REACTOR THERMAL-HYDRAULIC ANALYSIS
IMPROVEMENT AND APPLICATION OF THE CODE COBRA-IIIC/MIT

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by

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JAMES NORTH LOOMIS

Submitted to the Department of Nuclear Engineering
on November 6, 1980 in partial fulfillment of the
requirements for the Degree of Nuclear Engineer
and Master of Science in Nuclear Engineering

ABSTRACT

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 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 using transverse momentum coupling parameters for the single-pass method.

The improvements have been tested individually and during application of the improved code to 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 PWR and BWR transient 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 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.

The improved version of COBRA-IIIC/MIT was applied to BWR bypass analysis. Two small test cases were analyzed to gain an understanding of how to analyze bypass flow in the E.I. Hatch Unit I reactor. COBRA-IIIC/MIT was limited in the power and bypass flow combinations it could analyze. Estimated full power and full flow conditions were found to be outside the zone of COBRA-IIIC/MIT applicability. Transient THERMIT analysis was performed in an attempt to obtain steady state predictions. Oscillation of predicitons during this analysis indicated that THERMIT bypass analysis should be performed using a pressure drop boundary condition.

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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	 COBRA-IIIC/MIT	System PWR	 BWR	Operation S.S.	 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)

<u>Key</u>: + 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.

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

Table II-2

Summary of Cases Analyzed and Results from Ref. 11

	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 coce 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.

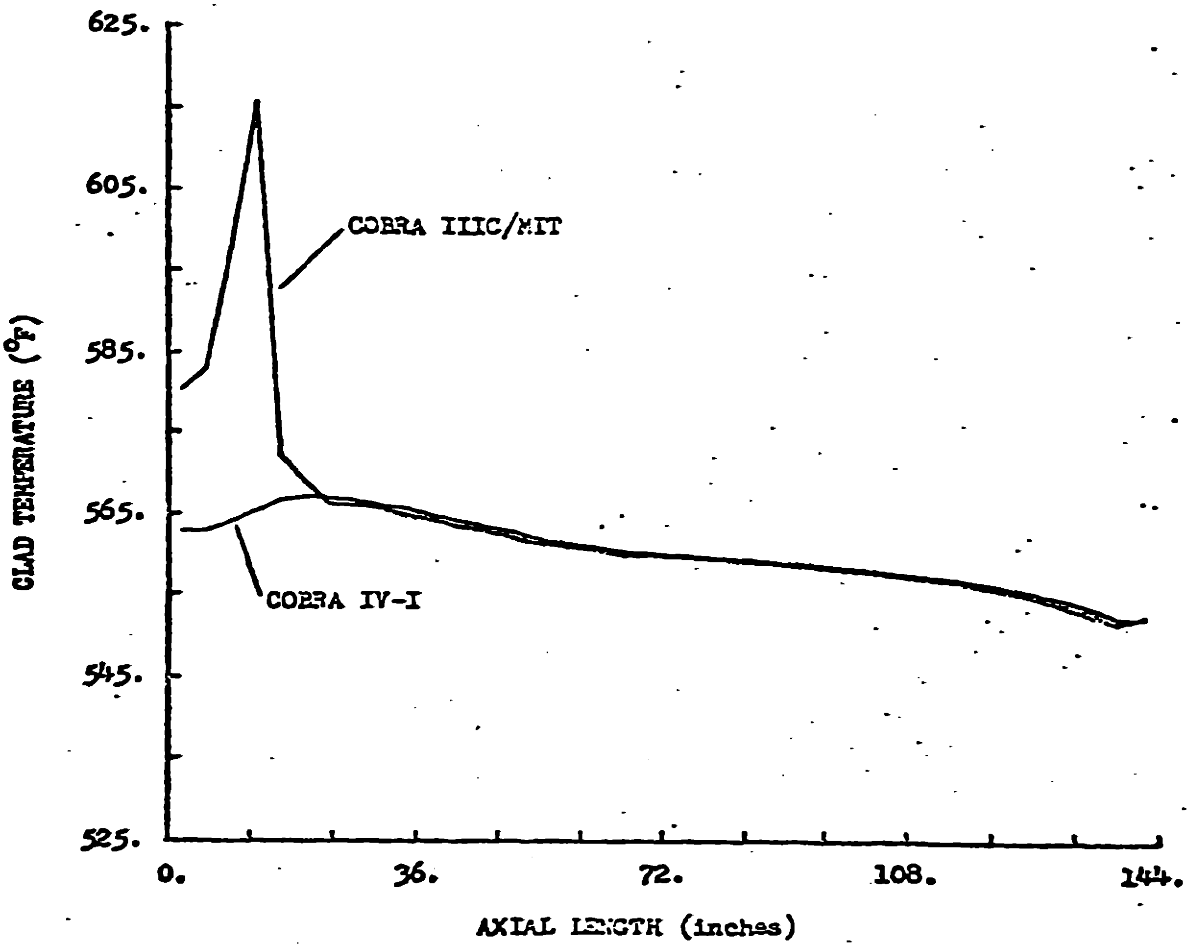

Figure II-1 (FIGURE 2.7 of Ref. 12)
CLAD TEMPERATURE VERSUS AXIAL LENGTH
RESULTS FOR STEADY STATE BWR CASE

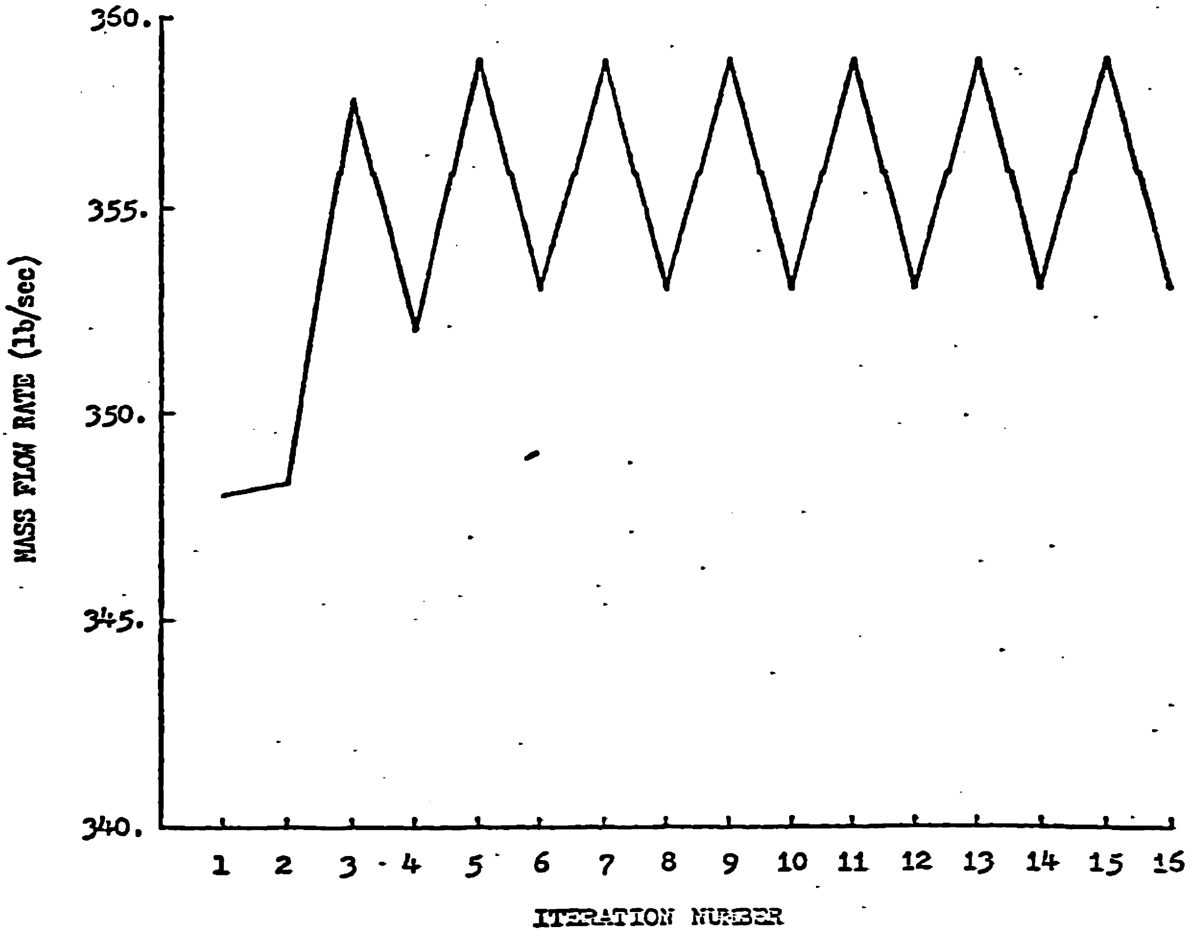

Figure II-2 (Fig. 3.4 of Ref. 12)

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.

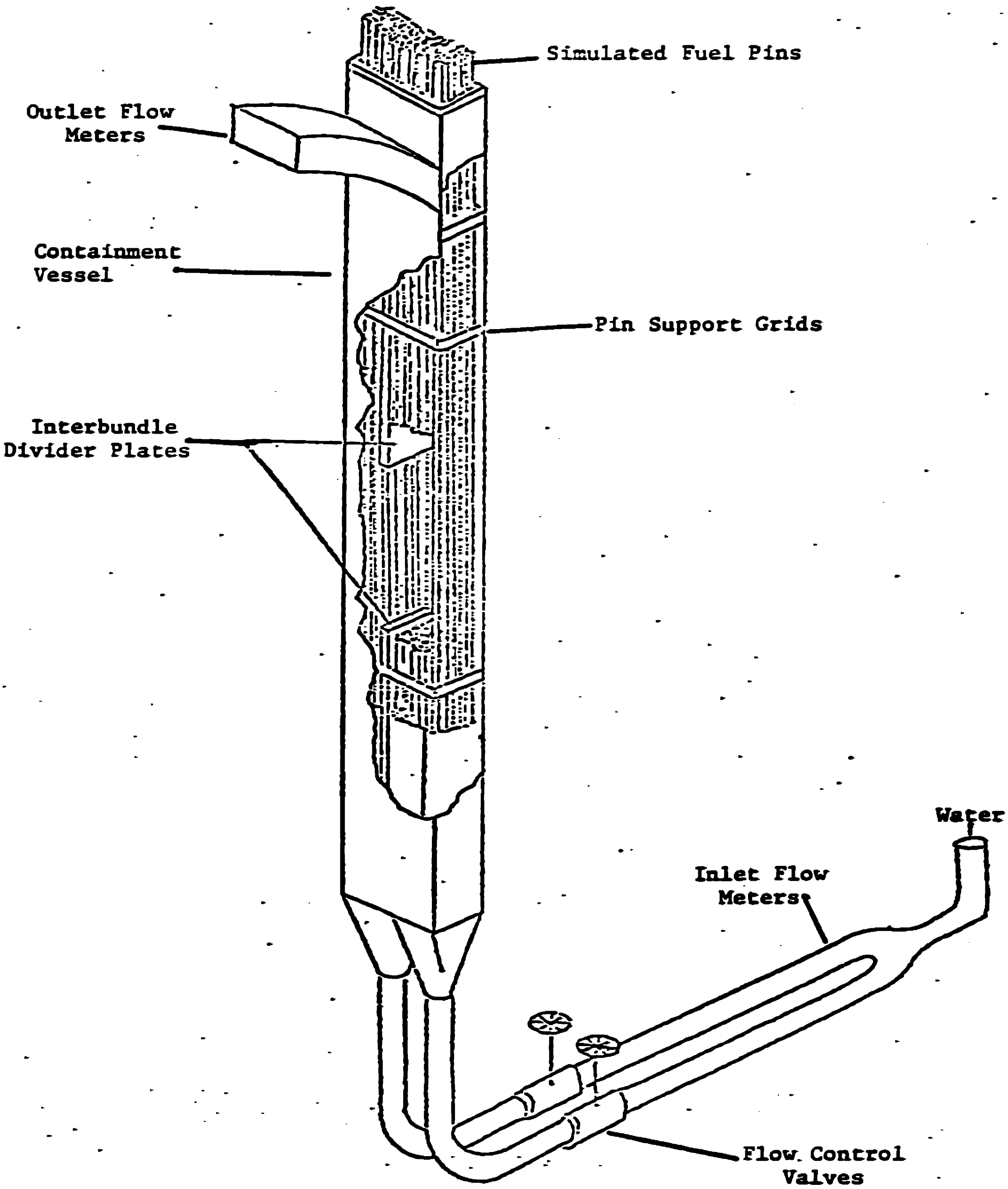

Figure II-3 (Fig. 5.2 of Ref. 12)

Schematic of B&W Apparatus

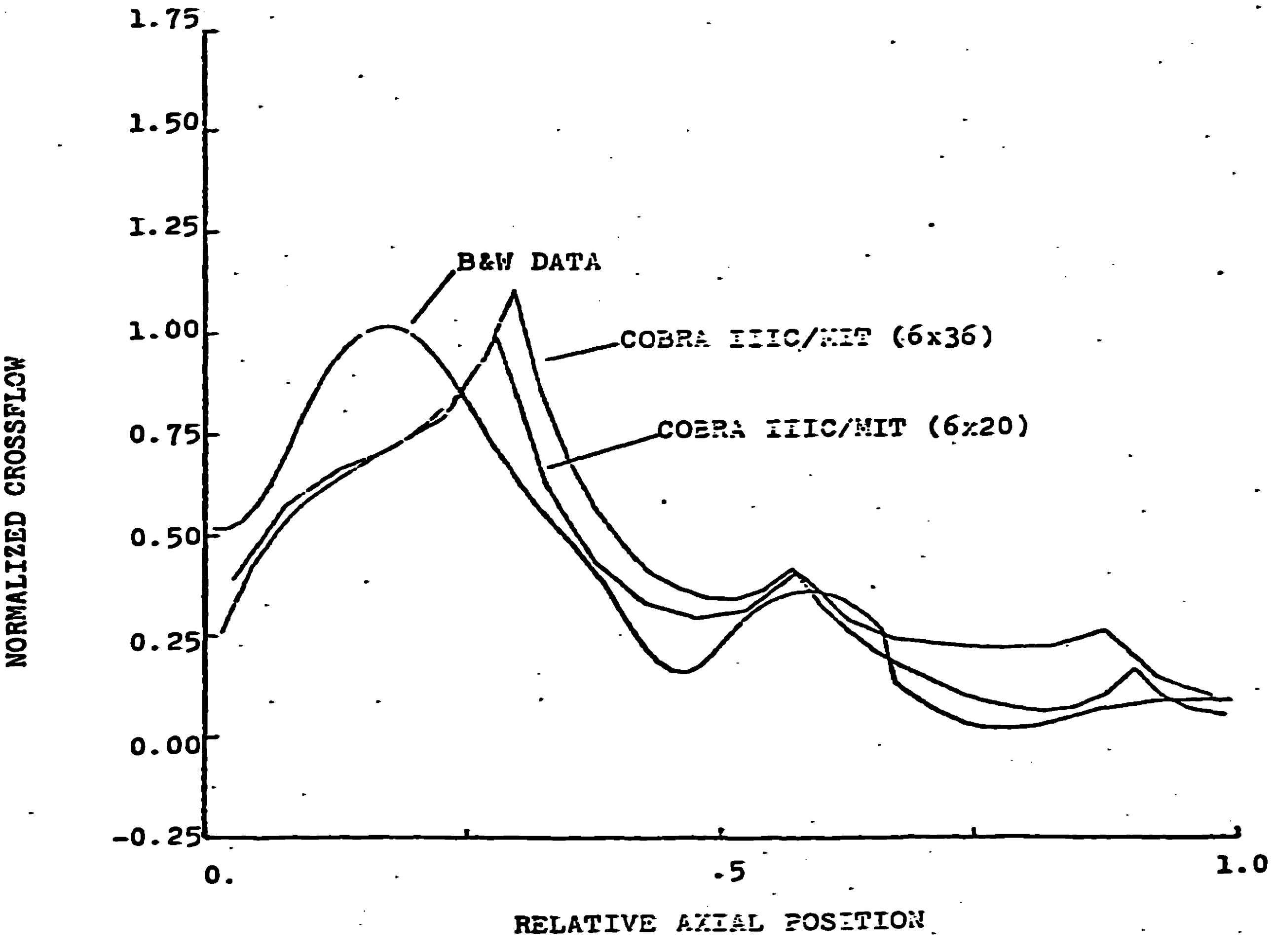

Figure II-4 (<u>FIGURE 3.18</u> of Ref. 11)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
COBRA-IIIC/MIT RESULTS FOR B&W CROSSFLOW EXPERIMENT

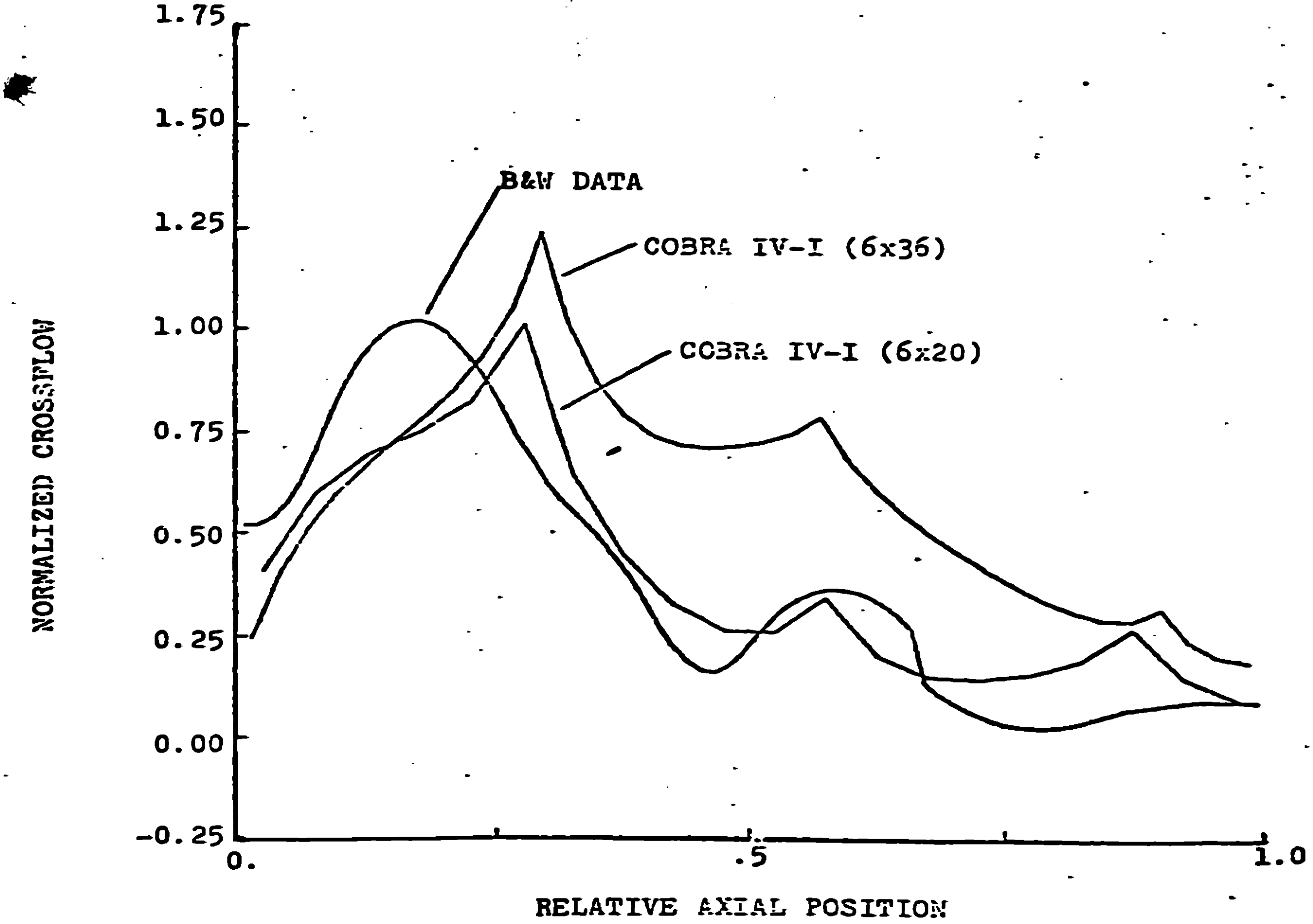

Figure II-5 (FIGURE 3.19 of Ref. 12)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
COBRA-IV-I RESULTS FOR B&W CROSSFLOW EXPERIMENT

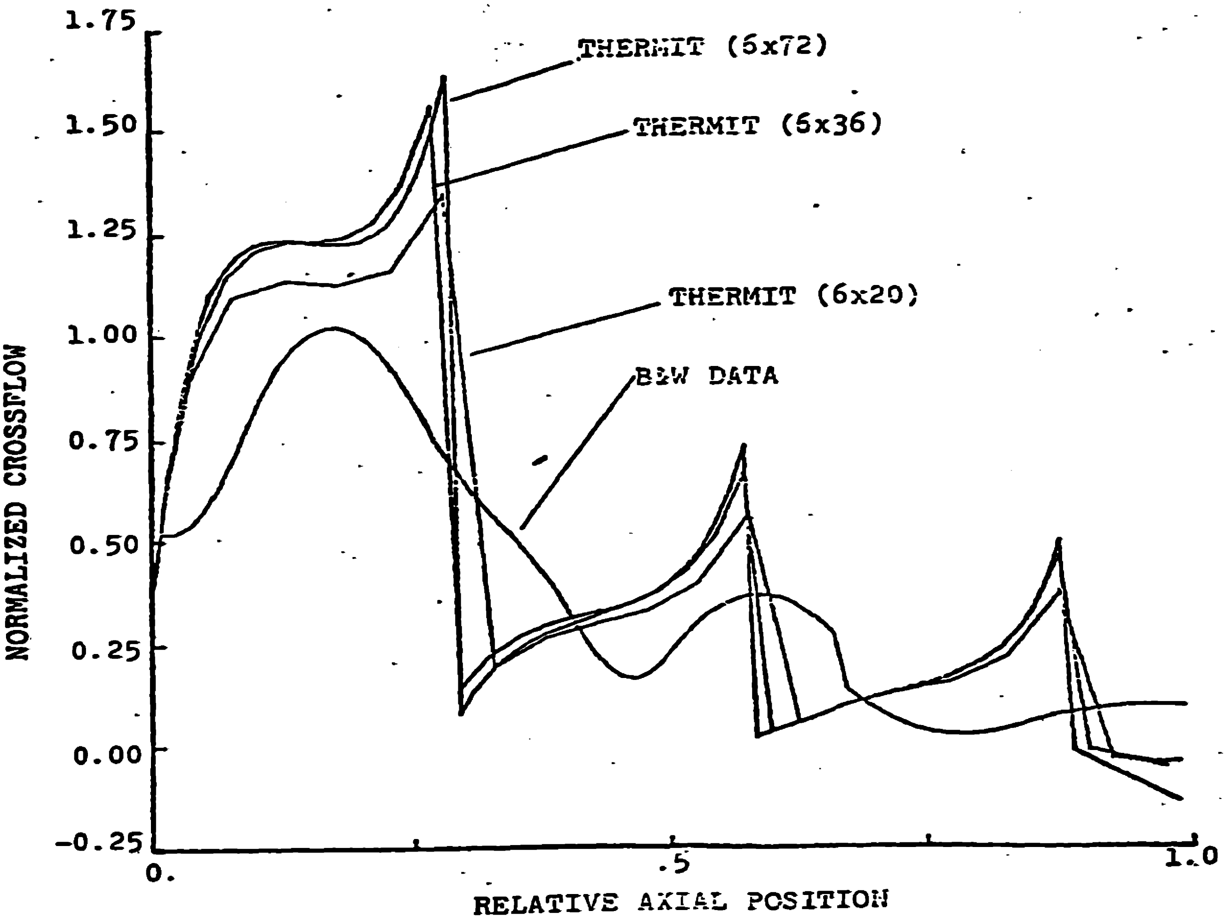

Figure II-6 (FIGURE 3.20 of Ref. 12)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
THERMIT RESULTS FOR B&W CROSSFLOW EXPERIMENT (Ref. App. H)

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) Flow and enthalpy predictions are sensitive to the turbulent mixing parameter, β, which varies greatly with respect to quality in the two-phase region.

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

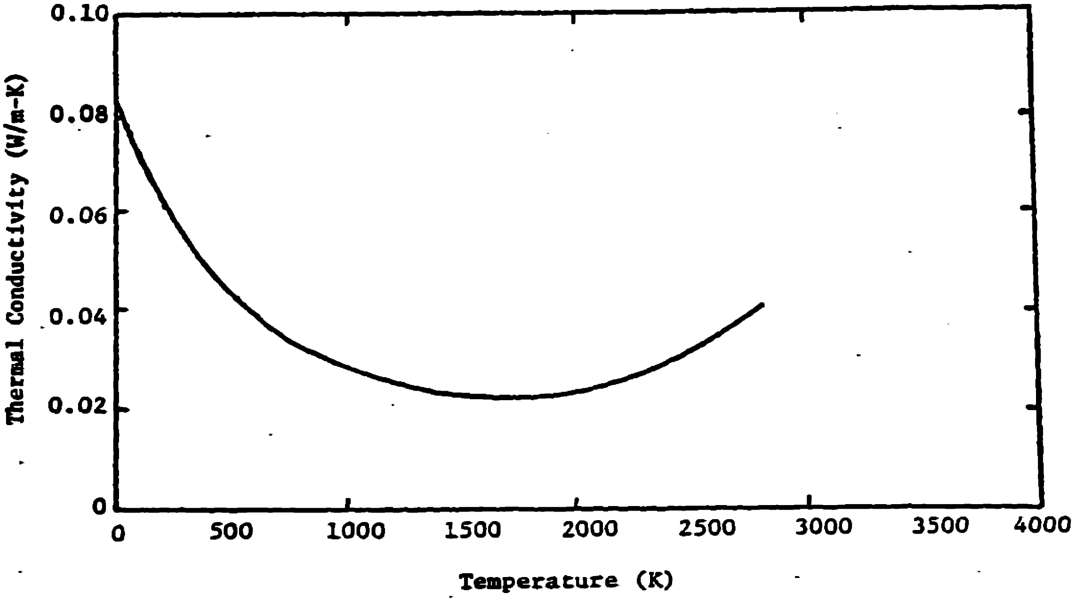

Figure III-1 (Based on Fig. A-2.1 of Ref. 15)
Thermal Conductivity of UO_2

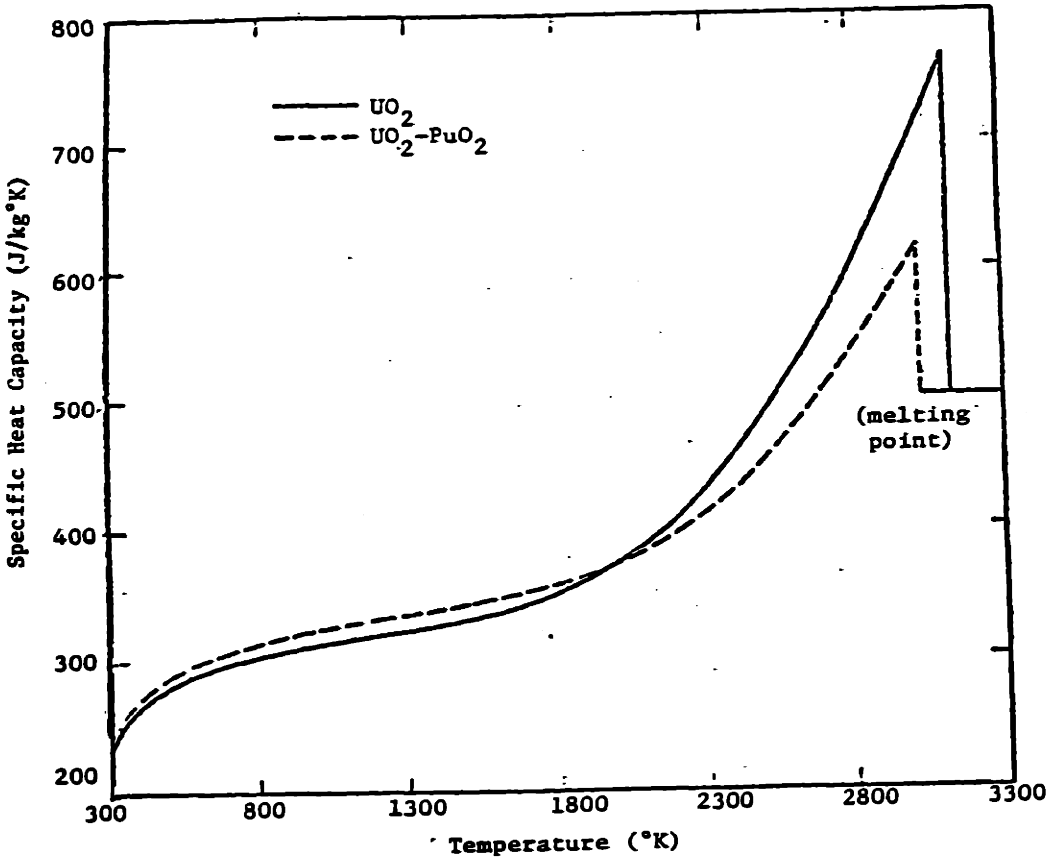

Figure III-2 (Fig. A-1.1 of Ref. 15)

Specific Heat Capacity of UO_2 and UO_2-P_uO_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 COBRA-IV-I heat transfer model is similar to the new heat transfer model because it can also construct a complete boiling curve. The COBRA-IV heat transfer model is described in Appendix F.

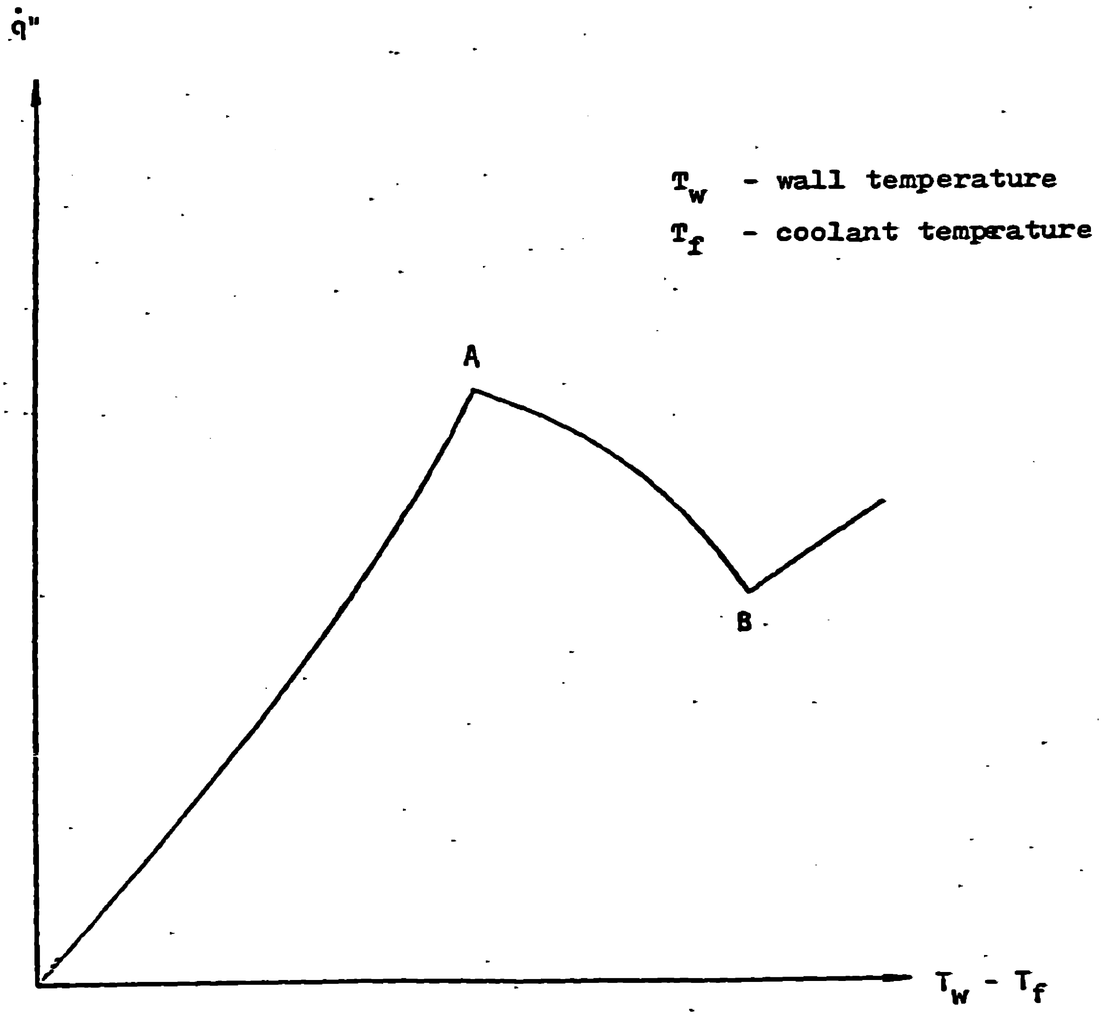

Figure III-3

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 to COBRA-IIIC/MIT to improve the prediction of turbulent mixing for two-phase flow in rod bundles. The model assumes existance 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 limitations:

System Pressure	$50 \leq P \leq 775$	psia
Mass Velocity	$7.3\times 10^4 \leq G \leq 3\times 10^6$	$lb/hr\text{-}ft^2$
Quality	$0 \leq x \leq .80$	
Gap Width	$0.2 \leq s \leq .10$	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 theBEXL correlation (Ref. 18) as part of a statistical treatment of the required thermal margin. The GEXL correlation is a critical quality - boiling

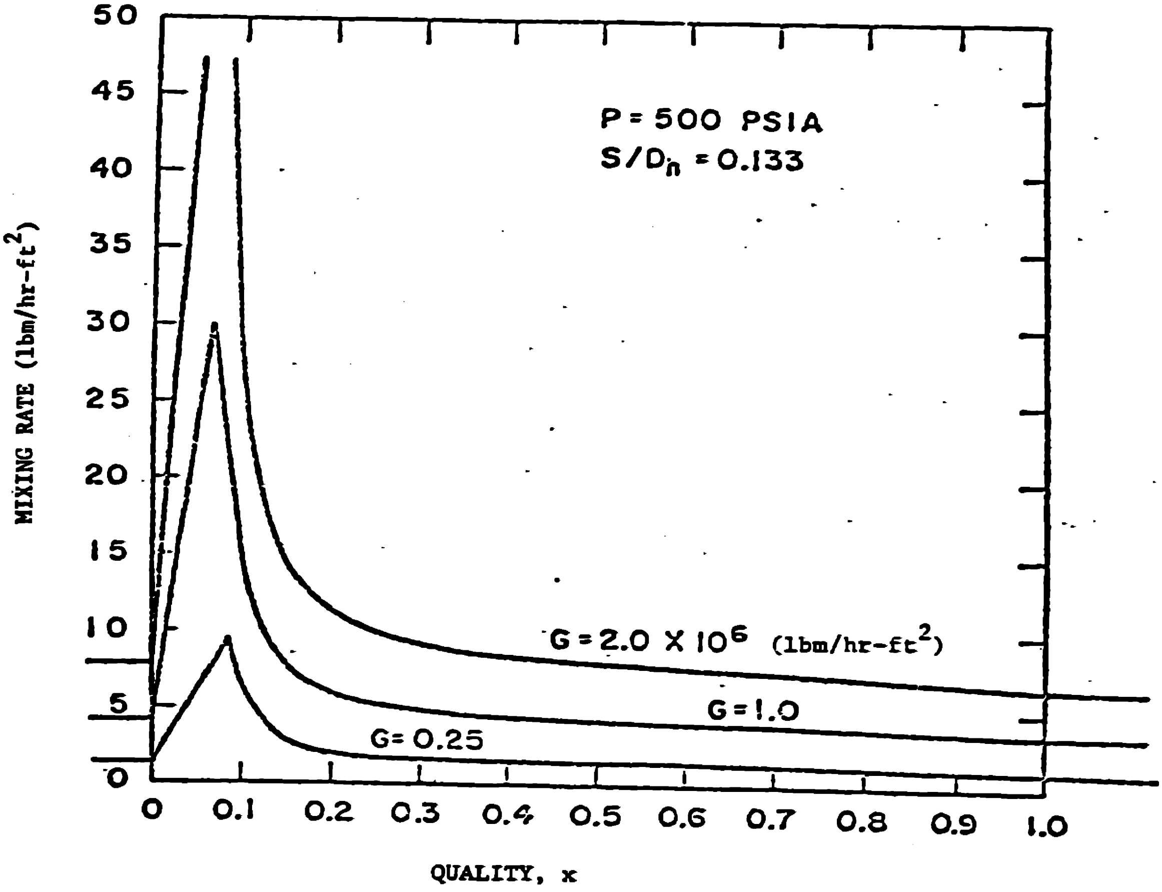

Figure III-4 (Fig. 8 of Ref. 16)

Mixing Rate Variation with Quality

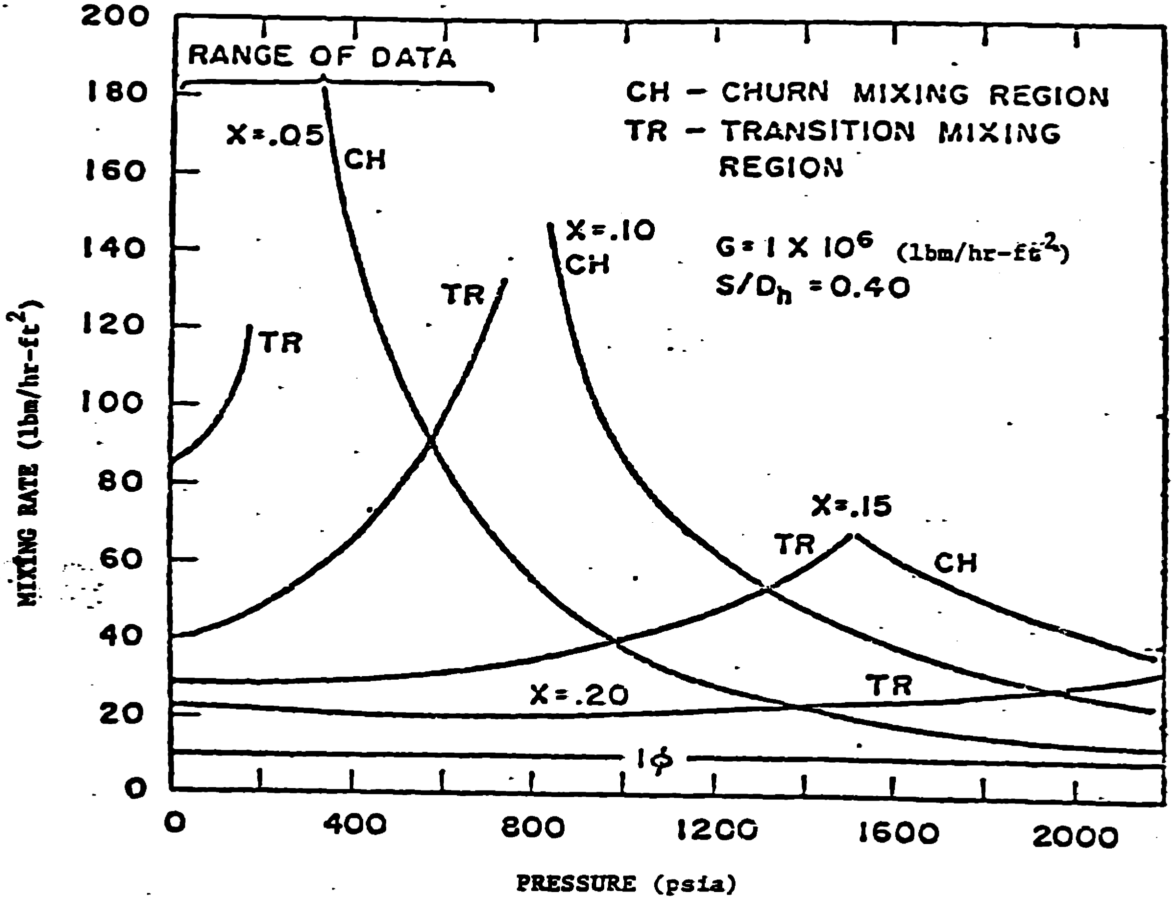

Figure III-5 (Fig. 9 of Ref. 16)

Mixing Rate Variation with Pressure

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 II-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,

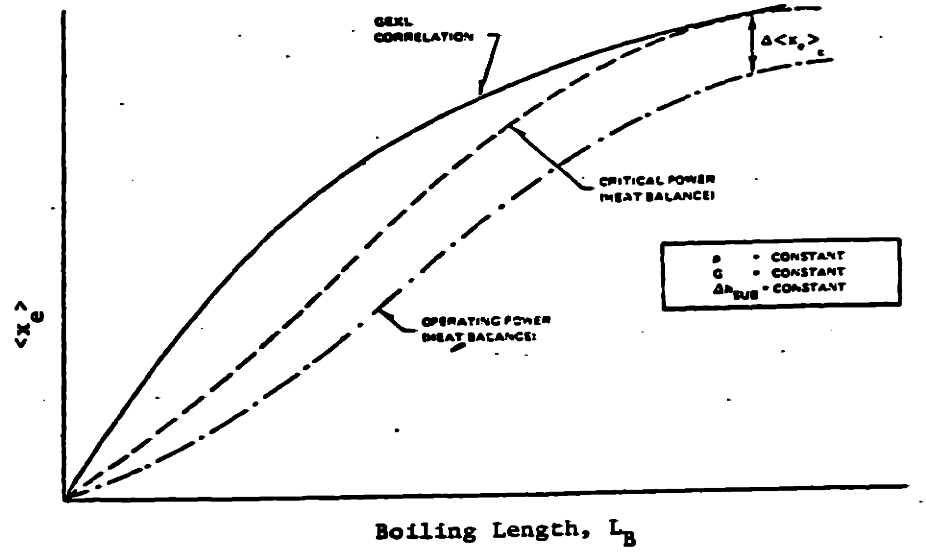

Figure III-6 (Fig. 4-40 of Ref. 19)

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:

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

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.

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

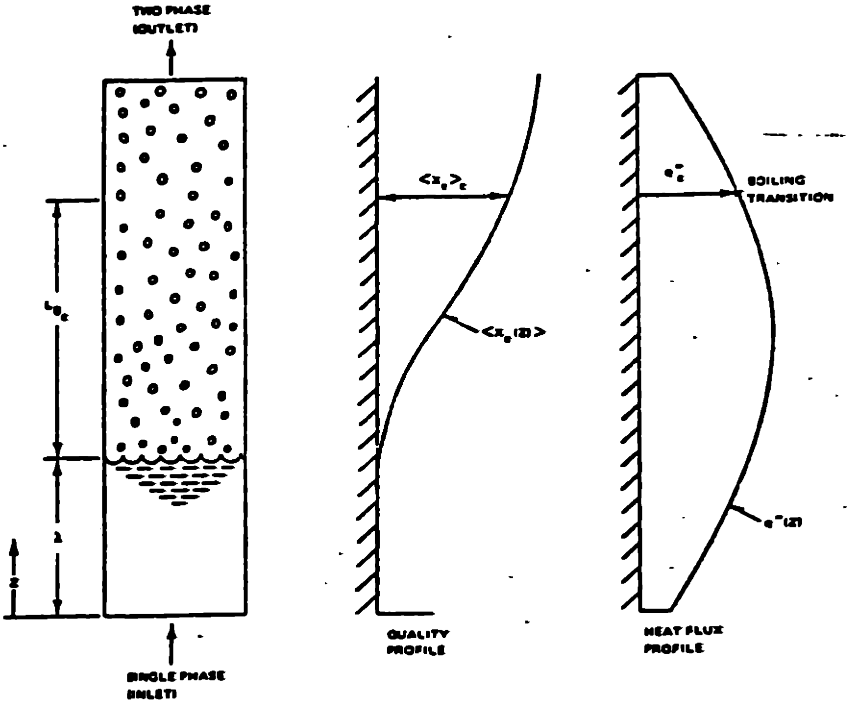


Figure III-7 (Fig. 4-27 of Ref.19)

Scehmatic Showing Relationship

Between L_{Bc}, $\langle x_e \rangle_c$ and the Boiling Transition

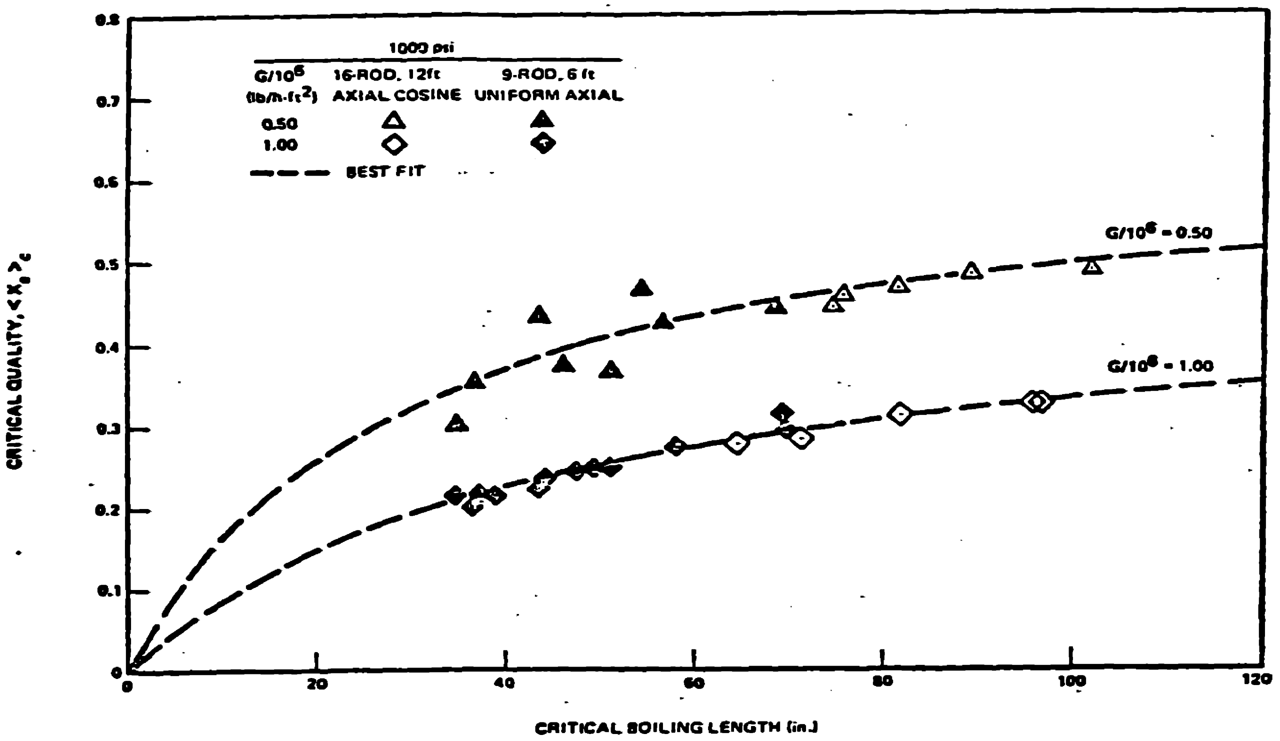


Figure III-8 (Fig. 4-31 of Ref. 19.)

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 $G \geqslant G_1$;

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

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

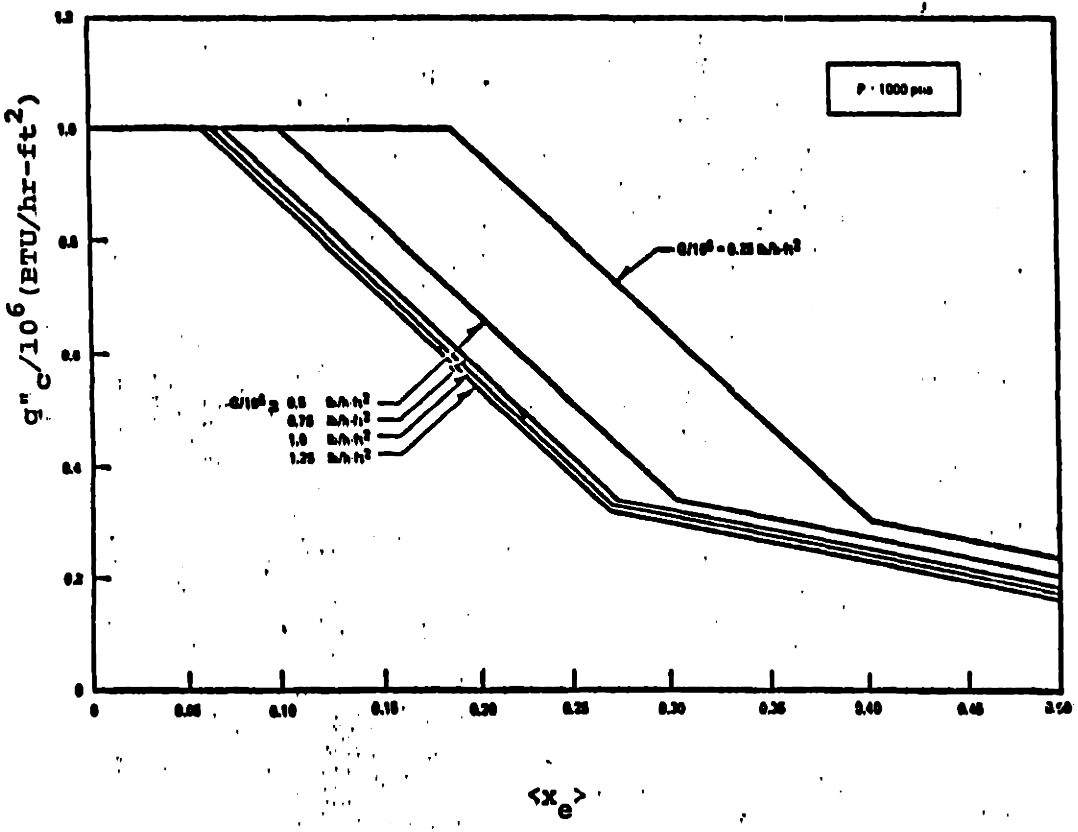


Figure III-9

<u>Hench-Levy Limit Lines</u>
(Ref. 18)

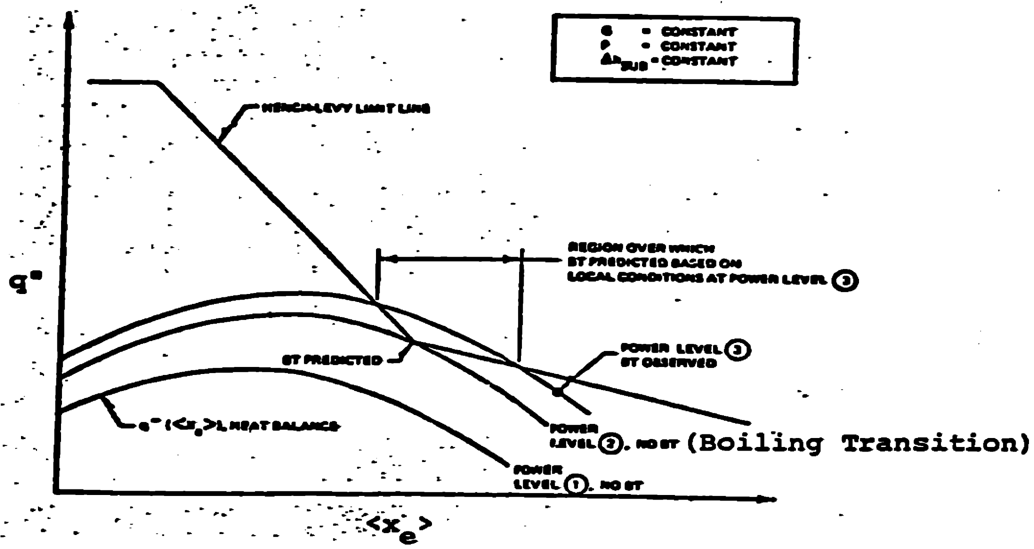


Figure III-10

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:

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

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

---

*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 subsectins 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 $\frac{MBTU}{hr\text{-}ft^2}$
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

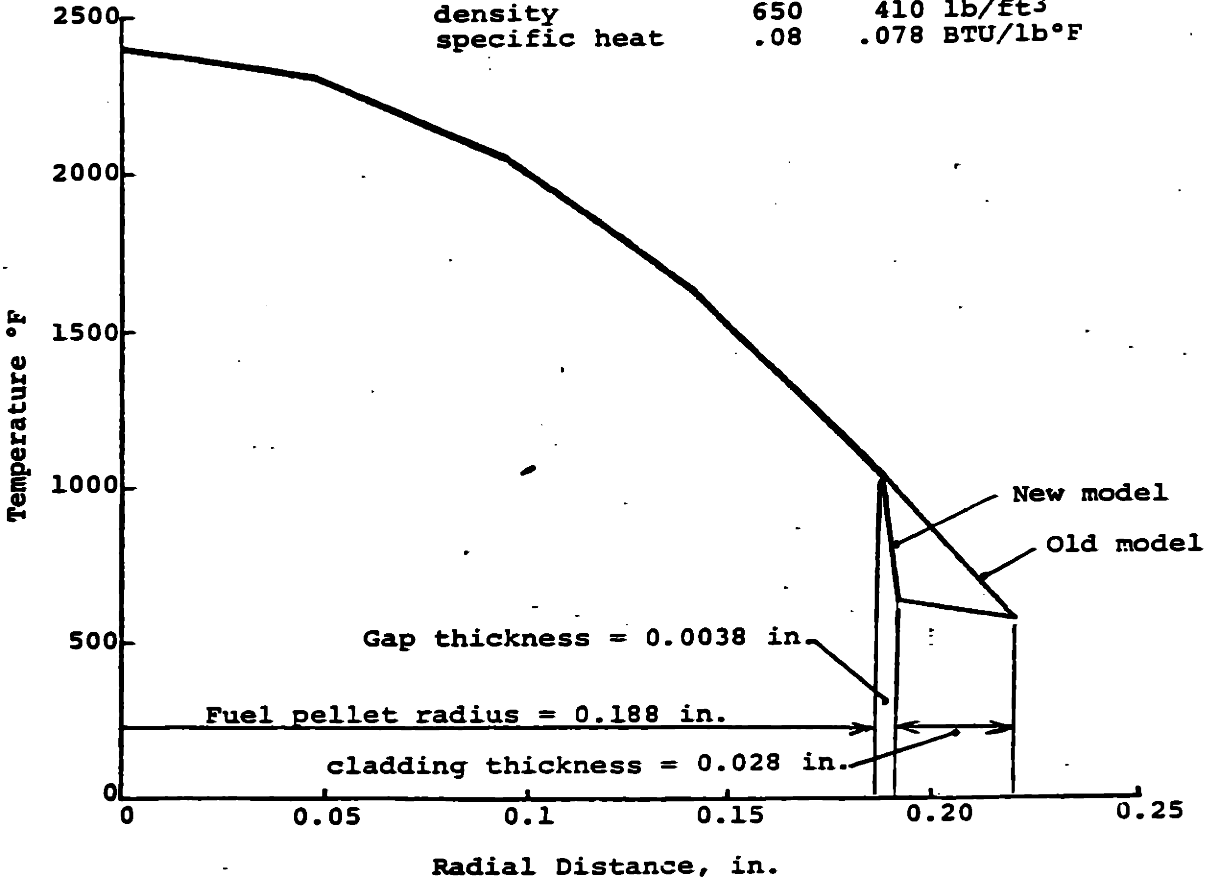


Figure IV-1

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 $Btu/hr\text{-}ft^2\text{-}°F$
Linear heat generation rate	5.8 Kw/ft

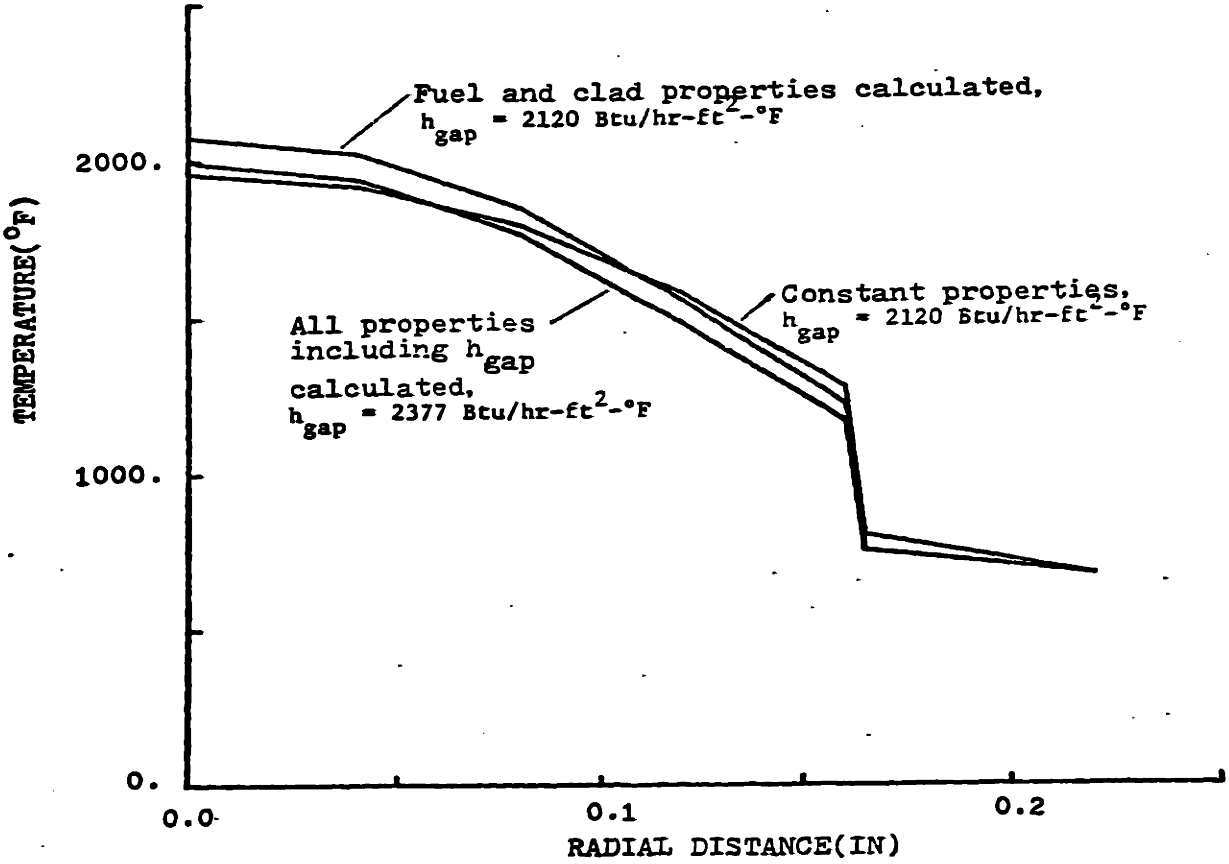


Figure IV-2

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=∞

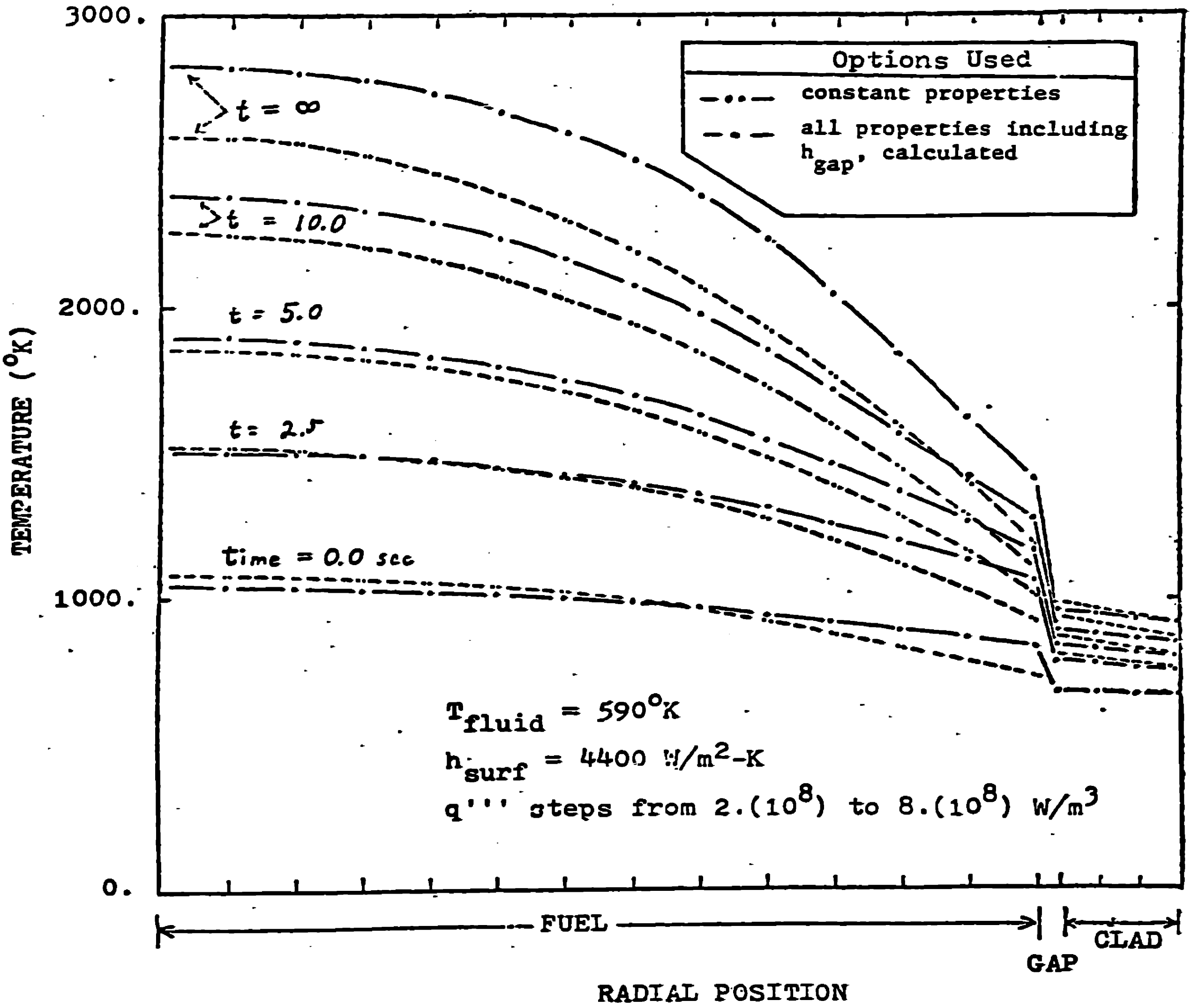


Figure IV-3

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 new rod-to-coolant heat transfer model was tested by running two test cases using the old and new heat transfer models. Steady state and transient pre-CHF 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.

