26480
1003 FORMAT('  INLET TEMPERATURES',10X,'***',20A4,'*** READIN (OPERA)')COB26490
1004 FORMAT('  PRESSURE TRANSIENT', 10X, '***', 20A4, '*** READIN (OPERCOB26500
    1A)')                                                                COB26510
1005 FORMAT('  INLET ENTHALPY TRANSIENT',4X, '***', 20A4, '*** READIN (COB26520
    1OPERA)')                                                            COB26530
1006 FORMAT('  INLET FLOW TRANSIENT', 8X, '***', 20A4, '*** READIN (OPECOB26540
    1RA)')                                                               COB26550
1007 FORMAT('  INLET POWER TRANSIENT', 7X, '***', 20A4, '*** READIN (OPCOB26560
    1ERA)')                                                              COB26570
1008 FORMAT('  AXIAL HEAT FLUX',13X '***', 20A4, '*** READIN(CARD20)') COB26580
1009 FORMAT('  RADIAL POWERS', 15X, '***', 20A4, '*** READIN(CARD20)') COB26590
1011 FORMAT(30X, '***', 20A4, '*** CONTINUED')                          COB26600
1030 FORMAT('  IVAR = ', I3, ' NOT 0 - ', I3, 6X, '***', 20A4, '*** REACOB26610
    1DIN')                                                               COB26620
     END                                                                 COB26630
     FUNCTION ROLIQ(P)                                                   COB26640
C    MEKIN NEW.      AUGUST  1974                                        COB26650
     U=ALOG(P)                                                           COB26660
     IF(P.LE.450.0) GO TO 2                                              COB26670
     U=U-7.0                                                             COB26680
     VLIQ=(((((-0.26381D-03*U+0.142678D-02)*U+0.21252D-02)*U             COB26690
    1+0.119227D-02)*U+0.197421D-02)*U+0.404696D-02)*U                    COB26700
    2+0.21963280D-1                                                      COB26710
     ROLIQ=1.0/VLIQ                                                      COB26720
     RETURN                                                              COB26730
2    VLIQ=(((((((0.468D-08*U-0.747D-07)*U+0.39696D-06)*U                 COB26740
    1-0.36945D-06)*U-0.204944D-05)*U+0.67462798D-05)*U                   COB26750
    2+0.33132739D-04)*U+0.10394514D-03)*U+0.16140836D-1                  COB26760
     ROLIQ=1.0/VLIQ                                                      COB26770
     RETURN                                                              COB26780
     END                                                                 COB26790
     FUNCTION ROVAP(P)                                                   COB26800
C    MEKIN NEW.      AUGUST  1974                                        COB26810
     U=ALOG(P)                                                           COB26820
     IF(P.LE.450.0) GO TO 2                                              COB26830
     U=U-7.0                                                             COB26840
     PVG=(((((0.47458752D01*U-0.65913524D01)*U-0.22430605D02)*U          COB26850
    1-0.27967054D02)*U-0.53007282D02)*U-0.61514691D02)*U                 COB26860
    2+0.43997464D03                                                      COB26870
     ROVAP=P/PVG                                                         COB26880
     RETURN                                                              COB26890
2    PVG=(((((((-0.186D-05*U-0.12008D-03)*U+0.67223D-03)*U               COB26900
    1-0.307139D-02)*U-0.631126D-02)*U+0.60001629D-01)*U                  COB26910
    2+0.11039315D01)*U+0.19257401D02)*U+0.33360056D03                    COB26920
     ROVAP=P/PVG                                                         COB26930
     RETURN                                                              COB26940
     END                                                                 COB26950
```

```
      FUNCTION S(K,I)                                                   COB26960
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THECOB26970
C   MAJOR SUBROUTINES OF COBRA-IIIC.                                    COB26980
C                                                                       COB26990
C                                                                       COB27000
      IMPLICIT INTEGER ($)                                              COB27010
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB27020
     1  ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB27030
     2  HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB27040
     3  J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB27050
     4  NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB27060
     5  NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB27070
     6  NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB27080
     7  QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB27090
     8  UF    ,VF    ,VFG   ,VG    ,Z                                   COB27100
C                                                                       COB27110
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB27120
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB27130
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB27140
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB27150
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB27160
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB27170
C                                                                       COB27180
C                                                                       COB27190
      LOGICAL  GRID                                                     COB27200
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB27210
C                                                                       COB27220
C                                                                       COB27230
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB27240
     1           $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB27250
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB27260
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB27270
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB27280
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB27290
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB27300
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB27310
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB27320
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB27330
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB27340
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB27350
C                                                                       COB27360
      COMMON  DATA(1)                                                   COB27370
      LOGICAL LDAT(1)                                                   COB27380
      INTEGER IDAT(1)                                                   COB27390
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB27400
C                                                                       COB27410
C                                                                       COB27420
      S = 0.                                                            COB27430
      IF(I.EQ.IDAT($IK+K))   S =  1.                                    COB27440
      IF(I.EQ.IDAT($JK+K))   S = -1.                                    COB27450
      RETURN                                                            COB27460
      END                                                               COB27470
      FUNCTION SATTEM(P)                                                COB27480
C   MEKIN NEW.     AUGUST  1974                                         COB27490
      REAL*8 U,XATTEM                                                   COB27500
```

```
      XX=ALOG(P)
      U=DBLE(XX)
      IF(P.LE.450.0) GO TO 2
      U=U-7.0D0
      XATTEM=((((-0.16074225D-00*U-0.69678576D0)*U+0.61781119D0)*U
     1+0.14657783D02)*U+0.12405875D03)*U+0.55599496D03
      SATTEM=SNGL(XATTEM)
      RETURN
    2 XATTEM=(((-0.198D-05*U+0.1405D-04)*U-3.265D-5)*U+
     1 2.3907D-3)
      XATTEM=(((XATTEM*U+0.434618D-02)*U+0.17363004D0)*U+0.22808149D01)
      XATTEM=((XATTEM*U+0.33446776D02)*U+0.10182494D3)
      SATTEM=SNGL(XATTEM)
      RETURN
      END
      SUBROUTINE SOLVE(NN,LMAX,MID,UL,X,B,NK)
      DIMENSION UL(NK,1),X(1),B(1)
C     STORE DIAGONAL BAND OF AAA MATRIX.  POSITION (K,L) IN SQUARE
C     ARRAY BECOMES (K,(MID-K+L) ) IN NEW ARRAY.
      N = NN
      IF(N.EQ.1) GO TO 5
      NP1 = N+1
C
      X(1) = B(1)
      DO 2 I = 2,N
      IM1 = I-1
      SUM = 0.0
      JMIN = MAX0(1,(I-MID+1) )
C  DOUBLE PRECISION MAY BE REQUIRED FOR INNER LOOP.
      DO 1 J = JMIN,IM1
      JJ = MID-I+J
    1 SUM = SUM + UL(I,JJ)*X(J)
    2 X(I) = B(I) - SUM
C
      X(N) = X(N)/UL(N,MID)
      DO 4 IBACK = 2,N
      I = NP1-IBACK
C         I GOES (N-1),...,1
      IP1 = I+1
      SUM = 0.0
C  DOUBLE PRECISION MAY BE REQUIRED FOR INNER LOOP.
      JMAX = MIN0(N,(I+MID-1) )
      DO 3 J = IP1,JMAX
      JJ = MID-I+J
    3 SUM = SUM + UL(I,JJ)*X(J)
    4 X(I) = (X(I)-SUM)/UL(I,MID)
      RETURN
    5 X(1) = B(1)/UL(1,MID)
      RETURN
      END
      SUBROUTINE SPLIT
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE
C   MAJOR SUBROUTINES OF COBRA-IIIC.
C
C
```

```
      IMPLICIT INTEGER ($)                                              COB28060
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB28070
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB28080
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB28090
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB28100
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB28110
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB28120
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB28130
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB28140
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB28150
C                                                                       COB28160
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB28170
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB28180
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB28190
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB28200
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB28210
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB28220
C                                                                       COB28230
C                                                                       COB28240
      LOGICAL  GRID                                                     COB28250
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB28260
C                                                                       COB28270
C                                                                       COB28280
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB28290
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB28300
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB28310
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB28320
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB28330
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB28340
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB28350
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB28360
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB28370
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB28380
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB28390
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB28400
C                                                                       COB28410
      COMMON  DATA(1)                                                   COB28420
      LOGICAL LDAT(1)                                                   COB28430
      INTEGER IDAT(1)                                                   COB28440
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB28450
C                                                                       COB28460
C                                                                       COB28470
      EQUIVALENCE (NCHAN,NCHANL)                                        COB28480
C  CORRECT FLOW ESTIMATE BY ITERATION. THIS PROCEDURE ASSUMES THERE IS NCOB28490
C  DENSITY CHANGE WITH LENGTH AND THAT NO DIVERSION CROSSFLOW IS OCCURRICOB28500
C  CONVERGENCE TOLERANCE IS E.                                          COB28510
      E=0.005                                                           COB28520
      SAVEDT = DT                                                       COB28530
      DT = 1.E+10                                                       COB28540
      DO 10 I=1,NCHANL                                                  COB28550
      DATA($F+I)=DATA($FINLE+I)                                         COB28560
   10 DATA($H+I)=DATA($HINLE+I)                                         COB28570
      DO 100 K=1,200                                                    COB28580
      CALL PROP(2,1)                                                    COB28590
      IF(IERROR.GT.1) GO TO 1000                                        COB28600
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      CALL VOID(1)                                                      COB28610
      DO 15 I=1,NCHANL                                                  COB28620
 15   DATA($VPA+I)=DATA($VP+I)/DATA($A+I)                               COB28630
      IF(IERROR.GT.1) GO TO 1000                                        COB28640
      IF(FTM.GT.0.) CALL MIX(1)                                         COB28650
      IF(IERROR.GT.1) GO TO 1000                                        COB28660
      CALL DIFFER(3,1)                                                  COB28670
      IF(IERROR.GT.1) GO TO 1000                                        COB28680
      DPAVG = 0.                                                        COB28690
      DO 20 I=1,NCHANL                                                  COB28700
 20   DPAVG=DPAVG+DATA($DPDX+I)*DATA($A+I)                              COB28710
      DPAVG = DPAVG/ATOTAL                                              COB28720
      J=2                                                               COB28730
      FTOT = 0.                                                         COB28740
      DO 30 I=1,NCHANL                                                  COB28750
      DELTAF=(DPAVG-DATA($DPDX+I))*0.5/DATA($DPDX+I)*DATA($F+I)         COB28760
      IF(FTM.GT.0.) DELTAF = DELTAF*0.5                                 COB28770
      FSAVE     =DATA($F+I)                                             COB28780
      DATA($F+I)=DATA($F+I)+DELTAF                                      COB28790
      IF        (DATA($F+I).LT.0.)  GO TO 1000                          COB28800
      IF(ABS    (DATA($F+I)-FSAVE)/FSAVE.GT. E)  J=1                    COB28810
      FTOT=FTOT+DATA($F+I)                                              COB28820
   30 CONTINUE                                                          COB28830
      DO 40 I=1,NCHANL                                                  COB28840
      DATA($F    +I)=DATA($F+I)*FLO/FTOT                                COB28850
 40   DATA($FINLE+I)=DATA($F+I)                                         COB28860
      IF(J.GT.1) GO TO 120                                              COB28870
  100 CONTINUE                                                          COB28880
 1000 WRITE(I3,1)  (I,DATA($F+I),DATA($DPDX+I),I=1,NCHAN)               COB28890
    1 FORMAT(40H FLOW SPLIT TO GIVE EQUAL DP/DX FAILED   /(I5,2E14.6))  COB28900
      IERROR = 8                                                        COB28910
  120 DT = SAVEDT                                                       COB28920
      RETURN                                                            COB28930
      END                                                               COB28940
      SUBROUTINE SURTEN(P,RL,RG,ST)                                     COB28950
C   MEKIN NEW.     AUGUST  1974                                         COB28960
      X=RL-RG                                                           COB28970
      X=0.000001*X**4                                                   COB28980
      ST=X*(4.60+1.84/EXP(0.685*X)+0.232*EXP(1.56*(X-15.0)))            COB28990
      ST=ST*6.8525E-05                                                  COB29000
      RETURN                                                            COB29010
      END                                                               COB29020
      SUBROUTINE TEMP (T,DUM,N,JJ,A,B)                                  COB29030
C     SUBROUTINE TEMP CALCULATES THE TRANSIENT TEMPERATURE DISTRIBUTION COB29040
C     IN A CYLINDERICAL OR PLATE NUCLEAR FUEL ELEMENT WHERE THE LARGEST COB29050
C     NUMBER NODE IS THE CLADDING.  FOR TRANSIENT CALCULATIONS, FLUID   COB29060
C     DATA AT T IS USED TO CALCULATE THE TEMPERATURE AT T+DT BY USING   COB29070
C     A STABLE IMPLICIT NUMERICAL TECHNIQUE.                            COB29080
C     SIMULTANEOUS EQUATIONS ARE SOLVED USING A COMPACT ELIMINATION     COB29090
C     SCHEME FOR TRI-DIAGONAL MATRICES.                                 COB29100
C                                                                       COB29110
C     THE VALUE OF T UPON ENTRY IS THE TEMPERATURE AT ORIGINAL TIME.    COB29120
C     AT EXIT T IS THE TEMPERATURE DELTA-T LATER IN TIME.               COB29130
C                                                                       COB29140
C                                                                       COB29150
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C                                                                       COB29160
      IMPLICIT INTEGER ($)                                              COB29170
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB29180
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB29190
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB29200
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB29210
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB29220
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB29230
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB29240
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB29250
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB29260
C                                                                       COB29270
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB29280
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB29290
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB29300
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB29310
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB29320
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB29330
C                                                                       COB29340
C                                                                       COB29350
      LOGICAL  GRID                                                     COB29360
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB29370
C                                                                       COB29380
C                                                                       COB29390
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB29400
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B     ,COB29410
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB29420
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB29430
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB29440
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB29450
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB29460
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB29470
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB29480
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB29490
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB29500
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB29510
C                                                                       COB29520
      COMMON  DATA(1)                                                   COB29530
      LOGICAL LDAT(1)                                                   COB29540
      INTEGER IDAT(1)                                                   COB29550
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB29560
C                                                                       COB29570
C                                                                       COB29580
      DIMENSION  A(3,1),B(1),T(1)                                       COB29590
      REAL  KFDR2                                                       COB29600
C                                                                       COB29610
C     SETUP A MATRIX OF THE FORM   A*T=B WHERE ONLY THE 3 DIAGONALS OF  COB29620
C     A ARE STORED.                                                     COB29630
      NM1 = NODESF-1                                                    COB29640
      NP1 = NODESF+1                                                    COB29650
      IF(NODESF.LE.0) GO TO 1000                                        COB29660
      J=IDAT($IDFUE+N)                                                  COB29670
      DR = DFUEL(J)*.5/FLOAT(NM1)                                       COB29680
      DR2 = DR**2                                                       COB29690
      RCFUEL = RFUEL(J)*CFUEL(J)/DT                                     COB29700
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      KFDR2  = KFUEL(J)/DR2
      HGAP1 = 1./(1./HGAP(J) + TCLAD(J)/KCLAD(J))
      QCLAD = 0.
C  J IS THE FUEL TYPE CODE.  CYLINDERICAL FUEL, J=1.  PLATE FUEL, J=2.
      IF(J.EQ.2) GO TO 101
C
C  THIS SECTION FOR CYLINDRICAL FUEL RODS.
      QFUEL=DATA($FLUX+N+MR*(JJ-1))*4.*DATA($D+N)/DFUEL(J)**2
      DO 100 I=1,NP1
      IF(I.GT.1) GO TO 10
      A(2,I) = RCFUEL + 4.*KFDR2
      A(3,I) = -4.*KFDR2
      GO TO 80
   10 IF(I.GT.NM1) GO TO 20
      A(1,I) = -KFDR2*(1.-1./FLOAT(2*I-2))
      A(2,I) = RCFUEL + 2.*KFDR2
      A(3,I) = -KFDR2*(1.+1./FLOAT(2*I-2))
      GO TO 80
   20 IF(I.EQ.NP1) GO TO 30
      A(1,I) = -2.*KFDR2
      A(2,I) = RCFUEL + 2.*KFDR2 + 2.*HGAP1/DR + HGAP1/DR/FLOAT(I-1)
      A(3,I) = -(2.*HGAP1/DR + HGAP1/DR/FLOAT(I-1))
      GO TO 80
 30   A(1,I)=-HGAP1/TCLAD(J)*DFUEL(J)/DATA($D+N)
      A(2,I)= RCLAD(J)*CCLAD(J)/DT+HGAP1/TCLAD(J) * DFUEL(J)/DATA($D+N)
     1 + HSURF/TCLAD(J)
   80 IF(I.EQ.NP1) GO TO 90
      B(I) = QFUEL + RCFUEL*T(I)
      GO TO 100
   90 B(I) = QCLAD + RCLAD(J)*CCLAD(J)/DT*T(I) + HSURF/TCLAD(J)*TFLUID
  100 CONTINUE
C     SOLVE FOR TEMPERATURES
      CALL GAUSS(1,NP1,A,B,T)
      RETURN
C
C  THIS SECTION FOR FLAT PLATE FUEL.
  101 QFUEL=DATA($FLUX+N+MR*(JJ-1))*2./DFUEL(J)
      DO 200 I=1,NP1
      IF(I.GT.1) GO TO 110
      A(2,I) = RCFUEL + KFDR2*2.
      A(3,I) = -2.*KFDR2
      GO TO 180
  110 IF(I.GT.NM1) GO TO 120
      A(1,I) = -KFDR2
      A(2,I) = RCFUEL + 2.*KFDR2
      A(3,I) = -KFDR2
      GO TO 180
  120 IF(I.EQ.NP1) GO TO 130
      A(1,I) = -2.*KFDR2
      A(2,I) = RCFUEL + 2.*KFDR2 + 2.*HGAP1/DR
      A(3,I) = -2.*HGAP1/DR
      GO TO 180
  130 A(1,I) = -HGAP1/TCLAD(J)
      A(2,I) =  RCLAD(J)*CCLAD(J)/DT + HGAP1/TCLAD(J) + HSURF/TCLAD(J)
  180 IF(I.EQ.NP1) GO TO 190
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```
      B(I) = QFUEL + RCFUEL*T(I)                                        COB30260
      GO TO 200                                                         COB30270
  190 B(I) = QCLAD + RCLAD(J)*CCLAD(J)/DT*T(I) + HSURF/TCLAD(J)*TFLUID  COB30280
  200 CONTINUE                                                          COB30290
C     SOLVE FOR TEMPERATURES                                            COB30300
      CALL GAUSS(1,NP1,A,B,T)                                           COB30310
      RETURN                                                            COB30320
 1000 IERROR = 15                                                       COB30330
      RETURN                                                            COB30340
      END                                                               COB30350
      SUBROUTINE TIDY                                                   COB30360
C                                                                       COB30370
C                                                                       COB30380
      IMPLICIT INTEGER ($)                                              COB30390
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB30400
     1  ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB30410
     2  HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB30420
     3  J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB30430
     4  NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB30440
     5  NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB30450
     6  NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB30460
     7  QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB30470
     8  UF    ,VF    ,VFG   ,VG    ,Z                                   COB30480
C                                                                       COB30490
C                                                                       COB30500
C                                                                       COB30510
      LOGICAL  GRID                                                     COB30520
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB30530
C                                                                       COB30540
C                                                                       COB30550
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB30560
     1           $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB30570
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB30580
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB30590
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB30600
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB30610
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB30620
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB30630
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB30640
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB30650
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB30660
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB30670
C                                                                       COB30680
      COMMON  DATA(1)                                                   COB30690
      LOGICAL LDAT(1)                                                   COB30700
      INTEGER IDAT(1)                                                   COB30710
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB30720
C                                                                       COB30730
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB30740
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB30750
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB30760
      DIMENSION NTHBOX(20,20)                                           COB30770
C                                                                       COB30780
C     TIDY UP FOR INPRIN.        TEMPORARY                              COB30790
      ZZ = 12.0*Z                                                       COB30800
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```
      DO 4 I=1,NCHANL
      DATA($AC+I) = 144.0*DATA($A+I)
      DATA($PW+I) = 12.0*DATA($PERIM+I)
      DATA($PH+I) = 12.0*DATA($HPERI+I)
      DATA($DC+I) = 12.0*DATA($DHYD+I)
      DATA($DR+I) = 12.0*DATA($D+I)
      DO 4 L=1,4
      IDAT($LC+I+MC*(L-1)) = 0
      DATA($DIST+I+MC*(L-1)) = 0.0
      DATA($GAPS+I+MG*(L-1)) = 0.0
    4 CONTINUE
C
      IF (NK.EQ.0) RETURN
      DO 12 K=1,NK
      I = IDAT($IK+K)
      J = IDAT($JK+K)
      DO 8 L=1,4
      IF (IDAT($LC+I+MC*(L-1)).EQ.0) GO TO 10
    8 CONTINUE
      WRITE (6,2004) K,J,I
   10 IDAT($LC+I+MC*(L-1)) = J
      DATA($DIST+I+MC*(L-1)) = DATA($LENGT+K)*12.0
   12 DATA($GAPS+I+MG*(L-1)) = DATA($GAP+K)*12.0
C
      RETURN
 2004 FORMAT(' CARDS4  GAP CONNECTION ', I3, '  CHANNEL ', I3,
     1 ' IS 5TH ADJACENT TO ', I3)
      END
      SUBROUTINE TOD(A)
      DIMENSION A(3),DATIM(5)
      CALL WHEN(DATIM)
      A(1)=DATIM(3)
      A(2)=DATIM(4)
      A(3)=DATIM(5)
      RETURN
      END
      SUBROUTINE ACOL(IFROM,IK,JK,KMAX,LOCA,MA,MS,NK,MG,IPILE)
      DIMENSION  IK(1),JK(1),LOCA(MG,14)
C     SET LOCA, DEFINING INTERACTING BOUNDARIES
C     IFROM = 1, CALLED FROM CARDS4,      = 2, FROM MAIN (OLD COBRA)
C     LOCA(K,1)=K.    LOCA(K,L),L=2,7 SPECIFIES UP TO  LOCA(K,8)
C     BOUNDARIES ADJACENT TO CHANNELS DEFINING BOUNDARY K.
      DO 8 K=1,NK
      IF (IPILE.GT.0) GO TO 107
      DO 103 L=2,13
  103 LOCA(K,L)=0
      GO TO 110
  107 DO 3 L=2,7
    3 LOCA(K,L)=0
  110 N=1
      LOCA(K,1) = K
      II = IK(K)
      JJ = JK(K)
    4 DO 7 KK=1,NK
      III = IK(KK)
```

```
      IF (III.GT.II) GO TO 7                                            COB31360
      JJJ = JK(KK)                                                      COB31370
      IF ( (II.EQ.III) .OR. (II.EQ.JJJ) ) GO TO 6                       COB31380
      GO TO 7                                                           COB31390
    6 IF ( (III+JJJ - II-JJ) .EQ. 0) GO TO 7                            COB31400
      N = N+1                                                           COB31410
      LL = III                                                          COB31420
      IF (II.EQ.III) LL=JJJ                                             COB31430
      WV = FLOAT(II-LL)/FLOAT(II-JJ)                                    COB31440
      LOCA(K,N) = KK                                                    COB31450
      IF (WV.LT.0.0) LOCA(K,N)=-KK                                      COB31460
    7 CONTINUE                                                          COB31470
      IF (IPILE.GT.0) GO TO 108                                         COB31480
      LOCA(K,14)=N                                                      COB31490
      GO TO 109                                                         COB31500
  108 LOCA(K,8)=N                                                       COB31510
  109 IF(II.GE.JJ) GO TO 8                                              COB31520
      II = JK(K)                                                        COB31530
      JJ = IK(K)                                                        COB31540
      GO TO 4                                                           COB31550
    8 CONTINUE                                                          COB31560
C                                                                       COB31570
C     FIND STRIPE WIDTH FOR AAA MATRIX IN DIVERT                        COB31580
      MAX = 0                                                           COB31590
      DO 10 K=1,NK                                                      COB31600
      N=LOCA(K,8)                                                       COB31610
      IF (IPILE.GT.0) GO TO 111                                         COB31620
      N=LOCA(K,14)                                                      COB31630
  111 DO 10 L=2,N                                                       COB31640
      LKL = IABS(LOCA(K,L))                                             COB31650
      J = IABS(K-LKL)                                                   COB31660
      IF (J.LT.MAX) GO TO 10                                            COB31670
      MAX = J                                                           COB31680
      KMAX = K                                                          COB31690
   10 CONTINUE                                                          COB31700
      MS = 2*MAX + 1                                                    COB31710
      CALL CORE2(MS,NK)                                                 COB31720
      RETURN                                                            COB31730
      END                                                               COB31740
      SUBROUTINE CARDS4(AC,DC,DIST,DR,GAPS,LC,MA,MG,N1,N2,NCHF,NFUELT,  COB31750
     1 PH,PHTOT,PRINT,PW,MC)                                            COB31760
C                                                                       COB31770
C=====NOTE THAT THESE COMMON AREAS ARE NOT IDENTICAL WIT THOSE          COB31780
C     IN OTHER ROUTINES                                                 COB31790
C                                                                       COB31800
C                                                                       COB31810
C                                                                       COB31820
      IMPLICIT INTEGER ($)                                              COB31830
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB31840
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB31850
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB31860
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB31870
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,DUM1  ,NDX   ,NF    ,COB31880
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB31890
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB31900
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     7  QAX    ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB31910
     8  UF     ,VF    ,VFG   ,VG    ,Z                                 COB31920
C                                                                      COB31930
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),   COB31940
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB31950
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB31960
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB31970
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB31980
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB31990
C                                                                      COB32000
C                                                                      COB32010
      LOGICAL  GRID,PRINT                                              COB32020
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                              COB32030
C                                                                      COB32040
C                                                                      COB32050
      COMMON /COBRA3/  DUM2  ,DUMC  ,DUM3  ,MN    ,MR    ,MS    ,MX    ,COB32060
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB32070
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB32080
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB32090
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB32100
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB32110
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB32120
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB32130
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB32140
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB32150
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB32160
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB32170
C                                                                      COB32180
      COMMON  DATA(1)                                                  COB32190
      LOGICAL LDAT(1)                                                  COB32200
      INTEGER IDAT(1)                                                  COB32210
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                           COB32220
C                                                                      COB32230
      EQUIVALENCE (NCHAN,NCHANL)                                       COB32240
C                                                                      COB32250
      DIMENSION  AC(1),DC(1),DR(1),PH(1),PRINT(12),PW(1),DIST(MC,1),   COB32260
     1   GAPS(MG,1),LC(MC,1),FXF(5),IGROUP(15),JB(20),IFRIC(15),       COB32270
     2   TEXT(20),MAAP(2,20)                                           COB32280
C                                                                      COB32290
C     MEKIN - ENTERED FOR PWR AND BWR SIMPLIFIED INPUT DATA.           COB32300
C     COMBINES CARD GROUPS 4, 7, 8 IE CHAN GEOMETRY, SPACERS AND RODS. COB32310
C     READ (A) INDICATORS, (B) CHAN GEOM + SPACERS FOR EACH GROUP,     COB32320
C     (C) ROD POWERS, (D) SPACER X/L, (E) CHANNELS IN GROUPS 2,3 ETC,  COB32330
C     (F) GAP CONNECTIONS, (G) FUEL DATA                               COB32340
C                                                                      COB32350
C     READ INDICATORS.     INITIALISE                                  COB32360
      READ (I2,1001) N1,N2,NGRID,NGRIDT,NODESF,NFUELT,NCHF, IMAP, ITEXT COB32370
      IF (N1.LE.15) GO TO 1                                            COB32380
      WRITE (I3,2001)                                                  COB32390
      IERROR = 1                                                       COB32400
      RETURN                                                           COB32410
    1 IF (ITEXT.LE.0) GO TO 3                                          COB32420
      DO 2 I=1,ITEXT                                                   COB32430
      READ (I2,1005) TEXT                                              COB32440
    2 WRITE(I3,1005) TEXT                                              COB32450
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```
    3 NCHANL = N2
      NROD = N2
      J6 = 2
      NRAMP = 1
      GRID = .FALSE.
      NGRT = MAX0(NGRIDT,1)
      IPILE = J7
      DO 4 I=1,NCHANL
      DO 4 L=1,6
      IDAT($LR+I+MR*(L-1))=0
      DATA($PHI+I+MR*(L-1))=0.
      IF (L.GT.4) GO TO 4
      LC(I,L) = 0
      GAPS(I,L) = 0.0
      DIST(I,L) = 0.0
    4 CONTINUE
C
C     READ GEOM AND SPACER DATA FOR EACH CHANNEL GROUP. SET GROUP 1
      DO 10 J=1,N1
      READ (I2,1002) N,I,FRAC,AC(I),PW(I),PH(I),GAPS(I,1),DIST(I,1),
     1    DR(I),DATA($PHI+I),M
      DATA($CD+I)=0.
      FXF(1) = 0.0
      IF (FRAC.LE.0.0) FRAC = 1.0
      AC(I) = FRAC*AC(I)
      PW(I) = FRAC*PW(I)
      PH(I) = FRAC*PH(I)
      DATA($PHI+I)=FRAC*DATA($PHI+I)
      IF (NGRID.EQ.0) GO TO 6
      READ(I2,1003) (DATA($CD+I+MC*(L-1)),L=1,NGRIDT),(FXF(L),L=1,NGRIDT
     1    )
 6    IDAT($NTYPE+I)=J
      IFRIC(J) = MAX0(N,1)
      IDAT($IDFUE+I)=MAX0(M,1)
      IGROUP(J) = I
      IF (J.GT.1) GO TO 10
C     SET ALL CHANNELS TEMPORARILY TO GROUP 1 VALUES.
      DO 8 K=1,NCHANL
      AC(K) = AC(I)
      PW(K) = PW(I)
      PH(K) = PH(I)
      GAPS(K,1) = GAPS(I,1)
      DIST(K,1) = DIST(I,1)
      DR(K) = DR(I)
      DATA($PHI  +K)=DATA($PHI  +I)
      IDAT($NTYPE+K)=1
      IDAT($IDFUE+K)=IDAT($IDFUE+I)
      DO 8 L=1,NGRT
      DATA($CD+K+MC*(L-1))=
     1DATA($CD+I+MC*(L-1))
    8 CONTINUE
   10 CONTINUE
      DO 12 K=1,MG
      DO 12 L=1,NGRT
 12   DATA($FXFLO+K+MG*(L-1))=FXF(L)
```

```
C
C     READ ROD POWER FACTORS AND SPACER LOCATIONS.
      II = MINO(NROD,16)
      READ(I2,1003) (DATA($RADIA+I),I=1,II)
      IF            (DATA($RADIA+1).GE.0.0)  GO TO 16
      DO 14 I=1,NROD
 14                  DATA($RADIA+I)=1.0
      GO TO 18
 16   IF(NROD.GT.16) READ(I2,1003) (DATA($RADIA+I),I=17,NROD)
 18   IF (NGRID.GT.0) READ (I2,1004) (GRIDXL(I),IGRID(I),I=1,NGRID)
C
C     READ CHANNEL NUMBERS NOT IN GROUP 1, SET DATA
      JCHECK = 1
      IF (N1.EQ.1) GO TO 28
      DO 26 J=2,N1
      ICHECK = 0
 20   READ(I2,1001) (JB(I),I=1,20)
      DO 22 JJ=1,20
      K = JB(JJ)
      IF (K.LE.0) GO TO 24
      I = IGROUP(J)
      AC(K) = AC(I)
      PW(K) = PW(I)
      PH(K) = PH(I)
      GAPS(K,1) = GAPS(I,1)
      DIST(K,1) = DIST(I,1)
      DR(K) = DR(I)
      DATA($PHI+K)=DATA($PHI+I)
      IDAT($NTYPE+K)=J
      IDAT($IDFUE+K)=IDAT($IDFUE+I)
      IF (K.EQ.I) ICHECK=1
      IF (K.EQ.IGROUP(1) ) JCHECK=0
      DO 22 L=1,NGRT
      DATA($CD+K+MC*(L-1))=
     1DATA($CD+I+MC*(L-1))
 22   CONTINUE
      GO TO 20
 24   IF (ICHECK.EQ.1) GO TO 26
      WRITE(I3,2002) J, IGROUP(J)
      IERROR = 1
      RETURN
 26   CONTINUE
      IF (JCHECK.EQ.1) GO TO 28
      J = 1
      WRITE(I3,2002) J, IGROUP(J)
      IERROR = 1
      RETURN
C
C     SET ROD POWER FRACTIONS AND CHANNEL PARAMETERS
 28   PHTOT = 0.0
      ATOTAL = 0.0
      DO 32 I = 1,NCHANL
      DO 30 J=1,NROD
 30   DATA($PWRF+I+MC*(J-1))=0
      DATA($PWRF+I+MC*(I-1))=DATA($PHI +I)
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      IDAT($LR+I)=I                                                     COB33560
      DATA($D+I)=DR(I)/12.0                                             COB33570
      DATA($PERIM+I)=PW(I)/12.0                                         COB33580
      DATA($HPERI+I)=PH(I)/12.0                                         COB33590
      DATA($AN   +I)=AC(I)/144.0                                        COB33600
      DATA($A    +I)=DATA($AN+I)                                        COB33610
      DC(I) = 4.*AC(I)/PW(I)                                            COB33620
      DATA($DHYD +I)=DC(I)/12.0                                         COB33630
      DATA($DHYDN+I)=DATA($DHYD+I)                                      COB33640
      PHTOT=PHTOT+    DATA($HPERI+I)                                    COB33650
 32   ATOTAL=ATOTAL+ DATA($AN+I)                                        COB33660
C                                                                       COB33670
      IF (IPILE.EQ.1) GO TO 34                                          COB33680
C     BWR.      NO CHANNEL INTERACTION                                  COB33690
      NSCBC = 0                                                         COB33700
      NBBC = 1                                                          COB33710
      J5 = 0                                                            COB33720
      ABETA = 0.0                                                       COB33730
      BBETA = 0.0                                                       COB33740
      GK = 0.0                                                          COB33750
      NK=0                                                              COB33760
      GO TO 120                                                         COB33770
C                                                                       COB33780
C     PWR.     READ AND SET GAP CONNECTIONS (IE BOUNDARIES)             COB33790
C     IMAP=1 FOR RECTANGULAR MAP. SAY HOW MANY CHAN ACROSS AND DOWN.    COB33800
C     IMAP=2 FOR PWR MAP. GIVE START AND END OF EACH ROW. LAST ROW ALL 0COB33810
C     IMAP=3 FOR CHANNEL-NUMBERED MAP. LAST ROW ALL 0.                  COB33820
C     IMAP=4 FOR SPECIFYING CHANNEL BOUNDARY NUMBERS                    COB33830
 34   NK = 0                                                            COB33840
      IRAD = 0                                                          COB33850
      ISIZE = 20                                                        COB33860
      NEXT = 1                                                          COB33870
      WRITE (I3,3001) IMAP                                              COB33880
      IF (IMAP.EQ.4) GO TO 70                                           COB33890
      IF (IMAP-2) 40,42,48                                              COB33900
 40   READ (I2,1001) ICROSS, IDOWN                                      COB33910
      ISTART = 1                                                        COB33920
      IEND = ICROSS                                                     COB33930
      GO TO 44                                                          COB33940
 42   READ(I2,1001) ISTART, IEND                                        COB33950
 44   JS = 0                                                            COB33960
      DO 46 J=1,ISIZE                                                   COB33970
      MAAP(2,J) = 0                                                     COB33980
      IF ( (J.LT.ISTART) .OR. (J.GT.IEND) ) GO TO 46                    COB33990
      JS = JS+1                                                         COB34000
      MAAP(2,J) = JS                                                    COB34010
 46   CONTINUE                                                          COB34020
      GO TO 49                                                          COB34030
 48   READ (I2,1001) (MAAP(2,J),J=1,ISIZE)                              COB34040
C     SET BOUNDARIES FOR IMAP = 1,2,3                                   COB34050
 49   JSMAX = 0                                                         COB34060
      WRITE (I3,3008)                                                   COB34070
      DO 66 I=1,ISIZE                                                   COB34080
C     SET BOUNDARIES ACROSS                                             COB34090
      DO 50 J=1,ISIZE                                                   COB34100
```