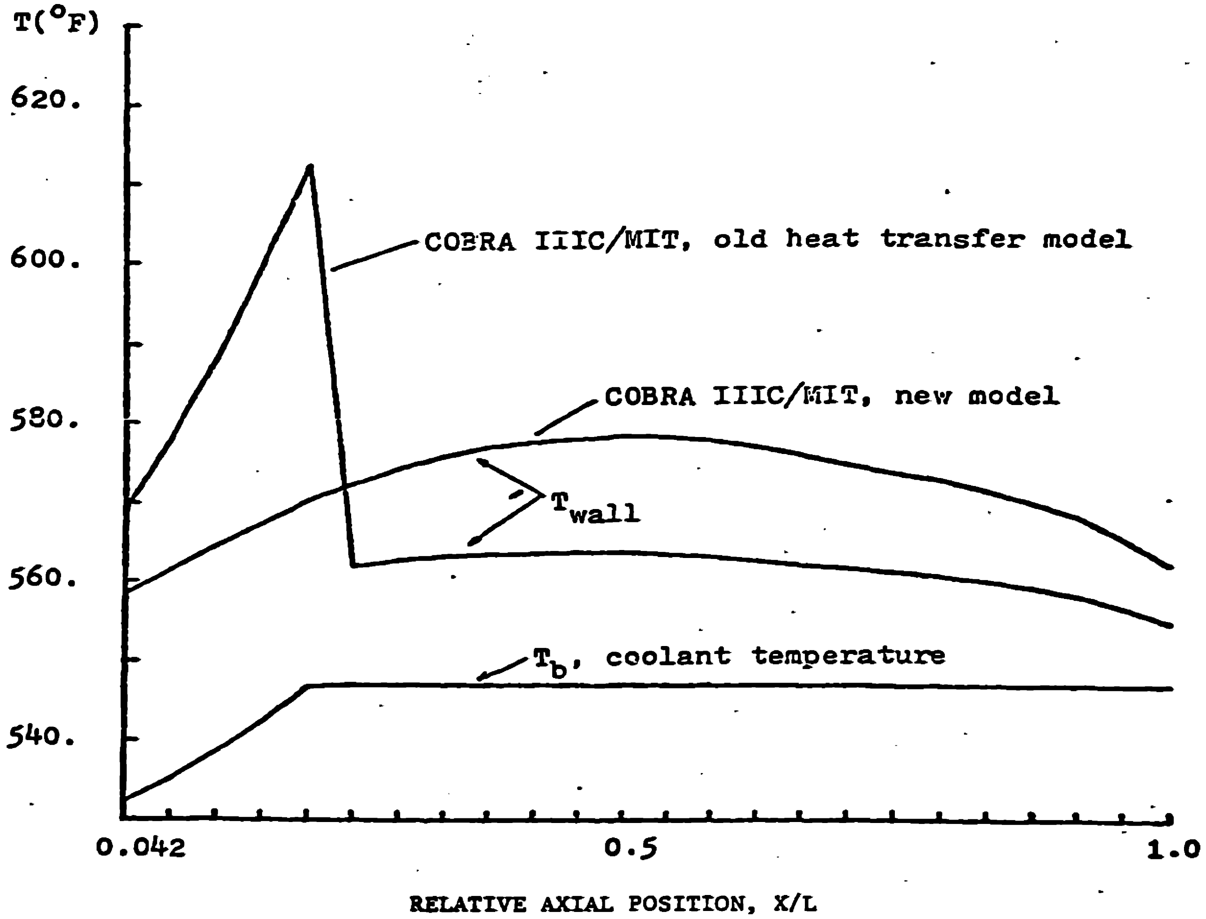


Figure IV-4

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.

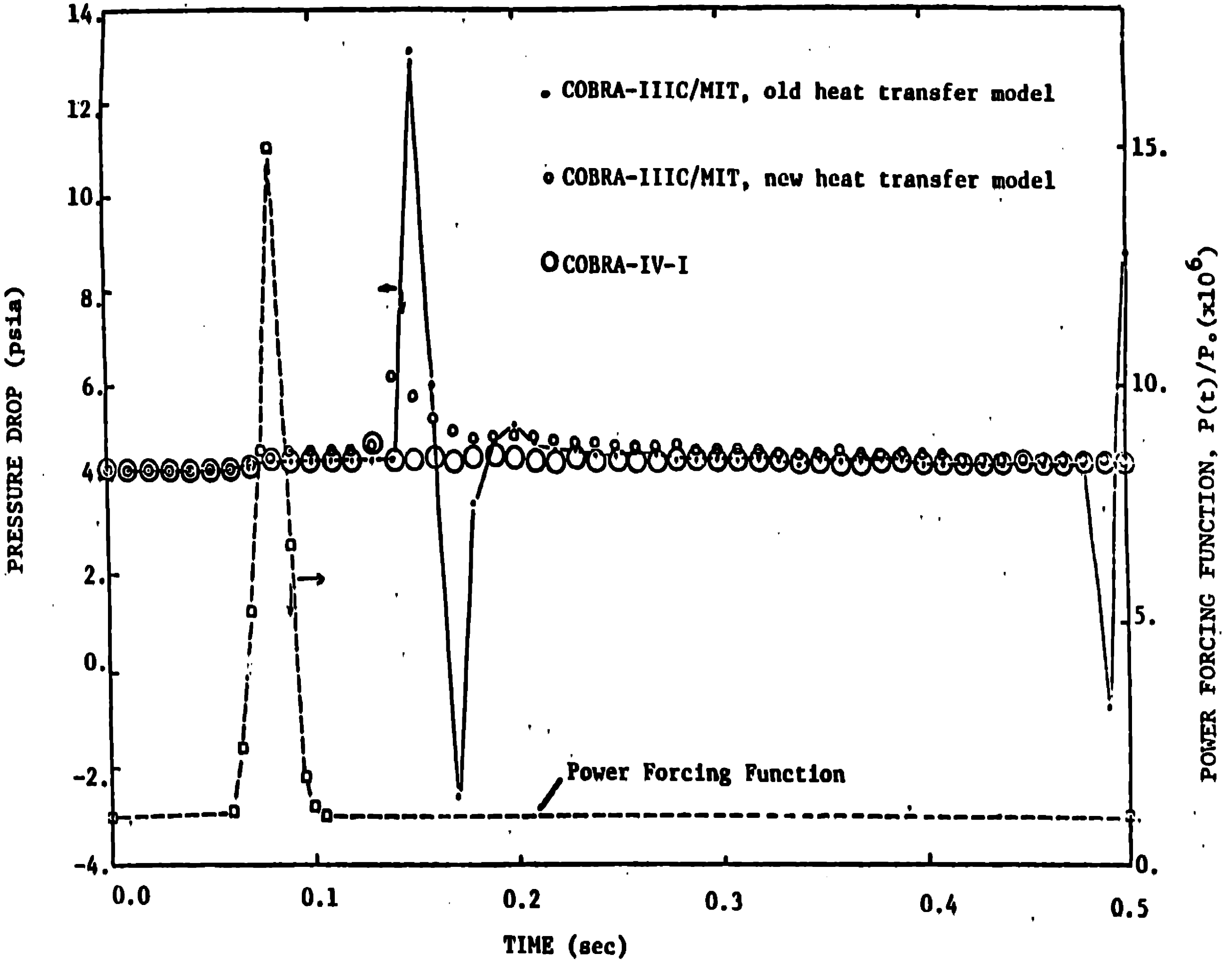


Figure IV-5
Channel Pressure Drop vs. Time

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 similar to 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 "a" coefficient was set equal to 0.286. "b" was given the smooth-tube friction factor correlation value of -0.2. Comparisons of predicted and measured axial friction pressure drops are given 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 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**

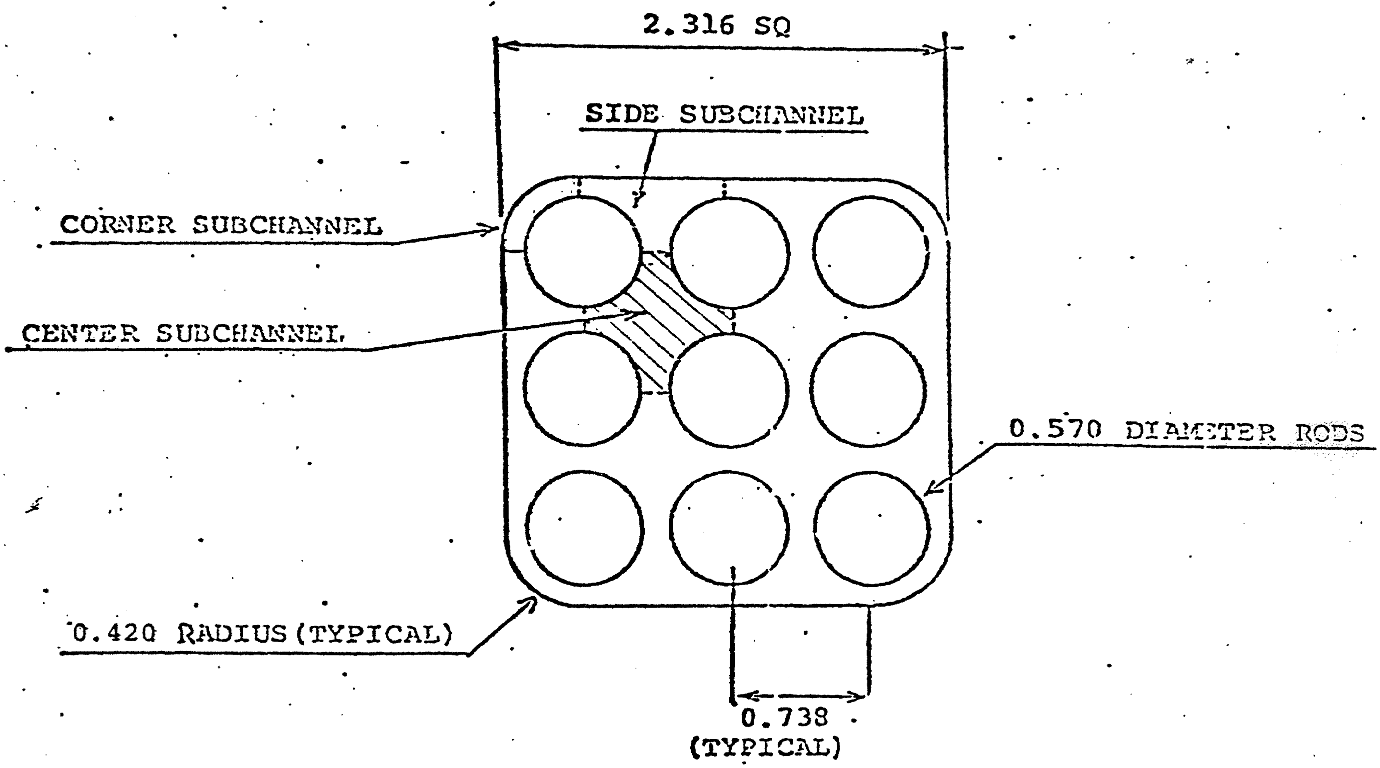


Table IV-1

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	$50 \leqslant P \leqslant 775$	psia
Mass Flux	$.073 \leqslant G \leqslant 3.$	Mlb/hr ft^2
Quality	$-0.2 \leqslant X \leqslant .80$	
Gap Width Between Subchannels	$.02 \leqslant S \leqslant .10$	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 (repeated)	1.610	1.60

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

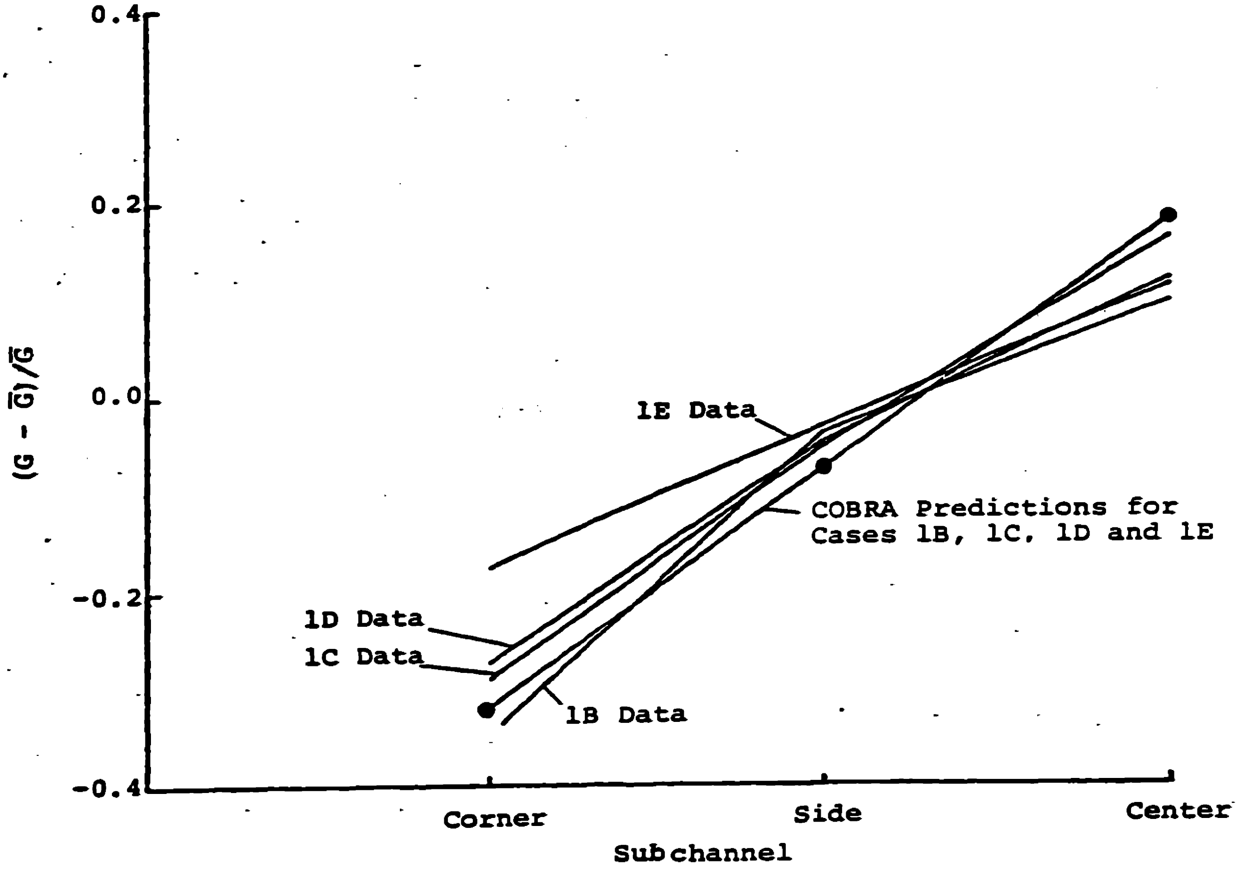


Figure IV-7

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 $\beta=0.02$. 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 overpredicted as exit quality increases, going from case 2G1 to 2G2 and on to case 2G3. The enthalpy distribution predictions using $\beta=0.02$ are essentially the same for all three cases.

Beus and $\beta=0.02$ 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. 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 the predictions of a temporary modification of the Beus mixing model, whereby the single-phase component of Beus mixng, W_L, is predicted using $\beta=0.02$. This change affects the mixing predictions from subcooled conditions up to the beginning of the transition mixing region shown in Figure IV-10. Mixing rate predictions in the transition mixing region are unaffected by the modification. The normalized enthalpy prediction of $\beta=0.02$ shown in Figure IV-9 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
$\overline{X}_{exit} = 0.038$

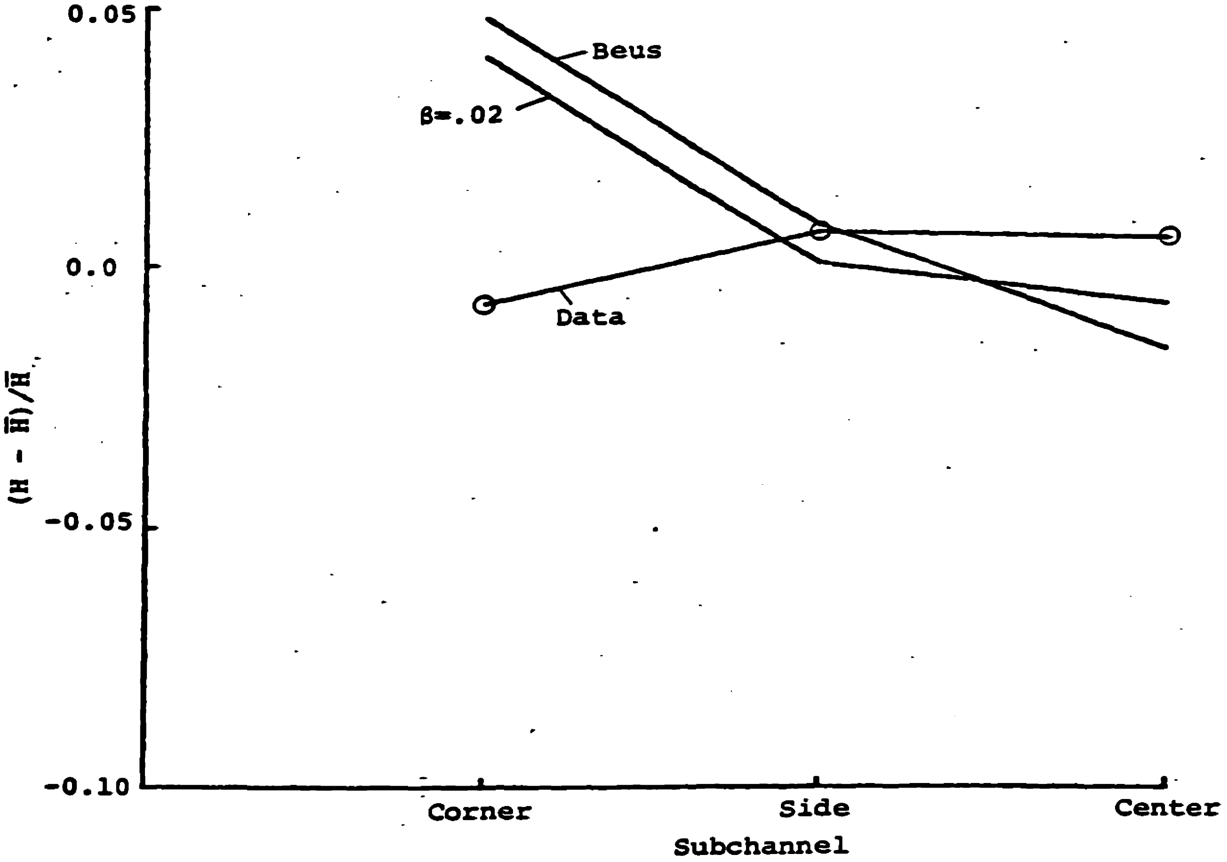


Figure IV-8

GE Mixing Test Case 2G1
Normalized Exit Enthalpy Distribution

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

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

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

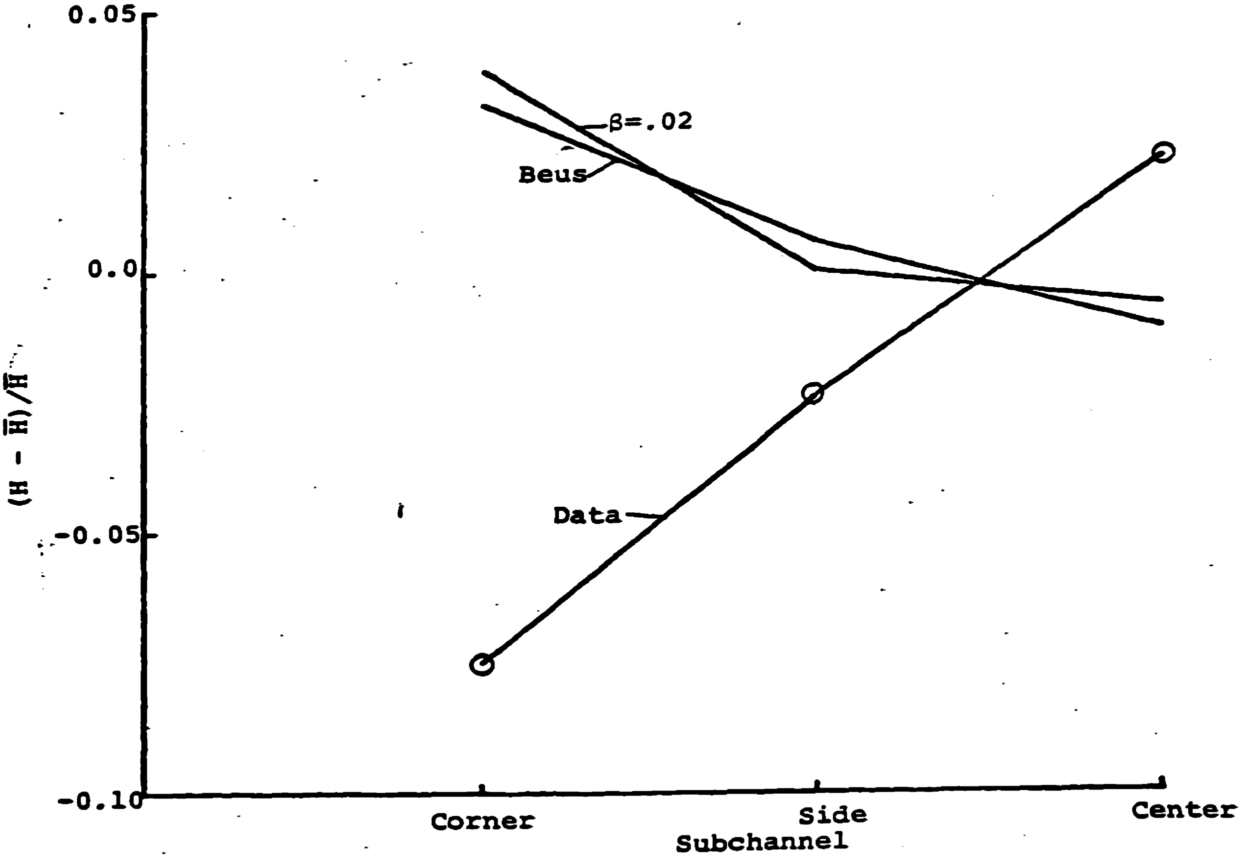


Figure IV-9

GE Mixing Test Case 2G2
Normalized Exit Enthalpy Distribution

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

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

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

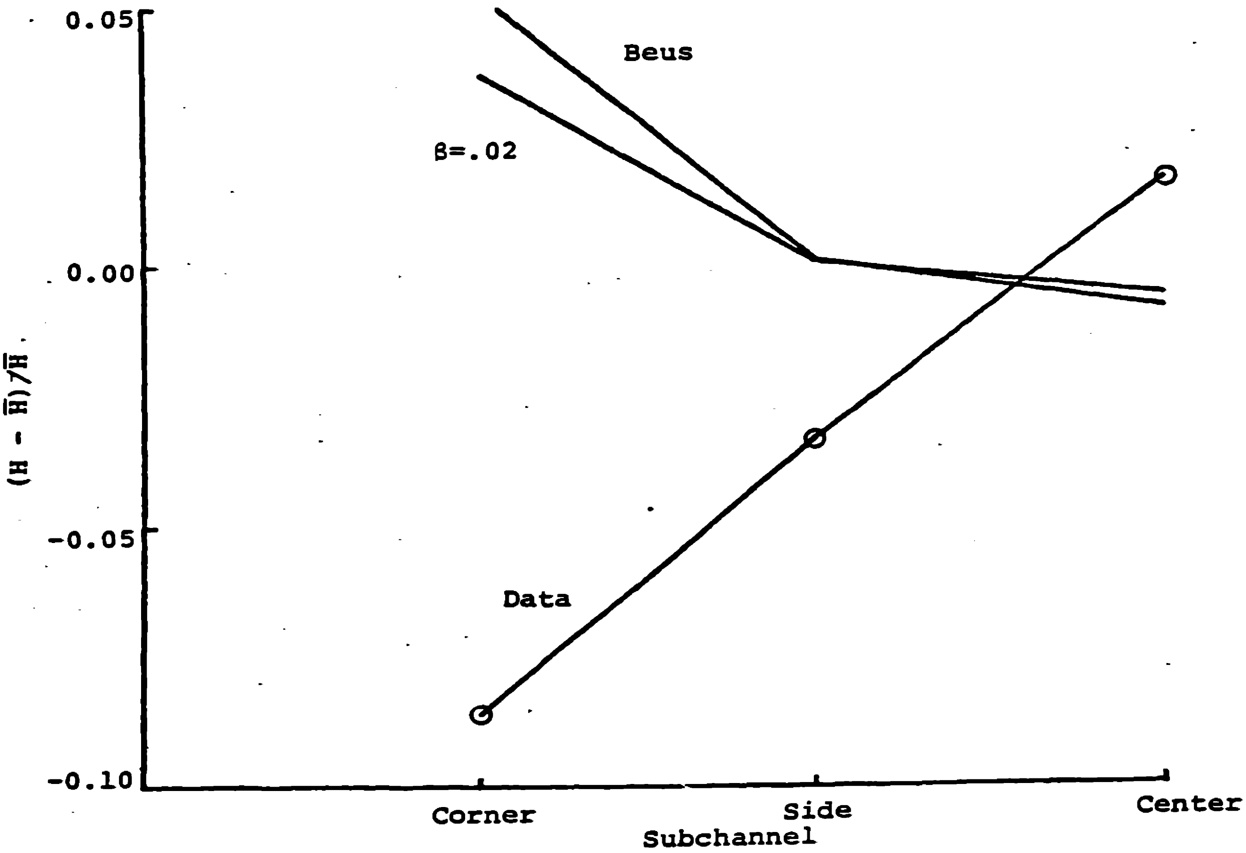


Figure IV-10

GE Test Case 2G3

Normalized Exit Enthalpy Distribution

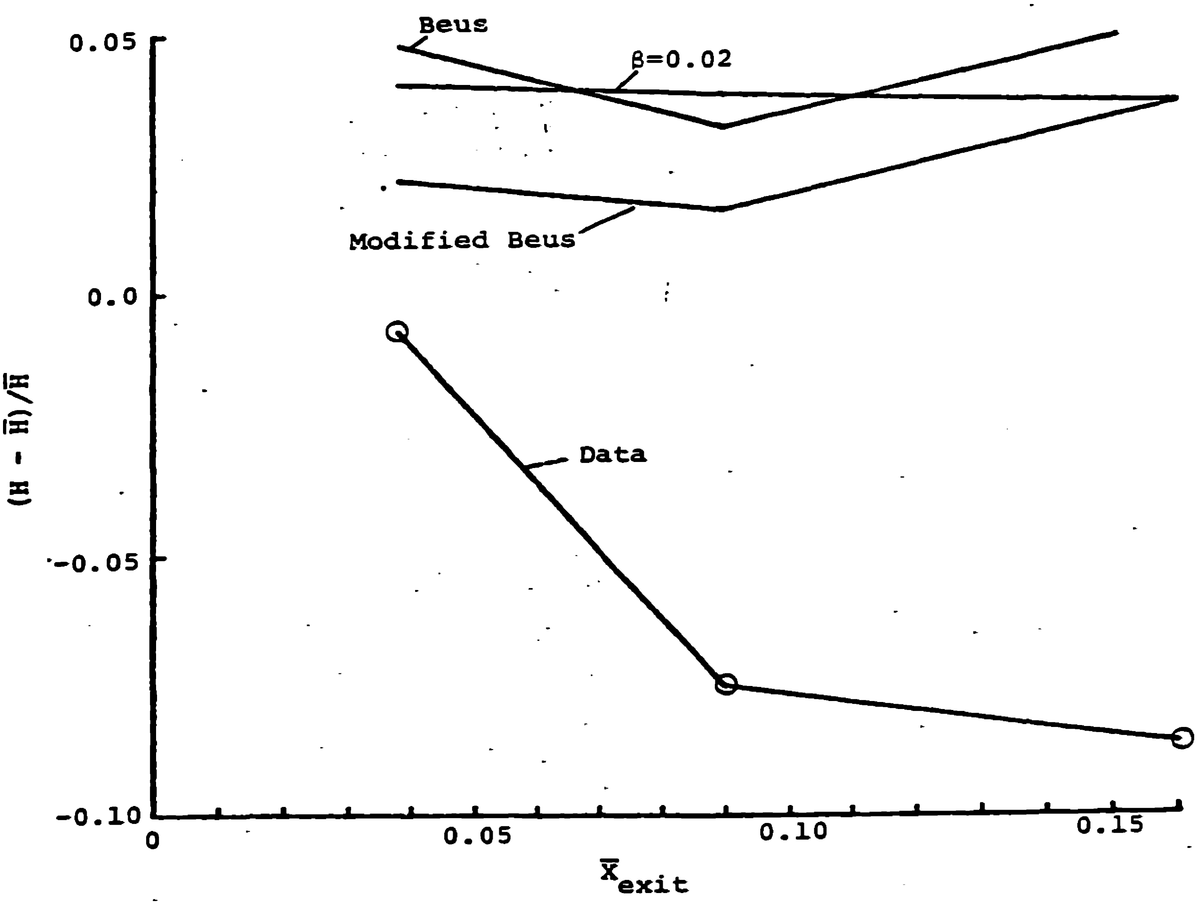


Figure IV-11

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

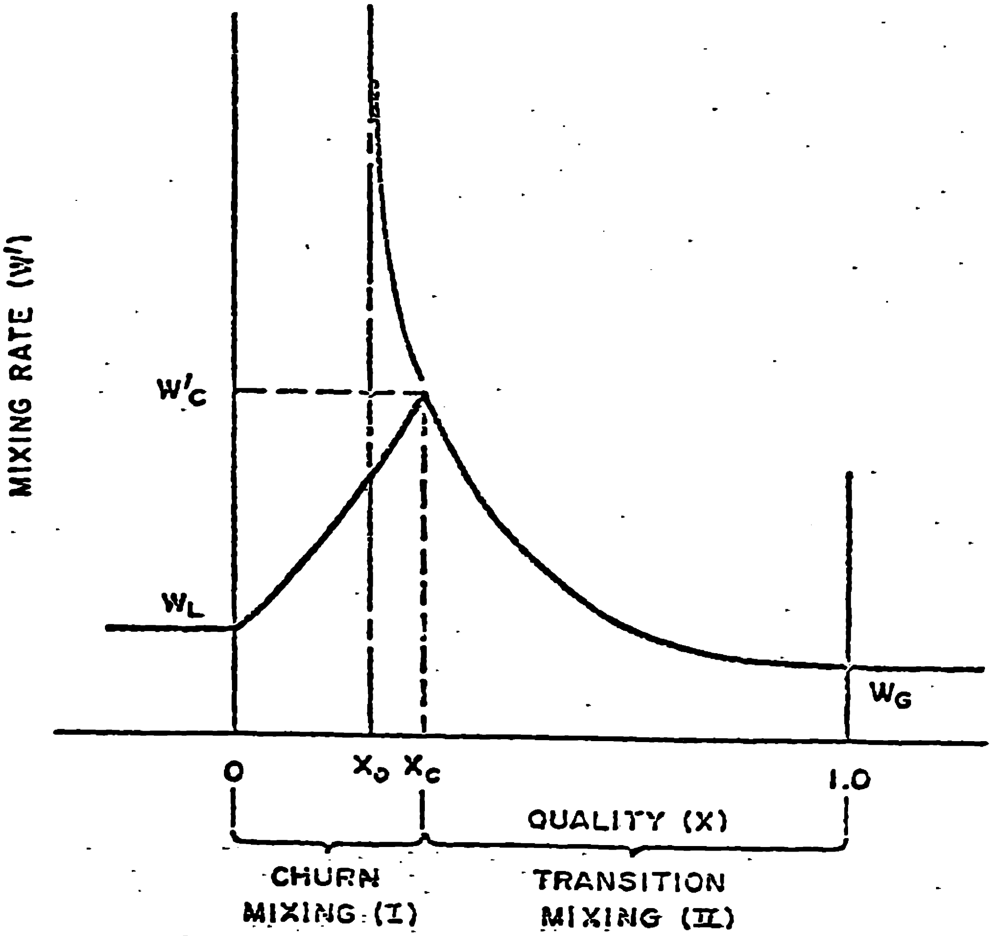


Figure IV-12

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

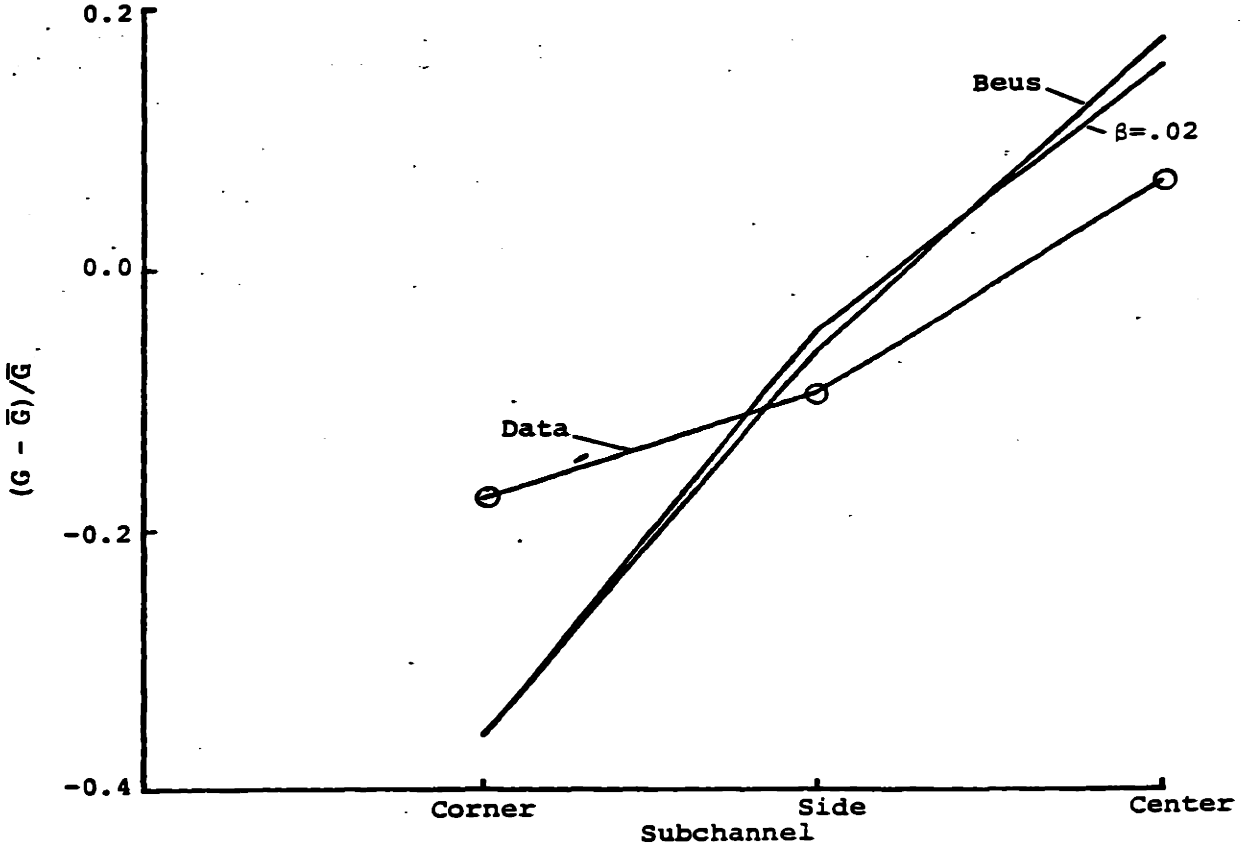


Figure IV-13

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

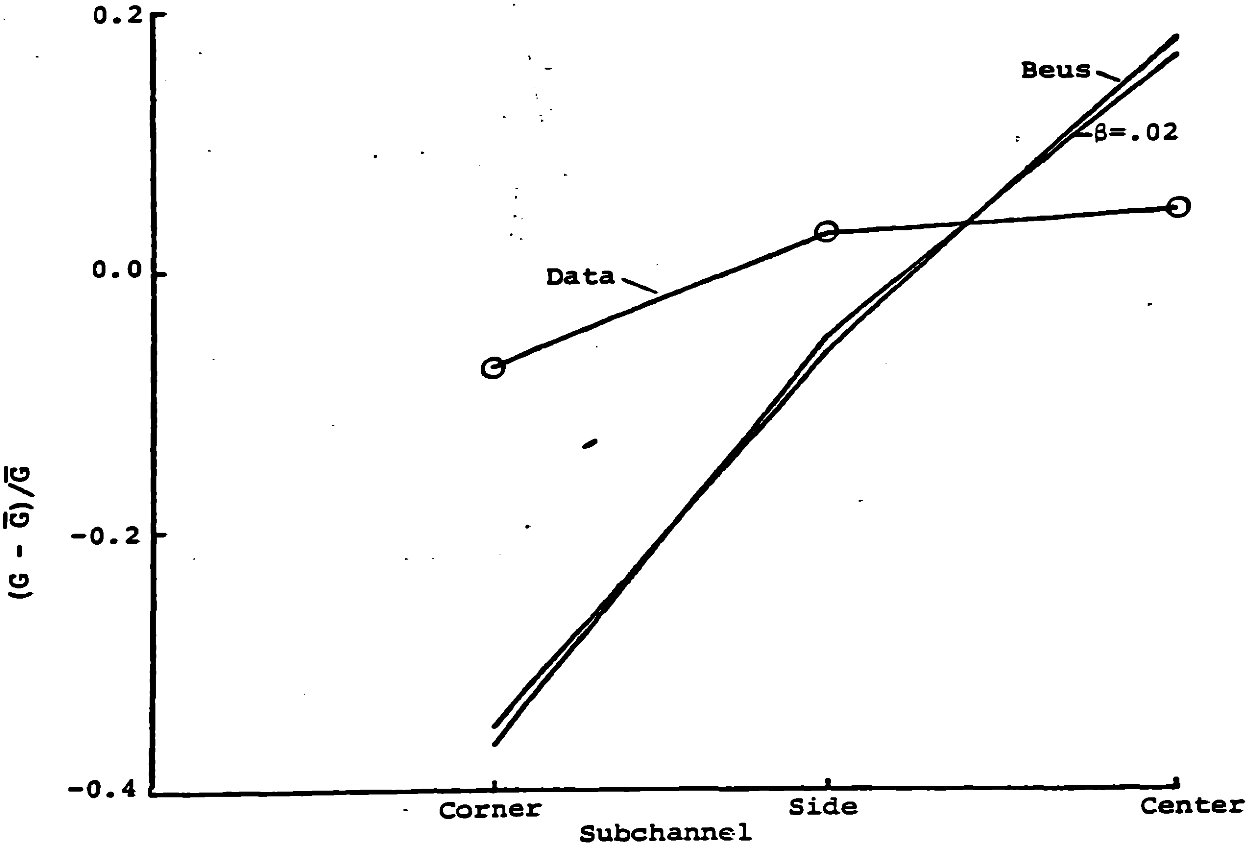


Figure IV-14

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

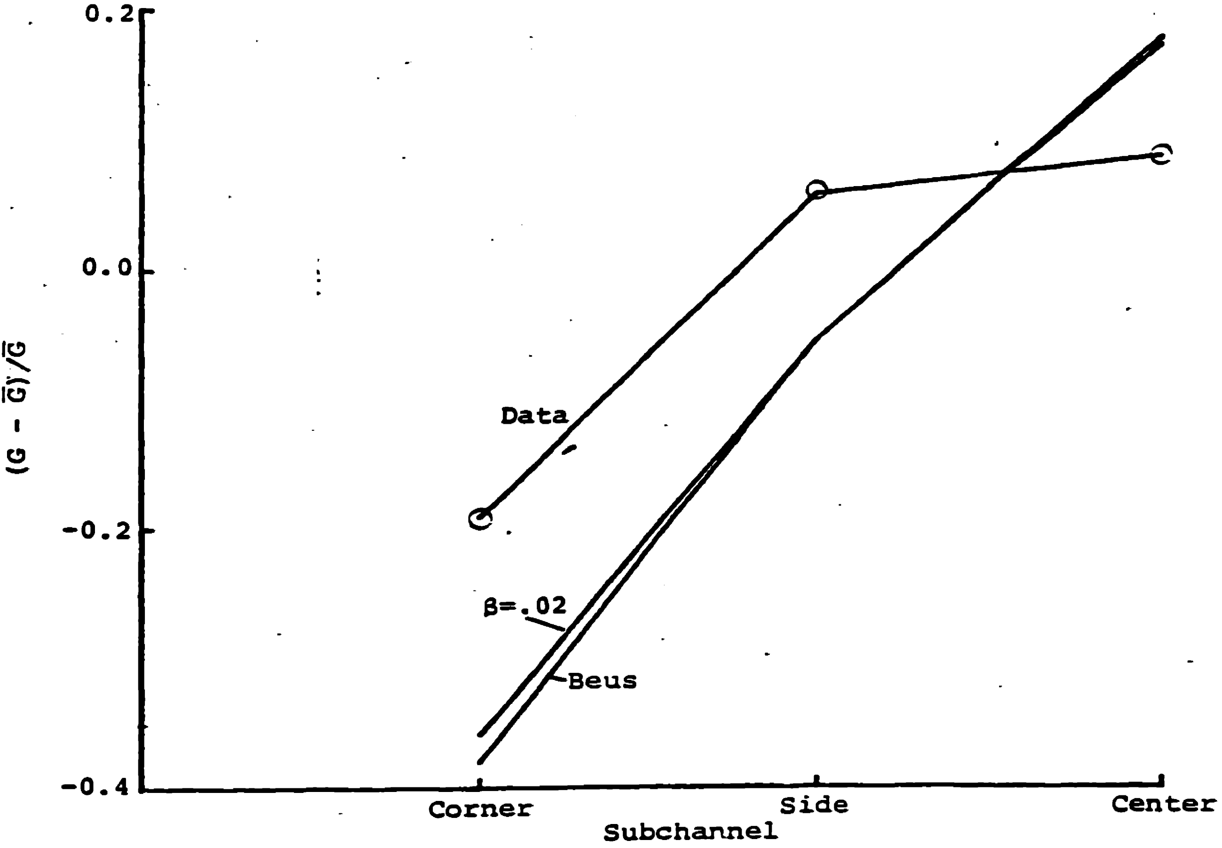


Figure IV-15

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 $\beta=0.02$ 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 $\beta=0.2$ mass flux distribution trends show little difference.

In conclusion, enthalpy distribution is predicted differently than data. Enthalpy is overpredicted in the corner subchannel and underpredicted in the center channel. Use of the Beus mixing model does not make much difference. A void-drift model or other similar approach is needed to account for the tendency of vapor to move toward the center of the bundle.

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 x 10^6; 2 x 10^6; 3 x 10^6 lbm/hr ft^2
Inlet Temperature	172°F to 484°F
Average Heat Flux	0.384 x 10^6; 0.56 x 10^6; 0.967 x 10^6 BTU/hr ft^2
Traverse Heating Ratio	Colder/Hotter: 0.86 Colder/Average: 1.02 Hotter/Average: 1.08

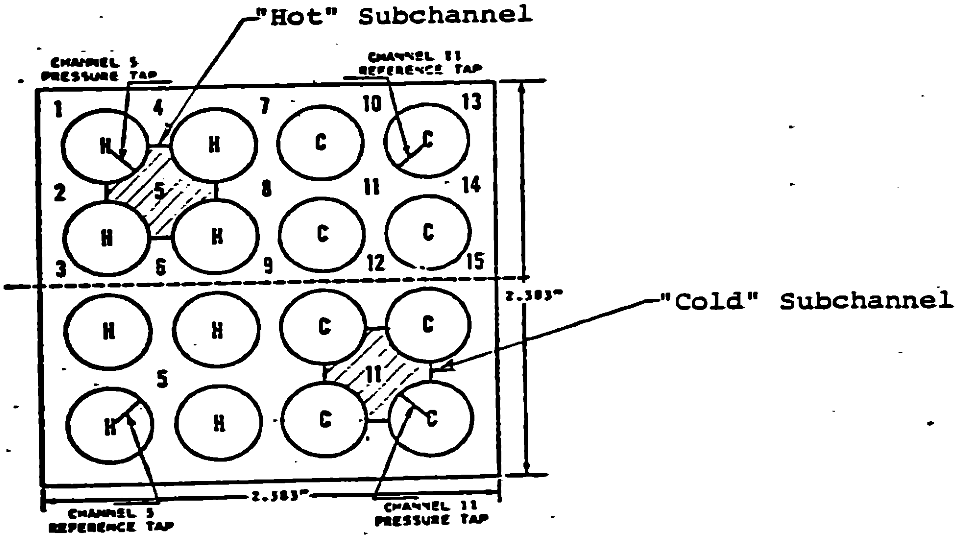


Table IV-3

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.

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

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

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

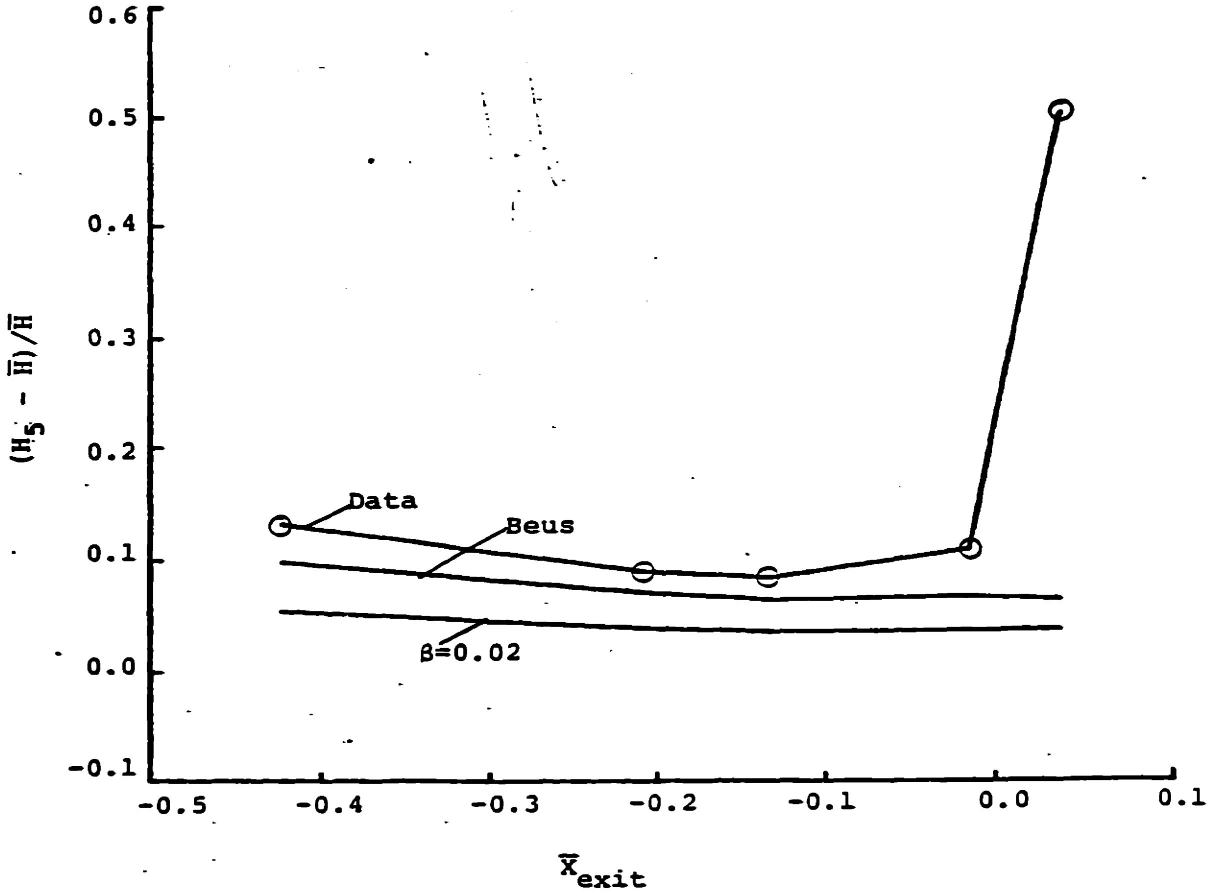


Figure IV-17

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

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

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

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

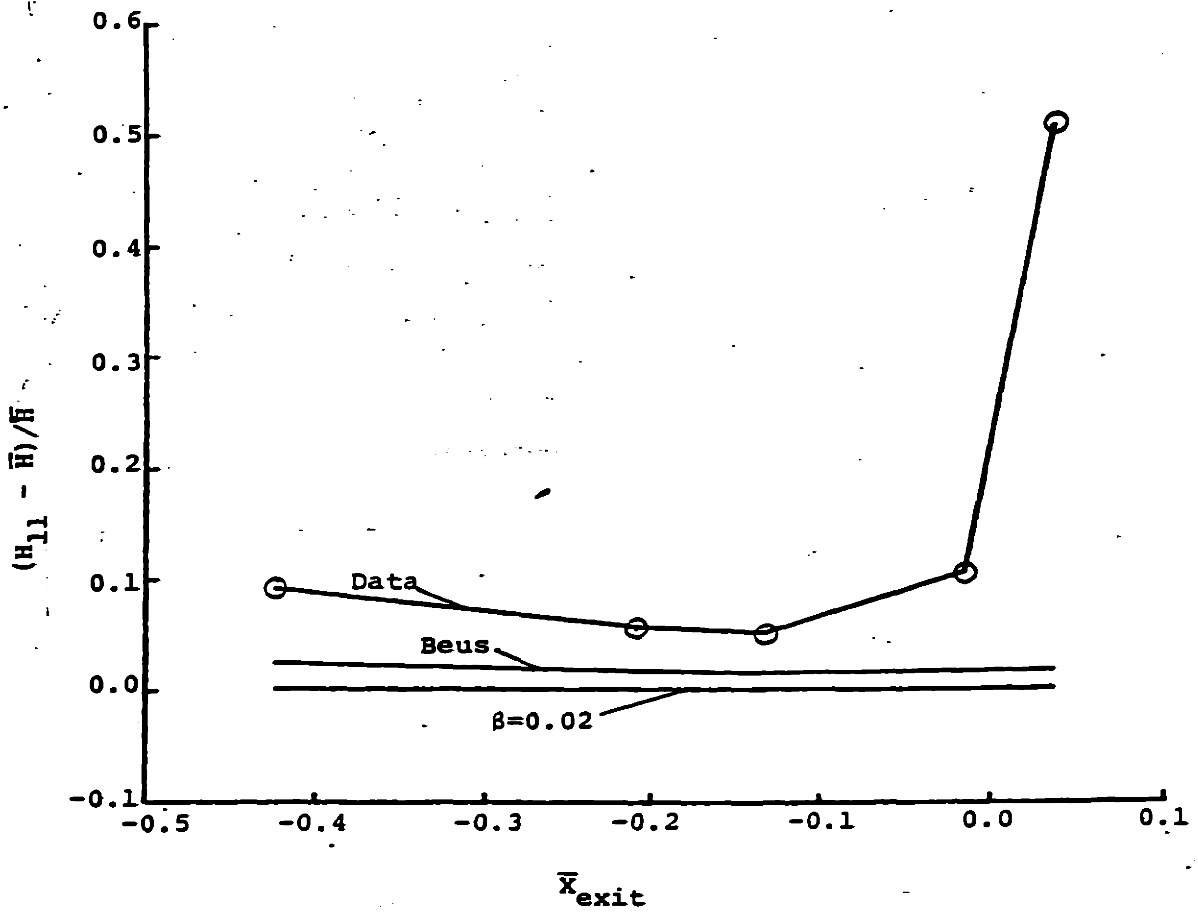


Figure IV-18

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

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

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

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

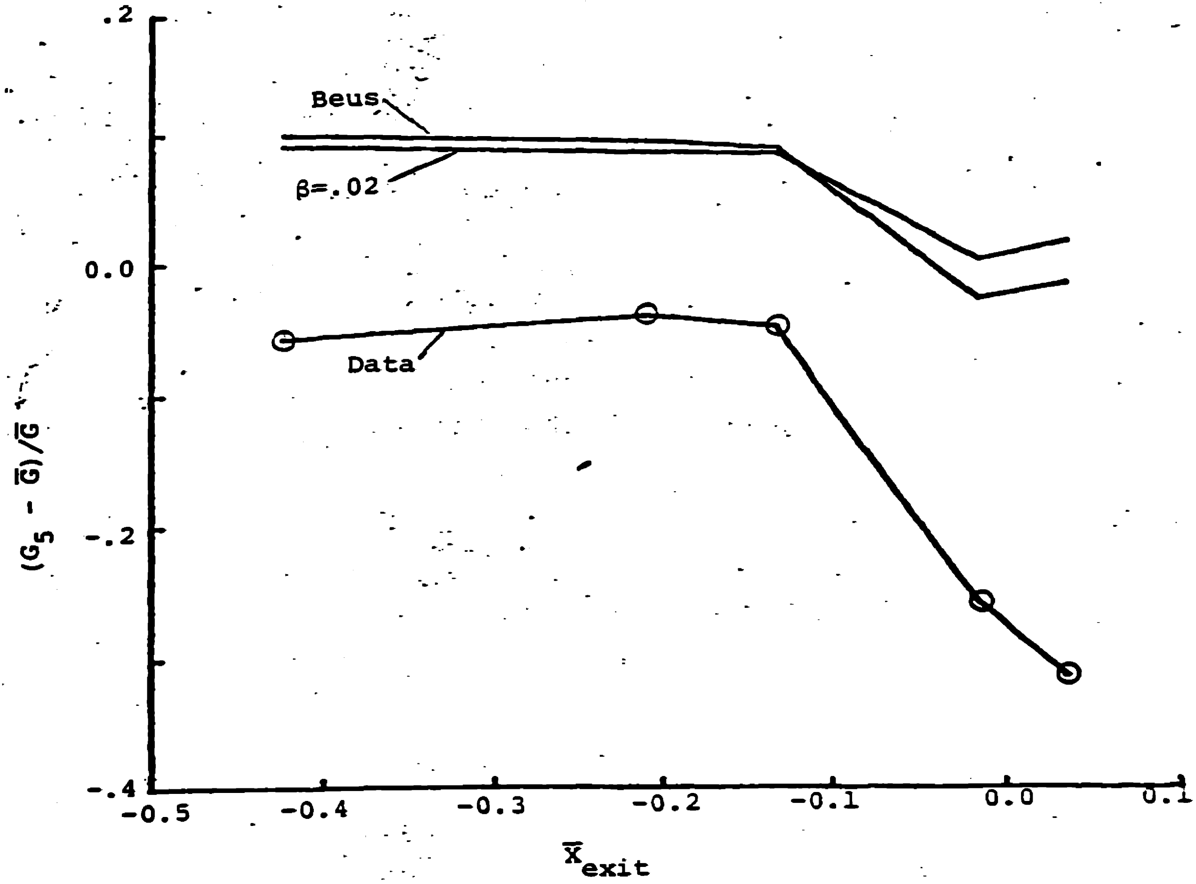


Figure IV-19

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

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

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

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

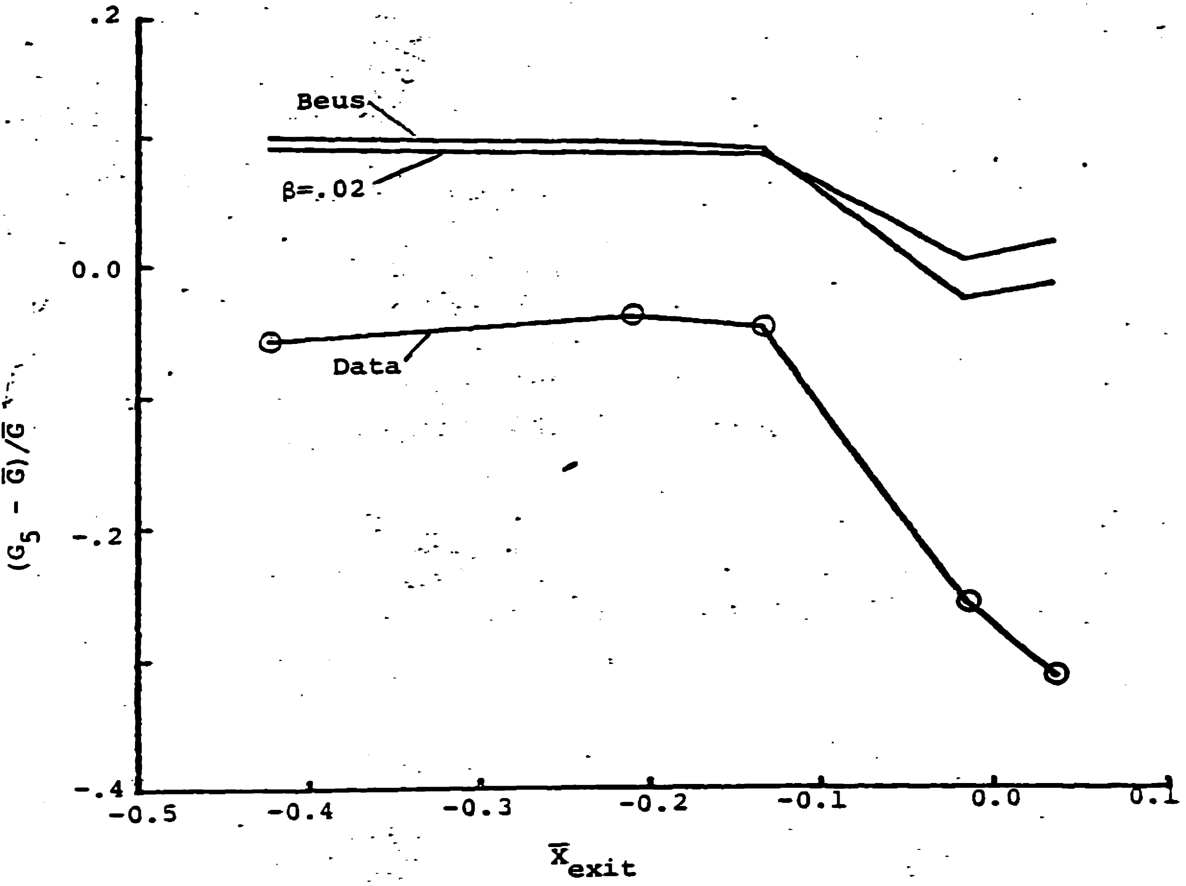


Figure IV-19

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

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

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

$P = 1200.$ psia

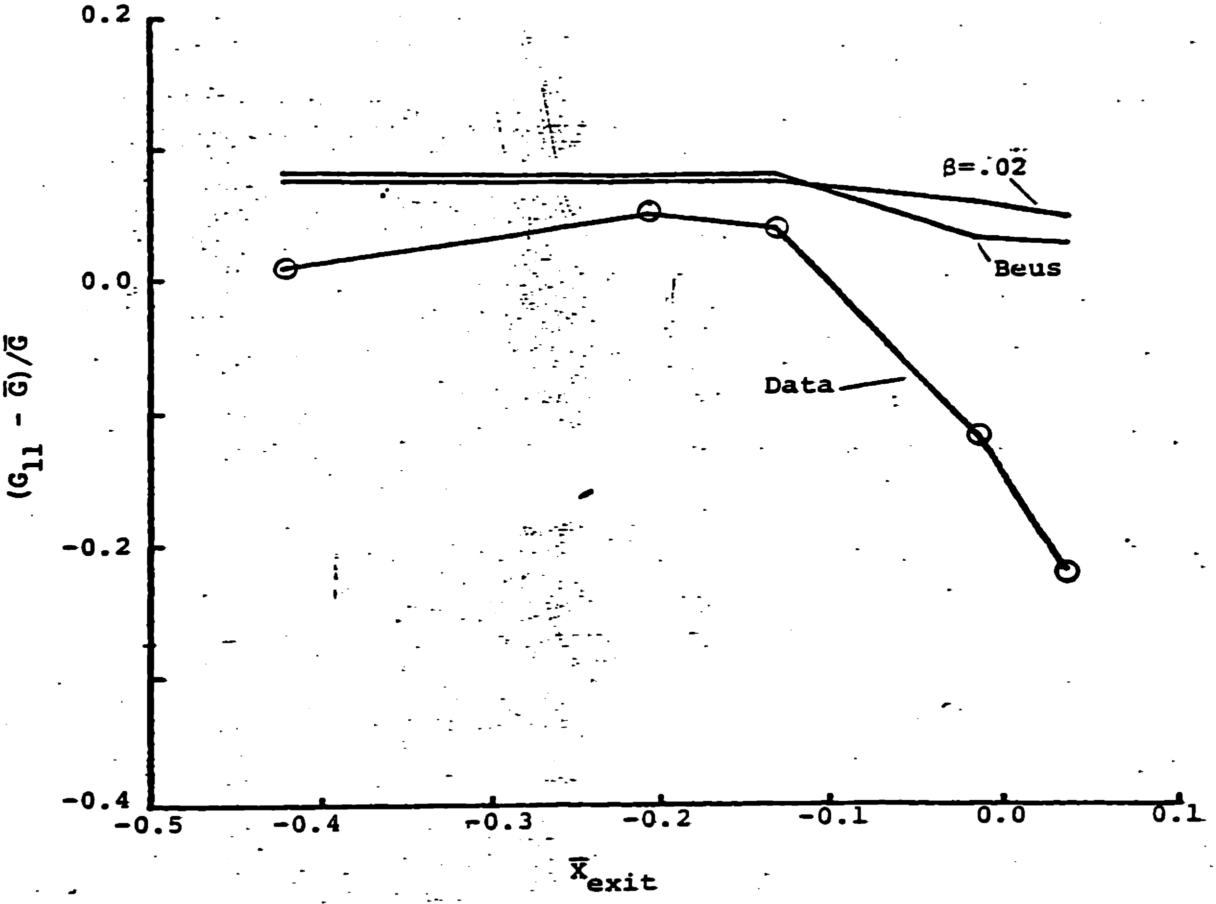


Figure IV-20

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 $\beta=0.02$ enthalpy predictions are less than the Beus predictions because $\beta=0.02$ 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. Data trends for boiling conditions are not well predicted. The Beus predictions are closer to data than $\beta=0.02$ 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.