```
      MAAP(1,J) = MAAP(2,J)                                             COB34110
      JSMAX = MAX0(JSMAX,MAAP(2,J))                                     COB34120
      IF (MAAP(2,J).NE.0) JMAX=J                                        COB34130
      IF (J.EQ.ISIZE) GO TO 50                                          COB34140
      IF ( (MAAP(2,J).EQ.0) .OR. (MAAP(2,J+1).EQ.0) ) GO TO 50          COB34150
      NK = NK+1                                                         COB34160
      IDAT($IK+NK) = MAAP(2,J)                                          COB34170
      IDAT($JK+NK) = MAAP(2,J+1)                                        COB34180
   50 CONTINUE                                                          COB34190
      IF (I.GT.1) GO TO 51                                              COB34200
      WRITE (I3,3002) (MAAP(1,J),J=1,JMAX)                              COB34210
      JUMP = 1                                                          COB34220
      GO TO 64                                                          COB34230
   51 IF (I.EQ.ISIZE) GO TO 66                                          COB34240
      IF (IMAP-2) 52,54,60                                              COB34250
   52 IF (I.GE.IDOWN) ISTART = ISIZE+1                                  COB34260
      GO TO 56                                                          COB34270
   54 READ(I2,1001) ISTART, IEND                                        COB34280
   56 DO 58 J=1,ISIZE                                                   COB34290
      MAAP(2,J) = 0                                                     COB34300
      IF ( (J.LT.ISTART) .OR. (J.GT.IEND) ) GO TO 58                    COB34310
      JS = JS+1                                                         COB34320
      MAAP(2,J) = JS                                                    COB34330
   58 CONTINUE                                                          COB34340
      GO TO 62                                                          COB34350
   60 READ(I2,1001) (MAAP(2,J),J=1,ISIZE)                               COB34360
   62 IC = NK                                                           COB34370
C     SET BOUNDARIES DOWN                                               COB34380
      DO 63 J=1,ISIZE                                                   COB34390
      IF (MAAP(2,J).NE.0) JMAX=J                                        COB34400
      IF ( (MAAP(1,J).EQ.0) .OR. (MAAP(2,J).EQ.0) ) GO TO 63            COB34410
      NK = NK+1                                                         COB34420
      IDAT($IK+NK) = MAAP(1,J)                                          COB34430
      IDAT($JK+NK) = MAAP(2,J)                                          COB34440
   63 CONTINUE                                                          COB34450
      IF (IC.EQ.NK) GO TO 68                                            COB34460
      WRITE (I3,3002) (MAAP(2,J),J=1,JMAX)                              COB34470
C     SET WOLD TO PRINT MAP OF RADIAL POWERS                            COB34480
      JUMP = 2                                                          COB34490
   64 IRAD = IRAD+1                                                     COB34500
      JB(IRAD) = JMAX                                                   COB34510
      DO 65 J=1,JMAX                                                    COB34520
      L = MAAP(JUMP,J)                                                  COB34530
      DATA($WOLD+IRAD+MG*(J-1))=-100.                                   COB34540
      IF (L.LE.0) GO TO 65                                              COB34550
      DATA($WOLD+IRAD+MG*(J-1))=DATA($RADIA+L)                          COB34560
   65 CONTINUE                                                          COB34570
      IF (JUMP.EQ.1) GO TO 51                                           COB34580
   66 CONTINUE                                                          COB34590
   68 CONTINUE                                                          COB34600
C     PRINT RADIAL POWER MAP                                            COB34610
      WRITE (I3,3010)                                                   COB34620
      DO 69 I=1,IRAD                                                    COB34630
      JMAX = JB(I)                                                      COB34640
   69 WRITE(I3,3011)  (DATA($WOLD+I+MG*(J-1)),J=1,JMAX)                 COB34650
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```
      IF (JSMAX.EQ.NCHANL) GO TO 76                                     COB34660
      WRITE (I3,2006) JSMAX,NCHANL                                      COB34670
      IERROR = 1                                                        COB34680
      RETURN                                                            COB34690
C                                                                       COB34700
C     SET BOUNDARIES FOR IMAP = 4                                       COB34710
   70 READ (I2,1001) (JB(J),J=1,20)                                     COB34720
      DO 74 I=1,20                                                      COB34730
      IF (JB(I).EQ.0) GO TO 76                                          COB34740
      IF (NEXT.EQ.0) GO TO 72                                           COB34750
      NK = NK+1                                                         COB34760
      IDAT($IK+NK) = JB(I)                                              COB34770
      NEXT = 0                                                          COB34780
      GO TO 74                                                          COB34790
   72 IDAT($JK+NK) = JB(I)                                              COB34800
      NEXT = 1                                                          COB34810
   74 CONTINUE                                                          COB34820
      GO TO 70                                                          COB34830
   76 DO 90 K=1,NK                                                      COB34840
   78 I=IDAT($IK+K)                                                     COB34850
      IF(IABS(I)-IABS(IDAT($JK+K)))  84,80,82                           COB34860
   80 WRITE(I3,2003)  K,I,IDAT($JK+K)                                   COB34870
      IERROR = 1                                                        COB34880
      RETURN                                                            COB34890
   82 IDAT($IK+K)  = IDAT($JK+K)                                        COB34900
      IDAT($JK+K)  = I                                                  COB34910
      GO TO 78                                                          COB34920
   84 M            = IDAT($JK+K)                                        COB34930
      DO 86 L=1,4                                                       COB34940
      IF (LC(I,L).EQ.0) GO TO 88                                        COB34950
   86 CONTINUE                                                          COB34960
      WRITE (I3,2004) K,M,I                                             COB34970
      IERROR = 1                                                        COB34980
      RETURN                                                            COB34990
   88 LC(I,L) = M                                                       COB35000
      NG         = IDAT($NTYPE+I)                                       COB35010
      N = IGROUP(NG)                                                    COB35020
      GAPS(I,L)=AMAX1(GAPS(M,1),GAPS(N,1))                              COB35030
      DIST(I,L)=DIST(N,1)                                               COB35040
      DATA($GAPN+K)=GAPS(I,L)/12.0                                      COB35050
      DATA($GAP +K)=DATA($GAPN+K)                                       COB35060
      DATA($LENGT+K)=DIST(I,L)/12.0                                     COB35070
      DATA($FACTO+K)=1.0                                                COB35080
   90 CONTINUE                                                          COB35090
C                                                                       COB35100
C     READ HALF-BOUNDARIES AND SET FACTOR(K) = 0.5                      COB35110
   92 READ (I2,1001) (JB(L),L=1,20)                                     COB35120
      IF (JB(1).EQ.0) GO TO 110                                         COB35130
      IEND = 100                                                        COB35140
      MARK = 1                                                          COB35150
      DO 98 M=1,10                                                      COB35160
      L = 2*M - 1                                                       COB35170
      JBL = JB(L)                                                       COB35180
      IF (JBL-JB(L+1)) 98,94,96                                         COB35190
   94 IEND = M                                                          COB35200
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```
      IF (JBL.EQ.0) GO TO 100                                           COB35210
      WRITE (I3,2005) JBL,JB(L+1)                                       COB35220
      IERROR = 1                                                        COB35230
      RETURN                                                            COB35240
   96 JB(L) = JB(L+1)                                                   COB35250
      JB(L+1) = JBL                                                     COB35260
   98 CONTINUE                                                          COB35270
  100 IC = MARK                                                         COB35280
      DO 102 K=1,NK                                                     COB35290
      IF((IDAT($IK+K).NE.JB(MARK)).OR.                                  COB35300
     1  (IDAT($JK+K).NE.JB(MARK +1)))  GO TO 102                        COB35310
      DATA($FACTO+K)=0.5                                                COB35320
      MARK = MARK+2                                                     COB35330
      IF (MARK.EQ.IEND) GO TO 110                                       COB35340
      IF (MARK.GE.20) GO TO 92                                          COB35350
  102 CONTINUE                                                          COB35360
      IF (IC.LT.MARK) GO TO 100                                         COB35370
      WRITE (I3,2005) JB(MARK), JB(MARK+1)                              COB35380
      IERROR = 1                                                        COB35390
      RETURN                                                            COB35400
C                                                                       COB35410
  110 CALL ACOL(1,IDAT($IK+1),IDAT($JK+1),KMAX,IDAT($LOCA+1),MA,MS,NK,  COB35420
     1    MG,IPILE)                                                     COB35430
  112 WRITE (I3,3003) NK                                                COB35440
      M = 1                                                             COB35450
  114 MM = MINO( (M+7),NK)                                              COB35460
      WRITE(I3,3004)  M,(IDAT($IK+K),IDAT($JK+K),K=M,MM)                COB35470
      M = MM+1                                                          COB35480
      IF (M.LE.NK) GO TO 114                                            COB35490
      WRITE (I3,3005) NK                                                COB35500
      M = 1                                                             COB35510
  116 MM = MINO( (M+24),NK)                                             COB35520
      DO 118 L=1,8                                                      COB35530
  118 WRITE(I3,3006)  L,(IDAT($LOCA+K+MG*(L-1)) ,K=M,MM)                COB35540
      M = MM+1                                                          COB35550
      WRITE (I3,3007)                                                   COB35560
      IF (M.LE.NK) GO TO 116                                            COB35570
      L = MS*NK                                                         COB35580
      WRITE (I3,3009) MS,KMAX,L,MA                                      COB35590
C                                                                       COB35600
C     SET NTYPE BACK TO INDICATE FRICTION TYPE                          COB35610
  120 DO 122 I=1,NCHANL                                                 COB35620
      NG=IDAT($NTYPE+I)                                                 COB35630
      IDAT($NTYPE+I)=IFRIC(NG)                                          COB35640
      IF (LC(I,1).GT.0) GO TO 122                                       COB35650
      GAPS(I,1) = 0.0                                                   COB35660
      DIST(I,1) = 0.0                                                   COB35670
  122 CONTINUE                                                          COB35680
C                                                                       COB35690
C     READ FUEL DATA                                                    COB35700
      IF(NODESF.EQ.0) GO TO 126                                         COB35710
      READ(I2,1003) (KFUEL(I),CFUEL(I),RFUEL(I),DFUEL(I),               COB35720
     1 KCLAD(I), CCLAD(I), RCLAD(I), TCLAD(I), HGAP(I),I=1,NFUELT)      COB35730
      DO 124 I=1,NFUELT                                                 COB35740
       KFUEL(I) = KFUEL(I)/3600.                                        COB35750
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      KCLAD(I) = KCLAD(I)/3600.                                         COB35760
      DFUEL(I) = DFUEL(I)/12.                                           COB35770
      TCLAD(I) = TCLAD(I)/12.                                           COB35780
 124  HGAP(I) = HGAP(I)/3600.                                           COB35790
C                                                                       COB35800
C     SET PRINT REQUIREMENTS                                            COB35810
 126  IF (J1.GT.1) RETURN                                               COB35820
      PRINT(4) = .TRUE.                                                 COB35830
      PRINT(7) = .TRUE.                                                 COB35840
      PRINT(8) = .TRUE.                                                 COB35850
      RETURN                                                            COB35860
C                                                                       COB35870
 1001 FORMAT(20I4)                                                      COB35880
 1002 FORMAT(I1,I4,8E9.3,I2)                                            COB35890
 1003 FORMAT(16E5.3)                                                    COB35900
 1004 FORMAT(8(E5.3,I5))                                                COB35910
 1005 FORMAT(20A4)                                                      COB35920
 2001 FORMAT(' CARDS4  N1.GT.15')                                       COB35930
 2002 FORMAT(' CARDS4  CHANNEL GROUP',I3,' CHANNEL',I4,' INCORRECT')    COB35940
 2003 FORMAT(' CARDS4  GAP CONNECTION ', I3, 'I AND J SAME IE ', 2I3)   COB35950
 2004 FORMAT(' CARDS4  GAP CONNECTION ', I3, '  CHANNEL ', I3,          COB35960
     1 ' IS 5TH ADJACENT TO ', I3)                                      COB35970
 2005 FORMAT(' CARDS4  HALF-BOUNDARY ', I4, ' - ', I4, 'NOT IN BOUNDARY COB35980
     1SET')                                                             COB35990
 2006 FORMAT(' CARDS4  HIGHEST NUMBER CHANNEL FOUND TO BE ', I3,        COB36000
     1 ' AND THIS NOT EQUAL TO NUMBER SPECIFIED, IE ', I3)              COB36010
 3001 FORMAT(1H1, '  CHANNEL DATA SET IN SUBROUTINE CARDS4 ( IMAP =',   COB36020
     1 I2, ' )', //)                                                    COB36030
 3002 FORMAT( /,20I6)                                                   COB36040
 3003 FORMAT(1H1, I5, ' BOUNDARIES AS BELOW (IK(K) - JK(K))', /)        COB36050
 3004 FORMAT(' (', I3, ') ', 8(6X, I3, ' - ', I3) )                     COB36060
 3005 FORMAT(///, '  LOCA(K,8) ARRAY SET IN ACOL', 5X,'K = 1 TO ',I3,//)COB36070
 3006 FORMAT(' (', I1, ') ', 25I5)                                      COB36080
 3007 FORMAT(/)                                                         COB36090
 3008 FORMAT('  CHANNEL NUMBERING MAP', //)                             COB36100
 3009 FORMAT(///, '  MAXIMUM OVERALL STRIPE WIDTH FOR ARRAY AAA IN DIVERCOB36110
     1T = ', I3, ' FOR BOUNDARY NO. ', I3, //, '  REQUIRE ', I6,' STORESCOB36120
     2 FOR AAA SIZE AND THIS OK SINCE LESS THAN ', I6, ' PROVIDED', //) COB36130
 3010 FORMAT(1H1, '  RADIAL POWER MAP    (-100 OR *** INDICATES NO CHANNCOB36140
     1EL)', /)                                                          COB36150
 3011 FORMAT(/, 20F6.3)                                                 COB36160
      END                                                               COB36170
      SUBROUTINE CHAN(IPART,NTHBOX,NTHBXX,ND1X,ND2X)                    COB36180
C                                                                       COB36190
C                                                                       COB36200
      IMPLICIT INTEGER ($)                                              COB36210
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB36220
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB36230
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB36240
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB36250
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB36260
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB36270
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB36280
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB36290
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB36300
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C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID,PRINT
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA     ,MC     ,MG     ,MN     ,MR     ,MS     ,MX     ,
     1          $$$    ,$A     ,$AAA   ,$AC    ,$ALPHA,$AN    ,$ANSWE,$B     ,
     1   $CCHAN,$CD    ,$CHFR  ,$CON   ,$COND  ,$CP    ,$D     ,$DC    ,$DFDX  ,
     2   $DHDX  ,$DHYD  ,$DHYDN,$DIST  ,$DPDX  ,$DPK   ,$DUR   ,$DR    ,$F     ,
     3   $FACTO,$FDIV  ,$FINLE,$FLUX  ,$FMULT,$FOLD  ,$FSP   ,$FSPLI,$FXFLO,
     4   $GAP   ,$GAPN  ,$GAPS  ,$H     ,$HFILM,$HINLE,$HOLD  ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK    ,$JBOIL,$JK    ,$LC    ,$LENGT,$LOCA  ,$LR    ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH    ,
     7   $PHI   ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF  ,$QC    ,$QF    ,$QPRIM,
     8   $QUAL  ,$RADIA,$RHO   ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD  ,
     9   $U     ,$UH    ,$USAVE,$USTAR,$V     ,$VISC  ,$VISCW,$VP    ,$VPA   ,
     A   $W     ,$WOLD  ,$WP    ,$WSAVE,$X     ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG
C
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP
C
      COMMON/ITPSV/ITMP
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
      COMMON /GAPFAC/ FACSL(70), FACSLK(70)
C
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),
     1JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),
     2YQ(30)
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ
      DIMENSION CARD(20),CDG(5),GP(250),JBSTOR(150),JB(20),
     1 NTHBOX(25,25),GAPREC(400)
C
C     IPART = 1   READ CHANNEL INPUT DATA
C     IPART = 2   PRINT CHANNEL INPUT DATA
C     OWN-ARRAY MAX SIZES. CARD(20), CDG(NGRIDT), GP(NCHANL), JB(MAXRD),
C       JBSTOR(NCTYP+3+NUMBER OF CHANNELS NOT OF TYPE 1)
C     DEFINE JBSTOR(L),L=1,NCTYP+1 = ARRAY POSITIONS STARTING EACH TYPE,
C     JBSTOR(NCTYP+2) = A CHANNEL NUMBER OF TYPE 1,
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C     CHN OF TYPE N IN JBSTOR(L),L=J,K WHERE J=JBSTOR(N),K=JBSTOR(N+1)-1COB36860
C                                                                       COB36870
      IF (IPART.EQ.2) GO TO 102                                         COB36880
      MAXRD = 14                                                        COB36890
      NFUELT = 1                                                        COB36900
      NCHANL = NTHBXX                                                   COB36910
      ITMP=0                                                            COB36920
      READ (I2,1001) CARD,IPILE,NCTYP,NGRID,NGRIDT,NODESF,NFXF,IFRM,    COB36930
     1  IHTM,IPROP                                                      COB36940
      WRITE (I3,1002) CARD                                              COB36950
      IF(NODESF.EQ.0) GO TO 2                                           COB36960
      IF (IFRM.EQ.0.AND.IHTM.EQ.0) GO TO 2                              COB36970
      READ(I2,2016) CARD,EPSF                                           COB36980
      WRITE(I3,2009) CARD                                               COB36990
CC IF EPSF=0. THEN SET TO DEFAULT VALUE                                 COB37000
      IF (EPSF.EQ.0.) EPSF=0.01                                         COB37010
    2 NROD = NCHANL                                                     COB37020
      J6 = 2                                                            COB37030
      NRAMP = 1                                                         COB37040
      GRID = .FALSE.                                                    COB37050
      NGRT = MAX0(NGRIDT,1)                                             COB37060
      J7 = IPILE                                                        COB37070
      DO 1109 I=1,MC                                                    COB37080
      DO 1109 J=1,MR                                                    COB37090
 1109 DATA($PWRF+I+MC*(J-1))=0.0                                        COB37100
      DO 4 I=1,MR                                                       COB37110
      DO 4 L=1,6                                                        COB37120
      IDAT($LR+I+MR*(L-1))=0                                            COB37130
      DATA($PHI+I+MR*(L-1)) =0.0                                        COB37140
    4 CONTINUE                                                          COB37150
C     READ AND SET CHANNEL DATA. (A) CHANNEL PARAMETERS, (B) GRID DATA, COB37160
C     (C) CHANNELS MAKING EACH TYPE (EXCEPT TYPE 1)                     COB37170
      JBIC = NCTYP+2                                                    COB37180
      JBSTOR(1) = JBIC                                                  COB37190
      JBSTOR(2) = JBIC+1                                                COB37200
      DO 20 I=1,NCTYP                                                   COB37210
      READ(I2,1003)CARD,N,J,FRAC,GAPWV,HRNUM,HRDI,CRNUM,CRDI,SIDE,CORN  COB37220
      WRITE(I3,1004) I,CARD                                             COB37230
      IF(FRAC.LE.0.0) FRAC=1.0                                          COB37240
      IF(J.EQ.2) GO TO 6                                                COB37250
      CHAR=CRNUM                                                        COB37260
      CHPW=CRDI                                                         COB37270
      CHPH=SIDE                                                         COB37280
      GO TO 8                                                           COB37290
    6 CHAR = SIDE*SIDE - 4.0*CORN*CORN - PI*(0.25*HRNUM*HRDI*HRDI       COB37300
     1 + 0.25*CRNUM*CRDI*CRDI - CORN*CORN)                              COB37310
      CHPH=HRNUM*PI*HRDI                                                COB37320
      CHPW=CHPH+4.0*(SIDE-2.0*CORN)+2.0*PI*CORN+CRNUM*PI*CRDI           COB37330
    8 CHDI = 4.0*CHAR/CHPW                                              COB37340
      CDG(1)=0.0                                                        COB37350
      IF(NGRID.LE.0) GO TO 9                                            COB37360
      READ(I2,1005) CARD,(CDG(L),L=1,NGRIDT)                            COB37370
      WRITE(I3,1006) I,CARD                                             COB37380
    9 M=1                                                               COB37390
      IF(I.EQ.1) GO TO 12                                               COB37400
```

```
      IFIRST=1                                                          COB37410
   10 READ(I2,1001) CARD,(JB(L),L=1,MAXRD)                              COB37420
      IF(IFIRST.EQ.0) WRITE(I3,1008) CARD                               COB37430
      IF (IFIRST.EQ.0) GO TO 12                                         COB37440
      WRITE(I3,1007) I,CARD                                             COB37450
      IFIRST=0                                                          COB37460
      M=JB(1)                                                           COB37470
      IF((M.GT.0).AND.(M.LE.NCHANL)) GO TO 12                           COB37480
      IERROR=1                                                          COB37490
      WRITE(I3,2001) I,M                                                COB37500
      RETURN                                                            COB37510
   12 DATA($A+M) = CHAR*FRAC/144.0                                      COB37520
      DATA($PERIM+M) = CHPW*FRAC/12.0                                   COB37530
      DATA($HPERI+M) = CHPH*FRAC/12.0                                   COB37540
      DATA($PHI+M) = HRNUM*FRAC                                         COB37550
      DATA($DHYD+M) = CHDI/12.0                                         COB37560
      DATA($D+M) = HRDI/12.0                                            COB37570
      IDAT($NTYPE+M) = MAX0(N,1)                                        COB37580
      GP(M)=GAPWV                                                       COB37590
      DO 18 L=1,NCHANL                                                  COB37600
      J=L                                                               COB37610
      IF(I.EQ.1) GO TO 14                                               COB37620
      IF(L.GT.MAXRD) GO TO 10                                           COB37630
      J=JB(L)                                                           COB37640
      IF(J.LE.0) GO TO 20                                               COB37650
      JBIC=JBIC+1                                                       COB37660
      JBSTOR(JBIC)=J                                                    COB37670
      JBSTOR(I+1) = JBIC+1                                              COB37680
   14 DATA($A+J) = DATA($A+M)                                           COB37690
      DATA($AN+J) = DATA($A+M)                                          COB37700
      DATA($PERIM+J) = DATA($PERIM+M)                                   COB37710
      DATA($HPERI+J) = DATA($HPERI+M)                                   COB37720
      DATA($DHYD+J) = DATA($DHYD+M)                                     COB37730
      DATA($DHYDN+J) = DATA($DHYD+M)                                    COB37740
      DATA($DR+J) = DATA($D+M)*12.                                      COB37750
      DATA($D +J) = DATA($D+M)                                          COB37760
      GP(J) = GP(M)                                                     COB37770
      IDAT($NTYPE+J) = IDAT($NTYPE+M)                                   COB37780
      IDAT($IDFUE+J) = 1                                                COB37790
      IF(DATA($RADIA+J).EQ.0.0) GO TO 17                                COB37800
      DATA($PHI+J) = DATA($PHI+M)                                       COB37810
      DATA($PHI+J+MR*(1-1))=DATA($PHI+M)                                COB37820
      DATA($PWRF+J+MC*(J-1)) = DATA($PHI+M)                             COB37830
      IDAT($LR+J) = J                                                   COB37840
      IDAT($LR+J+MR*(1-1)) =J                                           COB37850
   17 CONTINUE                                                          COB37860
      DO 16 K=1,NGRT                                                    COB37870
   16 DATA($CD+J+MC*(K-1)) = CDG(K)                                     COB37880
   18 CONTINUE                                                          COB37890
   20 CONTINUE                                                          COB37900
C     SET CHANNEL OF TYPE 1 INTO JBSTOR                                 COB37910
      L = JBSTOR(2)                                                     COB37920
      M = JBSTOR(NCTYP+1) - 1                                           COB37930
      DO 26 I=1,NCHANL                                                  COB37940
      DO 24 J=L,M                                                       COB37950
```

```
      IF (JBSTOR(J).EQ.I) GO TO 26
   24 CONTINUE
      JBSTOR(NCTYP+2) = I
      GO TO 28
   26 CONTINUE
C
   28 IF (NGRID.EQ.0) GO TO 30
C     READ GRID POSITIONS
      READ (I2,1009) CARD,(GRIDXL(I),IGRID(I),I=1,7)
      WRITE (I3,1010) CARD
      IF (NGRID.LE.10) GO TO 29
      WRITE (I3,2007) NGRID
      STOP
   29 IF (NGRID.LE.7) GO TO 30
      READ (I2,1009) CARD,(GRIDXL(I),IGRID(I),I=8,NGRID)
      WRITE (I3,1010) CARD
C     READ ROD LAYOUT
   30 IF(IPILE) 2031,2031,2032
 2031 READ(I2,2033) CARD,NN11,NN22,NN33,NN44,ITMP
 2033 FORMAT(20A4,T1,5I5)
      WRITE(I3,2034) CARD
 2034 FORMAT('  INDICATORS    ',14X,'***',20A4,'*** CHAN')
      IF (IFRM.EQ.1.AND.NN44.NE.1) GO TO 146
      NROD=NN22
      IF (NN11.EQ.0) GO TO 2182
      DO 2181 J=1,NN11
      READ (I2,2035) CARD,N,I,DATA($DR+I),DATA($RADIA+I),(IDAT($LR+I+
     1MR*(L-1)),DATA($PHI+I+MR*(L-1)),L=1,6)
 2035 FORMAT(20A4,T1,I1,I4,2E5.0,6(I3,E7.0))
      WRITE (I3,2047) CARD
 2047 FORMAT('  ROD DATA',20X,'***',20A4,'*** CHAN')
      IDAT($IDFUE+I)=N
      IF(N.LT.1) IDAT($IDFUE+I)=1
 2181 CONTINUE
 2182 DO 2185 I=1,NROD
      DO 2184 L=1,6
      IF(IDAT($LR+I+MR*(L-1))) 2184,2184,2183
 2183 K=IDAT($LR+I+MR*(L-1))
      DATA ($PWRF+K+MC*(I-1))=DATA($PHI+I+MR*(L-1))
 2184 CONTINUE
 2185 DATA($D+I)=DATA($DR+I)/12.
      IF(J1.LE.1) PRINT(8)=.TRUE.
      NODESF=NN33
      NFUELT=NN44
 2032 IF(NODESF.EQ.0) GO TO 34
C     READ FUEL THERMAL DATA
      READ(I2,1005) CARD, (KFUEL(I),CFUEL(I),RFUEL(I),DFUEL(I),
     1 KCLAD(I), CCLAD(I), RCLAD(I), TCLAD(I), HGAP(I),I=1,NFUELT)
      WRITE (I3,1011) CARD
      IF(IFRM.EQ.0) GO TO 31
      READ(I2,1003)CARD,NCF,NCC,THG
      WRITE(I3,2010)CARD
      THG=THG/12.
      IF ((NCF+NCC+1).NE.NODESF) GO TO 146
      IF(NODESF.GT.21) GO TO 146
```

```
      IF (IPROP.EQ.0) GO TO 31
      READ(I2,1005)CARD,FTD,FPUO2
      WRITE(I3,2012)CARD
      IF(IPROP.LE.1) GO TO 31
      READ(I2,1005)CARD,BURN,CPR,EXPR,FPRESS,GRGH,GMIX,PGAS
      WRITE(I3,2014)CARD
      IF((GMIX(1)+GMIX(2)+GMIX(3)+GMIX(4)).GT.1.01) GO TO 146
      GRGH=GRGH/12.
   31 DO 32 I=1,NFUELT
      KFUEL(I) = KFUEL(I)/3600.
      KCLAD(I) = KCLAD(I)/3600.
      DFUEL(I) = DFUEL(I)/12.
      TCLAD(I) = TCLAD(I)/12.
   32 HGAP(I) = HGAP(I)/3600.
C
C     SET WHOLE-CHANNEL AREA AND PH
   34 ATOTAL = 0.0
      PHTOT  = 0.0
      DO 36 I=1,NCHANL
      ATOTAL = ATOTAL + DATA($A+I)
   36 PHTOT  = PHTOT + DATA($HPERI+I)
      NK = 0
      IF (IPILE.EQ.2) GO TO 99
C
C     SET GAP BOUNDARY NUMBERING SYSTEM (PWR ONLY)
      IF(IPILE.GT.0) GO TO 3010
      DO 242 ND2=1,ND2X
      DO 238 ND1=2,ND1X
      I=NTHBOX(ND1-1,ND2)
      J=NTHBOX(ND1,ND2)
      IF((I.LE.0).OR.(J.LE.0)) GO TO  238
      IF((I-J).EQ.0) GO TO  238
      DO 5216 K=1,NK
      IF((I.EQ.IDAT($IK+K)).OR.(I.EQ.IDAT($JK+K))) GO TO 5215
      GO TO 5216
 5215 IF((J.EQ.IDAT($JK+K)).OR.(J.EQ.IDAT($IK+K))) GO TO 238
 5216 CONTINUE
      NK=NK+1
      IDAT($IK+NK) = I
      IDAT($JK+NK) = J
  238 CONTINUE
      IF(ND2.EQ.ND2X) GO TO  242
      DO 240 ND1=1,ND1X
      J=NTHBOX(ND1,ND2)
      I=NTHBOX(ND1,ND2+1)
      IF((I.LE.0).OR.(J.LE.0)) GO TO  240
      IF((I-J).EQ.0) GO TO  240
      DO 6216 K=1,NK
      IF((I.EQ.IDAT($IK+K)).OR.(I.EQ.IDAT($JK+K))) GO TO 6215
      GO TO 6216
 6215 IF((J.EQ.IDAT($JK+K)).OR.(J.EQ.IDAT($IK+K))) GO TO 240
 6216 CONTINUE
      NK=NK+1
      IDAT($IK+NK) = I
      IDAT($JK+NK) = J
```

```
  240 CONTINUE                                                        COB39060
  242 CONTINUE                                                        COB39070
      GO TO 3020                                                      COB39080
 3010 DO 42 ND2=1,ND2X                                                COB39090
      DO 38 ND1=2,ND1X                                                COB39100
      I=NTHBOX(ND1-1,ND2)                                             COB39110
      J=NTHBOX(ND1,ND2)                                               COB39120
      IF((I.LE.0).OR.(J.LE.0)) GO TO 38                               COB39130
      NK=NK+1                                                         COB39140
      IDAT($IK+NK) = I                                                COB39150
      IDAT($JK+NK) = J                                                COB39160
   38 CONTINUE                                                        COB39170
      IF(ND2.EQ.ND2X) GO TO 42                                        COB39180
      DO 40 ND1=1,ND1X                                                COB39190
      J=NTHBOX(ND1,ND2)                                               COB39200
      I=NTHBOX(ND1,ND2+1)                                             COB39210
      IF((I.LE.0).OR.(J.LE.0)) GO TO 40                               COB39220
      NK=NK+1                                                         COB39230
      IDAT($IK+NK) = I                                                COB39240
      IDAT($JK+NK) = J                                                COB39250
   40 CONTINUE                                                        COB39260
   42 CONTINUE                                                        COB39270
C                                                                     COB39280
C     SET GAP BOUNDARY PARAMETERS                                     COB39290
 3020 IF(IPILE.GT.0) GO TO 9006                                       COB39300
      M=1                                                             COB39310
 9014 MM=MIN0((M+13),NK)                                              COB39320
      READ (I2,9007) CARD,(GAPREC(I),I=M,MM)                          COB39330
 9007 FORMAT(20A4,T1,14E5.0)                                          COB39340
      WRITE(I3,9107) CARD                                             COB39350
 9107 FORMAT('  GAP INTERCONNECTIONS',8X,'***',20A4,'*** CHAN')       COB39360
      M=MM+1                                                          COB39370
      IF(M.LE.NK) GO TO 9014                                          COB39380
      IF (ITMP.EQ.0) GO TO 9076                                       COB39390
      IF (NK.LE.70) GO TO 9012                                        COB39400
      WRITE(I3,9010)                                                  COB39410
 9010 FORMAT(1H ,' ERROR DETECTED IN CHAN - TRANSVERSE ',             COB39420
     1  'COUPLING PARAMETER ARRAYS NOT LARGE ENOUGH FOR GREATER THAN', COB39430
     2  /,' 70 GAP INTERCONNECTIONS.')                                COB39440
      GO TO 146                                                       COB39450
C                                                                     COB39460
C  READ TRANSVERSE MOMENTUM COUPLING PARAMTERS                         COB39470
 9012 M=1                                                             COB39480
 9020 MM=MIN0((M+6),NK)                                               COB39490
      READ(I2,9007) CARD,(FACSL(I),FACSLK(I),I=M,MM)                  COB39500
      WRITE(I3,9025) CARD                                             COB39510
 9025 FORMAT('  GAP FACTOR PAIRS',12X,'***',20A4,'*** CHAN')          COB39520
      M=MM+1                                                          COB39530
      IF(M.LE.NK) GO TO 9020                                          COB39540
 9076 DO 9008 K=1,NK                                                  COB39550
 9078 I=IDAT($IK+K)                                                   COB39560
      IF (I-IDAT($JK+K)) 9084,9080,9082                               COB39570
 9080 WRITE(I3,2003) K,I,IDAT($JK+K)                                  COB39580
      IERROR=1                                                        COB39590
      RETURN                                                          COB39600
```

```
 9082 IDAT($IK+K)=IDAT($JK+K)
      IDAT($JK+K)=I
      GO TO 9078
 9084 M=IDAT($JK+K)
      DATA($GAPN+K)=GAPREC(K)/12.
      DATA($GAP+K)=DATA($GAPN+K)
      DATA($LENGT+K)=0.0
      DATA($FACTO+K)=1.0
 9008 CONTINUE
      GO TO 9009
 9006 DO 90 K=1,NK
  78  I =  IDAT($IK+K)
      IF (I-IDAT($JK+K)) 84,80,82
  80  WRITE (I3,2003) K,I,IDAT($JK+K)
      IERROR = 1
      RETURN
  82  IDAT($IK+K) = IDAT($JK+K)
      IDAT($JK+K) = I
      GO TO 78
  84  M = IDAT($JK+K)
      DATA($GAPN+K) = 0.5*(GP(I)+GP(M))/12.0
      DATA($GAP+K) = DATA($GAPN+K)
      DATA($LENGT+K) = 0.0
      DATA($FACTO+K) = 1.0
  90  CONTINUE
 9009 CONTINUE
C
C     SET LOCA ARRAY
C     DYNAMIC STORAGE CALL TO CORE2 FROM ACOL TO SET MA, MS IF GAPS.
      CALL ACOL(1,IDAT($IK+1),IDAT($JK+1),KMAX,IDAT($LOCA+1),MA,MS,NK,
     1MG,IPILE)
C
      IF (IPILE.EQ.0) GO TO 99
C     READ HALF-BOUNDARIES AND SET FACTOR(K)=0.5
      MMAX=MAXRD/2
   92 READ(I2,1001) CARD, (JB(L),L=1,MAXRD)
      WRITE(I3,1012) CARD
      MM = 0
      DO 98 M=1,MMAX
      MM = MM+1
      L=2*M-1
      IF(JB(L).LE.0) GO TO 99
      I=MIN0(JB(L),JB(L+1))
      J=MAX0(JB(L),JB(L+1))
      DO 94 K=1,NK
      IF ( (I.EQ.IDAT($IK+K)) .AND. (J.EQ.IDAT($JK+K)) ) GO TO 96
   94 CONTINUE
      IERROR=1
      WRITE(I3,2005) MM,I,J
      RETURN
   96 DATA($FACTO+K) = 0.5
   98 CONTINUE
      GO TO 92
C
C     READ FORCED FLOW BOUNDARIES HERE IF PROGRAMMED LATER
```

```
   99 DO 100 K=1,NK
      DO 100 L=1,5
  100 DATA($FXFLO+K+MG*(L-1)) = 0.0
      IF (NFXF.EQ.0) GO TO 101
      WRITE (I3,1013)
      IERROR = 1
  101 CONTINUE
      RETURN
C
C     IPART = 2.   PRINT CHANNEL DATA
  102 IPILE=J7
      WRITE(I3,1040) IPILE,NCHANL,NCTYP,NGRID,NGRIDT,NODESF,NFXF
      IF(NODESF.GT.0) WRITE(I3,1045) IFRM,IHTM,IPROP
      WRITE(I3,1050)
C
C     DRAW MAP OF CHANNELS AND CHECK TOTAL
      NUMCH=0
      DO 106 ND2=1,ND2X
      IMAX=0
      DO 104 ND1=1,ND1X
      NUMCH=MAX0(NUMCH,NTHBOX(ND1,ND2))
      IF(NTHBOX(ND1,ND2).GT.0) IMAX=ND1
  104 CONTINUE
      IF(IMAX.EQ.0) GO TO 108
      WRITE(I3,1052) (NTHBOX(I,ND2),I=1,IMAX)
  106 CONTINUE
  108 IF(NUMCH.EQ.NCHANL) GO TO 110
      IERROR=1
      WRITE(I3,2006) NUMCH,NCHANL
      RETURN
C
C      PRINT CHANNEL NUMBER IN EACH TYPE
  110 IF (NCTYP.EQ.1) GO TO 115
      WRITE (I3,1053)
      DO 114 I=2,NCTYP
      L=JBSTOR(I)
      M=JBSTOR(I+1) - 1
      WRITE(I3,1054) I,(JBSTOR(K),K=L,M)
  114 CONTINUE
C
C     PRINT CHANNEL DATA FOR EACH TYPE
  115 WRITE(I3,1055)
      DO 116 I=1,NCTYP
      L=JBSTOR(I)
      J=JBSTOR(L)
      DROD = DATA($D+J)*12.0
  116 WRITE(I3,1056) I,IDAT($NTYPE+J),DATA($A+J),DATA($PERIM+J),
     1 DATA($HPERI+J), DATA($PHI+J), DROD, GP(J)
C
C     PRINT GRID DATA
      IF(NGRID.GT.0) GO TO 118
      WRITE(I3,1057)
      GO TO 124
  118 WRITE(I3,1058) NGRID,NGRIDT,(IGRID(I),GRIDXL(I),I=1,NGRID)
      WRITE(I3,1059) NGRIDT
```

```
      ITMAX = 1
      IF (NFXF.GT.0) ITMAX = 2
      DO 122 ITTR=1,ITMAX
      DO 120 I=1,NCTYP
      L=JBSTOR(I)
      J=JBSTOR(L)
      IF(ITTR.EQ.1) WRITE(I3,1060) I,(DATA($CD+J+MC*(K-1)),K=1,NGRIDT)
      IF(ITTR.EQ.2) WRITE(I3,1060) I,(DATA($FXFLO+J+MG*(K-1)),K=1,
     1 NGRIDT)
  120 CONTINUE
      IF(ITTR.LT.ITMAX) WRITE(I3,1061) NGRIDT
  122 CONTINUE
C
  124 IF(IPILE.GT.0) GO TO 125
      WRITE(I3,2008) (I,IDAT($IDFUE+I),DATA($DR+I),DATA($RADIA+I),
     1(DATA($PHI+I+MR*(L-1)),IDAT($LR+I+MR*(L-1)),L=1,6),I=1,NROD)
C     PRINT FUEL THERMAL DATA
  125 IF(NODESF.EQ.0) GO TO 130
      WRITE (I3,1062) NODESF
      DO 126 J=1,NFUELT
      WV1 = KFUEL(J)*3600.0
      WV2 = DFUEL(J)*12.0
      WV3 = KCLAD(J)*3600.0
      WV4 = TCLAD(J)*12.0
      WV5 = HGAP(J)*3600.0
  126 WRITE(I3,1063) J,WV1,CFUEL(J),RFUEL(J),WV2,WV3,CCLAD(J),RCLAD(J),
     1 WV4,WV5
      WV6=THG*12.
      IF(IFRM.EQ.1) WRITE(I3,1080) NCF,NCC,WV6
      IF(IPROP.GE.1) WRITE(I3,1082) FTD,FPUO2
      IF(IPROP.EQ.2) WRITE(I3,1084) BURN,CPR,EXPR,FPRESS,GRGH,GMIX,PGAS
      IF(IHTM.EQ.1) WRITE(I3,1090)
      IF(IHTM.EQ.2) WRITE(I3,1092)
C
  130 IF (IPILE.EQ.2) GO TO 144
      IF(IPILE.EQ.0) GO TO 132
      DO 131 K=1,NK
  131 GAPREC(K)=DATA($GAPN+K)*12.0
C     PRINT ARRAYS IK, JK AND LOCA
  132 WRITE (I3,1064)
      WRITE (I3,1065) NK
      M = 1
  134 MM=MIN0((M+5),NK)
      WRITE (I3,1066) M,(IDAT($IK+K),IDAT($JK+K),GAPREC(K),K=M,MM)
      M = MM+1
      IF (M.LE.NK) GO TO 134
      WRITE (I3,1067) NK
      M = 1
  136 MM = MIN0( (M+24),NK)
      IF (IPILE.GT.0) GO TO 4207
      DO 8138 L=1,14
 8138 WRITE(I3,1068) L,(IDAT($LOCA+K+MG*(L-1)),K=M,MM)
      GO TO 4208
 4207 DO 138 L=1,8
  138 WRITE (I3,1068) L, (IDAT($LOCA+K+MG*(L-1)),K=M,MM)
```

```
 4208 M=MM+1
      WRITE (I3,1069)
      IF (M.LE.NK) GO TO 136
      L = MS*NK
      WRITE (I3,1070) MS,KMAX,L,MA
      IF (ITMP.EQ.0) GO TO 139
C
C  PRINT TRANSVERSE MOMENTUM COUPLING PARAMTERS
      WRITE(I3,1076)
      WRITE(I3,1078) (K,FACSL(K),FACSLK(K),K=1,NK)
C
C     PRINT HALF-BOUNDARIES
  139 IC = 0
      DO 140 K=1,NK
      IF (DATA($FACTO+K).EQ.1.0) GO TO 140
      IC = IC+1
      JBSTOR(IC) = K
  140 CONTINUE
      IF (IC.GT.1) GO TO 142
      WRITE (I3,1072)
      GO TO 144
  142 WRITE (I3,1073) (JBSTOR(K),K=1,IC)
  144 CONTINUE
      WRITE (I3,1074)
      RETURN
C
  146 WRITE(I3,1000)
      IERROR=1
      RETURN
C
 1000 FORMAT(1H ,' INPUT ERROR DETECTED BY CHAN.')
 1001 FORMAT(20A4, T1, 14I5)
 1002 FORMAT('  INDICATORS', 18X, '***', 20A4, '*** CHAN')
 1003 FORMAT(20A4, T1, 2I5, 8E5.0)
 1004 FORMAT('  CHANNEL DATA, TYPE', I3, 7X, '***', 20A4, '*** CHAN')
 1005 FORMAT(20A4, T1, 14E5.0)
 1006 FORMAT('  GRID DATA, TYPE', I3, 10X, '***' ,20A4, '*** CHAN')
 1007 FORMAT('  CHANNELS OF TYPE', I3, 9X, '***', 20A4, '*** CHAN')
 1008 FORMAT(30X, '***', 20A4, '*** CHAN')
 1009 FORMAT(20A4, T1, 7(E5.0,I5))
 1010 FORMAT('  GRID POSITIONS', 14X, '***', 20A4, '*** CHAN')
 1011 FORMAT('  FUEL THERMAL DATA', 11X, '***', 20A4, '*** CHAN')
 1012 FORMAT('  HALF-BOUNDARY CHANNEL PAIRS',1X, '***',20A4, '*** CHAN')
 1013 FORMAT('  FORCED FLOW NOT PROGRAMMED. STOP CALCULATION IN CHAN')
 1040 FORMAT(///, 43X, 'CHANNEL, ROD AND GRID DATA', /, 43X,
     1 '------- --- --- ---- ----', //, '  REACTOR TYPE', 8X,
     2 '=', I3, 5X, '(1=PWR,  2=BWR)', /, ' *NO. FUEL ASSEMBLIES =', I3,
     3 /, '  NO. ASSEMBLY TYPES  =', I3, /, '  NO. GRIDS', 11X, '=',
     4 I3, /, '  NO. GRID TYPES', 6X, '=', I3,/, '  NO. FUEL NODES', 6X,
     5 '=', I3, /, '  NO. FCD FLOW TYPES', 2X, '=', I3, /)
 1045 FORMAT(1H ,' FUEL ROD MODEL IND. =',I3,/,
     1  '  HEAT TRANSFER MODEL IND.=',I3,/,
     2  '  FUEL ROD PROP. IND. =',I3,//)
 1050 FORMAT(///,'  CHANNEL DATA', /, ' ------- ----',15X,
     1  '*CHANNEL NUMBERING MAP', /)
```

```
 1052 FORMAT(/, 25I5)                                                   COB41810
 1053 FORMAT(//, '  TYPE', 15X, 'CHANNEL NUMBERS')                      COB41820
 1054 FORMAT(I5, 3X, 30I4)                                              COB41830
 1055 FORMAT(//, '  TYPE', 6X, 'FRIC', 9X, 'AREA', 10X, 'WT PER', 9X,   COB41840
     1 'HT PER', 8X, 'NO. RODS', 7X, 'ROD DIA', 10X, 'GAP', /, 24X,     COB41850
     2 'SQ FT', 12X, 'FT', 13X, 'FT', 28X, 'IN', 13X, 'IN')             COB41860
 1056 FORMAT(I5, 5X, I5, F15.5, 2F15.3, F15.0, 2F15.4)                  COB41870
 1057 FORMAT(/, '  NO GRIDS', /)                                        COB41880
 1058 FORMAT(////, '  GRID DATA', /, '  ---- ----',                     COB41890
     1                              //, '  NO. GRIDS', 9X, '=', I3, /,  COB41900
     2 '  NO. GRID TYPES', 4X, '=', I3, /, '  TYPE AT X/L', 7X, '=',    COB41910
     3 8(I5,F8.4))                                                      COB41920
 1059 FORMAT(//,'  ASSY. TYPE',10X, 'GRID COEFF FOR GRID TYPES 1 -', I3)COB41930
 1060 FORMAT(I8, 7X, 11F10.4)                                           COB41940
 1061 FORMAT(//,'  ASSY. TYPE',10X, 'FORCED FLOW DIVERSION FACTORS FOR TCOB41950
     1YPES 1 -', I3)                                                    COB41960
 1062 FORMAT(////, 39H THERMAL PROPERTIES FOR FUEL MATERIAL             COB41970
     1 I8,18H RADIAL FUEL NODES  /                                      COB41980
     2 ' ------- ---------- --- ---- -------- ',//,                     COB41990
     3 37H                    FUEL PROPERTIES 25X,'CLAD PROPERTIES', /COB42000
     4 50H     TYPE     COND.     SP. HEAT   DENSITY    DIA.            COB42010
     5                 50H  COND.     SP. HEAT   DENSITY  THICK.   GAP COND. / COB42020
     6 49H       NO. (B/HR-FT-F) (B/LB-F)    (LB/FT3)  (IN.)            COB42030
     7                 52H(B/HR-FT-F) (B/LB-F)    (LB/FT3)  (IN.)  (B/HR-FT2-F))COB42040
 1063 FORMAT(I7,2X,F7.2,F11.4,F11.1,F9.4,2X,F7.2,F11.4,F11.1,F9.4,2X,   COB42050
     1 F9.2)                                                            COB42060
 1064 FORMAT(////, '  GAP BOUNDARY DATA', /, '  --- -------- ----', //) COB42070
 1065 FORMAT (I5,' BOUNDARIES AS BELOW (IK(K)-JK(K))',' - (EFFECTIVE RODCOB42080
     1 GAP)',/)                                                         COB42090
 1066 FORMAT(' (',I3, ') ',6(2X,I3,'-',I3,'  (',F7.4,')'))              COB42100
 1067 FORMAT(///, '  LOCA(K,8) ARRAY SET IN ACOL', 5X,'K = 1 TO ',I3,//)COB42110
 1068 FORMAT(' (',I2, ')',25I5)                                         COB42120
 1069 FORMAT(/)                                                         COB42130
 1070 FORMAT(///, '  MAXIMUM OVERALL STRIPE WIDTH FOR ARRAY AAA IN DIVERCOB42140
     1T = ', I3, ' FOR BOUNDARY NO. ', I3, //, '  REQUIRE ', I6,' STORESCOB42150
     2 FOR AAA SIZE AND THIS OK SINCE .LE.',I6, ' PROVIDED', //)        COB42160
 1072 FORMAT(/, '  NO HALF BOUNDARIES')                                 COB42170
 1073 FORMAT(/, '  GAP BOUNDARIES CROSSED BY LINE OF SYMMETRY, IE FACTORCOB42180
     1(K) = 0.5', /, 25I5)                                              COB42190
 1074 FORMAT(1H1)                                                       COB42200
 1076 FORMAT(/,'  TRANSVERSE MOMENTUM COUPLING PARAMETERS',             COB42210
     1         '  ---------- -------- -------- ----------',             COB42220
     2         '  GAP NO.     FACSL        FACSLK')                     COB42230
 1078 FORMAT(1H ,I6,5X,E9.2,3X,E9.2)                                    COB42240
C                                                                       COB42250
 1080 FORMAT(// ,' NEW FUEL ROD MODEL',/,                               COB42260
     1  ' --- ---- --- -----',/,                                        COB42270
     2  '  NUMBER OF FUEL PELLET NODES =',I5,/,                         COB42280
     3  '  NUMBER OF CLAD NODES        =',I5,/,                         COB42290
     4  '  GAP THICKNESS(IN)',11X,'= ',E12.5,/)                         COB42300
CC                                                                      COB42310
 1082 FORMAT(// ,' FUEL AND CLAD PROPERTIES WILL BE CALCULATED USING ', COB42320
     1  ' FUEL ROD TEMPERATURES.',/,                                    COB42330
     2  '  FRACTION THEORETICAL DEN(FUEL)=',E12.5,/,                    COB42340
     3  '  FRACTION PUO2 =',E12.5,/)                                    COB42350
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CC                                                                      COB42360
 1084 FORMAT(//,' GAP HEAT TRANSFER COEFFICIENTS WILL BE ',             COB42370
     1  'CALCULATED USING FUEL ROD TEMPERATURES.',/,                     COB42380
     2  '   BURNUP(MWD/MTU) =',E12.5,/,                                  COB42390
     3  '   COEFF. OF FUEL PRESSURE =',E12.5,/,                          COB42400
     4  '   EXPONENT OF FUEL PRESSURE =',E12.5,/,                        COB42410
     5  '   FUEL PRESSURE =',E12.5,/,                                    COB42420
     6  '   GAP ROUGHNESS, RMS(FT) =',E12.5,/,                           COB42430
     7  '   HELIUM FRACTION =',E12.5,/,                                  COB42440
     8  '   ARGON FRACTION =',E12.5,/,                                   COB42450
     9  '   KRYPTON FRACTION =',E12.5,/,                                 COB42460
     1  '   XENON FRACTION =',E12.5,/,                                   COB42470
     2  '   GAP GAS PRESSURE(PSIA) =',E12.5)                             COB42480
CC                                                                      COB42490
 1090 FORMAT(// ,' ROD-TO-COOLANT HEAT TRANSFER USING NEW MODEL FOR ',  COB42500
     1  'PRE-CHF CONDITIONS')                                            COB42510
 1092 FORMAT(// ,' ROD-TO-COOLANT HEAT TRANSFER USING NEW MODEL FOR ',  COB42520
     1  'PRE- AND POST-CHF CONDITIONS')                                  COB42530
C                                                                       COB42540
 2001 FORMAT('  INPUT DATA ERROR IN ITHO. FIRST CHANNEL OF TYPE', I3,   COB42550
     1 ' IS', I3)                                                        COB42560
 2003 FORMAT(' ITHO  GAP CONNECTION ', I3, '  I AND J SAME IE ', 2I3)   COB42570
 2005 FORMAT(I5, ' TH HALF-BOUNDARY ', I4, ' - ', I4,' NOT IN BOUNDARY SCOB42580
     1ET')                                                               COB42590
 2006 FORMAT(' ITHO  HIGHEST NUMBER CHANNEL FOUND TO BE ', I3,          COB42600
     1 ' AND THIS NOT EQUAL TO NUMBER SPECIFIED, IE ', I3)               COB42610
 2007 FORMAT('  NGRID GIVEN AS ', I3, '.  THIS TOO LARGE AS MAX ALLOWED COB42620
     1 IS 10.  CALCULATION STOPPED IN CHAN.')                            COB42630
 2008 FORMAT(////, '  ROD INPUT DATA',/,'  --- ----- ----',  /,         COB42640
     1  ' ROD  TYPE  DIA  RADIAL POWER    FRACTION OF POWER TO ADJA',    COB42650
     2  'CENT CHANNELS (ADJ. CHANNEL NO.)',/,'   NO.  NO.    (IN)    ',  COB42660
     3  'FACTOR',/(2I5,F8.4,F9.4,F11.4,1H(I2,1H)F9.4,1H(I2,1H)F9.4,      COB42670
     4  1H(I2,1H)F9.4,1H(I2,1H)F9.4,1H(I2,1H)F9.4,1H(I2,1H)))            COB42680
C                                                                       COB42690
 2009 FORMAT(1H ,1X,'EPSF',24X,'***',20A4,'*** CHAN')                   COB42700
 2010 FORMAT(1H ,1X,'NCF, NCC, THG',15X,'***',20A4,'*** CHAN')          COB42710
 2012 FORMAT(1H ,1X,'FTD, FPUO2',18X,'***',20A4,'*** CHAN')             COB42720
 2014 FORMAT(1H ,1X,'GAP DATA',20X,'***',20A4,'*** CHAN')               COB42730
 2016 FORMAT(20A4, T1, E8.0)                                            COB42740
C                                                                       COB42750
      END                                                               COB42760
      SUBROUTINE PRNTIM(IN)                                             COB42770
      RETURN                                                            COB42780
      END                                                               COB42790
      SUBROUTINE CHF(JSTART,JEND)                                       COB42800
C  CHF SEARCHES COBRA-IIIC OUTPUT AT THE END OF EACH TIME STEP FOR      COB42810
C  THE OCCURANCE OF CRITICAL HEAT FLUX.  THE SEARCH IS MADE ON EACH ROD COB42820
C  AT A SPECIFIED AXIAL LOCATION RANGE BY CONSIDERING EACH ROD AND THE  COB42830
C  ADJACENT CHANNELS.                                                   COB42840
C  ALTHOUGH THE BAW-2 AND W-3 CORRELATIONS ARE INCLUDED, USERS SHOULD   COB42850
C  PROGRAM OTHER CORRELATIONS OF THEIR CHOICE AS OPTIONS.               COB42860
C                                                                       COB42870
C                                                                       COB42880
      IMPLICIT INTEGER ($)                                              COB42890
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB42900
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     1  ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB42910
     2  HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB42920
     3  J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB42930
     4  NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB42940
     5  NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB42950
     6  NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB42960
     7  QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB42970
     8  UF    ,VF    ,VFG   ,VG    ,Z                                  COB42980
C                                                                      COB42990
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),   COB43000
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB43010
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB43020
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB43030
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB43040
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB43050
C                                                                      COB43060
C                                                                      COB43070
      LOGICAL  GRID                                                    COB43080
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                              COB43090
C                                                                      COB43100
C                                                                      COB43110
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB43120
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB43130
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB43140
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB43150
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB43160
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB43170
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB43180
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB43190
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB43200
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB43210
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB43220
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB43230
C                                                                      COB43240
      COMMON/CHFSV/CHSAVE(20,20,31)                                    COB43250
C                                                                      COB43260
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                COB43270
C                                                                      COB43280
      COMMON  DATA(1)                                                  COB43290
      LOGICAL LDAT(1)                                                  COB43300
      INTEGER IDAT(1)                                                  COB43310
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                           COB43320
C                                                                      COB43330
C                                                                      COB43340
      NDXP1 = NDX + 1                                                  COB43350
      DO 100 J=1,NDXP1                                                 COB43360
      DATA($MCHFR+J)=10.0                                              COB43370
      IDAT($MCFRC+J)=0                                                 COB43380
      IDAT($MCFRR+J)=0                                                 COB43390
      DO 100 N=1,NROD                                                  COB43400
      DATA($CHFR +N+MR*(J-1))=10.                                      COB43410
      IDAT($CCHAN+N+MR*(J-1))=0                                        COB43420
  100 CONTINUE                                                         COB43430
      IF (NCHF.EQ.5.AND.IHTM.NE.2) WRITE(6,2000)                       COB43440
 2000 FORMAT(1H ,'  ERROR DETECTED IN CHF - ',                         COB43450
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```
     1  ' NCHF=5 AND IHTM DOES NOT = 2.')                                COB43460
      DO 500 J=JSTART,JEND                                               COB43470
      CHFROD = 0                                                         COB43480
      DO 300 N=1,NROD                                                    COB43490
      XMCHFR = 10.                                                       COB43500
      IF(DATA($FLUX+N+MR*(J-1)).LE.0.0)  GO TO 300                       COB43510
      DO 290 L=1,6                                                       COB43520
      IF(IDAT($LR   +N+MR*(L-1)))  200,290,200                           COB43530
C  CALCULATE CHF RATIO FOR ROD N FACING CHANNEL I.                       COB43540
 200  I= IDAT($LR   +N+MR*(L-1))                                         COB43550
      XCHFR = 0.                                                         COB43560
      IF(NCHF.EQ.1) XCHFR = CHF1(N,I,J)/DATA($FLUX+N+MR*(J-1))           COB43570
      IF(NCHF.EQ.2) XCHFR = CHF2(N,I,J)/DATA($FLUX+N+MR*(J-1))           COB43580
      IF(NCHF.EQ.3) XCHFR = CHF3(N,I,J)/DATA($FLUX+N+MR*(J-1))           COB43590
      IF(NCHF.EQ.4) XCHFR = CHF4(N,I,J)                                  COB43600
CC  OPTION NCHF=5 OPERATIONAL ONLY IF IHTM=2                             COB43610
CC  BECAUSE CHSAVE CALCULATED IN HTCOR AND SAVED                         COB43620
      IF (NCHF.EQ.5.AND.IHTM.EQ.2)                                       COB43630
     1  XCHFR = CHSAVE(N,I,J)/DATA($FLUX+N+MR*(J-1))                     COB43640
      IF(XCHFR.LE.0.) GO TO 1000                                         COB43650
C  CALCULATE MINIMUM CHF RATIO FOR ROD N FACING CHANNEL I.               COB43660
      IF(XCHFR.GT.DATA($CHFR+N+MR*(J-1)))  GO TO 290                     COB43670
                  DATA($CHFR+N+MR*(J-1))=XCHFR                           COB43680
                  IDAT($CCHAN+N+MR*(J-1))=I                              COB43690
      CHFROD = N                                                         COB43700
  290 CONTINUE                                                           COB43710
C  DETERMINE MINIMUM CHF RATIO AT AXIAL LOCATION J.                      COB43720
      XMCHFR      =DATA($CHFR+N+MR*(J-1))                                COB43730
      IF(XMCHFR.GT.DATA($MCHFR+J          ) )  GO TO 300                 COB43740
      DATA($MCHFR+J)=XMCHFR                                              COB43750
      IDAT($MCFRR+J)=CHFROD                                              COB43760
      IDAT($MCFRC+J)=IDAT($CCHAN+N+MR*(J-1))                             COB43770
  300 CONTINUE                                                           COB43780
  500 CONTINUE                                                           COB43790
      RETURN                                                             COB43800
 1000 PRINT 1                                                            COB43810
    1 FORMAT (' ERROR IN CHF ROUTINE')                                   COB43820
      RETURN                                                             COB43830
      END                                                                COB43840
      FUNCTION CHF2(N,I,J)                                               COB43850
C                                                                        COB43860
C                                                                        COB43870
      IMPLICIT INTEGER ($)                                               COB43880
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB43890
     1  ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB43900
     2  HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB43910
     3  J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB43920
     4  NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB43930
     5  NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB43940
     6  NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB43950
     7  QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB43960
     8  UF    ,VF    ,VFG   ,VG    ,Z                                  COB43970
C                                                                        COB43980
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB43990
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),     COB44000
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     2    GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3    IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4    PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5    VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA     ,MC     ,MG     ,MN     ,MR     ,MS     ,MX     ,
     1           $$$    ,$A     ,$AAA   ,$AC    ,$ALPHA,$AN    ,$ANSWE,$B     ,
     1    $CCHAN,$CD    ,$CHFR  ,$CON   ,$COND  ,$CP    ,$D     ,$DC    ,$DFDX  ,
     2    $DHDX ,$DHYD  ,$DHYDN,$DIST  ,$DPDX  ,$DPK   ,$DUR   ,$DR    ,$F     ,
     3    $FACTO,$FDIV  ,$FINLE,$FLUX  ,$FMULT,$FOLD  ,$FSP   ,$FSPLI,$FXFLO,
     4    $GAP  ,$GAPN  ,$GAPS  ,$H     ,$HFILM,$HINLE,$HOLD  ,$HPERI,$IDARE,
     5    $IDFUE,$IDGAP,$IK     ,$JBOIL,$JK    ,$LC    ,$LENGT,$LOCA  ,$LR    ,
     6    $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH    ,
     7    $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF  ,$QC    ,$QF    ,$QPRIM,
     8    $QUAL ,$RADIA,$RHO   ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD  ,
     9    $U    ,$UH    ,$USAVE,$USTAR,$V     ,$VISC  ,$VISCW,$VP    ,$VPA   ,
     A    $W    ,$WOLD  ,$WP    ,$WSAVE,$X     ,$XCROS,$$A    ,$$B   ,$XPOLD
C
      COMMON   DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
C  W-3 CORRELATION INCLUDING, SPACER FACTOR, UNHEATED WALL CORRECTION,
C AXIAL FLUX FACTOR
C  REFERENCE, LS TONG, BOILING CRISIS AND CRITICAL HEAT FLUX
C   AEC CRITICAL REVIEW SERI5S,TID-25887(1972).
      DE=4.*DATA($A+I)/DATA($PERIM+I)
      DH=4.*DATA($A+I)/DATA($HPERI+I)
      RU = 1.-DE/DH
      XX=(DATA($H+I+MC*(J-1))-HF)/HFG
C  W-3 CORRELATION USING EQUILIBRIUM STEAM QUALITY
      CHF2    = ((2.022 - 0.0004302*PREF) + (0.1722 - 0.0000984*PREF)
     1 *EXP((18.2 - 0.004129*PREF)*XX))
     2 *((0.1484-1.596*XX+.1729*XX*ABS(XX))*DATA($F+I+MC*(J-1))/
     2                                       DATA($A+I)
     3 *.0036 + 1.037)
     4 *(1.157 - 0.869*XX)
     5 *(0.2664 + 0.8357*EXP(-37.812*DH))
     6 *(0.8258+0.000794*(HF-DATA($HINLE+I)))/.0036
C  UNHEATED WALL CORRECTION
      IF(RU.GT.0.) CHF2 = CHF2*(1. - RU*(13.76-1.372*EXP(1.78*XX)
     1 -4.732/(DATA($F+I+MC*(J-1))/DATA($A+I)*0.0036)**.0535
     1 -0.0619*(PREF*0.001)**.14
     2-11.101*DH**.1077))
C  SPACER FACTOR CORRECTION
C  USER SHOULD SELECT PROPER VALUE OF TDC
      TDC = .019
      IF(NGRID.GT.0) CHF2 = CHF2
```

```
     1 *(1.+.03*DATA($F+I+MC*(J-1))/DATA($A+I)*.0036*(TDC/.019)**.35)
C  AXIAL FLUX PROFILE CORRECTION
      FAXIAL = 1.
      IF(J.LE.IDAT($JBOIL+I))  GO TO 10
      C=1.8*(1.-XX)**4.31/(DATA($F+I+MC*(J-1))/DATA($A+I)*.0036)**.478
      SUM = 0.
      JS=IDAT($JBOIL+I)+1
      CE=C/2.
      DO 5 JJ=JS,J
    5 SUM=SUM+DATA($FLUX+N+MR*(JJ-1))*(EXP(CE*DATA($X+JJ))+
     1EXP(CE*DATA($X+JJ-1)))*(EXP(CE*DATA($X+JJ))-EXP(CE*DATA($X+JJ-1
     2)))
      FAXIAL=SUM*EXP(-CE*DATA($X+J))/DATA($FLUX+N+MR*(J-1))/
     1(1.-EXP(-C*(DATA($X+J)-DATA($X+JS-1))))
      FAXIAL=FAXIAL*EXP(-CE*DATA($X+J))
   10 CHF2 = CHF2/FAXIAL
      RETURN
      END
      FUNCTION CHF3(N,I,J)
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
```

```
     A    $W     ,$WOLD ,$WP    ,$WSAVE,$X     .$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C     HENCH-LEVY CORRELATION FOR CRITICAL HEAT FLUX
C
C
      G=DATA($F+I+MC*(J-1))*.0036/DATA($A+I)
      XE=(DATA($H+I+MC*(J-1))-HF)/HFG
      IF(DATA($FLUX+N+MR*(J-1)).LE.0.) GO TO 10
      XC1=0.273-0.212*(TANH(3.*G))**2
      XC2=0.5-0.269*(TANH(3.*G))**2+0.0346*(TANH(2.*G))**2
      IF(XE.GE.XC2) Q=0.6-0.7*XE-0.09*(TANH(2.*G))**2
      IF(XE.GT.XC1.AND.XE.LT.XC2) Q=1.9-3.3*XE-0.7*(TANH(3.*G))**2
      IF(XE.LT.XC1) Q=1.0
      Q=Q*1.E6
      Q=Q*(1.1-0.1*((PREF-600.)/400.)**1.25)
      Q=Q/3600
      CHF3=Q
      RETURN
C
   10 CHF3=10.*DATA($FLUX+N+MR*(J-1))
      RETURN
      END
      FUNCTION CHF4(N,I,J)
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
```

```
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB45660
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB45670
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB45680
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB45690
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB45700
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB45710
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB45720
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB45730
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB45740
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD  COB45750
C                                                                       COB45760
      COMMON  DATA(1)                                                   COB45770
      LOGICAL LDAT(1)                                                   COB45780
      INTEGER IDAT(1)                                                   COB45790
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB45800
C                                                                       COB45810
C  THE CISE CORRELATION IS USED TO ESTIMATE                             COB45820
C  CRITICAL POWER                                                       COB45830
C                                                                       COB45840
C                                                                       COB45850
      IF(J.LE.IDAT($JBOIL+I)) GO TO 100                                 COB45860
C                                                                       COB45870
      XLBL=.3048*DX*FLOAT(J-IDAT($JBOIL+I))                             COB45880
      G=4.88*DATA($F+I+MC*(J-1))/DATA($A+I)                             COB45890
      C1=(1.-PREF/3206.)                                                COB45900
      GSTAR=3375.*C1**3                                                 COB45910
      DH=.3048*DATA($DHYD+I)                                            COB45920
      A=C1/(G*.001)**.333                                               COB45930
      IF(G.LT.GSTAR) A=1./(1.+1.481E-4*C1**(-3)*G)                      COB45940
      B=0.199*(3206./PREF-1.)**0.4*G*DH**1.4                            COB45950
      XCR=(DATA($HPERI+I)*A*XLBL)/(DATA($PERIM+I)*(XLBL+B))             COB45960
      XE=(DATA($H+I+MC*(J-1))-HF)/HFG                                   COB45970
      HSUB=HF-DATA($H+I)                                                COB45980
      CPR=(XCR*HFG+HSUB)/(XE*HFG+HSUB)                                  COB45990
      CHF4=CPR                                                          COB46000
      RETURN                                                            COB46010
C                                                                       COB46020
  100 CHF4=10.                                                          COB46030
      RETURN                                                            COB46040
      END                                                               COB46050
      SUBROUTINE DIVERT(J)                                              COB46060
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THECOB46070
C   MAJOR SUBROUTINES OF COBRA-IIIC.                                    COB46080
C                                                                       COB46090
C                                                                       COB46100
      IMPLICIT INTEGER ($)                                              COB46110
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB46120
     1  ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB46130
     2  HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB46140
     3  J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB46150
     4  NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB46160
     5  NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB46170
     6  NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB46180
     7  QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB46190
     8  UF    ,VF    ,VFG   ,VG    ,Z                                   COB46200
```

```
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA     ,MC     ,MG     ,MN     ,MR     ,MS     ,MX     ,
     1          $$$    ,$A     ,$AAA   ,$AC    ,$ALPHA,$AN    ,$ANSWE,$B     ,
     1   $CCHAN,$CD    ,$CHFR  ,$CON   ,$COND  ,$CP    ,$D     ,$DC    ,$DFDX  ,
     2   $DHDX ,$DHYD  ,$DHYDN,$DIST   ,$DPDX  ,$DPK   ,$DUR   ,$DR    ,$F     ,
     3   $FACTO,$FDIV  ,$FINLE,$FLUX   ,$FMULT,$FOLD  ,$FSP   ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN  ,$GAPS  ,$H     ,$HFILM,$HINLE,$HOLD  ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK     ,$JBOIL,$JK    ,$LC    ,$LENGT,$LOCA ,$LR    ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH    ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF  ,$QC    ,$QF    ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO    ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD  ,
     9   $U    ,$UH    ,$USAVE,$USTAR,$V      ,$VISC  ,$VISCW,$VP    ,$VPA   ,
     A   $W    ,$WOLD  ,$WP    ,$WSAVE,$X     ,$XCROS,$$A    ,$$B    ,$XPOLD
C
      COMMON /GAPFAC/ FACSL(70), FACSLK(70)
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
      EQUIVALENCE (NCHAN,NCHANL)
C
C
      ABIT(IZ,Z1,Z2,Z3,Z4,Z5,Z6) = IZ*((2.0*Z1 - Z2 + DX/DT)/Z3 +
     1 Z4*ABS(Z5+Z6)*DX)
      IPILE =J7
C
      NKK = NK
      JM1 = J-1
      SLDX = SL*DX
      DTGC = DT*GC
      DXGC = DX*GC
C  CALCULATE USTAR
      DO 5 K=1,NKK
      II=IDAT($IK+K)
      JJ=IDAT($JK+K)
      DATA($USAVE+K)=DATA($USTAR+K)
      DATA($USTAR+K)=0.5*(DATA($U+II)+DATA($U+JJ))
    5 CONTINUE
C
C     SET AAA ARRAY USING LOCA (SET IN ACOL BASED ON INPUT DATA)
      LMAX = MS
```

```
      MID = (MS+1)/2                                                    COB46760
      DO 310 K=1,NK                                                     COB46770
      DO 290 L=1,LMAX                                                   COB46780
 290  DATA($AAA+K+NK*(L-1))=0.                                          COB46790
      II=IDAT($IK+K)                                                    COB46800
      JJ=IDAT($JK+K)                                                    COB46810
C  TRANSVERSE MOMENTUM PARAMETER IN NEXT EQUATION                       COB46820
      DATA($B+K)=(DATA($SP+K+MG*(J-1))-(DATA($DPDX+II)-DATA($DPDX+JJ))* COB46830
     1    DX)*SL*FACSL(K)*DATA($FACTO+K)+DATA($USAVE+K)*                COB46840
     +    DATA($W+K+MG*(JM1-1))/                                        COB46850
     2    DXGC+DATA($WOLD+K+MG*(J-1))/DTGC                              COB46860
      SAVE=ABIT(1,DATA($U+II),DATA($USTAR+K),DATA($A+II),DATA($DPK+II), COB46870
     1            DATA($F+II+MC*(JM1-1)),DATA($F+II+MC*(J-1)))          COB46880
     2    +ABIT(1,DATA($U+JJ),DATA($USTAR+K),DATA($A+JJ),DATA($DPK+JJ), COB46890
     3            DATA($F+JJ+MC*(JM1-1)),DATA($F+JJ+MC*(J-1)))          COB46900
      IF (IPILE.GT.0) GO TO 7213                                        COB46910
      NBOUND=IDAT($LOCA+K+MG*13)                                        COB46920
      GO TO 7214                                                        COB46930
 7213 NBOUND=IDAT($LOCA+K+MG*7)                                         COB46940
 7214 DO 300 LL=1,NBOUND                                                COB46950
      L      =IDAT($LOCA+K+MG* (LL-1))                                  COB46960
      IF (LL.EQ.1) GO TO 295                                            COB46970
      IZ = 1                                                            COB46980
      IF (L.LT.0) IZ=-1                                                 COB46990
      L = IABS(L)                                                       COB47000
      IJ = JJ                                                           COB47010
      IF( (II.EQ.IDAT($IK+L)).OR.                                       COB47020
     1    (II.EQ.IDAT($JK+L)))  IJ=II                                   COB47030
      SAVE = ABIT(IZ,DATA($U+IJ),DATA($USTAR+L),DATA($A+IJ),            COB47040
     1  DATA($DPK+IJ),DATA($F+IJ+MC*(JM1-1)),DATA($F+IJ+MC*(J-1)))      COB47050
  295 L = MID - K + L                                                   COB47060
C  TRANSVERSE MOMENTUM PARAMETER IN NEXT EQUATION                       COB47070
 300  DATA($AAA+K+NK*(L-1))=SAVE*SLDX*FACSL(K)/GC*DATA($FACTO+K)        COB47080
C  TRANSVERSE MOMENTUM PARAMETER IN NEXT EQUATION                       COB47090
      DATA($AAA+K+NK*(MID-1))=                                          COB47100
     1DATA($AAA+K+NK*(MID-1))+SL*FACSLK(K)*CIJ(K,J)*DATA($FACTO+K)+     COB47110
     2DATA($USTAR+K)/DXGC+1./DTGC                                       COB47120
  310 CONTINUE                                                          COB47130
      IF(J6.LT.1) GO TO 105                                             COB47140
C                                                                       COB47150
C  MODIFY SIMULTANEOUS EQUATIONS TO ACCOUNT FOR SPECIFIED VALUES OF     COB47160
C  CROSSFLOW GIVEN IN SUBROUTINE FORCE                                  COB47170
C                                                                       COB47180
      DO 90 K=1,NK                                                      COB47190
      IF(LDAT($FDIV+K))  GO TO 90                                       COB47200
      DO 85 L=1,NK                                                      COB47210
      LL=MID-K+L                                                        COB47220
      IF(LL.EQ.MID) GO TO 85                                            COB47230
      IF(LL.GT.LMAX.OR.LL.LT.1) GO TO 85                                COB47240
      IF(LDAT($FDIV+L))                                                 COB47250
     1                      DATA($B+K)=DATA($B+K)-DATA($AAA+K+NK*(LL-1))* COB47260
     1    DATA($W+L+MG*(J-1))                                           COB47270
   85 CONTINUE                                                          COB47280
   90 CONTINUE                                                          COB47290
      DO 100 K=1,NK                                                     COB47300
```

```
      IF(.NOT.LDAT($FDIV+K))  GO TO 100                                 COB47310
      DO 95 L=1,LMAX                                                    COB47320
      DATA($AAA+K+NK*(L-1)) = 0.0                                       COB47330
      LL = MAX0(1,(L+K-MID))                                            COB47340
      LL=MIN0(LL,NK)                                                    COB47350
      MPICU=MID+K-LL                                                    COB47360
   95 DATA($AAA+LL+NK*(MPICU-1))=0.0                                    COB47370
      DATA($AAA+K +NK*(MID-1)) = 1.0                                    COB47380
      DATA($B+K)=DATA($W+K+MG*(J-1))                                    COB47390
  100 CONTINUE                                                          COB47400
  105 IF(KDEBUG.LT.1) GO TO 110                                         COB47410
      WRITE(I3,2) ((DATA($AAA+K+NK*(L-1)),L=1,LMAX),DATA($B+K),K=1,NKK) COB47420
    2 FORMAT(1H0, 1P7E15.4)                                             COB47430
 110  CALL DECOMP(NK,IERROR,LMAX,MID,DATA($AAA+1),DATA($ANSWE+1),       COB47440
     1                             DATA($B+1),NK)                       COB47450
      IF(IERROR.GT.1) GO TO 1000                                        COB47460
      CALL SOLVE(NK,LMAX,MID,DATA($AAA+1),DATA($ANSWE+1),DATA($B+1),NK) COB47470
      DO 150 K=1,NKK                                                    COB47480
  150 DATA($W+K+MG*(J-1))=DATA($ANSWE+K)                                COB47490
      RETURN                                                            COB47500
 1000 WRITE(I3,1)                                                       COB47510
    1 FORMAT(24H ERROR IN DECOMP, DIVERT   )                            COB47520
      IERROR = 3                                                        COB47530
      RETURN                                                            COB47540
      END                                                               COB47550
      SUBROUTINE INDAT(INIT,NOPRIN)                                     COB47560
C                                                                       COB47570
C                                                                       COB47580
      IMPLICIT INTEGER ($)                                              COB47590
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB47600
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB47610
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB47620
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB47630
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB47640
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB47650
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB47660
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB47670
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB47680
C                                                                       COB47690
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB47700
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB47710
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB47720
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB47730
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB47740
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB47750
C                                                                       COB47760
C                                                                       COB47770
      LOGICAL  GRID,PRINT                                               COB47780
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB47790
C                                                                       COB47800
C                                                                       COB47810
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB47820
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB47830
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB47840
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB47850
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     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB47860
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB47870
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB47880
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB47890
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB47900
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB47910
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB47920
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A  ,$$B  ,$XPOLD  COB47930
C                                                                       COB47940
      COMMON  DATA(1)                                                   COB47950
      LOGICAL LDAT(1)                                                   COB47960
      INTEGER IDAT(1)                                                   COB47970
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB47980
C                                                                       COB47990
      EQUIVALENCE (NCHAN,NCHANL)                                        COB48000
C                                                                       COB48010
      COMMON /GAPFAC/ FACSL(70), FACSLK(70)                             COB48020
C                                                                       COB48030
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),  COB48040
     1 JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),COB48050
     2 YQ(30)                                                           COB48060
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB48070
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB48080
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB48090
CC                                                                      COB48100
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                 COB48110
CC                                                                      COB48120
      COMMON/LINK9/ENEH(400)                                            COB48130
C     READ IN INPUT DATA (MAIN 5365-8830)                               COB48140
      IF (INIT.EQ.2) GO TO 990                                          COB48150
C                                                                       COB48160
C     THE UNIVAC 1108 SETS THE CORE TO ZERO AT THE START OF EACH JOB    COB48170
C     THE INITIALIZATION BELOW IS TO INITIALIZED FOR OTHER MACHINES     COB48180
C     UNITS I2,I3, AND I8 ARE THE INPUT, OUTPUT, AND SAVE TAPE UNITS    COB48190
CC    BEGINNING OF VARIABLE BLOCK                                       COB48200
      I2=5                                                              COB48210
      I3=6                                                              COB48220
      READ(I2,68)  MC,MG,MN,MR,MX                                       COB48230
      WRITE(I3,3000)  MC,MG,MN,MR,MX                                    COB48240
 3000 FORMAT('1',T50,'PROBLEM SIZE'/T50,'MC=',I5/                       COB48250
     1    T50,'MG=',I5/T50,'MN=',I5/,T50,'MR=',I5/T50,'MX=',I5//)       COB48260
      MX=MX+1                                                           COB48270
      CALL CORE                                                         COB48280
C     ALL VALUES INITIALISED TO ZERO BETWEEN HERE AND 930 COULD PROBABLYCOB48290
C     BE LEFT OUT SINCE NOW INITIALISED IN CORE.  HOWEVER LEFT IN FOR   COB48300
C     TIME BEING FOR SAFETY AS NO TIME TO CHECK.                        COB48310
      IQP3 = 2                                                          COB48320
      PI = 355./113.                                                    COB48330
      I8=8                                                              COB48340
      GC = 32.2                                                         COB48350
      NAXL = 0                                                          COB48360
      NGXL = 0                                                          COB48370
      NGRID = 0                                                         COB48380
      NAX = 0                                                           COB48390
      IERROR = 0                                                        COB48400
```

```
      NGAPS = 0
      NAFACT = 0
      NSCBC = 0
      NBBC = 0
      J5 = 0
      J6 = 0
      NOPRIN=0
      J7=0
      NGRIDT = 0
      JUMP = 0
      NJUMP = 0
      NROD = 0
      NRAMP = 1
      NODESF = 0
      NFUELT = 0
      NOUT = 0
      NPCHAN = 0
      NPNODE = 0
      NARAMP = 1
      IG = 0
      ISAVE = 0
      IN = 0
CC  FUEL ROD AND HEAT TRANSFER MODEL INDICATORS INITIALIZED AS ZERO
      IFRM=0
      IHTM=0
      IPROP=0
      GRID = .FALSE.
      DO 900 I=1,MC
      DATA($HINLE+I)=0.
      DATA($FINLE+I)=0.
  900 DATA($QPRIM+I)=0.
      DO 905 K=1,MG
      FACSL(K)=1.
      FACSLK(K)=1.
      DATA($WP    +K)=0.
  905 LDAT($FDIV +K)=.FALSE.
      DO 930 J=1,MX
      DO 910 I=1,MC
      DATA($P     +I+MC*(J-1))=0.
      DATA($H     +I+MC*(J-1))=0.
      DATA($F+I+MC*(J-1))=0.
      DATA($RHO   +I+MC*(J-1))=0.
      DATA($HOLD  +I+MC*(J-1))=0.
      DATA($FOLD  +I+MC*(J-1))=0.
  910 DATA($RHOOL+I+MC*(J-1))=0.
      DO 920 N=1,MR
      DATA($FLUX +N+MR*(J-1))=0.
      IDAT($CCHAN+N+MR*(J-1))=0
      DO 918 L=1,MN
  918 DATA($TROD+L+MN*(N-1+MR*(J-1)))=0.
  920 CONTINUE
  930 CONTINUE
      READ (I2,52) MAXT
      IF(MAXT.LT.1) MAXT = 1000
C
```

```
C  READ CASE CONTROL CARD
  990 READ(I2,2) IPILE,KASE,J1,TEXT
      J7 = IPILE
       IERROR = 0
       ISAVE = 0
      DO 991 I = 1,11
      PRINT(I) = .FALSE.
      IF(J1.EQ.1) PRINT(I) = .TRUE.
  991 CONTINUE
C  CHECK FOR CONTINUATION OF CALCULATIONS
      IF(KASE.LT.1) STOP
      DO 915 J=1,MX
      DO 914 K=1,MG
      DATA($COND+K) = 0.0
      DATA($W    +K+MG*(J-1))=0.
      DATA($SP    +K+MG*(J-1))=0.
  914 DATA($WOLD+K+MG*(J-1))=0.
      DO 915 K=1,MC
      DATA($QC    +K+MC*(J-1))=0.
      DATA($QF    +K+MC*(J-1))=0.
  915 CONTINUE
      IDAT($IK+1) = 1
      IDAT($JK+1) = 1
      CALL DOY(DATE)
      CALL TOD(TIME)
      WRITE(I3, 3) KASE,TEXT,DATE,TIME
      IF(IPILE.EQ.0) WRITE(I3,1000)
      IF(IPILE.EQ.1) WRITE(I3,1001)
      IF(IPILE.EQ.2) WRITE(I3,1002)
C
C  READ GROUP CONTROL CARD
  995 READ(I2,1) NGROUP,N1,N2,N3,N4,N5,N6
      IF(NGROUP.EQ.20)  GO TO 230
      IF(NGROUP.LT.1) GO TO 250
      IF(NGROUP.GT.12) GO TO 240
      IF(NGROUP.LT. 0) GO TO 240
      GO TO (110,120,130,140,150,160,170,180,190,200,210,220),NGROUP
C
C  INPUT FOR CARD GROUP 1, PROPERTY TABLE
  110 CALL CARDS1(PP,TT,VVF,VVG,HHF,HHG,UUF,KKF,SSIGMA,N1,I2)
      NPROP = N1
      IF(J1.LE.1) PRINT(1)=.TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 2, FRICTION FACTOR AND TWO-PHASE FLOW CORRELATIO
  120 READ (I2,5) (AA(I),BB(I),CC(I),I=1,4)
      J2 = N1
      J3 = N2
      J4 = N3
      NVISCW = N4
      IF(J3.GT.4) READ(I2,41) NV,AV
      IF(J4.GT.4) READ(I2,41) NF,AF
      IF(J1.LE.1) PRINT(2) = .TRUE.
      GO TO 995
C
```