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

$q'' = .53 \frac{\text{MBTU}}{\text{hr ft}^2}$

P = 1200 psia

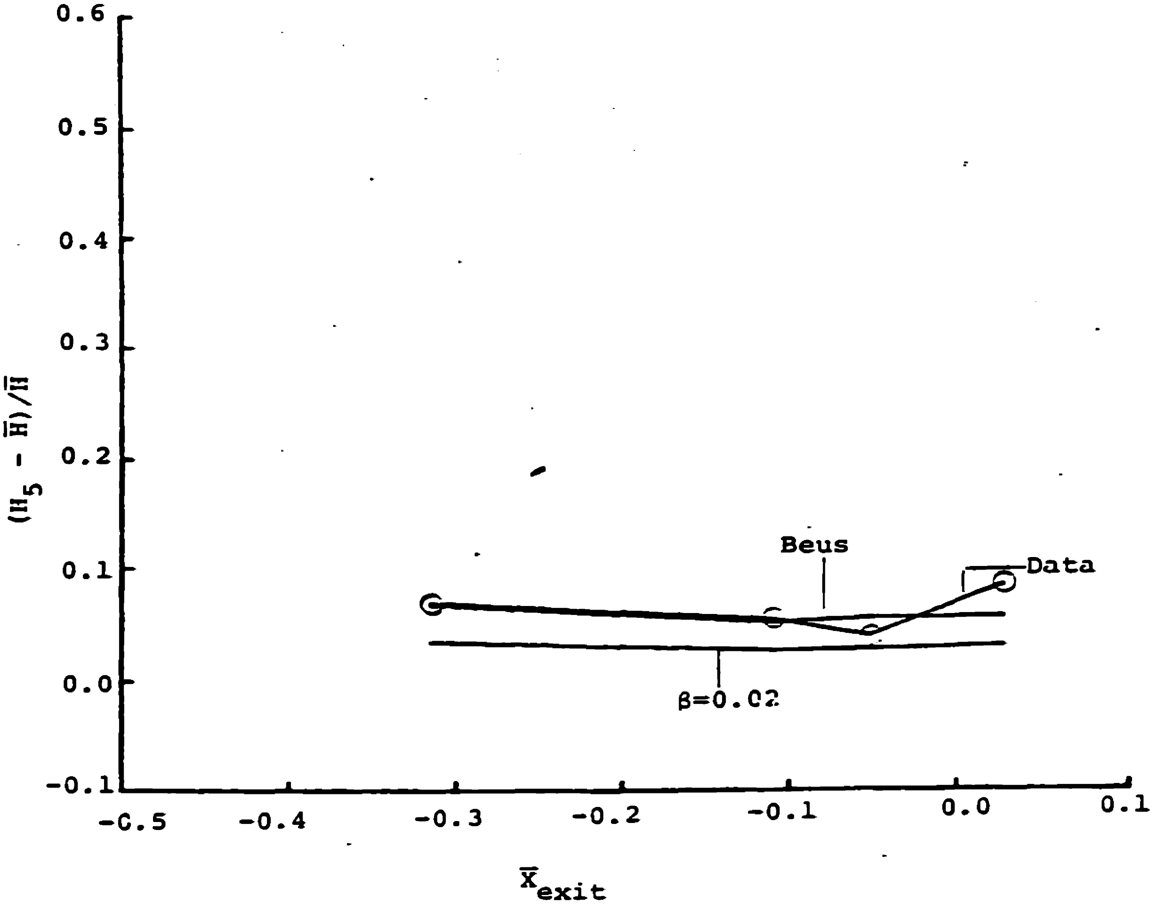


Figure IV-21

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

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

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

$P = 1200$ psia

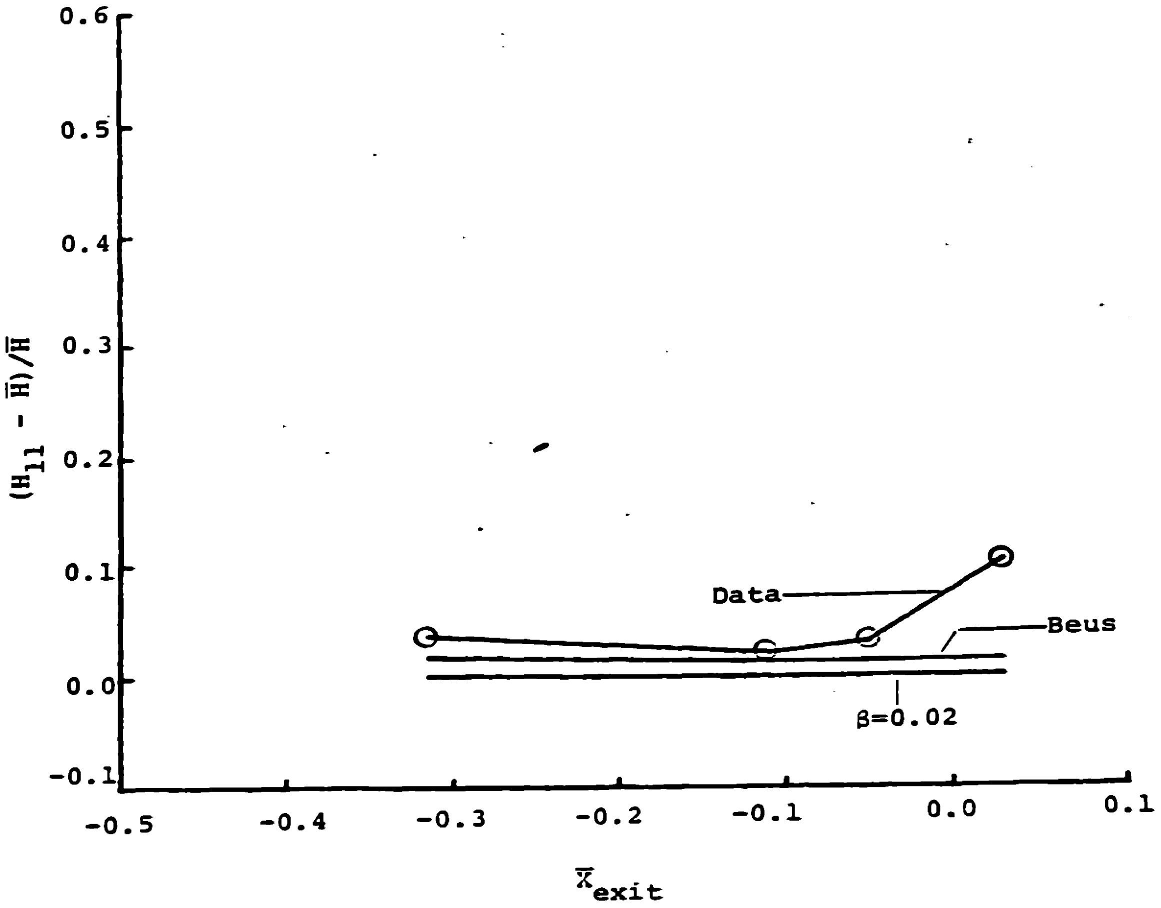


Figure IV-22

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

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

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

$P = 1200$ psia

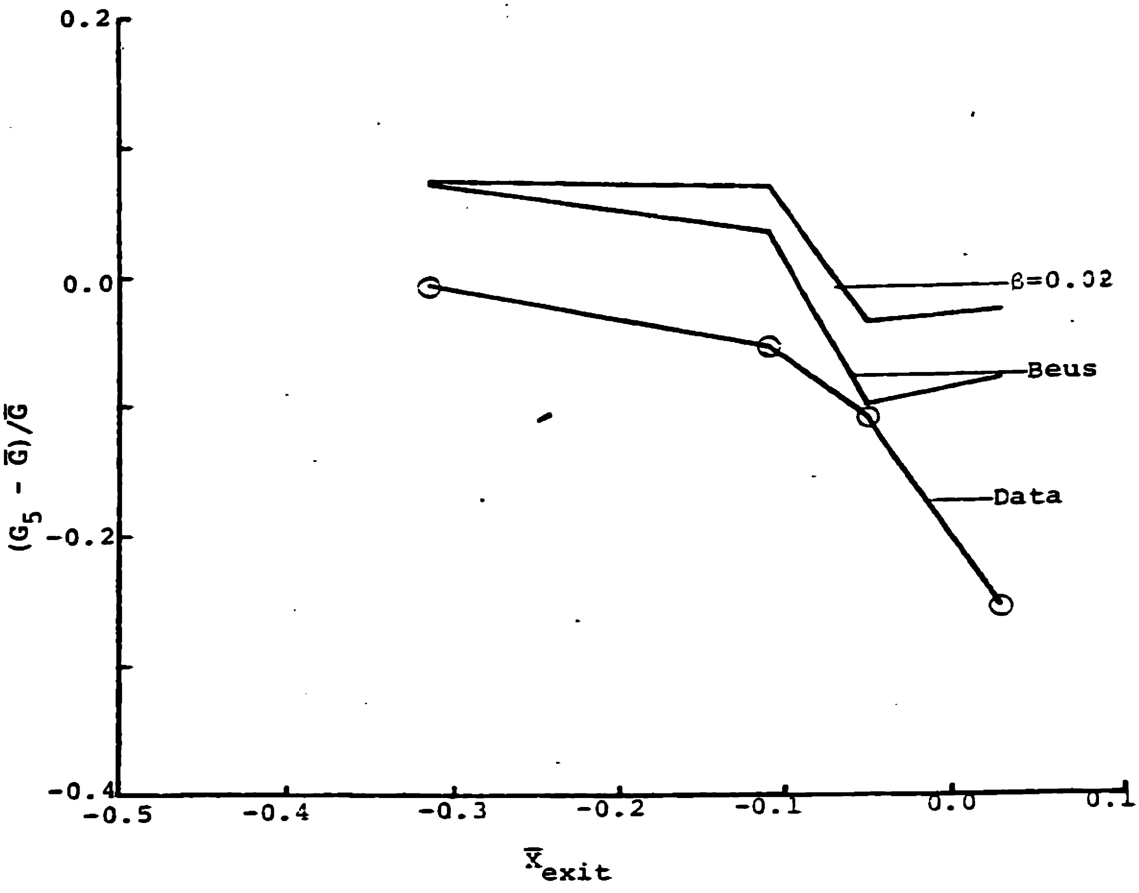


Figure IV-23

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

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

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

$P = 1200$ psia

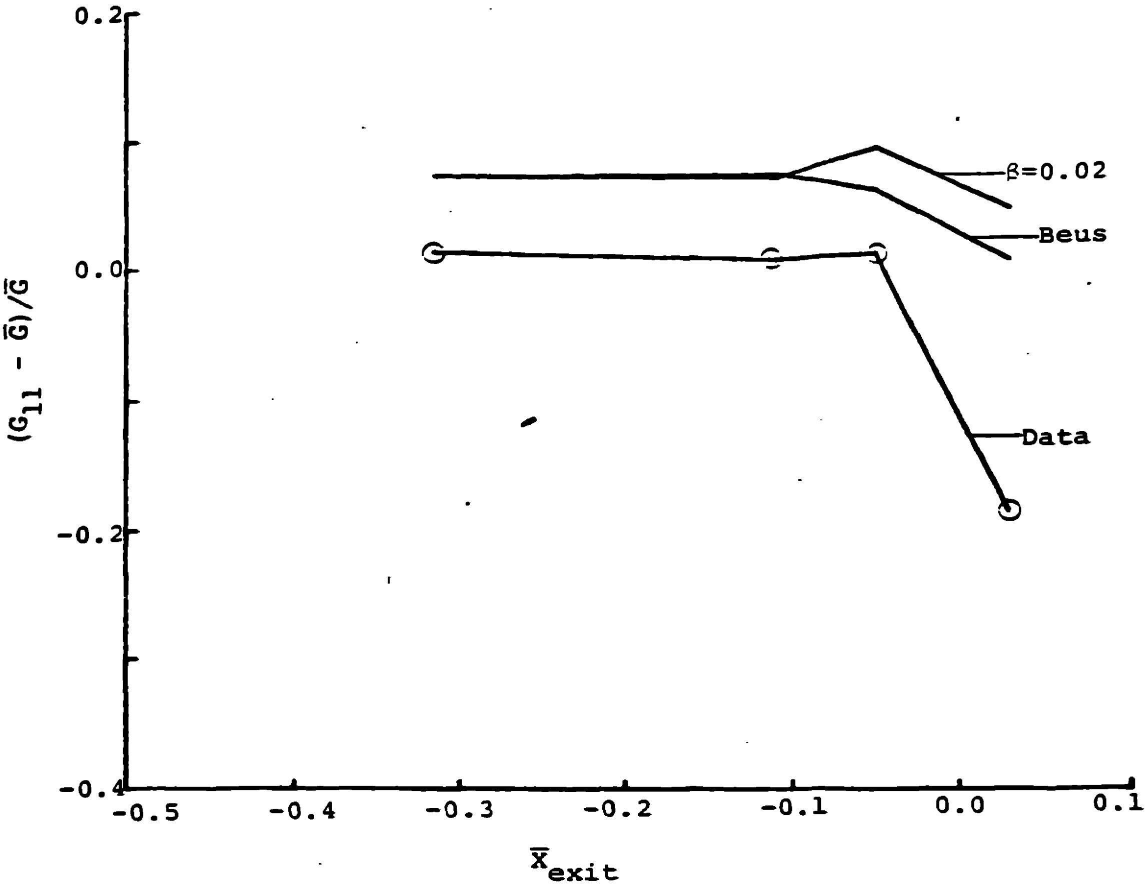


Figure IV-24

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.

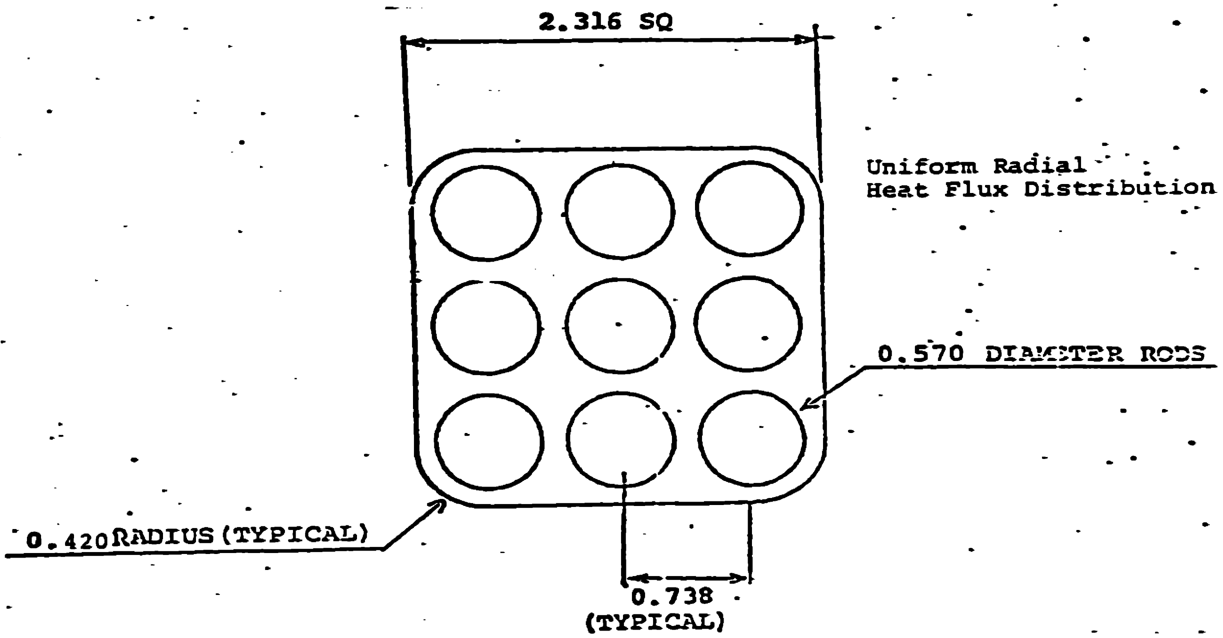
Single channel analysis MCPR and MCHFR predictions for test channels 3 and 4 are given in Table IV-4. All the Hench-Levy MCHFR predictions are conservative. The CISE-4 MCPR predictions are not nearly as conservative as the Hench-Levy MCHFR predictions. The MCPR predictions are slightly non-conservative 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



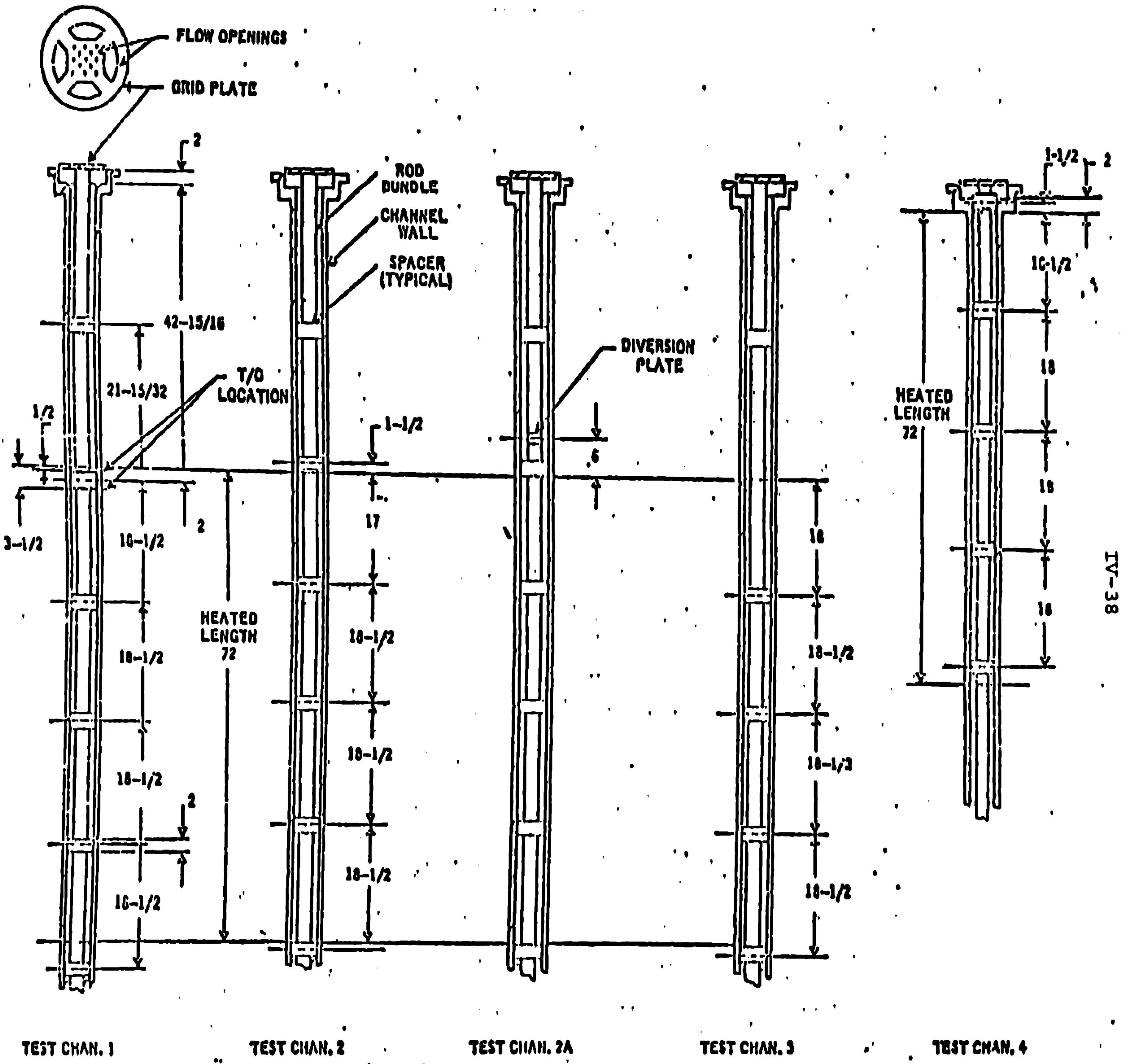


Figure IV-26

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

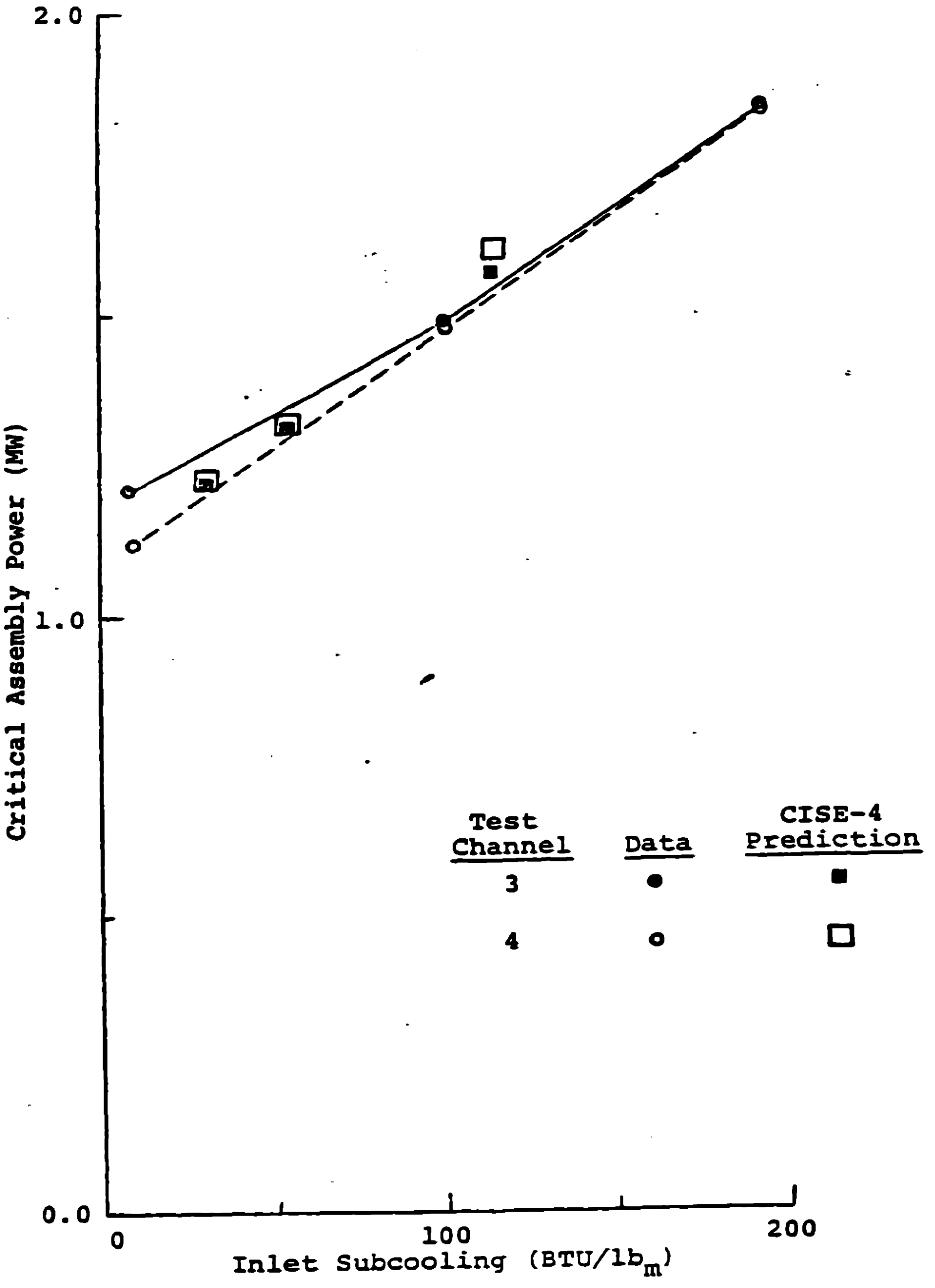


Figure IV-27

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

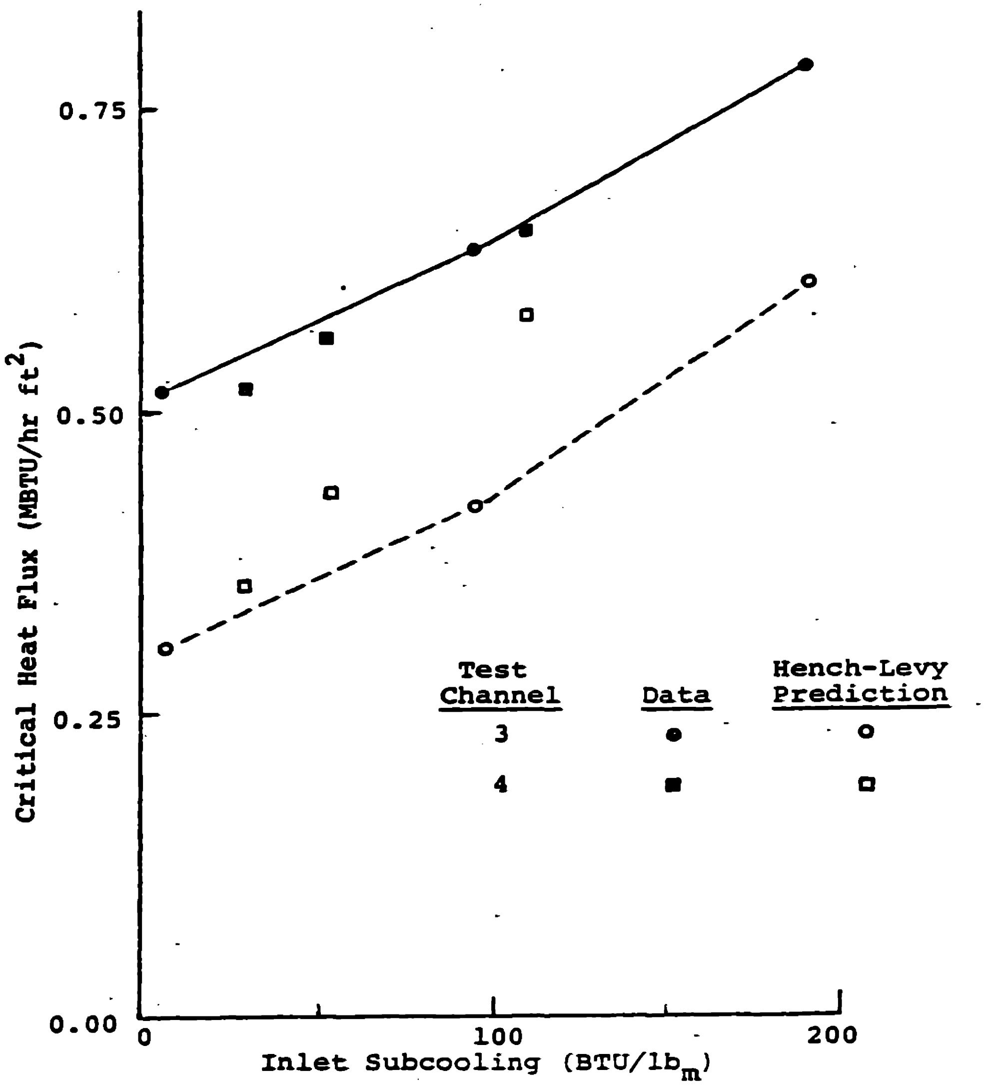


Figure IV-28

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.

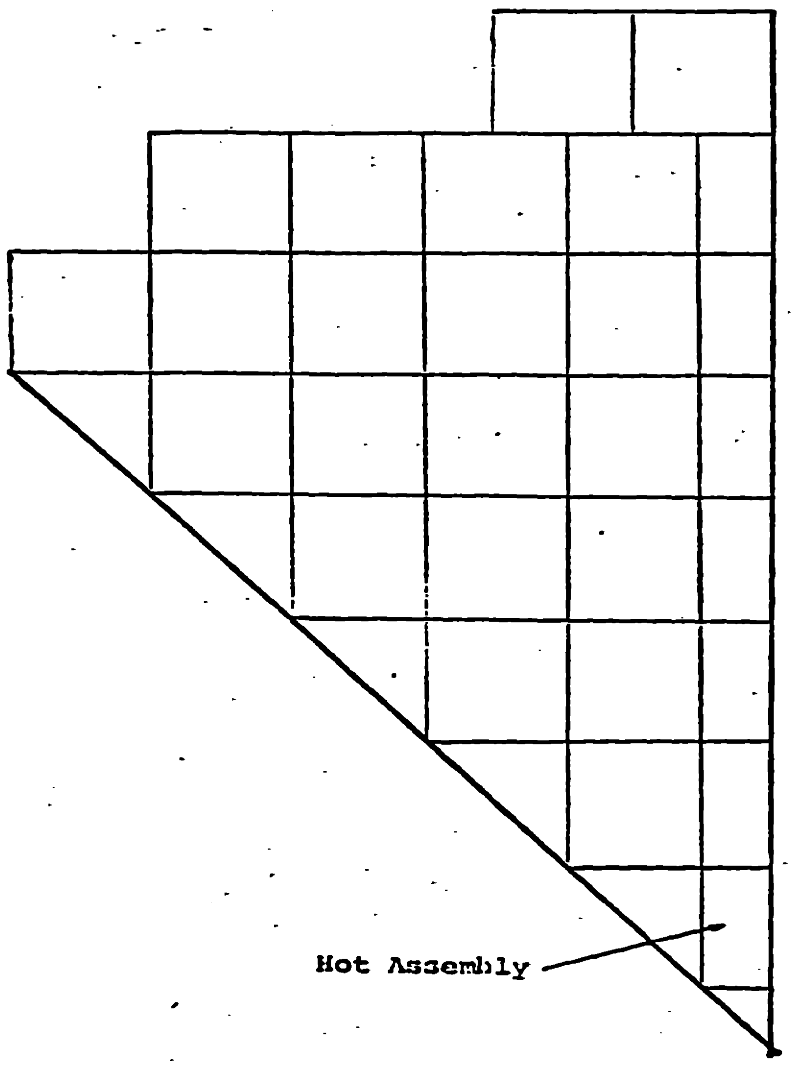
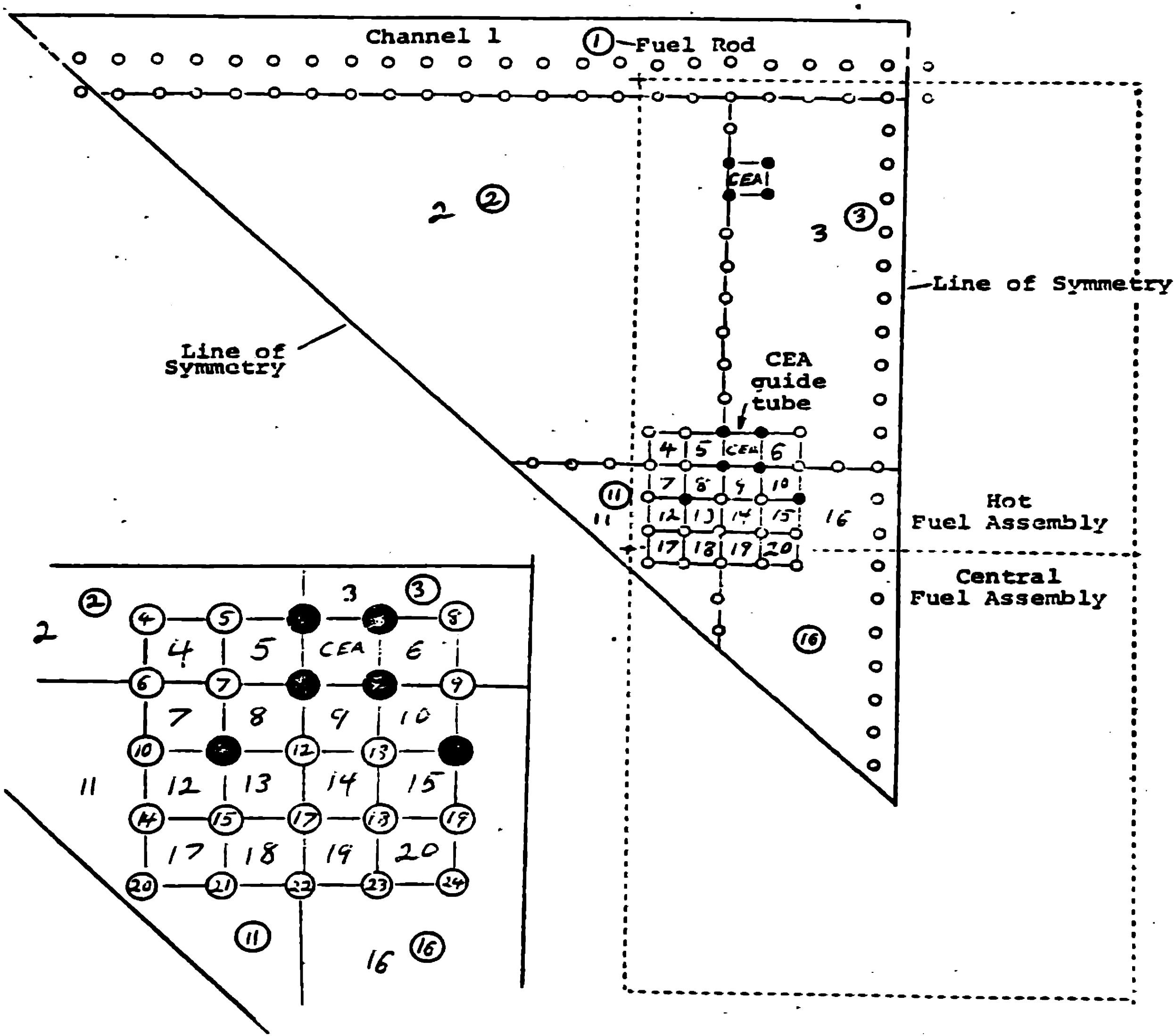


Figure IV-29

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.

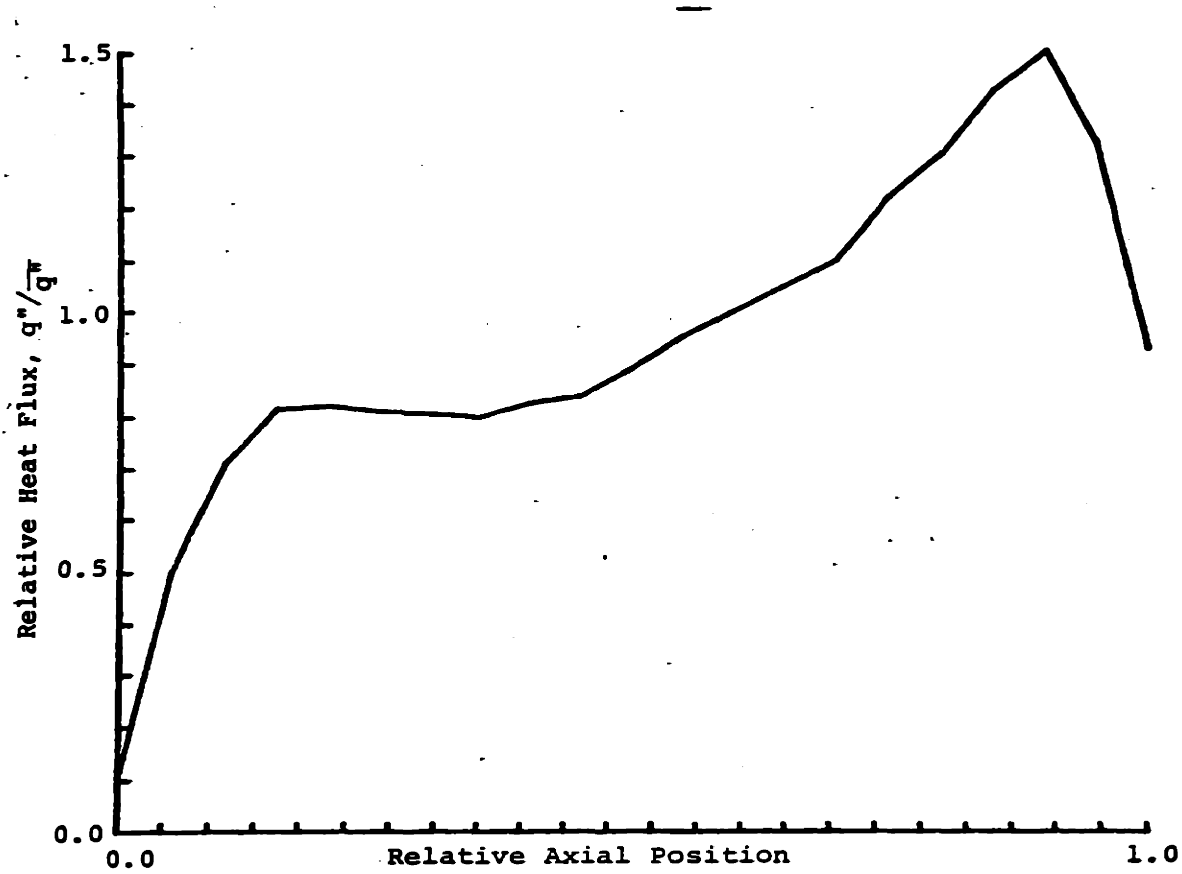


Figure IV-31

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

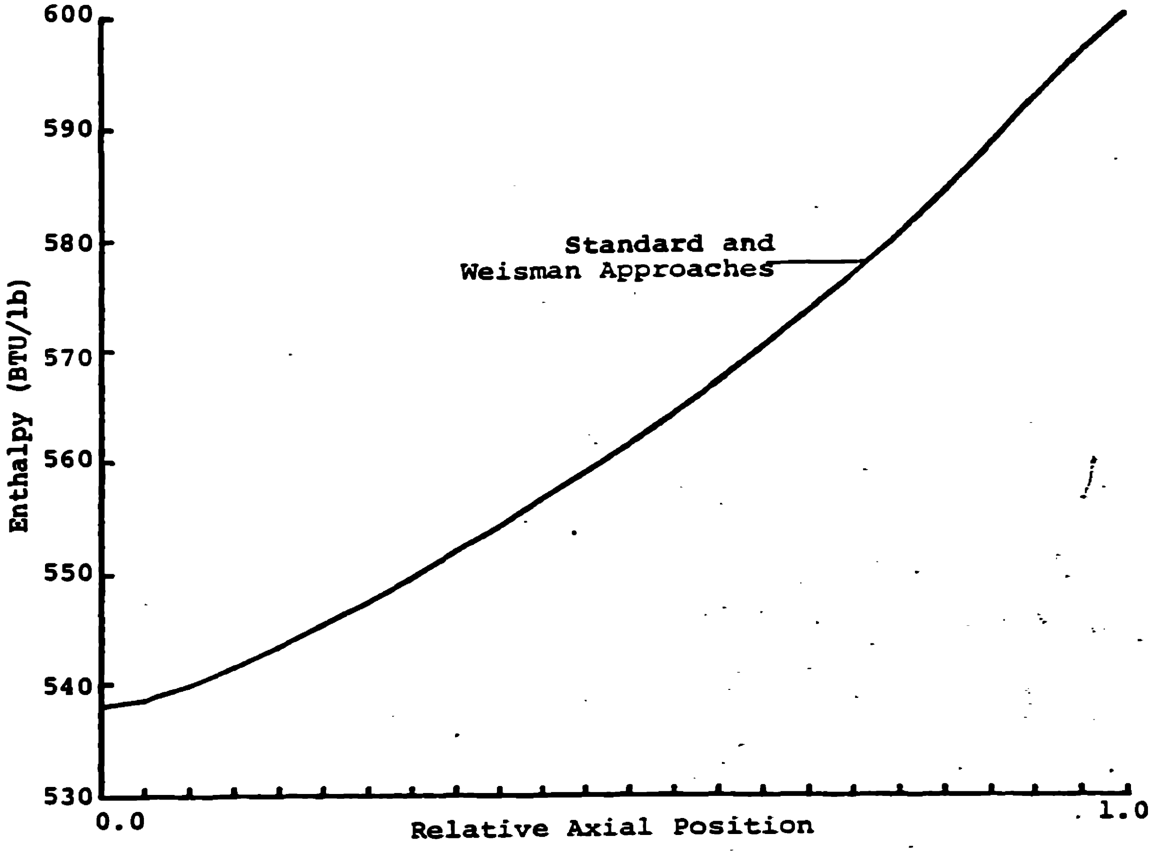


Figure IV-32

1/8 Core Single-Pass Analysis Case

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

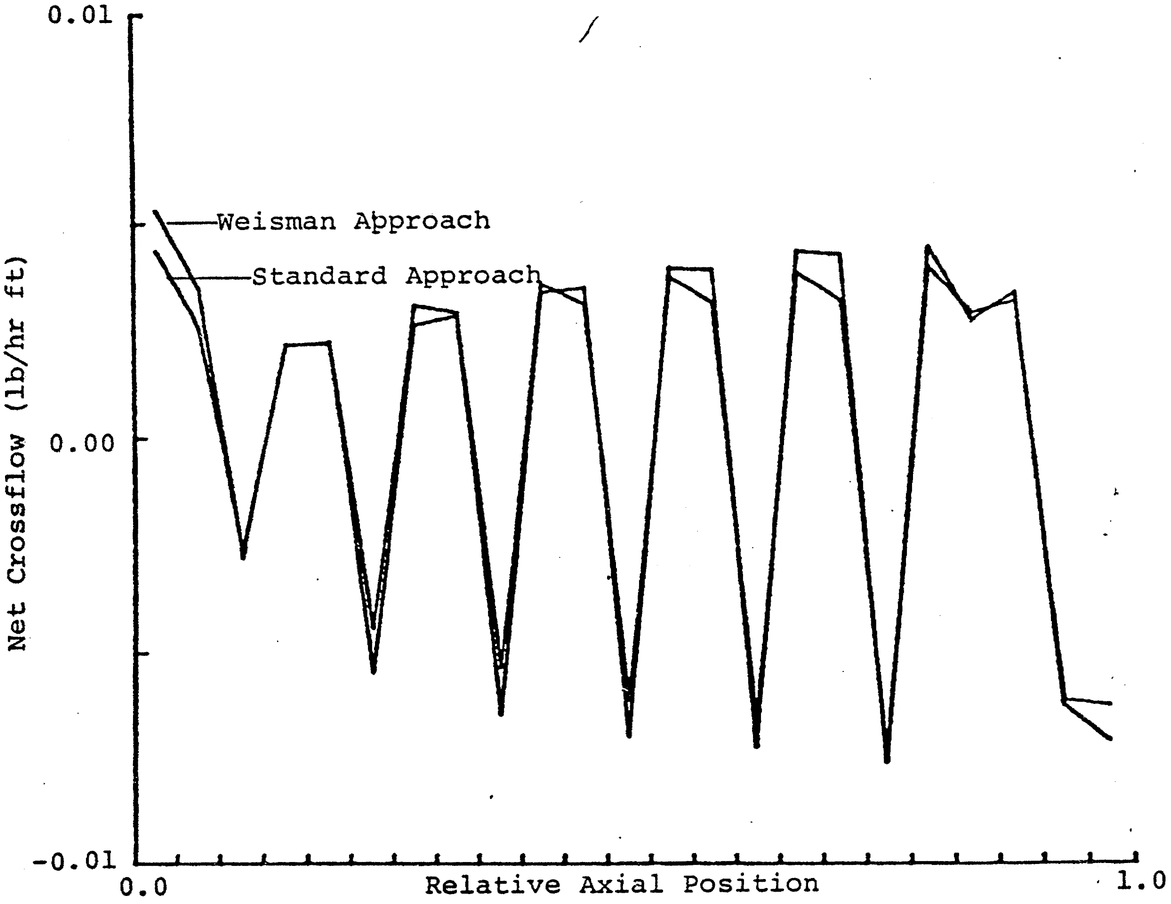


Figure IV-33

1/8 Core Single-Pass Analysis Case

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

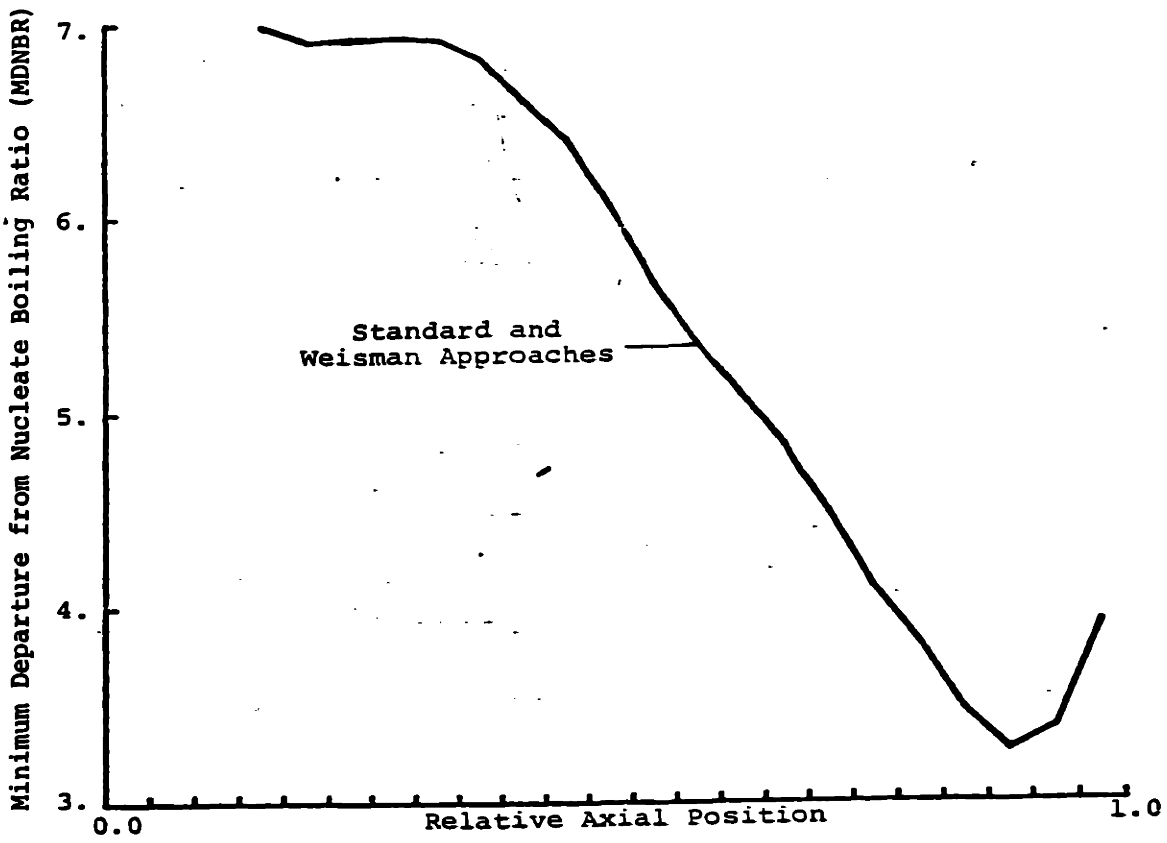


Figure IV-34

<u>1/8 Core Single-Pass Analysis Case</u>

<u>MDNBR vs. Axial Position</u>

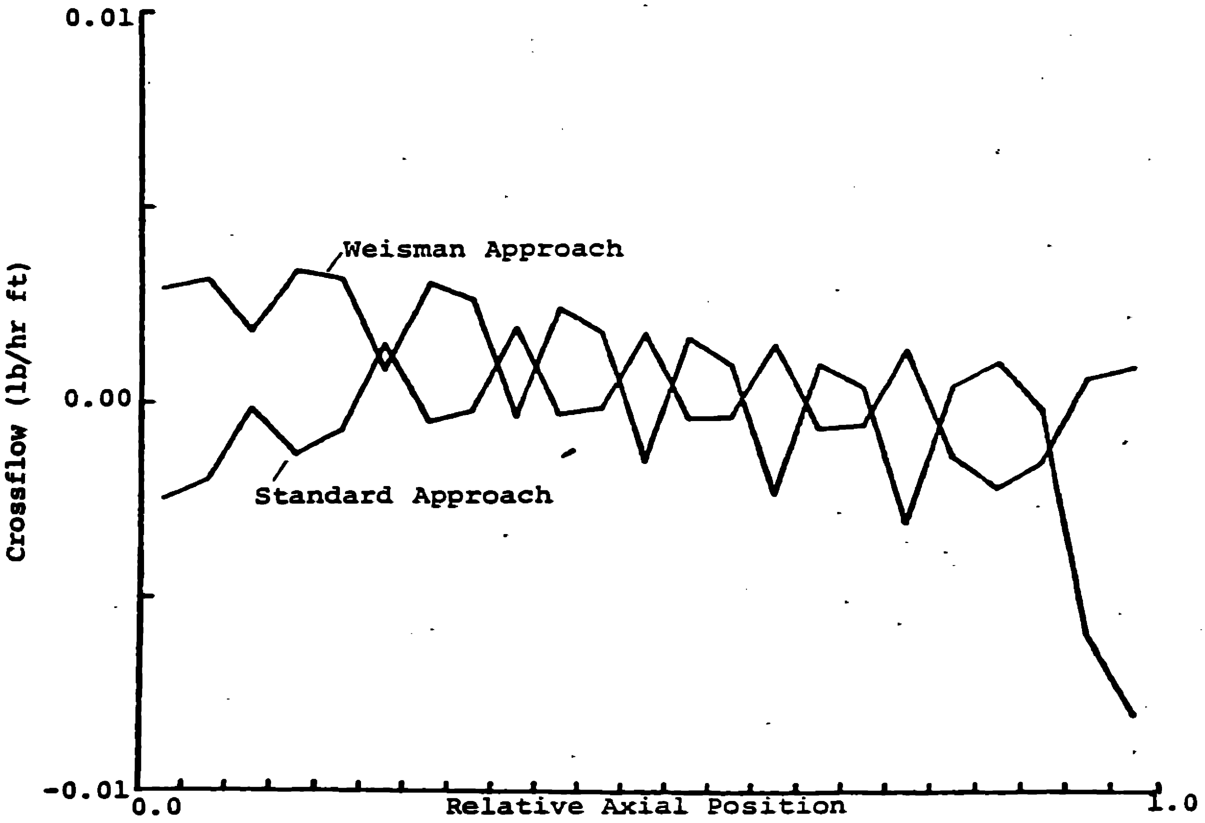


Figure IV-35

1/8 Core Single-Pass Analysis Case

Crossflow from Channel 7 to 11 vs. Relative Axial Position

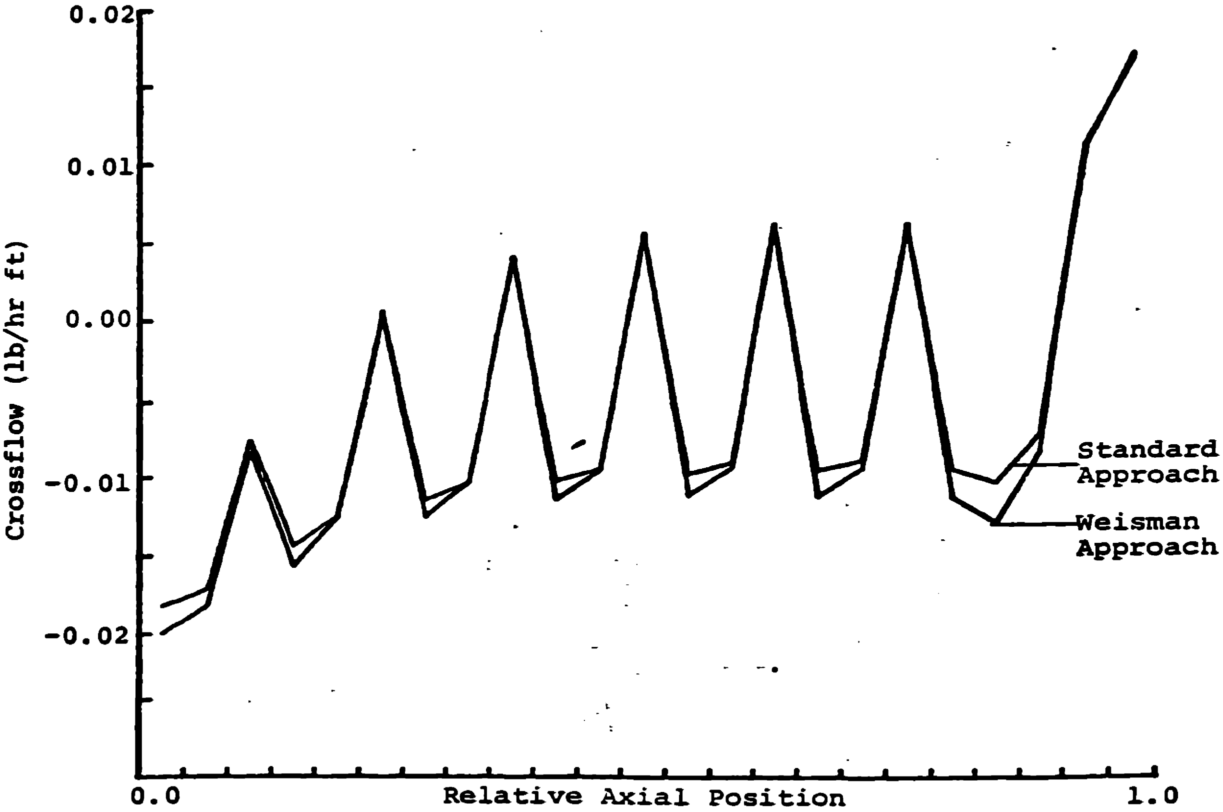


Figure IV-36

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-29. Rods 5 and 15 are the hot rods. MDNBR is predicted to occur on either rod 5 or 15 during the transient.

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*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).

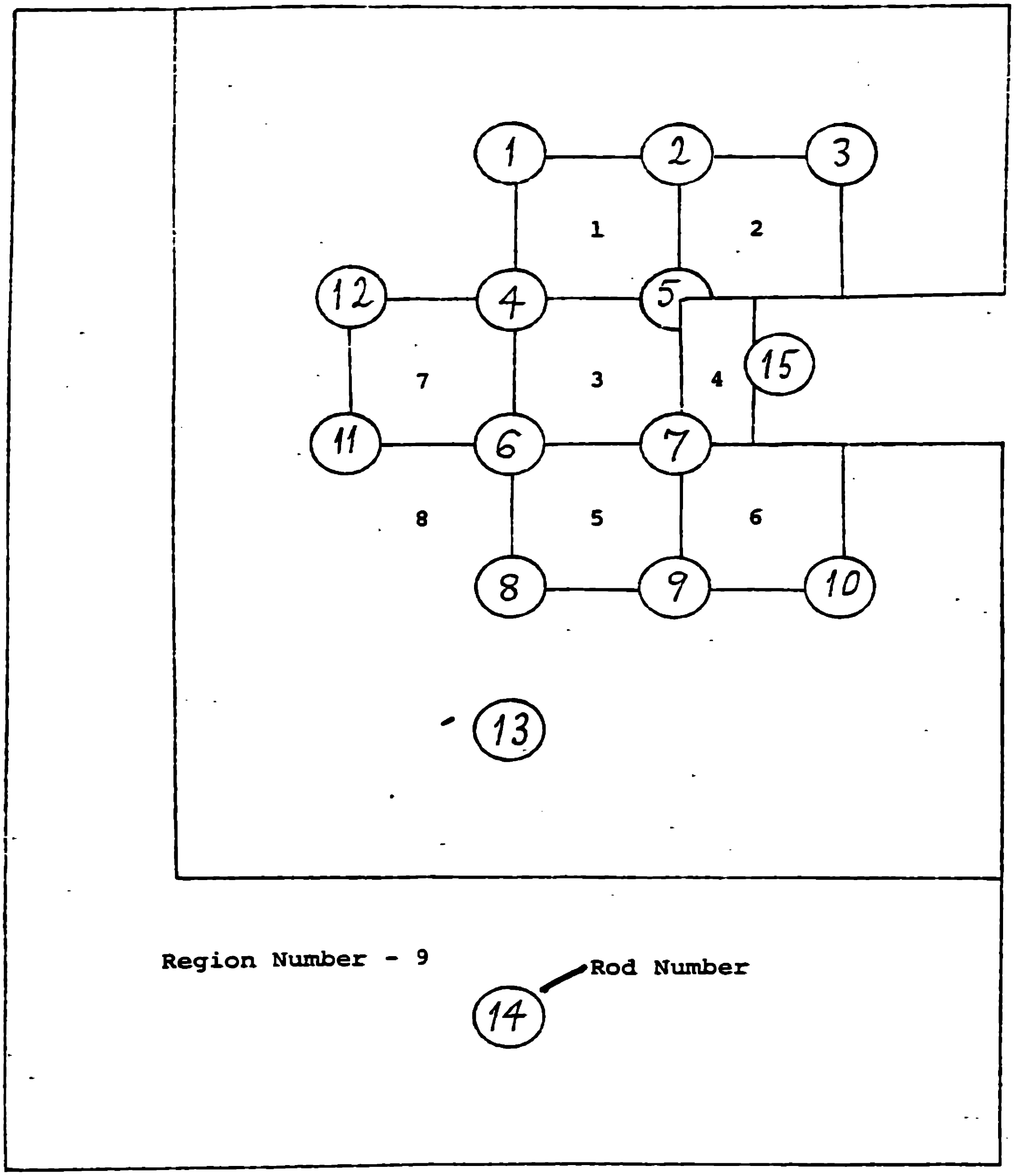


Figure IV-37

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-30. 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-31. 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

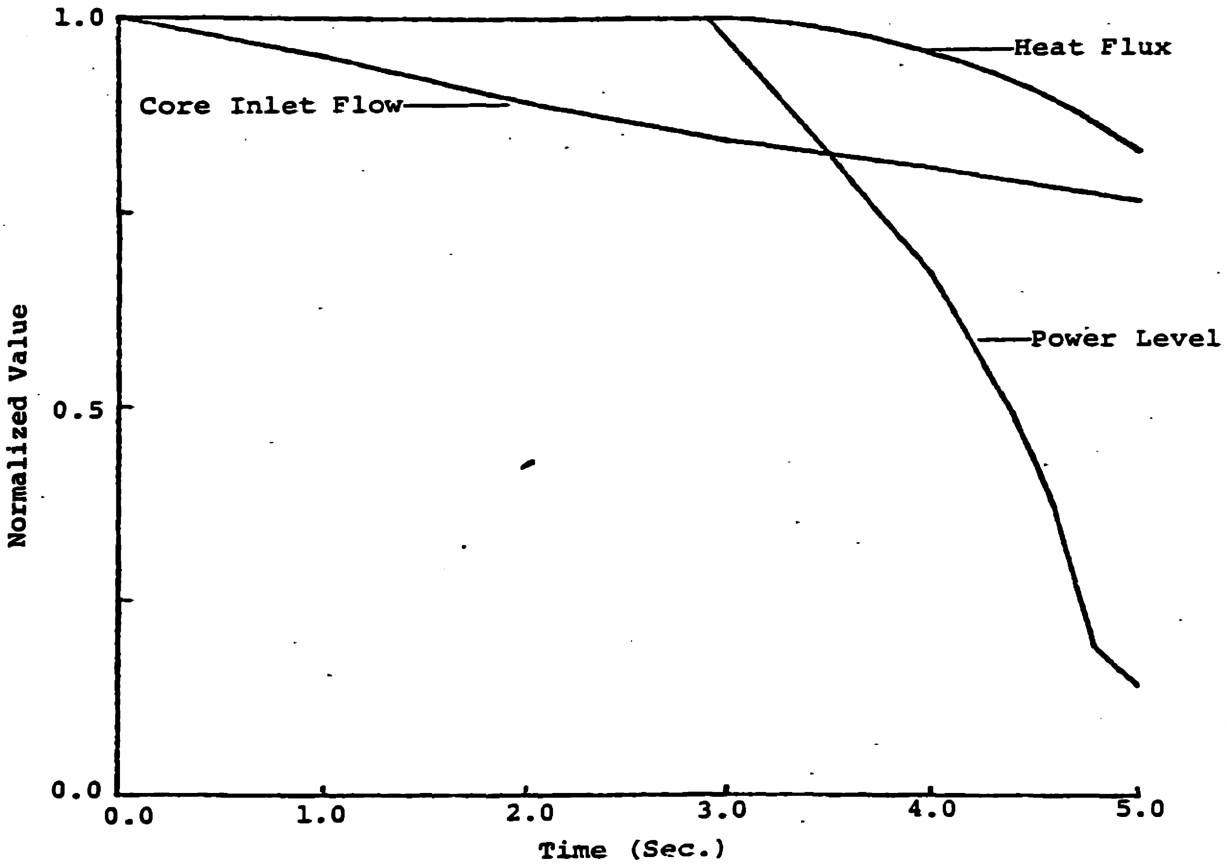


Figure IV-38

Transient Forcing Functions
PWR Loss of Flow Transient Test Case

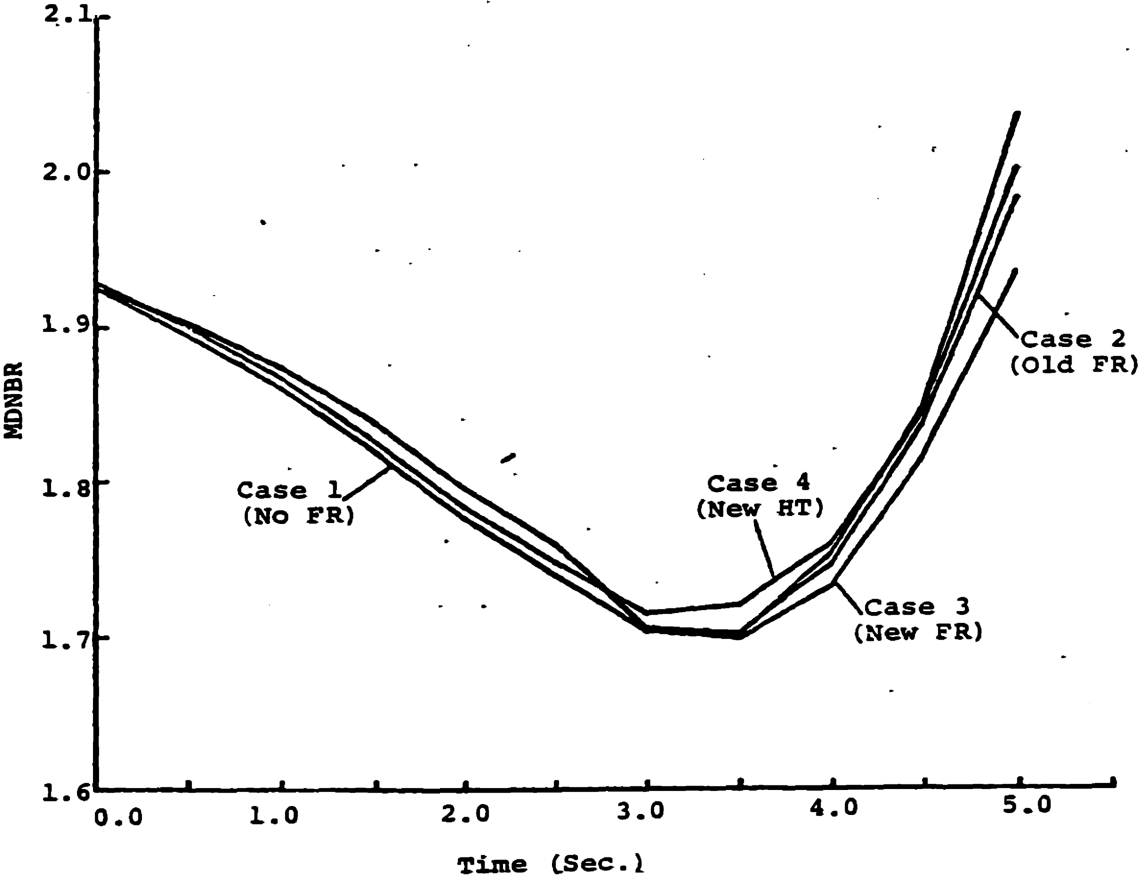


Figure IV-39

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-32. 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 51 axial heat flux problems. 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-33 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-34 and IV-35. Figure IV-34 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-35 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-34 and IV-35 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