```
C  INPUT FOR CARD GROUP 3, AXIAL HEAT FLUX TABLE
  130 IF (N1.GT.1) GO TO 135
      IQP3 = N1
      GO TO 995
  135 READ(I2,5) (Y(I),AXIAL(I),I=1,N1)
      NAX = N1
      IF(J1.LE.1) PRINT(3) = .TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 4, CHANNEL LAYOUT AND DIMENSIONS
  140 IF(IPILE.EQ.0) GO TO 1405
C     COMBINE CARD GROUPS 4, 7, 9 FOR PWR AND BWR.
      CALL CARDS4(DATA($AC+1),DATA($DC+1),DATA($DIST+1),
     1  DATA($DR+1),DATA($GAPS+1),
     1     IDAT($LC+1),MA,MG,N1,N2,NCHF,NFUELT, DATA($PH+1),
     2     PHTOT,PRINT,DATA($PW+1),MC)
      IF (IERROR.GE.1) GO TO 240
      CALL CORE3
      GO TO 995
 1405 DO 141 J=1,N1
      READ(I2,7)  N,I,DATA($AC+I),DATA($PW+I),DATA($PH+I),
     1     (IDAT($LC+I+MC*(L-1)),DATA($GAPS+I+MG*(L-1)),
     2     DATA($DIST+I+MC*(L-1)),L=1,4)
      IDAT($NTYPE+I)=N
      IF(N.LE.1)
     1IDAT($NTYPE+I)=1
  141 CONTINUE
  142 PHTOT = 0.
      ATOTAL = 0.
      K=0
      NCHANL = N2
      DO 147 I=1,NCHANL
      DO 146 L=1,4
      IF(IDAT($LC+I+MC*(L-1))) 144,146,143
  143 J= IDAT($LC+I+MC*(L-1))
      IF(J.LE.I) GO TO 146
      K=K+1
      DATA($FACTO+K)=1.
      GO TO 145
  144 J=-IDAT($LC+I+MC*(L-1))
      IF(J.LE.I) GO TO 146
      K=K+1
      DATA($FACTO+K)=0.5
  145 IDAT($JK+K)=J
      IDAT($IK+K)=I
      DATA($GAPN +K)=DATA($GAPS +I+MG*(L-1))/12.
      DATA($GAP  +K)=DATA($GAPN +K)
      DATA($LENGT+K)=DATA($DIST +I+MC*(L-1))/12.
  146 CONTINUE
      DATA($PERIM+I)=DATA($PW+I)/12.
      DATA($HPERI+I)=DATA($PH+I)/12.
      DATA($AN   +I)=DATA($AC+I)/144.
      DATA($A    +I)=DATA($AN+I)
      DATA($DC   +I)=DATA($AC+I)*4./DATA($PW+I)
      DATA($DHYD +I)=DATA($DC   +I)/12.
```

```
      DATA($DHYDN+I)=DATA($DHYD +I)
      PHTOT=PHTOT+DATA($HPERI +I)
 147  ATOTAL=ATOTAL+DATA($AN+I)
      NK=K
      CALL ACOL(2,IDAT($IK+1),IDAT($JK+1),KMAX,IDAT($LOCA+1),MA,MS,NK,
     1    MG,IPILE)
      IF(J1.LE.1) PRINT(4) = .TRUE.
      CALL CORE3
      GO TO 995
C
C  INPUT FOR CARD GROUP 5, CHANNEL AREA VARIATION TABLE
  150 DO 151 I=1,NCHANL
 151  IDAT($IDARE+I)=0
      NAXL = N2
      NARAMP = N3
      IF(NARAMP.LE.0) NARAMP = 1
      IF(N2.LT.1) GO TO 995
      READ(I2,5) (AXL(I),I=1,N2)
      NAFACT=N1
      DO 152 J=1,N1
      READ(I2,8)  I,(AFACT(J,L),L=1,N2)
      IDAT($IDARE+I)=J
  152 NCH(J)= I
      IF(J1.LE.1) PRINT(5) = .TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 6, GAP SIZE VARIATIONS TABLE
  160 DO 161 K=1,NK
 161  IDAT($IDGAP+K)=0
      NGXL = N2
      IF(N2.LT.1) GO TO 995
      READ(I2,5) (GAPXL(L),L=1,NGXL)
      NGAPS = N1
      DO 162 LL=1,NGAPS
      READ(I2,1) K
      IDAT($IDGAP+K)=LL
      NGAP(LL) = K
      READ (I2, 5) (GFACT(LL,L),L=1,NGXL)
  162 CONTINUE
      IF(J1.LE.1) PRINT(6) = .TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 7, SPACER DESIGN INFORMATION
  170 IF(IPILE.EQ.0) GO TO 1705
      WRITE(I3,1704) IPILE,NGROUP
 1704 FORMAT(' IPILE=',I2,' CARD GROUP',I2,
     1 ' INCORRECTLY ENTERED .CHECK DATA')
      IERROR = 1
      GO TO 240
 1705 J6 = N1
      NRAMP = N4
      IF(NRAMP.LT.1) NRAMP = 1
      GRID = .FALSE.
      NGRID = 0
      IF(J6.EQ.0) GO TO 995
```

```
      IF(J6.EQ.1) GO TO 171                                             COB50610
      IF(J6.EQ.2) GO TO 176                                             COB50620
      GO TO 995                                                         COB50630
  171 READ(I2,42) PITCH,DIA,THICK                                       COB50640
      PITCH = PITCH/12.                                                 COB50650
      DIA = DIA/12.                                                     COB50660
      THICK = THICK/12.                                                 COB50670
      NJUMP = N5                                                        COB50680
      DO 172 M=1,NK                                                     COB50690
      READ(I2,64) K,DUM,CROSS                                           COB50700
      DATA($DUR+K)=DUM                                                  COB50710
      DO 172 L=1,6                                                      COB50720
  172 DATA($XCROS+K+MG*(L-1))=CROSS(L)                                  COB50730
      READ(I2,68)  (IDAT($NWRAP+I),I=1,NCHANL)                          COB50740
      DO 173 I=1,NCHANL                                                 COB50750
  173 IDAT($NWRPS+I)=IDAT($NWRAP+I)                                     COB50760
      IF(J1.LE.1) PRINT(7) = .TRUE.                                     COB50770
      IF(NJUMP.EQ.3) JUMP = 3                                           COB50780
      IF(NJUMP.NE.3) GO TO 995                                          COB50790
      REWIND I8                                                         COB50800
      READ(I8) ((DATA($W+I+MG*(J-1)),I=1,MG),J=1,MX),                   COB50810
     1          ((DATA($P+I+MC*(J-1)),I=1,MC),J=1,MX),                  COB50820
     2        ((DATA($RHO+I+MC*(J-1)),I=1,MC),J=1,MX),                  COB50830
     3        ((DATA($F   +I+MC*(J-1)),I=1,MC),J=1,MX)                  COB50840
      REWIND I8                                                         COB50850
      GO TO 995                                                         COB50860
  176 NGRID = N2                                                        COB50870
      NGRIDT = N3                                                       COB50880
      READ(I2,66) (GRIDXL(I),IGRID(I),I=1,NGRID)                        COB50890
      DO 178 I=1,NGRIDT                                                 COB50900
      DO 177 K=1,NK                                                     COB50910
  177 DATA($FXFLO+K+MG*(I-1))=0.                                        COB50920
      DO 178 II=1,NCHANL                                                COB50930
  178 READ(I2,67)  J,DATA($CD+J+MC*(I-1)),K,DATA($FXFLO+K+MG*(I-1))     COB50940
      IF(J1.LE.1) PRINT(7) = .TRUE.                                     COB50950
      GO TO 995                                                         COB50960
C                                                                       COB50970
C  INPUT FOR CARD GROUP 8, ROD LAYOUT, DIMENSIONS, AND POWER FACTORS    COB50980
  180 IF(IPILE.EQ.0) GO TO 1805                                         COB50990
      WRITE(I3,1704) IPILE,NGROUP                                       COB51000
      IERROR = 1                                                        COB51010
      GO TO 240                                                         COB51020
 1805 NROD = N2                                                         COB51030
      DO 181 J=1,N1                                                     COB51040
      READ (I2,11) N,I,DATA($DR+I),                                     COB51050
     1                       DATA($RADIA+I),(IDAT($LR+I+MR*(L-1)),      COB51060
     1    DATA($PHI+I+MR*(L-1)),L=1,6)                                  COB51070
      IDAT($IDFUE+I)=N                                                  COB51080
      IF(N.LT.1)  IDAT($IDFUE+I)=1                                      COB51090
  181 CONTINUE                                                          COB51100
      DO 182 I=1,MC                                                     COB51110
      DO 182 J=1,MR                                                     COB51120
  182 DATA($PWRF+I+MC*(J-1))=0.                                         COB51130
      DO 185 I=1,NROD                                                   COB51140
      DO 184 L=1,6                                                      COB51150
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```
      IF(IDAT($LR+I+MR*(L-1)))  184.184.183
 183  K =IDAT($LR+I+MR*(L-1))
      DATA($PWRF+K+MC*(I-1))=DATA($PHI+I+MR*(L-1))
  184 CONTINUE
 185  DATA($D+I)=DATA($DR+I)/12.
      IF(J1.LE.1) PRINT(8) = .TRUE.
      NODESF = N3
      NFUELT = N4
      NCHF = N5
      IF(NODESF.EQ.0) GO TO 995
      READ (I2,79) (KFUEL(I), CFUEL(I), RFUEL(I), DFUEL(I),
     1 KCLAD(I), CCLAD(I), RCLAD(I), TCLAD(I), HGAP(I),I=1,NFUELT)
       DO 187 I = 1,NFUELT
       KFUEL(I) = KFUEL(I)/3600.
       KCLAD(I) = KCLAD(I)/3600.
       DFUEL(I) = DFUEL(I)/12.
       TCLAD(I) = TCLAD(I)/12.
       HGAP(I) = HGAP(I)/3600.
  187  CONTINUE
      GO TO 995
C
C  INPUT FOR CARD GROUP  9, CALCULATION VARIABLES
  190 READ(I2,14) KIJ,FTM,Z,THETA,NDX,NDT,TTIME,NTRIES,FERROR,SL
      IF(SL.LT.1.E-5) SL = .5
      ELEV = COS(THETA*PI/180.)
      IF(NTRIES.LT.1) NTRIES=20
      IF(FERROR.LE.0) FERROR = 1.E-3
       NDXP1 = NDX + 1
      NSKIPX = N1
      NSKIPT = N2
      KDEBUG = N3
      IF(NSKIPT.LT.1) NSKIPT = 1
      IF(NSKIPX.LT.1) NSKIPX = 1
      ZZ = Z
      Z = Z/12.
      IF(Z.LE.0.) GO TO 240
      IF(NDX.LT.1) GO TO 240
      DX = Z/FLOAT(NDX)
      DT = 0.
      IF(NDT.GT.0 .AND. TTIME.LE.0.) NDT = 0
      IF(NDT.GT.0) DT = TTIME/FLOAT(NDT)
      SAVEDT = DT
      DXX = DX*12.
      IF(J1.LE.1) PRINT(9) = .TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 10, MIXING PARAMETERS
  200 IF(IPILE.LT.2) GO TO 205
      WRITE(I3,1704) IPILE, NGROUP
      GO TO 995
  205 NSCBC = N1
      IF (NSCBC.NE.4) READ(I2,5) ABETA,BBETA
      DO 206I=1,MG
  206 ENEH(I)=1.0
      NBBC =N2
```

```
      J5 = N3
      IF(N2.GE.2) READ(I2,5) (XQUAL(I),BX(I),I=1,N2)
      IF(J5.EQ.0) GK = 0.
      IF(J5.EQ.1) READ(I2,5) GK
      IF(J1.LE.1) PRINT(10) = .TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 11, OPERATING CONDITIONS AND TRANSIENT FORCING F
  210 READ(I2,9) PEXIT,HIN,GIN,AFLUX
      PREF = PEXIT
      CALL PROP(1,1)
      IF(IERROR.GT.1) GO TO 240
      IN = N1
C  FOR N1=0, HIN IS THE INLET H.  FOR N1=1, HIN IS THE INLET T.
C  FOR N1=2, READ IN CHANNEL H.   FOR N1=3, READ IN CHANNEL T.
      IF(N1.GE.2) GO TO 214
      IF(N1.EQ.1) GO TO 211
      TIN = TF
      IF(HIN.LT.HF) CALL CURVE(TIN,HIN,TT,HHF,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 240
      GO TO 212
  211 TIN = HIN
      CALL CURVE(HIN,TIN,HHF,TT,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 240
  212 DO 213 I=1,NCHANL
 213  DATA($HINLE+I)=HIN
      GO TO 216
 214  READ(I2,10) (DATA($HINLE+I),I=1,NCHANL)
      IF(N1.LE.2) GO TO 216
      DO 215 I=1,NCHANL
      CALL CURVE(DATA($HINLE+I),DATA($HINLE+I),HHF,TT,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 240
  215 CONTINUE
  216 DO 2160 I=1,NCHANL
      DATA($TINLE+I)=TF
      IF(DATA($HINLE+I).LT.HF)
     1CALL CURVE(DATA($TINLE+I),DATA($HINLE+I),TT,HHF,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 240
 2160 CONTINUE
      IG = N2
C  FOR N2=0, GIN IS THE INLET G FOR EACH CHANNEL.  FOR N2=1, GIN IS THE
C  AVERAGE G BUT THE CHANNEL FLOWS ARE SPLIT TO GIVE EQUAL DP/DX.  FOR N
C  INDIVIDUAL CHANNEL TOTAL FLOW FRACTION IS READ AS INPUT
      FLO = GIN/.0036*ATOTAL
      DO 217 I=1,NCHANL
 217  DATA($FINLE+I)=GIN*DATA($AN+I)/.0036
      IF(N2.EQ.1) CALL SPLIT
      IF(IERROR.GT.1) GO TO 240
      IF(N2.LT.2) GO TO 219
      READ(I2,10)  (DATA($FSPLI+I),I=1,NCHANL)
      DO 218 I=1,NCHANL
 218  DATA($FINLE+I)=GIN*DATA($AN+I)*DATA($FSPLI+I)/.0036
  219 NP = N3
      IF(NP.GT.1) READ(I2,10) (YP(I),FP(I),I=1,NP)
      NH = N4
```

```
      IF(NH.GT.1) READ(I2,10) (YH(I),FH(I),I=1,NH)
      NG = N5
      IF(NG.GT.1) READ(I2,10) (YG(I),FG(I),I=1,NG)
      NQ = N6
      IF(NQ.GT.1) READ(I2,10) (YQ(I),FQ(I),I=1,NQ)
      IF(J1.LE.2) PRINT(11) = .TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 12, OUTPUT OPTIONS FOR CALCULATIONS
  220 NOUT = N1
      NPCHAN = N2
      IF(N2.LT.1) GO TO 221
      READ(I2,17)  (IDAT($PRNTC+I),I=1,N2)
  221 NPROD = N3
      NPNODE = N4
      IF(N3.LT.1) GO TO 222
      READ 17,     (IDAT($PRNTR+I),I=1,N3)
  222 IF(N4.LT.1) GO TO 225
      READ 17,     (IDAT($PRNTN+I),I=1,N4)
  225 GO TO 995
C     CARD GROUP 20  .  READ DATA VIA ITHO
 230  NOPRIN=N1
      CALL CARD20(NOPRIN)
      IF(IERROR.GT.0)  GO TO 240
      GO TO 995
C
C  INPUT DATA ERROR MESSAGE
  240 WRITE(I3,54)
      STOP
C
C  END OF INPUT
C
  250 RETURN
C
    1 FORMAT(7I5)
    2 FORMAT(I1, I4, I5, 17A4)
    3 FORMAT(15H1INPUT FOR CASE           I6,5X,16A4,A2,
     19H   DATE  2A4,7H TIME  2A4,A1      )
    5 FORMAT (12F5.3)
    7 FORMAT(I1,I4,3E5.2,4(I5,2E5.2))
    8 FORMAT ( I5/(12F5.3))
    9 FORMAT (6F10.0)
   10 FORMAT(12E5.0)
   11 FORMAT(I1,I4,2E5.2,6(I5,E5.2))
   14 FORMAT(4E5.2,2I5,E5.2,I5,4E5.2)
   17 FORMAT (36I2)
   41 FORMAT (I5,7E10.5)
   42 FORMAT(8E10.5)
   52 FORMAT (I5,6E12.6)
   54 FORMAT(//' INPUT DATA ERROR, THIS RUN STOPPED, CHECK INPUT')
   64 FORMAT(I5,10E5.2)
   66 FORMAT (6( E5.2,I5))
   67 FORMAT (I5,E5.2,I5,E5.2)
   68 FORMAT(10I5)
   79 FORMAT ( 9E5.2)
```

```
 1000 FORMAT(/,'  NORMAL COBRA INPUT DATA PRESENTATION'/)             COB52810
 1001 FORMAT(/,'  SIMILAR CHANNELS ALL CONNECTED EG.PWR'/)            COB52820
 1002 FORMAT(/,'  SIMILAR CHANNELS ALL SEPARATED EG.BWR'/)            COB52830
      END                                                             COB52840
      SUBROUTINE MODEL(IPART,CARD,IPILE)                              COB52850
C                                                                     COB52860
C                                                                     COB52870
      IMPLICIT INTEGER ($)                                            COB52880
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB52890
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB52900
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB52910
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB52920
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB52930
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB52940
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB52950
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB52960
     8   UF    ,VF    ,VFG   ,VG    ,Z                                 COB52970
C                                                                     COB52980
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),  COB52990
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), COB53000
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB53010
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),    COB53020
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),     COB53030
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                   COB53040
C                                                                     COB53050
C                                                                     COB53060
      LOGICAL  GRID                                                   COB53070
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                             COB53080
C                                                                     COB53090
C                                                                     COB53100
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB53110
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB53120
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB53130
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB53140
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB53150
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB53160
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB53170
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB53180
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB53190
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB53200
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB53210
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB53220
C                                                                     COB53230
      COMMON  DATA(1)                                                 COB53240
      LOGICAL LDAT(1)                                                 COB53250
      INTEGER IDAT(1)                                                 COB53260
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                          COB53270
C                                                                     COB53280
C                                                                     COB53290
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT, COB53300
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR, COB53310
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ           COB53320
      COMMON/LINK9/ENEH(400)                                          COB53330
      COMMON/SAVMOD/N1,N2,N3,N4,N5,N6,N7,N9                           COB53340
      DIMENSION CARD(20),TAG(2)                                       COB53350
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C                                                                       COB53360
      DATA TAG /4HW/GS, 4HW/GD /                                        COB53370
C                                                                       COB53380
C     IPART=1  SET HYDRAULIC MODEL                                      COB53390
C     IPART=2  PRINT HYDRAULIC MODEL                                    COB53400
C     SAME AS MEKIN CODING                                              COB53410
C                                                                       COB53420
C     PRESET MODEL IS CODED FIRST AND IS USED IF ALL N1-N7=0            COB53430
C     INDIVIDUAL PARTS OF MODEL MAY BE CHANGED BY                       COB53440
C     SETTING ANY OF N1-N7 POSITIVE NON-ZERO                            COB53450
C                                                                       COB53460
      IF(IPART.EQ.2) GO TO 30                                           COB53470
C     (N1) MIXING MODEL (CARD GROUP 10)                                 COB53480
      NSCBC=1                                                           COB53490
      NBBC=1                                                            COB53500
      J5=0                                                              COB53510
      GK=0.0                                                            COB53520
      ABETA=0.02                                                        COB53530
      BBETA=0.0                                                         COB53540
      IF(IPILE.EQ.2) ABETA=0.0                                          COB53550
C     (N2) SINGLE PHASE FRICTION (CARD GROUP 2)                         COB53560
      DO 4 I=1,4                                                        COB53570
      AA(I)=0.184                                                       COB53580
      BB(I)=-0.2                                                        COB53590
    4 CC(I)=0.0                                                         COB53600
      NVISCW=0                                                          COB53610
C     (N3) TWO PHASE FRICTION (CARD GROUP 2)                            COB53620
      J4=0                                                              COB53630
C     (N4) VOID FRACTION (CARD GROUP 2)                                 COB53640
      J2=0                                                              COB53650
      J3=0                                                              COB53660
C     (N5) FLOW DIVISION AT INLET (CARD GROUP 11)                       COB53670
      IG = 0                                                            COB53680
C     (N6) CONSTANTS (CARD GROUP 9)                                     COB53690
      NCHF = 0                                                          COB53700
      KIJ=0.5                                                           COB53710
      FTM=0.0                                                           COB53720
      SL=0.5                                                            COB53730
      THETA=0.0                                                         COB53740
      ELEV=1.0                                                          COB53750
C     (N7) ITERATION (CARD GROUP 9)                                     COB53760
      NTRIES=20                                                         COB53770
      FERROR=0.001                                                      COB53780
C     (N8) PHYSICAL PROPERTIES (CARD GROUP 1)                           COB53790
      NPROP=0                                                           COB53800
C     (N9) COUPLING PARAMETER FOR ENTHALPY EXCHANGE                     COB53810
      DO 3201 K=1,NK                                                    COB53820
 3201 ENEH(K)=1.0                                                       COB53830
C                                                                       COB53840
      READ(I2,1001) CARD,N1,N2,N3,N4,N5,N6,N7,NPROP,N9                  COB53850
      WRITE(I3,1009) CARD                                               COB53860
      IF((N1+N2+N3+N4+N5+N6+N7+NPROP+N9).EQ.0) RETURN                   COB53870
C                                                                       COB53880
      IF(N1.EQ.0) GO TO 6                                               COB53890
      IF (N1.EQ.2) NSCBC=2                                              COB53900
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      IF (N1.EQ.3) NSCBC=4                                              COB53910
      IF(IPILE.EQ.2) WRITE(I3,1010)                                     COB53920
      IF(N1.LT.3) READ(I2,1002) CARD,ABETA,BBETA                        COB53930
      IF(N1.EQ.1) WRITE(I3,1011) CARD                                   COB53940
    6 IF(N2.EQ.0) GO TO 8                                               COB53950
      READ(I2,1003) CARD,NVISCW,(AA(I),BB(I),CC(I),I=1,4)               COB53960
      WRITE(I3,1012) CARD                                               COB53970
    8 IF(N3.EQ.0) GO TO 10                                              COB53980
      READ(I2,1001) CARD,J4                                             COB53990
      WRITE(I3,1013) CARD                                               COB54000
      IF(J4.LE.4) GO TO 10                                              COB54010
      READ(I2,1003) CARD,NF,AF                                          COB54020
      WRITE(I3,1014) CARD                                               COB54030
   10 IF(N4.EQ.0) GO TO 12                                              COB54040
      READ(I2,1001) CARD,J2,J3                                          COB54050
      WRITE(I3,1015) CARD                                               COB54060
      IF(J3.LE.4) GO TO 12                                              COB54070
      READ(I2,1003) CARD,NV,AV                                          COB54080
      WRITE(I3,1014) CARD                                               COB54090
   12 IF(N5.EQ.0) GO TO 16                                              COB54100
      READ(I2,1001) CARD,IG                                             COB54110
      WRITE(I3,1016) CARD                                               COB54120
      IF(IG.LE.1) GO TO 16                                              COB54130
      CALL READIN(1,NCHANL,DATA($FINLE+1),CARD,CARD,1)                  COB54140
   16 IF(N6.EQ.0) GO TO 18                                              COB54150
      READ(I2,1003) CARD,NCHF,KIJ,FTM,SL,THETA                          COB54160
      WRITE(I3,1017) CARD                                               COB54170
      ELEV=COS(THETA*PI/180.0)                                          COB54180
   18 IF(N7.EQ.0) GO TO 20                                              COB54190
      READ(I2,1003) CARD,NTRIES,FERROR                                  COB54200
      WRITE (I3,1018) CARD                                              COB54210
   20 IF (NPROP.EQ.0) GO TO 22                                          COB54220
      READ (I2,1004) CARD, NPROP, N, PH, PP(2)                          COB54230
      WRITE (I3,1019) CARD                                              COB54240
      PP(1) = PH                                                        COB54250
      IF (N.LE.1) GO TO 22                                              COB54260
      PP(1) = 10.0                                                      COB54270
      IF (PH.LT.200.0) GO TO 22                                         COB54280
      R = 0.01*PH                                                       COB54290
      PP(1) = 6.0*R*R*R*(R-1.35)/(R-0.35)                               COB54300
   22 CONTINUE                                                          COB54310
      IF(N9.EQ.0) GO TO 3206                                            COB54320
      M=1                                                               COB54330
 3204 MM=MIN0((M+13),NK)                                                COB54340
      READ (I2,3202) CARD,(ENEH(K),K=M,MM)                              COB54350
 3202 FORMAT(20A4,T1,14E5.0)                                            COB54360
      WRITE(I3,3203) CARD                                               COB54370
 3203 FORMAT(' COUPLING FACTOR NH',10X,'***' ,20A4,'*** MODEL')         COB54380
      M=MM+1                                                            COB54390
      IF (M.LE.NK) GO TO 3204                                           COB54400
 3206 CONTINUE                                                          COB54410
      RETURN                                                            COB54420
C                                                                       COB54430
C     IPART = 2.  PRINT MODEL                                           COB54440
   30 WRITE (I3,1061)                                                   COB54450
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      IF ( (N1+N2+N3+N4+N5+N6+N7).EQ.0) WRITE (I3,1060)                 COB54460
      SIG=TAG(1)                                                        COB54470
      IF (NSCBC.EQ.2) SIG=TAG(2)                                        COB54480
      IF(N1.LT.3) WRITE (I3,1062) SIG, ABETA, BBETA                     COB54490
      IF(N1.EQ.3) WRITE(I3,1084)                                        COB54500
      WRITE (I3,1063) NVISCW, (I,AA(I),BB(I),CC(I),I=1,4)               COB54510
      WRITE (I3,1064) J4                                                COB54520
      IF (J4.GT.4) WRITE (I3,1065) (AF(I),I=1,NF)                       COB54530
      WRITE (I3,1066) J2,J3                                             COB54540
      IF (J3.GT.4) WRITE (I3,1065) (AV(I),I=1,NV)                       COB54550
      WRITE (I3,1067) IG                                                COB54560
      IF (IG.EQ.2) WRITE (I3,1068) (DATA($FINLE+I),I=1,NCHANL)          COB54570
      WRITE (I3,1069) NCHF,KIJ,FTM,SL,THETA                             COB54580
      WRITE (I3,1070) NTRIES,FERROR                                     COB54590
      IF(N9.GT.0) GO TO 40                                              COB54600
      WRITE(I3,1071)                                                    COB54610
      WRITE(I3,1072)                                                    COB54620
      GO TO 50                                                          COB54630
   40 WRITE (I3,1071)                                                   COB54640
      WRITE(I3,1080)                                                    COB54650
      WRITE(I3,1081)(K,ENEH(K),K=1,NK)                                  COB54660
   50 CONTINUE                                                          COB54670
      RETURN                                                            COB54680
C                                                                       COB54690
C                                                                       COB54700
 1001 FORMAT(20A4, T1, 14I5)                                            COB54710
 1002 FORMAT(20A4, T1, 14E5.0)                                          COB54720
 1003 FORMAT(20A4, T1, I5, 13E5.0)                                      COB54730
 1004 FORMAT(20A4, T1, 2I5, 2E5.0)                                      COB54740
C                                                                       COB54750
 1009 FORMAT('  HYDRAULIC MODEL INDICATORS',2X '***', 20A4, '*** MODEL')COB54760
 1010 FORMAT(/, '  * * * * * * * * * *   IS CHANGED MIXING MODEL VALID FCOB54770
     1OR BWR CASE?', /)                                                 COB54780
 1011 FORMAT('  MIXING COEFFICIENTS', 9X, '***', 20A4, '*** MODEL')     COB54790
 1012 FORMAT('  SINGLE-PHASE FRICTION', 7X, '***', 20A4, '*** MODEL')   COB54800
 1013 FORMAT('  TWO-PHASE FRICTION (J4)', 5X, '***', 20A4, '*** MODEL') COB54810
 1014 FORMAT('  POLYNOMIAL COEFFICIENTS', 5X, '***', 20A4, '*** MODEL') COB54820
 1015 FORMAT('  VOID FRACTION (J2, J3)', 6X '***', 20A4, '*** MODEL')   COB54830
 1016 FORMAT('  INLET FLOW DIVISION (IG)', 4X '***', 20A4, '*** MODEL') COB54840
 1017 FORMAT('  CONSTANTS', 19X, '***', 20A4, '*** MODEL')              COB54850
 1018 FORMAT('  ITERATION', 19X, '***', 20A4, '*** MODEL')              COB54860
 1019 FORMAT('  NPROP, N, PH, P2', 12X, '***', 20A4, '*** MODEL')       COB54870
 1060 FORMAT(///, '  PRESET HYDRAULIC MODEL USED')                      COB54880
 1061 FORMAT(43X, 'THERMAL - HYDRAULIC MODEL', /, 43X,                  COB54890
     1 '-------------------------')                                     COB54900
 1062 FORMAT(///, '  (1) MIXING', /, 6X, '------', /,                   COB54910
     1 '  MIXING COEFFICIENT (',A4,') = ',F6.3,'* (RE**', F5.2, ')', /, COB54920
     2 '  TWO-PHASE MIXING SAME AS SINGLE PHASE (NBBC=1)', /,           COB54930
     3 '  NO THERMAL CONDUCTION (GK=0.0)' )                             COB54940
 1063 FORMAT(///, '  (2) SINGLE-PHASE FRICTION', 10X,                   COB54950
     1 'F = A*(RE**B) + C', /, 6X, '------ ----- --------', /,          COB54960
     2 '  NVISCW = ', I2, 16X, '(=0 FOR NO WALL VISCOSITY CORRECTION, =1COB54970
     3 FOR INCLUSION)' /, '  FRIC TYPE', 5X, 'A', 9X, 'B', 9X, 'C', /,COB54980
     4 (I7, 3X, 3F10.4))                                                COB54990
 1064 FORMAT(///, '  (3) TWO-PHASE FRICTION', /, 6X,                    COB55000
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     1 '--- ----- --------', /, '  J4 = ', I2, 20X,                    COB55010
     2 '(J4=0 HOMOGENEOUS,  =1 ARMAND,  =2 BAROCZY,  =5 POLYNOMIAL IN QUCOB55020
     3ALITY)' )                                                         COB55030
 1065 FORMAT('  POLYNOMIAL COEFF', 5X, 1P7E15.4)                        COB55040
 1066 FORMAT(///, '  (4) VOID FRACTION', /, 6X, '---- --------', /,     COB55050
     1 '  J2 = ', I2, 20X, '(J2=0 NO SUBCOOLED VOID,   =1 LEVY MODEL)'  COB55060
     2 /, '  J3 = ', I2, 20X, '(J3=0 SLIP RATIO = 1,   =1 ARMAND,   =2 SCOB55070
     3MITH,   =5 SLIP POLYNOMIAL,    =6 VOID = F(QUAL)' )                COB55080
 1067 FORMAT(///, '  (5) FLOW DIVISION AT INLET', /, 6X,           '----COB55090
     1 -------- -- -----', /, '  IG = ', I2, 20X, '(IG=0 SAME G,   =1 SCOB55100
     2AME DP/DX,   =2 GIN/GAV RATIO GIVEN)' )                           COB55110
 1068 FORMAT('  FLOW SPLIT = ', 5X, 10F10.3/ (20X, 10F10.3) )           COB55120
 1069 FORMAT(///, '  (6) CONSTANTS', /, 6X, '---------', /,             COB55130
     1 '  CRITICAL HEAT FLUX (NCHF)', 8X, '=', I6, /,                   COB55140
     2 '  CROSS-FLOW RESISTANCE (KIJ)', 6X, '=', F10.3, /,              COB55150
     3' MOMENTUM TURBULENT FACTOR (FTM)', 2X, '=', F10.3, /,            COB55160
     4 '  TRANSVERSE MOMENTUM FACTOR (S/L)', 1X, '=', F10.3, /,         COB55170
     5 '  CHANNEL  ANGLE FROM VERTICAL', 5X, '=', F10.3, '   DEGREES')  COB55180
 1070 FORMAT(///, '  (7) ITERATION', /, 6X, '---------', /,             COB55190
     1 '  MAX. ALLOWABLE NO. ITERATIONS', 4X, '=', I6, /,               COB55200
     2 '  FLOW CONVERGENCE FACTOR', 10X, '=', 1PE12.3)                  COB55210
 1071 FORMAT (///,'  (8) COUPLING PARAMETER FOR THE MIXING TERM',/,6X,' COB55220
     1------------------------------------')                             COB55230
 1072 FORMAT('  NO ENTHALPY COUPLING PARAMETER IS USED')                COB55240
 1080 FORMAT ('  BOUNDARY-COUPLING PARAMETER')                          COB55250
 1081 FORMAT (8(2X,I5,'-',F7.3))                                        COB55260
 1084 FORMAT(///, '  (1) MIXING', /, 6X,'------', /,'      BEUS MODEL') COB55270
      END                                                               COB55280
      SUBROUTINE TABLES(CARD)                                           COB55290
C                                                                       COB55300
C                                                                       COB55310
      IMPLICIT INTEGER ($)                                              COB55320
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB55330
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB55340
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB55350
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB55360
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB55370
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB55380
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB55390
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB55400
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB55410
C                                                                       COB55420
C                                                                       COB55430
C                                                                       COB55440
      LOGICAL  GRID,PRINT                                               COB55450
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB55460
C                                                                       COB55470
C                                                                       COB55480
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB55490
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB55500
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB55510
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB55520
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB55530
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB55540
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB55550
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     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE.$NWRAP.$NWRPS.$P     .$PERIM,$PH    ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF ,$QC    ,$QF    ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO   ,$RHOOL,$SP   ,$T     ,$TDUMY,$TINLE,$TROD ,
     9   $U     ,$UH    ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP    ,$VPA   ,
     A   $W     ,$WOLD ,$WP    ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),
     1 JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),
     2 YQ(30)
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ
      DIMENSION CARD(20)
C
C     SET PRINTING PARAMETERS
C     FOR INPRIN
      IF (J1.GT.1) GO TO 4
      DO 2 I=1,11
    2 PRINT(I) = .TRUE.
      PRINT(5) = .FALSE.
      PRINT(6) = .FALSE.
C
C     FOR CALC (CARD GROUP 9)
    4 READ (I2,1001) CARD, KDEBUG
      WRITE (I3,1002) CARD
C
C     FOR EXPRIN (CARD GROUPS 9, 12)
      READ (I2,1001) CARD,NSKIPX, NSKIPT, NOUT, NPCHAN, NPROD, NPNODE
      WRITE (I3,1003) CARD
C     NSKIPX.   EVERY NSKIPX AXIAL STEP PRINTED.      (0 = 1)
C     NSKIPT.   EVERY NSKIPT TIME  STEP PRINTED.      (0 = 1)
C     NOUT = 0-3 FOR PRINTING (0) CHANNEL ONLY, (1) CHAN + CROSS FLOWS,
C     (2) CHAN + FUEL TEMP,  (3) CHAN + C-F + FUEL TEMP
C     NPCHAN = 0, ALL CHAN PRINTED.   .GT.0 READ CHANS REQD.
C     NPROD, NPNODE AS NPCHAN BUT FOR RODS AND NODES.
      IF (NSKIPX.LT.1) NSKIPX = 1
      IF (NSKIPT.LT.1) NSKIPT = 1
      IF (NPCHAN.LT.1) GO TO 6
      MROSI=1
 7209 MMJAVI=MIN0((MROSI+13),NPCHAN)
      READ(I2,1001) CARD,(IDAT($PRNTC+I),I=MROSI,MMJAVI)
      WRITE(I3,1004) CARD
      MROSI=MMJAVI+1
      IF(MROSI.LE.NPCHAN) GO TO 7209
    6 IF(NPROD.LT.1) GO TO 8
      MROSI=1
 8209 MMJAVI=MIN0 ((MROSI+13),NPROD)
      READ (I2,1001)CARD,(IDAT($PRNTR+I),I=MROSI,MMJAVI)
      WRITE (I3,1006) CARD
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      MROSI=MMJAVI+1
      IF (MROSI.LE.NPROD) GO TO  8209
    8 IF(NPNODE.LT.1) GO TO 10
      MROSI=1
 6209 MMJAVI=MINO((MROSI+13),NPNODE)
      READ(I2,1001) CARD,(IDAT($PRNTN+I),I=MROSI,MMJAVI)
      WRITE(I3,1007)CARD
      MROSI=MMJAVI+1
      IF (MROSI.LE.NPNODE) GO TO 6209
C
   10 IF (NPCHAN.GT.0) GO TO 14
      NPCHAN = NCHANL
      DO 12 I=1,NCHANL
   12 IDAT($PRNTC+I) = I
   14 IF (NPROD.GT.0) GO TO 18
      NPROD = NROD
      DO 16 I=1,NROD
   16 IDAT($PRNTR+I) = I
   18 IF (NPNODE.GT.0) GO TO 22
      NPNODE = NODESF+1
      DO 20 I=1,NPNODE
   20 IDAT($PRNTN+I) = I
   22 CONTINUE
C
      RETURN
C
 1001 FORMAT(20A4, T1, 14I5)
 1002 FORMAT('  KDEBUG', 22X, '***', 20A4, '*** TABLES')
 1003 FORMAT('  PRINTING', 20X, '***', 20A4, '*** TABLES')
 1004 FORMAT('  PRINT CHANNELS   ', 11X, '***', 20A4, '*** TABLES')
 1005 FORMAT('  PLUS REMAINDER')
 1006 FORMAT('  PRINT RODS       ', 11X, '***', 20A4, '*** TABLES')
 1007 FORMAT('  PRINT NODES      ', 11X, '***', 20A4, '*** TABLES')
      END
       BLOCK DATA
       IMPLICIT INTEGER*4 ($)
       REAL*8 $NAMES,$NAME1,$NAME2
       DIMENSION $LX(97),$NAME1(46),$NAME2(51),$NAMES(97)
       COMMON /COBRA5/  $NAMES,$LX,$TYPE
       EQUIVALENCE  ($NAMES(1),$NAME1(1)),($NAMES(47),$NAME2(1))
        DATA $NAME1 /8HA       ,8HAAA     ,8HAC      ,
     1 8HALPHA   ,
     18HAN      ,8HANSWER  ,8HB       ,8HCCHANL  ,8HCD      ,8HCHFR    ,
     28HCON     ,8HCOND    ,8HCP      ,8HD       ,8HDC      ,8HDFDX    ,
     38HDHDX    ,8HDHYD    ,8HDHYDN   ,8HDIST    ,8HDPDX    ,8HDPK     ,
     48HDUR     ,8HDR      ,8HF       ,8HFACTOR  ,8HFDIV    ,8HFINLET  ,
     58HFLUX    ,8HFMULT   ,8HFOLD    ,8HFSP     ,8HFSPLIT  ,8HFXFLOW  ,
     68HGAP     ,8HGAPN    ,8HGAPS    ,8HH       ,8HHFILM   ,8HHINLET  ,
     78HHOLD    ,8HHPERIM  ,8HIDAREA  ,8HIDFUEL  ,8HIDGAP   ,8HIK      /
        DATA $NAME2/
     88HJBOIL   ,8HJK      ,8HLC      ,8HLENGTH  ,8HLOCA    ,8HLR      ,
     98HMCHFR   ,8HMCHFRC  ,8HMCHFRR  ,8HNTYPE   ,8HNWRAP   ,8HNWRAPS  ,
     A8HP       ,8HPERIM   ,8HPH      ,8HPHI     ,8HPRINTC  ,8HPRINTR  ,
     B8HPRINTN  ,8HPW      ,8HPWRF    ,8HQC      ,8HQF      ,8HQPRIM   ,
     C8HQUAL    ,8HRADIAL  ,8HRHO     ,8HRHOOLD  ,8HSP      ,8HT       ,
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     D8HTDUMY   ,8HTINLET  ,8HTROD    ,8HU      ,8HUH      ,8HSAVE    ,COB56660
     G8HUSTAR   ,8HV       ,8HVISC    ,8HVISCW  ,8HVP      ,8HVPA     ,COB56670
     F8HW       ,8HWOLD    ,8HWP      ,8HWSAVE  ,8HX       ,8HXCROSS  ,COB56680
     G8HA       ,8HB       ,8HXPOLD   /                                COB56690
        INTEGER $TYPE(97) /7*1,2,18*1,3,15*1,7*2,1,2*2,1,5*2,4*1,3*2,  COB56700
     1  32*1/                                                          COB56710
       END                                                             COB56720
      SUBROUTINE CORE                                                  COB56730
      IMPLICIT INTEGER ($)                                             COB56740
      COMMON DATA(1)                                                   COB56750
      COMMON /COBRA3/  MA,MC,MG,MN,MR,MS,MX,$$$,$ORG(97)               COB56760
      INTEGER  $LX(97)                                                 COB56770
      COMMON /COBRA5/  $NAMES,$LX,$TYPE                                COB56780
      DIMENSION  $TYPE(97)                                             COB56790
      REAL*8  $NAMES(97)                                               COB56800
      MA = 1                                                           COB56810
      MS = 1                                                           COB56820
      IF (MG.LE.0) MG=1                                                COB56830
      IF (MN.LE.0) MN=1                                                COB56840
C   $******                                                            COB56850
      $$$=97                                                           COB56860
      DO 100  I=1,$$$                                                  COB56870
 100  $LX(I)=MC                                                        COB56880
      $LX( 2)=1                                                        COB56890
      $LX( 6)=MG                                                       COB56900
      $LX( 7)=MG                                                       COB56910
      $LX( 8)=MR*MX                                                    COB56920
      $LX( 9)=MC*5                                                     COB56930
      $LX(10)=MR*MX                                                    COB56940
      $LX(12)=MG                                                       COB56950
      $LX(14)=MR                                                       COB56960
      $LX(20)=MC*4                                                     COB56970
      $LX(23)=MG                                                       COB56980
      $LX(24)=MR                                                       COB56990
      $LX(25)=MC*MX                                                    COB57000
      $LX(26)=MG                                                       COB57010
      $LX(27)=MG                                                       COB57020
      $LX(29)=MR*MX                                                    COB57030
      $LX(31)=MC*MX                                                    COB57040
      $LX(34)=MG*5                                                     COB57050
      $LX(35)=MG                                                       COB57060
      $LX(36)=MG                                                       COB57070
      $LX(37)=MG*4                                                     COB57080
      $LX(38)=MC*MX                                                    COB57090
      $LX(41)=MC*MX                                                    COB57100
      $LX(44)=MR                                                       COB57110
      $LX(45)=MG                                                       COB57120
      $LX(46)=MG                                                       COB57130
      $LX(48)=MG                                                       COB57140
      $LX(49)=MC*4                                                     COB57150
      $LX(50)=MG                                                       COB57160
      $LX(51)=MG*14                                                    COB57170
      $LX(52)=MR*6                                                     COB57180
      $LX(53)=MX                                                       COB57190
      $LX(54)=MX                                                       COB57200
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```
      $LX(55)=MX
      $LX(59)=MC*MX
      $LX(62)=MR*6
      $LX(64)=MR
      $LX(65)=MN
      $LX(67)=MC*MR
      $LX(68)=MC*MX
      $LX(69)=MC*MX
      $LX(72)=MR
      $LX(73)=MC*MX
      $LX(74)=MC*MX
      $LX(75)=MG*MX
C     PROVIDE SPACE FOR SP IN BWR ITERATION.
      IF ($LX(75) .LT.3*MC) $LX(75) = 3*MC
      $LX(77)=MN
      $LX(79)=MN*MR*MX
      $LX(82)=MG
      $LX(83)=MG
      $LX(89)=MG*MX
      $LX(90)=MG*MX
      $LX(91)=MG
      $LX(92)=MG
      $LX(93)=MX
      $LX(94)=MG*6
      $LX(95)=3*MN
      $LX(96)=MN
C    *******
      $LX(97)=MC*MX
      $ORG(1)=1
      $LXX=0
      DO 110  I=1,$$$
      $LXX=$LXX+$LX(I)
      IF(I.GT.1)  $ORG(I)=$ORG(I-1)+$LX(I-1)
  110 CONTINUE
      KS=1
CC
CC    KMAX IN SUBROUTINE CORE EQUALS
CC    LENGTH OF DATA ARRAY GIVEN BELOW
CC
      KMAX=80000
      KFREE=KS
      KTOP = KS + KMAX - 1
      KS=KS+MOD(KS+1,2)
      IF(KMAX.LT.$LXX) GO TO 902
      DO 300 K=KS,KTOP
  300 DATA(K) = 0.0
      DO 400  N=1,$$$
  400 $ORG(N)=$ORG(N)+KS-1
      RETURN
C
      ENTRY CORE2(MSP,NKP)
      NK=NKP
      MS=MSP
      MA=NK*MS
      $LX(2)=MA
```

```
C    *******                                                            COB57760
      $ORG(2)=$ORG(97)+$LX(97)                                          COB57770
      $LXX=$LXX+$LX(2)                                                  COB57780
      IF(KMAX.LT.$LXX)  GO TO 902                                       COB57790
      RETURN                                                            COB57800
  901 WRITE(6,3001)                                                     COB57810
      STOP 1                                                            COB57820
  902 WRITE(6,3002)  KMAX,$LXX                                          COB57830
      STOP 1                                                            COB57840
C                                                                       COB57850
      ENTRY CORE3                                                       COB57860
C     FROM ITHO FOR PRINTING                                            COB57870
      WRITE (6,1000) MA, MC, MG, MN, MR, MS, MX                         COB57880
      WRITE(6,4500)                                                     COB57890
      WRITE(6,5000)                                                     COB57900
      WRITE(6,4000) (N,$NAMES(N),$LX(N),$ORG(N),$TYPE(N),N=1,$$$)       COB57910
      WRITE(6,3000)  KMAX                                               COB57920
      LOWER = 4.0*FLOAT(KMAX-$LXX)/1024.0                               COB57930
      WRITE (6,1004) $LXX, LOWER                                        COB57940
      RETURN                                                            COB57950
C                                                                       COB57960
 1000 FORMAT(///, '  DYNAMIC ARRAY SIZES', /, '  MA = ', I5, /,         COB57970
     1 '  MC = ', I5, /, '  MG = ', I5, /, '  MN = ', I5, /,            COB57980
     2 '  MR = ', I5, /, '  MS = ', I5, /, '  MX = ', I5)               COB57990
 1004 FORMAT(/, ' DYNAMIC STORAGE REQUIRED = ', I14, ' WORDS', //,      COB58000
     1 ' REGION SIZE ON JCL CARD COULD HAVE BEEN REDUCED BY ', I4, ' K')COB58010
 3000 FORMAT('0DYNAMIC ALLOCATION OF CORE GOT ',I10,' WORDS'/)          COB58020
 3001 FORMAT('0DYNAMIC ALLOCATION OF CORE FAILED'///)                   COB58030
 3002 FORMAT('0DYNAMIC ALLOCATION OF CORE GOT ONLY ',I10,' WORDS'/      COB58040
     1  ' NUMBER OF WORDS REQUIRED FOR THIS PROBLEM IS ',I10///)        COB58050
 4000 FORMAT('0',T35,40X,'1=REAL'/T35,40X,'2=INTEGER'/T35,40X,'3=LOGICALCOB58060
     1'//                                                               COB58070
     2     T35,'INDEX     NAME      LENGTH    ORIGIN    TYPE'/          COB58080
     3     T35,'-----     ------    ------    ------    ----'/          COB58090
     4     (T35,I5,5X,A6,I10,I10,I8))                                   COB58100
 4500 FORMAT(1H ,' THIS VERSION OF COBRA-IIIC/MIT DOES NOT ALLOW',      COB58110
     1  ' DYNAMIC STORAGE.')                                            COB58120
 5000 FORMAT(//,'  MAXIMUM PROBLEM SIZE LIMITED TO',/,                  COB58130
     1  '  80000 WORDS BY DIMENSION OF DATA ARRAY IN',/,                COB58140
     2  '  MAIN PROGRAM AND VALUE OF KMAX SET IN',/,                    COB58150
     3  '  CORE SUBROUTINE.')                                           COB58160
      END                                                               COB58170
      SUBROUTINE DIFFER(IPART,J)                                        COB58180
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THECOB58190
C   MAJOR SUBROUTINES OF COBRA-IIIC.                                    COB58200
C                                                                       COB58210
C                                                                       COB58220
      IMPLICIT INTEGER ($)                                              COB58230
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB58240
     1     ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB58250
     2     HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB58260
     3     J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB58270
     4     NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB58280
     5     NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB58290
     6     NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB58300
```

```
     7  QAX    ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8  UF     ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
      COMMON/LINK9/ENEH(400)
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
      EQUIVALENCE (NCHAN,NCHANL)
C
      IPILE = J7
      JM1 = J-1
      IF(IPART.LT.1 .OR. IPART.GT.4) GO TO 1000
      GO TO (100,200,300,400),IPART
C
C  PART 1, CALCULATE DH/DX FOR STEADY STATE AT X AND T.
  100 DO 120 I=1,NCHANL
  120 DATA($DHDX+I)=0.
      IF (IPILE.EQ.2) GO TO 185
      DO 180 K=1,NK
      I=IDAT($IK+K)
      L=IDAT($JK+K)
      WV=(DATA($H+I+MC*(J-1))-DATA($H+L+MC*(J-1)))
      IF(DATA($W+K+MG*(J-1)).LT.0.)  GO TO 140
      HWI = 0.0
      HWL=  DATA($W+K+MG*(J-1)) * WV
      GO TO 160
  140 HWI=  DATA($W+K+MG*(J-1)) * WV
      HWL = 0.0
```

```
 160  CONTINUE
      DATA($DHDX+I)=DATA($DHDX+I)+HWI-WV*DATA($WP+K)/ENEH(K)-(DATA($T+I)
     1    -DATA($T+L))*DATA($COND+K)
      DATA($DHDX+L)=DATA($DHDX+L)+HWL+WV*DATA($WP+K)/ENEH(K)+(DATA($T+I)
     1    -DATA($T+L))*DATA($COND+K)
  180 CONTINUE
  185 DO 190 I=1,NCHANL
 190  DATA($DHDX+I)=(DATA($DHDX+I)+DATA($QPRIM+I)+DATA($QC+I+MC*J)/DX)
     1               /DATA($F+I+MC*(J-1))
      GO TO 500
C
C  PART 2, CALCULATE DF/DX FOR STEADY STATE AT X AND T
  200 DO 220 I=1,NCHANL
 220  DATA($DFDX+I)=0.
      IF (IPILE.EQ.2) GO TO 500
      DO 240 K=1,NK
      I =IDAT($IK+K)
      L =IDAT($JK+K)
      DATA($DFDX+I)=DATA($DFDX+I)-DATA($W+K+MG*(J-1))
 240  DATA($DFDX+L)=DATA($DFDX+L)+DATA($W+K+MG*(J-1))
      GO TO 500
C
C  PART 3, CALCULATE DP/DX WITHOUT W
  300 DO 302 I=1,NCHANL
 302  DATA($DPDX+I)=0.
      IF (FTM.LE.0.0) GO TO 306
      IF (IPILE.EQ.2) GO TO 306
      DO 304 K=1,NK
      I=IDAT($IK+K)
      L=IDAT($JK+K)
      WV=(DATA($U+I)-DATA($U+L))*DATA($WP+K)
      DATA($DPDX+I)=DATA($DPDX+I)+WV
      DATA($DPDX+L)=DATA($DPDX+L)-WV
  304 CONTINUE
  306 DO 390 I=1,NCHANL
      SAVE=0.5*DATA($FSP+I)*DATA($FMULT+I)*DATA($V+I)/DATA($DHYD+I)
     1    +(DATA($VP+I)/DATA($A+I)-DATA($VPA+I))*DATA($A+I)/DX
      IF(.NOT.GRID) GO TO 310
      IF(NRAMP.LE.0) GO TO 1000
      DUMY = FLOAT(ITERAT)/FLOAT(NRAMP)
      IF(DUMY.GT.1.) DUMY = 1.
      SAVE=SAVE+.5*DUMY*DATA($CD+I+MC*(NGTYPE-1))*DATA($VP+I)/DX
 310  DATA($DPK+I)=SAVE/(DATA($A+I)*DATA($A+I))
      JJ = JM1
      IF (J.GT.1) GO TO 382
      JJ = 1
 382  FLOWSQ=ABS(DATA($F+I+MC*(JJ-1)))*
     1           DATA($F+I+MC*(JJ-1))
C     JK INSERT
       IF(IPILE.EQ.2)  FLOWSQ= DATA($F+I+MC*(J-1))**2
      DATA($DPDX+I)=-DATA($DPK+I)*FLOWSQ/GC-DATA($RHO+I+MC*(J-1))*
     1    ELEV-DATA($DPDX+I)*FTM/(DATA($A+I)*GC)
      IF(DT.GT.100.) GO TO 390
C        T R INSERT
      RHODIF=DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))
```

```
      RHODOT=RHODIF/DT
C     JK INSERT
       IF(IPILE.NE.2)  GO TO 385
      DATA($DPDX+I)=DATA($DPDX+I)+RHODOT/GC*2.*DATA($U+I)
     1   +(DATA($FOLD+I+MC*(J-1))-DATA($F+I+MC*(J-1)))/DATA($A+I)/DT/GC
       GO TO 390
 385  DATA($DPDX+I)=DATA($DPDX+I)+RHODOT/GC*(2.*DATA($U+I)+DX/DT
     1    +DATA($DPK+I)*ABS(DATA($F+I+MC*(JM1-1))+DATA($F+I+MC*(J-1)))*
     2    DATA($A+I)*DX)+       (DATA($FOLD+I+MC*(J-1))-DATA($F+I+MC*(JM1
     3    -1)))/DATA($A+I)/DT/GC
  390 CONTINUE
      GO TO 500
C
C  PART 4, CALCULATE DP/DX WITH W
  400 IF (J.EQ.1) GO TO 500
      DO 410 I=1,NCHANL
 410  DATA($DHDX+I)=0.
      IF (IPILE.EQ.2) GO TO 425
      DO 420 K=1,NK
      I=IDAT($IK+K)
      L=IDAT($JK+K)
      DATA($DHDX+I)=DATA($DHDX+I)+((2.*DATA($U+I)-DATA($USTAR+K)+DX/DT)
     1     /DATA($A+I)+DATA($DPK+I)*ABS(DATA($F+I+MC*(JM1-1))+
     2     DATA($F+I+MC*(J-1)))*DX)*DATA($W+K+MG*(J-1))
      DATA($DHDX+L)=DATA($DHDX+L)-((2.*DATA($U+L)-DATA($USTAR+K)+DX/DT)
     1     /DATA($A+L)+DATA($DPK+L)*ABS(DATA($F+L+MC*(JM1-1))+
     2     DATA($F+L+MC*(J-1)))*DX)*DATA($W+K+MG*(J-1))
  420 CONTINUE
  425 DO 430 I=1,NCHANL
 430  DATA($DPDX+I)=DATA($DPDX+I)+DATA($DHDX+I)/GC
C
  500 CONTINUE
      RETURN
 1000 IERROR = 2
      RETURN
      END
      SUBROUTINE HEAT(J)
C     CALCULATE THE HEAT INPUT TO EACH SUBCHANNEL AT POSITION J.
C     IF NODES GREATER THAN ZERO, CALCULATE HEAT INPUT USING THERMAL
C     CONDUCTION. OTHERWISE HEAT INPUT IS DEFINED BY HEAT GENERATION.
C     POWER = AVERAGE INTERNAL HEAT GENERATION.
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
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     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB59960
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB59970
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB59980
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB59990
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB60000
C                                                                       COB60010
C                                                                       COB60020
      LOGICAL  GRID                                                     COB60030
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB60040
C                                                                       COB60050
C                                                                       COB60060
      COMMON /COBRA3/  MA     ,MC     ,MG     ,MN     ,MR     ,MS     ,MX     ,COB60070
     1          $$$    ,$A     ,$AAA   ,$AC    ,$ALPHA,$AN    ,$ANSWE,$B     ,COB60080
     1  $CCHAN,$CD    ,$CHFR ,$CON   ,$COND ,$CP    ,$D     ,$DC    ,$DFDX ,COB60090
     2  $DHDX ,$DHYD ,$DHYDN,$DIST  ,$DPDX ,$DPK   ,$DUR   ,$DR    ,$F     ,COB60100
     3  $FACTO,$FDIV ,$FINLE,$FLUX  ,$FMULT,$FOLD  ,$FSP   ,$FSPLI,$FXFLO,COB60110
     4  $GAP  ,$GAPN ,$GAPS ,$H     ,$HFILM,$HINLE,$HOLD  ,$HPERI,$IDARE,COB60120
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK    ,$LC    ,$LENGT,$LOCA ,$LR    ,COB60130
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH    ,COB60140
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF ,$QC    ,$QF    ,$QPRIM,COB60150
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD ,COB60160
     9  $U    ,$UH   ,$USAVE,$USTAR,$V     ,$VISC ,$VISCW,$VP    ,$VPA  ,COB60170
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X     ,$XCROS,$$A   ,$$B   ,$XPOLD  COB60180
C                                                                       COB60190
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB60200
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB60210
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB60220
C                                                                       COB60230
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,      COB60240
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG                            COB60250
C                                                                       COB60260
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                 COB60270
C                                                                       COB60280
      COMMON /TIMEST/ NT                                                COB60290
C                                                                       COB60300
      COMMON  DATA(1)                                                   COB60310
      LOGICAL LDAT(1)                                                   COB60320
      INTEGER IDAT(1)                                                   COB60330
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB60340
C                                                                       COB60350
      EQUIVALENCE (NCHAN,NCHANL)                                        COB60360
C                                                                       COB60370
      IPILE = J7                                                        COB60380
      NP1 = NODESF+1                                                    COB60390
C  BYPASS THE HEAT FLUX CALCULATION IF BEYOND THE FIRST ITERATION AND   COB60400
C  IF FUEL TEMPERATURES ARE NOT TO BE CALCULATED.                       COB60410
      IF(ITERAT.GT.1 .AND. NODESF.LT.1) GO TO 60                        COB60420
C  BYPASS THE HEAT FLUX CALCULATION USING THE FUEL TEMPERATURE MODEL    COB60430
C  IF BEYOND THE FIRST ITERATION, AND IF FUEL TEMPERATURES HAVE BEEN    COB60440
C  CALCULATED AND IF A TRANSIENT CALCULATION IS BEING PERFORMED.        COB60450
      IF(ITERAT.GT.1 .AND. NODESF.GT.0 .AND. DT.LT.100.) GO TO 60       COB60460
      IF(IQP3.LE.1) GO TO 170                                           COB60470
      CALL CURVE(QAX,(DATA($X+J)-DX*0.5)/Z,AXIAL,Y,NAX,IERROR,1)        COB60480
  170 CONTINUE                                                          COB60490
C  DETERMINE THE HEAT FLUX FROM EACH ROD.                               COB60500
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```
      DO 50 N=1,NROD
      IF(IQP3.LE.1) GO TO 160
C     CALCULATE FORCED HEAT FLUX FROM EACH ROD.
      DATA($FLUX+N+MR*(J-1))=AFLUX*DATA($RADIA+N)*QAX*POWER/.0036
      GO TO 150
 160  K=IDAT($IDFUE+N)
      IF(K.EQ.1)  DATA($FLUX+N+MR*(J-1))=DATA($QF+N+MC*(J-1))
     1  /(DATA($HPERI+N)*DX)
C
      IF(K.EQ.2) DATA($FLUX+N+MR*(J-1))=DATA($QF+N+MC*(J-1))
     1  /(DATA($HPERI+N)*DX)
  150 CONTINUE
      IF(NODESF.LT.1) GO TO 50
C  CORRECT HEAT FLUX FOR THERMAL CAPACITY USING TRANSIENT FUEL MODEL.
C     CALCULATE AVERAGE FLUID TEMPERATURE, HEAT TRANSFER COEFFICIENT.
CC  START OF LOOP FOR OBTAINING STEADY STATE FUEL ROD TEMPERATURES.
      DO 40 INN=1,50
      SAVE = 0.
      TFLUID = 0.
      HSURF = 0.
      IF (IPILE.EQ.0) GO TO 6
      TFLUID=DATA($T+N)
      CALL HTRAN(N,N,J-1,HSURF,TFLUID,IHTM,NT)
      IF (IERROR.GT.1) RETURN
      GO TO 7
    6 DO 9 L=1,6
      IF(IDAT($LR+N+MR*(L-1))) 9,9,10
 10   I=IDAT($LR+N+MR*(L-1))
      DUMY=DATA($PHI+N+MR*(L-1))
      SAVE = SAVE + DUMY
      TFLUID=TFLUID+DATA($T+I)*DUMY
      CALL HTRAN(N,I,J-1,HTC,DATA($T+I),IHTM,NT)
      HSURF = HSURF + DUMY*HTC
      IF(IERROR.GT.1) RETURN
    9 CONTINUE
      IF(SAVE.LE.0.) GO TO 1000
      TFLUID = TFLUID/SAVE
      HSURF = HSURF/SAVE
C
C     CALCULATE FUEL TEMPERATURE
C
    7 DO 8 I=1,NP1
 8    DATA($TDUMY+I)=DATA($TROD+I+MN*(N-1+MR*(J-1)))
      IF(IFRM.EQ.0) GO TO 20
      QP=DATA($FLUX+N+MR*(J-1))*4.*DATA($D+N)/(DFUEL(1)**2)
      CALL TEMFR(DATA($TDUMY+1),DT,N,TFLUID,HGAP(1),HSURF,QP,INN,NT)
      GO TO 22
   20 CALL TEMP(DATA($TDUMY+1),DT,N,J,DATA($$A+1),DATA($$B+1))
      IF(IERROR.GT.1) RETURN
   22 DO 24 I=1,NP1
   24 DATA($TROD+I+MN*(N-1+MR*(J-1)))=DATA($TDUMY+I)
      IF (IHTM.EQ.0.AND.IPROP.EQ.0) GO TO 45
      IF (NT.GT.1) GO TO 45
      IF(INN.LT.2) GO TO 40
      IF (ABS(DATA($TDUMY+1)-FTOLD).GT.EPSF) GO TO 40
```

```
      GO TO 45                                                          COB61060
   40 FTOLD=DATA($TDUMY+1)                                              COB61070
      WRITE(I3,55) N,J                                                  COB61080
   55 FORMAT(1H1,' FUEL TEMPERATURES FAILED TO CONVERGE IN FUEL ROD ',  COB61090
     1  I3,' AT AXIAL LEVEL ',I3,'.  MAXIMUM ITERATIONS = 50.')         COB61100
      GO TO 1000                                                        COB61110
   45 DATA($FLUX+N+MR*(J-1))=HSURF*(DATA($TROD+NP1+MN*(N-1+MR*(J-1)))   COB61120
     1  -TFLUID)                                                        COB61130
   50 CONTINUE                                                          COB61140
   60 IF (IPILE.EQ.0) GO TO 70                                          COB61150
      IF (NODESF.LT.1) GO TO 66                                         COB61160
      DO 65 I=1,NCHANL                                                  COB61170
C     JK INSERT                                                         COB61180
      CALL HTRAN(I,I,J-1,HSURF,DATA($T+I),IHTM,NT)                      COB61190
  65   DATA($QPRIM+I)= DATA($PWRF+I+MC*(I-1))* PI * DATA($D+I)          COB61200
     1 *HSURF *(DATA($TROD+NP1+MN*(I-1+MR*(J-1)))- DATA($T+I))          COB61210
      RETURN                                                            COB61220
   66 DO 68 I=1,NCHANL                                                  COB61230
   68 DATA($QPRIM+I)=DATA($PWRF+I+MC*(I-1))*PI*DATA($D+I)*              COB61240
     1    DATA($FLUX+I+MR*(J-1))                                        COB61250
      RETURN                                                            COB61260
C     CALCULATE HEAT INPUT TO EACH CHANNEL.                             COB61270
   70 DO 100 I=1,NCHANL                                                 COB61280
      SAVE = 0.                                                         COB61290
      DO 90 N=1,NROD                                                    COB61300
      DUMY=DATA($PWRF+I+MC*(N-1))                                       COB61310
      IF(DUMY.GT.0.)  SAVE=SAVE+DUMY*DATA($FLUX+N+MR*(J-1))*PI*DATA($D+NCOB61320
     1    )                                                             COB61330
   90 CONTINUE                                                          COB61340
  100  DATA($QPRIM+I)=SAVE                                              COB61350
      RETURN                                                            COB61360
 1000 IERROR = 14                                                       COB61370
      RETURN                                                            COB61380
      END                                                               COB61390
      SUBROUTINE HTRAN(N,I,JJ,HTC,TLIQ,IHTM,NT)                         COB61400
C                                                                       COB61410
C  CALCULATES ROD-TO-COOLANT HEAT TRANSFER COEFFICIENT, HTC             COB61420
C                                                                       COB61430
      IMPLICIT INTEGER($)                                               COB61440
      COMMON/PSAVE/P,ROV,ROL,TSAT                                       COB61450
C                                                                       COB61460
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB61470
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB61480
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB61490
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB61500
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB61510
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB61520
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB61530
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB61540
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB61550
C                                                                       COB61560
C                                                                       COB61570
C                                                                       COB61580
C                                                                       COB61590
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB61600
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     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB61610
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB61620
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB61630
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB61640
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB61650
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB61660
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB61670
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB61680
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB61690
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB61700
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD  COB61710
C                                                                       COB61720
      COMMON DATA(1)                                                    COB61730
      LOGICAL LDAT(1)                                                   COB61740
      INTEGER IDAT(1)                                                   COB61750
C                                                                       COB61760
C   CHOICE BETWEEN OLD AND NEW HEAT TRANSFER MODELS MADE HERE           COB61770
      IF (IHTM.EQ.0) GO TO 300                                          COB61780
      NP1=NODESF+1                                                      COB61790
CC                                                                      COB61800
CC  VALUES CONVERTED TO SI UNITS FOR USE BY HTCOR                       COB61810
CC                                                                      COB61820
      TW=TCON( DATA($TROD+NP1+MN*(N-1+MR*(JJ))) )                       COB61830
C                                                                       COB61840
C  LOW WALL TEMP. INDICATES THAT ROD TEMP. NOT YET                      COB61850
C  CALCULATED - SO OLD HEAT TRANSFER MODEL USED.                        COB61860
C                                                                       COB61870
      IF (TW.LT.280.) GO TO 300                                         COB61880
      TL=TCON(TLIQ)                                                     COB61890
      TV=TL                                                             COB61900
      XX=DATA($QUAL+I)                                                  COB61910
      ALP=DATA($ALPHA+I)                                                COB61920
      IF (XX.LE.0.) VL=.3048*DATA($F+I+MC*(JJ-1))/                      COB61930
     1  (DATA($RHO+I+MC*(JJ-1))*(1.-ALP)*DATA($A+I))                    COB61940
      IF (XX.GT.0.) VL=.3048*((DATA($F+I+MC*(JJ-1))*                    COB61950
     1  (1.-XX))/(RHOF*(1.-ALP)*DATA($A+I)))                            COB61960
      VV=VL                                                             COB61970
      IF (XX.GT.0.) VV=.3048*DATA($F+I+MC*(JJ-1))*XX/                   COB61980
     1  (RHOG*ALP*DATA($A+I))                                           COB61990
      HD=.3048*DATA($DHYD+I)                                            COB62000
      ROV=DCON(RHOG)                                                    COB62010
      ROL=DCON(RHOF)                                                    COB62020
C                                                                       COB62030
C  CONVERT PRESSURE FROM PSI TO N/M**2                                  COB62040
C                                                                       COB62050
      P=6.893E3*(PREF)                                                  COB62060
C                                                                       COB62070
C  NO CHF CHECK IN HTCOR IF NT AND ITERAT BOTH EQUAL ONE                COB62080
C  BECAUSE START OF BOILING INDICATORS WILL NOT                         COB62090
C  BE SET YET IN THIS CASE                                              COB62100
C                                                                       COB62110
      NHTM=IHTM                                                         COB62120
      IF (NT.EQ.1.AND.ITERAT.EQ.1) NHTM=1                               COB62130
C                                                                       COB62140
      CALL HTCOR(IDUM1,QV,QL,HVFC,HLNB,HLFC,TW,TL,TV,P,ALP,XX,          COB62150
```

```
     1  ROV,ROL,VV,VL,HO,NHTM,CHFR.TSAT.DATA($FLUX+N+MR*(JJ)).
     2  NCHF,N,I,JJ,I3)
C
      HTC=4.896E-5*(HVFC+HLFC)
CC  ONLY CONSIDER FORCED CONVECTION WHEN TW VERY CLOSE TO TL
      IF (ABS(TW-TL).LT..0001) RETURN
      HTC=HTC+4.896E-5*(QV+QL+HLNB*(TW-TSAT))/(TW-TL)
      IF (NT.GT.1) RETURN
C
C  LARGE CHANGES IN PREDICTED HEAT TRANSFER COEFF. ARE DAMPED FOR
C  STEADY STATE CALCULATIONS
C
      HTCOLD=DATA($FLUX+N+MR*(JJ))/(DATA($TROD+NP1+MN*(N-1
     1  +MR*(JJ)))-TLIQ)
      IF ((ABS(HTC-HTCOLD)/HTCOLD).LT..001) RETURN
      HTC=0.8*HTC+0.2*HTCOLD
      RETURN
C
  300 HTC=HCOOL(N,I,JJ)
      RETURN
      END
      SUBROUTINE SCHEME(JUMP,AAA)
C
C  THIS SUBROUTINE SETS UP AND PERFORMS THE SOLUTION OF THE FINITE
C  DIFFERENCE SCHEME AT EACH SPATIAL LOCATION X AT A SELECTED TIME T.
C
C
C
      IMPLICIT INTEGER ($)
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,
     8   UF    ,VF    ,VFG   ,VG    ,Z
C
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
C
C
      LOGICAL  GRID
      REAL     KIJ, KF, KKF, KCLAD, KFUEL
C
C
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
```

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     3 $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4 $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5 $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6 $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7 $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8 $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9 $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
     A $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A  ,$$B   ,$XPOLD
C
      COMMON   DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE   (DATA(1),IDAT(1),LDAT(1))
C
      EQUIVALENCE   (NCHAN,NCHANL)
C
      DIMENSION AAA(1)
    1 FORMAT('1ERROR DETECTED IN SUBROUTINE SCHEME AT NODE',I3,
     1 '    X =',E10.5,' FEET'/' CALCULATION FOR THIS CASE STOPPED')
    2 FORMAT(' NODE',I3,'    X =',E10.5)
    3 FORMAT('     I        H(I,J)        F(I,J)        P(I,J)      H(I,J-1)     F
     1(I,J-1)     P(I,J-1)')
    4 FORMAT('     I      QUAL(I)     ALPHA(I)      RHO(I,J)        VP(I)
     1 V(I)      FMULT(I)')
    5 FORMAT('     K     W(K,J-1)        W(K,J)          WP(K)      USTAR(K)    SP
     1(K,J-1)      SP(K,J)')
    6 FORMAT('     I      DHDX(I)         UH(I)       DPDX(I)      QPRIM(I)    FO
     1LD(I,J) RHOOLD(I,J)')
   16 FORMAT(3I5,4E12.6)
   52 FORMAT( I5,6E12.6)
C     MEKIN.   IPILE = 0,1,2 FOR STANDARD COBRA, PWR, BWR
      IPILE = J7
      NCHANL = NCHANL
      FMIN = .0001
      NDXP1 = NDX+1
      IF(JUMP.EQ.3) GO TO 400
      JUMP = 2
C
C  BEGIN STEPPING THROUGH CHANNEL
  400 DO 450 J=1,NDXP1
      CALL PRNTIM (3)
      JP1 = J+1
      JM1 = J-1
      IF(J.GT.1) GO TO 405
C  SET CONDITIONS AT START OF CHANNEL
      DO 401 I=1,NCHANL
  401 DATA($QPRIM+I)=0.
      CALL FORCE(1)
      IF(IERROR.GT.1) GO TO 440
      CALL AREA(1)
      IF(IERROR.GT.1) GO TO 440
      CALL PROP(2,1)
      IF(IERROR.GT.1) GO TO 440
      CALL VOID(1)
      IF(IERROR.GT.1) GO TO 440
```