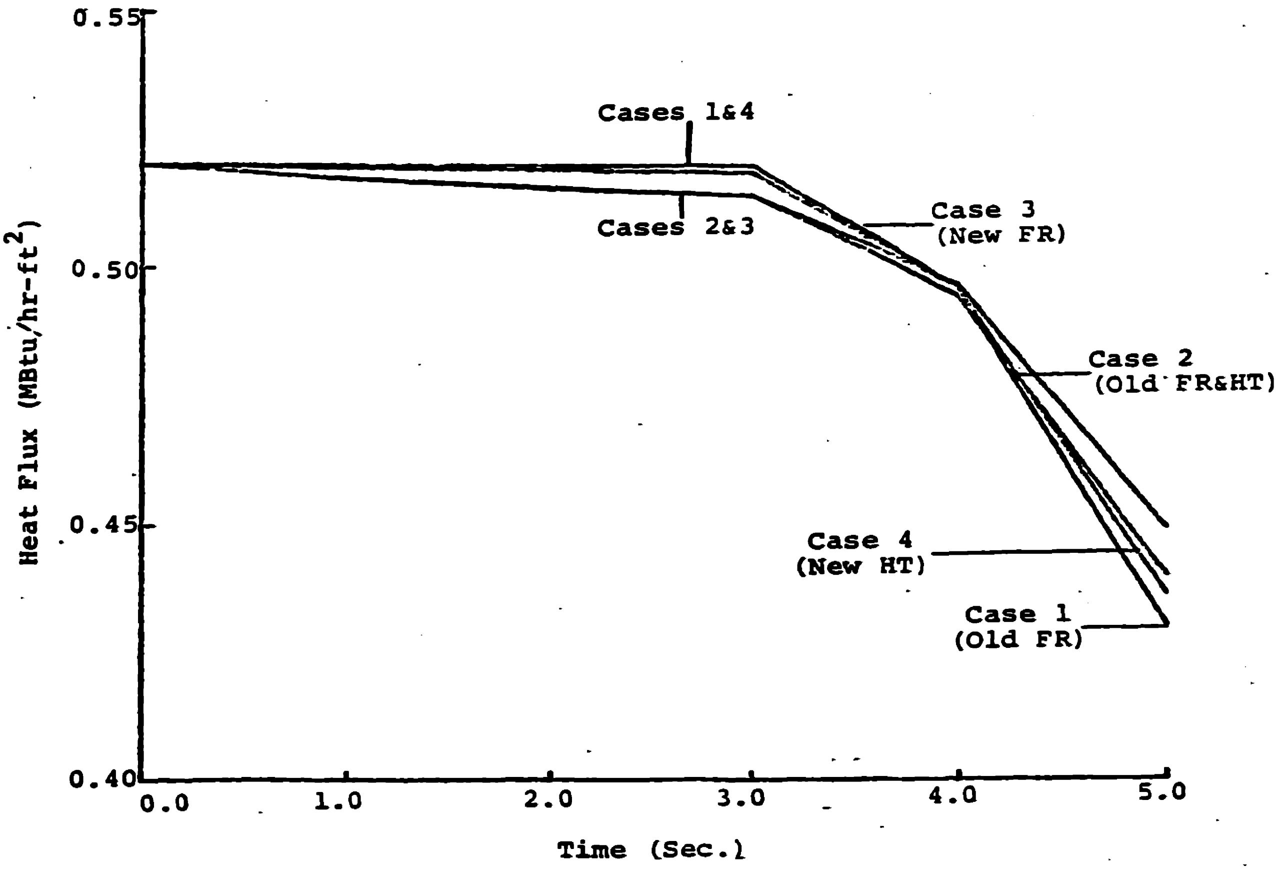


Figure IV-40

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

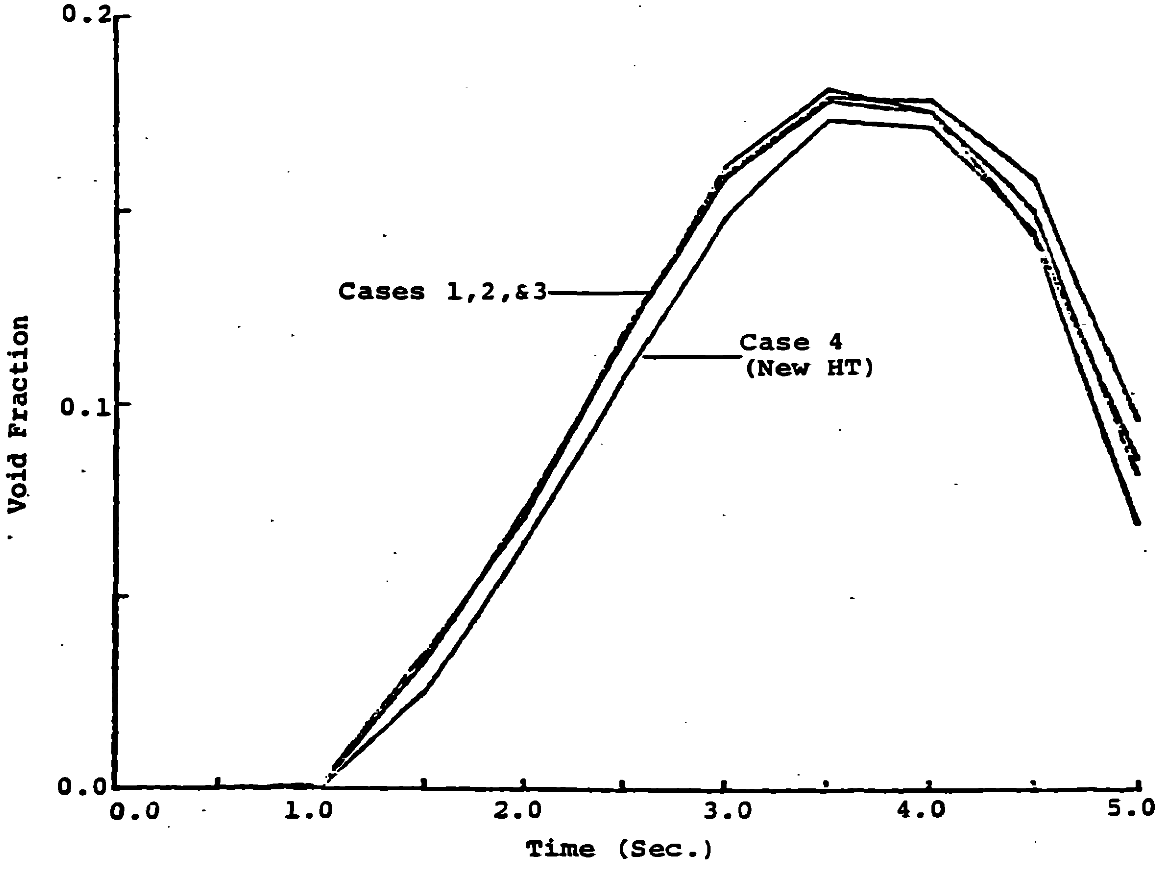


Figure IV-41

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

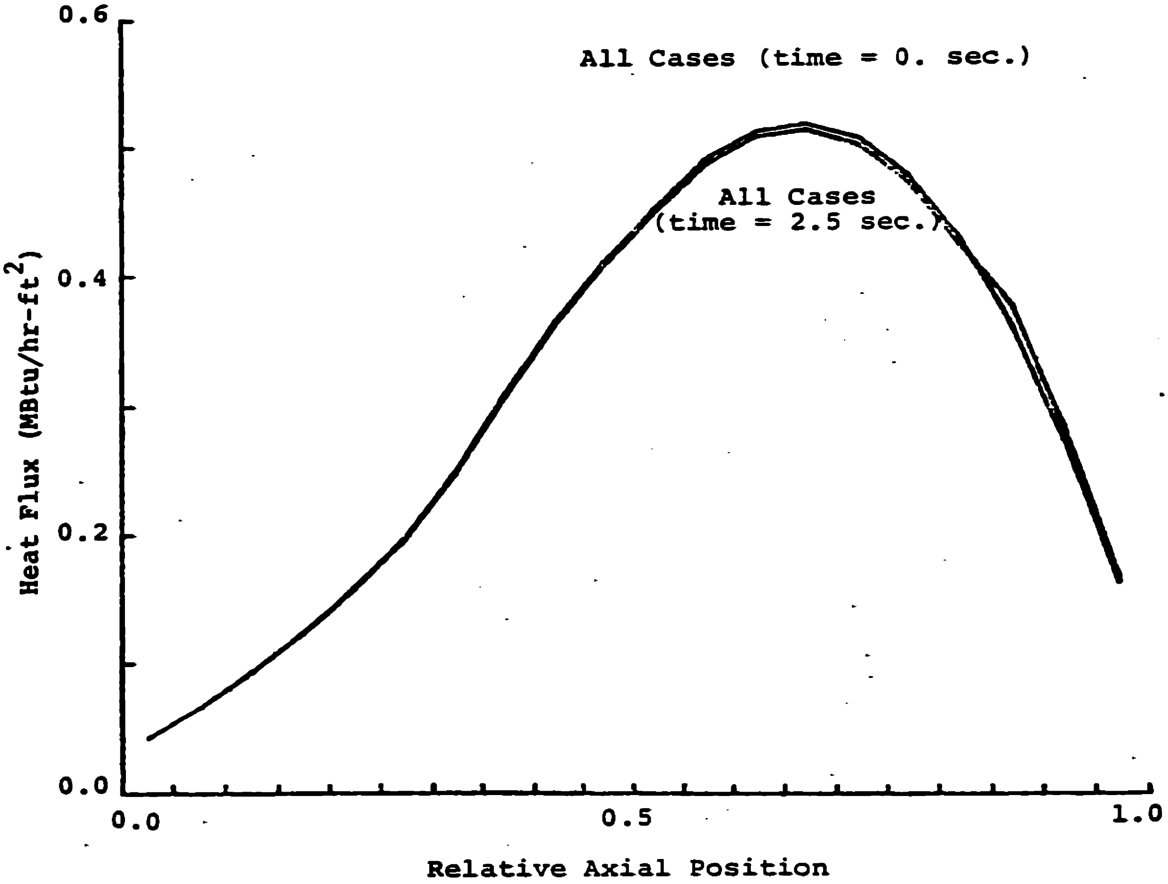


Figure IV-42

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

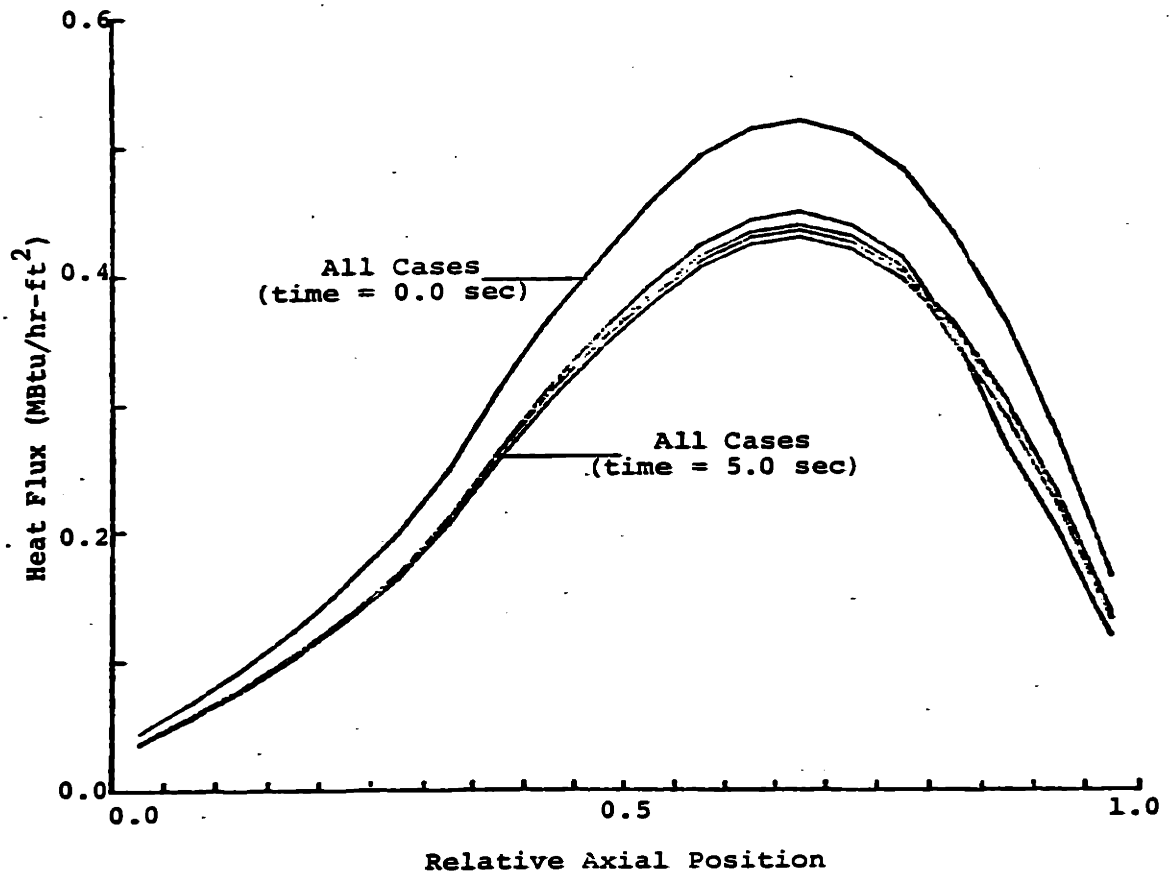


Figure IV-43

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

predictions. Figures IV-36, IV-37 and IV-38 contain axial clad surface temperature profiles for rod 15. Clad temperature profiles at 0.0 seconds are shown in Figure IV-36. 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-37 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-38 shows Analysis Case 4 axial clad temperature profile predictions. These predictions of the new ehat 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.

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-39.

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-39. 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.

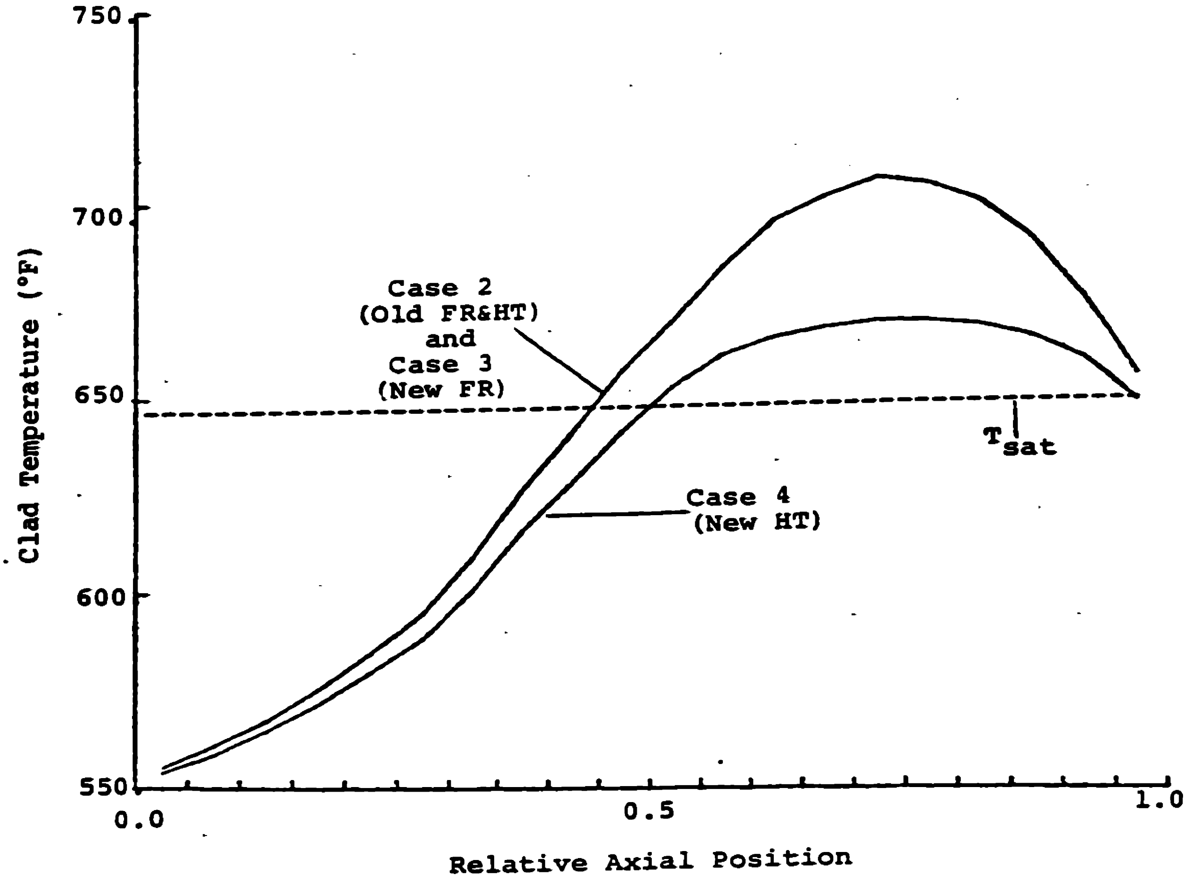


Figure IV-44

Axial Clad Temperature Profile
Rod 15, Time = 0
PWR Loss of Flow Transient Test Case

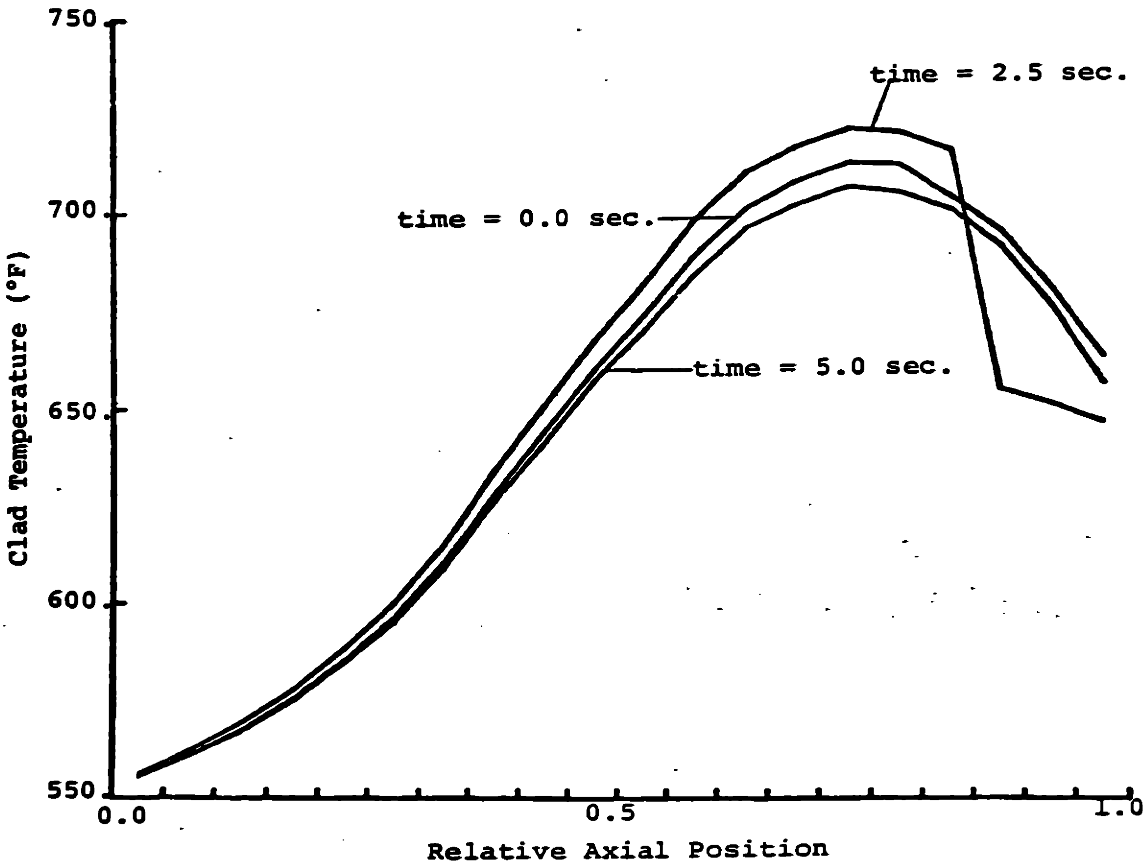


Figure IV-45

Axial Clad Temperature Profile
Rod 15
Analysis Case 2 (Old FR&HT)
PWR Loss of Flow Transient Test Case

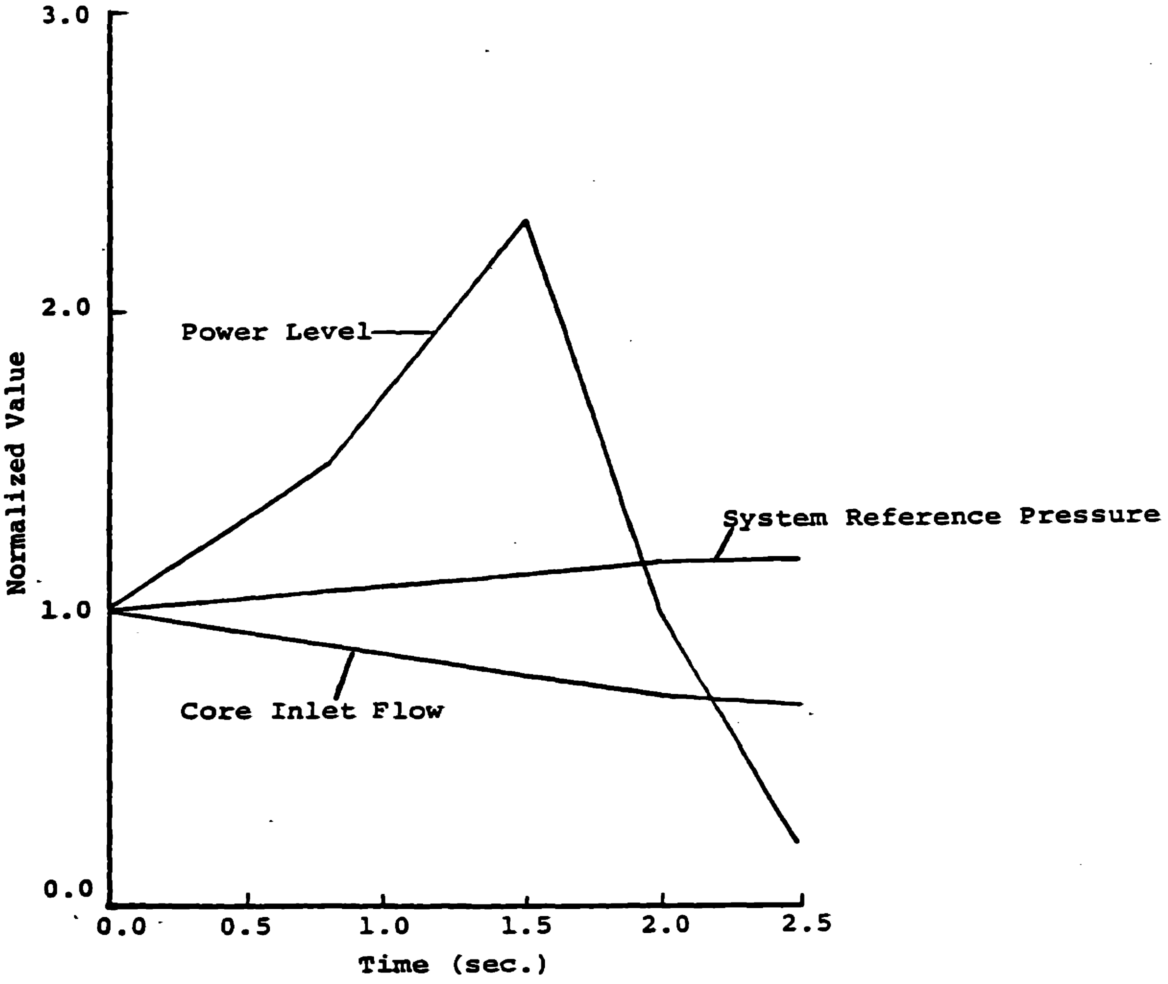


Figure IV-46

Transient Forcing Functions
BWR Turbine Trip Transient Test Case

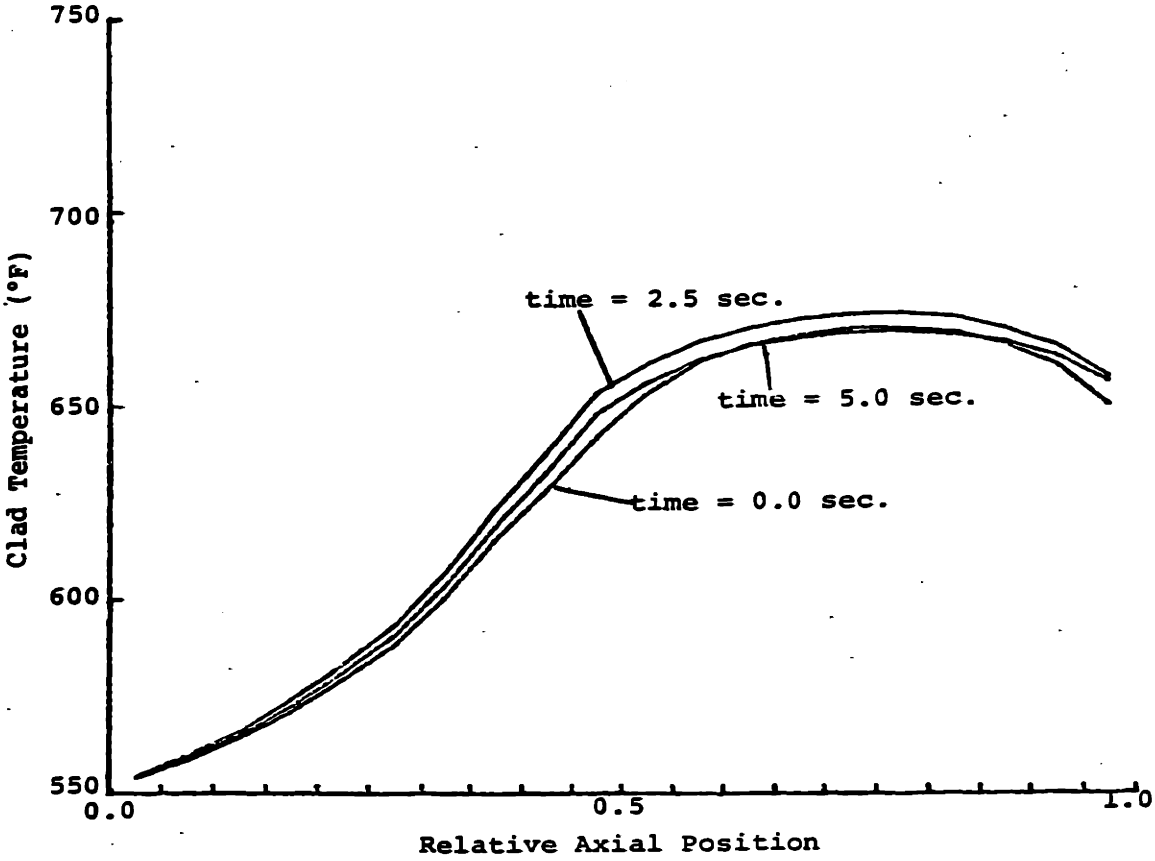


Figure IV-47

Axial Clad Temperature Profile
Rod 15
Analysis Case 4 (New HT)
PWR Loss of Flow 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-40. 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-41. 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-42 and IV-43, 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-44. 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-45 and IV-46. Void fraction profiles at 0.0 and 2.0 seconds are shown in Figure IV-45. All analysis cases start with the same void fraction

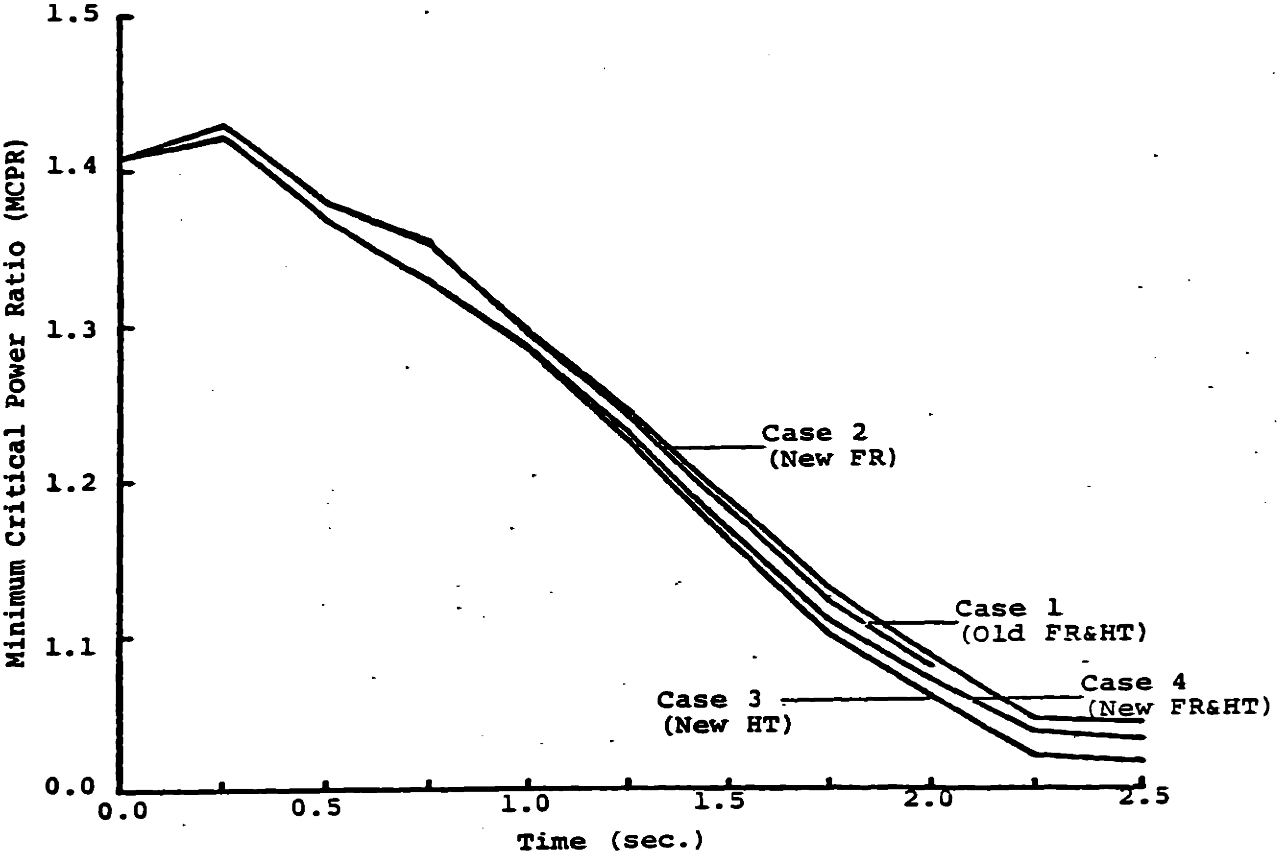


Figure IV-48

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

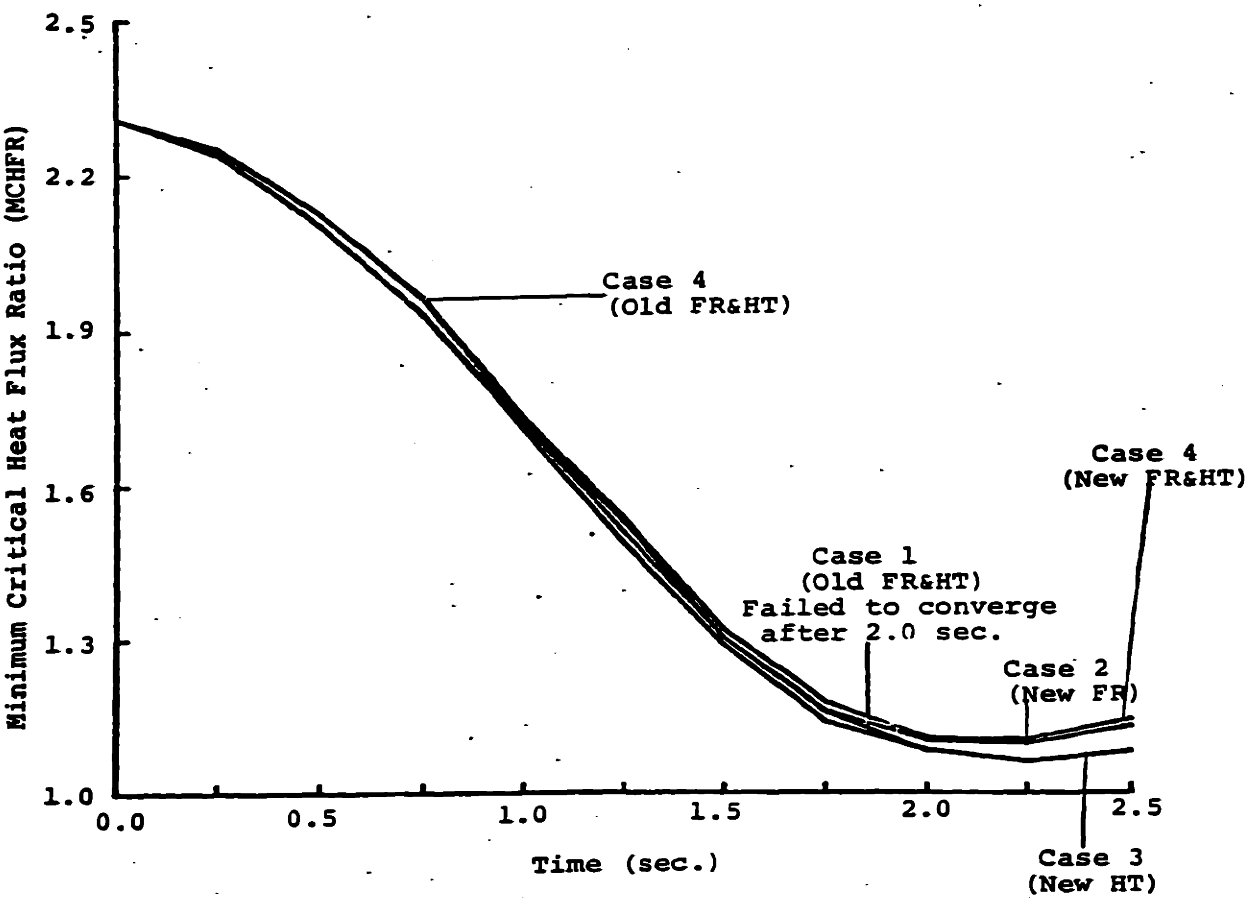


Figure IV-49

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

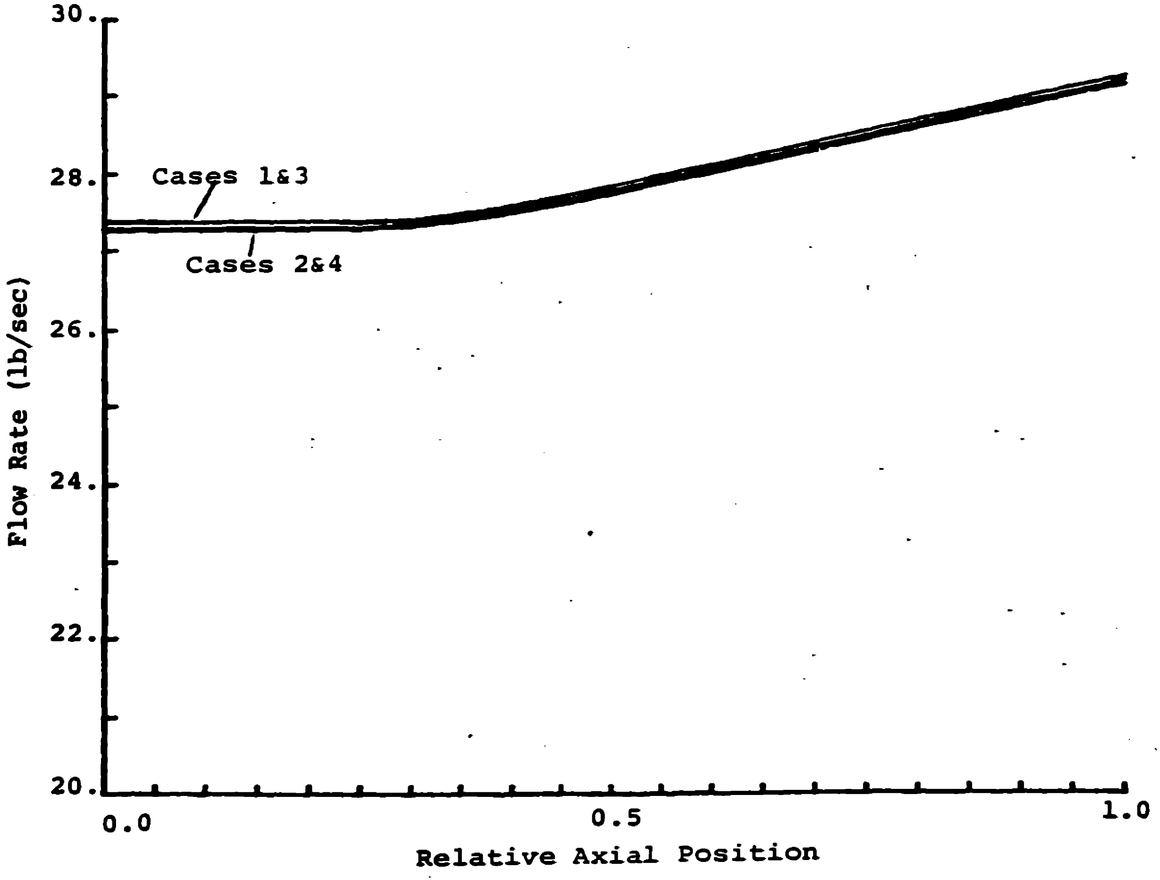


Figure IV-50

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

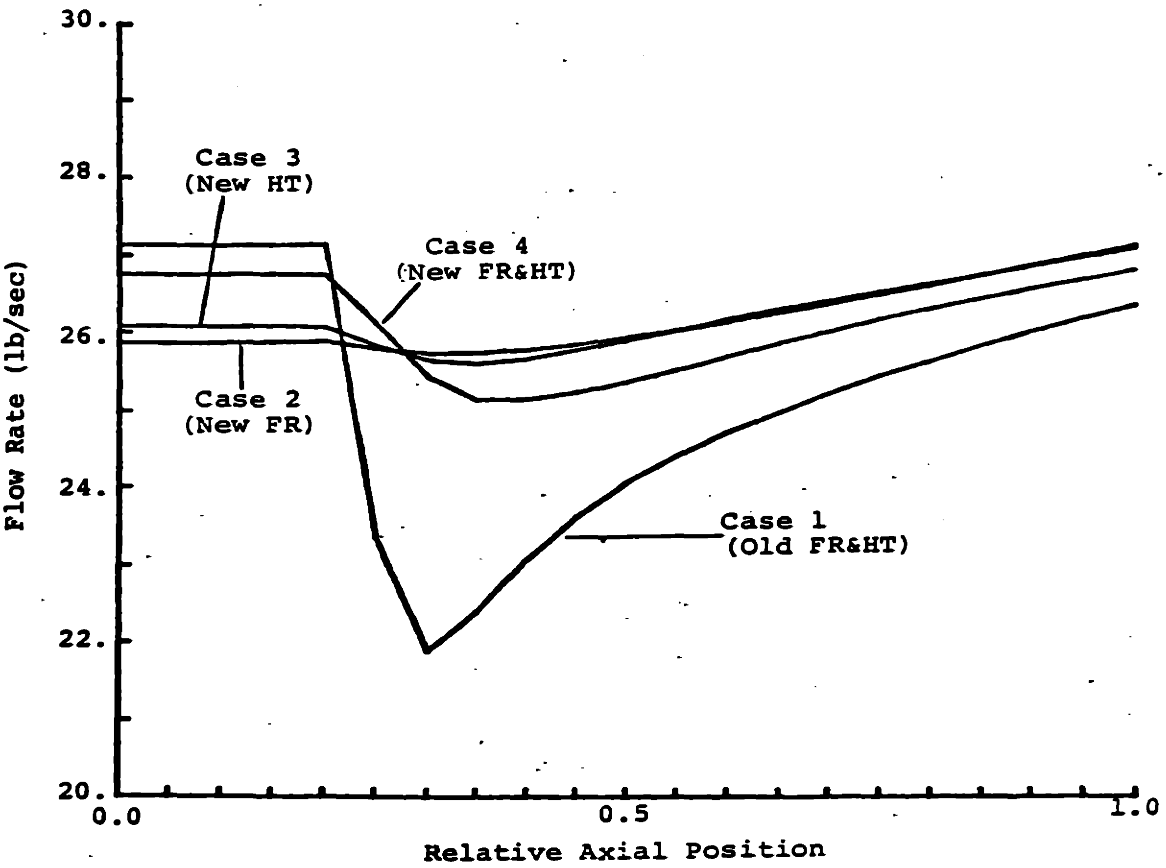


Figure IV-51

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

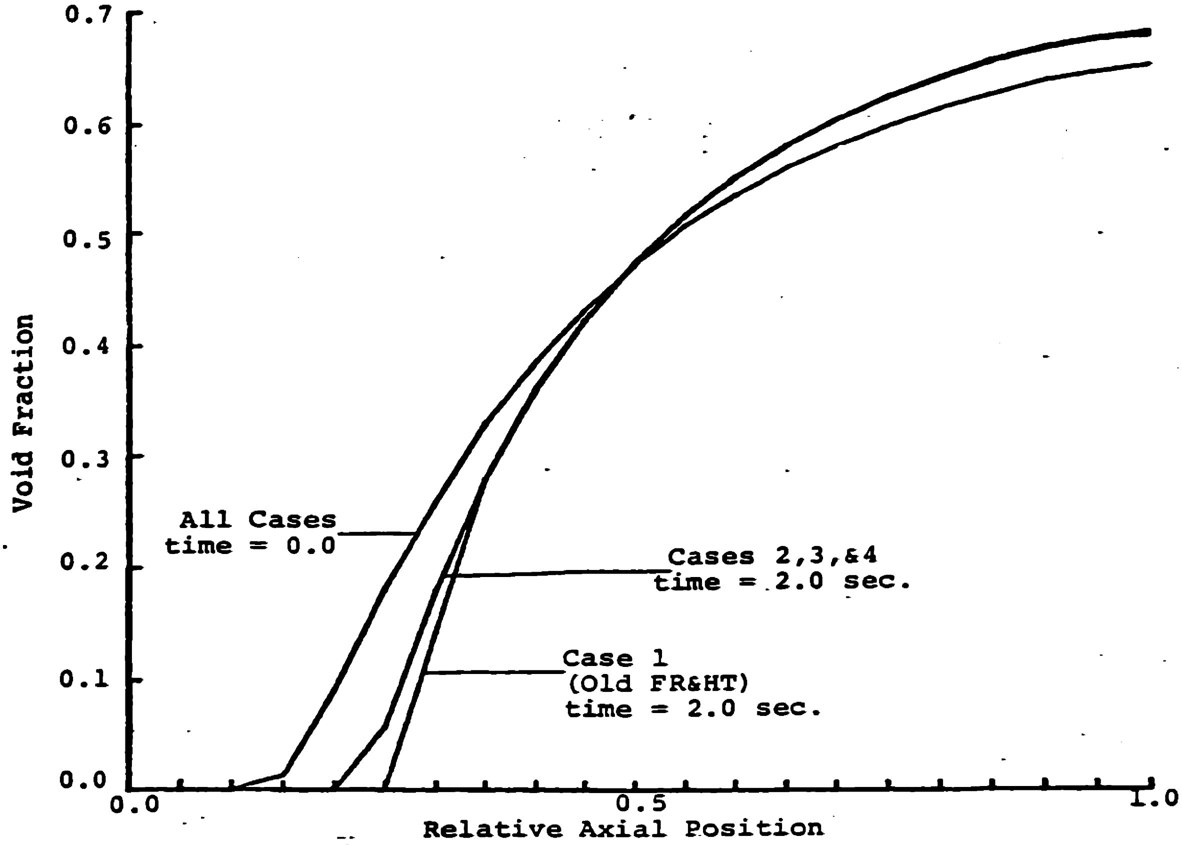


Figure IV-52

Axial Void Fraction Profile
Channel 2
BWR Turbine Trip Transient Test Case

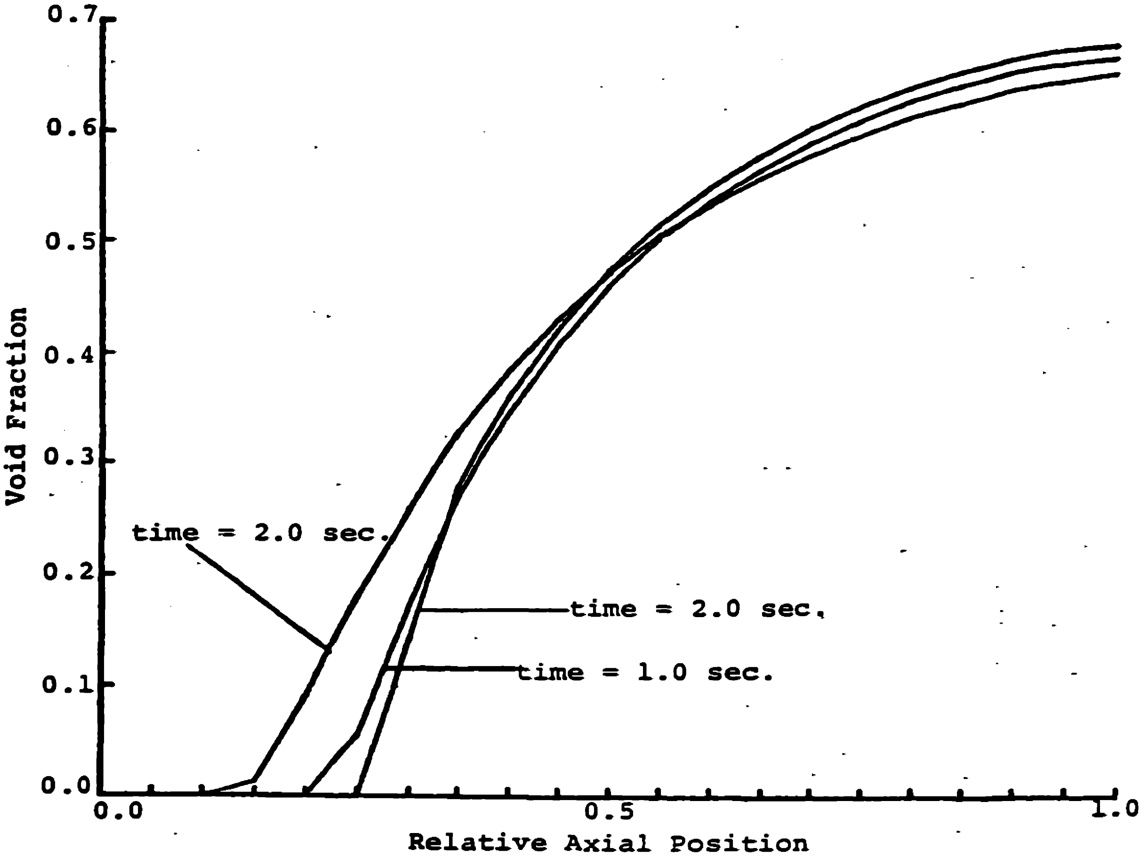


Figure IV-53

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-46. 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-47, IV-48 and IV-49. Clad temperature profiles at 0.0 seconds are shown in Figure IV-47. Analysis Cases 1 and 2 predict one profile using the new 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-49. 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-50 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

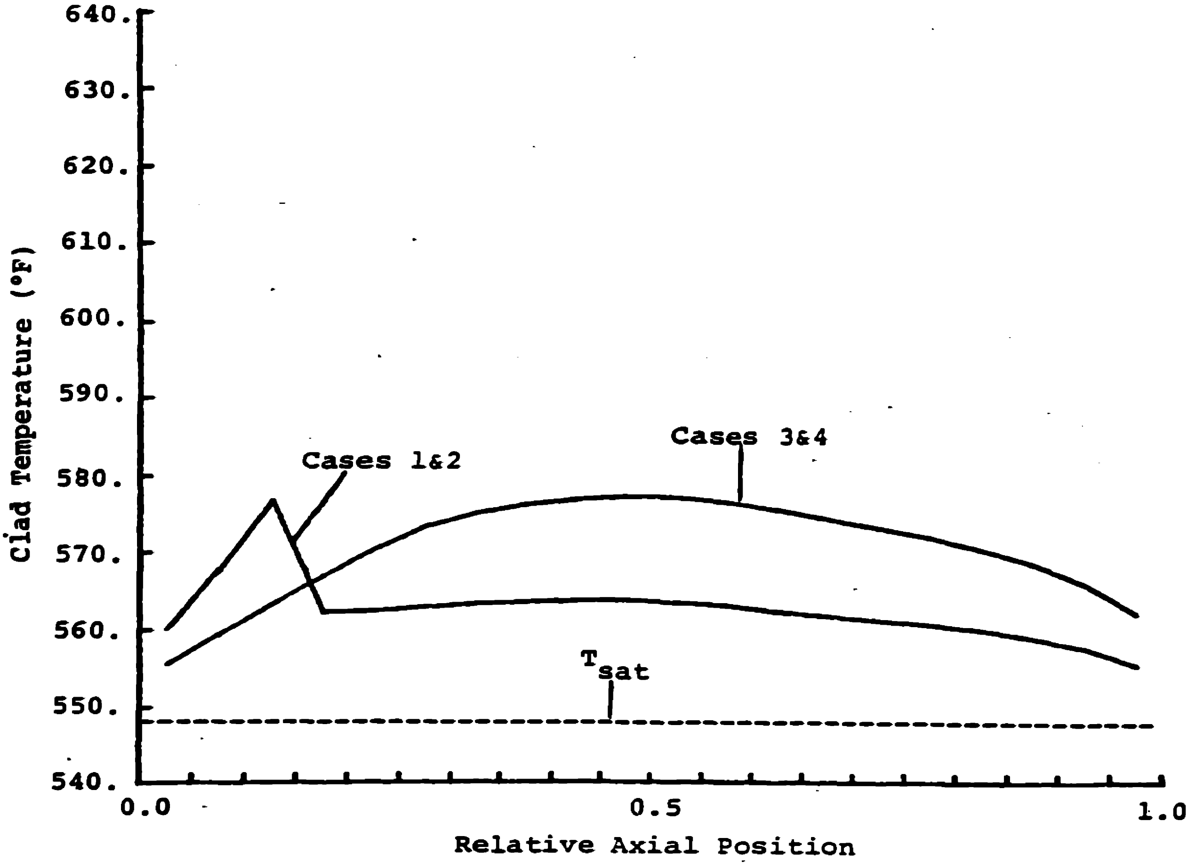


Figure IV-54

Axial Clad Temperature Profile
Rod 2, time = 0.0 sec.
BWR Turbine Trip Transient Test Case

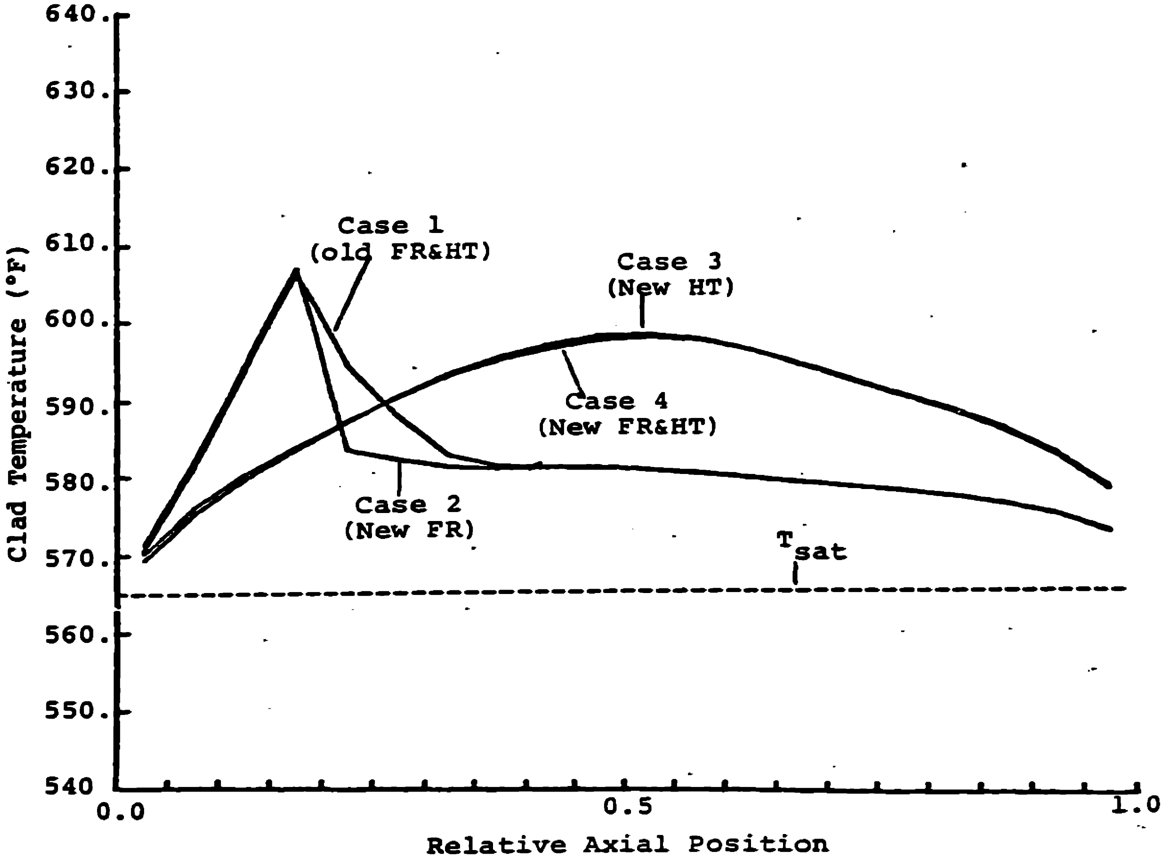


Figure IV-55

Axial Clad Temperature Profile
Rod 2, time = 2.0 sec.
BWR Turbine Trip Transient Test Case

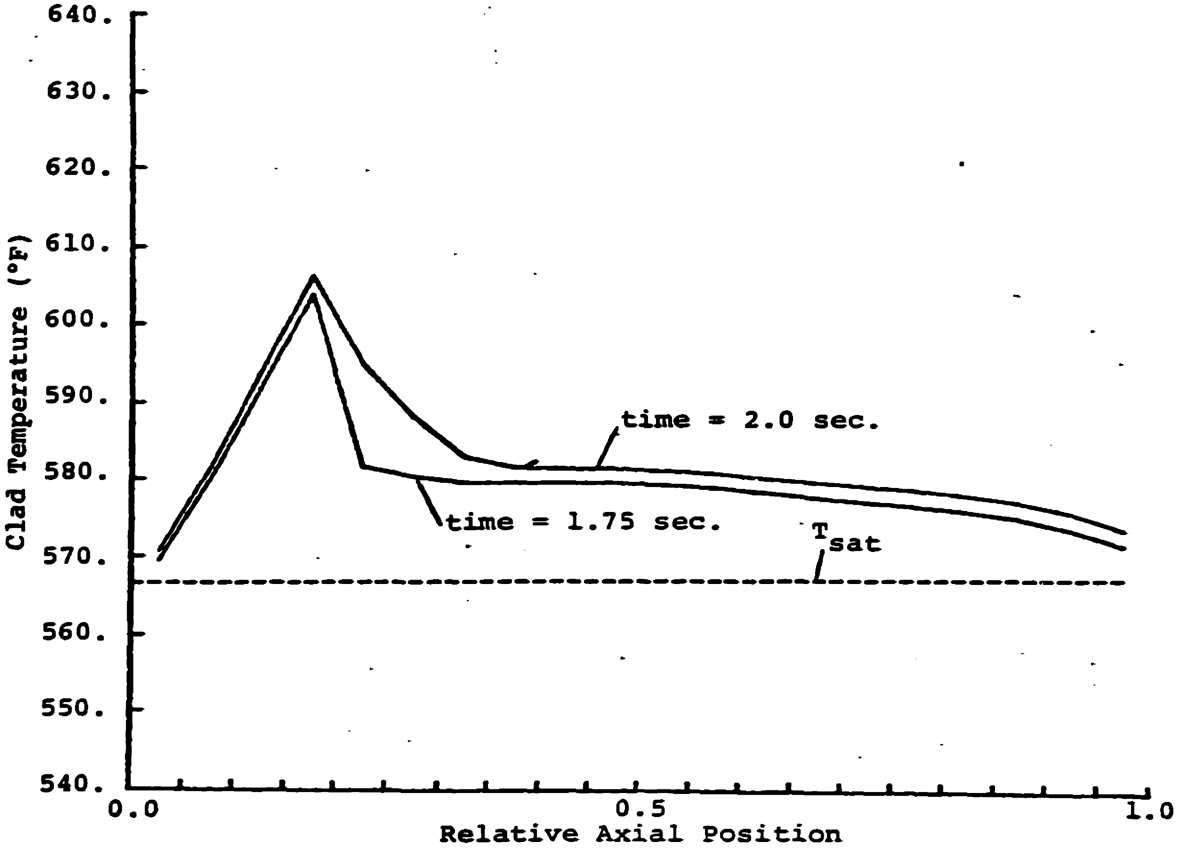


Figure IV-56

Axial Clad Temperature Profile
Rod 2
Analysis Case 1 (Old FR&HT)
BWR Turbine Trip Transient Test Case

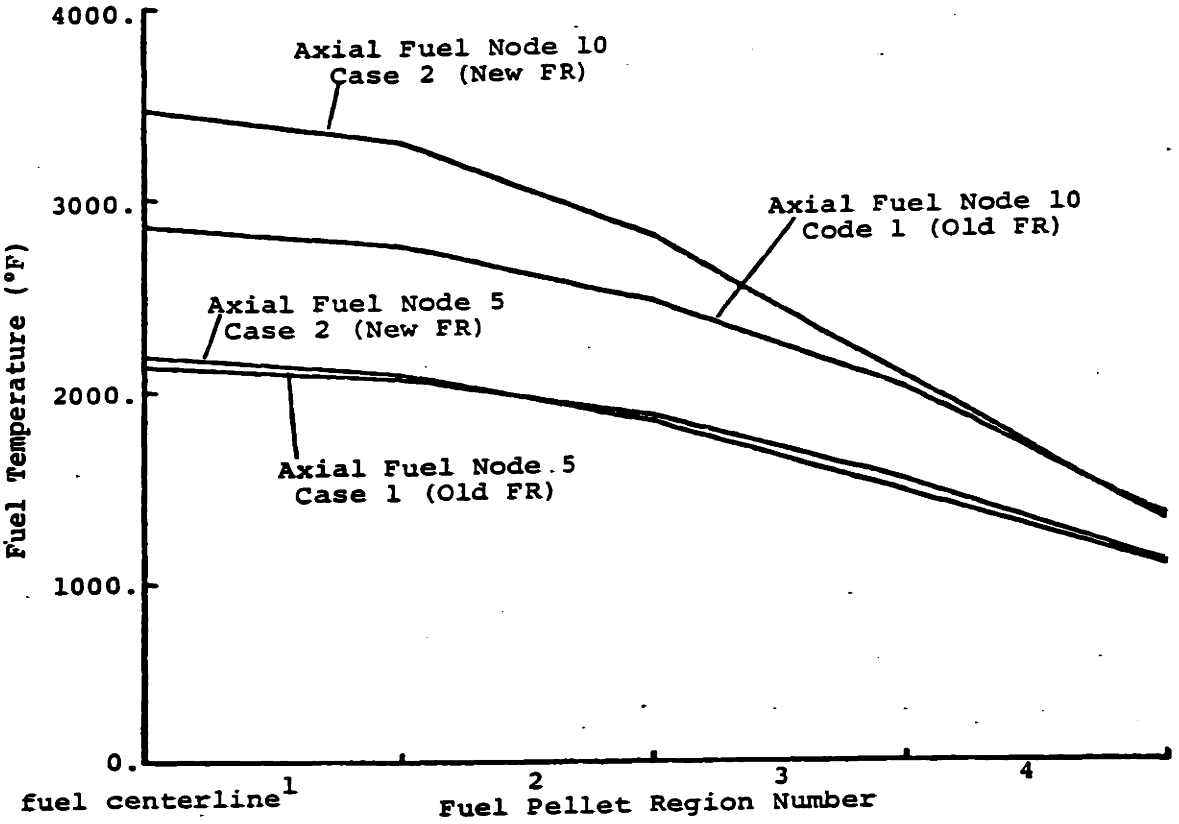


Figure IV-57

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-50 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-51 and IV-52 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-51. Predictions are farther apart in the vicinity of the core midplane. Centerline temperature predictions for rod 2 are shown in Figure IV-52. 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

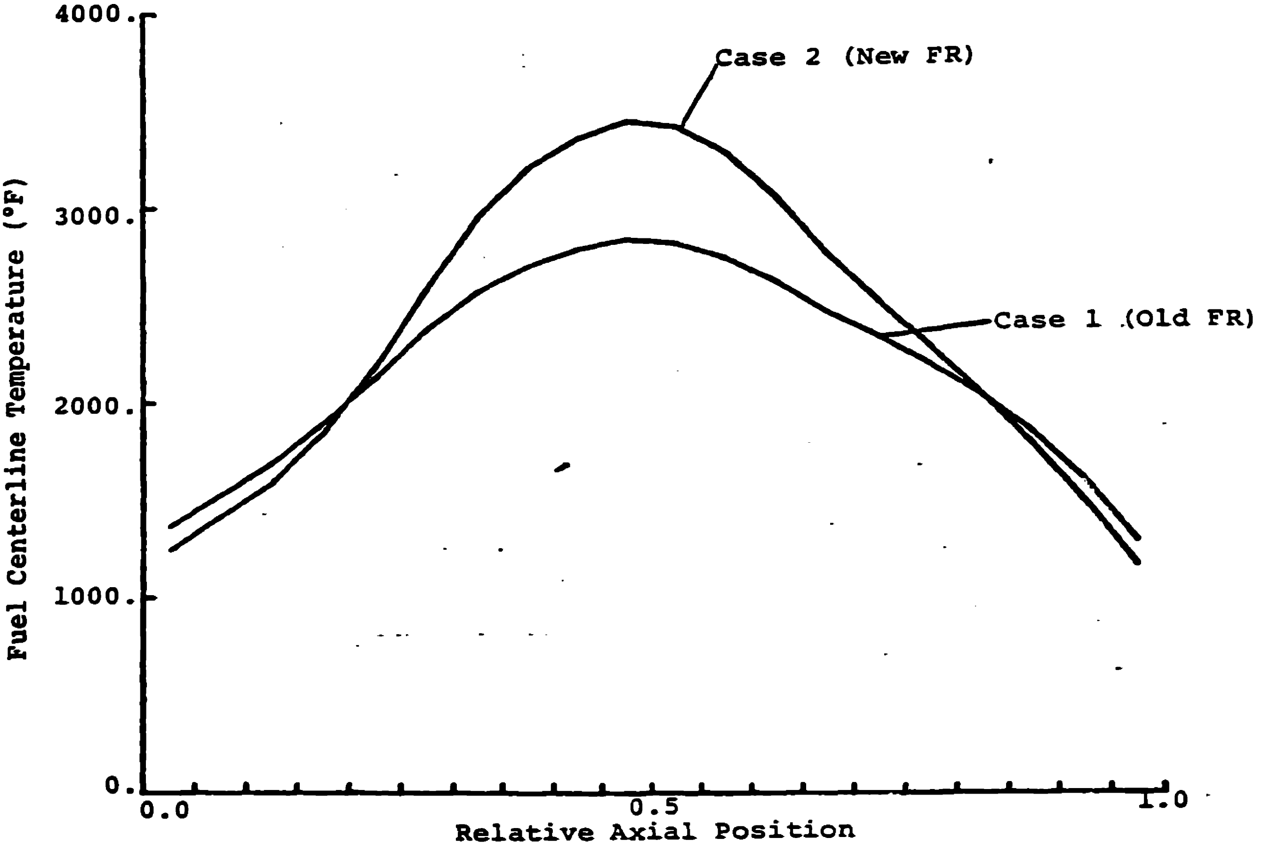


Figure IV-58

Centerline Temperature vs. Axial Position
Rod 1, Time = 0.0 sec.
BWR Turbine Trip Transient Test Case

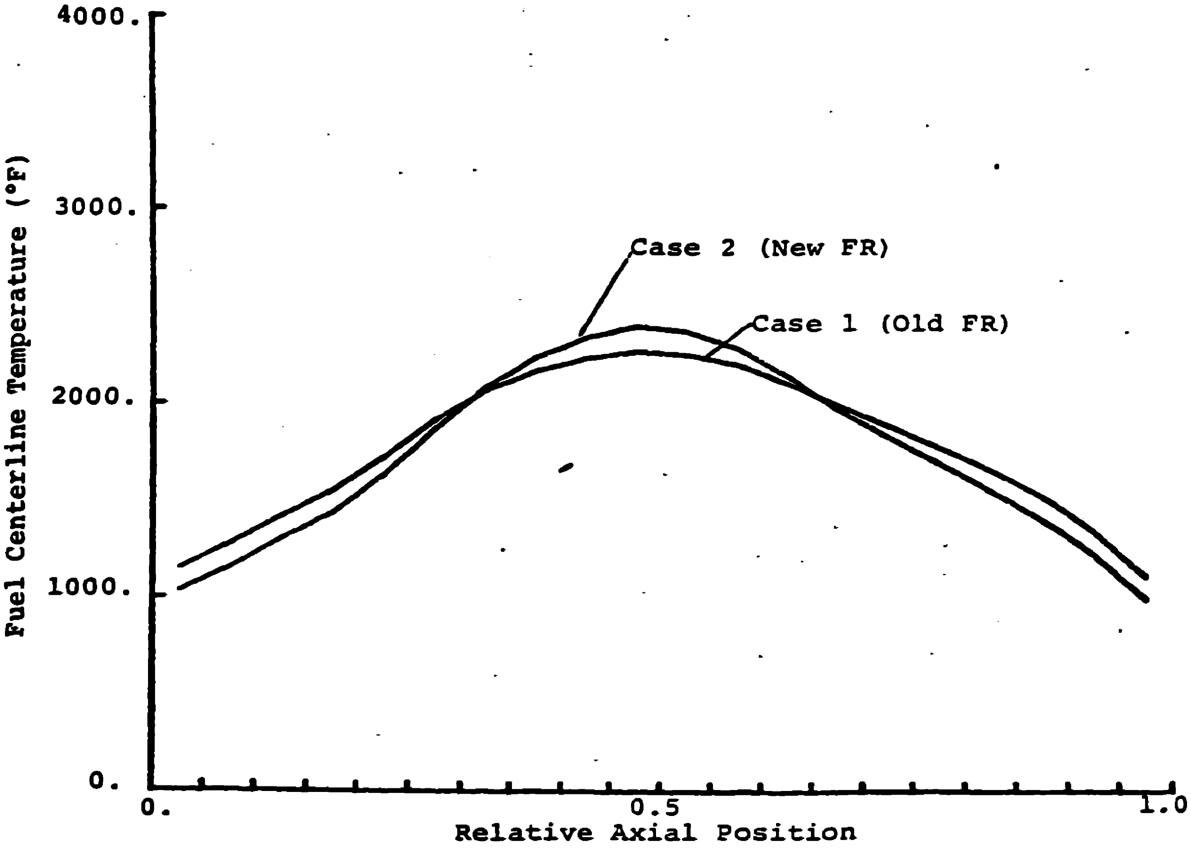


Figure IV-59

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. Application to BWR Bypass Analysis

1. Introduction

Conditions in the bypass channels surrounding enclosed fuel assembly channels affect the operation of a BWR. Boiling in the bypass channels, if it occurs, would affect power distribution and instrument response in the reactor core. As preliminary work for bypass analysis of the E.I. Hatch Unit I reactor, two small test cases were analyzed to gain an understanding of how bypass flow analysis can be performed for an entire reactor. It is specifically desired to know the range of COBRA-IIIC/MIT applicability and whether recirculation is present under operating conditions. The range of COBRA-IIIC/MIT applicability has been investigated to a greater extent than the question of recirculation. The first test case consists of nineteen analysis channels representing the bypass region surrounding ten enclosed fuel assemblies. The nineteen channel test case geometry was analyzed by Carlson and Gott (Ref. 45). This geometry contains some of the complexities of a full scale analysis, such as multiple flow paths and circular flow paths between analysis channels. The second test case consists of four channels representing a smaller bypass region. The first small test case was analyzed using COBRA-IIIC/MIT for varying power and flow conditions. The second small test case was analyzed using COBRA-IIIC/MIT and THERMIT. THERMIT is a three-dimensional two-fluid code. THERMIT, unlike COBRA-IIIC/MIT, has the capability to consider recirculation. The small size of the second small test case made THERMIT analysis economical. Heat transfer to bypass coolant was approximated by fixed heat fluxes from the channel walls for all analyses. The results of small test case analyses indicate general behavior of bypass coolant flow and provide an understanding of approaches to BWR bypass analysis.