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      GO TO 428                                                          COB63260
  405 IF(JUMP.EQ.3) GO TO 420                                            COB63270
      IF(NGRID.LT.1) GO TO 410                                           COB63280
      GRID = .FALSE.                                                     COB63290
      DO 408 I=1,NGRID                                                   COB63300
      ZG = GRIDXL(I)*Z                                                   COB63310
      IF(ZG.GT.DATA($X+JM1).AND.                                         COB63320
     1   ZG.LE.DATA($X+J))  GO TO 409                                    COB63330
  408 CONTINUE                                                           COB63340
      GO TO 410                                                          COB63350
  409 NGTYPE = IGRID(I)                                                  COB63360
      GRID = .TRUE.                                                      COB63370
C  CALCULATE PARAMETERS TO BE SAVED FROM PREVIOUS SPACE                  COB63380
  410 DO 411  I=1,NCHANL                                                 COB63390
      DATA($VPA+I)=DATA($VP+I)/DATA($A+I)                                COB63400
  411 CONTINUE                                                           COB63410
  420 CALL HEAT(J)                                                       COB63420
      IF(IERROR.GT.1) GO TO 440                                          COB63430
      IF (IPILE.EQ.2) GO TO 423                                          COB63440
      CALL MIX(JM1)                                                      COB63450
      IF(IERROR.GT.1) GO TO 440                                          COB63460
  423 CALL DIFFER(1,JM1)                                                 COB63470
      IF(IERROR.GT.1) GO TO 440                                          COB63480
C                                                                        COB63490
C   CALCULATE ENTHALPY AND ESTIMATE FLOW AT X.                           COB63500
      DO 425 I=1,NCHANL                                                  COB63510
C     JK INSERT                                                          COB63520
       IF(ITERAT.EQ.1.AND.JUMP.NE.3.OR.IPILE.EQ.2) DATA($F+I+MC*(J-1))=  COB63530
     1                                 DATA($F+I+MC*(JM1-1))             COB63540
      DATA($H+I+MC*(J-1))=(DATA($H+I+MC*(JM1-1))+DX/DT/DATA($UH+I)*      COB63550
     1    DATA($HOLD+I+MC*(J-1))+DX*DATA($DHDX+I))/(1.0+DX/DT/           COB63560
     2    DATA($UH+I))                                                   COB63570
  425 CONTINUE                                                           COB63580
      IF(JUMP.EQ.3) GO TO 450                                            COB63590
      CALL FORCE(J)                                                      COB63600
      IF(IERROR.GT.1) GO TO 440                                          COB63610
      CALL AREA(J)                                                       COB63620
      IF(IERROR.GT.1) GO TO 440                                          COB63630
      CALL PROP(2,J)                                                     COB63640
      IF(IERROR.GT.1) GO TO 440                                          COB63650
      CALL VOID(J)                                                       COB63660
      IF(IERROR.GT.1) GO TO 440                                          COB63670
      CALL DIFFER(3,J)                                                   COB63680
      IF(IERROR.GT.1) GO TO 440                                          COB63690
      IF (IPILE.NE.2) GO TO 4255                                         COB63700
      CALL SEPRAT(1,J,JUMP)                                              COB63710
      IF(IERROR.GT.1) GO TO 440                                          COB63720
      GO TO 435                                                          COB63730
 4255 DO 426 K=1,NK                                                      COB63740
      DATA($WSAVE+K)=DATA($W+K+MG*(J-1))                                 COB63750
  426 CONTINUE                                                           COB63760
C  CALCULATE THE DIVERSION CROSSFLOW AT X.                               COB63770
      CALL PRNTIM (4)                                                    COB63780
      CALL DIVERT(J)                                                     COB63790
      CALL PRNTIM (5)                                                    COB63800
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      IF(IERROR.GT.1) GO TO 440
C  CALCULATE THE FLOW AT X AND CHECK FOR CONVERGENCE.
      CALL DIFFER(2,J)
      IF(IERROR.GT.1) GO TO 440
      DO 4270 I=1,NCHANL
      FSAVE=DATA($F+I+MC*(J-1))
C          T R INSERT
      RHODIF=DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))
      IF(DT.LT.0.001.AND.ABS(RHODIF).LT.0.001) RHODIF=0.0
      DATA($F+I+MC*(J-1))=DATA($F+I+MC*(JM1-1))+DX*DATA($DFDX+I)-DX/DT*
     1     RHODIF*DATA($A+I)
C  THE FOLLOWING STATEMENT PROVIDES DAMPING TO ASSIST IN MORE RAPID
C  CONVERGENCE, ESPECIALLY WHEN USING THE SUBCOOLED VOID OPTION.
C  USERS MAY WISH TO TRY OTHER COMBINATIONS OF CONSTANTS.
      DATA($F+I+MC*(J-1))=0.2*FSAVE+0.8*DATA($F+I+MC*(J-1))
      IF(ABS(DATA($F+I+MC*(J-1))-FSAVE)/FSAVE.GT.FERROR)  JUMP=1
      IF(DATA($F+I+MC*(J-1)).LT.FMIN)  DATA($F+I+MC*(J-1))=FMIN
 4270 CONTINUE
C  CALCULATE SP AT X-DX.
      CALL DIFFER(4,J)
      IF(IERROR.GT.1) GO TO 440
C  THE FACTOR DAMPING WAS ADDED AFTER PUBLICATION.  A VALUE OF ZERO WAS
C  USED FOR THE SAMPLE PROBLEMS.  A VALUE OF 0.5 HAS BEEN FOUND TO SPEED
C  CONVERGENCE FOR MANY PROBLEMS.  USERS MAY WISH TO TRY OTHER VALUES.
       DAMPNG = 0.
      DO 430 K=1,NK
      II=IDAT($IK+K)
      JJ=IDAT($JK+K)
      DATA($SP+K+MG*(JM1-1))=DAMPNG*DATA($SP+K+MG*(JM1-1))+(1.-DAMPNG)*
     1   (DATA($SP+K+MG*(J-1))-(DATA($DPDX+II)-DATA($DPDX+JJ))*DX)
  430 CONTINUE
  435 DO 427 I=1,NCHANL
  427 DATA($P+I+MC*(J-1))=DATA($P+I+MC*(JM1-1))+DX*DATA($DPDX+I)
  428 CONTINUE
      IF(KDEBUG.LT.1) GO TO 450
      GO TO 445
  440 WRITE(I3,1) J,DATA($X+J)
      GO TO 446
  445 WRITE(I3,2)J,DATA($X+J)
  446 WRITE(I3,3)
      WRITE(I3,52) (I,DATA($H   +I+MC*(J  -1)),DATA($F    +I+MC*(J  -1)),
     1             DATA($P    +I+MC*(J  -1)),DATA($H    +I+MC*(JM1-1)),
     2             DATA($F    +I+MC*(JM1-1)),DATA($P    +I+MC*(JM1-1)),
     1 I=1,NCHANL)
      WRITE(I3,4)
      WRITE(I3,52) (I,DATA($QUAL +I          ),DATA($ALPHA+I          ),
     1             DATA($RHO  +I+MC*(J  -1)),DATA($VP   +I          ),
     2             DATA($V    +I          ),DATA($FMULT+I          ),
     1 I=1,NCHANL)
      WRITE(I3,5)
      WRITE(I3,52) (K,DATA($W   +K+MG*(JM1-1)),DATA($W   +K+MG*(J  -1)),
     1             DATA($WP   +K          ),DATA($USTAR+K          ),
     2             DATA($SP   +K+MG*(JM1-1)),DATA($SP   +K+MG*(J  -1)),
     1 K=1,NK)
      WRITE(I3,6)
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      WRITE(I3,52) (I,DATA($DHDX +I         ),DATA($UH    +I          ),  COB64360
     1             DATA($DPDX +I            ),DATA($QPRIM+I           ),  COB64370
     2             DATA($FOLD +I+MC*(J  -1)),DATA($RHOOL+I+MC*(J  -1)),   COB64380
     1  I=1,NCHANL)                                                       COB64390
      IF(IERROR.GT.1) RETURN                                              COB64400
  450 CONTINUE                                                            COB64410
      IF(JUMP.EQ.3) RETURN                                                COB64420
C  CORRECT SUBCHANNEL PRESSURES TO ZERO EXIT PRESSURE.                    COB64430
C  PRESSURE P(I,J) IS THE PRESSURE ABOVE THE EXIT REFERENCE PRESSURE.     COB64440
      DO 460 I=1,NCHANL                                                   COB64450
      PEXIT=DATA($P+I+MC*(NDXP1-1))                                       COB64460
      DO 460 J=1,NDXP1                                                    COB64470
 460  DATA($P+I+MC*(J-1))=DATA($P+I+MC*(J-1)) - PEXIT                     COB64480
      IF (IPILE.NE.2) RETURN                                              COB64490
      CALL SEPRAT(2,J,JUMP)                                               COB64500
      RETURN                                                              COB64510
      END                                                                 COB64520
        FUNCTION SCQUAL(I,J)                                              COB64530
C  LEVY SUBCOOLED MODEL.  CALCULATES TRUE QUALITY AS A CORRECTION TO      COB64540
C  THE EQUILIBRIUM QUALITY.                                               COB64550
C                                                                         COB64560
C                                                                         COB64570
      IMPLICIT INTEGER ($)                                                COB64580
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB64590
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB64600
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB64610
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,      COB64620
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB64630
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB64640
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB64650
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB64660
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB64670
C                                                                         COB64680
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),      COB64690
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),     COB64700
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),   COB64710
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),        COB64720
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),         COB64730
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                       COB64740
C                                                                         COB64750
C                                                                         COB64760
      LOGICAL  GRID                                                       COB64770
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                 COB64780
C                                                                         COB64790
C                                                                         COB64800
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB64810
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB64820
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB64830
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB64840
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB64850
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB64860
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB64870
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB64880
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB64890
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB64900
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     9   $U     ,$UH   ,$USAVE,$USTAR,$V     ,$VISC ,$VISCW,$VP   ,$VPA  ,COB64910
     A   $W     ,$WOLD ,$WP   ,$WSAVE,$X     ,$XCROS,$$A   ,$$B   ,$XPOLD COB64920
C                                                                        COB64930
      COMMON  DATA(1)                                                    COB64940
      LOGICAL LDAT(1)                                                    COB64950
      INTEGER IDAT(1)                                                    COB64960
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                             COB64970
C                                                                        COB64980
C                                                                        COB64990
      XP=DATA($QUAL+I)                                                   COB65000
       DATA($XPOLD+I)=0.                                                 COB65010
      SCQUAL = XP                                                        COB65020
      IF(DATA($QPRIM+I).LE.0.)  RETURN                                   COB65030
      CNC = 0.015                                                        COB65040
       JJ=J                                                              COB65050
C  *******   THE FOLLOWING CARDS CORRECT THE LEVY MODEL   ******         COB65060
       YB=CNC/UF  *3600.   *SQRT( SIGMA    *GC*DATA($DHYD+I)/VF)         COB65070
       TAUW= DATA($FSP+I)*.125*VF     *(DATA($F+MC*(J-1)+I)/             COB65080
     1      DATA($A+I))**2/GC                                            COB65090
      PR=DATA($CP+I)*UF/KF                                               COB65100
      Q= DATA($QPRIM+I)/(DATA($HPERI+I)/VF     *DATA($CP+I)*             COB65110
     1    SQRT(TAUW*GC*VF      ))                                        COB65120
C     JK INSERT                                                          COB65130
       RE=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($DHYD+I)/DATA($VISC+I)     COB65140
       IF(RE.LT.2000.)  RE=2000.                                         COB65150
       HTC=DATA($CON+I) /DATA($DHYD+I)*.023*RE**.8*PR**.4                COB65160
      DELTAT=DATA($QPRIM+I)/DATA($HPERI +I)/HTC                          COB65170
C  *******                                                               COB65180
      IF(YB.GE.0..AND. YB.LT.5.) DELTAT = DELTAT - Q*PR*YB               COB65190
      IF(YB.GE.5..AND. YB.LT.30.)DELTAT = DELTAT - 5.*Q*(PR+ALOG(1.+PR*( COB65200
     1 YB*.2-1.)))                                                       COB65210
      IF(YB.GE.30.) DELTAT = DELTAT - 5.*Q*(PR+ALOG(1.+5.*PR)            COB65220
     1 + .5*ALOG(YB/30.))                                                COB65230
      XD=-DATA($CP+I)*DELTAT/HFG                                         COB65240
      ARG=DATA($QUAL+I)/XD-1.                                            COB65250
      IF (ARG.LT.-15.0) GO TO 140                                        COB65260
      IF(ARG.GT.0.) ARG = 0.                                             COB65270
      XP =DATA($QUAL+I)-XD*EXP(ARG)                                      COB65280
C  *******   THE FOLLOWING CARDS CORRECT THE LEVY MODEL   ******         COB65290
       IF(DATA($QUAL+I).LT.XD) XP=0.                                     COB65300
       IF(J7.EQ.2)  GO TO 130                                            COB65310
       IF(ITERAT.EQ.1) DATA($XPOLD+I+MC*(J-1))=XP                        COB65320
       DUMY=DATA($XPOLD+I+MC*(J-1))                                      COB65330
       XP=.99*XP+.01*DUMY                                                COB65340
 130   IF(JJ.EQ.1)  JJ=2                                                 COB65350
       XP=AMAX1(XP,DATA($XPOLD+I+MC*(JJ-2)))                             COB65360
       DATA($XPOLD+I+MC*(J-1))=XP                                        COB65370
 140  SCQUAL = XP                                                        COB65380
      RETURN                                                             COB65390
      END                                                                COB65400
      SUBROUTINE SEPRAT(IPART,J,JUMP)                                    COB65410
C                                                                        COB65420
C     FLOW ITERATION FOR SEPARATED CHANNELS (EG BWR)                     COB65430
C     CALLED FROM SCHEME                                                 COB65440
C     SP USED FOR (1) DM/DP (2) DM (3) DP                                COB65450
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C                                                                      COB65460
C                                                                      COB65470
C                                                                      COB65480
      IMPLICIT INTEGER ($)                                             COB65490
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB65500
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB65510
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB65520
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB65530
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB65540
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB65550
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB65560
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB65570
     8   UF    ,VF    ,VFG   ,VG    ,Z                                 COB65580
C                                                                      COB65590
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),   COB65600
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),  COB65610
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB65620
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),     COB65630
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),      COB65640
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                    COB65650
C                                                                      COB65660
C                                                                      COB65670
      LOGICAL  GRID                                                    COB65680
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                              COB65690
C                                                                      COB65700
C                                                                      COB65710
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB65720
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB65730
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB65740
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB65750
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB65760
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB65770
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB65780
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB65790
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB65800
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB65810
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB65820
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB65830
C                                                                      COB65840
      COMMON /REFP/ PO                                                 COB65850
C                                                                      COB65860
      COMMON  DATA(1)                                                  COB65870
      LOGICAL LDAT(1)                                                  COB65880
      INTEGER IDAT(1)                                                  COB65890
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                           COB65900
C                                                                      COB65910
C                                                                      COB65920
      IF (IPART.EQ.2) GO TO 10                                         COB65930
C     DO 2 I=1,NCHANL                                                  COB65940
C     DATA($DFDX+I)=0.0                                                COB65950
C2    DATA($F+I+MC*(J-1))=DATA($F+I+MC*(J-2))-DX/DT*(DATA($RHO+I+MC*(J-1COB65960
C    1    ))-DATA($RHOOL+I+MC*(J-1)))*DATA($A+I)                       COB65970
C     CALL DIFFER(3,J)                                                 COB65980
      RETURN                                                           COB65990
C                                                                      COB66000
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   10 PMIN=100000.0                                                   COB66010
      PMAX=-1000.0                                                    COB66020
      DO 12 I=1,NCHANL                                                COB66030
      WV=DATA($P+I)                                                   COB66040
      IF (WV.LT.PMIN) PMIN=WV                                         COB66050
      IF (WV.GT.PMAX) PMAX=WV                                         COB66060
   12 CONTINUE                                                        COB66070
      IF(ABS(1.-PMIN/PMAX).LT.FERROR)  RETURN                         COB66080
      JUMP=1                                                          COB66090
      IF(ITERAT.GT.1) GO TO 16                                        COB66100
      FTOT=0.0                                                        COB66110
      DO 14 I=1,NCHANL                                                COB66120
      FTOT=FTOT+DATA($F+I)                                            COB66130
      IF (DATA($SP+I).GT.0.0) GO TO 14                                COB66140
       DATA($SP+I)=0.7*DATA($F+I)/(DATA($P+I)-DATA($RHO+I+MC*NDX)*    COB66150
     1    ELEV*Z)                                                     COB66160
   14 CONTINUE                                                        COB66170
      GO TO 20                                                        COB66180
   16 DO 18 I=1,NCHANL                                                COB66190
       DELTAP=     (DATA($P+I) -DATA($SP+I+2*MC))                     COB66200
       IF( ABS(DELTAP).LT..001)  GO TO 18                             COB66210
       DATA($SP+I)=( DATA($F+I)-DATA($SP+I+MC))/DELTAP                COB66220
 18    CONTINUE                                                       COB66230
   20 SUM1=0.0                                                        COB66240
      SUM13=0.0                                                       COB66250
      DO 22 I=1,NCHANL                                                COB66260
      SUM1=SUM1+DATA($SP+I)                                           COB66270
      SUM13=SUM13+DATA($SP+I)*DATA($P+I)                              COB66280
      DATA($SP+I+MC)=DATA($F+I)                                       COB66290
   22 DATA($SP+I+MC*2)=DATA($P+I)                                     COB66300
C     JK INSERT                                                       COB66310
       P113=SUM13/SUM1                                                COB66320
       IF (ITERAT.EQ.1.AND.DT.GT.1000.) GO TO 23                      COB66330
       IF(P113.LE.0..OR.P113.GT.2*P0) P113=P0                         COB66340
   23  P0=P113                                                        COB66350
        IF(P0.LT.0.) P0=ABS(P0)                                       COB66360
      SUMF=0.0                                                        COB66370
      DO 24 I=1,NCHANL                                                COB66380
       DATA($F+I)=DATA($F+I)+DATA($SP+I)*(P0-DATA($P+I))              COB66390
   24 SUMF=SUMF+DATA($F+I)                                            COB66400
      DO 26 I=1,NCHANL                                                COB66410
   26 DATA($F+I)=DATA($F+I)*FTOT/SUMF                                 COB66420
      RETURN                                                          COB66430
      END                                                             COB66440
      SUBROUTINE VOID (J)                                             COB66450
C                                                                     COB66460
C                                                                     COB66470
      IMPLICIT INTEGER ($)                                            COB66480
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB66490
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB66500
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB66510
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB66520
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB66530
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB66540
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB66550
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     7   QAX    ,RHOF   ,RHOG   ,SIGMA ,SL     ,TF     ,TFLUID,THETA ,THICK ,COB66560
     8   UF     ,VF     ,VFG    ,VG    ,Z                                    COB66570
C                                                                          COB66580
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),        COB66590
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),       COB66600
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),     COB66610
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),          COB66620
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),           COB66630
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                         COB66640
C                                                                          COB66650
C                                                                          COB66660
      LOGICAL  GRID                                                         COB66670
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                   COB66680
C                                                                          COB66690
C                                                                          COB66700
      COMMON /COBRA3/  MA     ,MC     ,MG     ,MN     ,MR     ,MS     ,MX   ,COB66710
     1         $$$    ,$A     ,$AAA   ,$AC    ,$ALPHA,$AN    ,$ANSWE,$B    ,COB66720
     1   $CCHAN,$CD   ,$CHFR ,$CON   ,$COND ,$CP    ,$D     ,$DC    ,$DFDX ,COB66730
     2   $DHDX ,$DHYD ,$DHYDN,$DIST  ,$DPDX ,$DPK   ,$DUR   ,$DR    ,$F    ,COB66740
     3   $FACTO,$FDIV ,$FINLE,$FLUX  ,$FMULT,$FOLD ,$FSP   ,$FSPLI,$FXFLO,COB66750
     4   $GAP  ,$GAPN ,$GAPS ,$H     ,$HFILM.$HINLE,$HOLD  .$HPERI,$IDARE,COB66760
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK    ,$LC    ,$LENGT,$LOCA ,$LR   ,COB66770
     6   $MCHFR,$MCFRC,SMCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH   ,COB66780
     7   $DUM  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF ,$QC    ,$QF    ,$QPRIM,COB66790
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD ,COB66800
     9   $U    ,$UH   ,$USAVE,$USTAR,$V     ,$VISC ,$VISCW,$VP    ,$VPA  ,COB66810
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X     ,$XCROS,$$A   ,$$B   ,$XPOLD   COB66820
C                                                                          COB66830
      COMMON /PPSV/ PPI                                                     COB66840
C                                                                          COB66850
      COMMON  DATA(1)                                                       COB66860
      LOGICAL LDAT(1)                                                       COB66870
      INTEGER IDAT(1)                                                       COB66880
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                                COB66890
C                                                                          COB66900
C                                                                          COB66910
      EQUIVALENCE (NCHAN,NCHANL)                                            COB66920
      $PHI=$FMULT                                                           COB66930
      DO 200 I=1,NCHAN                                                      COB66940
      PSI = 0.                                                              COB66950
      DPSIDH = 0.                                                           COB66960
      IF(J3.EQ.0) GO TO 40                                                  COB66970
      DATA($H+I+MC*(J-1))=DATA($H+I+MC*(J-1))-.1                            COB66980
      DATA($QUAL+I)      =(DATA($H+I+MC*(J-1))-HF)/HFG                      COB66990
      IF(J2.EQ.1)          DATA($QUAL+I)=SCQUAL(I,J)                        COB67000
      IF(DATA($QUAL+I).LE.0.)  DATA($QUAL+I)=0.                             COB67010
      DATA($ALPHA+I) = BVOID(I,J)                                           COB67020
      PSI=RHOF*DATA($QUAL+I)*(1.-DATA($ALPHA+I))-RHOG*DATA($ALPHA+I)*       COB67030
     1     (1.-DATA($QUAL+I))                                               COB67040
      DATA($H+I+MC*(J-1))=DATA($H+I+MC*(J-1))+.1                            COB67050
   40 DATA($QUAL+I)      =(DATA($H+I+MC*(J-1))-HF)/HFG                      COB67060
      IF(J2.EQ.1)  DATA($QUAL+I)=SCQUAL(I,J)                                COB67070
      IF          (DATA($QUAL+I).LE.0.)  GO TO 150                          COB67080
      XP=          DATA($QUAL+I)                                            COB67090
      DATA($ALPHA+I)=BVOID(I,J)                                             COB67100
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C  CALCULATE TWO-PHASE DENSITY.
C   *******   THE FOLLOWING CARDS CORRECT THE CALCULATION OF RHO AND VP
      DATA($RHO+I+MC*(J-1))=RHOG*DATA($ALPHA+I)+1./DATA($V+I)*(1.-
     1    DATA($ALPHA+I))
C  CALCULATE TWO-PHASE SPECIFIC VOLUME FOR MOMENTUM.
      DATA($VP+I)=DATA($V+I)*(1.-XP)**2/(1.-DATA($ALPHA+I))+VG*XP**2/
     1    DATA($ALPHA+I)
C     JK INSERT
       IF(J7.NE.2)  GO TO 3
       IF(J.EQ.1)  GO TO 3
      RHODIF = DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))
       DATA($F+I+MC*(J-1))= DATA($F+I+MC*(J-2))-DX/DT*RHODIF*DATA($A+I)
 3     CONTINUE
C  TWO-PHASE FRICTIONAL PRESSURE GRADIENT MULTIPLIERS.
      DATA($PHI+I)=1.
      IF(J4.EQ.0)    DATA($PHI+I)=RHOF/DATA($RHO+I+MC*(J-1))
      GWV = 3600.0*DATA($F+I+MC*(J-1))/DATA($A+I)
      IF (J4.EQ.2) CALL BAROC(2,PREF,XP,GWV,DATA($PHI+I),PPI)
      IF(J4.NE.1) GO TO 50
      DATA($PHI+I)=1.
      XA=DATA($ALPHA+I)
      IF(XA.GT.0.0.AND.XA.LE.0.6)XXX=(1.-XP)**2/(1.-XA)**1.42
      IF(XA.GT.0.6.AND.XA.LE.0.9)XXX=.478*(1.-XP)**2/(1.-XA)**2.2
      IF(XA.GT.0.9.AND.XA.LE.1.0)XXX=1.73*(1.-XP)**2/(1.-XA)**1.64
      DATA($PHI+I)=XXX
   50 IF(J4.NE.5) GO TO 140
      DATA($PHI+I)=AF(1)
      XX           =DATA($QUAL+I)
      DO 130 K=2,NF
      DATA($PHI+I)=DATA($PHI +I)+AF(K)*XX
  130 XX           =DATA($QUAL+I)*XX
  140 DATA($U  +I)=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($VP+I)
      IF(J3.EQ.0) GO TO 145
      DPSIDH=-10.*(PSI-RHOF*DATA($QUAL+I)*(1.-DATA($ALPHA+I))+RHOG*
     1    DATA($ALPHA+I)*(1.-DATA($QUAL+I)))
  145 DATA($UH+I)=DATA($F+I+MC*(J-1))/DATA($A+I)/(DATA($RHO+I+MC*(J-1))
     1    -HFG*DPSIDH)
      GO TO 200
C  TWO-PHASE FLOW PARAMETERS WITHOUT BOILING.
  150 DATA($ALPHA+I)=0.0
      DATA($RHO  +I+MC*(J-1))=1.0/DATA($V+I)
C     JK INSERT
       IF(J7.NE.2)  GO TO 4
       IF(J.EQ.1)  GO TO 4
      RHODIF = DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))
       DATA($F+I+MC*(J-1))= DATA($F+I+MC*(J-2))-DX/DT*RHODIF*DATA($A+I)
 4     CONTINUE
      DATA($VP   +I)=DATA($V+I)
      DATA($U    +I)=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($VP+I)
      DATA($UH   +I)=DATA($U+I)
      DATA($PHI  +I)=1.0
      DATA($QUAL +I)=0.0
  200 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE STATE(P,TV,TL,ROV,ROL,EV,EL,TSAT,DTSDP,
     1   DELDP,DEVDP,DELDT,DEVDT,DRLDP,DRVDP,DRLDT,DRVDT,IOP,IERR)
C
C
C     SUBROUTINE STATE CALCULATES THE STATE DYNAMIC PROPERTIES OF
C     WATER. THE PRESENT VERSION USES FITS DUE TO BILL RIVARD OF
C     GROUP T-3 OF THE LASL THEORETICAL DIVISION.
C     TAKEN FROM TRAC AND RECODED TO IMPROVE EFFICIENCY.
C     SI UNITS ARE USED
C
C     INPUT VARIABLES
C        1. P    PRESSURE
C        2. TL   TEMPERATURE OF THE LIQUID
C        3. TV   TEMPERATURE OF THE VAPOR
C        4. IOP  OPTION SELECTOR - NOT IN PRESENT VERSION
C
C     OUTPUT VARIABLES
C        1. EV      INTERNAL ENERGY OF THE VAPOR
C        2. EL      INTERNAL ENERGY OF THE LIQUID
C        3. TSAT    SATURATION TEMPERATURE
C        4. ROL     DENSITY OF THE LIQUID
C        5. ROV     DENSITY OF THE VAPOR
C        6. DTSDP   DERIVATIVE OF TSAT WRT PRESSURE
C        7. DELDP   DERIVATIVE OF TL WRT PRESSURE
C        8. DEVDP   DERIVATIVE OF TV WRT PRESSURE
C        9. DELDT   DERIVATIVE OF EL WRT TL
C       10. DEVDT   DERIVATIVE OF EV WRT TV
C       11. DRLDP   DERIVATIVE OF ROL WRT PRESSURE
C       12. DRVDP   DERIVATIVE OF ROV WRT PRESSURE
C       13. DRLDT   DERIVATIVE OF ROL WRT TL
C       14. DRVDT   DERIVATIVE OF ROV WRT TV
C       15. IERR    ERROR FLAG (INPUT VARIABLE OUT OF RANGE)
C
C     CONSTANTS USED IN FITS
C
C     FOR TSAT, CPS
      DATA TSC1,TSC2, TSEXP  /9.0395, 255.2, 0.223/
      DATA CPS1,CPS2, CPSEXP  /9.5875E2, .00132334, -0.8566/
C       CPS2 = -CPSEXP * TCRINV
C     FOR ES, GAMS  IF P < 20 BARS
      DATA G11,G12,G13  /2.6104106E6, -4.995E10, 3.403E5/
      DATA G14,G15,G16  /1.0665544, 1.02E-8, -2.548E-15/
C          G11,G14 ARE ADJUSTED SO THAT ES RESP. GAMS JUMPS LESS THAN
C             1 PART IN 1.E-8 ACROSS P = 20 BARS.
      DATA G17 /-5.096E-15/
C       G17 = 2.* G16
C     FOR ES, GAMS  IF P > 20 BARS
      DATA G21,G22,G23  /2.5896E6, 6.350E-3, -1.0582E-9/
      DATA G24,G25,G26  /1.0764, 3.625E-10, -9.063E-17/
      DATA G27,G28  /-2.1164E-9, -18.126E-17/
C       G27 = 2.* G23,    G28 = 2.* G26
C
      DATA P20B /2.0E6/
      DATA TCRIT /647.3/
      DATA TCRINV /.00154488/
```

```
      DATA CC,CCI,CCM  /1.3, .76923, 0.3/
C
      DATA RL0,RL1,RL2  /1.E3, -2.E-5, -.15E-9/
      DATA RL22  /-.3E-9/
C       RL22 = 2.*RL2
      DATA CL2I  /0.657E-6/
C
C    FOR EL  IF TL < 300 DEG C
      DATA SL0,SL1,SL2,SL3  /-1.4655677D+06, 6.9269554D+03,
     1  -7.7423067E0, 7.2803006D-03/
C           SL0 IS CHOSEN SO THE JUMP IN EL AT 300 DEG C IS AS
C               SMALL AS POSSIBLE
      DATA SL22,SL33 /-15.484613, 2.1840901E-2/
C       SL22 = 2.* SL2,    SL33 = 3.* SL3
C    FOR EL  IF TL > 300 DEG C
      DATA SH0,SH1,SH2,SH3  /-8.9, 2.3639439E+04,
     1  -7.7434017E+01, 7.0215574E-02/
      DATA SH22,SH33 /-1.5486803E2, 2.1064672E-1/
C       SH22 = 2.* SH2,    SH33 = 3.* SH3
C
C    FOR VAPOR
      DATA A11,A12,A13  /1.2959E-3, 593.59, 1.6847E-3/
C
      DATA  HALF,ZERO,ONE,TWO  /0.5, 0., 1., 2./
C
C  -----------------------------------------
C
C     CHECK THAT P, TL, TV, ARE WITHIN RANGE OF FITS
C
      IF (P.GE.1.0E+3.AND.P.LE.190.0E+5) GO TO 5
        IERR = 1
        RETURN
    5 IF (TL.GE.280.0.AND.TL.LE.647.0) GO TO 10
        IERR = 2
        RETURN
   10 IF(TV.GE.280.0) GO TO 20
        IERR = 3
        RETURN
   20 IERR = 0
C
C    CALCULATE SATURATION PROPERTIES
C
C       1. TSAT     SATURATION TEMPERATURE
C       2. DTSDP     DERIVATIVE OF TSAT WRT PRESSURE
C       3. ES       SATURATION INTERNAL ENERGY
C       4. DPES     DERIVATIVE OF ES WRT PRESSURE
C       5. GAMS     GAMMA SUB S
C       6. DPGAMS   DERIVATIVE OF GAMS WRT PRESSURE
C       7. CPS      C SUB PS
C       8. DPCPS    DERIVATIVE OF CPS WRT PRESSURE
C       9. GAMSM    GAMS-ONE
C
      TSAT = TSC1* P**TSEXP
      PINV = ONE/ P
      DTSDP  = TSAT*TSEXP*PINV
```

```
      TSAT = TSAT + TSC2
C
      T1 = ONE - TSAT*TCRINV
      CPS = CPS1* T1**CPSEXP
      DPCPS = CPS2*CPS/T1 *DTSDP
C
      IF (P.GT.P20B) GO TO 150
        T2 = ONE/ (G13+P)
        T1 = T2*G12
        ES = G11 + T1
        DPES = -T1*T2
        GAMS = G14 + P*(G15 + P*G16)
        DPGAMS = G15+G17*P
        GO TO 200
  150 CONTINUE
        ES = G21+(G23*P+G22)*P
        DPES = G22+G27*P
        GAMS = G24+(G26*P+G25)*P
        DPGAMS = G25 + G28*P
  200 GAMSM = GAMS - ONE
C
C
C     CALCULATE LIQUID PROPERTIES
C
C
C        1. INTERNAL ENERGY AND ITS DERIVATIVES
C
      DELDP = 0.
      IF (TL.GE.573.15) GO TO 220
        EL = SL0 + TL*(SL1 + TL*(SL2 + TL*SL3))
        DELDT = SL1 + TL*(SL22 + TL*SL33)
        GO TO 240
  220 CONTINUE
        EL = SH0 + TL*(SH1 + TL*(SH2 + TL*SH3))
        DELDT = SH1 + TL*(SH22 + TL*SH33)
  240 CONTINUE
C
C        2. DENSITY AND ITS DERIVATIVES
C
      ROL = RL0 + EL*(RL1 + EL*RL2)  + P*CL2I
      DRLDP = CL2I
      DRLDE = RL1 + EL*RL22
      DRLDT = DRLDE*DELDT
C
C     CALCULATE VAPOR PROPERTIES
C
      DT = TV-TSAT
      IF (DT.LE.ZERO) GO TO 250
C
C     SUPERHEATED VAPOR
C
C        1. BETA A WORKING PARAMETER
C        2. CAPK A WORKING PARAMETER
C        3. DBETAP  DERIVATIVE OF BETA WRT PRESSURE
C        4. DCAPKP  DERIVATIVE OF CAPK WRT PRESSURE
```

```
C        5. DEVDT
C        6. DEVDP
C        7. ROV
C        8. DRVDE
C        9. DRVDP
C
      T1 = ONE/(A11*CPS-ONE)
      T1SQ = T1*T1
      BETA = TSAT*TSAT*(ONE - T1SQ)
      T2 = TSAT*T1
      DE = A12*(DT+SQRT(TV*TV-BETA)-T2)
      EV = ES + DE
      CAPK = A13*DE+TSAT+T2
      DBETAP = TWO*(BETA*DTSDP+T2*T2*T2*A11*DPCPS)/TSAT
      DCAPKP = -A13*DPES + (ONE + T1)*DTSDP
     1  -TSAT*A11*T1SQ*DPCPS
      T3 = ONE-BETA/(CAPK*CAPK)
      DEVDT = ONE/(HALF*T3*A13)
      DEVDP = -HALF*(T3*DCAPKP+DBETAP/CAPK)*DEVDT
      T4 = ONE/(GAMSM*ES+CCM*DE)
      ROV = P*T4
      DRVDE = -ROV*CCM*T4
      DRVDT = DRVDE*DEVDT
      DRVDP = ROV*(PINV-(ES*DPGAMS+(GAMSM-CCM)*DPES)*T4)
     1   + DRVDE*DEVDP
      GO TO 300
  250 CONTINUE
C
C     SUBCOOLED VAPOR
C
      DEVDT = CPS * CCI
      DE = DT * DEVDT
      EV = ES + DE
      T1 = ONE/ CPS
      DEVDP = -(DTSDP -CC*T1*(DPES +DE*DPCPS*T1) )*DEVDT
      T1 = ONE/ GAMSM
      T2 = ONE/ EV
      ROV = P *T1*T2
      DRVDE = -ROV *T2
      DRVDT = DRVDE * DEVDT
      DRVDP = ROV *(PINV - DPGAMS*T1) + DRVDE*DEVDP
C
  300 CONTINUE
      RETURN
      END
      SUBROUTINE TEMFR(TDUMY,DT,N,TFLUID,HGAP,HSURF,QP,III,NT)
C
C  OVERSEES NEW FUEL ROD MODEL CALCULATIONS
C
      IMPLICIT INTEGER($)
      COMMON /MCOND/ CND(22),RCP(22),RAD(22),RRDR(22),
     1  VM(22),VP(22),QPPP(22)
C
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG
```

```
C                                                                       COB69860
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                 COB69870
C                                                                       COB69880
      DIMENSION TDUMY(1)                                                COB69890
C                                                                       COB69900
CC                                                                      COB69910
CC  QP IS VOLUMETRIC HEAT GENERATION RATE IN FUEL(BTU/SEC-FT**3)        COB69920
CC                                                                      COB69930
      DO 20 JJ=1,NCF                                                    COB69940
   20 QPPP(JJ)=QP                                                       COB69950
      RDELT=1./DT                                                       COB69960
      IF(NT.EQ.1) RDELT=0.                                              COB69970
      IF(NT.EQ.1.AND.III.EQ.1) GO TO 30                                 COB69980
      IF (IPROP.EQ.0) GO TO 30                                          COB69990
      CALL RPROP(TDUMY(1),NCF,NGP,NDM1,HGAP,IPROP)                      COB70000
   30 CALL RTEMPF(TDUMY(1),RDELT,RADR,HSURF,TFLUID,NDS,NDM1)            COB70010
      RETURN                                                            COB70020
      END                                                               COB70030
      SUBROUTINE INITRC                                                 COB70040
C                                                                       COB70050
C  INITIALIZE ARRAYS FOR NEW FUEL ROD MODEL                             COB70060
C                                                                       COB70070
      IMPLICIT INTEGER($)                                               COB70080
      REAL KCLAD,KFUEL                                                  COB70090
C                                                                       COB70100
C                                                                       COB70110
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB70120
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB70130
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB70140
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB70150
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB70160
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB70170
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB70180
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB70190
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB70200
C                                                                       COB70210
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB70220
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB70230
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB70240
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB70250
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB70260
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB70270
C                                                                       COB70280
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB70290
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB70300
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB70310
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB70320
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB70330
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB70340
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB70350
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB70360
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB70370
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB70380
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB70390
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB70400
```

```
C
      COMMON /MCOND/ CND(22),RCP(22),RAD(22),RRDR(22),
     1  VM(22),VP(22),QPPP(22)
C
C
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG
C
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP
C
      COMMON DATA(1)
C
C  INITIALIZE ROD CONDUCTION ARRAYS
C   AND MAKE INITIALIZING CALL TO GAP CONDUCTANCE SUBROUTINE
C
C  GEOMETRY ARRAYS
C
      RADR=DATA($D+1)/2.
      THC=TCLAD(1)
      NDM1=NODESF
      NDS=NODESF+1
      NGP=NCF+1
      DRF=0.5*DFUEL(1)/NCF
      DRC=THC/NCC
      RAD(1)=0.0
      DO 10 K=1,NCF
   10   RAD(K+1)=K*DRF
      RAD(NGP+1)=RAD(NCF+1)+THG
      DO 20 K=1,NCC
   20   RAD(NGP+1+K)=RAD(NGP+1)+K*DRC
      DO 30 K=1,NDM1
        IF(K.EQ.NGP)RRDR(K)=.5*(RAD(K+1)+RAD(K))
        IF(K.NE.NGP)RRDR(K)=.5*(RAD(K+1)+RAD(K))/(RAD(K+1)-RAD(K))
   30   CONTINUE
      VM(1)=0.0
      VP(1)=DRF*DRF/8.0
      DO 40 K=2,NDM1
        RP=0.5*(RAD(K+1)+RAD(K))
        RM=0.5*(RAD(K)+RAD(K-1))
        VP(K)=0.5*(RP*RP-RAD(K)*RAD(K))
   40   VM(K)=0.5*(RAD(K)*RAD(K)-RM*RM)
      RM=0.5*(RADR+RAD(NDM1))
      VM(NDS)=0.5*(RADR*RADR-RM*RM)
      VP(NDS)=0.0
C  ASSUME NO HEAT GENERATED IN GAP OR CLADDING
      DO 105 K=NGP,NDM1
  105 QPPP(K)=0.
C
C  MATERIAL PROPERTY ARRAYS
C
      DO 110 K=1,NCF
        CND(K)=KFUEL(1)
  110   RCP(K)=CFUEL(1)*RFUEL(1)
      CND(NGP)=HGAP(1)
      RCP(NGP)=0.0
```

```
      DO 120 K=1,NCC
        CND(NGP+K)=KCLAD(1)
  120   RCP(NGP+K)=CCLAD(1)*RCLAD(1)
C
C  INITIALIZE GAP CONDUCTANCE DATA
C
      IF(IPROP.LT.2)GO TO 205
      CALL MPG(.TRUE.,BURN,EFFB,FRAC,D3,D4,D5,GRGH,THG,RAD(NGP),
     1 D6,D7,D8,D9,D10,D11)
  205 CONTINUE
      RETURN
      END
      SUBROUTINE RTEMPF (TR,RDT,RADR,HSURF,TFLUID,NODES,NDM1)
C
C  GAUSSIAN SOLUTION OF TRIDIAGONAL TEMPERATURE PROBLEM IN FUEL ROD
C
      COMMON /MCOND/ CND(22),RCP(22),RAD(22),RRDR(22),
     1  VM(22),VP(22),QPPP(22)
C
      DIMENSION A1(23),A2(22),A3(22),B(22),TR(1)
      FSS=1.
      FTR=1.-FSS
      RDELT=RDT
C
C  SET UP COEFFICIENTS OF TRIDIAGONAL MATRIX
C
      A1(1)=0.0
      A2(1)=RRDR(1)*CND(1)+RDELT*VP(1)*RCP(1)
      B(1)=VP(1)*QPPP(1)+RDELT*VP(1)*RCP(1)*TR(1)
      DO 100 K=2,NDM1
        A1(K)=-RRDR(K-1)*CND(K-1)
        A2(K)=-A1(K)+RRDR(K)*CND(K)+RDELT*(VP(K)*RCP(K)+VM(K)*RCP(K-1))
        B(K)=VP(K)*QPPP(K)+VM(K)*QPPP(K-1)+RDELT*(VP(K)*RCP(K)+VM(K)*
     1   RCP(K-1))*TR(K)
  100   CONTINUE
      A1(NODES)=-RRDR(NDM1)*CND(NDM1)
      A2(NODES) = -A1(NODES) + RDELT*VM(NODES)*RCP(NDM1) +
     +  RADR*FSS*HSURF
      B(NODES) = VM(NODES)*QPPP(NDM1) +
     +  RDELT*VM(NODES)*RCP(NDM1)*TR(NODES) +
     +  RADR*HSURF*(TFLUID-FTR*TR(NODES))
      A1(NODES+1)=0.0
C
C  FORWARD ELIMINATION
C
      A2(1)=1./A2(1)
      A3(1)=A1(2)*A2(1)
      B(1)=B(1)*A2(1)
      DO 200 K=2,NODES
        A2(K)=1./(A2(K)-A1(K)*A3(K-1))
        A3(K)=A1(K+1)*A2(K)
        B(K)=(B(K)-A1(K)*B(K-1))*A2(K)
  200   CONTINUE
CC
CC  BACKWARD SUBSTITUTION
```

```
CC
      TR(NODES)=B(NODES)
      DO 250 K=1,NDM1
      KK = NODES-K
  250 TR(KK)=B(KK)-TR(KK+1)*A3(KK)
C
C
      RETURN
      END
      SUBROUTINE RPROP(TRN,NCF,NGP,NDM1,HGAP,IPROP)
C
C  GET MATERIAL AND GAP PROPERTIES FOR ROD CONDUCTION CALCULATION
C
      COMMON /MCOND/ CND(22),RCP(22),RAD(22),RRDR(22),
     1  VM(22),VP(22),QPPP(22)
C
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG
C
      DIMENSION TRN(1)
C
C  COMPUTE FUEL PROPERTIES
C
      DO 100 K=1,NCF
        ATEMP=0.5*(TRN(K+1)+TRN(K))
        CALL MPF(ATEMP,FTD,FPUO2,RCP(K),CND(K))
  100   CONTINUE
C
C  COMPUTE CLAD PROPERTIES
C
      KSTART=NGP+1
      DO 200 K=KSTART,NDM1
        ATEMP=0.5*(TRN(K+1)+TRN(K))
        CALL MPC(ATEMP,RCP(K),CND(K))
  200   CONTINUE
C
C  CALCULATE GAP HEAT TRANSFER COEFFICIENT
C
      IF(IPROP.LT.2) GO TO 300
      TGAP=(TRN(NGP)+TRN(NGP+1))*0.5
      CALL MPG(.FALSE.,BURN,EFFB,FRAC,FPRESS,CPR,EXPR,GRGH,THG,
     1 RAD(NGP),PGAS,TGAP,GMIX,TRN(NGP),TRN(NGP+1),HGAP)
  300 CONTINUE
      CND(NGP)=HGAP
      RCP(NGP)=0.0
  305 RETURN
      END
      SUBROUTINE MPF (TFUEL, FTD, FPUO2, RCP, COND)
C
C  CALCULATES HEAT CAPACITY AND CONDUCTIVITY OF UO2 AND PUO2 FUELS AS
C     FUNCTIONS OF TEMPERATURE, FRACTION OF THEORETICAL DENSITY, AND
C     PLUTONIUM CONTENT
C
C  ARGUMENTS
C     INPUT      TFUEL    TEMPERATURE (DEG F)
```

```
C               FTD      FRACTION OF THEORETICAL DENSITY
C               FPUO2    PLUTONIUM FRACTION BY VOLUME
C    RETURN     RCP     HEAT CAPACITY (BTU/FT**3-DEG F)
C               COND    CONDUCTIVITY (BTU/SEC-FT-DEG F)
C
C  THIS SUBROUTINE IS BASED ON EXPRESSIONS USED IN MATPRO; SEE
C    TREE-NUREG-1005, APPENDIX A. THOSE EXPRESSIONS HAVE BEEN APPROXI-
C    MATED BY POLYNOMIAL FITS WHOSE MAXIMUM ERRORS ARE ABOUT ONE
C    STANDARD DEVIATION IN EXPERIMENTAL DATA.
C       RCP ERROR =  2 PER CENT      300 < TEM < 3000 DEG K
C       COND ERROR = 10 PER CENT      400 < TEM < 2500 DEG K
C
      DIMENSION RC(4), RCM(4), CN(3), CNM(3)
      DATA  RC /1.78E6, 3.62E3, -2.61, 6.59E-4/
      DATA RCM /1.81E6, 3.72E3, -2.57, 6.13E-4/
      DATA  CN /10.8, -8.84E-3, 2.25E-6/
      DATA CNM /9.88, -8.44E-3, 2.25E-6/
      DATA CVTC,CVTRC/1.61E-4, 1.49E-5/
C
C-----------------------------------------------
C
      TEM=.5556*(TFUEL+459.7)
      IF (FPUO2.GT.1.E-7)  GO TO 20
C
C  UO2 FUEL
C
   10 RCP = FTD*( RC(1)+ TEM*(RC(2) +TEM*(RC(3) +TEM*RC(4))) )
      BT = 2.74 - TEM * 5.8E-4
      POR = 1.- BT*(1.- FTD)
C--THE FACTOR  /(1.-BT*(1.-.95)) IS INCORPORATED IN THE FIT CN(3)
      COND = POR*( CN(1)+ TEM*(CN(2)+ TEM*CN(3)) )
      GO TO 100
C
C  MIXED OXIDE FUEL
C
   20 RCP = FTD *(1.+.045+FPUO2) *
     *         (RCM(1)+ TEM*(RCM(2)+ TEM*(RCM(3)+ TEM*RCM(4))) )
      BT = 2.74 - TEM * 5.8E-4
      POR = FTD / (1.+ BT*(1.-FTD))
C          THE FACTOR (1.+BT*(1.-.96))/.96 IS INCORPORATED IN CNM(3)
      COND = POR*( CNM(1)+ TEM*(CNM(2)+ TEM*CNM(3)) )
C
C
  100 CONTINUE
CC COND CONVERTED FROM (W/M-DEG K) TO (BTU/SEC-FT-DEG F)
      COND=COND*CVTC
CC RCP CONVERTED FROM (J/M**3-DEG K) TO (BTU/FT**3-DEG F)
      RCP=RCP*CVTRC
      RETURN
      END
      SUBROUTINE  MPG (INIT, BURN, EFFB, FRAC, PRESS, CPR, EXPR, GRGH,
     1      THG, RADFU, PG, TG, GMIX, TF, TC, HGAP)
C
C  CALULATES GAP HEAT TRANSFER COEFFICIENT, IN THREE PARTS:
C     1. OPEN GAP COMPONENT, BASED ON CONDUCTIVITY OF A MIXTURE OF FOUR
```

```
C        NOBLE GASES; A SMALL GAP CORRECTION IS APPLIED IF PGAS > 0.
C     2. CONTRIBUTION FROM PARTIAL FUEL-CLAD CONTACT
C     3. RADIATION COMPONENT
C  IF RADFU > (RADFU+THG) - ROUGH, THEN IN ADDITION TO THE ABOVE:
C     4. CLOSED GAP LAW = CPR * (PRESS**EXPR)
C
C  PARTS 1 & 2 ARE BASED ON TREE-NUREG-1005, APPENDIX C, WITH CRACKED
C    PELLET MODEL; PART 4 IS USER-SUPPLIED.
C
C  MPG IS CALLED WITH INIT = .TRUE. TO PERFORM INITIALIZATION
C   NORMAL CALLS HAVE INIT = .FALSE.
C
C  ARGUMENTS: INIT = .TRUE.
C    INPUT       BURN      BURNUP (MWD/MTU)
C                GRGH      ROOT MEAN SQUARE OF FUEL PELLET AND CLADDING
C                            SURFACE ROUGHNESSES (FT)
C                THG       GAP THICKNESS (FT)
C    RETURN      GRGH      IF GRGH  = 0 ON INPUT, A DEFAULT VALUE OF
C                            1.34E-6 FEET IS RETURNED
C                EFFB      FRACTIONAL EFFECT OF BURNUP, USED IN PARTIAL
C                            FUEL-CLAD CONTACT MODEL
C                FRAC      FRACTION OF FUEL PERIMETER IN LIGHT CONTACT
C                            WITH CLAD
C
C  ARGUMENTS: INIT = .FALSE. (NORMAL ENTRY)
C    INPUT       FRAC      FRACTION OF FUEL PERIMETER TOUCHING CLAD
C                PRESS     PRESSURE OF FUEL AGAINST CLAD FOR CLOSED GAP
C                CPR       COEFFICIENT OF PRESS
C                EXPR      EXPONENT OF PRESS
C                GRGH      RMS OF FUEL AND CLAD GRGH NESSES (FT)
C                THG       GAP THICKNESS (FT)
C                PG        PRESSURE OF GAS MIXTURE IN GAP, FOR SMALL GAP
C                            CORRECTION FACTOR (PSIA)
C                TG        TEMPERATURE OF GAS MIXTURE IN GAP (DEG F)
C                GMIX      FOUR MOLE FRACTIONS OF NOBLE GASES
C                            1. HELIUM
C                            2. ARGON
C                            3. KRYPTON
C                            4. ZENON
C                              THE FOUR ELEMENTS OF GMIX MUST SUM TO 1
C                TF        TEMPERATURE OF FUEL PELLET SURFACE (DEG F)
C                TC        TEMPERATURE OF INNER CLAD SURFACE (DEG F)
C    RETURN      HGAP      GAP HEAT TRANSFER COEFFICIENT (BTU/FT**3-DEG F)
C
      LOGICAL  INIT
      DIMENSION  GMIX(4)
C
      DIMENSION AM(4,4), BM(4,4)
C       COMBINING FACTORS WHICH ARE FUNCTIONS ONLY OF THE MOLECULAR
C       WEIGHTS OF THE FOUR NOBLE GASES
      DATA AM / 0.,   .295, .232, .194,
     2          .362, 0.,   .309, .332,
     3          .413, .235, 0.,   .286,
     4          .435, .260, .232, 0.    /
      DATA BM / 0.,   1.78, 2.14, 2.39,
```

```
     2          .563, 0.,   1.20, 1.35,
     3          .467, .831, 0.,   1.12,
     4          .418, .743, .894, 0.    /
      DIMENSION CC(4), EE(4), CON(4), CSR(4)
      DATA CC / 3.366E-3, 3.421E-4, 4.029E-5, 4.726E-5 /
      DATA EE / .668, .701, .872, .923 /
C
C---------------------------------------------------
C
CC CONVERT TO DGAP(M)
      DGAP = THG*.3048
CC TEMPERATURES CONVERTED FROM (DEG F) TO (DEG K)
      TCLAD=.5556*(TC+459.67)
      TGAS=.5556*(TG+459.67)
      TFUEL=.5556*(TF+459.67)
      TGAS=.5556*(TG+459.67)
CC CONVERT TO PGAS(N/M**2)
      PGAS=PG*6.893E3
CC CONVERT TO ROUGH(M)
      ROUGH=GRGH*.3048
C
      IF (INIT) GO TO 200
C
C  NOBLE GAS CONDUCTIVITIES
C
      CON(1) = 0.
      DO  10  I = 1, 4
        IF (GMIX(I).LT.1.E-6)  GO TO 10
        CON(I) = CC(I) *(TGAS**EE(I))
        CSR(I) = SQRT(CON(I))
   10   CONTINUE
C  SMALL GAP CORRECTION FOR HELIUM:
      GAP = AMAX1  (ROUGH, DGAP)
      FAC = PGAS * GAP
      IF (FAC.LT.1.E-9)  GO TO 15
        CON(1) = CON(1) / (1.+ CON(1)*.2103*SQRT(TGAS)/FAC)
        CSR(1) = SQRT(CON(1))
   15 CONTINUE
C
C  MIXTURE CONDUCTIVITY
C
      GCOND = 0.
      DO  30  I = 1, 4
        IF (GMIX(I).LT.1.E-6) GO TO 30
        XSUM = GMIX(I)
        DO  20  J = 1, 4
          IF (J.EQ.I) GO TO 20
          IF (GMIX(J).LT.1.E-6) GO TO 20
          TS = CSR(J) + CSR(I)*BM(I,J)
          XSUM = XSUM + GMIX(J)*AM(I,J)*TS*TS/CON(J)
   20     CONTINUE
        GCOND = GCOND + CON(I)*GMIX(I)/XSUM
   30 CONTINUE
C
      HGAP = GCOND /(DGAP + ROUGH)
```

```
C
C  PARTIAL FUEL-CLAD CONTACT MODEL
C
      HGAP = (1.-FRAC)*HGAP + FRAC*GCOND/ROUGH
C
C  RADIATION HEAT TRANSFER CONTRIBUTION
C
      REMISF = AMAX1(1.1485, AMIN1(2.451, -.154+TFUEL*1.3025E-3 ))
      REMISC = 1.33
      RFVIEW = REMISF + (REMISC-1.)*RADFU/(RADFU+THG)
C
      HGAP = HGAP +
     +   5.279E-8*(TFUEL+TCLAD)*(TFUEL*TFUEL+TCLAD*TCLAD)/RFVIEW
CC  CONVERT HGAP FROM (W/M**2-DEG K)) TO (BTU/SEC-FT**2-DEG F)
      HGAP=HGAP*4.89E-5
CC
C
C  CLOSED GAP CONTACT HEAT TRANSFER
C
      IF (DGAP .GE. ROUGH)  RETURN
      HGAP = HGAP +  CPR * (PRESS **EXPR)
C
C
C
      RETURN
C
C  INITIALIZATION OF MPG, CALLED ONLY ONCE
C
  200 IF (GRGH.LE.0.)  GRGH = 1.34E-6
C
C  FRACTION OF FUEL IN LIGHT CONTACT WITH CLAD, A FUNCTION OF BURNUP
C
C--FRACTIONAL EFFECT OF BURNUP, INDEPENDENT OF FUEL RADIUS
      IF (BURN-600.) 210,210,220
  210   EFFB = 0.
        GO TO 230
  220 CONTINUE
        TS = .001*BURN - .6
        TS = TS*TS
        EFFB = 1.- 1./(TS*TS + 1.)
  230 CONTINUE
C--FRACTION OF CIRCUMFERENCE OF FUEL IN LIGHT CONTACT WITH CLAD
      A1 = 100. - 98.*EFFB
      A2 = 4. - .5*EFFB
      FRAC = 1./ (A1*(100.*DGAP/RADFU)**A2 + 1.42857) + .3
      RETURN
      END
      SUBROUTINE MPC (TCL, RCP, COND)
C
C  CALCULATES HEAT CAPACITY AND CONDUCTIVITY OF ZIRCALOY AS A FUNCTION
C    OF TEMPERATURE
C
C  ARGUMENTS
C    INPUT      TCL      TEMPERATURE (DEG F)
C    RETURN     RCP      HEAT CAPACITY (BTU/FT**3-DEG F)
```

```
C               COND     CONDUCTIVITY (BTU/SEC-FT-DEG F)
C
C  THIS SUBROUTINE IS BASED ON DATA IN TREE-NUREG-1005, APPENDIX B.
C    CONDUCTIVITY IS USED UNCHANGED. HEAT CAPACITY HAS BEEN FIT
C    LINEARLY IN THE ALPHA PHASE (TEM < 1190), BY A CONSTANT IN THE
C    BETA PHASE (TEM > 1254), AND BY AN INVERTED VEE IN THE TRANSITION.
C    ERROR IS 5 PER CENT IN THE ALPHA PHASE, 300 < TEM < 1190 DEG K.
C
      DIMENSION CN(4)
      DATA CN /7.51, 2.09E-2, -1.45E-5, 7.67E-9 /
      DATA CVTC,CVTRC/1.61E-4, 1.49E-5/
C
C---------------------------------------------------
C
C  HEAT CAPACITY
C
CC CONVERT TO TEM (DEG K)
      TEM=.5556*(TCL+459.67)
      IF (TEM.GT.1090.)  GO TO 20
C  ALPHA PHASE:    (0 < TEM < 1090 DEG K, USUAL CASE)
      RCP = 1673456. + TEM * 721.6
      GO TO 50
C
   20 IF (TEM.GE.1254.)  GO TO 30
        RCP = 5346400. - 36080.*ABS(TEM-1170.)
        GO TO 50
   30   RCP = 2315680.
C
   50 CONTINUE
C
C  CONDUCTIVITY
C
      COND = CN(1)+ TEM*(CN(2)+ TEM*(CN(3)+ TEM*CN(4)))
C
CC CONVERT COND FROM (W/M-DEG K) TO (BTU/SEC-FT-DEG F)
      COND = COND*CVTC
CC CONVERT RCP FROM (J/M**3-DEG K) TO (BTU/FT**3-DEG F)
      RCP = RCP*CVTRC
      RETURN
      END
      SUBROUTINE HTCOR(IHTR,QV,QL,HVFC,HLNB,HLFC,TW,TL,TV,P,ALP,X,
     1         ROV,ROL,VV,VL,HD,IHTM,CHFR,TSAT,FLUX,NCHF,NN,II,JJ,I3)
C
C  THIS ROUTINE COMPUTES HEAT TRANSFER COEFFICIENTS AND/OR HEAT
C  FLUXES
C
C  THE TOTAL HEAT FLUX IS ASSUMED TO BE OF THE FORM:
C  Q=QV+QL+HVFC(TW-TV)+HLNB(TW-TSAT)+HLFC(TW-TL)
C
C  NORMALLY QV AND QL WILL BE ZERO AND ONE OR MORE OF THE HEAT
C  TRANSFER COEFFICIENTS HVFC, HLNB, AND HLFC WILL BE NON-ZERO.
C  IN TRANSITION BOILING, HOWEVER, THE HEAT TRANSFER COEFFICIENTS ARE
C  ZERO AND Q=QV+QL.
C
C  NOMENCLATURE:
```

```
C
C  QV      HEAT FLUX TO VAPOR (W/M**2)
C  QL      HEAT FLUX TO LIQUID (W/M**2)
C  HVFC    CONVECTION HEAT TRANSFER COEFFICIENT TO VAPOR (W/M**2 K)
C  HLNB    NUCLEATE BOILING HEAT TRANSFER COEFFICIENT (W/M**2 K)
C  HLFC    CONVECTION HEAT TRANSFER COEFFICIENT TO LIQUID (W/M**2 K)
C  TW      WALL TEMPERATURE (K)
C  TL      LIQUID TEMPERATURE (K)
C  TV      VAPOR TEMPERATURE (K)
C  P       PRESSURE (P)
C  ALP     VAPOR VOLUME FRACTION
C  ROV     VAPOR DENSITY (KG/M**3)
C  ROL     LIQUID DENSITY (KG/M**3)
C  VV      VAPOR VELOCITY (M/S)
C  VL      LIQUID VELOCITY (M/S)
C  HD      HYDRAULIC DIAMETER (M)
C  TSAT    SATURATION TEMPERATURE (K)
C
C
C  NOTE: THE FOLLOWING QUANTITIES ARE AVAILABLE AND,
C  IF DESIRED, COULD BE ADDED TO THE ARGUMENT LIST OF
C  HTCOR AND THE CORRESPONDING CALL STATEMENT:
C
C  TCHF    TEMPERATURE AT CRITICAL HEAT FLUX
C  TMSFB   MINIMUM STABLE FILM BOILING TEMPERATURE
C  QCHF    CRITICAL HEAT FLUX
C  QMSFB   HEAT FLUX AT TMSFB
C
      COMMON/HTSAVE/BETAV,BETAL,CPV,CPL,HFG,SPVV,SPVL,
     1  ROVS,ROLS,EV,EL,DTSDP,DELDP,DEVDP,DELDT,DEVDT,
     2  DRLDP,DRVDP,DRLDT,DRVDT
C
      COMMON/CHFSV/CHSAVE(20,20,31)
C
      DATA GCON/9.8066/
      HVFC=0.0
      HLFC=0.0
      HLNB=0.0
      CHFR=1.0
      QV=0.0
      QL=0.0
      IHTR=0
      VVA=ABS(VV)
      VLA=ABS(VL)
      RHD=1./HD
C  PROPERTIES CALCULATED ONCE EACH TIME STEP AND SAVED
      IF(JJ.GT.1.OR.II.GT.1) GO TO 4
C
C  OBTAIN FLUID PROPERTIES
C  (RUNNING TIME COULD BE SHORTENED BY REPLACING THE
C  FOLLOWING CALL TO STATE AND THE SUBSEQUENT COMPUTATION OF
C  HFG, BETAV, BETAL, CPV, AND CPL BY APPROPRIATE FITS TO
C  THESE QUANTITIES)
C
C  PROPERITES OBTAINED FROM STATE AT SATURATION TEMP. CORRESP.
```

```
C  TO PRESSURE P.
C
      TSAT1 = 9.0395*POW(P,.223E0) + 255.2
      CALL STATE(P,TSAT1,TSAT1,ROVS,ROLS,EV,EL,TSAT,DTSDP,DELDP,
     1 DEVDP,DELDT,DEVDT,DRLDP,DRVDP,DRLDT,DRVDT,2,IERR)
      SPVV = 1./ROVS
      SPVL = 1./ROLS
      HFG = EV+P*SPVV -EL-P*SPVL
      BETAV = -DRVDT*SPVV
      BETAL = -DRLDT*SPVL
      CPV = DEVDT -P*DRVDT*SPVV*SPVV
      CPL = DELDT -P*DRLDT*SPVL*SPVL
    4 CONTINUE
      VISV = VISVP(TV)
      VISL = VISLQ(TL)
      CNDV = CONDV(P,TV)
      CNDL = CONDL(P,TL)
      SIG = SURTT(TL)
C
      GV = ALP*ROV*VVA
      GL = (1.-ALP)*ROL*VLA
      G = GV + GL
   10 CONTINUE
C
C           ... DETERMINE HEAT TRANSFER REGIME ...
C
C  TEST QUALITY
C
      IF(X.GE.0.99)GO TO 300
C
C  TEST FOR COLD WALL
C
      IF(TW.LE.TSAT)GO TO 200
C
      IF(IHTM.LT.2)GO TO 30
C
C  COMPUTE MINIMUM STABLE FILM BOILING TEMPERATURE
C
      IF (P.GT.68.96E5) GO TO 20
      THN = 581.5 + .01876*SQRT( AMAX1(P-1.0345E5,(0.)) )
      GO TO 25
   20 THN = 630.37 + .00432*SQRT(P-68.96E5)
   25 CONTINUE
      PSI=0.0
      IF (P.LT.4.827E5) PSI = 127.3 - 26.37E-5*P
C     CALL MPC(TW,RCP,COND)
C     RRKCPW = 1./(RCP*COND)
C  INVERSE OF ROCP OF ZIRCALOY TIMES CONDUCTIVITY OF OXIDE
      RRKCPW = 3.1E-7 - 1.3E-10*TW
      RKCPL=ROL*CNDL*CPL
C
      TMSFB = THN + (THN-TL)*POW(RKCPL*RRKCPW,.5E0) - PSI
C
C  TEST WHETHER TWALL EXCEEDS TMSFB
C
```

```
      IF(TW.LT.TMSFB)GO TO 30
C
C  COMPUTE FILM BOILING HEAT TRANSFER COEFFICIENT
C
      CALL FILM(HVFC,ALP,ROV,ROL,VVA,VLA,HD,RHD,TL,TV,TW,TSAT,HFG,
     1 CPV,CPL,P,VISV,VISL,BETAV,SIG,IHTR,X)
      GO TO 1000
C
C
   30 CONTINUE
C
C  DETERMINE HEAT TRANSFER COEFFICIENTS USING CHEN CORRELATION
C
      RVISL = 1./VISL
      XTTI=POW(X/(1.-X),.9E0) *SQRT(ROL/ROV) *POW(VISV*RVISL,.1E0)
      F=1.0
      GX = G
      IF(TL.LT.TSAT) GO TO 32
      IF(XTTI.GT.0.1)F=2.35*POW(XTTI+.213E0,.736E0)
      GX = GL
   32 PRL = VISL*CPL/CNDL
      REL = GX*HD*RVISL
      HLF = .023*F*CNDL*RHD* POW(REL,.8E0) *POW(PRL,.4E0)
      RETP = REL *POW(F,1.25E0)*1.E-4
      S=.1
      IF(RETP.LT.70.0.AND.RETP.GE.32.5) S=1./(1.+.42*POW(RETP,.78E0))
      IF(RETP.LT.32.5) S=1./(1.+.12*POW(RETP,1.14E0))
      HS = .00122*S*SQRT(CNDL*CPL/(SIG*GCON) ) *POW(PRL,-.29E0) *
     *        POW(ROL,.25E0) *POW(CPL*ROL/(HFG*ROV),.24E0)
      PWALL = (.11062558*(TW-255.2))**4.4843049
      HLN = HS*POW(TW-TSAT,.24E0)*POW(PWALL-P,.75E0)
C
C  COMPUTE HEAT FLUX AS PREDICTED BY CHEN'S CORRELATION AND
C  COMPARE AGAINST THE CRITICAL HEAT FLUX
C
      QCHEN = HLF*(TW-TL) + HLN*(TW-TSAT)
      IF(IHTM.LT.2) GO TO 400
C
C  CALCULATE CRITICAL HEAT FLUX
C
C
CC BTU/S-FT**2 = 11400. W/M**2
C
      CVTHF=11400.
      IF (NCHF.EQ.5.AND.(NN.GT.20.OR.II.GT.20.OR.JJ.GT.30)) GOTO 2000
      IF(NCHF.EQ.1) QCHF=CVTHF*CHF1(NN,II,JJ+1)
      IF (NCHF.EQ.2) QCHF=CVTHF*CHF2(NN,II,JJ+1)
      IF (NCHF.EQ.3) QCHF=CVTHF*CHF3(NN,II,JJ+1)
      IF (NCHF.EQ.4) QCHF=CVTHF*CHF4(NN,II,JJ+1)*FLUX
      IF(NCHF.EQ.5) CALL CHF5(QCHF,ALP,ROV,ROL,G,P,X,HD,HFG,SIG)
      CHSAVE(NN,II,JJ)=QCHF/CVTHF
C
      IF(QCHEN.LE.QCHF) GO TO 400
C
C
```

```
C  SOLVE THE EQUATION
C       HLFC*(TCHF-TL) +HLNB*(TCHF-TSAT)**1.24*(PWALL-P)**.75  = QCHF
C  FOR TCHF USING NEWTON'S ITERATION
C
      TCHF=AMAX1(TL,TSAT+.1)
      DO 35 K=1,10
        TCS=AMAX1(TCHF-TSAT,(0.))
        PWALL=(.11062558*(TCHF-255.2))**4.4843049
        DQ = QCHF-HLF*(TCHF-TL)-HS*POW(TCS,1.24E0)*POW(PWALL-P,.75E0)
        DQDT = HLF + HS*POW(TCS,.24E0)*POW(PWALL-P,.75E0) *
     *    (1.24 + 3.3632287*TCS*PWALL/((TCHF-255.2)*(PWALL-P)) )
        DTCHF = DQ/DQDT
        TCHF = TCHF + DTCHF
        IF(ABS(DTCHF).LE.0.1)GO TO 40
   35   CONTINUE
   40 CONTINUE
      GO TO 500
C
C          ... INDIVIDUAL CORRELATIONS FOLLOW ...
C
C
C  CONVECTION TO SINGLE PHASE LIQUID
C  MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS
C
C  NOTE: MCADAMS SHOULD EVALUATE PROPERTIES AT A LIQUID FILM TEMP
C
  200 CONTINUE
      T1=ROL*ROL*GCON*BETAL*CPL*ABS(TW-TL)/(VISL*CNDL)
      HMA=.13*CNDL*POW(T1,.333333E0)
      REL=ROL*VLA*HD/VISL
      PRL=VISL*CPL/CNDL
      VISW=VISLQ(TW)
       HST=.023*CNDL*RHD*POW(REL,.8E0)*POW(PRL,.33E0)*
     1 POW(VISL/VISW,.14E0)
      HLFC=AMAX1(HMA,HST)
      CHFR=100.0
      IHTR=1
      IF(HMA.GT.HST) IHTR=2
      GO TO 1000
C
C  CONVECTION TO SINGLE PHASE VAPOR
C  MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS
C
C  NOTE:  MCADAMS SHOULD EVALUATE PROPERTIES AT A VAPOR FILM TEMP
C
  300 CONTINUE
      T1=ROV*ROV*GCON*BETAV*CPV*ABS(TW-TV)/(VISV*CNDV)
      HMA=.13*CNDV*POW(T1,.333333E0)
      REV=ROV*VVA*HD/VISV
      PRV=VISV*CPV/CNDV
      VISW=VISVP(TW)
      HST=.023*CNDV*RHD*POW(REV,.8E0)*POW(PRV,.33E0)*
     1  POW(VISV/VISW,.14E0)
      HVFC=AMAX1(HMA,HST)
      IHTR=9
```

```
      IF(HMA.GT.HST) IHTR=10
      GO TO 1000
C
C  SUBCOOLED OR SATURATED NUCLEATE BOILING
C  CHEN CORRELATION
C
  400 CONTINUE
      HLFC = HLF
      HLNB = HLN
      IHTR=4
      IF(TL.LT.TSAT) IHTR=3
      GO TO 1000
C
C  TRANSITION BOILING
C
  500 CONTINUE
      CALL FILM(HVTB,ALP,ROV,ROL,VVA,VLA,HD,RHD,TL,TV,TMSFB,TSAT,HFG,
     1 CPV,CPL,P,VISV,VISL,BETAV,SIG,IHTR,X)
      RDTMC = 1./(TMSFB-TCHF)
      EPS = (TMSFB-TW)*RDTMC
      EPS2 = EPS*EPS
      QMSFB=HVTB*(TMSFB-TV)
      QV=(1.-EPS2)*QMSFB
      QL=EPS2*QCHF
      DQLDTW = -2.*EPS*QCHF*RDTMC
      DQVDTW = 2.*EPS*QMSFB*RDTMC
      HLFC = DQLDTW
      QL = QL + DQLDTW*(TL-TW)
      HVFC = DQVDTW
      QV = QV + DQVDTW*(TV-TW)
      IHTR=5
C
C
C
 1000 CONTINUE
      RETURN
 2000 WRITE(I3,2020)
 2020 FORMAT(1H ,' ERROR DETECTED IN SUBROUTINE HTCOR.  ATTEMPT TO USE',
     1  ' NCHF=5 OPTION FOR TOO LARGE A PROBLEM.')
      CALL EXIT
      END
      SUBROUTINE FILM(H,ALP,ROV,ROL,VVA,VLA,HD,RHD,TL,TV,TW,TSAT,HFG,
     1  CPV,CPL,P,VISV,VISL,BETAV,SIG,IHTR,X)
      DATA GCON,PI2/9.8066,6.2831853/
C
C  NOTE: IN BROMLEY'S AND MCADAMS' CORRELATIONS VAPOR PROPERTIES
C        ARE EVALUATED AT BULK VAPOR TEMPERATURE AND NOT
C        AT VAPOR FILM TEMPERATURE.
C        IN GROENEVELD'S CORRELATION THE VAPOR PRANDTL NUMBER
C        IS EVALUATED AT BULK VAPOR TEMPERATURE AND NOT
C        AT WALL TEMPERATURE.
C
C
C   HIGH FLOW FILM BOILING
C   GROENEVELD 5.7 OR MODIFIED DITTUS-BOELTER (FOR LOW PRESSURE)
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C                                                                       COB77560
      CNDV = CONDV(P,TV)                                                COB77570
      REV = HD*ROV*(VLA+ALP*(VVA-VLA))/VISV                             COB77580
      PRV = VISV*CPV/CNDV                                               COB77590
      IF(P.LT.1.33E6) GO TO 10                                          COB77600
      Y = 1.-.1*POW((1.-X)*((ROL/ROV)-1.),.4E0)                         COB77610
      HGDB = .052*CNDV*RHD *POW(REV,.688E0)*POW(PRV,1.26E0)*            COB77620
     1  POW(Y,-1.06E0)                                                  COB77630
      IHTR = 6                                                          COB77640
      GO TO 20                                                          COB77650
   10 HGDB = .023*CNDV*RHD *POW(REV,.800E0)*POW(PRV,0.40E0)             COB77660
      IHTR = 7                                                          COB77670
   20 CONTINUE                                                          COB77680
      H = HGDB                                                          COB77690
C                                                                       COB77700
C   TEST FOR LOW OR HIGH FLOW                                           COB77710
C                                                                       COB77720
      AJG =      ALP *ROV*VVA/SQRT(GCON*HD*ROV*(ROL-ROV))               COB77730
      AJF = (1.-ALP)*ROL*VLA/SQRT(GCON*HD*ROL*(ROL-ROV))                COB77740
      AJ = SQRT(AJG)+SQRT(AJF)                                          COB77750
      IF(AJ.GE.2.0) RETURN                                              COB77760
C                                                                       COB77770
C   LOW FLOW FILM BOILING                                               COB77780
C   BROMLEY PLUS MAX OF MCADAMS AND FORCED CONVECTION(AS FOR HIGH FLOW) COB77790
C                                                                       COB77800
      CLAM = PI2*SQRT(SIG/(ROL-ROV))                                    COB77810
      HFGP = HFG+0.5*CPV*(TW-TSAT)                                      COB77820
      T1 = GCON*(ROL-ROV)*ROV*(CNDV**3)*HFGP/(CLAM*VISV*(TW-TSAT))      COB77830
      HMB = .62*POW(T1,.25E0)                                           COB77840
C                                                                       COB77850
      T1 = ROV*ROV*GCON*BETAV*CPV*ABS(TW-TV)/(VISV*CNDV)                COB77860
      HMA = .13*CNDV*POW(T1,.333333E0)                                  COB77870
C                                                                       COB77880
      H = (1.-ALP)*HMB + ALP*AMAX1(HGDB,HMA)                            COB77890
      IHTR = 8                                                          COB77900
C                                                                       COB77910
      RETURN                                                            COB77920
      END                                                               COB77930
      SUBROUTINE CHF5(QCHF,ALP,ROV,ROL,G,P,X,HD,HFG,SIG)                COB77940
C                                                                       COB77950
C  DETERMINES CRITICAL HEAT FLUX                                        COB77960
C                                                                       COB77970
      DATA GCON/9.8066/                                                 COB77980
      DATA EE /2.7182818/                                               COB77990
C                                                                       COB78000
      PBAR=1.0E-5*P                                                     COB78010
      GHI=1350.0                                                        COB78020
      GLO=27.0                                                          COB78030
      IF(PBAR.GE.83.0.AND.X.GE.0.5)GHI=270.0                            COB78040
      IF(G.LT.GLO)GO TO 20                                              COB78050
C                                                                       COB78060
C  BIASI CORRELATION FOR HIGH FLOW                                      COB78070
C                                                                       COB78080
      EN=-0.4                                                           COB78090
      IF(HD.LT.0.01)EN=-0.6                                             COB78100
```

```
      GT=AMAX1(G,GHI)
      Q10=0.0
      IF(GT.LT.300.0)GO TO 10
      F=.7249 + .099*PBAR*POW(EE,-(.032)*PBAR)
      G6=POW(GT,(-.166667))
      Q10=2.764E7*POW(100.E0*HD,EN)*G6*(1.468*F*G6-X)
   10 CONTINUE
      H=-1.159 + .149*PBAR*POW(EE,-.019E0*PBAR) + 8.99*PBAR/
     1 (10.+PBAR*PBAR)
      Q11=15.048E7*H*POW(100.E0*HD,EN)*POW(GT,(-.6))*(1.0-X)
      QB=AMAX1(Q10,Q11)
      QCHF=QB
C
C
      IF(G.GE.GHI)GO TO 100
   20 CONTINUE
C
C  CHF-VOID CORRELATION FOR LOW FLOW
C
      T1=SIG*GCON*GCON*(ROL-ROV)*ROV*ROV
      QVC=.1178*(1.-ALP)*HFG*POW(T1,(.25))
      QCHF=QVC
C
C
      IF(G.LE.GLO)GO TO 100
C
C  LINEAR INTERPOLATION BETWEEN BIASI AND CHF-VOID
C
      WT=(G-GLO)/(GHI-GLO)
      QCHF=WT*QB+(1.-WT)*QVC
C
  100 CONTINUE
      RETURN
      END
      FUNCTION POW(A,B)
C
C  THIS FUNCTION IS CALLED WHENEVER A LOW ACCURACY EXPONENTIATION
C   WOULD BE ADEQUATE
C
      POW=A**B
      RETURN
      END
      FUNCTION  CONDL (P, TL)
C
C  THERMAL CONDUCTIVITY OF LIQUID WATER
C    W/M DEG K    FUNCTION OF    PASCAL,  DEG K
C
C  ERROR OF APPROXIMATION < 5 PERCENT FOR  273 < TL < 573 DEG K
C  VALUE AT 150 BAR, 300 DEG C = .55
C
      TS = TL - 415.
      CONDL = .686 - 5.87E-6*TS*TS + 7.3E-10*P
      RETURN
      END
      FUNCTION  CONDV (P, TV)
```

```
C
C  THERMAL CONDUCTIVITY OF DRY STEAM
C    W/M DEG K     FUNCTION OF     PASCAL,  DEG K
C
C  ERROR OF APPROXIMATION < 10 PERCENT FOR  373 < TV < 623 AND
C    P IN SUPERHEATED REGION
C  FOR LOW P, CONDV DEPENDS MORE ON TV, FOR P > 50 BAR CONDV DEPENDS
C    MORE ON P.
C  VALUE AT SATURATION FOR 70 BAR = .061
C
      CONDV = -.0123 + P*(7.8E-9 + P*2.44E-16) +
     +            1.25E-11*TV*(80.E5 - P)
      RETURN
      END
      FUNCTION VISLQ (TL)
C
C  VISCOSITY OF SATURATED LIQUID WATER
C    KG/M SEC    FUNCTION OF     DEG K
C
C  ERROR OF APPROXIMATION = 6 PERCENT FOR  273 < TL < 623 DEG K
C    MAY ALSO BE USED FOR NON-SATURATED CONDITIONS AT SAME TL
C    THIS FIT HAS A SINGULARITY AT TL = 251 DEG K
C  VALUE AT 250 DEG C = .107E-3
C
      VISLQ = 25.3 / (-8.58E4 + TL*(91.+ TL))
      RETURN
      END
      FUNCTION  VISVP (TV)
C
C  VISCOSITY OF SATURATED STEAM
C    KG/M SEC    FUNCTION OF     DEG K
C
C  ERROR OF APPROXIMATION = 3 PERCENT FOR  373 < TV < 623 DE K
C    MAY ALSO BE USED FOR NON-SATURATED CONDITIONS AT SAME TV
C    THIS FIT HAS A SINGULARITY AT TV = 822 DEG K
C  VALUE AT 250 DEG C = .174E-4
C
      IF(TV.GT.623.) GO TO 50
      VISVP = 11.4 / (1.37E6 - TV*(844.+ TV))
      RETURN
 50     VISVP= 4.07E-8*TV-3.7E-7
      RETURN
      END
C
      FUNCTION TCON(T)
C  CONVERTS FROM F TO K
      TCON=5./9.*(T-32.)+273.15
      RETURN
      END
      FUNCTION DCON(RHO)
C CONVERTS FROM LB/FT**3 TO KG/M**3
      DCON=RHO*16.0185
      RETURN
      END
      FUNCTION SURTT (TL)
```

```
C
C  SURFACE TENSION OF LIQUID WATER
C    KG(F)/M     FUNCTION OF    DEG K
C  ( 1 KG(F)= 9.80665 KG M/SEC**2 )
C  ALSO EQUAL TO SURFACE TENSION / GRAVITATIONAL ACCELERATION CONSTANT
C  IN UNITS OF KG/M
C
C  ERROR OF APPROXIMATION = 2 PERCENT FOR 373 < TL < 623 DEG K
C  VALUE AT 250 DEG C = .0026
C
      SURTT = (80.72 - TL*.126) / (5140.+ TL)
      IF(SURTT.LT.0.0)   SURTT=0.0
      RETURN
      END
```

APPENDIX O

Sample Input and Output for the Improved Version of COBRA-IIIC/MIT

Sample input and output for the improved version of COBRA-IIIC/MIT is presented in this section. Sample output is given for the PWR and BWR transient test case described in Section IV.C. Both sample output decks select the new fuel rod modeling option. Sample output obtained from the BWR transient test case sample input is given. The sample output was shortened by removing the pages of output for predictions between 0.0 and 2.5 seconds.

Sample Input Deck for BWR Transient Test Case-Page 1 of 1

```
    2     1    10     2    40 <———————— first card
 2000
2   1     2    BWR TURBINE TRIP W/O BYPASS  NEW FUEL ROD MODEL
   20
    1     2     1
   26.1512
    0. .430.0208 .470.0625 .550.1042 .640.1458 .740.1875 .850.2292 .970
.2708 1.10.3125 1.21.3542 1.29.3958 1.34.4375 1.38.4792 1.40.5208 1.39
.5630 1.36.6042 1.30.6458 1.23.6875 1.15.7292 1.08.7708 1.01.8125 .930
.8542 .840.8958 .740.9375 .600 .979 .430 1.00 .350
 1.40 1.04
 150.    20    50  2.5
    2     2     9     3     6     0     1     0     1
 1.0E-02
    1     1    1.        62. .48315.82118.394.08
  33.    1.   10.
    1     1    1.        62. .48315.82118.394.08
  33.    1.   9.0
    2
 0.01     1.0714     2.2143     2.3571     2.5000     2.6429     2.7857     2
.9289     2 0.99      3
   2.   .08 640..4100 8.80 .076 405..0320500.9
    4     1.0045
  .95    0.
               1     1     1     1
    2
    1     2
    1
    3  0.5         0.5
    0528.6 1.101031.
    3          3     5
  0.0   1.0   2.01.165   2.51.165
  0.0   1.0   2.0  0.7   5.0  0.5
  0.0   1.0   0.8  1.5   1.5 2.31   2.0   1.0   2.5 0.25

          5     2
```

* * END OF CARD DECK

Sample Input Deck for PWR Transient Test Case-Page 1 of 2

```
    9    18    10    15    20 <------------ first card
 2000
0    1     1 .     MAINE YANKEE - 3 PUMP LOF TRANSIENT  NEW FR MODEL
   20
    3     6     6
    0     8     8     8     8     8
    0     2     1     0     8     8
    6     4     3     5     5     8
    8     0     7     0     6     8
    8     8     8     8     8     8
    9     9     9     9     9     9
   21.1821
   0. .100   .05 .175   .10 .250   .15 .350   .20 .450   .25 .575   .30 .700
  .35 .900   .40 1.10   .45 1.25   .50 1.40   .55 1.52   .601.640   .651.660
  .701.680   .751.590   .801.500   .851.275   .901.050   .95 .710   1.0   .35

136.7    20    20    5.
    0     5     9     3     7     0     1     0     1 .
  1.0E-02
    1     1    1.          1.   .44.18431.3821.382
1.105.46051.015
    1     1    1.        0.85   .44.23091.6951.178
1.105.46051.015
    2     6
    1     1    1.        0.40   .44.0918.9083.5496
1.105.46051.015
    4
    1     1    1.       152.0   .4433.00251.0210.1
1.105.46051.015
    8
    1     1    1.       4418.   .44895.86813.6107.
1.105.46051.015
    9
.0050      1.0877     2.2194     2.3511     2.4828     2.6144     2.7461     2
.8778      2 .995     3
   15    15     7    .1
1    1   .441.475  1   .2654  8   .7692
1    2   .441.475  1   .2564  2   .2564   8   .5128
1    3   .441.475  2   .3089  8   .7166
1    4   .441.475  1   .2564  3   .2867   7   .2564  8   .2564
1    5   .441.611  1   .2442  2   .2942   3   .2730
1    6   .441.475  3   .2867  5   .2564   7   .2564  8   .2564
1    7   .441.475  3   .2867  4   .2039   5   .2564  6   .3089
1    8   .441.475  5   .2564  8   .7692
1    9   .441.475  5   .2564  6   .2564   8   .5128
1   10   .441.475  6   .3089  8   .7166
1   11   .441.475  7   .2564  8   .7692
1   12   .441.475  7   .2564  8   .7692
1   13   .441.264  8   168.0
1   14   .44.9495  9   4716.
1   15   .441.711  4   .1943
  1.5 0.08 650..3675  8.8 .078 410.  .028 600.
    5     1.0075
  .95    0.
.2796 .280 .140.1396 .140 .280.1396 .140 .140.2796 .140 .140 .4207.280
    2     1     0     1     1     1     0     1
.0062 -.10
    1 .184 -0.2
    1     0
    2
```

Sample Input Deck for PWR Transient Test Case-Page 2 of 2

```
.95  .95  .95  .95  .95  .95  .95  .951.002
  2  0.5   0..2413   0.
 30    1 600.2600.
  1 546. 2.292200.
           7    7
0.0  1.0  1.0 0.95  2.0 0.89  3.0 0.84  4.00.805  5.00.765  6.00.730
0.0  1.0  2.9  1.0  4.0 0.67  4.4 0.49  4.6 0.37  4.8 0.19  5.0 0.14

       2    3    2    3
  3    4
  5   14   15
```

*** END OF CARD DECK ***

Sample Output for BWR Transient Test Case

PROBLEM SIZE
MC= 2
MG= 1
MN= 10
MR= 2
MX= 40

SIMILAR CHANNELS ALL SEPARATED EG.BWR

COBRA INPUT DATA

NB. DATA READ FROM CARD20 WOULD BE READ OR SET WITH THE NEUTRONICS DATA IN MEKIN

CARD IMAGES

```
                                 0....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
IMAP ND1X ND2X                ***    1    2    1                                                                  *** CARD20
NAX AFLUX                     ***   26.1512                                                                       *** CARD20
AXIAL HEAT FLUX               ***    0. .430.0208 .470.0625 .550.1042 .640.1458 .740.1875 .850.2292 .970          *** READIN(CARD20)
                              ***.2708 1.10.3125 1.21.3542 1.29.3958 1.34.4375 1.38.4792 1.40.5208 1.39           *** CONTINUED
                              ***.5630 1.36.6042 1.30.6458 1.23.6875 1.15.7292 1.08.7708 1.01.8125 .930           *** CONTINUED
                              ***.8542 .840.8958 .740.9375 .600 .979 .430 1.00 .350                               *** CONTINUED
RADIAL POWERS                 *** 1.40 1.04                                                                       *** READIN(CARD20)
Z NDX NDT TTIME               *** 150.   20   50   2.5                                                            *** CARD20
INDICATORS                    ***    2    2    9    3    6    0    1    0    1                                   *** CHAN
EPSF                          *** 1.0E-02                                                                         *** CHAN
CHANNEL DATA, TYPE  1         ***    1    1   1.        62. .48315.82118.394.08                                   *** CHAN
GRID DATA, TYPE  1            ***  33.    1.  10.                                                                 *** CHAN
CHANNEL DATA, TYPE  2         ***    1    1   1.        62. .48315.82118.394.08                                   *** CHAN
GRID DATA, TYPE  2            ***  33.    1.  9.0                                                                 *** CHAN
CHANNELS OF TYPE  2           ***    2                                                                            *** CHAN
GRID POSITIONS                *** 0.01    1.0714    2.2143    2.3571    2.5000    2.6429    2.7857    2             *** CHAN
GRID POSITIONS                ***.9289    2 0.99    3                                                             *** CHAN
FUEL THERMAL DATA             ***   2.  .08 640..4100 8.80 .076 405..0320500.9                                    *** CHAN
NCF, NCC, THG                 ***    4    1.0045                                                                  *** CHAN
FTD, FPUO2                    ***  .95    0.                                                                      *** CHAN
HYDRAULIC MODEL INDICATORS    ***              1    1    1    1                                                   *** MODEL
TWO-PHASE FRICTION (J4)       ***    2                                                                            *** MODEL
VOID FRACTION (J2, J3)        ***    1    2                                                                       *** MODEL
INLET FLOW DIVISION (IG)      ***    1                                                                            *** MODEL
CONSTANTS                     ***    3 0.5       0.5                                                              *** MODEL
IN H(OR T)IN GIN PEXIT        ***    0528.6 1.101031.                                                             *** OPERA
TRANS INDIC FOR P H G Q       ***    3         3    5                                                             *** OPERA
PRESSURE TRANSIENT            ***  0.0  1.0  2.01.165  2.51.165                                                   *** READIN (OPERA)
INLET FLOW TRANSIENT          ***  0.0  1.0  2.0  0.7  5.0  0.5                                                   *** READIN (ORERA)
INLET POWER TRANSIENT         ***  0.0  1.0  0.8  1.5  1.5 2.31  2.0  1.0  2.5 0.25                               *** READIN (ORERA)
KDEBUG                        ***                                                                                 *** TABLES
PRINTING                      ***         5    2                                                                  *** TABLES
                                 0....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
```

```
DYNAMIC ARRAY SIZES
MA =      1
MC =      2
MG =      1
MN =     10
MR =      2
MS =      1
MX =     41
THIS VERSION OF COBRA-IIIC/MIT DOES NOT ALLOW DYNAMIC STORAGE.