2. Nineteen Channel Test Case

2.a. Description of Nineteen Channel Test Case Geometry and Operating Conditions

The nineteen channel test case geometry represents the bypass regions associated with ten assemblies as shown in Fig. IV-60. The bypass flow analysis channels are numbered from one to nineteen in the figure. The assemblies are numbered from one to ten. The assemblies are separated by wide and narrow gaps. Control blades may be inserted at the intersection of wide gaps. Two configurations of the nineteen channel geometry will be considered. First, without any control rods inserted and secondly, with the control rod associated with bypass channel ten partially inserted. The fuel assembly and flow channel dimensions are included in Table IV-8 along with system pressure and inlet enthalpy. Other operating conditions which overlap and differ from those analyzed by Carlson and Gott are specified in Section 2.b. The original core design had holes drilled in the core support to augment bypass flow. Later, these holes were plugged, reducing bypass flow. Carlson and Gott did not take reduction of bypass flow into account in their bypass analyses.

2.b Description of Modeling

The nineteen channel geometry was analyzed using COBRA-IIIC/MIT. Heat transfer to the bypass coolant was represented by fixed heat fluxes from the channel walls. Each assembly wall used the axial heat flux profile shown in Fig. IV-61. The boundary conditions used for the flow solution scheme were as follows:

- Channel outlet pressures all equal to a single specified value.

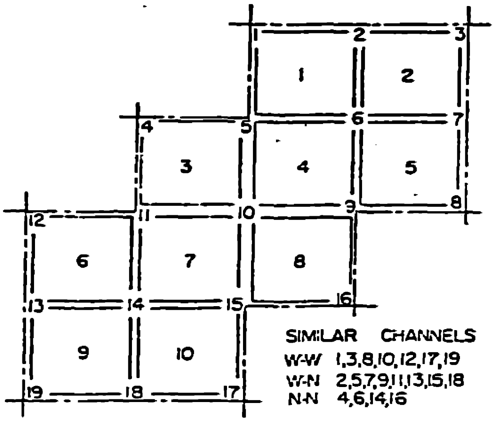


Figure IV - 60 (Fig. 3 of Ref. 45)

Nineteen Channel Test Case Geometry

Table IV-8 (Table I of Ref. 45)

Nineteen Channel Geometry and Operating Conditions

Number	Area (mm^2)	Wetted Perimeter (mm)	Heated Perimeter (mm)	Adjacent Channels and Spacing (mm)			
Subchannel Data, Control Rods Withdrawn							
1	1406.1	138.13	138.13	2, 9.53	5, 9.53		
2	2061.4	276.35	276.35	1, 9.53	3, 9.53	6, 9.53	
3	1406.1	138.13	138.13	2, 9.53	7, 9.53		
4	678.5	138.13	138.13	5, 4.75	11, 4.75		
5	3092.8	414.27	414.27	1, 9.53	4, 4.75	6, 9.53	10, 19.1
6	2714.2	552.45	552.45	2, 9.53	5, 9.53	7, 9.53	9, 9.53
7	2061.4	276.35	276.35	3, 9.53	6, 9.53	8, 9.53	
8	1406.1	138.13	138.13	7, 9.53	9, 9.53		
9	3092.8	414.27	414.27	6, 9.53	8, 9.53	10, 19.1	16, 4.75
10	5524.4	552.45	552.45	5, 19.1	9, 19.1	11, 19.1	15, 19.1
11	3092.8	414.27	414.27	4, 4.75	10, 19.1	12, 9.53	14, 9.53
12	1406.1	138.13	138.13	11, 9.53	13, 9.53		
13	2061.4	276.35	276.35	12, 9.53	14, 9.53	19, 9.53	
14	2714.2	552.45	552.45	11, 9.53	13, 9.53	15, 9.53	18, 9.53
15	3092.8	414.27	414.27	10, 19.1	14, 9.53	16, 4.75	17, 9.53
16	678.5	138.13	138.13	9, 4.75	15, 4.75		
17	1406.1	138.13	138.13	15, 9.53	18, 9.53		
18	2061.4	276.35	276.35	14, 9.53	17, 9.53	19, 9.53	
19	1406.1	123.13	138.13	13, 9.53	18, 9.53		
Subchannel Data, Central Control Rod Inserted							
5	2778.0	414.27	414.27	1, 9.53	4, 4.75	6, 9.53	10, 12.4
9	2778.0	414.27	414.27	6, 9.53	8, 9.53	10, 12.4	16, 4.75
10	3612.0	552.45	552.45	5, 12.4	9, 12.4	11, 12.4	15, 12.4
11	2778.0	414.27	414.27	4, 4.75	10, 12.4	12, 9.53	14, 9.53
15	2778.0	414.27	414.27	10, 12.4	14, 9.53	16, 4.75	17, 9.53

Table IV-8 (cont'd.)

Fuel Assembly Data	
Perimeter	0.5525 m
Channel Length	4.262 m
Operating Conditions	
System pressure	7.135 MPa
Inlet enthalpy	1.226 MJ/kg

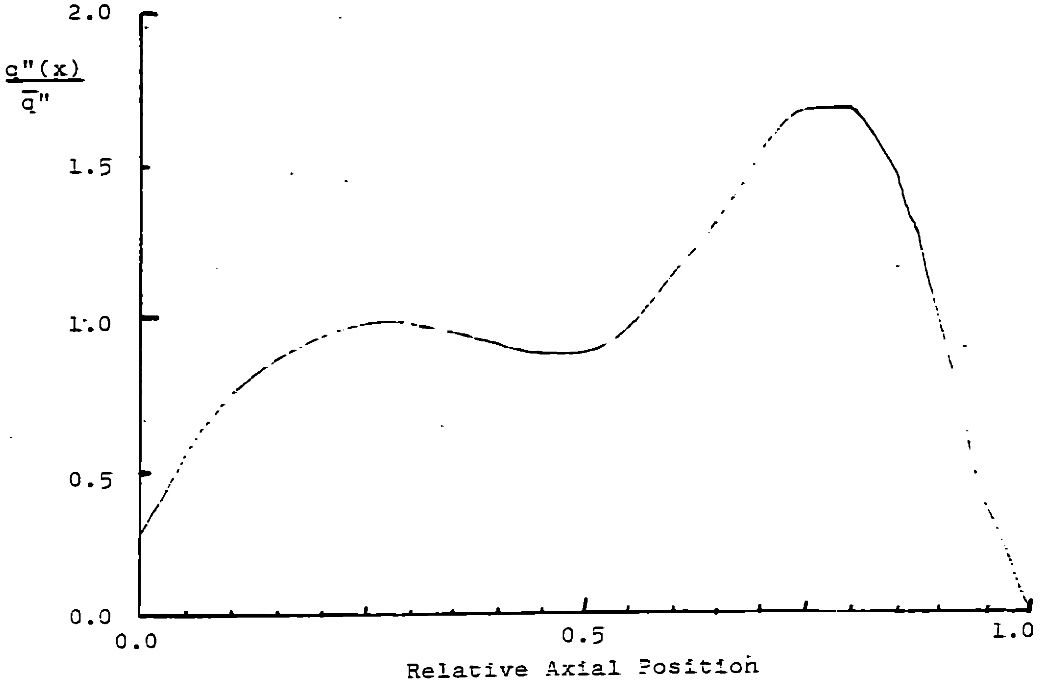


Figure IV-61

Axial Heat Flux Profile

Bypass Analysis

- A specified total inlet flow rate is split using an iterative scheme to give equal pressure drops across the first axial node of all channels. The flow split scheme assumes there is no crossflow and no density change as coolant flows in the axial direction.

The four nineteen channel bypass cases listed in Table IV-9 were each analyzed for varying average inlet flow rates and average heat fluxes. The cases differ in the heat apportionment method used and whether all control rods are out or one control rod is partially inserted. Two heat apportionment methods were used. Both methods rely on fixed heat fluxes, hence, no actual heat transfer calculations are made. The two heat apportionment methods will be referred to as the old and new heat apportionment methods. The old heat apportionment method evenly divides the heat transferred from a fuel assembly to surrounding bypass channels according to the fraction of fuel assembly wall perimeter in contact with each channel. The old heat apportionment method approximates the apportionment expected if the Carlson and Gott analysis methodology were applied. The new heat apportionment method approximates the apportionment expected if the heat transfer model which is developing from new understandings (Ref. 46) were applied. Nineteen channel bypass cases one to three use the radial power factors shown in Fig. IV-62. These factors are for the highest power region of a core. Case four has a flat radial power distribution. It represents the situation of radial peaking factors all equal unity.

Various phenomena were modeled using COBRA-IIIC/MIT options as indicated in Table IV-10. Options used for PWR analysis are included in the table for comparison. COBRA-IIIC/MIT input for a nineteen channel bypass case is given in Appendix P.

Table IV-9

Nineteen Channel Bypass Cases

Case Number	Heat Apportionment*	Control Rod
1	New	Out
2	Old**	Out
3	Old**	
4	New - Flat radial distribution	Out

* See accompanying text for explanation of heat apportionment methods.

** The old heat apportionment method divides the heat transfer from each bundle to associated bypass channels in a manner which closely approximates the apportionment used in Carlson and Gott analyses.

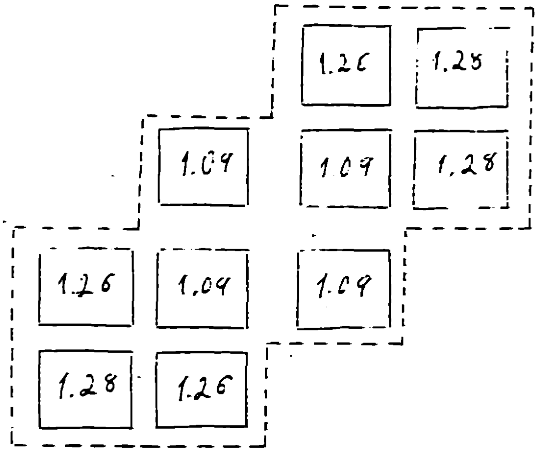


Figure IV-62

Radial Peaking Factors

Nineteen Channel Bypass Cases One, Two and Three

Table IV-10

COBRA-IIIC/MIT Options Used for Bypass Analysis

Phenomenon	"Standard" PWR Analysis	BWR Bypass Analysis
Subcooled voids	Levy model	No subcooled void model
1-phase friction	$f = 0.184\ Re^{-.2}$	same
2-phase friction	no multiplier	same
wall viscocity correction	yes	no
K_{ij} (transverse friction coefficient)	0.5	same
s/ℓ	0.5 (or 0.24)	0.094*
turbulent enthalpy mixing	$\beta = 0.02$	same
thermal conduction	none	same
boundary conditions	equal ΔP over first node and outlet pressures equal for all channels	same

* ℓ is based on centroid-to-centroid distance. s is the average of gap widths.

2.c Analysis Case Results

2.c.i COBRA-IIIC/MIT Applicability Limits

COBRA-IIIC/MIT applicability limits were obtained by analyzing the four cases listed in Table IV-9 for various combinations of power and flow. COBRA-IIIC/MIT provides predictions for some power and flow combinations and fails to provide predictions for other combinations. Failure occurs by either a failure of the flow solution to converge within a specified maximum number of iterations or, when the power-to-flow ratio is made larger, by extreme code failure. The extreme code failures occurred during property lookups under conditions approaching stagnant flow and,ultimately, flow reversal. Some channels had near-zero flow rates and unreasonably high enthalpy when these extreme failures occurred.

The most severe conditions for which COBRA-IIIC/MIT predictions can be obtained are shown in Fig. IV-63 as limits of applicability for each of the four nineteen channel bypass cases. COBRA-IIIC/MIT failed in the zone below the lines. The limit line for case three, which has a control rod partially inserted,is higher than the lines for cases one, two and four which have no control rods inserted. The case four limit of applicability is shown only for $\overline{q''}$ = 0.0132 MBtu/hr-ft^2. The flat power distribution of case four gives it the largest applicability zone. The point labeled "full power and full flow conditions" is below all the lines of applicability in Fig. IV-63. This point was obtained using two assumptions. The first assumption is that 2% of assembly power will be transferred to bypass coolant. The second assumption is that the core bypass flow rate is that shown in Fig. IV-64 for 100% core flow after core support plate hole plugging. In addition, no control rods are inserted. From the location of this point relative to the lines of applicability, it appears that COBRA-IIIC/MIT will

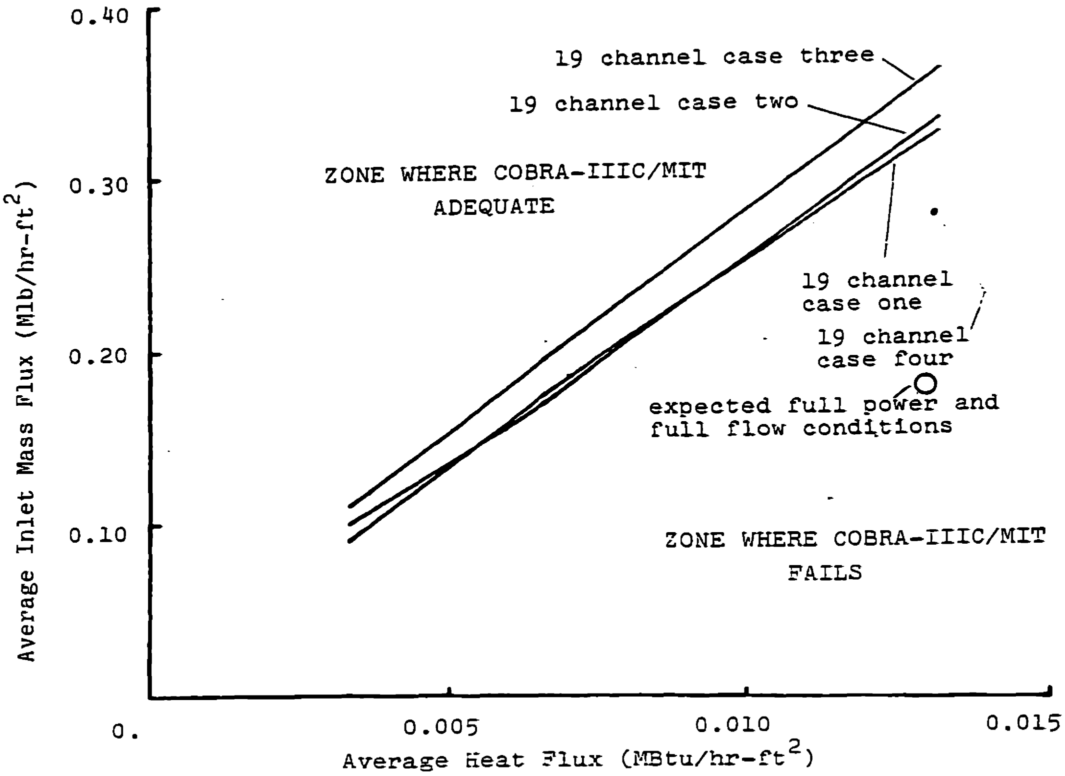
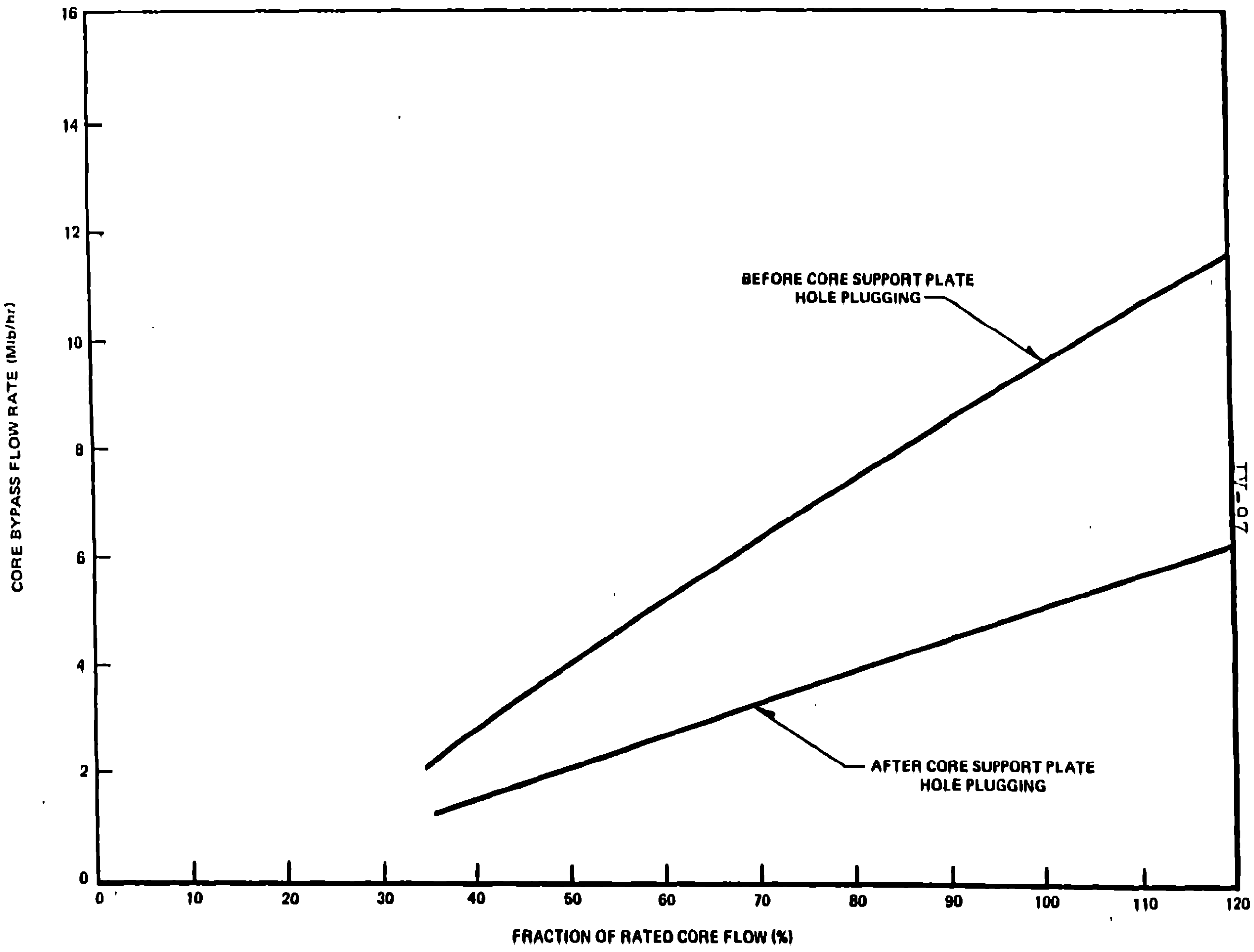


Figure IV-63

Mass Flux vs. Heat Flux

COBRA-IIIC/MIT Applicability Limits for Nineteen Channel Cases



Core Bypass Flow for Cycle 1

Figure IV-64 (Fig. 23 of Ref. 47)

not be able to provide predictions for bypass cases of interest at full power and probably lower power levels, as well.

Analyses made during the process of determining COBRA-IIIC/MIT applicability limits for each of the four nineteen channel cases is given in Tables IV-11 through IV-14. The particular analyses used in Fig. IV-63 are listed in Table IV-15.

2.c.ii Nineteen Channel Bypass Case One Predictions

Case one has no control rods inserted and uses the new heat apportionment method. COBRA-IIIC/MIT predictions are shown in Figs. IV-65 through IV-72 for $\bar{q}'' = 0.0132$ MBtu/hr-ft^2. Figures IV-65 through IV-68 are for $\bar{G} = 0.3290$ Mlb/hr-ft^2. Axial mass flux profiles are shown in Fig. IV-65. Up to a relative axial position, x/L equal to 0.75, flow is redistributing to give channels with larger hydraulic diameters, the wide-wide (W-W) channels, a larger mass flux than the narrow-narrow (N-N) channels. The flow split scheme to give equal pressure drop across the first node worked poorly since the frictional pressure drop is a small fraction of the total pressure drop. Otherwise, the flow split scheme would function better and less redistribution would occur within the axial distance from the inlet to $x/L = 0.75$. Near $x/L = 0.75$, vapor starts to form in the channels, as Fig. IV-65 shows in a plot of α vs x. At $x/L = 0.9$, flow has redistributed to give the N-N channels greater mass flux than the W-W channels. Production of vapor in the N-N channels draws in flow from other channels because the total pressure drop is heavily dominated by gravitational pressure drop. The rapid change in density which occurs when voids are produced is seen in Fig. IV-67 which shows axial density profiles for each channel. Channels 6 and 14 are both N-N channels and are adjacent to assemblies with high radial peaking factors, as Fig. IV-62

Table IV-11

Nineteen Channel Bypass Case One
COBRA-IIIC/MIT Analysis Results

$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	Success ?	Iterations	X_{max}	α_{max}
0.0132	0.3150	no			
"	0.3200	no			
"	0.3208	no			
"	0.3290	yes	15	0.005	0.089
"	0.3368	yes	13	0.004	0.080
0.0066	0.1600	no			
"	0.1650	no			
"	0.1700	no			
"	0.1750	yes	15	0.002	0.037
"	0.1800	yes			
0.0033	0.0800	no			
"	0.0900	yes	12	0.000	0.007
"	0.1000	yes			

Table IV-12

Nineteen Channel Bypass Case Two
COBRA-IIIC/MIT Analysis Results

$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	Success ?	Iterations	X_{max}	α_{max}
0.0132	0.3208	no			
"	0.3369	yes	16	0.006	0.110
0.0066	0.1700	no			
"	0.1750	yes	17	0.003	0.059
0.0033	0.0950	no			
"	0.1000	yes	17	0.000	0.000

Table IV-13

Nineteen Channel Bypass Case Three
COBRA-IIIC/MIT Analysis Results

$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	Success ?	Iterations	X_{max}	α_{max}
0.0132	0.3368	no			
"	0.3600	no			
"	0.3650	yes	18	0.007	0.127
"	0.3700	yes	17		
"	0.3800	yes	5		
0.0066	0.1900	no			
"	0.1950	yes	17	0.000	0.009
"	0.2000	yes	17		
"	0.2100	yes	16		
0.0033	0.1050	no			
"	0.1100	yes	19	0.000	0.000

Table IV-14

Nineteen Channel Bypass Case Four

COBRA-IIIC/MIT Analysis Results

$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	Success ?	Iterations	X_{max}	α_{max}
0.0132	0.2000	no			
"	0.2200	no			
"	0.2500	no			
"	0.2700	no			
"	0.2750	no			
"	0.2800	yes	20	0.010	0.163
"	0.2900	yes	15		
"	0.3290	yes	14	0.005	0.091
"	0.3368	yes	11	0.004	0.081

Table IV-15

Nineteen Channel Bypass Cases

Limits of COBRA-IIIC/MIT Applicability

Case	$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	X_{max}	α_{max}
1	0.0132	0.3290	0.005	0.084
2	0.0132	0.3369	0.006	0.110
3	0.0132	0.3650	0.007	0.127
4	0.0132	0.2800	0.010	0.163
1	0.0066	0.1750	0.002	0.037
2	0.0066	0.1750	0.003	0.059
3	0.0066	0.1950	0.000	0.009
1	0.0033	0.0900	0.000	0.007
2	0.0033	0.1000	0.000	0.000
3	0.0033	0.1100	0.000	0.000

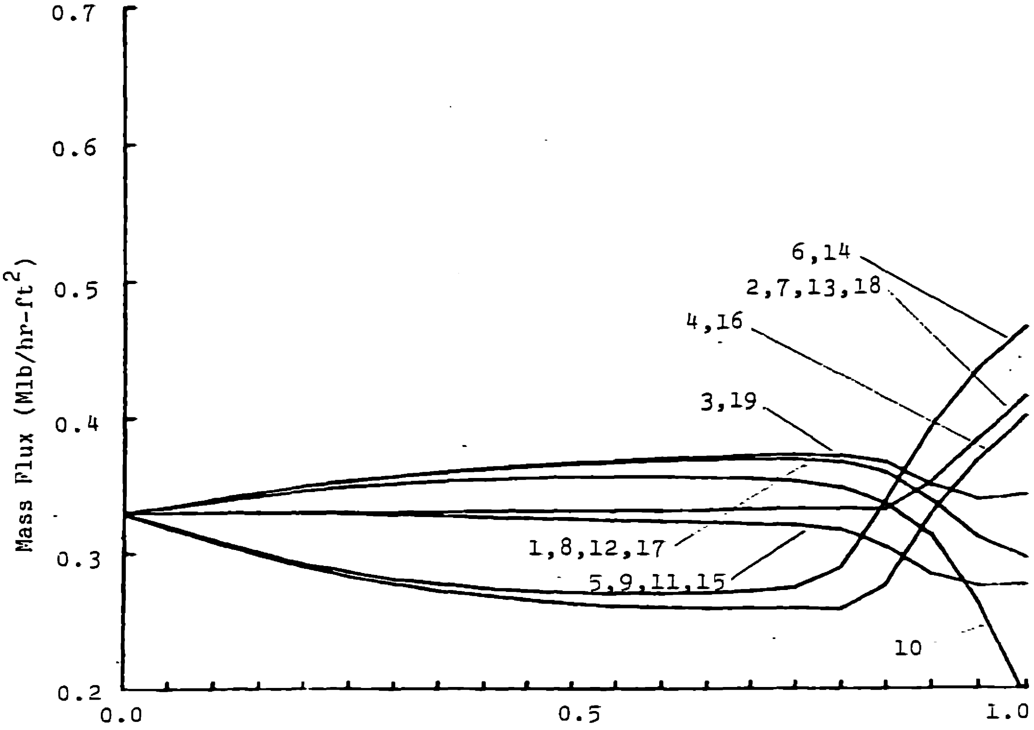


Figure IV-65

Axial Mass Flux Profiles

Nineteen Channel Bypass Case One

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3290$ Mlb/hr-ft^2

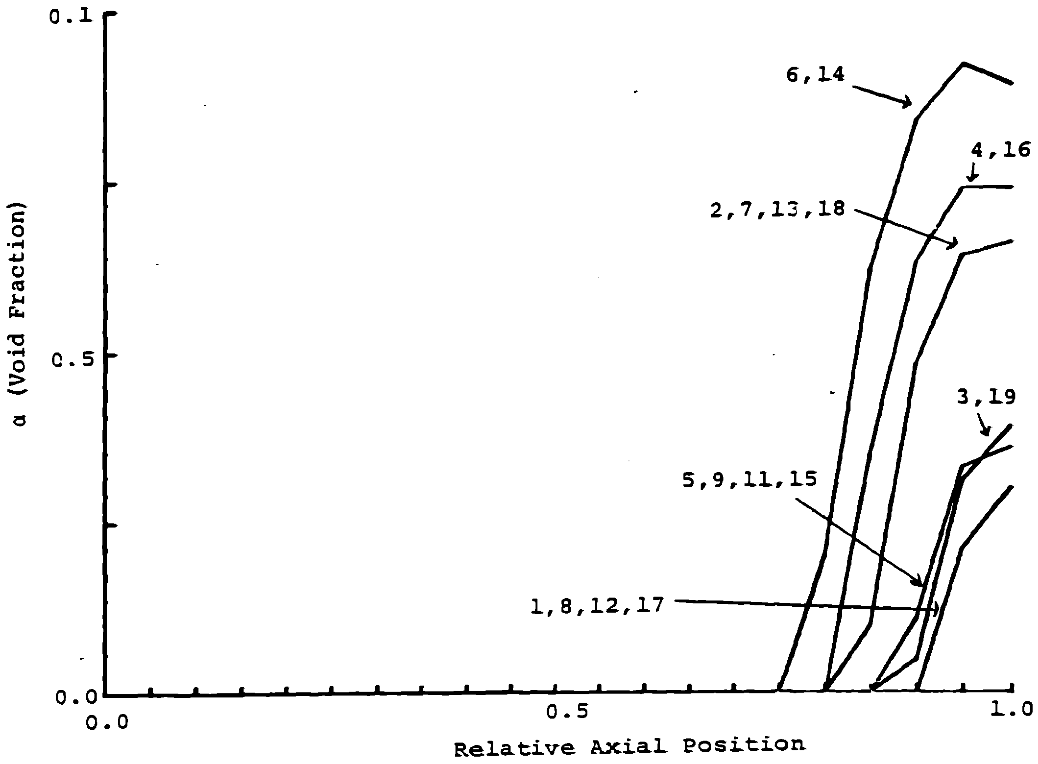


Figure IV-66

Axial Void Fraction Profiles

Nineteen Channel Bypass Case One

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3290$ Mlb/hr-ft^2

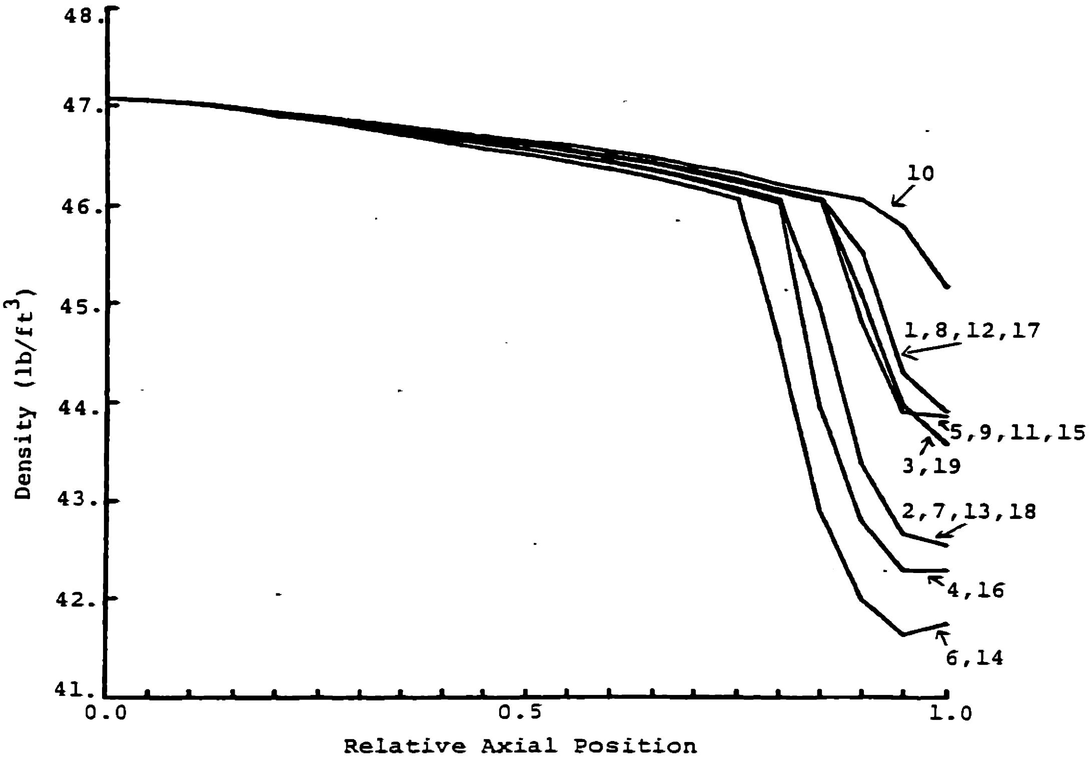


Figure IV-67

Axial Density Profiles

Nineteen Channel Bypass Case One

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3290$ Mlb/hr-ft^2

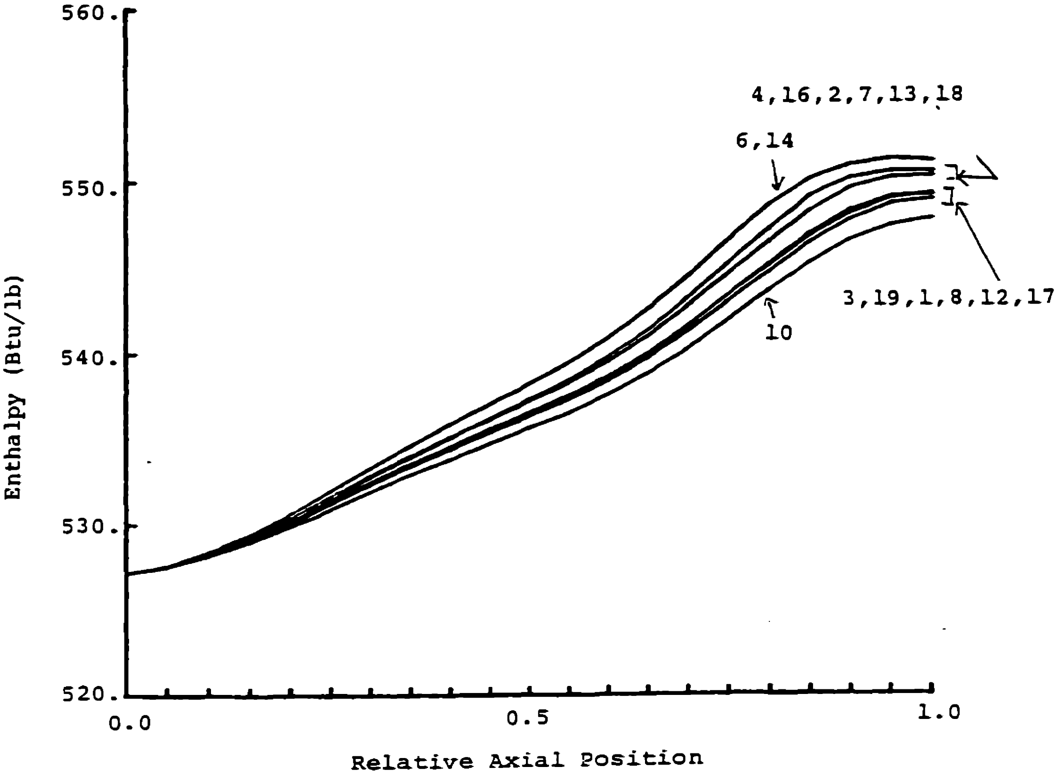


Figure IV-68

Axial Enthalpy Profiles

Nineteen Channel Bypass Case One

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3290$ Mlb/hr-ft^2

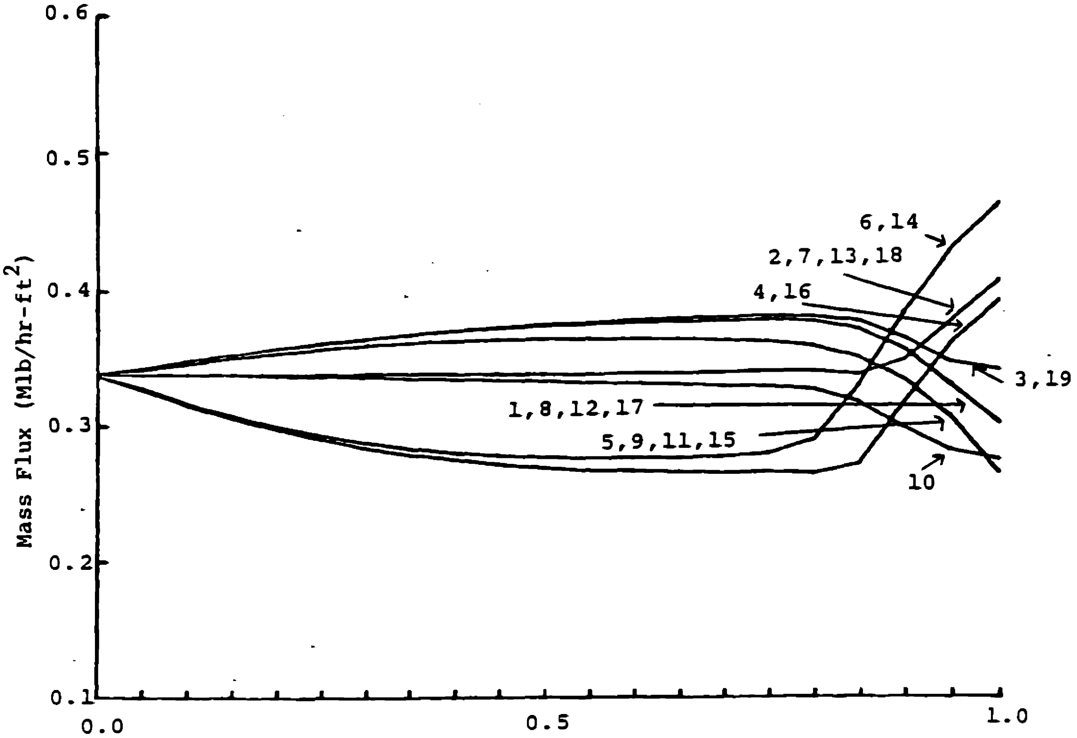


Figure IV-69

Axial Mass Flux Profiles

Nineteen Channel Bypass Case One

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3368$ Mlb/hr-ft^2

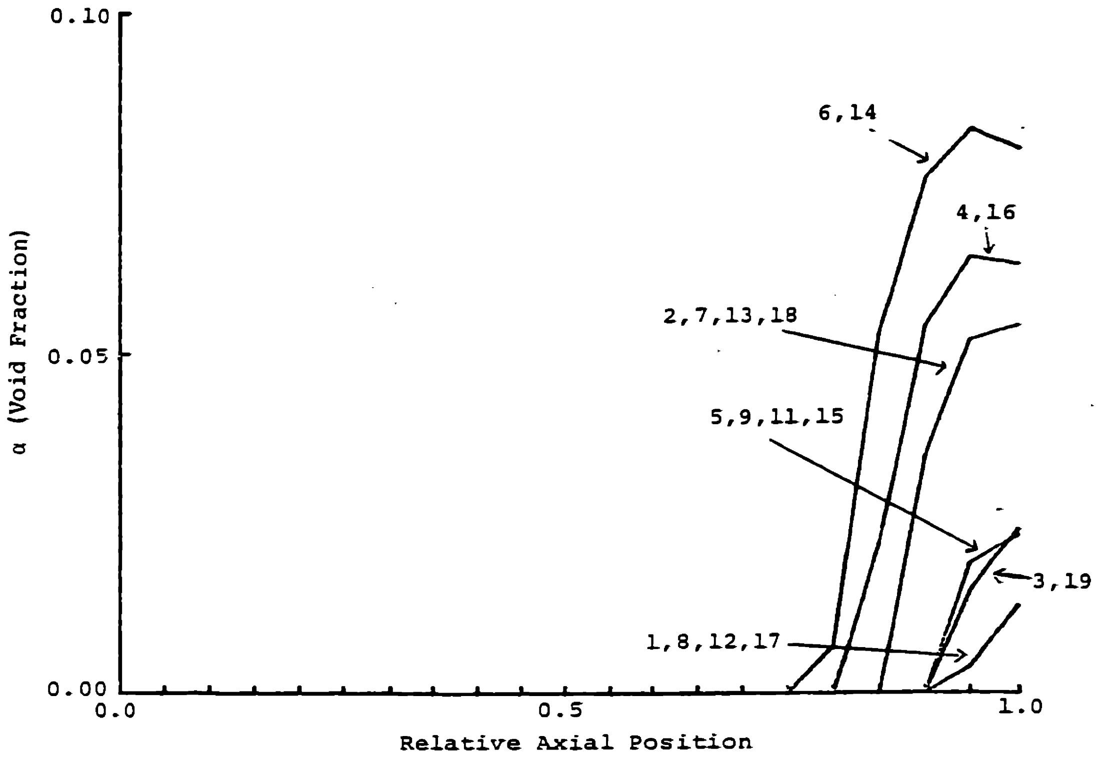


Figure IV-70

Axial Void Fraction Profiles

Nineteen Channel Bypass Case One

$\overline{q}''$ = 0.0132 MBtu/hr-ft^2

$\overline{G}$ = 0.3368

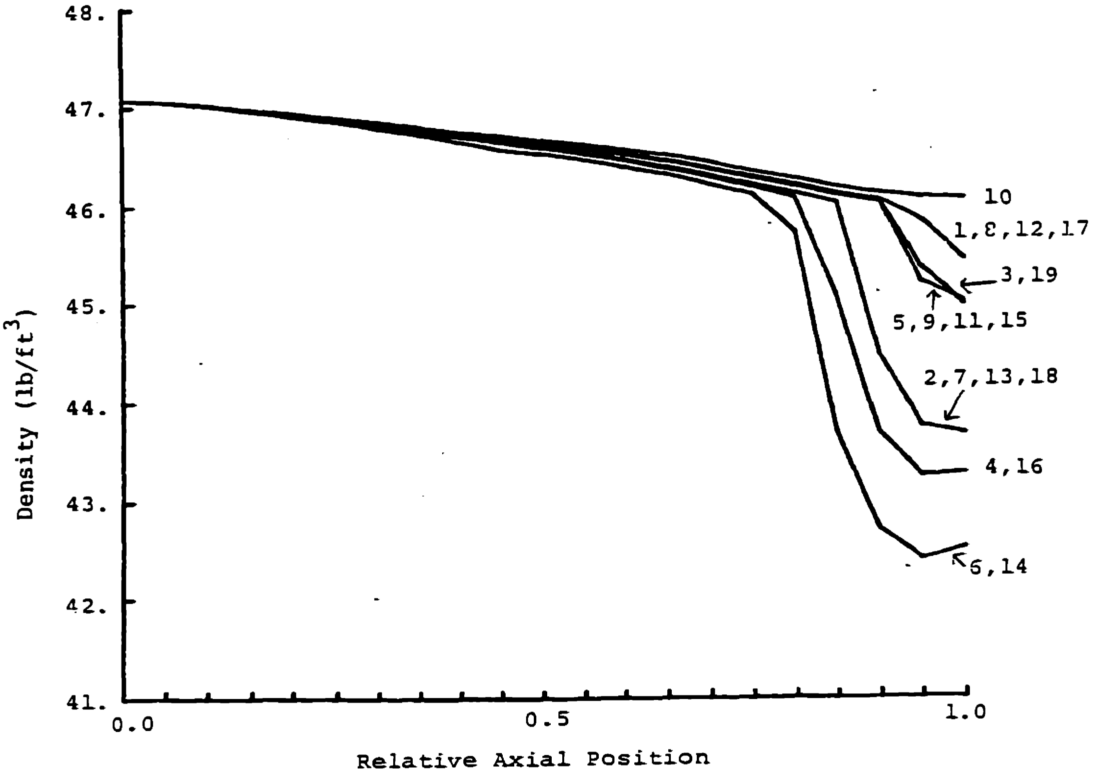


Figure IV-71

Axial Density Profiles

Nineteen Channel Bypass Case One

$\bar{q}'' = 0.0132$ MBtu/hr-ft^2

$\bar{G} = 0.3368$

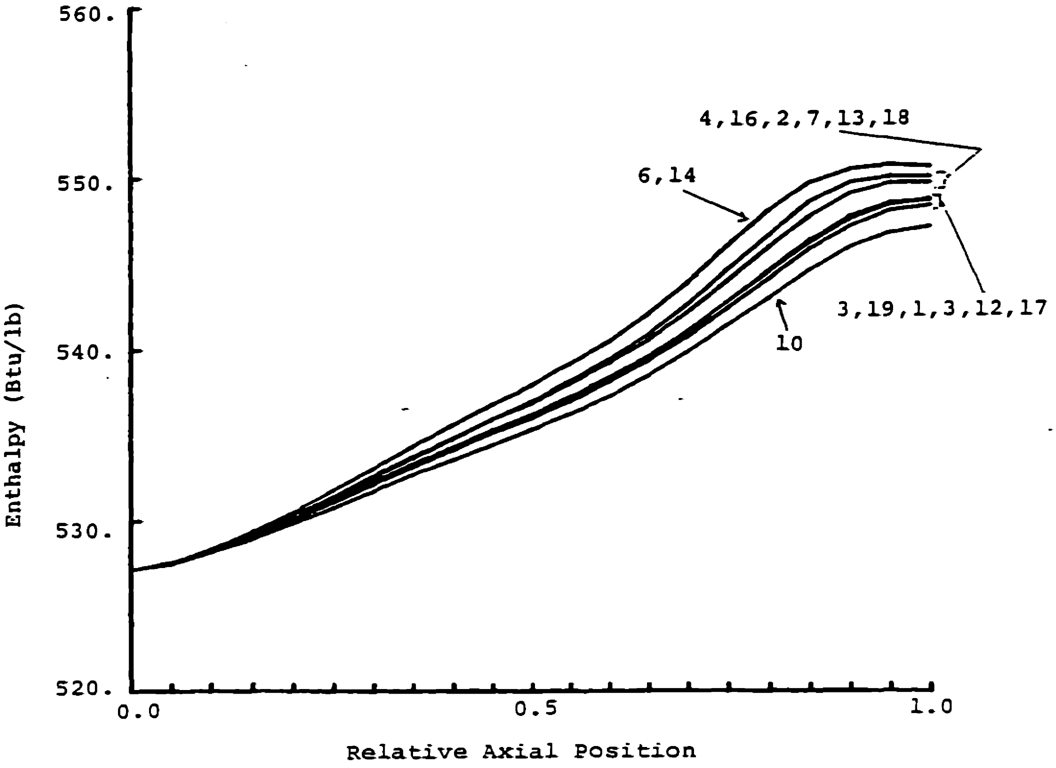


Figure IV-72

Axial Enthalpy Profiles

Nineteen Channel Bypass Case One

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3368$ Mlb/hr-ft^2

shows. Density in channels 6 and 14 drops very low and then partially recovers as coolant is drawn in from neighboring channels. Axial enthalpy profiles are shown in Fig. IV-68. Channels 6 and 14 have the highest enthalpy while channel 10, a W-W channel has the lowest enthalpy because it is adjacent to assemblies with low radial peaking factors and it has a large hydraulic diameter.

Figures IV-69 through IV-72 correspond to Fig. IV-65 through IV-68 for average mass flux equal to 0.3368 Mlb/hr-ft^2. At this higher flow rate, the start of boiling occurs at a higher axial position, as seen in Fig. IV-70 which shows axial void fraction profiles. The flow redistribution induced by boiling is less for $\overline{G}$ = 0.3368 than for $\overline{G}$ = 0.3290 since less boiling is present. At $\overline{G}$ = 0.3208 Mlb/hr-ft^2 (and $\overline{q}''$ = 0.0132 MBtu/hr-ft^2) COBRA-IIIC/MIT failed to converge. When failure occurred, the gravitational component of pressure drop in channel 10 was 99% of the total pressure drop. In a situation where the stabilizing influence of frictional pressure drop is outweighed by gravitational pressure drop, calculational stability is low. Also, crossflow is significant in comparison to axial flow, contrary to a basic assumption of the COBRA-IIIC/MIT code. Thus, two factors are present which can cause failure of the COBRA-IIIC/MIT code, even in the absence of reverse flow. Reverse flow is outside the capability of the code's marching solution technique. Failures at lower average heat fluxes (0.0066 and 0.0033 MBtu/hr-ft^2) also occurred when the gravitational component of pressure drop was at least 99% of the total pressure drop.

2.c.iii Nineteen Channel Bypass Case Two Predictions

Case two has no control rods inserted and uses the old (similar to Carlson and Gott) heat apportionment method. Case two predictions for $\overline{q}''$ = 0.0132 MBtu/hr-ft^2 and $\overline{G}$ = 0.3369 Mlb/hr-ft^2 are shown in Figs. IV-73 and IV-74. Figure IV-73 shows axial mass flux profiles. Axial mass flux

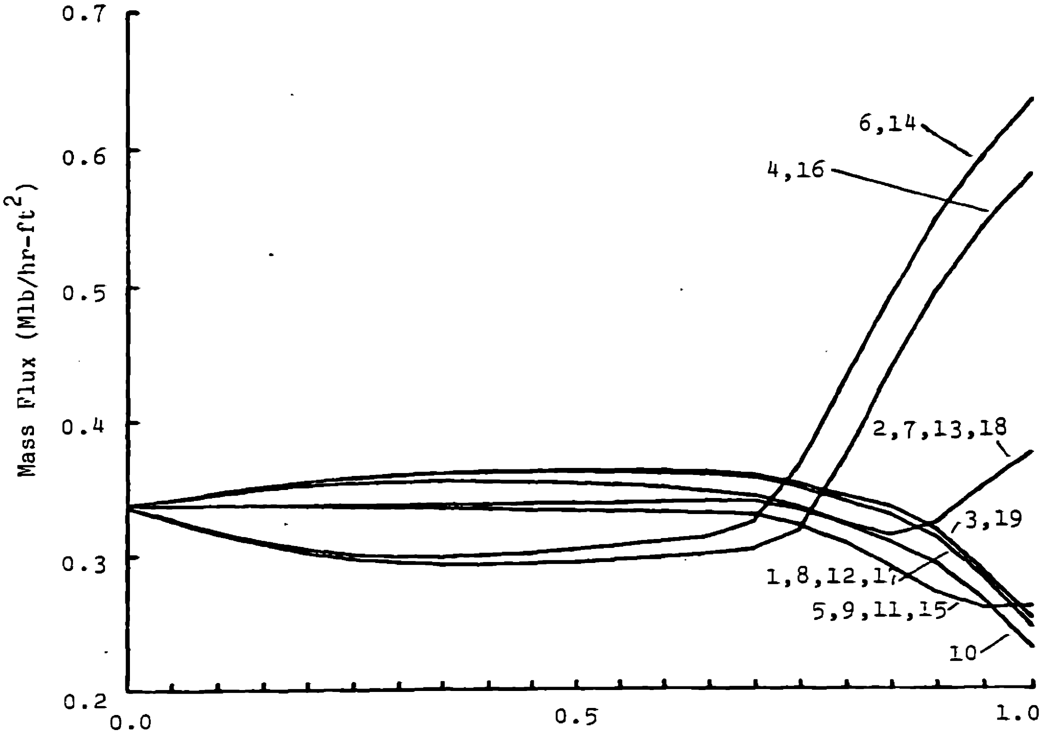


Figure IV-73

Axial Mass Flux Profiles

Nineteen Channel Bypass Case Two

$\overline{q}''$ = 0.0132 MBtu/hr-ft^2

$\overline{G}$ = 0.3369 Mlb/hr-ft^2

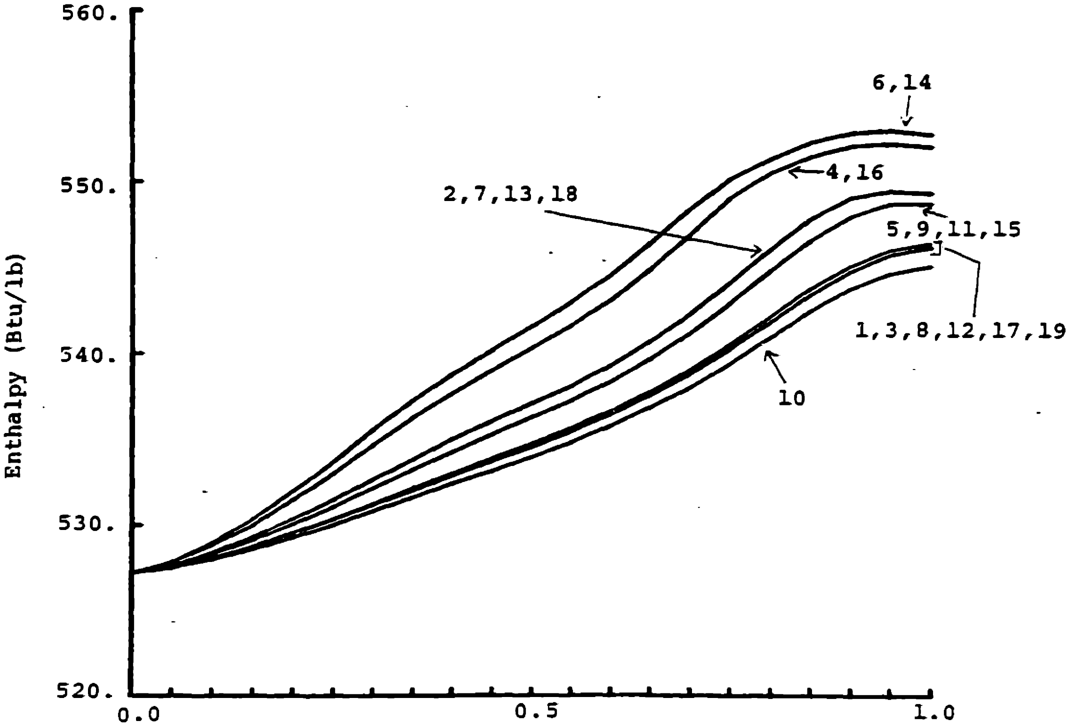


Figure IV-74

Axial Enthalpy Profiles

Nineteen Channel Bypass Case Two

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3369$ Mlb/hr-ft^2

becomes extremely large in N-N channels 6, 14, 4, and 16. The dip in channel 10 mass flux is about the same as in Fig. IV-69. Axial enthalpy profiles are shown in Fig. IV-74. The spread of axial enthalpy profiles is greater than seen for case one in Fig. IV-72. The old power distribution has a greater difference in enthalpy profiles because the old power distribution increases the power-to-flow ratio differences between the channel types (W-W, W-N and N-N). In general, the channels of case two behaved according to channel type. Near bypass channel outlets, flow is diverted from W-W channels to N-N channels via the W-N channels over the axial distance where boiling is present. COBRA-IIIC/MIT failures for case two were similar to those for case one. The gravitational pressure drop was at least 99% of the total pressure drop in channel 10 when failures occurred.

2.c.iv Nineteen Channel Bypass Case Three Predictions

Case three has a control rod inserted approximately halfway into channel ten and uses the old power apportionment method. COBRA-IIIC/MIT predictions are shown in Figs. IV-75, IV-76 and IV-77 for $\bar{q}'' = 0.0132$ MBtu/hr-ft^2 and $\bar{G} = 0.3650$ Mlb/hr-ft^2. Axial mass flux profiles are shown in Fig. IV-75. Mass flux in channel 10 drops when the channel flow area becomes larger near $x/L = 0.5$ and returns to the higher value in the top half of the bypass channel. Figure IV-76 shows axial enthalpy profiles. Channel 10 has a higher enthalpy relative to the other channels with the control rod inserted than it has without, as may be seen by comparing Figs. IV-76 and IV-74. Channel 10 has higher enthalpy because the mass flow rate is less over most of the axial length with the control rod inserted. Enthalpy profiles in channels other than 10 are nearly the same in Figs. IV-74 and IV-77, indicating that the effect of the control rod is not strongly felt by channels in the vicinity of 10 under the conditions analyzed. Figure IV-77 shows axial density profiles.

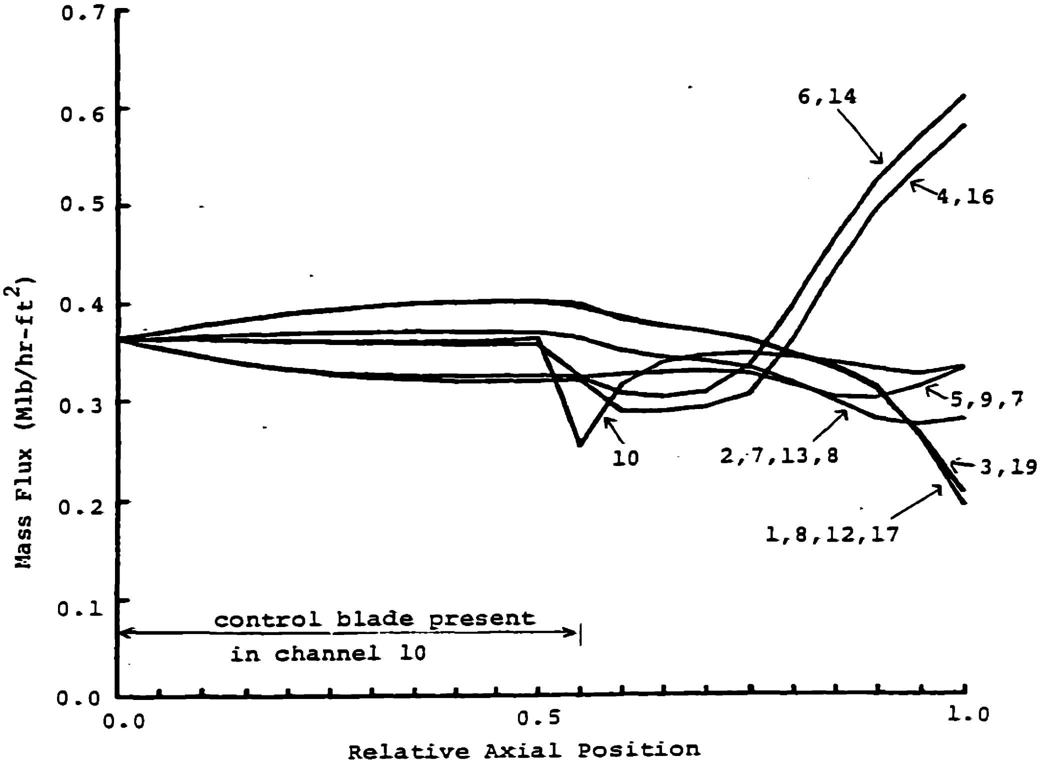


Figure IV-75

Axial Mass Flux Profiles

Four Channel Bypass Case Three

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.1668$ Mlb/hr-ft^2

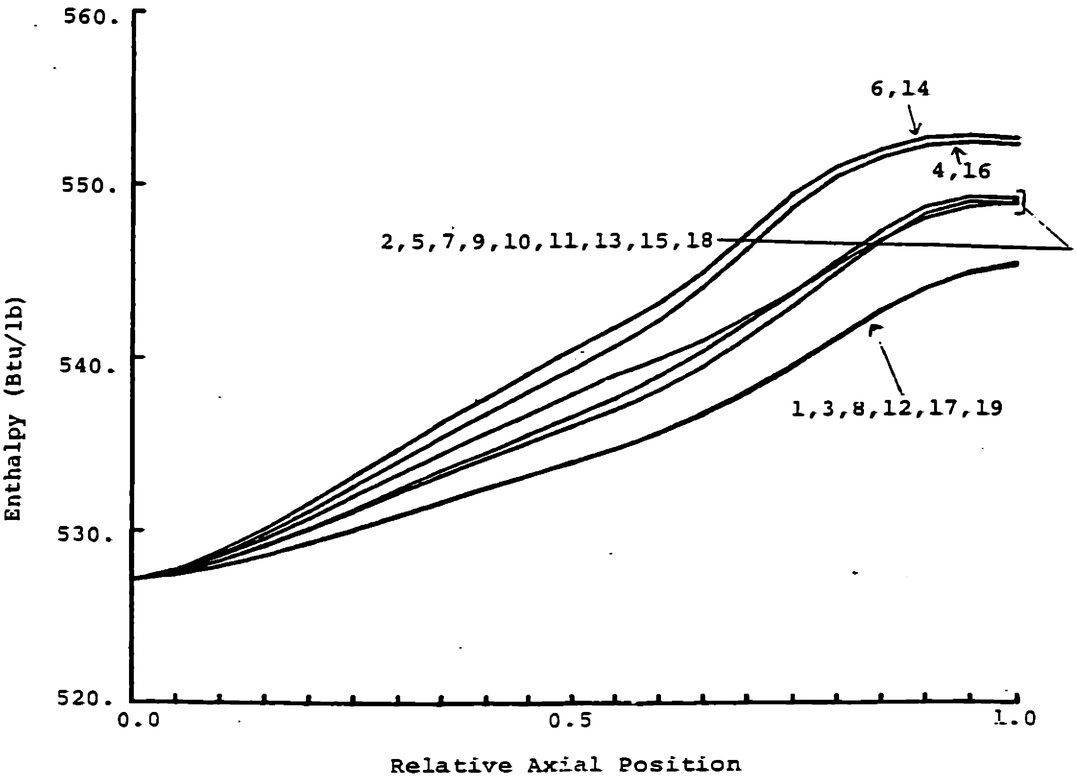


Figure IV-76

Axial Enthalpy Profiles

Nineteen Channel Bypass Case Three

$\overline{q}''$ = 0.0132 MBtu/hr-ft^2

$\overline{G}$ = 0.3650 Mlb/hr-ft^2

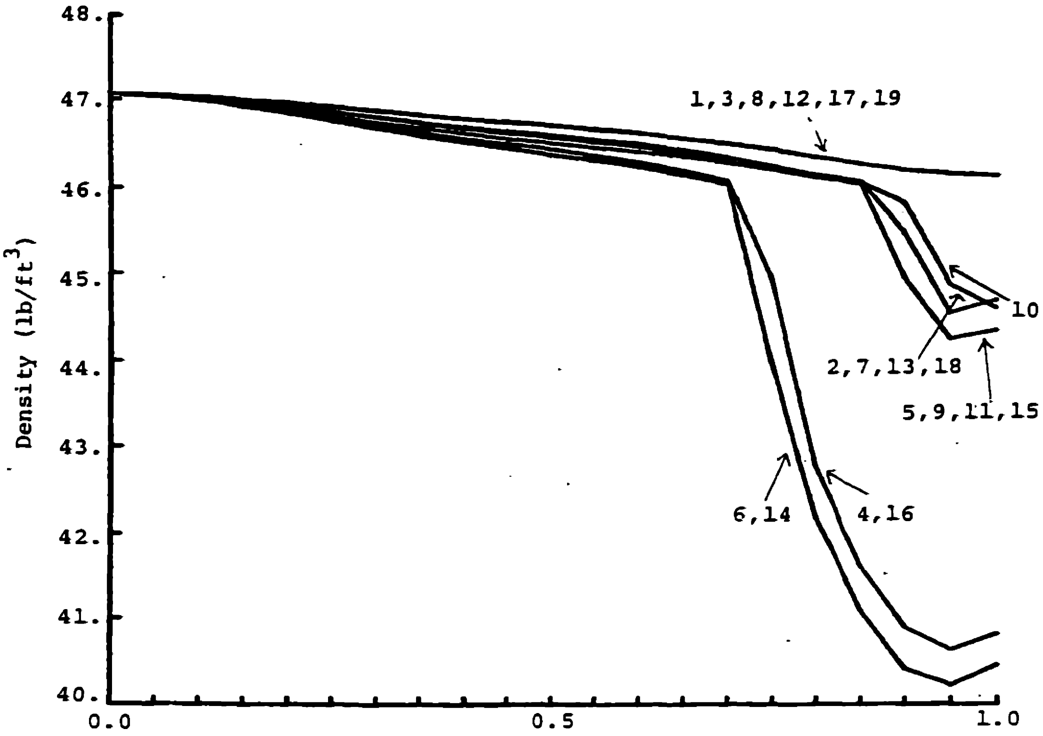


Figure IV-77

Axial Density Profile

Nineteen Channel Bypass Case Three

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3650$ Mlb/hr-ft^2

Boiling in channel 10 is indicated by a sharp dip in density. Case three failures occurred in the same way as for cases one and two.