MAXIMUM PROBLEM SIZE LIMITED TO
80000 WORDS BY DIMENSION OF DATA ARRAY IN
MAIN PROGRAM AND VALUE OF KMAX SET IN
CORE SUBROUTINE.
```

1=REAL

3=LOGICAL

INDEX	NAME	LENGTH	ORIGIN	TYPE
1	A	2	1	1
2	AAA	1	3	1
3	AC	2	4	1
4	ALPHA	2	6	1
5	AN	2	8	1
6	ANSWER	1	10	1
7	B	1	11	1
8	CCHANL	82	12	2
9	CD	10	94	1
10	CHFR	82	104	1
11	CON	2	186	1
12	COND	1	188	1
13	CP	2	189	1
14	D	2	191	1
15	DC	2	193	1
16	DFDX	2	195	1
17	DHDX	2	197	1
18	DHYD	2	199	1
19	DHYDN	2	201	1
20	DIST	8	203	1
21	DPDX	2	211	1
22	DPK	2	213	1
23	DUR	1	215	1
24	DR	2	216	1
25	F	82	218	1
26	FACTOR	1	300	1
27	FDIV	1	301	3
28	FINLET	2	302	1
29	FLUX	82	304	1
30	FMULT	2	386	1
31	FOLD	82	388	1
32	FSP	2	470	1
33	FSPLIT	2	472	1
34	FXFLOW	5	474	1
35	GAP	1	479	1
36	GAPN	1	480	1
37	GAPS	4	481	1
38	H	82	485	1
39	HFILM	2	567	1
40	HINLET	2	569	1
41	HOLD	82	571	1
42	HPERIM	2	653	1
43	IDAREA	2	655	2
44	IDFUEL	2	657	2
45	IDGAP	1	659	2
46	IK	1	660	2
47	JBOIL	2	661	2
48	JK	1	663	2
49	LC	8	664	2
50	LENGTH	1	672	1
51	LOCA	14	673	2
52	LR	12	687	2
53	MCHFR	41	699	1
54	MCHFRC	41	740	2
55	MCHFRR	41	781	2
56	NTYPE	2	822	2
57	NWRAP	2	824	2
58	NWRAPS	2	826	2
59	P	82	828	1
60	PERIM	2	910	1
61	PH	2	912	1
62	PHI	12	914	1

63	PRINTC	2	926	2
64	PRINTR	2	[illegible]	2
65	PRINTN	10	930	2
66	PW	2	940	1
67	PWRF	4	942	1
68	QC	82	946	1
69	QF	82	1028	1
70	QPRIM	2	1110	1
71	QUAL	2	1112	1
72	RADIAL	2	1114	1
73	RHO	82	1116	1
74	RHOOLD	82	1198	1
75	SP	41	1280	1
76	T	2	1321	1
77	TDUMY	10	1323	1
78	TINLET	2	1333	1
79	TROD	820	1335	1
80	U	2	2155	1
81	UH	2	2157	1
82	SAVE	1	2159	1
83	USTAR	1	2160	1
84	V	2	2161	1
85	VISC	2	2163	1
86	VISCW	2	2165	1
87	VP	2	2167	1
88	VPA	2	2169	1
89	W	41	2171	1
90	WOLD	41	2212	1
91	WP	1	2253	1
92	WSAVE	1	2254	1
93	X	41	2255	1
94	XCROSS	6	2296	1
95	A	30	2302	1
96	B	10	2332	1
97	XPOLD	82	2342	1

DYNAMIC ALLOCATION OF CORE GOT 80000 WORDS

DYNAMIC STORAGE REQUIRED = 2423 WORDS

REGION SIZE ON JCL CARD COULD HAVE BEEN REDUCED BY 303 K

PROCESSED INPUT DATA

* = SET IN NEUTRONICS (CARD20)

OPERATING CONDITIONS

PRESSURE	(PSIA)	=	1031.00
AV. INLET MASS VELOCITY	(MLB/SQFT.HR)	=	1.1000
IN= 0 INLET ENTHALPY	(BTU/LB)	=	528.600
*CHANNEL LENGTH	(IN)	=	150.00
*NO. OF AXIAL INTERVALS		=	20
*NO. OF TIME STEPS		=	50
*TOTAL TIME OF TRANSIENT	(SEC)	=	2.50

FORCING FUNCTION FOR PRESSURE

TIME (SEC)	PRESSURE FACTOR
0.0	1.0000
2.0000	1.1650
2.5000	1.1650

FORCING FUNCTION FOR INLET FLOW

TIME (SEC)	INLET FLOW FACTOR
0.0	1.0000
2.0000	0.7000
5.0000	0.5000

FORCING FUNCTION FOR HEAT FLUX

TIME (SEC)	HEAT FLUX FACTOR
0.0	1.0000
0.8000	1.5000
1.5000	2.3100
2.0000	1.0000
2.5000	0.2500

CHANNEL, ROD AND GRID DATA

REACTOR TYPE = 2 (1=PWR, 2=BWR)
*NO. FUEL ASSEMBLIES = 2
NO. ASSEMBLY TYPES = 2
NO. GRIDS = 9
NO. GRID TYPES = 3
NO. FUEL NODES = 6
NO. FCD FLOW TYPES = 0

FUEL ROD MODEL IND. = 1
HEAT TRANSFER MODEL IND.= 0
FUEL ROD PROP. IND. = 1

CHANNEL DATA

*CHANNEL NUMBERING MAP

1 2

TYPE CHANNEL NUMBERS

2 2

TYPE	FRIC	AREA SQ FT	WT PER FT	HT PER FT	NO. RODS	ROD DIA IN	GAP IN
1	1	0.10986	9.858	7.840	62.	0.4830	0.0
2	1	0.10986	9.858	7.840	62.	0.4830	0.0

GRID DATA
---- ----

NO. GRIDS = 9
NO. GRID TYPES = 3
TYPE AT X/L = 1 0.0100 2 0.0714 2 0.2143 2 0.3571 2 0.5000 2 0.6429 2 0.7857 2 0.9289
3 0.9900

ASSY. TYPE	GRID COEFF FOR GRID TYPES 1 - 3		
1	33.0000	1.0000	10.0000
2	33.0000	1.0000	9.0000

THERMAL PROPERTIES FOR FUEL MATERIAL 6 RADIAL FUEL NODES
------- ---------- --- ---- --------

	FUEL PROPERTIES				CLAD PROPERTIES				
TYPE NO.	COND. (B/HR-FT-F)	SP. HEAT (B/LB-F)	DENSITY (LB/FT3)	DIA. (IN.)	COND. (B/HR-FT-F)	SP. HEAT (B/LB-F)	DENSITY (LB/FT3)	THICK. (IN.)	GAP COND. (B/HR-FT2-F)
1	2.00	0.0800	640.0	0.4100	8.80	0.0760	405.0	0.0320	500.90

NEW FUEL ROD MODEL
--- ---- --- -----

NUMBER OF FUEL PELLET NODES = 4
NUMBER OF CLAD NODES = 1
GAP THICKNESS(IN) = 0.45000E-02

FUEL AND CLAD PROPERTIES WILL BE CALCULATED USING FUEL ROD TEMPERATURES.
FRACTION THEORETICAL DEN(FUEL)= 0.95000E+00
FRACTION PUO2 = 0.0

THERMAL - HYDRAULIC MODEL

(1) MIXING

MIXING COEFFICIENT (W/GS) = 0.020* (RE** 0.0)
TWO-PHASE MIXING SAME AS SINGLE PHASE (NBBC=1)
NO THERMAL CONDUCTION (GK=0.0)

(2) SINGLE-PHASE FRICTION

F = A*(RE**B) + C

NVISCW = 0 (=0 FOR NO WALL VISCOSITY CORRECTION, =1 FOR INCLUSION)

FRIC TYPE	A	B	C
1	0.1840	-0.2000	0.0
2	0.1840	-0.2000	0.0
3	0.1840	-0.2000	0.0
4	0.1840	-0.2000	0.0

(3) TWO-PHASE FRICTION

J4 = 2 (J4=0 HOMOGENEOUS, =1 ARMAND, =2 BAROCZY, =5 POLYNOMIAL IN QUALITY)

(4) VOID FRACTION

J2 = 1 (J2=0 NO SUBCOOLED VOID, =1 LEVY MODEL)
J3 = 2 (J3=0 SLIP RATIO = 1, =1 ARMAND, =2 SMITH, =5 SLIP POLYNOMIAL, =6 VOID = F(QUAL)

(5) FLOW DIVISION AT INLET

IG = 1 (IG=0 SAME G, =1 SAME DP/DX, =2 GIN/GAV RATIO GIVEN)

(6) CONSTANTS

CRITICAL HEAT FLUX (NCHF) = 3
CROSS-FLOW RESISTANCE (KIJ) = 0.500
MOMENTUM TURBULENT FACTOR (FTM) = 0.0
TRANSVERSE MOMENTUM FACTOR (S/L) = 0.500
CHANNEL ANGLE FROM VERTICAL = 0.0 DEGREES

(7) ITERATION

MAX. ALLOWABLE NO. ITERATIONS = 20
FLOW CONVERGENCE FACTOR = 1.000E-03

(8) COUPLING PARAMETER FOR THE MIXING TERM

PHYSICAL PROPERTIES

P	T	VF	VG	HF	HG	VISC	KF	SIGMA
706.7	504.23	0.02052	0.64875	492.85	1201.01	0.24742	0.34494	0.00158
723.7	506.90	0.02058	0.63261	496.05	1200.59	0.24588	0.34381	0.00156
740.8	509.53	0.02064	0.61718	499.20	1200.15	0.24438	0.34269	0.00154
757.8	512.11	0.02071	0.60242	502.31	1199.69	0.24292	0.34159	0.00151
774.9	514.64	0.02077	0.58827	505.37	1199.21	0.24149	0.34049	0.00149
791.9	517.13	0.02083	0.57471	508.40	1198.71	0.24010	0.33940	0.00147
809.0	519.58	0.02090	0.56170	511.39	1198.20	0.23874	0.33832	0.00145
826.0	522.00	0.02096	0.54921	514.34	1197.67	0.23742	0.33725	0.00142
843.1	524.37	0.02102	0.53720	517.26	1197.13	0.23613	0.33619	0.00140
860.1	526.71	0.02109	0.52565	520.14	1196.57	0.23486	0.33513	0.00138
877.2	529.01	0.02115	0.51453	522.99	1196.00	0.23363	0.33408	0.00136
894.2	531.28	0.02121	0.50382	525.80	1195.42	0.23242	0.33304	0.00134
911.3	533.52	0.02128	0.49349	528.59	1194.82	0.23123	0.33201	0.00132
928.3	535.73	0.02134	0.48353	531.35	1194.21	0.23008	0.33099	0.00130
945.4	537.90	0.02140	0.47391	534.07	1193.59	0.22894	0.32997	0.00128
962.4	540.05	0.02147	0.46462	536.77	1192.96	0.22783	0.32896	0.00126
979.5	542.16	0.02153	0.45564	539.45	1192.32	0.22674	0.32795	0.00124
996.5	544.25	0.02159	0.44696	542.09	1191.66	0.22567	0.32696	0.00123
1013.6	546.31	0.02166	0.43855	544.72	1191.00	0.22463	0.32597	0.00121
1030.6	548.35	0.02172	0.43042	547.31	1190.32	0.22360	0.32498	0.00119
1047.7	550.36	0.02178	0.42253	549.89	1189.64	0.22259	0.32400	0.00117
1064.7	552.34	0.02185	0.41489	552.44	1188.94	0.22160	0.32303	0.00115
1081.8	554.30	0.02191	0.40748	554.97	1188.23	0.22063	0.32206	0.00114
1098.8	556.24	0.02197	0.40029	557.47	1187.52	0.21967	0.32110	0.00112
1115.9	558.16	0.02203	0.39331	559.96	1186.79	0.21873	0.32014	0.00110
1132.9	560.05	0.02210	0.38654	562.43	1186.05	0.21780	0.31919	0.00109
1150.0	561.92	0.02216	0.37995	564.88	1185.30	0.21690	0.31824	0.00107
1167.0	563.77	0.02222	0.37354	567.30	1184.55	0.21600	0.31730	0.00106
1184.1	565.60	0.02229	0.36732	569.72	1183.78	0.21512	0.31637	0.00104
1201.1	567.41	0.02235	0.36126	572.11	1183.00	0.21425	0.31543	0.00103

FUEL ROD TEMP. CONVERGENCE CRITERIA = .10000E-01

CHANNEL EXIT SUMMARY RESULTS

CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*46*34

MASS BALANCE - -

MASS FLOW IN	0.67137E+02	LB/SEC
MASS FLOW OUT	0.67137E+02	LB/SEC
MASS FLOW ERROR	0.0	LB/SEC

ENERGY BALANCE - -

FLOW ENERGY IN	0.35489E+05	BTU/SEC
ENERGY ADDED	0.82320E+04	BTU/SEC
FLOW ENERGY OUT	0.45523E+05	BTU/SEC
ENERGY ERROR	0.18027E+04	BTU/SEC

CHANNEL (NO.)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/FT3)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)
1	711.35	548.39	13.27	0.255	0.750	31.5056	1.0324
2	648.63	548.39	17.59	0.158	0.651	35.6318	1.1676

CHANNEL RESULTS
CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*46*34

BUNDLE AVERAGED RESULTS

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)
0.0	23.82	528.60	533.53	47.00	0.0	0.0	67.1373	1.1000
7.5	16.45	532.17	536.39	46.82	0.0	0.0	67.1373	1.1000
15.0	15.97	536.49	539.82	45.82	0.0	0.005	67.1373	1.1000
22.5	15.70	541.65	543.90	43.04	0.0	0.069	67.1373	1.1000
30.0	15.42	547.76	548.39	39.09	0.001	0.159	67.1373	1.1000
37.5	14.84	554.92	548.39	35.20	0.012	0.248	67.1373	1.1000
45.0	14.55	563.23	548.39	31.76	0.025	0.327	67.1373	1.1000
52.5	14.24	572.46	548.39	28.90	0.039	0.392	67.1373	1.1000
60.0	13.55	582.30	548.39	26.55	0.054	0.446	67.1373	1.1000
67.5	13.23	592.53	548.39	24.56	0.070	0.491	67.1373	1.1000
75.0	12.44	602.98	548.39	22.87	0.087	0.530	67.1373	1.1000
82.5	12.10	613.36	548.39	21.44	0.103	0.563	67.1373	1.1000
90.0	11.75	623.40	548.39	20.24	0.118	0.590	67.1373	1.1000
97.5	10.84	632.86	548.39	19.22	0.133	0.614	67.1373	1.1000
105.0	10.48	641.64	548.39	18.36	0.147	0.633	67.1373	1.1000
112.5	10.11	649.77	548.39	17.62	0.159	0.650	67.1373	1.1000
120.0	9.09	657.26	548.39	16.99	0.171	0.665	67.1373	1.1000
127.5	8.71	664.02	548.39	16.45	0.181	0.677	67.1373	1.1000
135.0	8.33	669.93	548.39	16.01	0.191	0.687	67.1373	1.1000
142.5	7.25	674.73	548.39	15.66	0.198	0.695	67.1373	1.1000
150.0	0.0	678.06	548.39	15.43	0.203	0.700	67.1373	1.1000

CHANNEL RESULTS
CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*46*34

TIME = 0.0 SECONDS DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)
0.0	23.82	528.60	533.53	47.00	0.0	0.0	31.5056	1.0324
7.5	17.32	532.97	537.02	46.78	0.0	0.0	31.5056	1.0324
15.0	16.86	538.25	541.21	44.97	0.0	0.024	31.5056	1.0324
22.5	16.59	544.56	546.19	40.61	0.0	0.124	31.5056	1.0324
30.0	16.31	552.03	548.39	36.15	0.007	0.226	31.5056	1.0324
37.5	15.75	560.79	548.39	32.26	0.021	0.315	31.5056	1.0324
45.0	15.46	570.95	548.39	28.91	0.037	0.392	31.5056	1.0324
52.5	15.16	582.23	548.39	26.17	0.054	0.455	31.5056	1.0324
60.0	14.47	594.26	548.39	23.92	0.073	0.506	31.5056	1.0324
67.5	14.14	606.77	548.39	22.02	0.092	0.549	31.5056	1.0324
75.0	13.35	619.55	548.39	20.40	0.112	0.586	31.5056	1.0324
82.5	13.00	632.23	548.39	19.04	0.132	0.618	31.5056	1.0324
90.0	12.63	644.51	548.39	17.88	0.151	0.644	31.5056	1.0324
97.5	11.70	656.08	548.39	16.90	0.169	0.667	31.5056	1.0324
105.0	11.32	666.81	548.39	16.08	0.186	0.685	31.5056	1.0324
112.5	10.93	676.75	548.39	15.37	0.201	0.702	31.5056	1.0324
120.0	9.88	685.92	548.39	14.77	0.215	0.715	31.5056	1.0324
127.5	9.49	694.17	548.39	14.25	0.228	0.727	31.5056	1.0324
135.0	9.09	701.40	548.39	13.83	0.240	0.737	31.5056	1.0324
142.5	7.96	707.27	548.39	13.50	0.249	0.744	31.5056	1.0324
150.0	0.0	711.35	548.39	13.27	0.255	0.750	31.5056	1.0324

CHANNEL RESULTS
CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*46*34

TIME = 0.0 SECONDS DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)
0.0	23.82	528.60	533.53	47.00	0.0	0.0	35.6318	1.1676
7.5	15.57	531.47	535.83	46.85	0.0	0.0	35.6318	1.1676
15.0	15.07	534.94	538.59	46.68	0.0	0.0	35.6318	1.1676
22.5	14.81	539.08	541.87	45.47	0.0	0.013	35.6318	1.1676
30.0	14.52	543.99	545.74	42.03	0.0	0.092	35.6318	1.1676
37.5	13.93	549.74	548.39	38.14	0.004	0.181	35.6318	1.1676
45.0	13.63	556.41	548.39	34.61	0.014	0.261	35.6318	1.1676
52.5	13.33	563.83	548.39	31.64	0.026	0.329	35.6318	1.1676
60.0	12.63	571.72	548.39	29.18	0.038	0.386	35.6318	1.1676
67.5	12.31	579.94	548.39	27.11	0.051	0.433	35.6318	1.1676
75.0	11.53	588.34	548.39	25.34	0.064	0.473	35.6318	1.1676
82.5	11.20	596.67	548.39	23.85	0.077	0.508	35.6318	1.1676
90.0	10.87	604.73	548.39	22.59	0.089	0.536	35.6318	1.1676
97.5	9.98	612.33	548.39	21.54	0.101	0.561	35.6318	1.1676
105.0	9.63	619.38	548.39	20.64	0.112	0.581	35.6318	1.1676
112.5	9.28	625.91	548.39	19.87	0.122	0.599	35.6318	1.1676
120.0	8.30	631.93	548.39	19.21	0.132	0.614	35.6318	1.1676
127.5	7.94	637.35	548.39	18.65	0.140	0.626	35.6318	1.1676
135.0	7.57	642.10	548.39	18.19	0.147	0.637	35.6318	1.1676
142.5	6.54	645.95	548.39	17.83	0.153	0.645	35.6318	1.1676
150.0	0.0	648.63	548.39	17.59	0.158	0.651	35.6318	1.1676

CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*46*34

TIME = 0.0 SECONDS TEMPERATURE DATA FOR ROD 1, FUEL TYPE 1

DISTANCE (IN.)	FLUX (MBTU/HR-FT2)	CHFR	CHANNEL	TEMPERATURE(F) T(1)	T(2)	T(3)	T(4)	T(5)	T(6)	T(7)
0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.5	0.1012	0.0	0	1233.0	1205.6	1126.0	1000.5	838.2	602.8	572.1
15.0	0.1221	8.108	1	1413.8	1377.4	1272.4	1110.0	904.4	620.3	583.5
22.5	0.1461	6.780	1	1593.8	1545.8	1409.2	1202.2	947.1	607.3	563.1
30.0	0.1729	5.726	1	1853.7	1788.8	1606.3	1337.5	1017.8	615.5	563.2
37.5	0.2028	4.883	1	2185.3	2096.1	1849.1	1497.2	1096.8	625.1	563.9
45.0	0.2352	4.210	1	2603.6	2482.6	2147.8	1683.9	1183.0	635.8	565.0
52.5	0.2612	3.791	1	2973.2	2828.7	2416.4	1844.4	1251.7	644.1	565.5
60.0	0.2784	3.433	1	3221.0	3066.3	2607.7	1956.2	1296.9	649.3	565.7
67.5	0.2896	3.080	1	3379.7	3221.6	2738.3	2032.3	1326.4	652.8	565.8
75.0	0.2959	2.795	1	3467.1	3308.2	2813.5	2076.3	1343.1	654.7	565.9
82.5	0.2936	2.597	1	3434.7	3276.0	2785.3	2059.7	1336.7	653.7	565.5
90.0	0.2842	2.464	1	3302.6	3145.8	2673.7	1994.4	1311.5	650.4	565.1
97.5	0.2678	2.395	1	3065.9	2916.9	2486.2	1884.9	1267.8	644.9	564.4
105.0	0.2485	2.361	1	2787.1	2653.3	2279.2	1762.6	1216.6	638.5	563.6
112.5	0.2301	2.331	1	2530.8	2415.1	2095.5	1651.4	1167.7	632.4	563.1
120.0	0.2121	2.309	1	2296.2	2198.4	1928.4	1547.3	1119.9	626.5	562.4
127.5	0.1911	2.342	1	2046.9	1968.0	1743.4	1431.4	1064.1	619.4	561.6
135.0	0.1672	2.458	1	1791.7	1730.8	1559.4	1305.1	1000.2	611.2	560.5
142.5	0.1359	2.805	1	1497.8	1455.5	1334.1	1148.2	916.4	600.2	559.0
150.0	0.0945	3.815	1	1163.8	1139.2	1067.3	953.5	805.2	585.3	556.5

CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*46*34

TIME = 0.0 SECONDS TEMPERATURE DATA FOR ROD 2, FUEL TYPE 1

DISTANCE (IN.)	FLUX (MBTU/HR-FT2)	CHFR	CHANNEL	TEMPERATURE(F) T(1)	T(2)	T(3)	T(4)	T(5)	T(6)	T(7)
0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.5	0.0752	0.0	0	1029.5	1011.3	957.7	871.8	757.8	582.9	560.0
15.0	0.0907	0.0	0	1149.5	1126.0	1057.5	948.6	806.3	595.3	567.7
22.5	0.1085	9.126	2	1295.1	1264.8	1176.8	1038.9	861.9	609.5	576.7
30.0	0.1285	7.708	2	1438.5	1399.7	1288.1	1116.2	899.9	601.0	562.0
37.5	0.1506	6.574	2	1634.4	1584.0	1440.3	1223.7	958.3	607.9	562.2
45.0	0.1747	5.668	2	1871.2	1805.0	1619.2	1346.1	1022.0	615.6	562.7
52.5	0.1940	5.103	2	2082.2	2000.7	1774.4	1448.8	1073.2	621.8	563.1
60.0	0.2068	4.789	2	2232.5	2139.6	1882.9	1518.7	1106.8	625.7	563.3
67.5	0.2151	4.603	2	2335.9	2235.1	1956.9	1565.6	1128.8	628.3	563.4
75.0	0.2198	4.470	2	2396.1	2290.7	1999.8	1592.4	1141.2	629.8	563.4
82.5	0.2181	4.311	2	2373.5	2269.7	1983.6	1582.2	1136.4	629.0	563.2
90.0	0.2111	4.259	2	2284.6	2187.7	1920.1	1542.2	1117.6	626.5	562.8
97.5	0.1989	4.326	2	2136.8	2051.2	1813.8	1474.0	1085.0	622.3	562.1
105.0	0.1846	4.468	2	1974.5	1900.8	1695.3	1396.5	1046.9	617.4	561.5
112.5	0.1709	4.631	2	1829.8	1766.4	1588.0	1324.7	1010.5	612.8	561.0
120.0	0.1576	4.830	2	1697.1	1642.5	1487.9	1256.2	974.8	608.3	560.5
127.5	0.1420	5.165	2	1552.6	1507.0	1376.8	1178.7	933.2	602.9	559.8
135.0	0.1242	5.710	2	1398.9	1362.2	1256.4	1092.7	885.6	596.6	558.9
142.5	0.1009	6.833	2	1213.2	1186.2	1107.6	983.7	823.1	588.2	557.5
150.0	0.0702	9.632	2	990.0	973.4	924.3	845.3	740.1	576.9	555.4

CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*46*34

TIME = 0.0 SECONDS

H-L CRITICAL HEAT FLUX SUMMARY

DISTANCE	FLUX	MCHFR	ROD	CHANNEL
0.0	0.0	0.0	0	0
7.5	0.0	0.0	0	0
15.0	0.122	8.108	1	1
22.5	0.146	6.780	1	1
30.0	0.173	5.726	1	1
37.5	0.203	4.883	1	1
45.0	0.235	4.210	1	1
52.5	0.261	3.791	1	1
60.0	0.278	3.433	1	1
67.5	0.290	3.080	1	1
75.0	0.296	2.795	1	1
82.5	0.294	2.597	1	1
90.0	0.284	2.464	1	1
97.5	0.268	2.395	1	1
105.0	0.249	2.361	1	1
112.5	0.230	2.331	1	1
120.0	0.212	2.309	1	1
127.5	0.191	2.342	1	1
135.0	0.167	2.458	1	1
142.5	0.136	2.805	1	1
150.0	0.094	3.815	1	1

ITERATIONS = 3

CHANNEL RESULTS
CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*47*30

TIME = 2.50000 SECONDS DATA FOR CHANNEL 1

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)
0.0	13.85	528.60	533.53	47.00	0.0	0.0	20.4713	0.6708
7.5	10.98	536.00	539.43	46.62	0.0	0.0	20.4706	0.6708
15.0	10.68	544.82	546.40	46.17	0.0	0.0	20.4708	0.6708
22.5	10.46	554.83	554.20	44.26	0.0	0.012	20.4491	0.6701
30.0	10.24	567.05	563.58	37.86	0.0	0.164	20.4198	0.6691
37.5	9.91	581.34	567.41	32.26	0.015	0.298	20.4174	0.6691
45.0	9.70	597.89	567.41	27.85	0.042	0.402	20.4318	0.6695
52.5	9.48	616.20	567.41	24.44	0.072	0.484	20.4554	0.6703
60.0	9.09	635.65	567.41	21.75	0.104	0.548	20.4849	0.6713
67.5	8.86	655.82	567.41	19.56	0.137	0.600	20.5186	0.6724
75.0	8.40	676.36	567.41	17.73	0.171	0.644	20.5554	0.6736
82.5	8.15	696.66	567.41	16.21	0.204	0.680	20.5949	0.6749
90.0	7.90	716.25	567.41	14.94	0.236	0.710	20.6368	0.6762
97.5	7.34	734.63	567.41	13.88	0.266	0.735	20.6809	0.6777
105.0	7.07	751.62	567.41	13.00	0.294	0.756	20.7272	0.6792
112.5	6.81	767.26	567.41	12.26	0.319	0.774	20.7758	0.6808
120.0	6.15	781.57	567.41	11.63	0.343	0.789	20.8269	0.6825
127.5	5.88	794.34	567.41	11.10	0.364	0.801	20.8809	0.6842
135.0	5.61	805.37	567.41	10.67	0.382	0.812	20.9383	0.6861
142.5	4.90	814.10	567.41	10.35	0.396	0.819	20.9995	0.6881
150.0	0.0	819.82	567.41	10.14	0.405	0.824	21.0654	0.6903

CHANNEL RESULTS
CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*47*30

TIME = 2.50000 SECONDS DATA FOR CHANNEL 2

DISTANCE (IN.)	DELTA-P (PSI)	ENTHALPY (BTU/LB)	TEMPERATURE (DEG-F)	DENSITY (LB/CU-FT)	EQUIL QUALITY	VOID FRACTION	FLOW (LB/SEC)	MASS FLUX (MLB/HR-FT2)
0.0	13.85	528.60	533.53	47.00	0.0	0.0	24.2869	0.7958
7.5	9.90	533.23	537.23	46.76	0.0	0.0	24.2869	0.7958
15.0	9.56	538.76	541.62	46.48	0.0	0.0	24.2876	0.7959
22.5	9.34	545.28	546.76	46.15	0.0	0.0	24.2900	0.7959
30.0	9.11	552.68	552.53	45.70	0.0	0.0	24.2937	0.7961
37.5	8.76	561.54	559.37	41.81	0.0	0.070	24.2951	0.7961
45.0	8.52	571.77	567.16	36.54	0.0	0.196	24.3264	0.7971
52.5	8.29	583.13	567.41	32.40	0.018	0.294	24.3712	0.7986
60.0	7.88	595.21	567.41	29.12	0.038	0.372	24.4280	0.8005
67.5	7.65	607.73	567.41	26.47	0.058	0.435	24.4915	0.8026
75.0	7.19	620.48	567.41	24.28	0.079	0.488	24.5586	0.8048
82.5	6.95	633.09	567.41	22.49	0.100	0.530	24.6283	0.8070
90.0	6.71	645.24	567.41	21.01	0.120	0.566	24.6997	0.8094
97.5	6.17	656.63	567.41	19.78	0.138	0.595	24.7723	0.8118
105.0	5.92	667.14	567.41	18.77	0.156	0.619	24.8456	0.8142
112.5	5.67	676.80	567.41	17.91	0.171	0.639	24.9195	0.8166
120.0	5.06	685.64	567.41	17.18	0.186	0.657	24.9937	0.8190
127.5	4.80	693.52	567.41	16.57	0.199	0.671	25.0683	0.8215
135.0	4.54	700.31	567.41	16.08	0.210	0.683	25.1437	0.8239
142.5	3.88	705.69	567.41	15.70	0.219	0.692	25.2205	0.8264
150.0	0.0	709.21	567.41	15.46	0.224	0.698	25.2990	0.8290

CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*47*30

TIME = 2.50000 SECONDS TEMPERATURE DATA FOR ROD 1, FUEL TYPE 1

DISTANCE (IN.)	FLUX (MBTU/HR-FT2)	CHFR	CHANNEL	TEMPERATURE(F) T(1)	T(2)	T(3)	T(4)	T(5)	T(6)	T(7)
0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.5	0.1108	0.0	0	1312.7	1284.0	1198.9	1059.7	875.0	622.5	589.5
15.0	0.1327	7.036	1	1510.6	1472.7	1361.1	1181.6	948.1	645.6	606.3
22.5	0.1523	6.130	1	1711.5	1662.5	1520.6	1297.9	1015.6	667.7	623.0
30.0	0.1869	4.994	1	1993.0	1926.3	1734.5	1437.5	1069.6	639.6	583.7
37.5	0.2183	4.276	1	2348.3	2257.9	2000.9	1613.1	1150.5	647.4	582.1
45.0	0.2522	3.702	1	2787.1	2667.9	2326.3	1818.9	1239.0	657.7	582.4
52.5	0.2791	3.345	1	3164.7	3026.5	2615.8	1996.4	1309.4	666.0	582.8
60.0	0.2967	2.847	1	3412.9	3267.7	2819.4	2120.4	1355.5	671.4	583.0
67.5	0.3083	2.410	1	3570.4	3423.2	2956.9	2205.0	1385.6	674.8	583.1
75.0	0.3148	2.030	1	3656.7	3509.3	3035.4	2254.0	1402.6	676.8	583.1
82.5	0.3124	1.717	1	3624.8	3477.5	3006.0	2235.5	1396.1	675.8	582.9
90.0	0.3027	1.444	1	3494.1	3347.5	2889.2	2162.9	1370.5	672.6	582.4
97.5	0.2858	1.204	1	3258.1	3116.6	2690.5	2041.5	1326.0	667.0	581.8
105.0	0.2659	1.142	1	2975.9	2846.1	2468.5	1906.1	1273.7	660.6	581.2
112.5	0.2468	1.162	1	2711.8	2597.2	2259.8	1783.3	1223.5	654.5	580.7
120.0	0.2280	1.190	1	2466.0	2367.5	2087.7	1668.3	1174.1	648.4	580.1
127.5	0.2061	1.250	1	2200.9	2120.4	1890.5	1540.3	1116.2	641.2	579.4
135.0	0.1807	1.359	1	1926.1	1863.4	1682.4	1400.6	1049.3	632.7	578.5
142.5	0.1472	1.605	1	1606.2	1562.1	1433.0	1226.6	960.5	621.3	577.0
150.0	0.1022	2.250	1	1238.5	1212.6	1135.9	1009.7	841.2	605.7	574.8

CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL [illegible] TIME [illegible]

TIME = 2.[illegible] SECONDS TEMPERATURE DATA FOR ROD 2, FUEL TYPE 1

DISTANCE (IN.)	FLUX (MBTU/HR-FT2)	CHFR	CHANNEL	TEMPERATURE(F) T(1)	T(2)	T(3)	T(4)	T(5)	T(6)	T(7)
0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.5	0.0828	0.0	0	1088.4	1069.1	1011.3	915.3	785.2	595.9	570.9
15.0	0.0993	9.403	2	1220.7	1196.0	1122.4	1001.3	839.1	611.8	582.0
22.5	0.1180	7.913	2	1380.7	1348.9	1254.9	1101.9	900.2	629.9	594.7
30.0	0.1353	6.901	2	1541.9	1502.1	1385.6	1199.3	957.9	647.6	607.5
37.5	0.1630	5.727	2	1755.2	1702.9	1551.0	1311.2	1006.6	631.6	582.8
45.0	0.1887	4.949	2	2011.9	1943.9	1748.4	1446.2	1072.8	638.2	581.6
52.5	0.2092	4.462	2	2238.5	2155.5	1919.0	1559.4	1125.6	643.5	580.8
60.0	0.2225	4.196	2	2398.5	2304.6	2037.9	1636.6	1160.4	647.5	580.9
67.5	0.2312	4.037	2	2507.8	2406.5	2118.8	1688.4	1183.2	650.2	581.0
75.0	0.2361	3.798	2	2571.1	2465.6	2165.6	1718.0	1196.1	651.7	581.0
82.5	0.2343	3.555	2	2547.3	2443.4	2147.9	1706.8	1191.1	650.9	580.8
90.0	0.2270	3.399	2	2453.7	2356.1	2078.6	1662.6	1171.7	648.4	580.4
97.5	0.2142	3.332	2	2296.9	2209.9	1962.3	1587.4	1137.9	644.1	579.9
105.0	0.1992	3.317	2	2123.2	2047.8	1832.2	1501.7	1098.2	639.1	579.3
112.5	0.1847	3.311	2	1967.3	1902.0	1714.0	1422.2	1060.0	634.3	578.9
120.0	0.1704	3.325	2	1823.5	1767.0	1603.4	1346.3	1022.4	629.6	578.4
127.5	0.1538	3.425	2	1656.0	1618.6	1480.4	1260.3	978.4	624.0	577.7
135.0	0.1346	3.656	2	1497.7	1459.3	1346.6	1164.7	927.7	617.5	576.9
142.5	0.1093	4.252	2	1293.1	1264.8	1180.8	1043.3	860.5	608.7	575.7
150.0	0.0755	5.918	2	1045.5	1028.0	975.6	888.6	770.4	596.6	573.7

CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL DATE 9/24/80 TIME 14*47*30

TIME = 2.50000 SECONDS

H-L CRITICAL HEAT FLUX SUMMARY

DISTANCE	FLUX	MCHFR	ROD	CHANNEL
0.0	0.0	0.0	0	0
7.5	0.0	0.0	0	0
15.0	0.133	7.036	1	1
22.5	0.152	6.130	1	1
30.0	0.187	4.994	1	1
37.5	0.218	4.276	1	1
45.0	0.252	3.702	1	1
52.5	0.279	3.345	1	1
60.0	0.297	2.847	1	1
67.5	0.308	2.410	1	1
75.0	0.315	2.030	1	1
82.5	0.312	1.717	1	1
90.0	0.303	1.444	1	1
97.5	0.286	1.204	1	1
105.0	0.266	1.142	1	1
112.5	0.247	1.162	1	1
120.0	0.228	1.190	1	1
127.5	0.208	1.250	1	1
135.0	0.181	1.359	1	1
142.5	0.147	1.605	1	1
150.0	0.102	2.250	1	1

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