2.d Summary of Nineteen Channel Case Results

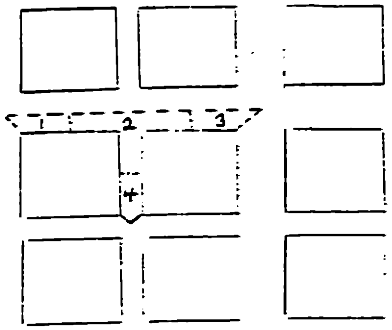
The nineteen channel case results are summarized as follows:

- COBRA-IIIC/MIT limits of applicability are similar for all four cases. Estimated full power and full flow conditions are outside the zone of COBRA-IIIC/MIT applicability.
- COBRA-IIIC/MIT failed when the gravitational component of pressure drop comprised at least 99% of the total pressure drop. This situation is conducive to recirculation and flow instability.
- Channels behaved according to bypass channel type (W-W, W-N and N-N). Near bypass channel outlets, flow was diverted from W-W channels to N-N channels via the W-N channels when boiling occurred.

3. Four Channel Test Case

3.a Description of Four Channel Test Case Geometry and Operating Conditions

The four channel bypass case geometry represents the bypass flow region associated with two assembly halves, as shown in Fig. IV-78. The four channel geometry includes all three bypass channel types, W-W, W-N and N-N. Channels 1 and 2 are 1/8 sections of W-W channels. Channel 3 is a 1/2 section of a W-N channel. Channel 4 is a 1/4 section of a N-N channel. No control rod is inserted. The radial power distribution is flat. The same inlet enthalpy and system pressure used for the nineteen channel bypass cases were also used for the four channel test case.



Channel	Area (in^2)	Wetted Perimeter (in)	Heated Perimeter (in)
1	1.090	2.719	2.719
2	3.195	10.880	10.880
3	1.090	2.719	2.719
4	1.052	5.438	5.438

Figure IV - 78

Four Channel Bypass Case Geometry

3.b Description of Modeling

The four channel bypass case was analyzed using COBRA-IIIC/MIT and THERMIT. All analyses used the new heat apportionment method. All analyses were made using the axial heat flux profile shown previously in Fig. IV-61. The four channel case was analyzed by COBRA-IIIC/MIT using the same options used for the nineteen channel bypass cases (see Table IV-10). Sixty axial nodes were again used for COBRA-IIIC/MIT analysis.

THERMIT represented the four channel case using the geometry shown in Fig. IV-79. THERMIT analysis used the options listed in Table IV-16. The axial length was divided into ten axial nodes to keep THERMIT computational time within reasonable limits. "Steady state" THERMIT predictions were obtained by running a transient calculation for two time periods. No transverse flow was calculated during the first time period. Then the calculation was restarted with reduced time step size and calculation of transverse flow. THERMIT analysis of the four channel case used boundary conditions similar to those used by COBRA. Inlet flows and outlet pressures were specified. Outlet pressures were equal. Inlet flows were equal. A pressure drop boundary condition would be a better approach. The physical situation has factors which are potential sources of hydrodynamic instability. Voiding is occurring near the outlets of parallel channels and the flow rate is low. The destabilizing factors are counterbalanced to some extent by the presence of flow restrictions near the channel inlets. However, this stabilizing factor was not accounted for in the THERMIT analysis since a pressure drop boundary condition was not used. A pressure drop boundary condition requires specification of loss coefficients for the inlet orifices.

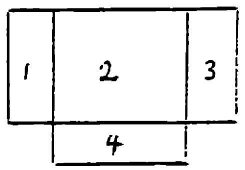


Figure IV-79

THERMIT Four Channel Bypass Case Representation

Table IV-16

THERMIT Options Used for Bypass Analysis

```
          Thermal-Hydraulic Options In Use

Pressure boundary condition at core exit
Velocity boundary condition at core inlet
Nigmatulin  boiling model
MIT  interfacial momentum exchange model
Constant property fuel pin model
Steady-state heat transfer calculation without CHF check
Constant heat flux boundary condition
Bias:    critical heat flux correlation
Transverse friction model - Gunter-Shaw
Transverse   velocity used in transverse momentum calculations
Transverse flow is not calculated
No mixing model
Gravitational constant          =   -9.81000
Transverse hydraulic diameter   =  0.30000E-01
Transverse friction multiplier  =  0.50000E+01


          Friction Model

Axial          f =  0.184*Re**-0.200
Transverse     f =  1.920*Re**-0.145
Grid spacer    K =  3.000*Re**-0.100


          Iteration Control Parameters

Dump indicator (0/1)(no/yes)       =    1
Max number of Newton iterations    =    3
Max number of inner iterations     =   20
Convergence crit. for newton iter= 0.10000E-06
Convergence crit. for inner iter = 0.10000E-06
```

3.c Analysis Case Results

3.c.i COBRA-IIIC/MIT Applicability Limits

COBRA-IIIC/MIT applicability limits were found for the four channels bypass case by varying power and flow rates. The most adverse combinations of power and flow for which COBRA four channel bypass case predictions were obtained are included in Fig. IV-80. COBRA results can be obtained over a wider range of conditions for the four channel case than for the nineteen channel cases. The greater geometrical simplicity of the four channel case is a factor which helps give COBRA the capability to analyze a wider range of conditions. Four channel and nineteen channel applicability limits become closer at low average heat fluxes. Table IV-17 lists four channel analyses made during determination of four channel case applicability limits. The particular four channel analyses contained in the limit line of Fig. IV-80 are described in Table IV-18.

3.c.ii Four Channel Bypass Case Predictions

Four channel bypass case predictions were obtained using COBRA-IIIC/MIT and THERMIT. COBRA-IIIC/MIT predictions are shown in Figs. IV-81 through IV-87. THERMIT predictions are shown in Figs. IV-88 and IV-89. COBRA predictions will be discussed first. Predictions for $\overline{G}$ = 0.3368 Mlb/hr-ft^2 and $\overline{q}"$ = 0.0132 MBtu/hr-ft^2 are shown in Figs. IV-81, IV-82 and IV-83. Axial mass flux profiles are shown in Fig. IV-81. The profiles are close to the predictions obtained for the nineteen channel bypass case one under the same $\overline{G}$ and $\overline{q}"$. Compare Fig. IV-81 with IV-65. The profiles reflect the behavior of different bypass channel types. Similarly, density and enthalpy profiles predicted for the four channel case match the predictions for different channel types obtained during nineteen channel bypass case one analysis. The similarity is seen by comparing Figs. IV-82 and IV-67 and Figs. IV-83 and IV-68. Thus, the four channel predictions

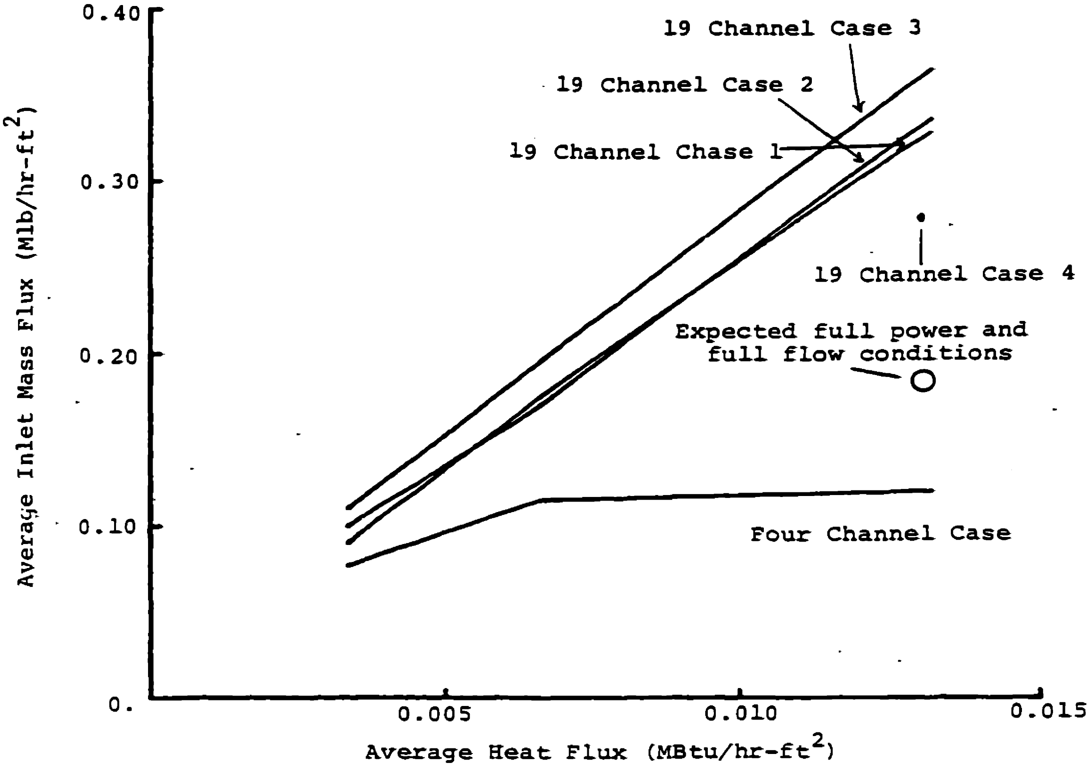


Figure IV-80

Mass Flux vs. Heat Flux

COBRA-IIIC/MIT Applicability Limits

Table IV-17

Four Channel Bypass Case

COBRA-IIIC/MIT Analysis Results

$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	Success ?	Iterations	X_{max}	α_{max}
0.0132	0.0900	no			
"	0.1000	no			
"	0.1050	no			
"	0.1100	no			
"	0.1150	no			
"	0.1200	yes	19	0.065	0.577
"	0.1400	yes	15		
"	0.1700	yes	11		
"	0.2000	yes	12		
"	0.3290	yes	12	0.005	0.088
"	0.3368	yes	11	0.004	0.078
0.0066	0.1000	no			
"	0.1100	no			
"	0.1150	yes	17	0.018	0.268
"	0.1200	yes	15		
"	0.1400	yes	13		
"	0.1800	yes	10		

Table IV-17 (continued)

Four Channel Bypass Case

COBRA-IIIC/MIT Analysis Results

$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	Success ?	Iterations	X_{max}	α_{max}
0.0033	0.0700	no			
"	0.0750	no			
"	0.0775	yes	18	0.005	0.088
"	0.0800	yes	15		
"	0.0900	yes	9		

Table IV-18

Four Channel Bypass Case

Limits of COBRA-IIIC/MIT Applicability

$\bar{q}''$ (MBtu/hr-ft^2)	$\bar{G}$ (Mlb/hr-ft^2)	X_{max}	α_{max}
0.0132	0.1200	0.065	0.577
0.0066	0.1150	0.018	0.268
0.0033	0.0775	0.005	0.088

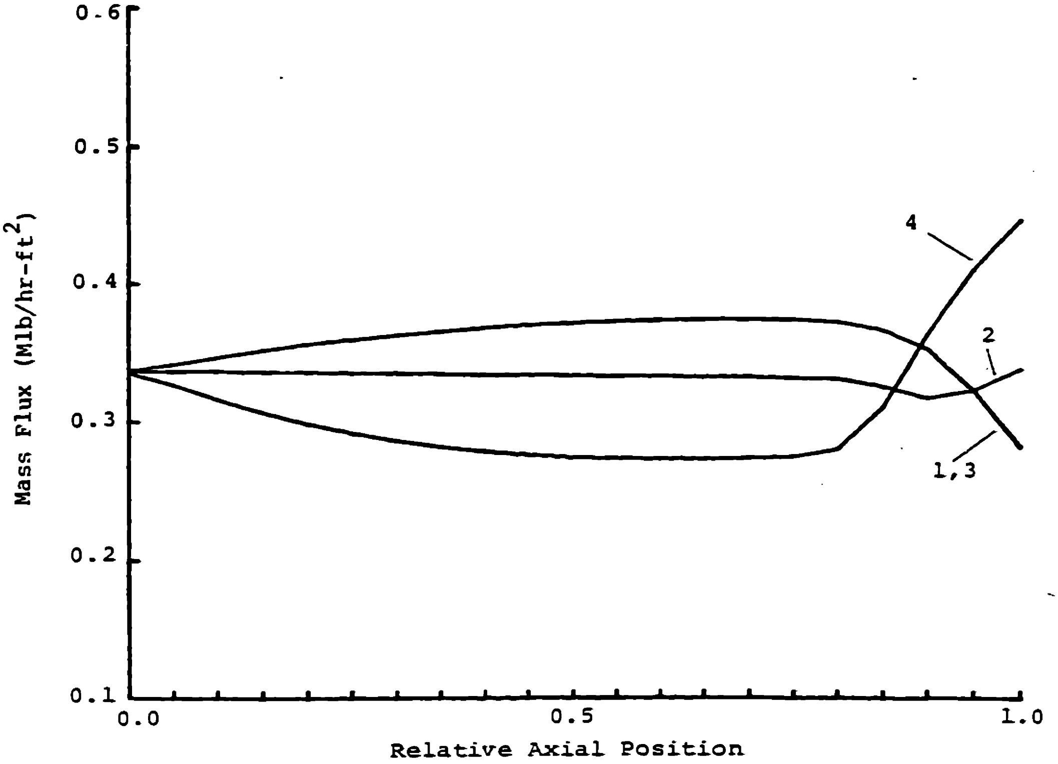


Figure IV-81

Axial Mass Flux Profiles

Four Channel Bypass Case
$\overline{q}'' = 0.0132$ MBtu/hr-ft^2
$\overline{G} = 0.3368$ Mlb/hr-ft^2

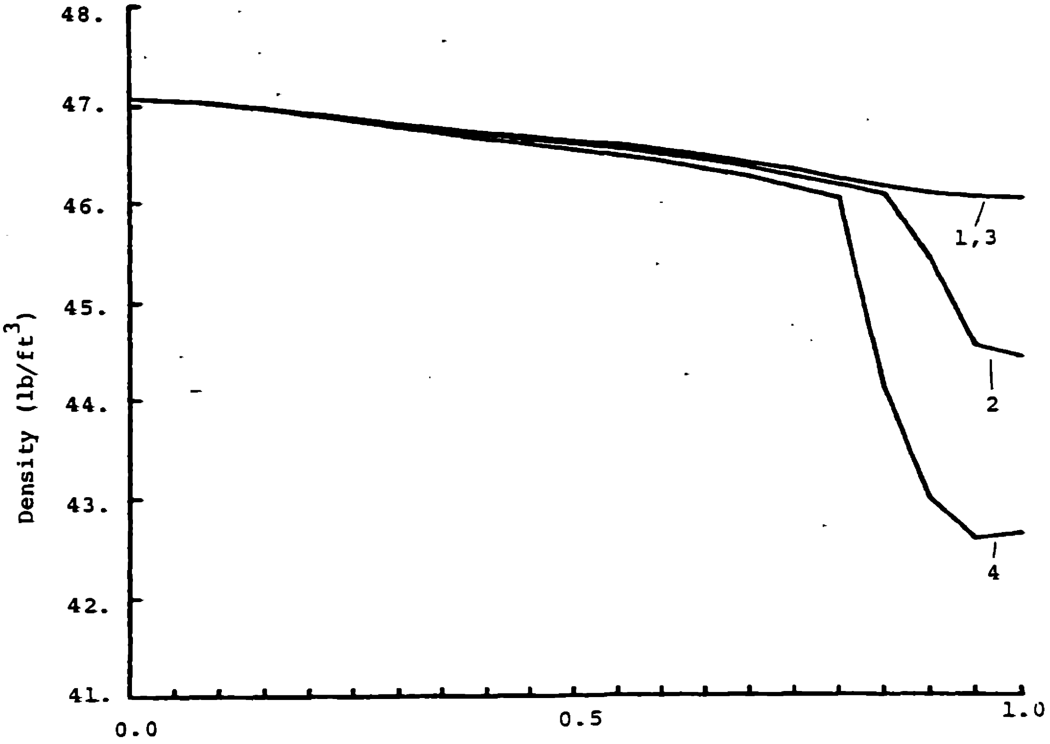


Figure IV-82

Axial Density Profiles

Four Channel Bypass Case

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3368$ Mlb/hr-ft^2

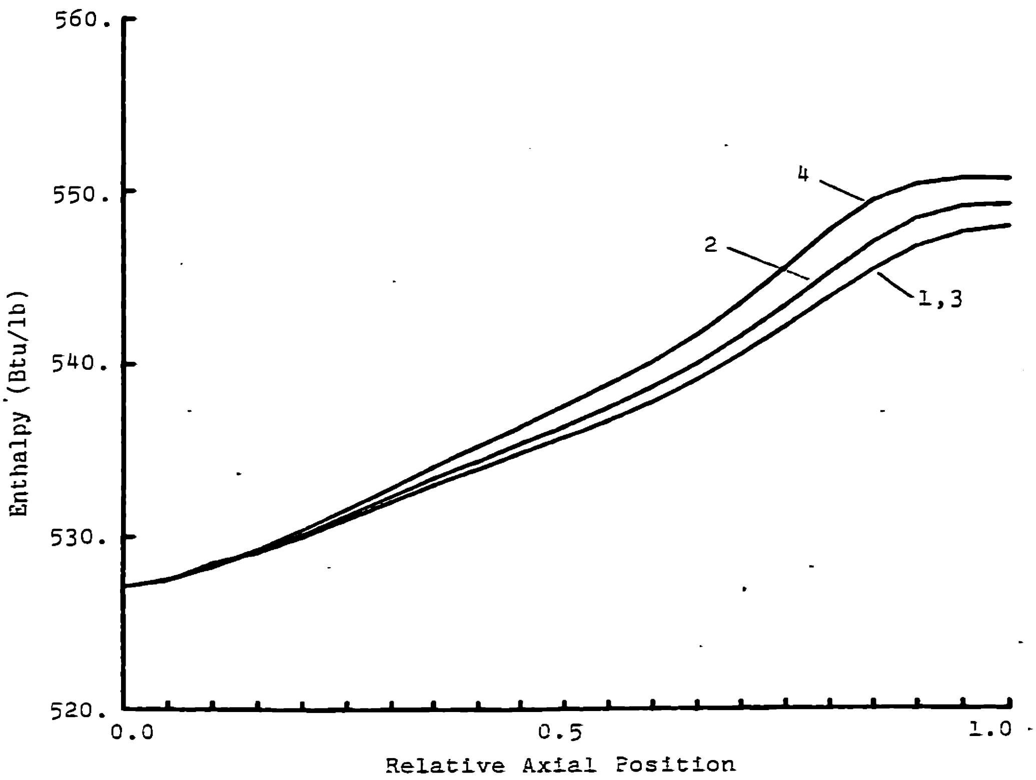


Figure IV-83

Axial Enthalpy Profiles

Four Channel Bypass Case

$\overline{q}'' = 0.0132$ MBtu/hr-ft^2

$\overline{G} = 0.3368$ Mlb/hr-ft^2

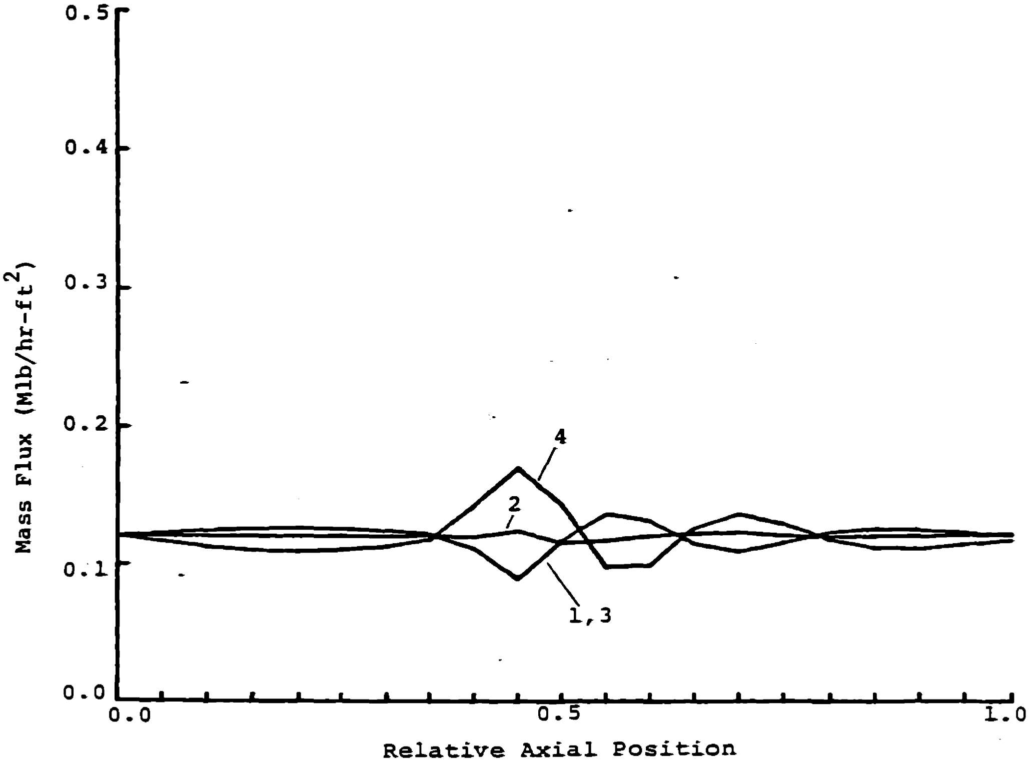


Figure IV-84

Axial Mass Flux Profiles

Four Channel Bypass Case
$\overline{q}'' = 0.0132$ MBtu/hr-ft^2
$\overline{G} = 0.1200$ Mlb/hr-ft^2

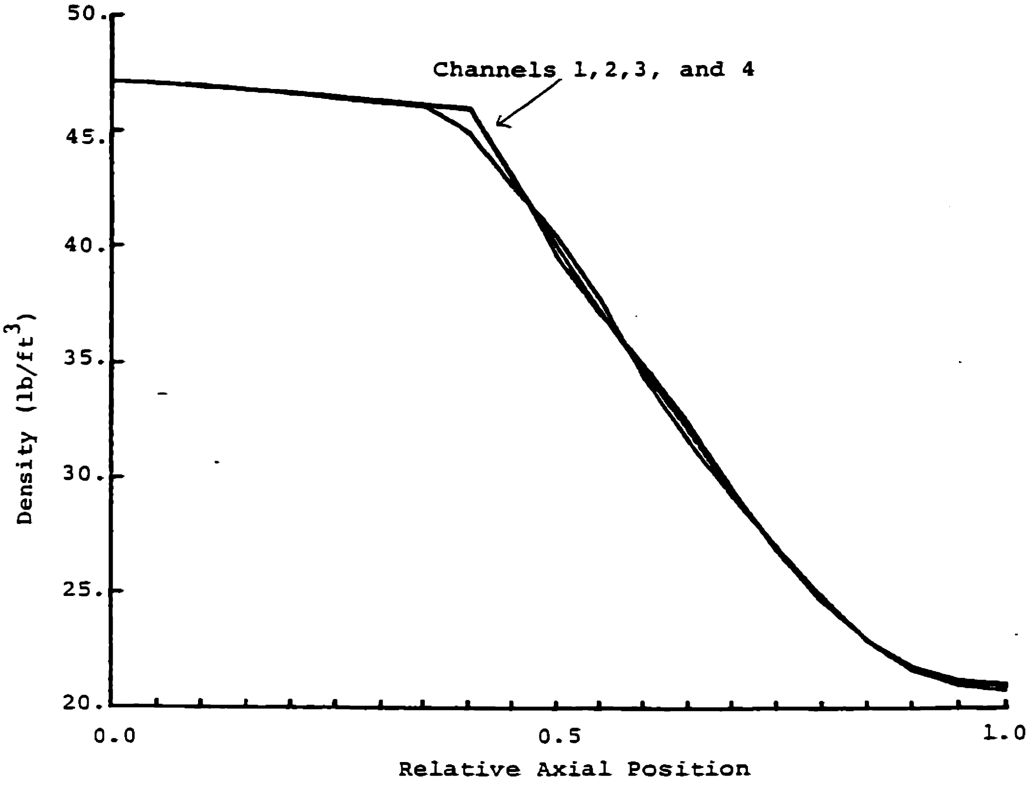


Figure IV-85

Axial Density Profiles

Four Channel Bypass Case
$\overline{q}''$ = 0.0132 MBtu/hr-ft^2
$\overline{G}$ = 0.1200 Mlb/hr-ft^2

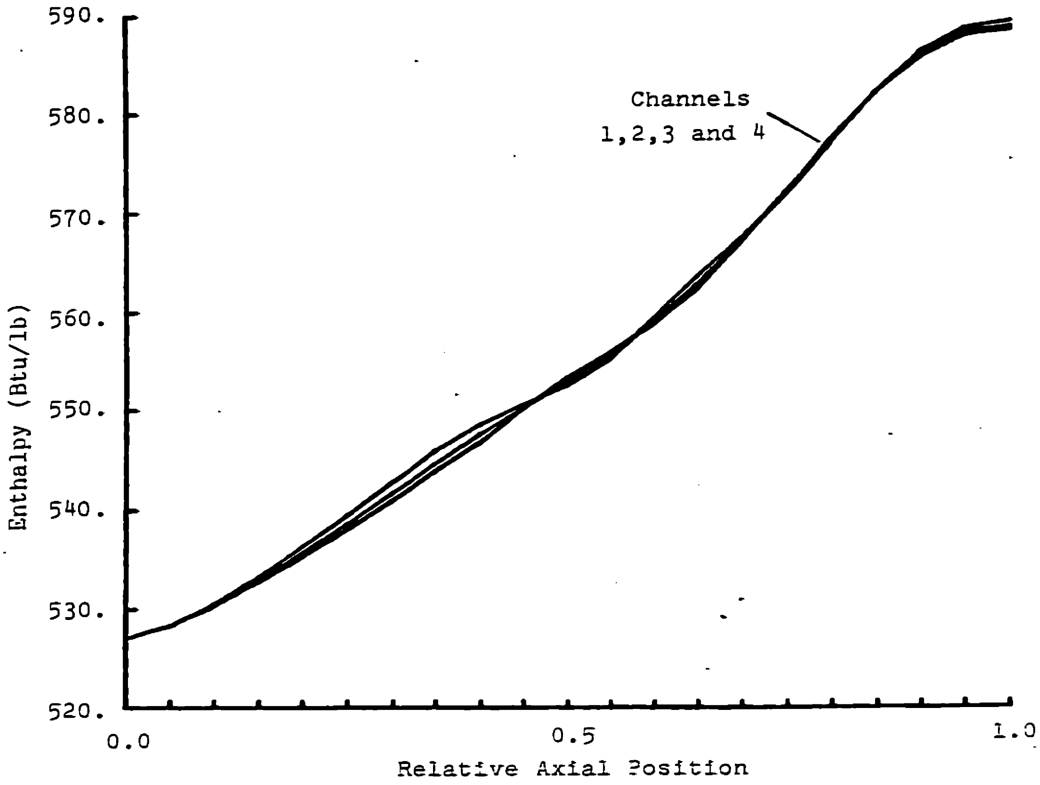


Figure IV-36

Axial Enthalpy Profiles
Four Channel Bypass Case
$\bar{q}'' = 0.0132$ MBtu/hr-ft^2
$\bar{G} = 0.1200$ Mlb/hr-ft^2

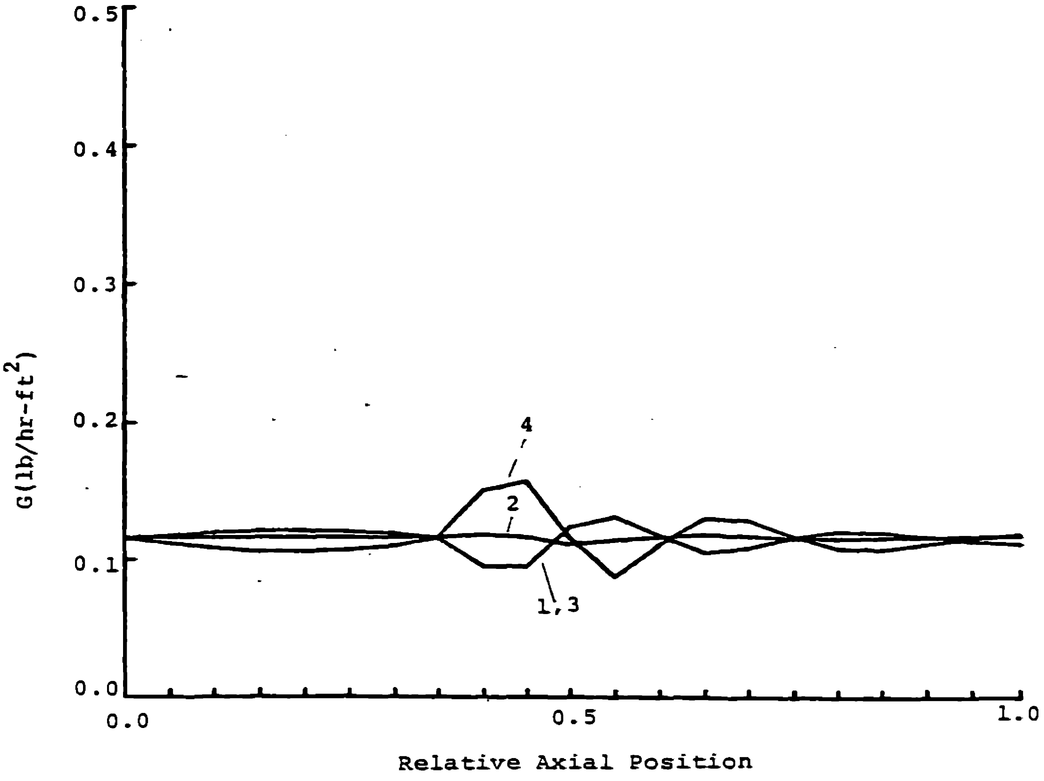


Figure IV-87

Axial Mass Flux Profiles

Four Channel Bypass Case
$\overline{q}'' = 0.0132$ MBtu/hr-ft^2
$\overline{G} = 0.1150$ Mlb/hr-ft^2

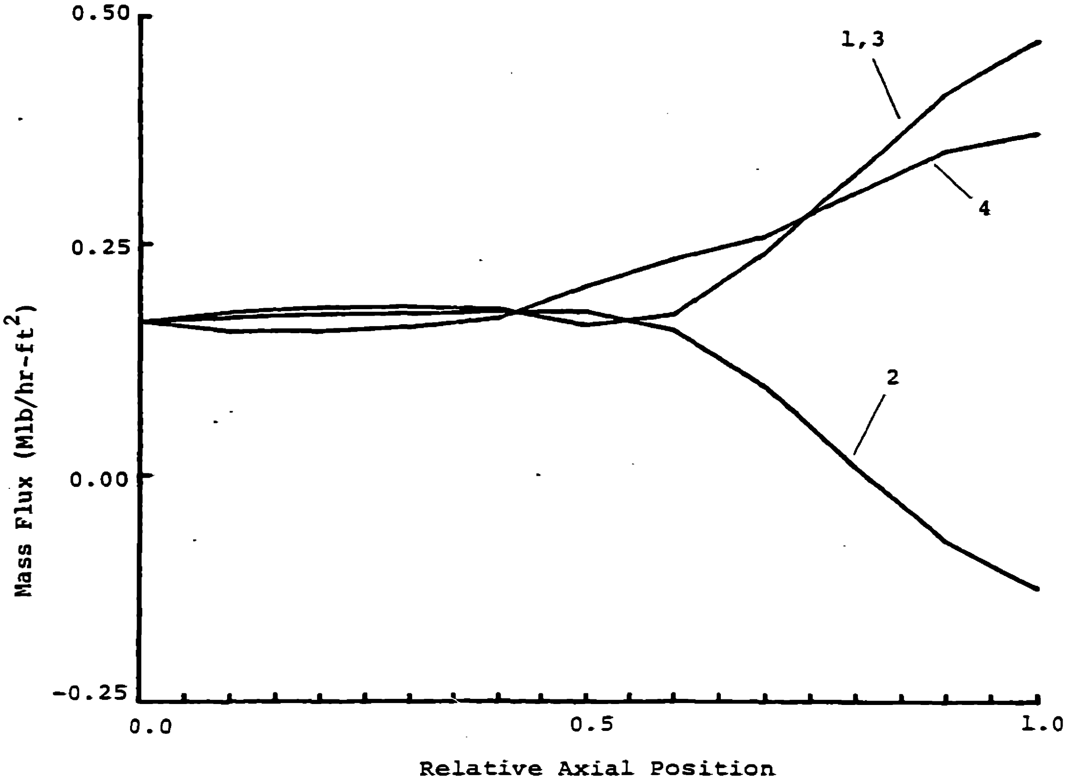


Figure IV-88

Axial Mass Flux Profiles

Four Channel Bypass Case
THERMIT Predictions

$\bar{q}''$ = 0.0132 MBtu/hr-ft^2
$\bar{G}$ = 0.1668 Mlb/hr-ft^2

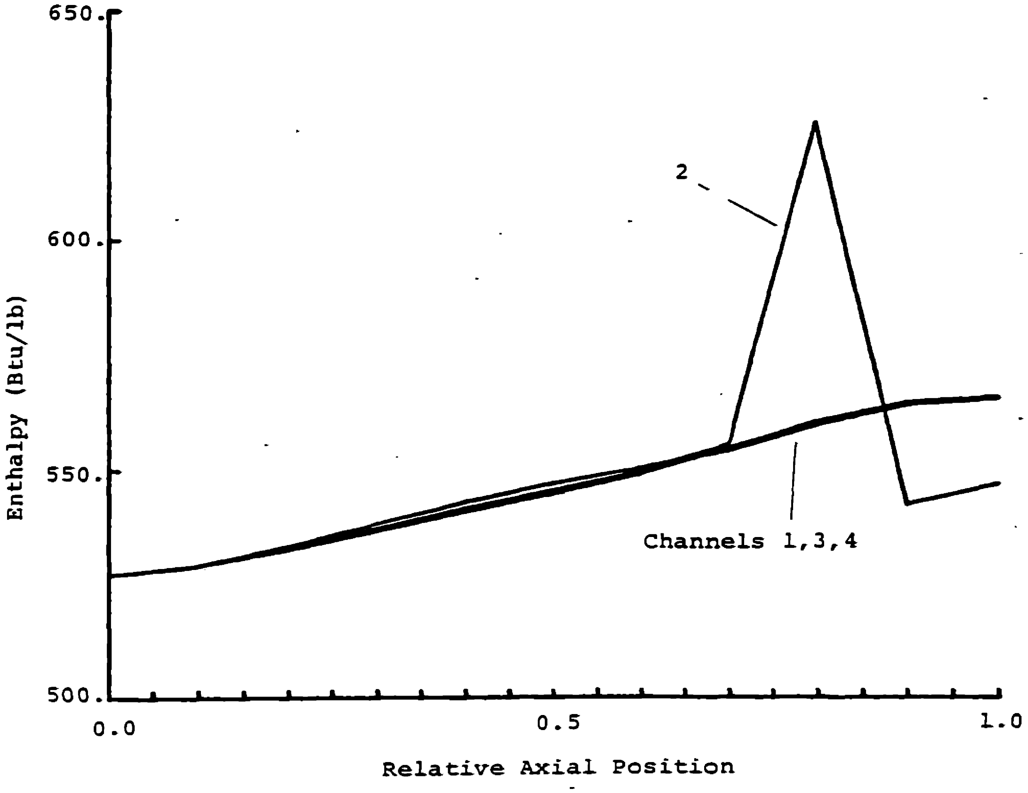


Figure IV-89

Axial Enthalpy Profiles
Four Channel Bypass Case
THERMIT Predictions
$\overline{q}'' = 0.0132$ MBtu/hr-ft^2
$\overline{G} = 0.1668$ Mlb/hr-ft^2

are similar to the nineteen channel case one analysis predictions for $\overline{G}$ = 0.3368 Mlb/hr-ft^2 and $\overline{q}''$ = 0.0132 MBtu/hr-ft^2.

COBRA four channel bypass case predictions for $\overline{G}$ = .1200 Mlb/hr-ft^2, the lowest flow rate for which predictions could be obtained with $\overline{q}''$ = 0.0132 MBtu/hr-ft^2, are shown in Figs. IV-84, IV-85 and IV-86. Axial mass flux profiles are shown in Fig. IV-84. These profiles are much different than those observed in other COBRA predictions. The start of boiling near x/L = 0.4 produces flow oscillations that damp out by the end of the channels. The axial density and enthalpy profiles, shown in Figs. IV-85 and IV-86 are also much different than those observed in other COBRA predictions. The density and enthalpy predictions indicate that the channels are thermally communicating much more than previously observed in other bypass analysis predictions. The oscillating crossflow between channels 1 and 3 and channel 4 via channel 2 implied by the axial mass flux profiles shown in Fig. IV-84 is providing mixing between channels. Figure IV-87 shows axial mass flux profiles for $\overline{G}$ = 0.1150 Mlb/hr-ft^2, a low rate at which COBRA failed to converge. The profiles are similar to those seen in Fig. IV-84 for $\overline{G}$ = 0.1200 Mlb/hr-ft^2. The oscillation of flow along the axial direction is evidence of an unstable situation which is causing COBRA to fail. COBRA handles some degree of instability for the four channel geometry which it may not be able to tolerate for the nineteen channel geometry.

THERMIT predictions for the four channel case were obtained by performing transient calculations, as described earlier. When THERMIT calculations were stopped, the energy error was going from positive to negative, indicating a buildup of energy within the bypass channels, as would be expected when a stagnant pocket of vapor is building up within the four channels. THERMIT predictions for the four channel bypass case are shown in Figs. IV-88 and IV-89 for

$\bar{q}'' = 0.0132$ MBtu/hr-ft^2 and $\bar{G} = 0.1668$ Mlb/hr-ft^2. This power-flow combination is close to the estimated full power conditions. Lack of stability was seen in residual variations of THERMIT predictions with time. The transient THERMIT calculations were stopped while the solution was still varying, so the predictions shown in the figures are not actually steady state predictions. Axial mass flux profiles are shown in Fig. IV-88. Flow becomes negative in the upper half of channel 2. Liquid travels downward and vapor travels upward, resulting in a negative net mass flux in channel 2. Axial enthalpy profiles shown in Fig. IV-89 indicate a buildup of vapor near $x/L = 0.75$ in channel 2. Since the THERMIT predictions shown in the figures are not actually steady state predictions, they have limited usefulness for comparison with COBRA-IIIC/MIT results. However, it is useful to compare general prediction trends. Comparison of Figs. IV-88 and IV-84 and Figs. IV-89 and IV-85 allows a rough comparison between THERMIT and COBRA predictions. The comparison is rough because different average mass fluxes are used in the THERMIT and COBRA predictions being compared. Similar general trends in THERMIT and COBRA predictions are seen in the predictions up to near $x/L = 0.5$. In the upper half, beyond $x/L = 0.5$, where THERMIT predictions show recirculation, there is no similarity between THERMIT and COBRA predictions.

3.d Summary of Four Channel Case Results

- COBRA-IIIC/MIT had a wider range of applicability for the four channel case than for any of the nineteen channel cases. However, predictions in the extended range of applicability showed signs of instability which were not assessed using THERMIT predictions since actual steady state THERMIT predictions within the extended range were not available.

- COBRA-IIIC/MIT four channel predictions were similar to nineteen channel case one predictions within the range of applicability for nineteen channels.
- THERMIT predictions in the vicinity of estimated full power conditions showed recirculation, oscillations, and countercurrent flow. A pressure drop boundary condition would be better than the boundary conditions used for THERMIT analysis.

4. Summary of Bypass Analysis Results and Recommendations for Future Work

The results of bypass analysis and recommendations for future work are summarized in the following:

- COBRA-IIIC/MIT cannot analyze bypass flow for some power and flow combinations.
- Estimated full power and full flow conditions are outside the COBRA-IIIC/MIT zone of applicability. Plugging of holes in the core plate has reduced the bypass flow through the E.I. Hatch reactor. Carlson and Gott analyses did not take into account the reduced bypass flow. Other operational conditions are likely to also be outside the zone of COBRA-IIIC/MIT applicability.
- THERMIT predictions indicate a possibility of some recirculation under full power and full flow conditions. THERMIT analysis should be performed using a pressure drop boundary condition rather than specified inlet flows and outlet pressures. Also, the variable axial nodalization capability of THERMIT should be used to give finer axial nodalization to the upper portion of the bypass channels and coarser axial nodalization to the lower portion. The upper portion of bypass channels can have boiling and consequently, large changes in density and large

crossflows. Variation of axial node size allows efficient allocation of compuational resources.

The first two items will be discussed using Fig. IV-90 which contains one COBRA-IIIC/MIT limit of applicability line and a point indicating approximate full power and full flow conditions. The applicability limit line is selected where it is expected to be for analysis. The nineteen channel case three limit line is selected as the COBRA-IIIC/MIT limit line because a realistic case can have some rods inserted. The other three nineteen channel case gave no consideration to rod insertion and thus had larger zones of COBRA-IIIC/MIT applicability. The COBRA-IIIC/MIT four channel case limit of applicability line is not used in the figure because the four channel predictions in the extended zone of applicability looked questionable. The full power and full flow conditions are in the zone where COBRA-IIIC/MIT fails. Since expected bypass conditions are in the zone where COBRA-IIIC/MIT fails, another code having greater capabilities is needed. THERMIT is a code which offers greater capabilities.

THERMIT predictions were obtained using specified inlet velocities and outlet pressures as boundary conditions. During the attempt to obtain steady state predictions using a transient calculation, variations in predictions indicated hydrodynamic instability. For the purposes of better representation of the physical situation, which includes taking into account stabilizing factors, a pressure drop boundary condition should be used by THERMIT. Orifices at the inlets of the bypass channels should be represented in THERMIT analysis.

In summary, a code such as THERMIT, having the capability to use a pressure drop boundary condition, is needed for bypass analysis of the E.I. Hatch Unit I reactor.

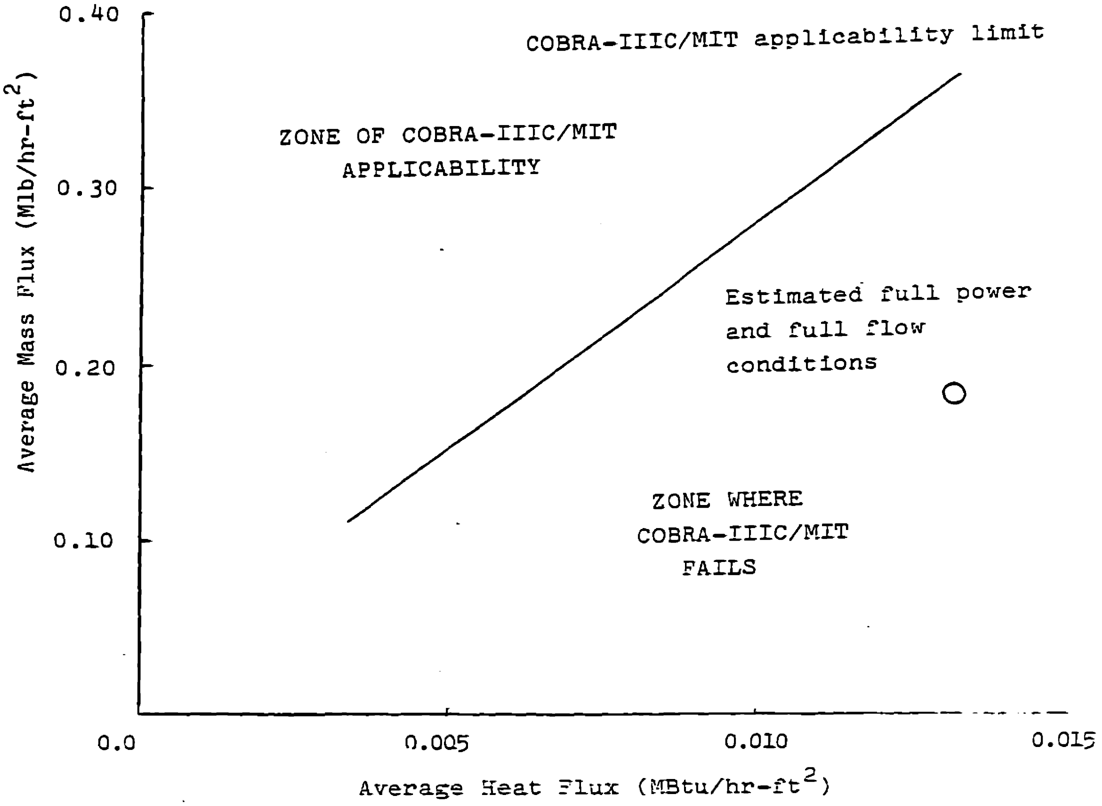


Figure IV-90

Mass Flux vs. Heat Flux
COBRA-IIIC/MIT Applicability Limit

E. 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 make 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.
- CISE-4 MCPR predictions are consistent 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.
- COBRA-IIIC/MIT limits of applicability for BWR bypass analysis of the E.I. Hatch reactor have been obtained in terms of power and flow. Expected full power and full flow conditions are outside the zone of COBRA-IIIC/MIT applicability.
- THERMIT should be used with a pressure drop boundary condition for bypass analysis. THERMIT's variable

axial nodalization feature should be used to give finer axial nodalization to the upper portion of bypass channels.

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 CHRR 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.

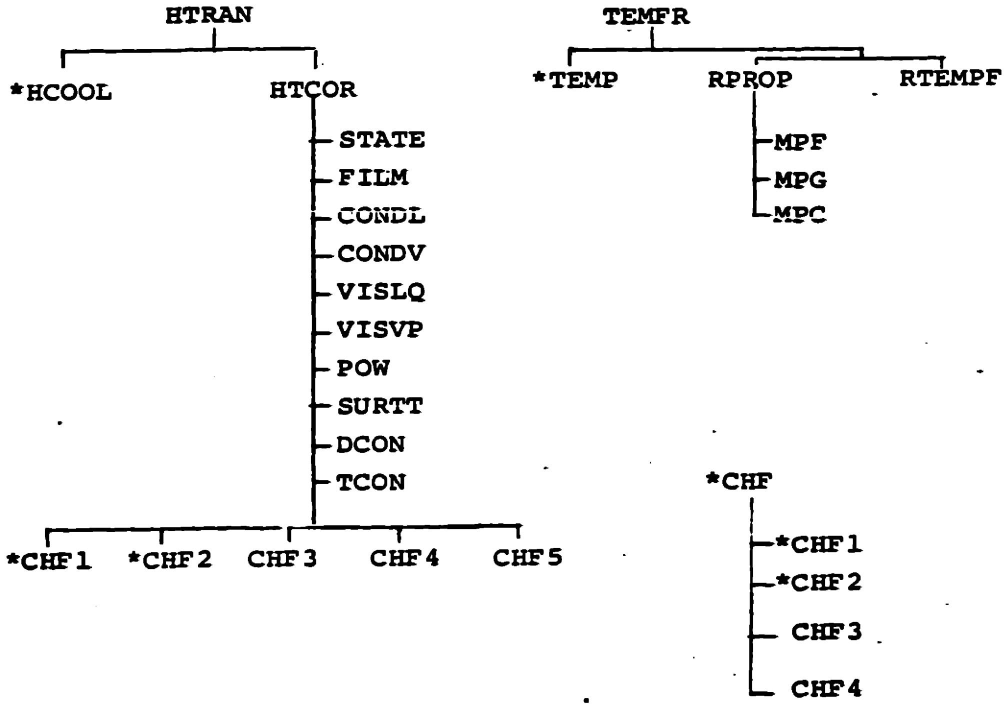
The improvements have been tested individually and during application of the improved code to transient test cases. Testing mainly involved comparison of the predictions of different modeling options and in some instances, comparison of predictions with experimental measurements. The testing results 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.

The improved version of COBRA-IIIC/MIT was applied to BWR bypass analysis. Two small test cases were analyzed to gain an understanding of how to analyze bypass flow in the E.I. Hatch Unit I reactor. COBRA-IIIC/MIT was used to analyze a nineteen channel test case geometry. COBRA-IIIC/MIT and THERMIT, a code with greater capabilities, were used to analyze a four channel test case geometry. COBRA-IIIC/MIT was limited in the power and bypass flow combinations it could analyze. Estimated full power and full flow conditions were found to be outside the zone of COBRA-IIIC/MIT applicability. Transient THERMIT analysis was performed in an attempt to obtain steady state predictions. Oscillation of predictions during this analysis indicated that THERMIT bypass analysis should be performed using a pressure drop boundary condition and modeling of flow restrictions at bypass channel inlets, rather than using only inlet flow and outlet pressure boundary conditions.

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.

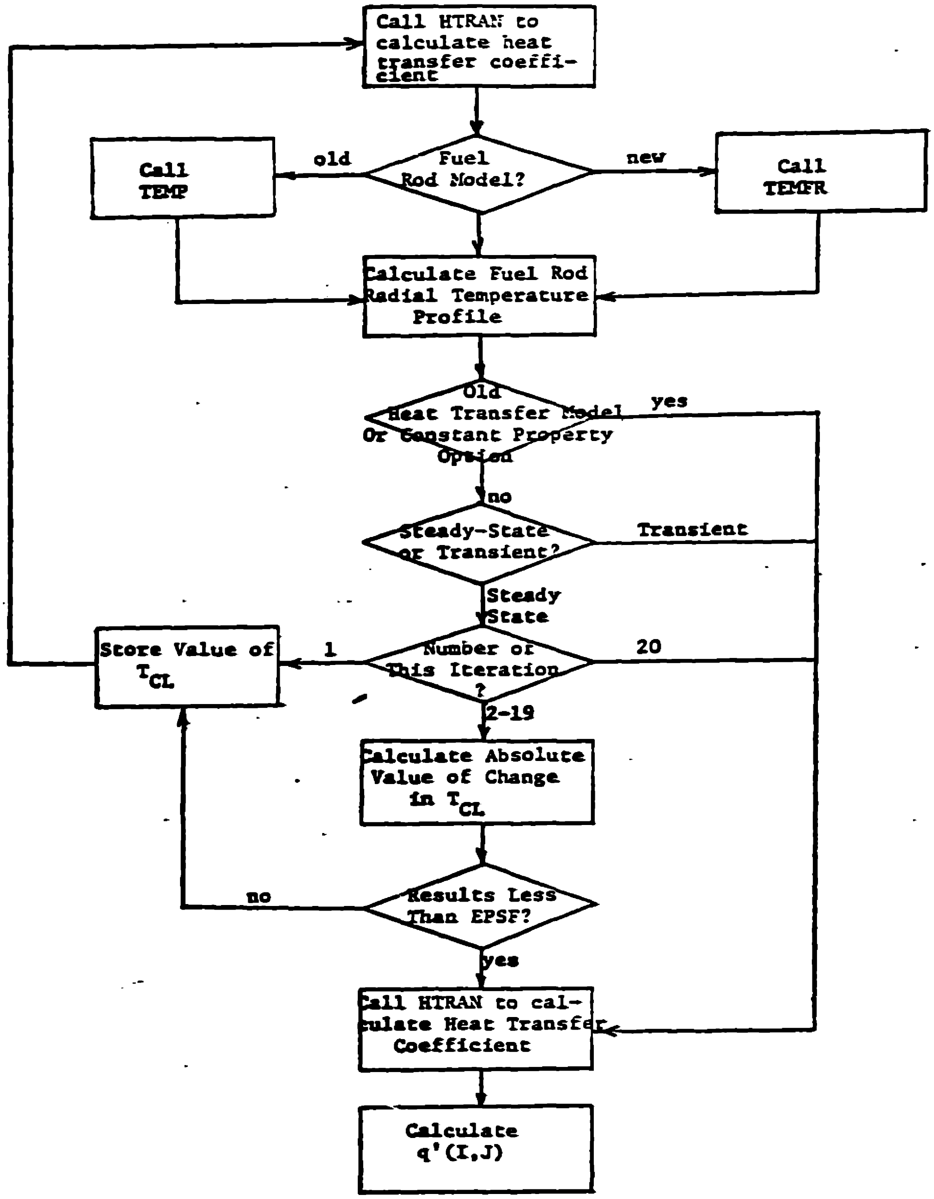


Figure C-1

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, determines critical heat flux when IHTM = 2.
CHF4,
or CHF5

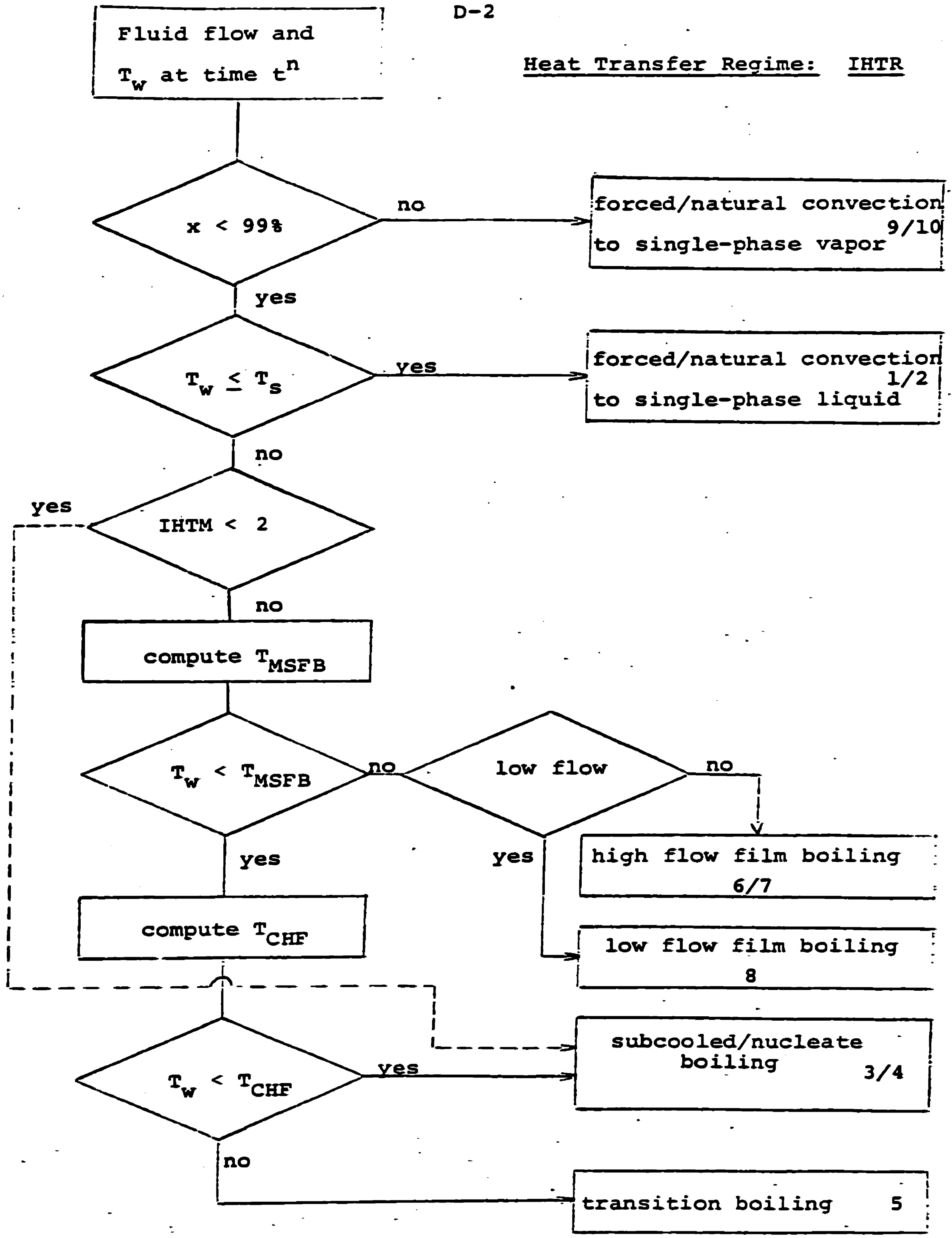

Heat Transfer Regime: IHTR
Fluid flow and
T_w at time t^n
$x < 99\%$
no
forced/natural convection to single-phase vapor 9/10
yes
$T_w \leq T_s$
yes
forced/natural convection to single-phase liquid 1/2
no
IHTM < 2
yes
no
compute T_{MSFB}
$T_w < T_{MSFB}$
no
low flow
no
high flow film boiling 6/7
yes
low flow film boiling 8
yes
compute T_{CHF}
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 $Re = \frac{GD}{\mu}$ $Pr = \frac{\mu C_p}{k}$	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	$q'' = h_{FC}(T_w - T_f) + h_{NB}(T_w - T_s)$ $h_{FC} = 0.023\frac{k_f}{D}Re_f^{0.8}Pr_f^{0.4}F$ $h_{NB} = 0.00122S\left[\frac{k_f C_{p_f}}{\sigma}\right]^{0.5} Pr_f^{-0.29}$ $* \rho_f^{0.25}(P_w - P)^{0.75}$ $* [\frac{C_{p_f}(T_w - T_s)\rho_f}{h_{fg}\rho_g}]^{0.24}$	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 $0.5\frac{\text{MBTU}}{\text{hr-ft}^2}$

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 $\left(\dfrac{\rho^2 g\beta[T_w - T]}{\mu^2}\right)$	-
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

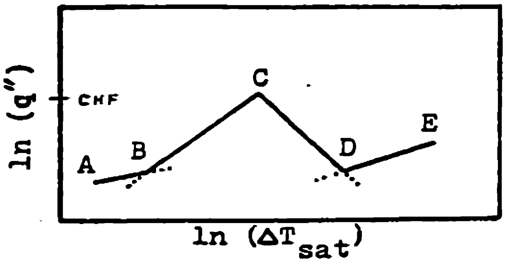
Subscripts

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.

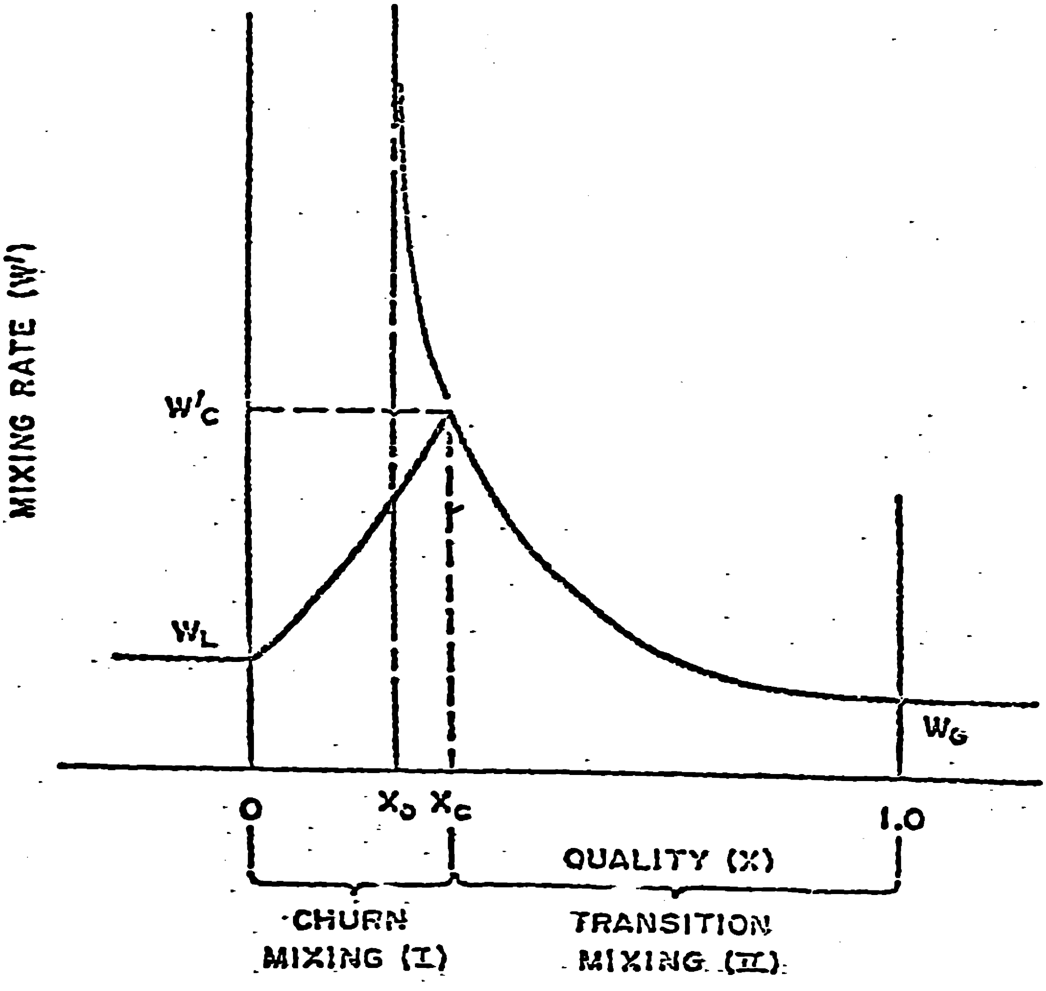

Figure G.1 (Fig. 4 of Ref. 17)

Plot of Mixing Model Showing Variation with Quality

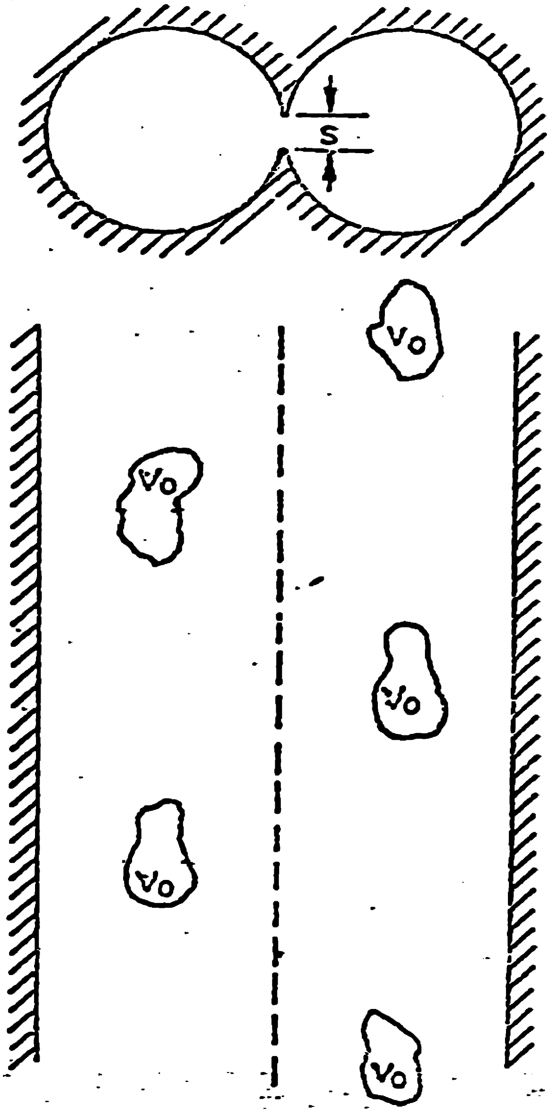

Figure G-2 (Based on Figure 2 of Ref. 17)

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_I, 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 ($lbm/hr-ft^2$)
L = channel length (ft)
T = temperature (°F)
W = mixing rate (lbm/hr-ft)
μ = viscosity (lbm/hr-ft)
ρ = density ($lbm/hr-ft^3$)
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.

Table H-2 (cont.)

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 H-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 (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 $b = 168(P_{CR}/P - 1)^{0.4}G/10^6D_e^{1.4}$	
Biasi/Void-CHF	16	For $\lvert G\rvert \geq 10^6 \text{lb hr}^{-1}\text{ft}^{-2}$ 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 $4.4 \text{ lb hr}^{-1}\text{ft}^{-2}$ $D = 0.01$ 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 countercurrent flow conditions in Freon. Extension to water is justified on the basis of the proven wide range of applicability of the Zuber correlation.

Table H-2 (cont.)

Correlation	Ref.	Equation	Range of Data Base
Biasi/Void-CHF (cont.)		For $10^6 > \|G\| > 2 * 10^4$ 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) $q''_{CHF} = (1 - \alpha)0.9\pi 24^{-1} H_{fg}\rho_g^{0.5} * [gg_c\sigma(\rho_f - \rho_g)]^{0.25}$ For $2 * 10^4 \geq \|G\| \geq 0$ 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 $\|G\| \geq 2 * 10^5$ 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
$<x_e>$	Bundle average quality	-
$<x_e>_c$	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:

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

where

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

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)

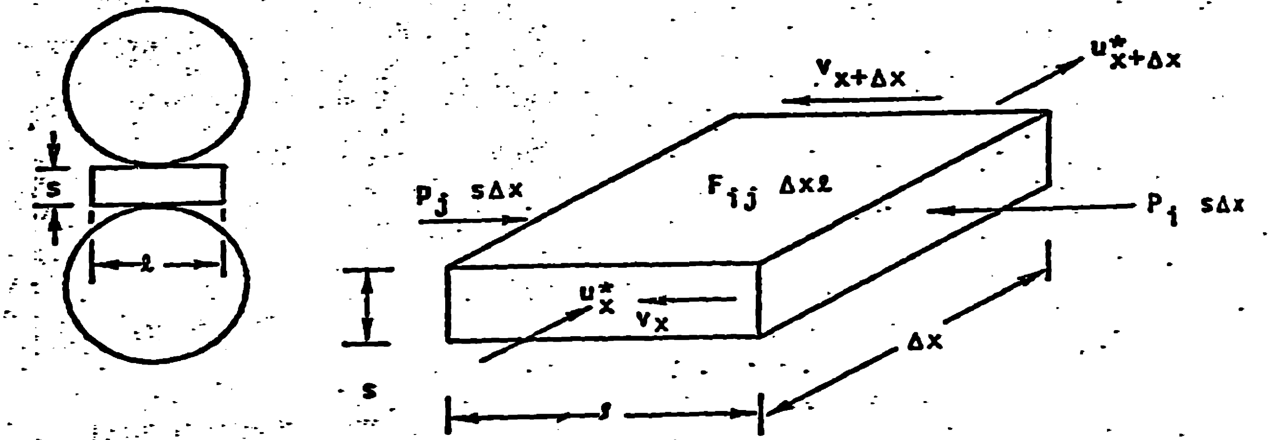

Figure I-1

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.

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

where

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

and

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

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

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.

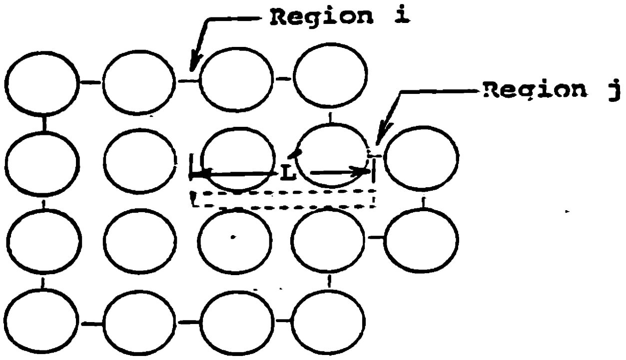

Figure I-2

Transverse Momentum Control Volume for Weisman Approach

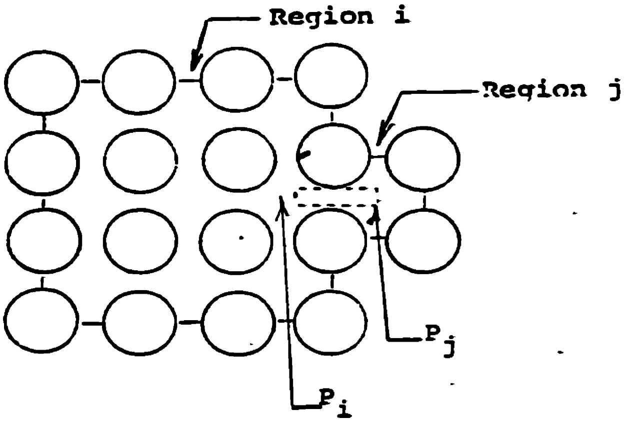

Figure I-3

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

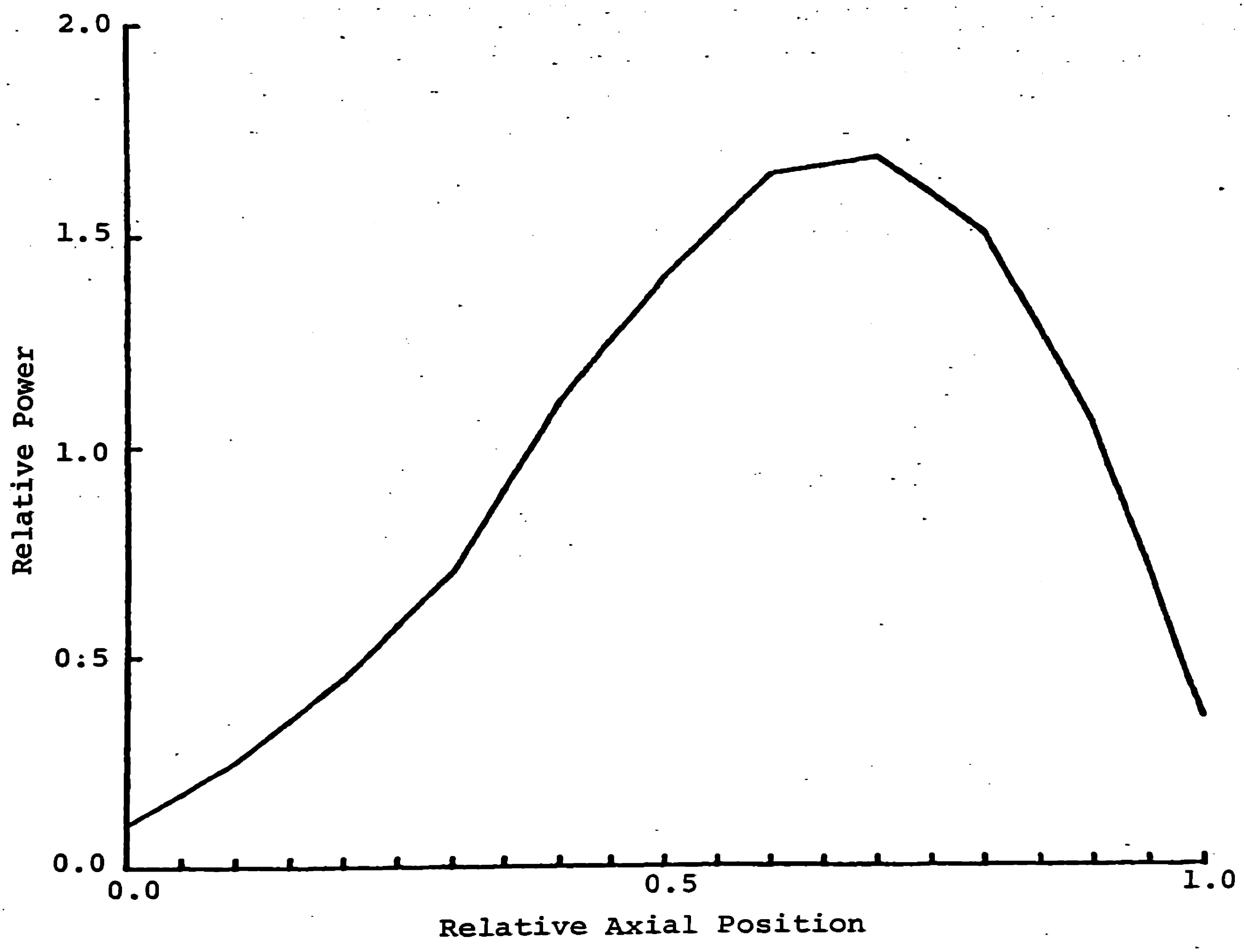

Figure K-1

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.

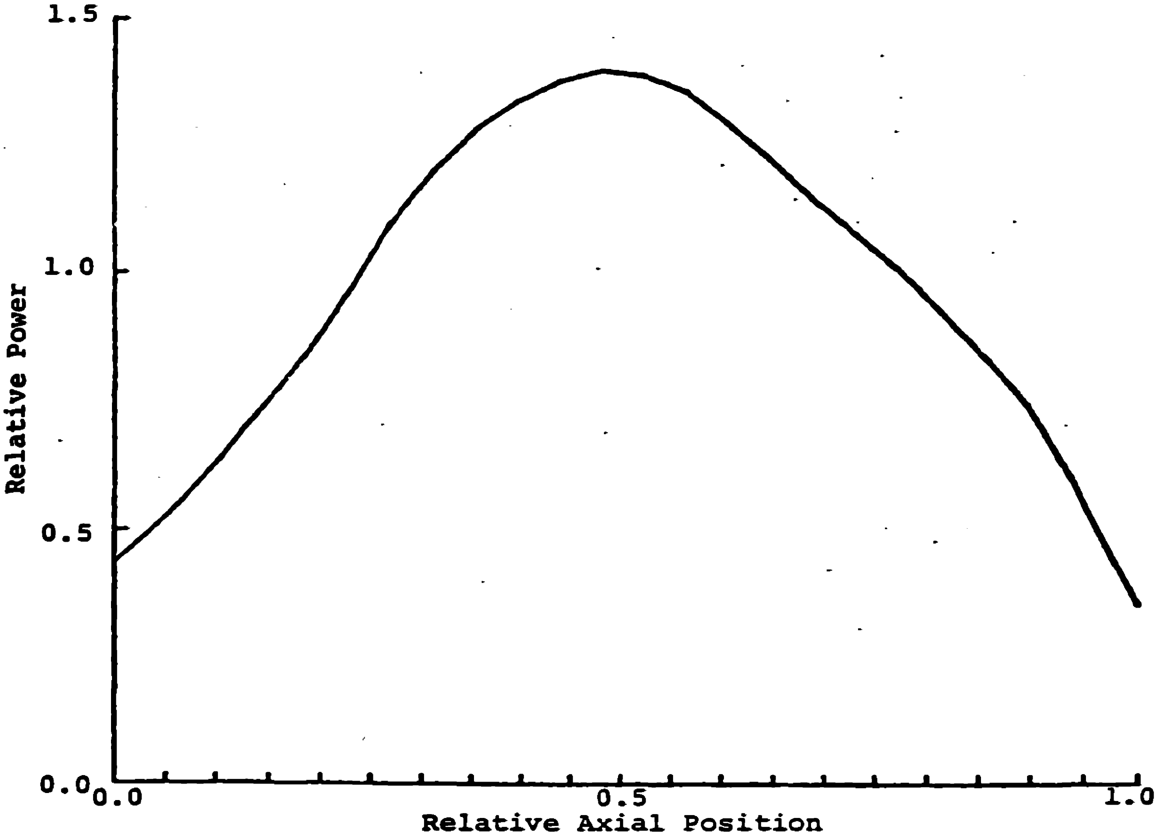

Figure L-1

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 - 500.9 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	Grid Coefficient 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 COBR III-C. = 1 print entire output = 2 print only operation conditions
TEXT	I7A4	11 - 78	Alphanumeric information to identify case

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	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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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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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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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			
TEXT			

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	≤ 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	3(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 since the channels are not connected) ar 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)).

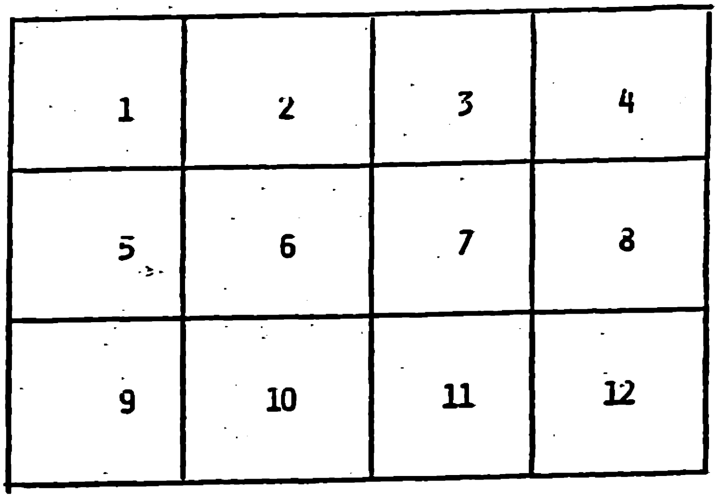

Figure 1.

Rectangular Matrix of Channels

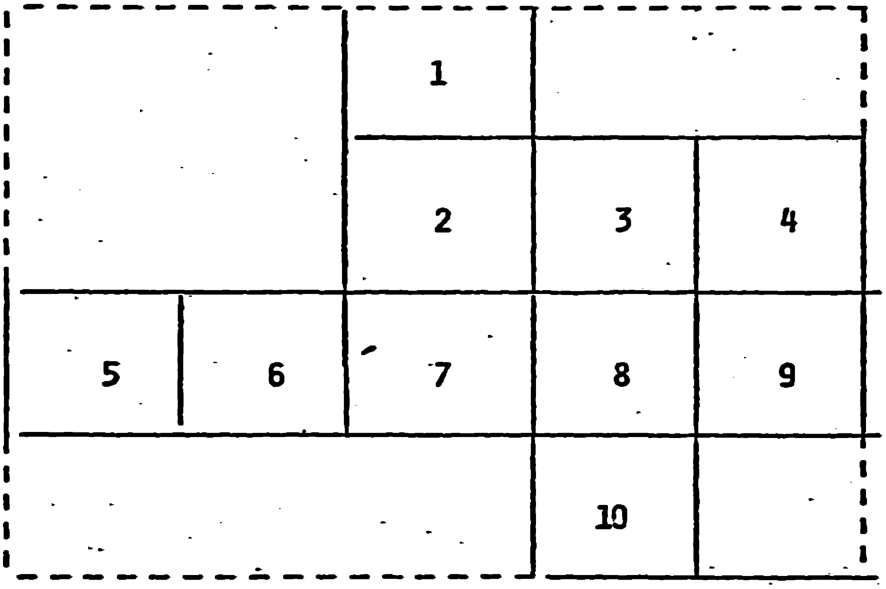

FIGURE 2
Irregular Pattern of Channels

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

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(3612).

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(3612). 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(3612).

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	> 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

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
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.
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:

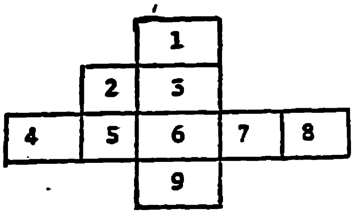
(1) If NGROUP = 0, this acts as a trigger to stop reading Input Data and to start the hydraulic calculation (.e.g., after card T30).

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

$$\begin{matrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 2 & 3 & 0 & 0 \\ 4 & 5 & 6 & 7 & 8 \\ 0 & 0 & 9 & 0 & 0 \end{matrix}$$

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:

$$\begin{matrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \\ 9 & 10 & 11 & 12 \end{matrix}$$

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.

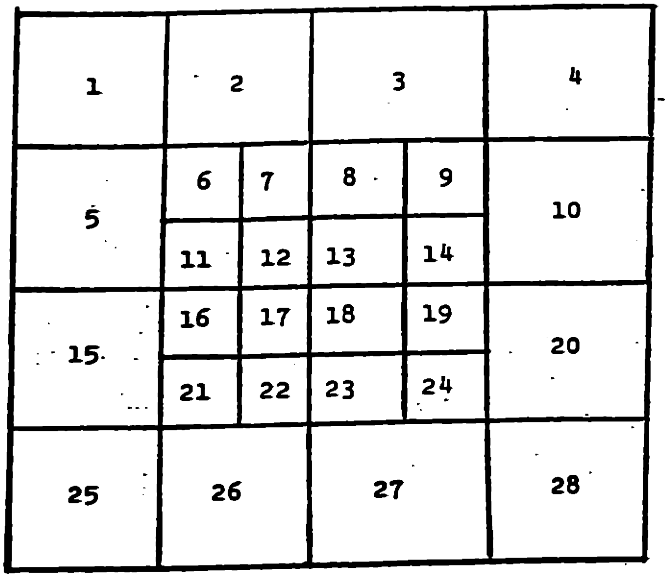
For IMAP=3, ND1X=7, ND2X=4, cards

```
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 <u>and</u> 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^{2}h. 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$\geq$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

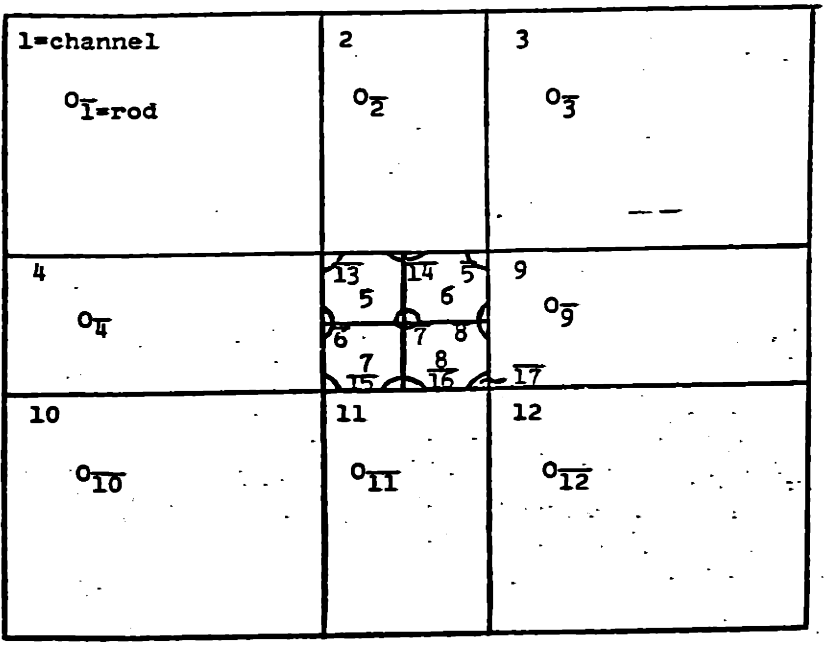
NCHANL = No. of channels in problem (≤MC in Card C1). It is set to the highest value of the channel map array NTHBOX -- see cards C5-C7.

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 T1a	
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
<u>If J=1</u>:				
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	--
<u>If J=2</u>:				
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 power)
(2) 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)	--

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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 1.6×10^{-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.

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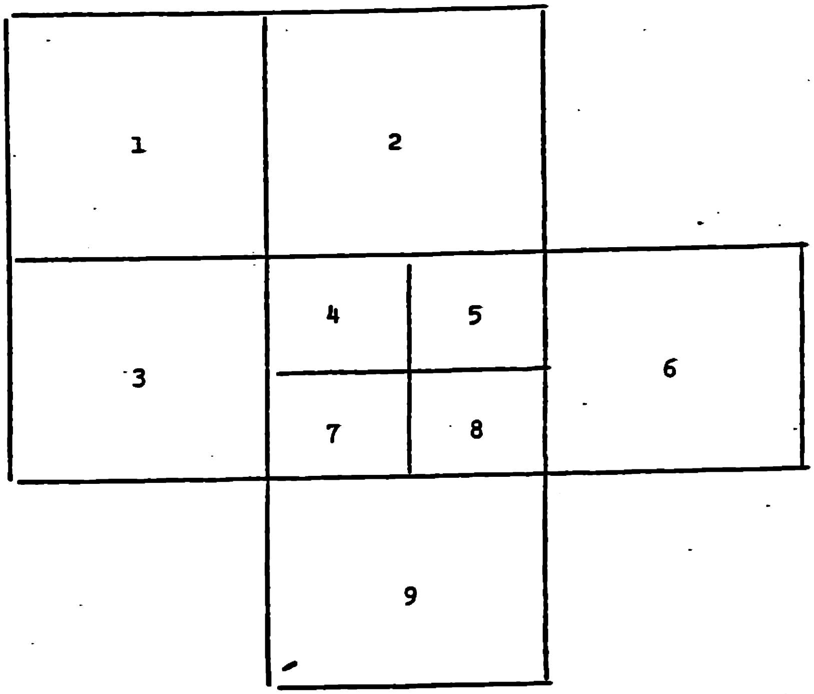
Card(s) Type T6d	Effective rod gap for interconnection between channels (in)
Required to be present:	Only if IPILE=0
FORMAT READ list:	(GAPREC(I),I=1,NK) where NK is the total number of gap interconnections
FORTRAN FORMAT:	14E5.0
Read from Subroutine:	CHAN

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	8-9

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."

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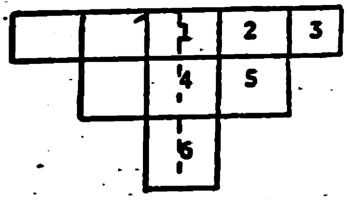
Card(s) Type	T7a	PWR "Half-Boundaries"
Required to be present		Only if IPILE=1
FORTRAN READ list:		(II(L), JJ(L), L=1, N) where II(N)=0
FORTRAN FORMAT:		(14I5)
Read from Subroutine:		CHAN

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-N.9 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 FORMAT:	(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

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

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≤X≤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.

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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	<u>N=1</u>, PH=lowest pressure (psia) in problem. <u>N=2</u>, 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 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.

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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) ≥ 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) $\geqslant 1$
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

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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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

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   ,COB00560
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB00570
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB00580
     9   $U    ,$UH   ,$USAVE;$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB00590
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA  ,$SB   ,$XPOLD  COB00600
C                                                                       COB00610
      COMMON  DATA(1)                                                   COB00620
      LOGICAL LDAT(1)                                                   COB00630
      INTEGER IDAT(1)                                                   COB00640
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB00650
      EQUIVALENCE (NCHAN,NCHANL)                                        COB00660
C                                                                       COB00670
C                                                                       COB00680
      DIMENSION  AFAC(10), GFAC(10)                                     COB00690
C                                                                       COB00700
C  CALCULATE CHANNEL AREA IF REQUIRED.                                  COB00710
      DO 5 I=1,NCHANL                                                   COB00720
      DATA($A    +I)=DATA($AN    +I)                                    COB00730
 5    DATA($DHYD +I)=DATA($DHYDN+I)                                     COB00740
      DO 6 K=1,NK                                                       COB00750
 6    DATA($CAP   +K)=DATA($CAPN +K)                                    COB00760
      IF(NAXL.EQ.0) GO TO 101                                           COB00770
      DO 100 I=1,NCHANL                                                 COB00780
      JJ=IDAT($IDARE+I)                                                 COB00790
      IF(JJ.LT.1) GO TO 100                                             COB00800
      DO 10 K=1,NAXL                                                    COB00810
   10 AFAC(K) = AFACT(JJ,K)                                             COB00820
      CALL CURVE(FF,(DATA($X+J)/Z),AFAC,AXL,NAXL,IERROR,1)              COB00830
      IF(IERROR.GT.1) GO TO 1000                                        COB00840
      IF(DT.LT.100.) GO TO 20                                           COB00850
      DUMY = FLOAT(ITERAT)/FLOAT(NARAMP)                                COB00860
      IF(DUMY.GT.1.) DUMY = 1.                                          COB00870
      IF(FF.LE.0.) GO TO 1000                                           COB00880
      FF = 1.-(1.-FF)*DUMY                                              COB00890
 20   DATA($A    +I)=DATA($AN    +I)*FF                                 COB00900
      DATA($DHYD +I)=DATA($DHYDN+I)*FF                                  COB00910
  100 CONTINUE                                                          COB00920
  101 IF(J6.NE.1) GO TO 110                                             COB00930
C  MODIFY AREA AND HYDRAULIC DIAMETER FOR WIRE WRAPS IN SUBCHANNELS.    COB00940
      DO 102 I=1,NCHANL                                                 COB00950
      DATA($A+I)=DATA($A+I)-FLOAT(IDAT($NWRAP+I))*PI*THICK**2*0.25      COB00960
 102  DATA($DHYD+I)=4.*DATA($A+I)/(DATA($PERIM+I)+FLOAT(IDAT($NWRAP+I))*COB00970
     1    PI*THICK)                                                     COB00980
C                                                                       COB00990
C  CALCULATE GAP SPACING IF REQUIRED.                                   COB01000
  110 IF(NGXL.EQ.0) GO TO 210                                           COB01010
      DO 200 K=1,NK                                                     COB01020
      L=IDAT($IDGAP+K)                                                  COB01030
      IF(L.LT.1) GO TO 200                                              COB01040
      DO 120 I=1,NGXL                                                   COB01050
  120 GFAC(I) = GFACT(L,I)                                              COB01060
      CALL CURVE(FF,(DATA($X+J)/Z),GFAC,GAPXL,NGXL,IERROR,1)            COB01070
      IF(IERROR.GT.1) GO TO 1000                                        COB01080
      IF(FF.LE.0.) GO TO 1000                                           COB01090
      DATA($GAP  +K)=DATA($GAPN +K)*FF                                  COB01100
```

```
  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,.404,.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)) )                          COB01660
     3 /((Y1-Y2)*(X1-X2))                                               COB01670
C                                                                       COB01680
C     ZLINE IS VALUE OF YB AT XB, INTERPOLATED LINEARLY BETWEEN (XA,YA) COB01690
C     AND (XC,YC)                                                       COB01700
C     ZRECT IS VALUE OF Z AT (XX,YY), LINEARLY INTERPOLATED BETWEEN Z11 COB01710
C     AT (X1,Y1), Z12 AT (X1,Y2), Z21 AT (X2,Y1) AND Z22 AT (X2,Y2)     COB01720
C     IPART = 1,  ENTER WITH PRESSURE AND SET ARRAY CORAB               COB01730
C     IPART = 2,  ENTER WITH MASS VELOCITY AND QUALITY, INTERPOLATE     COB01740
C     IN CORAB TO OBTAIN MULTIPLIER.                                    COB01750
C                                                                       COB01760
      IF (IPART.EQ.2) GO TO 41                                          COB01770
C     SET PHYSICAL PROPERTY INDEX FROM PRESSURE.                        COB01780
      IF((P.LT.11.429).OR.(P.GT.3204.0)) WRITE(I3,1001) P               COB01790
      IF(P.GT.1429.5) GO TO 8                                           COB01800
      YY=A1(4)                                                          COB01810
      DO 2 I=1,3                                                        COB01820
      L=4-I                                                             COB01830
    2 YY=YY*P/3204+A1(L)                                                COB01840
      PX = YY                                                           COB01850
      GO TO 12                                                          COB01860
    8 CONTINUE                                                          COB01870
      YY=A2(4)                                                          COB01880
      DO 10 I=1,3                                                       COB01890
      L=4-I                                                             COB01900
   10 YY=YY*P/3204+A2(L)                                                COB01910
      PX = YY*P/(3204-P+YY*P)                                           COB01920
   12 PPI = ALOG(PX)                                                    COB01930
   13 CONTINUE                                                          COB01940
      IMAX=14                                                           COB01950
      IF(PX.LT.PP(1)) PX = PP(1)                                        COB01960
      J=1                                                               COB01970
   14 IF(PX.LE.PP(J)) GO TO 16                                          COB01980
      J=J+1                                                             COB01990
      GO TO 14                                                          COB02000
C                                                                       COB02010
C     SET MULTIPLIER AT G = 1.0                                         COB02020
   16 DO 22 I=1,IMAX                                                    COB02030
      IF(I.EQ.1) CORAB(I,4)=1.0                                         COB02040
      IF(I.EQ.IMAX) CORAB(IMAX,4)=1.0/PX                                COB02050
      IF((I.EQ.1).OR.(I.EQ.IMAX)) GO TO 22                              COB02060
      M=I-1                                                             COB02070
      IF(J.GT.2) GO TO 15                                               COB02080
      WV=ZLINE(ALOG(PP(1)),ALOG(COEF(M,1)),ALOG(PP(2)),ALOG(COEF(M,2)), COB02090
     1PPI)                                                              COB02100
      CORAB(I,4)=EXP(WV)                                                COB02110
      GO TO 22                                                          COB02120
   15 IF(I.GE.8) GO TO 17                                               COB02130
      IF((J.LT.4).OR.(J.GT.5)) GO TO 17                                 COB02140
      ZN=EXP(ZNN(1,M)+ZNN(2,M)*PPI+ZNN(3,M)*PPI*PPI)                    COB02150
      GO TO 19                                                          COB02160
   17 IF (J.LE.7) GO TO 18                                              COB02170
      WV = ZLINE(ALOG(PP(7)),ALOG(COEF(M,7)), 0.0,0.0,PPI)              COB02180
      CORAB(I,4)=EXP(WV)                                                COB02190
      GO TO 22                                                          COB02200
```

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   18 IF(J.EQ.1) J=2                                                    COB02210
      ZN1 = ALOG((COEF(M,J-1) - 1.0 + QQ(I))*PP(J-1))/ALOG(QQ(I))      COB02220
      ZN2 = ALOG((COEF(M,J  ) - 1.0 + QQ(I))*PP(J  ))/ALOG(QQ(I))      COB02230
      ZN = ZLINE(ALOG(PP(J-1)),ALOG(ZN1),ALOG(PP(J)),ALOG(ZN2),PPI)    COB02240
      ZN = EXP(ZN)                                                      COB02250
   19 CORAB(I,4) = 1.0 - QQ(I) + (QQ(I)**ZN)/PX                         COB02260
   22 CONTINUE                                                          COB02270
C                                                                       COB02280
C     SET CORAB MATRIX USING MASS VELOCITY CORRECTION FACTOR.           COB02290
      IND1=1.0                                                          COB02300
      BIT=0.15                                                          COB02310
   30 IF(PPI.LT.X(IND1+1)) GO TO 32                                     COB02320
      IND1=IND1+1                                                       COB02330
      GO TO 30                                                          COB02340
   32 IND2=0.0                                                          COB02350
      DO 34 K=2,4                                                       COB02360
   34 IF((PPI.GT.(X(K)-BIT)).AND.(PPI.LT.(X(K)+BIT))) IND2=K            COB02370
      DO 38 I=1,IMAX                                                    COB02380
      N=I-1                                                             COB02390
      DO 38 J=1,7                                                       COB02400
      IF((I.EQ.1).AND.(J.LT.7)) GO TO 35                                COB02410
      IF((I.EQ.IMAX).AND.(J.LT.7)) GO TO 35                             COB02420
      M=J-1                                                             COB02430
      IF(J.EQ.1) M=J                                                    COB02440
      IF(J.EQ.7) GO TO 37                                               COB02450
      YY=ZLINE(X(IND1),DAT(N,IND1,M),X(IND1+1),DAT(N,IND1+1,M          COB02460
     1),PPI)                                                            COB02470
      IF(IND2.EQ.0.0) GO TO 36                                          COB02480
      X1=X(IND2)-BIT                                                    COB02490
      X2=X(IND2)+BIT                                                    COB02500
      Y1=ZLINE(X(IND2-1),DAT(N,IND2-1,M),X(IND2),DAT(N,IND2,M),X1)     COB02510
      Y2=ZLINE(X(IND2),DAT(N,IND2,M),X(IND2+1),DAT(N,IND2+1,M),X2)     COB02520
      YY=0.5*(ZLINE(X1,Y1,X2,Y2,PPI)+YY)                                COB02530
      GO TO 36                                                          COB02540
   35 YY=1.0                                                            COB02550
   36 CORAB(I,J)=YY*CORAB(I,4)                                          COB02560
      GO TO 38                                                          COB02570
   37 CORAB(I,J)=1.0                                                    COB02580
   38 CONTINUE                                                          COB02590
      RETURN                                                            COB02600
C                                                                       COB02610
C     INTERPOLATE IN CORAB ARRAY TO FIND MULTIPLIER.                    COB02620
   41 G=GWV*1.0E-06                                                     COB02630
      IF(G.GE.1000.0)G = 1000.0                                         COB02640
      IND1=1                                                            COB02650
   42 IF(Q.LE.QQ(IND1)) GO TO 44                                        COB02660
      IND1=IND1+1                                                       COB02670
      GO TO 42                                                          COB02680
   44 CONTINUE                                                          COB02690
      IND2=1                                                            COB02700
   46 IF(G.LT.GG(IND2)) GO TO 48                                        COB02710
      IND2=IND2+1                                                       COB02720
      GO TO 46                                                          COB02730
   48 G2=GG(IND2)                                                       COB02740
      G1=GG(IND2-1)                                                     COB02750
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      G3=G                                                              COB02760
      IF(G.LE.1.0) GO TO 50                                             COB02770
      G1=1.0/G1                                                         COB02700
      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          $SS   ,$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    ,COB03310
     7   $PHI   ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF  ,$QC    ,$QF    ,$QPRIM,COB03320
     8   $QUAL  ,$RADIA,$RHO   ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD  ,COB03330
     9   $U     ,$UH    ,$USAVE,$USTAR,$V     ,$VISC  ,$VISCW,$VP    ,$VPA   ,COB03340
     A   $W     ,$WOLD  ,$WP    ,$WSAVE,$X     ,$XCROS,$$A   ,$$B   ,$XPOLD  COB03350
C                                                                        COB03360
      COMMON  DATA(1)                                                    COB03370
      LOGICAL LDAT(1)                                                    COB03380
      INTEGER IDAT(1)                                                    COB03390
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                             COB03400
C                                                                        COB03410
C                                                                        COB03420
      XP=DATA($QUAL+I)                                                   COB03430
      BVOID = 0.                                                         COB03440
      IF(XP.LE.0.) RETURN                                                COB03450
      DATA($ALPHA+I)=0.                                                  COB03460
      IF(J3.EQ.0) DATA($ALPHA+I)=XP*VG/((1.-XP)*VF+XP*VG)                COB03470
      IF(J3.EQ.1)DATA($ALPHA+I)=(0.833+.167*XP)*XP*VG/((1.-XP)*VF+XP*VG)COB03480
      IF (J3.EQ.2) GO TO 85                                              COB03490
      IF(J3.EQ.5) DATA($ALPHA+I)=XP*VG/((1.-XP)*VF*AV(1)+XP*VG)          COB03500
      IF(J3.NE.6) GO TO 90                                               COB03510
                  DATA($ALPHA+I)=AV(1)                                   COB03520
      XX=DATA($QUAL+I)                                                   COB03530
      DO 80 K=2,NV                                                       COB03540
      DATA($ALPHA+I)=DATA($ALPHA+I)+AV(K)*XX                             COB03550
   80 XX            =DATA($QUAL+I)*XX                                    COB03560
      GO TO 90                                                           COB03570
C     SMITH SLIP CORRELATION                                             COB03580
   85 SLP = 0.4 + 0.6*((0.4+XP*(VG/VF-0.4))/(0.4+0.6*XP))**0.5           COB03590
      DATA($ALPHA+I) = XP*VG/(SLP*(1.0-XP)*VF+XP*VG)                     COB03600
   90  BVOID        =DATA($ALPHA+I)                                      COB03610
      RETURN                                                             COB03620
      END                                                                COB03630
      SUBROUTINE CALC                                                    COB03640
C                                                                        COB03650
C                                                                        COB03660
      IMPLICIT INTEGER ($)                                               COB03670
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX     ,COB03680
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF     ,COB03690
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2     ,COB03700
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,        COB03710
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF     ,COB03720
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP  ,COB03730
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF   ,COB03740
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK  ,COB03750
     8   UF    ,VF    ,VFG   ,VG    ,Z                                   COB03760
C                                                                        COB03770
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB03780
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB03790
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB03800
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB03810
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB03820
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB03830
C                                                                        COB03840
C                                                                        COB03850
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      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         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B     ,COB03910
     1   $CCHAN,$CD   ,SCHFR ,$CON  ,SCOND ,$CP   ,$D    ,$DC   ,$DFDX ,COB03920
     2   $DHDX ,$DHYD ,$DHYDN,SDIST ,SDPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB03930
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,SFMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB03940
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,SHFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB03950
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ;COB03960
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,SNWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB03970
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,SQPRIM,COB03980
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB03990
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB04000
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$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,IB,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
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CC                                                                      COB04410
CC  TIMING IS EXPECTED TO RETURN CPU TIME                               COB04420
CC  (IN HUNDREDTHS OF A SECOND) AS AN INTEGER                           COB04430
CC                                                                      COB04440
      CALL TIMING(ICPU)                                                 COB04450
      TSTART=FLOAT(ICPU)/100.                                           COB04460
CC                                                                      COB04470
CC INITIALIZE FUEL ROD VARIABLES IF NEW FUEL ROD MODEL USED             COB04480
CC                                                                      COB04490
      IF (IFRM.EQ.0) GO TO 409                                          COB04500
      CALL INITRC                                                       COB04510
C                                                                       COB04520
C     START TRANSIENT DO LOOP                                           COB04530
  409 DO 500 NT=1,NDTP1                                                 COB04540
      CALL PRNTIM (1)                                                   COB04550
      IERROR = 0                                                        COB04560
      IF (IQP3.GT.1) GO TO 710                                          COB04570
      CALL QPR3(NCHANL,    KASE,TEXT,DATE,TIME,DATA($X+1))              COB04580
  710 CONTINUE                                                          COB04590
      DT = SAVEDT                                                       COB04600
      IF(NT.EQ.1) DT = 1.E+10                                           COB04610
      ETIME = DT*FLOAT(NT-1)                                            COB04620
C  ESTABLISH CHANNEL BOUNDARY CONDITIONS AND FORCING FUNCTION VALUES.   COB04630
C                                                                       COB04640
C     SET TRANSIENT PRESSURE                                            COB04650
      DUMY = 1.                                                         COB04660
      IF(NP.GT.1)                                                       COB04670
     1CALL CURVE (DUMY,ETIME,FP,YP,NP,IERROR,1)                         COB04680
      IF(IERROR.GT.1) GO TO 505                                         COB04690
      PREF = DUMY*PEXIT                                                 COB04700
      CALL PROP(1,1)                                                    COB04710
      IF(IERROR.GT.1) GO TO 505                                         COB04720
C                                                                       COB04730
C     SET TRANSIENT INLET ENTHALPY                                      COB04740
      DUMY = 1.                                                         COB04750
      IF(NH.GT.1)                                                       COB04760
     1CALL CURVE (DUMY,ETIME,FH,YH,NH,IERROR,1)                         COB04770
      IF(IERROR.GT.1) GO TO 505                                         COB04780
      DO 402 I=1,NCHANL                                                 COB04790
      DATA($HOLD+I)=DATA($H   +I)                                       COB04800
      DATA($H   +I)=DATA($HINLE+I)*DUMY                                 COB04810
      IF(IN.EQ.1 .OR. IN.EQ.3)                                          COB04820
     1CALL CURVE(DATA($H+I),DATA($TINLE+I)*DUMY,HHF,TT,NPROP,IERROR,1)  COB04830
  402 CONTINUE                                                          COB04840
C                                                                       COB04850
C     SET TRANSIENT INLET FLOW                                          COB04860
      DUMY = 1.                                                         COB04870
      IF(NG.GT.1)                                                       COB04880
     1 CALL CURVE(DUMY,ETIME,FG,YG,NG,IERROR,1)                         COB04890
      IF(IERROR.GT.1) GO TO 505                                         COB04900
      IF ( (IPILE.EQ.2) .AND. (NT.GT.1) ) GO TO 404                     COB04910
C     STEADY STATE AND PWR.                                             COB04920
      DO 403 I=1,NCHANL                                                 COB04930
      DATA($FOLD+I)=DATA($F+I)                                          COB04940
  403 DATA($F   +I)=DATA($FINLE+I)*DUMY                                 COB04950
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      GO TO 407                                                         COB04960
C     BWR.  UPDATE INLET FLOW FOR DUMY AND LAST TRANSIENT.              COB04970
  404 SUMSS = 0.0                                                       COB04980
      SUMTR = 0.0                                                       COB04990
      DO 405 I=1,NCHANL                                                 COB05000
      SUMSS = SUMSS + DATA($FINLE+I)                                    COB05010
  405 SUMTR = SUMTR + DATA($F+I)                                        COB05020
      WV = DUMY*SUMSS/SUMTR                                             COB05030
      DO 406 I=1,NCHANL                                                 COB05040
      DATA($FOLD+I)=DATA($F+I)                                          COB05050
  406 DATA($F+I) = WV*DATA($F+I)                                        COB05060
  407 CONTINUE                                                          COB05070
C                                                                       COB05080
C     SET TRANSIENT POWER                                               COB05090
      DUMY = 1.                                                         COB05100
      IF(NQ.GT.1)                                                       COB05110
     1CALL CURVE (DUMY,ETIME,FQ,YQ,NQ,IERROR,1)                         COB05120
      IF(IERROR.GT.1) GO TO 505                                         COB05130
      POWER = DUMY                                                      COB05140
C                                                                       COB05150
C     SET BAROCZY PRESSURE DROP ARRAY                                   COB05160
      IF (J4.EQ.2) CALL BAROC(1,PREF,0.0,0.0,RUB,PPI)                   COB05170
C                                                                       COB05180
C BEGIN ITERATION TO OBTAIN SOLUTION.                                   COB05190
      DO 430 NN=1,NTRIES                                                COB05200
      CALL PRNTIM (2)                                                   COB05210
      DO 410 I=1,NCHANL                                                 COB05220
  410 IDAT($NWRAP+I)=IDAT($NWRPS+I)                                     COB05230
      ITERAT = NN                                                       COB05240
      CALL SCHEME(JUMP,DATA($AAA+1))                                    COB05250
      CALL PRNTIM (6)                                                   COB05260
      IF(IERROR.GT.1) GO TO 440                                         COB05270
      CALL TIMING(ICPU)                                                 COB05280
      MTIME=IFIX(FLOAT(ICPU)/100.-TSTART)                               COB05290
      IF(MTIME.LT.MAXT) GO TO 429                                       COB05300
      WRITE(13,102)                                                     COB05310
      GO TO 440                                                         COB05320
  429 IF(JUMP.LT.1 .OR. JUMP.GT.3) GO TO 505                            COB05330
      GO TO (430,440,440),JUMP                                          COB05340
  430 CONTINUE                                                          COB05350
      WRITE(13,22) NTRIES                                               COB05360
      IERROR = 1                                                        COB05370
C                                                                       COB05380
C SET CONDITIONS FOR NEXT TIME STEP                                     COB05390
  440 IF(JUMP.EQ.3) GO TO 441                                           COB05400
      CALL PRNTIM (7)                                                   COB05410
      IF(NJUMP.GT.0) JUMP = 3                                           COB05420
      IF(NJUMP.NE.2) GO TO 441                                          COB05430
      REWIND 18                                                         COB05440
      WRITE(18) ((DATA($W+I+MG*(J-1)),I=1,MG),J=1,MX),                  COB05450
     1           ((DATA($P+I+MC*(J-1)),I=1,MC),J=1,MX),                 COB05460
     2          ((DATA($RHO+I+MC*(J-1)),I=1,MC),J=1,MX),                COB05470
     3          ((DATA($F   +I+MC*(J-1)),I=1,MC),J=1,MX)                COB05480
      END FILE 18                                                       COB05490
      REWIND 18                                                         COB05500
```

```
  441 DO 445 J=1,NDXP1                                                  COB05510
      DO 443 K=1,NK                                                     COB05520
      DATA($WOLD+K+MG*(J-1))=                                           COB05530
     1DATA($W    +K+MG*(J-1))                                           COB05540
  443 CONTINUE                                                          COB05550
      DO 444 I=1,NCHANL                                                 COB05560
      DATA($FOLD +I+MC*(J-1))=DATA($F    +I+MC*(J-1))                   COB05570
      DATA($HOLD +I+MC*(J-1))=DATA($H    +I+MC*(J-1))                   COB05580
      DATA($RHOOL+I+MC*(J-1))=DATA($RHO  +I+MC*(J-1))                   COB05590
  444 CONTINUE                                                          COB05600
  445 CONTINUE                                                          COB05610
      CALL EXPRIN                                                       COB05620
      IF(KT.GE.NSKIPT) KT=0                                             COB05630
      IF(ISAVE.GT.0) GO TO 505                                          COB05640
      IF(IERROR.GT.0) GO TO 505                                         COB05650
  500 CONTINUE                                                          COB05660
      CALL PRNTIM (8)                                                   COB05670
C                                                                       COB05680
C  END OF PROBLEM,  LOOK FOR NEW CASE                                   COB05690
      GO TO 990                                                         COB05700
  505 WRITE(I3,55) SIGNAL(IERROR)                                       COB05710
      WRITE(I3,55) SIGNAL(ISAVE)                                        COB05720
  990 RETURN                                                            COB05730
C                                                                       COB05740
   22 FORMAT (23H0FAILURE INTEGRATION IN,I4,17H ITERATIONS AT X=        COB05750
     1,F8.4,2I10)                                                       COB05760
   55 FORMAT (10H ERROR IN ,A6,'  **  CALCULATION FOR THIS CASE STOPPED'COB05770
     1)                                                                 COB05780
  102 FORMAT(///' * * * ABNORMAL EXIT THROUGH MAXIMUM TIME * * *'//)    COB05790
      END                                                               COB05800
      SUBROUTINE CARDS1(PP,TT,VVF,VVG,HHF,HHG,UUF,KKF,SSIGMA,N1,I2)     COB05810
      DIMENSION  PP(1),TT(1),VVF(1),VVG(1),HHF(1),HHG(1),UUF(1),KKF(1), COB05820
     1    SSIGMA(1)                                                     COB05830
      REAL KKF                                                          COB05840
C                                                                       COB05850
      I2=5                                                              COB05860
C  MEKIN NEW  PHYS PROP FROM CARDS OR POLYNOMIALS                       COB05870
      IF (N1.LE.0) GO TO 6                                              COB05880
      READ(I2,4) (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HHG(I),UUF(I),       COB05890
     1 KKF(I),SSIGMA(I),I=1,N1)                                         COB05900
    4 FORMAT(E5.2,F5.1,7F10.0)                                          COB05910
      RETURN                                                            COB05920
C                                                                       COB05930
C    P2 TO BE HIGHER THAN OPERATING PRESSURE                            COB05940
C    N=1,PH TO BE LOWER THAN P FOR H-IN                                 COB05950
C    N=2,PH TO BE LOWER THAN H-IN.                                      COB05960
C    N1=NUMBER OF PRESSURE INTERPOLATION STEPS                          COB05970
    6 READ(I2,8) N,PH,P2,N1                                             COB05980
    8 FORMAT(I5,2F10.3,I5)                                              COB05990
      P1=PH                                                             COB06000
      IF(N.EQ.1) GO TO 10                                               COB06010
      P1=10.0                                                           COB06020
      IF(PH.LT.161.3) GO TO 10                                          COB06030
      H=0.01*PH                                                         COB06040
      P1=6.0*H*H*H*(H-1.35)/(H-0.35)                                    COB06050
```

```
   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                                  COBC6360,
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 ,$DHYDN,SDIST ,$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,$MCFRR,SNTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB06570
     7   $PHI  ,$PRNTC,$PRNTR,SPRNTN,SPW   ,$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
```

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     A   SW    ,SWOLD ,SWP   ,SWSAVE,SX    ,SXCROS,SSA  ,SSB  ,SXPOLD    COB06610
C                                                                       COB06620
      COMMON  DATA(1)                                                   COB06630
      LOGICAL LDAT(1)                                                   COB06640
      INTEGER IDAT(1)                                                   COB06650
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB06660
C                                                                       COB06670
C                                                                       COB06680
      COMMON/LINK3/DXX,ETIME,GIN,HIN,IB,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB06690
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB06700
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB06710
      DIMENSION NTHBOX(25,25)                                           COB06720
      DIMENSION CARD(20)                                                COB06730
C                                                                       COB06740
C     SIMULATE NEUTRONIC INPUT TO MEKIN ITHO                            COB06750
C                                                                       COB06760
      WRITE (I3,1010)                                                   COB06770
      DO 2 ND1 = 1,20                                                   COB06780
      DO 2 ND2 = 1,20                                                   COB06790
    2 NTHBOX(ND1,ND2) = 0                                               COB06800
      NTHBXX = 0                                                        COB06810
      READ (I2,1001) CARD, IMAP, ND1X, ND2X                             COB06820
      WRITE (I3,1011) CARD                                              COB06830
      IF ( (ND1X.LE.25) .AND. ( ND2X.LE.25) ) GO TO 4                   COB06840
      WRITE (I3,1012) ND1X,ND2X                                         COB06850
      STOP                                                              COB06860
C                                                                       COB06870
    4 IF (IMAP-2) 6,10,14                                               COB06880
C     IMAP = 1.    RECTANGULAR MATRIX                                   COB06890
    6 DO 8 ND2 = 1,ND2X                                                 COB06900
      DO 8 ND1 = 1,ND1X                                                 COB06910
      NTHBXX = NTHBXX+1                                                 COB06920
    8 NTHBOX(ND1,ND2) = NTHBXX                                          COB06930
      GO TO 18                                                          COB06940
C                                                                       COB06950
C     IMAP = 2.    GIVE START AND END OF EACH ROW.                      COB06960
   10 DO 12 ND2=1,ND2X                                                  COB06970
      READ (I2,1001) CARD, ISTART, IFIN                                 COB06980
      WRITE (I3,1013) ND2, CARD                                         COB06990
      DO 12 ND1=1,ND1X                                                  COB07000
      IF ( (ND1.LT.ISTART) .OR. (ND1.GT.IFIN) ) GO TO 12                COB07010
      NTHBXX = NTHBXX+1                                                 COB07020
      NTHBOX(ND1,ND2) = NTHBXX                                          COB07030
   12 CONTINUE                                                          COB07040
      GO TO 18                                                          COB07050
C                                                                       COB07060
C     IMAP = 3.    READ NTHBOX                                          COB07070
   14 MAXRD = 14                                                        COB07080
      MP1 = MAXRD+1                                                     COB07090
      MORE = ND1X - MAXRD                                               COB07100
      DO 16 ND2 = 1,ND2X                                                COB07110
      READ (I2,1001) CARD, (NTHBOX(ND1,ND2),ND1=1,MAXRD)                COB07120
      WRITE (I3,1014) ND2, CARD                                         COB07130
      IF (MORE.LE.0) GO TO 15                                           COB07140
      READ (I2,1001) CARD, (NTHBOX(ND1,ND2),ND1=MP1,ND1X)               COB07150
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      WRITE (13,1014) ND2, CARD                                         COB07160
   15 DO 16 ND1=1,ND1X                                                  COB07170
      IF (NTHBOX(ND1,ND2).GT.NTHBXX) NTHBXX=NTHBOX(ND1,ND2)             COB07180
   16 CONTINUE                                                          COB07190
C                                                                       COB07200
C     READ HEAT FLUX PARAMETERS.                                        COB07210
   18 READ (12,1003) CARD, N1, AFLUX                                    COB07220
      WRITE (13,1015) CARD                                              COB07230
      IF (N1.GT.1) GO TO 22                                             COB07240
      IQP3 = N1                                                         COB07250
      DO 20 I=1,NTHBXX                                                  COB07260
   20 DATA($RADIA+I) = 1.0                                              COB07270
      GO TO 24                                                          COB07280
   22 NAX = N1                                                          COB07290
      CALL READIN(8,NAX,Y,AXIAL,CARD,2)                                 COB07300
      CALL READIN(9,NTHBXX,DATA($RADIA+1),CARD,CARD,1)                  COB07310
C                                                                       COB07320
   24 READ (12,1004) CARD,Z, NDX, NDT, TTIME                            COB07330
      WRITE (13,1016) CARD                                              COB07340
C                                                                       COB07350
      CALL ITHO(NTHBOX,NTHBXX,ND1X,ND2X)                                COB07360
      IF (NOPRIN.EQ.0) CALL TIDY                                        COB07370
      CALL PRECAL                                                       COB07380
      RETURN                                                            COB07390
C                                                                       COB07400
 1001 FORMAT(20A4, T1, 14I5)                                            COB07410
 1003 FORMAT(20A4, T1, I5, 13E5.0)                                      COB07420
 1004 FORMAT(20A4, T1, E5.0, 2I5, 10E5.0)                               COB07430
 1010 FORMAT(1H1, 42X, 'COBRA INPUT DATA', /, 43X,                      COB07440
     1 '----------------', //, '  NB. DATA READ FROM CARD20 WOULD BE REACOB07450
     2D OR SET WITH THE NEUTRONICS DATA IN MEKIN', ///, '  CARD IMAGES',COB07460
     3 /, 2X, '---- ------', /, 32X, '0....+....1....+....2....+....3...COB07470
     4.+....4....+....5....+....6....+....7....+....8')                 COB07480
 1011 FORMAT('  IMAP ND1X ND2X', 14X, '***', 20A4, '*** CARD20')        COB07490
 1012 FORMAT('  INPUT DATA ERROR IN CARD20. ND1X, ND2X = ', 2I5,        COB07500
     1 ' IE GREATER THAN 25 FOR EACH ALLOWED')                          COB07510
 1013 FORMAT('  ND2=',I3, ' ISTART IFIN', 9X, '***', 20A4, '*** CARD20')COB07520
 1014 FORMAT('  ND2=', I3, ' NTHBOX', 14X, '***', 20A4, '*** CARD20')   COB07530
 1015 FORMAT('  NAX AFLUX', 19X, '***', 20A4, '*** CARD20')             COB07540
 1016 FORMAT('  Z NDX NDT TTIME', 13X, '***', 20A4, '*** CARD20')       COB07550
C                                                                       COB07560
      END                                                               COB07570
      FUNCTION CHF1(N,I,J)                                              COB07580
C                                                                       COB07590
C                                                                       COB07600
      IMPLICIT INTEGER ($)                                              COB07610
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB07620
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB07630
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB07640
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB07650
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB07660
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB07670
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB07680
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB07690
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB07700
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C                                                                       COB07710
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB07720
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB07730
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB07740
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB07750
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB07760
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB07770
C                                                                       COB07780
C                                                                       COB07790
      LOGICAL  GRID                                                     COB07800
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB07810
C                                                                       COB07820
C                                                                       COB07830
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB07840
     1          $SS   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB07850
     1  $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB07860
     2  $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB07870
     3  $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB07880
     4  $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB07890
     5  $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB07900
     6  $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB07910
     7  $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB07920
     8  $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB07930
     9  $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB07940
     A  $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA  ,$SB  ,$XPOLD   COB07950
C                                                                       COB07960
      COMMON  DATA(1)                                                   COB07970
      LOGICAL LDAT(1)                                                   COB07980
      INTEGER IDAT(1)                                                   COB07990
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB08000
C                                                                       COB08010
C                                                                       COB08020
C  BAW-2 CHF CORRELATION                                                COB08030
      DATA A0, B0,A1,A2,A3,A4,A5,A6,A7,A8,A9 / 1.15509, 4.8844,         COB08040
     1 0.3702E+8, 2.1289E-3, 0.83040, 0.68479E-3, 4.5756E+4, 1.0996E-2, COB08050
     2 0.71186, 0.20729E-3, 547.49/                                     COB08060
      REAL KD                                                           COB08070
      DATA  A21,A22,A23,KD /  2.9840, 7.82293, 0.45758, 1.02508 /       COB08080
      QA=DATA($A +I)                                                    COB08090
      QP=DATA($PERIM+I)                                                 COB08100
      QF=DATA($F+I +MC*(J-1))                                           COB08110
      QH=DATA($H+I +MC*(J-1))                                           COB08120
      RAT=QF/QA                                                         COB08130
      DE=4.*QA/QP                                                       COB08140
      XX=(QH-HF)/HFG                                                    COB08150
      CHF1=(A0-B0*DE)*(A1*(A2*RAT)**(A3+A4*(PREF-2000.))                COB08160
     1    -A9*RAT*XX*HFG)/(A5*(A6*RAT)**(A7+A8*(PREF-2000.)))           COB08170
C  AXIAL FLUX CORRECTION FACTOR                                         COB08180
      FAXIAL = 1.                                                       COB08190
      IF(J.EQ.1) GO TO 10                                               COB08200
      C=A21*(1.-XX)**A22/(RAT*.0036)**A23                               COB08210
      SUM = 0.                                                          COB08220
      JS = 2                                                            COB08230
      DO 5 JJ=JS,J                                                      COB08240
    5 SUM=SUM+DATA($FLUX+N+MR*(JJ-1))*(EXP(C*DATA($X+JJ))-              COB08250
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     1                                     EXP(C*DATA($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/  ADETA ,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(7E14.8)                                                    COB09570
  112 FORMAT(54HOSINGULAR 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                                                     COB09910
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB09920
C                                                                       COB09930
C                                                                       COB09940
      COMMON /COBRA3/  MA     ,MC     ,MG     ,MN     ,MR     ,MS     ,MX     ,COB09950
     1          $SS    ,$A     ,$AAA   ,$AC    ,$ALPHA,$AN    ,$ANSWE,$B     ,COB09960
     1   $CCHAN,$CD    ,$CHFR ,$CON   ,$COND ,$CP    ,$D     ,$DC    ,$DFDX ,COB09970
     2   $DHDX ,$DHYD ,$DHYDN,$DIST  ,$DPDX ,$DPK   ,$DUR   ,$DR    ,$F     ,COB09980
     3   $FACTO,$FDIV ,$FINLE,$FLUX  ,$FMULT,$FOLD  ,$FSP   ,$FSPLI,$FXFLO,COB09990
     4   $GAP  ,$GAPN ,$GAPS ,$H     ,$HFILM,$HINLE,$HOLD  ,$HPERI,$IDARE,COB10000
     5   $IDFUE,$IDGAP,$IK    ,$JBOIL,$JK    ,$LC    ,$LENGT,$LOCA ,$LR    ,COB10010
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P     ,$PERIM,$PH    ,COB10020
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW    ,$PWRF ,$QC    ,$QF    ,$QPRIM,COB10030
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP    ,$T     ,$TDUMY,$TINLE,$TROD ,COB10040
     9   $U     ,$UH    ,$USAVE,$USTAR,$V     ,$VISC ,$VISCW,$VP    ,$VPA  ,COB10050
     A   $W     ,$WOLD ,$WP    ,$WSAVE,$X     ,$XCROS,$SA   ,$SB   ,$XPOLD  COB10060
C                                                                       COB10070
      COMMON  DATA(1)                                                   COB10080
      LOGICAL LDAT(1)                                                   COB10090
      INTEGER IDAT(1)                                                   COB10100
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB10110
C                                                                       COB10120
      EQUIVALENCE (NCHAN,NCHANL)                                        COB10130
C                                                                       COB10140
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),  COB10150
     1 JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),COB10160
     2 YQ(30)                                                           COB10170
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB10180
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB10190
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB10200
      DIMENSION CHFCOR(5),CHFLBL(5)                                     COB10210
      DATA CHFCOR /4HBAW2,4HW-3 ,4HH-L ,4HC-4 ,4HB-VC/                  COB10220
      DATA CHFLBL /4HDNBR,4HDNBR,4HCHFR,4HCPR ,4HCHFR/                  COB10230
       DATA H1,H2,H3,H4,H5 / 1H(, 1H,, 1H), 4H  W(, 4H)WP( /            COB10240
      DATA H6, H7, H8 /1HW, 1HX, 2HT( /                                 COB10250
C     PRINT OUTPUT (COBRA CARDS MAIN1822 - MAIN2331)                    COB10260
      ISAVE = IERROR                                                    COB10270
      IERROR = 0                                                        COB10280
      IF(NCHF.GT.0 .AND. ISAVE.EQ.0) CALL CHF(3,NDXP1)                  COB10290
      KT = KT+1                                                         COB10300
      IF(KT.LT.NSKIPT) GO TO 500                                        COB10310
      CALL TOD(TIME)                                                    COB10320
C                                                                       COB10330
C  PRINT RESULTS                                                        COB10340
      IF(ETIME.GT.0.) GO TO 457                                         COB10350
C  COMPUTE MASS AND ENERGY BALANCE                                      COB10360
      FLOIN = 0.                                                        COB10370
      FLOOUT = 0.                                                       COB10380
      ENGIN = 0.                                                        COB10390
      ENGOUT = 0.                                                       COB10400
      NDXP1 = NDX+1                                                     COB10410
      DO 448 I=1,NCHANL                                                 COB10420
      FLOIN =FLOIN +DATA($F     +I)                                     COB10430
      FLOOUT=FLOOUT+DATA($F     +I+MC*(NDXP1-1))                        COB10440
      ENGIN =ENGIN +DATA($F     +I)*DATA($H+I)                          COB10450
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 448  ENGOUT=ENGOUT+DATA($F     +I+MC*(NDXP1-1))*                       COB10460
     1                DATA($H     +I+MC*(NDXP1-1))                        COB10470
      FLOERR = FLOOUT - FLOIN                                             COB10480
      ENGADD = AFLUX*Z*PHTOT/.0036                                        COB10490
      ENGERR =  ENGOUT - ENGIN - ENGADD                                   COB10500
      WRITE(13,99) KASE,TEXT,DATE,TIME,FLOIN,ENGIN,FLOOUT,ENGADD,FLOERR,COB10510
     1ENGOUT,ENGERR                                                       COB10520
C  PREPARE CHANNEL EXIT SUMMARY                                           COB10530
      J = NDXP1                                                           COB10540
      DO 450 I=1,NCHANL                                                   COB10550
      OUTPUT(1) = TF                                                      COB10560
      IF(DATA($H+I+MC*(J-1)).LT.HF)  CALL CURVE(OUTPUT(1),                COB10570
     1   DATA($H+I+MC*(J-1)),TT,HHF,NPROP,IERROR,1)                       COB10580
      OUTPUT(2)=(DATA($H+I+MC*(J-1))-HF)/HFG                              COB10590
      IF(OUTPUT(2).LT.0.) OUTPUT(2) = 0.                                  COB10600
      OUTPUT(3)=(RHOF-DATA($RHO+I+MC*(J-1)))/(RHOF-RHOG)                  COB10610
      IF(OUTPUT(3).LT.0.) OUTPUT(3) = 0.                                  COB10620
      OUTPUT(4)=DATA($F+I+MC*(J-1))/DATA($AN+I)*.0036                     COB10630
      WRITE(13,100) I,DATA($H+I+MC*(J-1)),OUTPUT(1),DATA($RHO+I+          COB10640
     1    MC*(J-1)),OUTPUT(2),OUTPUT(3),           DATA($F  +I+MC*(J-1)),COB10650
     2    OUTPUT(4)                                                       COB10660
  450 CONTINUE                                                            COB10670
      IF(IERROR.GT.1) GO TO 505                                           COB10680
C  COMPUTE BUNDLE AVERAGED RESULTS                                        COB10690
  452 WRITE(13,25) KASE,TEXT,DATE,TIME                                    COB10700
      WRITE(13,101)                                                       COB10710
      WRITE(13,82)                                                        COB10720
      DO 456 J=1,NDXP1,NSKIPX                                             COB10730
      SAVE1 = 0.                                                          COB10740
      SAVE2 = 0.                                                          COB10750
      SAVE3 = 0.                                                          COB10760
      SAVE4 = 0.                                                          COB10770
      DO 454 I=1,NCHANL                                                   COB10780
      SAVE1=SAVE1+DATA($P+I+MC*(J-1))*DATA($AN+I)                         COB10790
      SAVE2=SAVE2+DATA($H+I+MC*(J-1))*DATA($F+I+MC*(J-1))                 COB10800
      SAVE3=SAVE3+DATA($F+I+MC*(J-1))                                     COB10810
  454 SAVE4=SAVE4+DATA($RHO+I+MC*(J-1))*DATA($AN+I)                       COB10820
      OUTPUT(1)=DATA($X+J)*12.                                            COB10830
      OUTPUT(2) = SAVE1/ATOTAL/144.                                       COB10840
      OUTPUT(3) = SAVE2/SAVE3                                             COB10850
      OUTPUT(4) = TF                                                      COB10860
      IF(OUTPUT(3).LT.HF) CALL CURVE(OUTPUT(4),OUTPUT(3),TT,HHF,NPROP,   COB10870
     1 IERROR,1)                                                          COB10880
      IF(IERROR.GT.1) GO TO 505                                           COB10890
      OUTPUT(5) = SAVE4/ATOTAL                                            COB10900
      OUTPUT(6) = 0.                                                      COB10910
      IF(OUTPUT(3).GT.HF) OUTPUT(6) = (OUTPUT(3)-HF)/HFG                  COB10920
      OUTPUT(7) = 0.                                                      COB10930
      IF(OUTPUT(5).LT.RHOF) OUTPUT(7) = (RHOF-OUTPUT(5))/(RHOF-RHOG)      COB10940
      OUTPUT(8) = SAVE3                                                   COB10950
      OUTPUT(9) = SAVE3/ATOTAL*.0036                                      COB10960
      WRITE(13,81) (OUTPUT(II),II=1,9)                                    COB10970
  456 CONTINUE                                                            COB10980
      IF(IERROR.GT.1) GO TO 505                                           COB10990
C  PRINT CHANNEL AND ROD RESULTS AS DEFINED BY OUTPUT OPTIONS            COB11000
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  457 DO 460 JJ=1,NPCHAN                                                COB11010
      I=IDAT($PRNTC+JJ)                                                 COB11020
      WRITE(13,25) KASE, TEXT, DATE, TIME                               COB11030
      WRITE(13,80) ETIME,I                                              COB11040
      WRITE(13,82)                                                      COB11050
      DO 458 J=1,NDXP1,NSKIPX                                           COB11060
      OUTPUT(1)=DATA($X+J)*12.                                          COB11070
      OUTPUT(3)=DATA($H+I+MC*(J-1))                                     COB11080
      OUTPUT(2)=DATA($P+I+MC*(J-1))/144.                                COB11090
      OUTPUT(4) = TF                                                    COB11100
      IF(       DATA($H+I+MC*(J-1)).LT.HF)CALL CURVE(OUTPUT(4),         COB11110
     1          DATA($H+I+MC*(J-1)),TT,HHF,NPROP,IERROR,1)              COB11120
      IF(IERROR.GT.1) GO TO 505                                         COB11130
      OUTPUT(5)=DATA($RHO+I+MC*(J-1))                                   COB11140
      OUTPUT(6) = 0.                                                    COB11150
      IF(DATA($H+I+MC*(J-1)).GT.HF)  OUTPUT(6)=(                        COB11160
     1   DATA($H+I+MC*(J-1))-HF)/HFG                                    COB11170
      OUTPUT(7) = 0.                                                    COB11180
      IF(DATA($RHO+I+MC*(J-1)).LT.RHOF)  OUTPUT(7)=(RHOF-               COB11190
     1   DATA($RHO+I+MC*(J-1)))/(RHOF-RHOG)                             COB11200
      OUTPUT(8)=DATA($F+I+MC*(J-1))                                     COB11210
      OUTPUT(9)=DATA($F+I+MC*(J-1))/DATA($AN+I)*.0036                   COB11220
      WRITE(13,81) (OUTPUT(II),II=1,9)                                  COB11230
  458 CONTINUE                                                          COB14240
  460 CONTINUE                                                          COB11250
      IF(NOUT.LT.1) GO TO 499                                           COB11260
      IF(NOUT.EQ.2) GO TO 470                                           COB11270
      DO 465 M=1,NK,10                                                  COB11280
      MM = M+9                                                          COB11290
      IF(NK.LE.MM) MM=NK                                                COB11300
      WRITE(13,31)KASE,TEXT,DATE,TIME,H7,(H6,H1,IDAT($IK+K),H2,IDAT($JK+COB11310
     1   K),H3,K=M,MM)                                                  COB11320
      DO 465 J=1,NDXP1,NSKIPX                                           COB11330
      XDUMY=DATA($X+J)*12.                                              COB11340
      WRITE(13,30) XDUMY,(DATA($W+K+MG*(J-1)),K=M,MM)                   COB11350
  465 CONTINUE                                                          COB11360
      IF(NOUT.EQ.1) GO TO 499                                           COB11370
  470 IF(NPROD.LT.1) GO TO 4990                                         COB11380
      DO 485 NN=1,NPROD                                                 COB11390
      N=IDAT($PRNTR+NN)                                                 COB11400
      NDUMY=IDAT($IDFUE+N)                                              COB11410
      II=1                                                              COB11420
      IF(NCHF.GT.0) II=NCHF                                             COB11430
      WRITE(13,94) KASE, TEXT, DATE, TIME, ETIME, N, NDUMY,CHFLBL(II),  COB11440
     1    (H8,IDAT($PRNTN+I),H3,I=1,NPNODE)                             COB11450
      DO 483 J=1,NDXP1,NSKIPX                                           COB11460
      XDUMY=DATA($X+J)*12.                                              COB11470
      DO 480 II=1,NPNODE                                                COB11480
      I=IDAT($PRNTN+II)                                                 COB11490
  480 DATA($TDUMY+II)=                                                  COB11500
     1           DATA($TROD+I+MN*(N-1+MR*(J-1)))                        COB11510
      DFLUX=DATA($FLUX+N+MR*(J-1))*.0036                                COB11520
      IF(IDAT($CCHAN+N+MR*(J-1)).EQ.0)  DATA($CHFR+N+MR*(J-1))=0.       COB11530
      IF(NODESF.GT.1) WRITE(13,95) XDUMY,DFLUX,DATA($CHFR+N+MR*(J-1)),  COB11540
     1    IDAT($CCHAN+N+MR*(J-1)),(DATA($TDUMY+I),I=1,NPNODE)           COB11550
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      IF(NODESF.LT.1) WRITE(I3,95) XDUMY,DFLUX,DATA($CHFR+N+MR*(J-1)),  COB11560
     1    IDAT($CCHAN+N+MR*(J-1))                                        COB11570
  483 CONTINUE                                                           COB11580
  485 CONTINUE                                                           COB11590
 4990 IF(NCHF.LT.1) GO TO 499                                            COB11600
      WRITE(I3,96)  KASE,TEXT,DATE,TIME,ETIME,CHFCOR(NCHF),CHFLBL(NCHF) COB11610
      DO 4995 J=1,NDXP1,NSKIPX                                           COB11620
      XDUMY=DATA($X+J)*12.                                               COB11630
      N=    IDAT($MCFRR+J)                                               COB11640
      DFLUX = 0.                                                         COB11650
      IF(N.NE.0)  DFLUX=DATA($FLUX+N+MR*(J-1))*.0036                     COB11660
      IF(N.EQ.0)  DATA($MCHFR+J)=0.                                      COB11670
      WRITE(I3,97) XDUMY,DFLUX,DATA($MCHFR+J),IDAT($MCFRR+J),            COB11680
     1                                        IDAT($MCFRC+J)             COB11690
 4995 CONTINUE                                                           COB11700
  499  WRITE(I3,75) ITERAT                                               COB11710
  500 CONTINUE                                                           COB11720
  505 CONTINUE                                                           COB11730
      RETURN                                                             COB11740
C                                                                        COB11750
   25 FORMAT(17H1CHANNEL RESULTS   /                                     COB11760
     1  5H CASEI5,5X17A4,  9H   DATE   2A4,7H TIME    2A4,A1/)           COB11770
   30 FORMAT(F7.1,10F10.5)                                               COB11780
   31 FORMAT (68H1DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J),COB11790
     1 (LB/SEC-FT).                                                      COB11800
     1    // 5H CASEI5 , 5X, 17A4,                                       COB11810
     29H   DATE  2A4,7H  TIME  2A4,A1 ///                                COB11820
     3 5X,A1,2X,10(2X,A1,A1,I2,A1,I2,A1))                                COB11830
   75 FORMAT (// 14H ITERATIONS =    I4)                                 COB11840
   80 FORMAT(8H TIME =  F8.5,  9H SECONDS                                COB11850
     1  20H    DATA FOR CHANNEL   I3/)                                   COB11860
   81 FORMAT(F6.1,F12.2,2F12.2,F10.2,2F9.3,F11.4,F12.4)                  COB11870
   82 FORMAT (' DISTANCE   DELTA-P    ENTHALPY   TEMPERATURE DENSITY     COB11880
     1EQUIL     VOID        FLOW     MASS FLUX'/ '  (IN.)       (PSI)    (COB11890
     1BTU/LB)    (DEG-F)   (LB/CU-FT) QUALITY FRACTION   (LB/SEC) (MLB/HCOB11900
     1R-FT2)')                                                           COB11910
   94 FORMAT(5H1CASEI5,5X17A4,9H   DATE   2A4,7H TIME    2A4,A1//        COB11920
     1  8H TIME =  F8.5,9H SECONDS                                       COB11930
     2 28H    TEMPERATURE DATA FOR ROD  I3,                              COB11940
     3 12H,  FUEL TYPE  I2//                                             COB11950
     4 ' DISTANCE  FLUX       ',A4,'  CHANNEL                TEMP',      COB11960
     5  'ERATURE(F)'/,22H  (IN.)  (MBTU/HR-FT2)   13X,10(4X,A2,I2,A1))  COB11970
   95 FORMAT(F8.1,F9.4,F9.3,I4,5X,10(F9.1))                              COB11980
   96 FORMAT(5H1CASEI5,5X17A4,9H   DATE   2A4,7H TIME    2A4,A1//        COB11990
     1 8H TIME =  F8.5,9H SECONDS  //                                    COB12000
     2A7,  ' CRITICAL HEAT FLUX SUMMARY'/                                COB12010
     3 ' DISTANCE   FLUX   M',A4,'     ROD    CHANNEL')                  COB12020
   97 FORMAT(F8.1,2F8.3,2I8)                                             COB12030
   99 FORMAT('1CHANNEL EXIT SUMMARY RESULTS'/                            COB12040
     1  5H CASEI5,5X17A4,  9H   DATE   2A4,7H TIME    2A4,A1//           COB12050
     2' MASS BALANCE - -      ',17X,                                     COB12060
     410X,'ENERGY BALANCE - -       ',/                                  COB12070
     3,'     MASS FLOW IN      ',E12.5,' LB/SEC',                        COB12080
     410X,'   FLOW ENERGY IN       ',E12.5,' BTU/SEC',/                  COB12090
     3'     MASS FLOW OUT     ',E12.5,' LB/SEC',                         COB12100
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     410X,'   ENERGY ADDED        ',E12.5,' BTU/SEC',/             COB12110
     3'     MASS FLOW ERROR  ',E12.5,' LB/SEC',                    COB12120
     410X,'   FLOW ENERGY OUT     ',E12.5,' BTU/SEC',/             COB12130
     449X,'   ENERGY ERROR        ',E12.5,' BTU/SEC',//            COB12140
     7' CHANNEL ENTHALPY TEMPERATURE DENSITY   EQUIL     VOID     FLOW COB12150
     8  MASS FLUX'/                                                COB12160
     9'  (NO.) (BTU/LB)  (DEG-F)    (LB/FT3) QUALITY  FRACTION  (LB/SEC)COB12170
     1 (MLB/HR-FT2)')                                              COB12180
 100 FORMAT(I6,2F10.2,F10.2,2F9.3,F10.4,F12.4)                     COB12190
 101 FORMAT(' BUNDLE AVERAGED RESULTS'/)                           COB12200
     END                                                           COB12210
     SUBROUTINE FIZPRP(IPART,NPROP)                                COB12220
C                                                                  COB12230
     COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), COB12240
    1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), COB12250
    2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB12260
    3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),  COB12270
    4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),   COB12280
    5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                 COB12290
C                                                                  COB12300
     REAL KKF                                                      COB12310
C                                                                  COB12320
C    IPART = 1, SET PHYSICAL PROPERTIES                            COB12330
C    IPART = 2, PRINT PHYSICAL PROPERTIES                          COB12340
C    CODING SAME AS FOR COBRA                                      COB12350
C                                                                  COB12360
     IF (IPART.EQ.2) GO TO 10                                      COB12370
C    ENTER WITH NPROP PMAX (=PP(1)) PMIN (=PP(2)) SET IN OPERA OR MODELCOB12380
     P1 = PP(1)                                                    COB12390
     P2 = PP(2)                                                    COB12400
   6 A = (P2-P1)/FLOAT(NPROP-1)                                    COB12410
     DO 8 I=1,NPROP                                                COB12420
     P=P1+(I-1.0)*A                                                COB12430
     PP(I)=P                                                       COB12440
     TT(I)=SATTEM(P)                                               COB12450
     RL=ROLIQ(P)                                                   COB12460
     VVF(I)=1.0/RL                                                 COB12470
     RG=ROVAP(P)                                                   COB12480
     VVG(I)=1.0/RG                                                 COB12490
     H=HLIQ(P)                                                     COB12500
     HHF(I)=H                                                      COB12510
     HHG(I)=HVAP(P)                                                COB12520
     CALL HAPROP(P,H,CP,UUF(I),KKF(I))                             COB12530
     CALL SURTEN(P,RL,RG,SSIGMA(I))                                COB12540
   8 CONTINUE                                                      COB12550
     RETURN                                                        COB12560
C                                                                  COB12570
  10 WRITE (6,1003)                                                COB12580
     WRITE (6,1004) (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HHG(I),UUF(I), COB12590
    1 KKF(I),SSIGMA(I),I=1,NPROP)                                  COB12600
     RETURN                                                        COB12610
C                                                                  COB12620
1003 FORMAT(////, '  PHYSICAL PROPERTIES', /, 2X,'-------- ----------',COB12630
    1 //, 4X, "P', 9X, 'T', 8X, 'VF', 8X, 'VG', 8X, 'HF', 8X, 'HG', COB12640
    2 7X, 'VISC', 8X, 'KF', 6X, 'SIGMA', /)                        COB12650
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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,$SA  ,$SB  ,$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                                                COB13210
C  FORCED DIVERSION CROSSFLOW FROM WIRE WRAPS                            COB13220
  100 IF(PITCH.LE.0.) GO TO 1000                                        COB13230
      NN = Z/PITCH                                                      COB13240
      NN = NN+1                                                         COB13250
      DO 115 K=1,NN                                                     COB13260
      IF(DATA($X+J).LE.PITCH*FLOAT(K))  GO TO 118                       COB13270
  115 CONTINUE                                                          COB13280
  118 PL = K-1                                                          COB13290
C  PL IS THE PITCH LENGTH CONTAINING X(J).                              COB13300
C  FIND THE WRAP CROSSINGS IN DX.                                       COB13310
      DO 130 K=1,NK                                                     COB13320
      II=IDAT($IK+K)                                                    COB13330
      JJ=IDAT($JK+K)                                                    COB13340
      DO 130 L=1,6                                                      COB13350
      IF(DATA($XCROS+K+MG*(L-1)))  119,130,119                          COB13360
  119  XC = (ABS(DATA($XCROS+K+MG*(L-1)))+PL)*PITCH                     COB13370
      IF(XC.GT.DATA($X+J).OR.                                           COB13380
     1   XC.LE.DATA($X+JM1))  GO TO 130                                 COB13390
      LDAT($FDIV+K) = .TRUE.                                            COB13400
C  ADD AND SUBSTRACT WIRE WRAPS FROM SUBCHANNEL AT EACH WRAP CROSSING.   COB13410
      IF(DATA($XCROS+K+MG*(L-1)))  120,130,121                          COB13420
  120  IDAT($NWRAP+II)=IDAT($NWRAP+II)+1                                COB13430
      IDAT($NWRAP+JJ)=IDAT($NWRAP+JJ)-1                                 COB13440
      GO TO  123                                                        COB13450
  121  IDAT($NWRAP+II)=IDAT($NWRAP+II)-1                                COB13460
      IDAT($NWRAP+JJ)=IDAT($NWRAP+JJ)+1                                 COB13470
  123 IF(NRAMP.LE.0) GO TO 1000                                         COB13480
      DUMY = FLOAT(ITERAT)/FLOAT(NRAMP)                                 COB13490
      IF(DUMY.GT.1.) DUMY = 1.                                          COB13500
      DATA($W+K+MG*(J-1))=DATA($GAP+K)*PI*(DIA+THICK)*DATA($DUR+K)/DX   COB13510
     1     *DUMY                                                        COB13520
      IF(DATA($XCROS+K+MG*(L-1)))  124,130,125                          COB13530
  124  DATA($W+K+MG*(J-1))=-DATA($W+K+MG*(J-1))*DATA($F+JJ+MC*(J-1))/   COB13540
     1DATA($A+JJ)                                                       COB13550
      DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($FACTO+K)            COB13560
      GO TO  130                                                        COB13570
  125  DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($F+II+MC*(J-1))/    COB13580
     1DATA($A+II)                                                       COB13590
      DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($FACTO+K)            COB13600
  130 CONTINUE                                                          COB13610
      RETURN                                                            COB13620
  200 IF(.NOT.GRID) RETURN                                              COB13630
      DO 230 K=1,NKK                                                    COB13640
      IF(ABS(DATA($FXFLO+K+MG*(NGTYPE-1))).LT.1.0E-10)  GO TO 230       COB13650
C  ZERO FORCED FLOW FRACTION DOES NOT BLOCK THE NATURAL DIVERSION CROSSFCOB13660
      II=IDAT($IK+K)                                                    COB13670
      JJ=IDAT($JK+K)                                                    COB13680
      LDAT($FDIV+K)=.TRUE.                                              COB13690
      IF(NRAMP.LE.0) GO TO 1000                                         COB13700
      DUMY = FLOAT(ITERAT)/FLOAT(NRAMP)                                 COB13710
      IF(DUMY.GT.1.) DUMY = 1.                                          COB13720
      DUMY=DUMY*DATA($FXFLO+K+MG*(NGTYPE-1))/DX                         COB13730
      IF(DUMY.GT.0.)  DATA($W+K+MG*(J-1))=DUMY*DATA($F+II+MC*(J-1))     COB13740
      IF(DUMY.LT.0.)  DATA($W+K+MG*(J-1))=DUMY*DATA($F+JJ+MC*(J-1))     COB13750
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      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),  COB14310
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB14320
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB14330
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB14340
C                                                                       COB14350
C                                                                       COB14360
      LOGICAL  GRID                                                     COB14370
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB14380
C                                                                       COB14390
C                                                                       COB14400
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB14410
     1          $$S   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB14420
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB14430
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB14440
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB14450
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB14460
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB14470
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB14480
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB14490
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB14500
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB14510
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB14520
C                                                                       COB14530
      COMMON  DATA(1)                                                   COB14540
      LOGICAL LDAT(1)                                                   COB14550
      INTEGER IDAT(1)                                                   COB14560
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB14570
C                                                                       COB14580
C                                                                       COB14590
      IF (N+1) 6,4,2                                                    COB14600
    2 IF (DATA($QUAL+I).GT.0.0) GO TO 6                                 COB14610
C     SINGLE PHASE AND ENTRY FROM PROP (N=-1)                           COB14620
    4 RE=DATA($F+I+MC*(JJ-1))/DATA($A+I)*DATA($DHYD+I)/DATA($VISC+I)    COB14630
      IF(RE.LT.2000.) RE = 2000.                                        COB14640
      PR=DATA($CP+I)*DATA($VISC+I)/DATA($CON+I)                         COB14650
C     HCOOL          =0.023*DATA($CON+I)/DATA($DHYD+I)*RE**.8*PR**.4    COB14660
      HCOOL      = 0.134*DATA($CON+I)/DATA($DHYD+I)*RE**.65*PR**.4      COB14670
      RETURN                                                            COB14680
C                                                                       COB14690
C     TWO PHASE AND ENTRY FROM PROP(N=-2)                               COB14700
    6 FI = 3600.0*DATA($QPRIM+I)/DATA($HPERI+I)                         COB14710
      IF(FI.LT.0.) FI=ABS(FI)                                           COB14720
      DTSAT = 0.072*(FI**0.5)*EXP(-PREF/1260.0)                         COB14730
      IF (N.GE.0) GO TO 8                                               COB14740
      HCOOL = DTSAT                                                     COB14750
      RETURN                                                            COB14760
    8 DTTOT = DTSAT + TF - DATA($T+I)                                   COB14770
      HCOOL = FI/(3600.0*DTTOT)                                         COB14780
      RETURN                                                            COB14790
      END                                                               COB14800
      FUNCTION HLIQ(P)                                                  COB14810
C    MEKIN NEW.     AUGUST  1974                                        COB14820
      U=ALOG(P)                                                         COB14830
      IF(P.LE.265.0) GO TO 2                                            COB14840
      U=U-7.0                                                           COB14850
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      HLIQ=(((((-0.58728711D00*U+0.11490811D01)*U+0.74153448D01)*U      COB14860
     1+0.1080109D02)*U+0.13091584D02)*U+0.37492429D02)*U                COB14870
     2+0.16078158D03)*U+0.55715337D03                                   COB14800
      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-0.44206696D02)*U-0.46351642D02)*U               COB15020
     2+0.11876082D04                                                    COB15030
      RETURN                                                            COB15040
2     HVAP=((((((-0.3674D-04*U-0.5662D-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,$SA  ,$SB  ,$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,IB,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)                                       COB15960
  265 IF(.NOT.PRINT(2)) GO TO 270                                       COB15970
      WRITE(I3,28)                                                      COB15980
      DO 266 J=1,4                                                      COB15990
      IF(AA(J).GT.0. .OR. CC(J).GT.0.) WRITE(I3,29)  J,AA(J),BB(J),CC(J)COB16000
  266 CONTINUE                                                          COB16010
      IF(NVISCW.EQ.0) WRITE(I3,61)                                      COB16020
      IF(NVISCW.EQ.1) WRITE(I3,62)                                      COB16030
      WRITE (I3,44)                                                     COB16040
      IF(J2.EQ.0) WRITE(I3,45)                                          COB16050
      IF(J2.EQ.1) WRITE(I3,46)                                          COB16060
      IF(J3.EQ.0) WRITE(I3,47)                                          COB16070
      IF(J3.EQ.1) WRITE(I3,48)                                          COB16080
      IF(J3.EQ.5) WRITE(I3,49) AV(1)                                    COB16090
      IF(J3.EQ.6) WRITE(I3,57) NV,(AV(I),I=1,NV)                        COB16100
      IF(J4.EQ.0) WRITE(I3,58)                                          COB16110
      IF(J4.EQ.1) WRITE(I3,59)                                          COB16120
      IF(J4.EQ.5) WRITE(I3,60) NF,(AF(I),I=1,NF)                        COB16130
  270 IF(.NOT.PRINT(3)) GO TO 275                                       COB16140
      WRITE(I3,6) (Y(I),AXIAL(I),I=1,NAX)                               COB16150
  275 IF(.NOT.PRINT(4)) GO TO 280                                       COB16160
      WRITE(I3,12)                                                      COB16170
      DO 277 I=1,NCHANL                                                 COB16180
      IF((DATA($AC+I).LT.9.99).AND.                                     COB16190
     1   (DATA($PW+I).LT.9.99))  GO TO 276                              COB16200
      WRITE(I3,1003)  I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),         COB16210
     1    DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),                COB16220
     2    DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)          COB16230
      GO TO 277                                                         COB16240
  276 WRITE(I3,1004)  I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),         COB16250
     1    DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),                COB16260
     2    DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)          COB16270
  277 CONTINUE                                                          COB16280
  280 IF(NAXL  .LT.1) GO TO 285                                         COB16290
      IF(.NOT.PRINT(5)) GO TO 285                                       COB16300
      N=1                                                               COB16310
      NN=10                                                             COB16320
      DO 284 LL=1,4                                                     COB16330
      IF(NN.GT.NAFACT) NN = NAFACT                                      COB16340
      WRITE (I3,19) (H1,NCH(J),H3,J=N,NN)                               COB16350
      DO 283 I=1,NAXL                                                   COB16360
  283 WRITE(I3,38) AXL(I), (AFACT(J,I),J=N,NN)                          COB16370
      N=N+10                                                            COB16380
      NN=NN+10                                                          COB16390
      IF(N.GE.NAFACT) GO TO 285                                         COB16400
  284 CONTINUE                                                          COB16410
  285 IF(NGXL .LT.1) GO TO 290                                          COB16420
      IF(.NOT.PRINT(6)) GO TO 290                                       COB16430
      N = 1                                                             COB16440
      NN= 10                                                            COB16450
      DO 289 LL = 1,6                                                   COB16460
      IF(NN.GT.NGAPS) NN=NGAPS                                          COB16470
      DO 286 M=N,NN                                                     COB16480
      K = NGAP(M)                                                       COB16490
      IM(M)=IDAT($IK+K)                                                 COB16500
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 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.                                           COB17060
  302  CONTINUE                                                         COB17070
  305 IF(.NOT.PRINT(9)) GO TO 310                                       COB17080
      WRITE(I3,18) KIJ,FTM,SL,ZZ,THETA,NDX,DXX,NDT,TTIME,DT,NTRIES,     COB17090
     1 FERROR                                                           COB17100
  310 IF(IFRM.EQ.0.AND.IHTM.EQ.0) GO TO 307                             COB17110
      WRITE(I3,17) EPSF                                                 COB17120
  307 IF(.NOT.PRINT(10))GO TO 315                                       COB17130
      WRITE(I3,35)                                                      COB17140
      IF(NSCBC.LT.1) WRITE(I3, 32) ABETA                                COB17150
      IF(NSCBC.EQ.1) WRITE(I3, 33) ABETA, BBETA                         COB17160
      IF(NSCBC.EQ.2) WRITE(I3, 34) ABETA, BBETA                         COB17170
      IF(NSCBC.EQ.3) WRITE(I3,39) ABETA, BBETA                          COB17180
      IF (NSCBC.EQ.4) WRITE(I3,41)                                      COB17190
      IF(NBBC-1) 311,311,312                                            COB17200
  311 IF (NSCBC.NE.4) WRITE(I3,36)                                      COB17210
      GO TO 314                                                         COB17220
  312 WRITE (I3,37) (XQUAL(I),BX(I),I=1,NBBC)                           COB17230
  314 IF(J5.EQ.1) WRITE(I3,65) GK                                       COB17240
  315 IF(.NOT.PRINT(11)) GO TO 318                                      COB17250
      WRITE(I3,21) PEXIT,HIN,GIN,TIN,AFLUX                              COB17260
      IF(IN.EQ.0) WRITE(I3,87)                                          COB17270
      IF(IN.EQ.1) WRITE(I3,88)                                          COB17280
      IF(IN.EQ.2) WRITE(I3,89)                                          COB17290
      IF(IN.EQ.3) WRITE(I3,90)                                          COB17300
      IF(IG.EQ.0) WRITE(I3,91)                                          COB17310
      IF(IG.EQ.1) WRITE(I3,92)                                         \COB17320
      IF(IG.EQ.2) WRITE(I3,93)                                          COB17330
      IF(NP.GT.1) WRITE(I3,83) (YP(I),FP(I),I=1,NP)                     COB17340
      IF(NH.GT.1) WRITE(I3,84) (YH(I),FH(I),I=1,NH)                     COB17350
      IF(NG.GT.1) WRITE(I3,85) (YG(I),FG(I),I=1,NG)                     COB17360
      IF(NQ.GT.1) WRITE(I3,86) (YQ(I),FQ(I),I=1,NQ)                     COB17370
  318 IF(KDEBUG) 400,400,319                                            COB17380
  319  WRITE(I3,50)  ((IDAT($LC+I+MC*(L-1)),I=1,NCHANL),L=1,4)          COB17390
       WRITE(I3,50)   (IDAT($IK+K),IDAT($JK+K),K=1,NK)                  COB17400
       WRITE(I3,51)  (DATA($FACTO+K),K=1,NK)                            COB17410
       WRITE(I3,50) ((IDAT($LR+NR+MR*(L-1)),NR=1,NROD),L=1,6)           COB17420
       WRITE(I3,51) ((DATA($PWRF+I+MC*(NR-1)),NR=1,NROD),I=1,NCHANL)    COB17430
       WRITE(I3,51)  (DATA($D+NR)            ,NR=1,NROD),               COB17440
     1               (DATA($RADIA+NR)        ,NR=1,NROD)                COB17450
  400 CONTINUE                                                          COB17460
      RETURN                                                            COB17470
C                                                                       COB17480
    6 FORMAT (23H0HEAT FLUX DISTRIBUTION  /23H  X/L     RELATIVE FLUX / COB17490
     1(F7.3,F12.3))                                                     COB17500
   12 FORMAT(22H0SUBCHANNEL INPUT DATA  /                               COB17510
     1109H CHANNEL    TYPE   AREA   WETTED    HEATED    HYDRAULIC    (ADJCOB17520
     2ACENT CHANNEL NO., SPACING, CENTROID DISTANCE)        /           COB17530
     3 55H   NO.            (SQ-IN) PERIM.    PERIM.    DIAMETER      / COB17540
     4 25X,                        30H (IN)      (IN)       (IN)      /)COB17550
   13 FORMAT(22H0FLUID PROPERTY TABLE ,/,                               COB17560
     1 60H     P          T         VF         VG         HF         HG COB17570
     1 30H  VISC.        KF       SIGMA    ,/,                          COB17580
     1 (F8.1,F10.2,F8.5,F12.5,2F10.2,3F10.5))                           COB17590
   15 FORMAT(15H0ROD INPUT DATA  /    96H   ROD  TYPE  DIA  RADIAL POWER COB17600
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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(20I5)                                                      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 40H      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          30H      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    UNIFORM 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)))              COB18710
 1004 FORMAT(I5,I7,4F10.6,4X,4(1H(I3,1H,F5.3,1H,F5.3,1H)))              COB18720
      END                                                                COB18730
      SUBROUTINE ITHO(NTHBOX,NTHBXX,ND1X,ND2X)                           COB18740
C                                                                        COB18750
C                                                                        COB18760
      IMPLICIT INTEGER ($)                                               COB18770
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB18780
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB18790
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB18800
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB18810
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB18820
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB18830
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB18840
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB18850
     8   UF    ,VF    ,VFG   ,VG    ,Z                                   COB18860
C                                                                        COB18870
      LOGICAL  GRID                                                      COB18880
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                COB18890
C                                                                        COB18900
      DIMENSION NTHBOX(25,25)                                            COB18910
      DIMENSION CARD(20)                                                 COB18920
C                                                                        COB18930
C     CONTROL FOR THERMAL-HYDRAULIC INPUT DATA                           COB18940
C                                                                        COB18950
C     WRITE (I3,1001)                                                    COB18960
C     WRITE(I3,1002)                                                     COB18970
      CALL CHAN(1,NTHBOX,NTHBXX,ND1X,ND2X,CARD)                          COB18980
      CALL MODEL(1,CARD,IPILE)                                           COB18990
      CALL OPERA(1,CARD)                                                 COB19000
      CALL FIZPRP(1,NPROP)                                               COB19010
      CALL TABLES(CARD)                                                  COB19020
      WRITE(I3,1002)                                                     COB19030
      CALL CORE3                                                         COB19040
      IF (IERROR.EQ.0) GO TO 2                                           COB19050
      WRITE (I3,1004)                                                    COB19060
      RETURN                                                             COB19070
C                                                                        COB19080
    2 CONTINUE                                                           COB19090
      WRITE (I3,1003)                                                    COB19100
      CALL OPERA(2,CARD)                                                 COB19110
      CALL CHAN(2,NTHBOX,NTHBXX,ND1X,ND2X,CARD)                          COB19120
      CALL MODEL(2,CARD,IPILE)                                           COB19130
      CALL FIZPRP(2,NPROP)                                               COB19140
      RETURN                                                             COB19150
C                                                                        COB19160
 1001 FORMAT(1H1, 42X, 'THERMAL - HYDRAULIC INPUT DATA', /, 43X,         COB19170
     1 '------------------------------', ////, '  CARD IMAGES', /, 2X,   COB19180
     2 '---- ------')                                                    COB19190
 1002 FORMAT(32X, '0....*....1....*....2....*....3....*....4....*....5..COB19200
     1..*....6....*....7....*....8')                                     COB19210
 1003 FORMAT(1H1, 42X, 'PROCESSED INPUT DATA', /, 43X,                   COB19220
     1 '--------------------', /, '  * = SET IN NEUTRONICS (CARD20)',    COB19230
     2 ///)                                                              COB19240
 1004 FORMAT('  ERROR SIGNAL IN ITHO')                                   COB19250
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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          $SS   ,$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,$SA   ,$SB   ,$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)                              COB19810
      DAVG=4.*ABAR/PBAR                                                 COB19820
      GAVG=FBAR/ABAR                                                    COB19830
      XAVG = 0.                                                         COB19840
      IF(AMAX1(DATA($QUAL+II),DATA($QUAL+JJ)).GT.0.) XAVG=0.5*QBAR      COB19850
      IF(XAVG.GT.0..AND.NBBC.GE.2) GO TO 80                             COB19860
      UAVG=0.5*VBAR                                                     COB19870
      IF(NSCBC.GE.1) RE =  GAVG*DAVG/UAVG                               COB19880
      IF(NSCBC.EQ.0) DATA($WP+K)=DATA($GAP+K)*GAVG*ABETA                COB19890
      IF(NSCBC.EQ.1) DATA($WP+K)=DATA($GAP+K)*GAVG*ABETA*RE**BBETA      COB19900
      IF(NSCBC.EQ.2) DATA(3WP+K)=DAVG        *GAVG*ABETA*RE**BBETA      COB19910
      IF(NSCBC.EQ.3.AND.DATA($LENGT+K).LE.0.)  GO TO 1000               COB19920
      IF(NSCBC.EQ.3) DATA($WP+K)=DATA($GAP+K)/DATA($LENGT+K)*DAVG*GAVG  COB19930
     1     *ABETA*RE**BBETA                                             COB19940
      IF(NSCBC.EQ.4) GO TO 50                                           COB19950
      DATA($WP+K)=DATA($WP+K)*DATA($FACTO+K)                            COB19960
      GO TO 100                                                         COB19970
CC    BEUS MIXING MODEL USED WHEN NSCBC=4                               COB19980
   50 WL=0.0035*UAVG*RE**0.9                                            COB19990
      ARBAR=ABAR*0.5                                                    COB20000
      B1=0.04*(DATA($GAP+K)/DAVG)**1.5                                  COB20010
      XC=(0.4/GAVG*SQRT(32.2*RHOF*DAVG*(RHOF-RHOG))+0.6)/(SQRT(RHOF     COB20020
     1  /RHOG)+0.6)                                                     COB20030
CC    SLIP RATIO, GAM, BASED ON SMITH CORRELATION                       COB20040
      GAM=1.                                                            COB20050
      IF(XAVG.LE.0.) GO TO 52                                           COB20060
      ALP=1./(1.+0.4*RHOG/RHOF*(1./XAVG-1.)+(1.-0.4)*RHOG/RHOF*(1.      COB20070
     1  /XAVG-1.)*SQRT((RHOF/RHOG+0.4*(1./XAVG-1.))/(1.+0.4*(1./XAVG    COB20080
     2  -1.))))                                                         COB20090
      GAM=XAVG/(1.-XAVG)*(1.-ALP)/ALP*RHOF/RHOG                         COB20100
      IF(XAVG.GT.XC) GO TO 55                                           COB20110
   52 DATA($WP+K)=WL+B1*ARBAR*GAVG/DAVG*RHOF/RHOG*(GAM-1.)/GAM*XAVG     COB20120
      GO TO 100                                                         COB20130
   55 XOXC=0.57*RE**0.0417                                              COB20140
      TK=0.5556*(TF+459.67)                                             COB20150
      VISCG=0.672*VISVP(TK)                                             COB20160
      WG=0.0035*VISCG*(GAVG*GAM*DAVG/VISCG)**0.9                        COB20170
      WC=WL+B1*ARBAR*GAVG/DAVG*RHOF/RHOG*(GAM-1.)/GAM*XC                COB20180
      DATA($WP+K)=(WG+(WC-WG)*((1.-XOXC)/(XAVG/XC-XOXC)))*DATA($FACTO+K)COB20190
      GO TO 100                                                         COB20200
   80 CALL CURVE (XBETA,XAVG,BX,XQUAL,NBBC,IERROR,1)                    COB20210
      IF(IERROR.GT.1) GO TO 1000                                        COB20220
      DATA($WP+K)=             GAVG*DAVG*XBETA *DATA($FACTO+K)          COB20230
  100 IF(J5.EQ.0) GO TO 240                                             COB20240
      CAVG=0.5*(DATA($CON+II)+DATA($CON+JJ))                            COB20250
      IF(DATA($LENGT+K).LE.0.0)  GO TO 1000                             COB20260
      DATA($COND+K)=CAVG*DATA($GAP+K)/DATA($LENGT+K)*GK*DATA($FACTO+K)  COB20270
  240 CONTINUE                                                          COB20280
      RETURN                                                            COB20290
 1000 IERROR = 4                                                        COB20300
      RETURN                                                            COB20310
      END                                                               COB20320
      SUBROUTINE OPERA(IPART,CARD)                                      COB20330
C                                                                       COB20340
C                                                                       COB20350
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      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), BB(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  ,$AC   ,SALPHA,$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 ,$GAFS ,$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,$SA  ,$SB   ,$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,IB,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 (IMCKIN.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))               COB22010
 1031 FORMAT (/, 38H   FORCING FUNCTION FOR HEAT FLUX     /               COB22020
     1        38H      TIME   HEAT FLUX                /                  COB22030
     2        23H     (SEC)      FACTOR   /  (F10.4,F13.4))               COB22040
 1040 FORMAT('  INPUT DATA ERROR. NDX OR Z .LT.0.  STOP (OPERA)')         COB22050
      END                                                                 COB22060
      SUBROUTINE PRECAL                                                   COB22070
C                                                                         COB22080
C                                                                         COB22090
      IMPLICIT INTEGER ($)                                                COB22100
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB22110
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB22120
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB22130
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB22140
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHANL,NCHF  ,NDX   ,NF    ,COB22150
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB22160
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB22170
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB22180
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB22190
C                                                                         COB22200
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),      COB22210
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),     COB22220
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),   COB22230
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),        COB22240
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),         COB22250
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                       COB22260
C                                                                         COB22270
C                                                                         COB22280
      LOGICAL  GRID                                                       COB22290
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                 COB22300
C                                                                         COB22310
C                                                                         COB22320
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB22330
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB22340
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB22350
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB22360
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB22370
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB22380
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB22390
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB22400
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB22410
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB22420
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB22430
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA   ,$SB   ,$XPOLD COB22440
C                                                                         COB22450
      COMMON  DATA(1)                                                     COB22460
      LOGICAL LDAT(1)                                                     COB22470
      INTEGER IDAT(1)                                                     COB22480
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                              COB22490
C                                                                         COB22500
C                                                                         COB22510
      COMMON/LINK3/DXX,ETIME,GIN,HIN,IB,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,    COB22520
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,    COB22530
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ               COB22540
C                                                                         COB22550
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C     PREPARE TO START CALCULATION (IN CALC)                            COB22560
      CALL PROP(1,1)                                                    COB22570
      IF (IERROR.GT.0) GO TO 20                                         COB22580
      NDXP1 = NDX + 1                                                   COB22590
      DX = Z/FLOAT(NDX)                                                 COB22600
      DXX = DX*12.0                                                     COB22610
      DT = 0.0                                                          COB22620
      IF ( (NDT.GT.0) .AND. (TTIME.LE.0.0) ) NDT=0                      COB22630
      IF (NDT.GT.0) DT = TTIME/FLOAT(NDT)                               COB22640
      SAVEDT = DT                                                       COB22650
C     SET HINLET                                                        COB22660
      HIN = DATA($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                                                   COR22830
      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          $SS    ,$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,$SA   ,$SB   ,$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 TABLECOB23500
     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))               COB23660
      VF    =    VVF(I-1) + VALUE*(   VVF(I)-   VVF(I-1))               COB23670
      VG    =    VVG(I-1) + VALUE*(   VVG(I)-   VVG(I-1))               COB23680
      UF    =    UUF(I-1) + VALUE*(   UUF(I)-   UUF(I-1))               COB23690
      TF    =     TT(I-1) + VALUE*(    TT(I)-    TT(I-1))               COB23700
      KF    =    KKF(I-1) + VALUE*(   KKF(I)-   KKF(I-1))               COB23710
      SIGMA = SSIGMA(I-1) + VALUE*(SSIGMA(I)-SSIGMA(I-1))               COB23720
      HFG = HG-HF                                                       COB23730
      VFG = VG-VF                                                       COB23740
      RHOG = 1./VG                                                      COB23750
      RHOF = 1./VF                                                      COB23760
      RETURN                                                            COB23770
C                                                                       COB23780
C  PART 2, CALCULATE LIQUID PROPERTIES AND PARAMETERS                   COB23790
  100 NCHAN = NCHANL                                                    COB23800
      IF(J.GT.1) GO TO 102                                              COB23810
      DO 101 I=1,NCHAN                                                  COB23820
 101  IDAT($JBOIL+I)=0                                                  COB23830
  102 DO 150 I=1,NCHAN                                                  COB23840
      DATA($VISCW+I)=UF                                                 COB23850
      DATA($VISC +I)=UF                                                 COB23860
      DATA($T     +I)=TF                                                COB23870
      DATA($CON   +I)=KF                                                COB23880
      DATA($V     +I)=VF                                                COB23890
      HH=DATA($H+I+MC*(J-1))                                            COB23900
      IF(HH.GT.HF) GO TO 105                                            COB23910
      CALL CURVE(DATA($VISC+I),HH,UUF,HHF,NPROP,IERROR,1)               COB23920
      IF(IERROR.GT.1) GO TO 1000                                        COB23930
      CALL CURVE(DATA($V    +I),HH,VVF,HHF,NPROP,IERROR,2)              COB23940
      CALL CURVE(DATA($T    +I),HH,TT ,HHF,NPROP,IERROR,2)              COB23950
      CALL CURVE(DATA($CON +I),HH,KKF,HHF,NPROP,IERROR,2)               COB23960
 105  TM=DATA($T     +I)-1.                                             COB23970
      CALL CURVE (HM,TM,HHF,TT,NPROP,IERROR,1)                          COB23980
      IF(IERROR.GT.1) GO TO 1000                                        COB23990
      DATA($CP+I)=HH-HM                                                 COB24000
      IF(HH.GT.HF)  DATA($CP+I)=HF-HM                                   COB24010
      DATA($VISC +I)=DATA($VISC +I)/3600.                               COB24020
      DATA($CON  +I)=DATA($CON  +I)/3600.                               COB24030
      RE=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($DHYD+I)/DATA($VISC+I)     COB24040
      IF(RE.LT.0.) WRITE(I3,1) I,J,RE,DATA($F+I+MC*(J-1)),DATA($VISC+I) COB24050
      IF(RE.LT.2000.) RE = 2000.                                        COB24060
      PR=DATA($CP+I)*DATA($VISC+I)/DATA($CON+I)                         COB24070
      IF(DATA($H+I+MC*(J-1)).GT.HF.AND.IDAT($JBOIL+I).NE.0)             COB24080
     1    GO TO 120                                                     COB24090
      IF(IHTM.NE.0.AND.J.NE.1) GO TO 108                                COB24100
C     DATA($HFILM+I)=0.023*DATA($CON+I)/DATA($DHYD+I)*RE**.8*PR**.4     COB24110
      DATA($HFILM+I) = HCOOL(-1,I,J)                                    COB24120
      DTWALL=DATA($QPRIM+I)/DATA($HPERI+I)/DATA($HFILM+I)               COB24130
C  DETERMINE THE START OF NUCLEATE BOILING                              COB24140
      IF(IDAT($JBOIL+I).GT.0)     GO TO 106                             COB24150
      IF(DATA($QPRIM+I).LT.0.0)  GO TO 106                              COB24160
C     TLBOIL=TF-DTWALL+60.*EXP(-PREF/900.)*(DATA($QPRIM+I)/             COB24170
      TLBOIL=TF-DTWALL+ HCOOL(-2,I,J)                                   COB24180
      IF(DATA($T+I).GE.TLBOIL.AND.NCHF.NE.4) IDAT($JBOIL+I)=J           COB24190
      IF(NCHF.EQ.4.AND.DATA($H+I+MC*(J-1)).GE.HF) IDAT($JBOIL+I)=J      COB24200
```

```
  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(!DAT($JBOIL+I).NE.0) GO TO 112                                 COB24340
      IF(TWALL.GE.TF.AND.NCHF.NE.4) IDAT($JBOIL+I)=J                    COB24350
      IF(DATA($M+I+MC*(J-1)).GE.HF.AND.NCHF.EQ.4) IDAT($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($VISC+I))**0.6-1.0))                    COB24470
  150 CONTINUE                                                          COB24480
      RETURN                                                            COB24490
  200 WRITE(13,6) PREF,PP                                               COB24500
      GO TO 1001                                                        COB24510
  210 WRITE(13,5) PREF,PP                                               COB24520
      GO TO 1001                                                        COB24530
 1000 WRITE(13,7)                                                       COB24540
 1001 IERROR = 11                                                       COB24550
      RETURN                                                            COB24560
      END                                                               COB24570
      SUBROUTINE QPR3(NCHANL,   IKASE,TEXT,DATE,TIME,X)                 COB24580
C                                                                       COB24590
C                                                                       COB24600
      IMPLICIT INTEGER ($)                                              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),
     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,$IK   ,$JDOIL,$JK   ,$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,$SA   ,$SB   ,$XPOLD
C
       COMMON/LINK3/DXX,ETIME,GIN,HIN,IB,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ
       COMMON  DATA(1)
       LOGICAL LDAT(1)
       INTEGER IDAT(1)
       EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
       DIMENSION  JB(10),TEXT(17),DATE(2),TIME(3),X(1)
C
       READ (12,700) ZM
       WRITE (13,1000) ZM
       IF (ZM.GE.0.0) GO TO 505
       IF (ZM.LT.-1.01) GO TO 500
       ZM = 3413.0/3.6
       GO TO 505
  500  ZM = 1000.0/3.6
  505  WRITE (13,1001) ZM
       NDXP1=NDX+1
       DO 601 I=1,NCHANL
  601  READ(12,700)  (DATA($QF+I+MC*(J-1)),J=2,NDXP1)
       IF(IQP3.EQ.0) GO TO 705
       DO 602 I=1,NCHANL
  602  READ(12,700)  (DATA($QC+I+MC*(J-1)),J=2,NDXP1)
  705  CONTINUE
C
C      PRINT INPUT FUEL NODAL POWERS
       WRITE(13,650)
       DO 621 I=1,NCHANL,10
       DO 5 K=1,10
     5 JB(K)=I+K-1
       II=I+9
       IF(NCHANL.LE.II) II=NCHANL
```

```
      L=II-I+1                                                          COB25310
      WRITE(13,655) (JB(K),K=1,L)                                       COB25320
      DO 621 J=1,NDX                                                    COB25330
      WRITE(13,30) 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(13,660)                                                     COB25490
      DO 622 I=1,NCHANL,10                                              COB25500
      CC 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(13,655) (JB(K),K=1,L)                                       COB25560
      DO 622 J=1,NDX                                                    COB25570
      WRITE(13,30) 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($RADIA+I)*WV                                COB25720
      WRITE (13,1004) (DATA($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 (13,1002) SUMF1,SUMF, SUMC1,SUMC, SUMT1,SUMT                COB25810
      AFLUX = SUMT1*3.413/(PHTOT*Z)                                     COB25820
      WRITE(13,1003) AFLUX                                              COB25830
      RETURN                                                            COB25840
C                                                                       COB25850
```

```
   30 FORMAT(I5, 2X, 10F10.5)                                          COB25860
  650 FORMAT( //,'  HEAT GENERATION IN    FUEL')                       COB25870
  655 FORMAT(//, '  NODE  ROD', I4, I9, 8I10, /)                       COB25880
  660 FORMAT( //,'  HEAT GENERATION IN COOLANT')                       COB25890
  700 FORMAT(8E10.0)                                                   COB25900
 1000 FORMAT(1H1,     ' READ NODAL POWERS IN SUBROUTINE QPR3 AND MULTIPLYCOB25910
     1 GIVEN VALUES BELOW BY ZM', //, '  ZM GIVEN AS', F10.4, 7X,      COB25920
     2 '(.GE.0.0  USED AS MULTIPLIER TO CONVERT TO BTU/SEC)', /, 30X,  COB25930
     3 '(.EQ.-1.0 TO CONVERT MW TO BTU/SEC)', /, 30X,                  COB25940
     4 '(.EQ.-2.0 TO CONVERT MBTU/HR TO BTU/SEC)' )                    COB25950
 1001 FORMAT(/, '  ZM TAKEN TO BE ', F11.5)                            COB25960
 1002 FORMAT(/, '  POWER IN FUEL    = ',  F9.2, ' MW  IE ', F9.2,      COB25970
     1 ' KBTU/SEC', /, 8X, 'IN COOLANT = ', F9.2 , ' MW  IE ', F9.2,   COB25980
     2 ' KBTU/SEC', /, 8X, 'TOTAL      = ', F9.2,  ' MW  IE ', F9.2,   COB25990
     3 ' KBTU/SEC')                                                    COB26000
 1003 FORMAT(/, '  AVERAGE HEAT FLUX = ', F10.4, ' MBTU/SQFT.HR')      COB26010
 1004 FORMAT(//, '  RADIAL POWER FACTORS FOR EACH CHANNEL', /,         COB26020
     1 (6X, 10F10.4, 22X) )                                            COB26030
      END                                                              COB26040
      SUBROUTINE READIN(IVAR,N,A,B,CARD,M)                             COB26050
      DIMENSION A(1),B(1),CARD(20)                                     COB26060
C                                                                      COB26070
C     READ AND PRINT CARD IMAGES.                                      COB26080
C     IVAR IDENTIFIES A, B AND THUS PRINTING                           COB26090
C     IF M=1, READ (A(I),I=1,N).     M=2, READ (A(I),B(I),I=1,N)  16E5.0COB26100
C                                                                      COB26110
      IDI = 14/M                                                       COB26120
      IVMAX = 9                                                        COB26130
      DO 20 I=1,N,IDI                                                  COB26140
      II = I + IDI-1                                                   COB26150
      IF (II.GT.N) II=N                                                COB26160
      IF (M.EQ.1) READ (5,1000) CARD, (A(L),L=I,II)                    COB26170
      IF (M.EQ.2) READ (5,1000) CARD, (A(L),B(L),L=I,II)               COB26180
      IF (I.GT.1) GO TO 11                                             COB26190
      IF ( (IVAR.LT.1) .OR. (IVAR.GT.IVMAX) ) GO TO 30                 COB26200
      GO TO (1,2,3,4,5,6,7,8,9), IVAR                                  COB26210
    1 WRITE (6,1001) CARD                                              COB26220
      GO TO 20                                                         COB26230
    2 WRITE (6,1002) CARD                                              COB26240
      GO TO 20                                                         COB26250
    3 WRITE (6,1003) CARD                                              COB26260
      GO TO 20                                                         COB26270
    4 WRITE (6,1004) CARD                                              COB26280
      GO TO 20                                                         COB26290
    5 WRITE (6,1005) CARD                                              COB26300
      GO TO 20                                                         COB26310
    6 WRITE (6,1006) CARD                                              COB26320
      GO TO 20                                                         COB26330
    7 WRITE (6,1007) CARD                                              COB26340
      GO TO 20                                                         COB26350
    8 WRITE (6,1008) CARD                                              COB26360
      GO TO 20                                                         COB26370
    9 WRITE (6,1009) CARD                                              COB26380
      GO TO 20                                                         COB26390
   11 WRITE (6,1011) CARD                                              COB26400
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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
     1-0.369450D-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
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      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),SSICMA(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          $$3   ,$A    ,$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    ,$HFILM,SHINLE,SHOLD ,$HPERI,$IDARE,COB27290
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB27300
     6   SMCHFR,SMCFRC,SMCFRR,SNTYPE,SNWRAP,SNWRPS,$P    ,$PERIM,$PH   ,COB27310
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB27320
     8   $QUAL ,$RADIA,SRHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB27330
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB27340
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA   ,$SB   ,$XPOLD COB27350
C                                                                       COB27360
      COMMON  DATA(1)                                                   COB27370
      LOGICAL LDAT(1)                                                   COB27380
      INTEGER IDAT(1)                                                   COB27390
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB27400
C                                                                       COB27410
C                                                                       COB27420
      S = 0.                                                            COB27430
      IF(I.EQ.IDAT($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
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```
      XX=ALOG(P)                                                        COB27510
      U=DBLE(XX)                                                        COB27520
      IF(P.LE.450.0) GO TO 2                                            COB27530
      U=U-7.0D0                                                         COB27540
      XATTEM=((((-0.16074225D-00*U-0.69678576D0)*U+0.61781119D0)*U      COB27550
     1+0.14657783D02)*U+0.12405875D03)*U+0.55599496D03                  COB27560
      SATTEM=SNGL(XATTEM)                                               COB27570
      RETURN                                                            COB27580
    2 XATTEM=(((-0.190D-05*U+0.1405D-04)*U-3.265D-5)*U+                 COB27590
     1 2.3907D-3)                                                       COB27600
      XATTEM=(((XATTEM*U+0.434618D-02)*U+0.17363004D0)*U+0.22808149D01) COB27610
      XATTEM=((XATTEM*U+0.33446776D02)*U+0.10182494D3)                  COB27620
      SATTEM=SNGL(XATTEM)                                               COB27630
      RETURN                                                            COB27640
      END                                                               COB27650
      SUBROUTINE SOLVE(NN,LMAX,MID,UL,X,B,NK)                           COB27660
      DIMENSION UL(NK,1),X(1),B(1)                                      COB27670
C     STORE DIAGONAL BAND OF AAA MATRIX.   POSITION (K,L) IN SQUARE     COB27680
C     ARRAY BECOMES (K,(MID-K+L) ) IN NEW ARRAY.                        COB27690
      N = NN                                                            COB27700
      IF(N.EQ.1) GO TO 5                                                COB27710
      NP1 = N+1                                                         COB27720
C                                                                       COB27730
      X(1) = B(1)                                                       COB27740
      DO 2 I = 2,N                                                      COB27750
      IM1 = I-1                                                         COB27760
      SUM = 0.0                                                         COB27770
      JMIN = MAX0(1,(I-MID+1) )                                         COB27780
C  DOUBLE PRECISION MAY BE REQUIRED FOR INNER LOOP.                     COB27790
      DO 1 J = JMIN,IM1                                                 COB27800
      JJ = MID-I+J                                                      COB27810
    1 SUM = SUM + UL(I,JJ)*X(J)                                         COB27820
    2 X(I) = B(I) - SUM                                                 COB27830
C                                                                       COB27840
      X(N) = X(N)/UL(N,MID)                                             COB27850
      DO 4 IBACK = 2,N                                                  COB27860
      I = NP1-IBACK                                                     COB27870
C        I GOES (N-1),...,1                                             COB27880
      IP1 = I+1                                                         COB27890
      SUM = 0.0                                                         COB27900
C  DOUBLE PRECISION MAY BE REQUIRED FOR INNER LOOP.                     COB27910
      JMAX = MIN0(N,(I+MID-1) )                                         COB27920
      DO 3 J = IP1,JMAX                                                 COB27930
      JJ = MID-I+J                                                      COB27940
    3 SUM = SUM + UL(I,JJ)*X(J)                                         COB27950
    4 X(I) = (X(I)-SUM)/UL(I,MID)                                       COB27960
      RETURN                                                            COB27970
    5 X(1) = B(1)/UL(1,MID)                                             COB27980
      RETURN                                                            COB27990
      END                                                               COB28000
      SUBROUTINE SPLIT                                                  COB28010
C   THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THECOB28020
C   MAJOR SUBROUTINES OF COBRA-IIIC.                                    COB28030
C                                                                       COB28040
C                                                                       COB28050
```

```
      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          $SS   ,$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,$SA   ,$SB   ,$XPOLD COB28400
C                                                                       COB28410
      COMMON  DATA(1)                                                   COB28420
      LOGICAL LDAT(1)                                                   COB28430
      INTEGER IDAT(1)                                                   COB28440
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB28450
C                                                                       COB28460
C                                                                       COB28470
      EQUIVALENCE (NCHAN,NCHANL)                                        COB28480
C  CORRECT FLOW ESTIMATE BY ITERATION. THIS PROCEDURE ASSUMES THERE IS NCOB28490
C  DENSITY CHANGE WITH LENGTH AND THAT NO DIVERSION CROSSFLOW IS OCCURRICOB28500
C  CONVERGENCE TOLERANCE IS E.                                          COB28510
      E=0.005                                                           COB28520
      SAVEDT = DT                                                       COB28530
      DT = 1.E+10                                                       COB28540
      DO 10 I=1,NCHANL                                                  COB28550
      DATA($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($F+I)        COB28760
      IF(FIM.GT.0.) DELTAF = DELTAF*0.5                                 COB28770
      FSAVE     =DATA($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+6.0525E-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,$SA   ,$SB   ,$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                                             COB29710
      HGAP1 = 1./(1./HGAP(J) + TCLAD(J)/KCLAD(J))                       COB29720
      QCLAD = 0.                                                        COB29730
C  J IS THE FUEL TYPE CODE.  CYLINDERICAL FUEL, J=1.  PLATE FUEL, J=2.  COB29740
      IF(J.EQ.2) GO TO 101                                              COB29750
C                                                                       COB29760
C  THIS SECTION FOR CYLINDRICAL FUEL RODS.                              COB29770
      QFUEL=DATA($FLUX+N+MR*(JJ-1))*4.*DATA($D+N)/DFUEL(J)**2           COB29780
      DO 100 I=1,NP1                                                    COB29790
      IF(I.GT.1) GO TO 10                                               COB29800
      A(2,I) = RCFUEL + 4.*KFDR2                                        COB29810
      A(3,I) = -4.*KFDR2                                                COB29820
      GO TO 80                                                          COB29830
   10 IF(I.GT.NM1) GO TO 20                                             COB29840
      A(1,I) = -KFDR2*(1.-1./FLOAT(2*I-2))                              COB29850
      A(2,I) = RCFUEL + 2.*KFDR2                                        COB29860
      A(3,I) = -KFDR2*(1.+1./FLOAT(2*I-2))                              COB29870
      GO TO 80                                                          COB29880
   20 IF(I.EQ.NP1) GO TO 30                                             COB29890
      A(1,I) = -2.*KFDR2                                                COB29900
      A(2,I) = RCFUEL + 2.*KFDR2 + 2.*HGAP1/DR + HGAP1/DR/FLOAT(I-1)    COB29910
      A(3,I) = -(2.*HGAP1/DR + HGAP1/DR/FLOAT(I-1))                     COB29920
      GO TO 80                                                          COB29930
 30   A(1,I)=-HGAP1/TCLAD(J)*DFUEL(J)/DATA($D+N)                        COB29940
      A(2,I)= RCLAD(J)*CCLAD(J)/DT+HGAP1/TCLAD(J) * DFUEL(J)/DATA($D+N) COB29950
     1 + HSURF/TCLAD(J)                                                 COB29960
   80 IF(I.EQ.NP1) GO TO 90                                             COB29970
      B(I) = QFUEL + RCFUEL*T(I)                                        COB29980
      GO TO 100                                                         COB29990
   90 B(I) = QCLAD + RCLAD(J)*CCLAD(J)/DT*T(I) + HSURF/TCLAD(J)*TFLUID  COB30000
  100 CONTINUE                                                          COB30010
C     SOLVE FOR TEMPERATURES                                            COB30020
      CALL GAUSS(1,NP1,A,B,T)                                           COB30030
      RETURN                                                            COB30040
C                                                                       COB30050
C  THIS SECTION FOR FLAT PLATE FUEL.                                    COB30060
  101 QFUEL=DATA($FLUX+N+MR*(JJ-1))*2./DFUEL(J)                         COB30070
      DO 200 I=1,NP1                                                    COB30080
      IF(I.GT.1) GO TO 110                                              COB30090
      A(2,I) = RCFUEL + KFDR2*2.                                        COB30100
      A(3,I) = -2.*KFDR2                                                COB30110
      GO TO 180                                                         COB30120
  110 IF(I.GT.NM1) GO TO 120                                            COB30130
      A(1,I) = -KFDR2                                                   COB30140
      A(2,I) = RCFUEL + 2.*KFDR2                                        COB30150
      A(3,I) = -KFDR2                                                   COB30160
      GO TO 180                                                         COB30170
  120 IF(I.EQ.NP1) GO TO 130                                            COB30180
      A(1,I) = -2.*KFDR2                                                COB30190
      A(2,I) = RCFUEL + 2.*KFDR2 + 2.*HGAP1/DR                          COB30200
      A(3,I) = -2.*HGAP1/DR                                             COB30210
      GO TO 180                                                         COB30220
  130 A(1,I) = -HGAP1/TCLAD(J)                                          COB30230
      A(2,I) =  RCLAD(J)*CCLAD(J)/DT + HGAP1/TCLAD(J) + HSURF/TCLAD(J)  COB30240
  180 IF(I.EQ.NP1) GO TO 190                                            COB30250
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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          $SS   ,SA    ,$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,$SA   ,$SB   ,$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,IB,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                                                   COB30810
      DATA($AC+I) = 144.0*DATA(SA+I)                                    COB30820
      DATA($PW+I) = 12.0*DATA($PERIM+I)                                 COB30830
      DATA($PH+I) = 12.0*DATA($HPERI+I)                                 COB30840
      DATA($DC+I) = 12.0*DATA($DHYD+I)                                  COB30850
      DATA($DR+I) = 12.0*DATA($D+I)                                     COB30860
      DO 4 L=1,4                                                        COB30870
      IDAT($LC+I+MC*(L-1)) = 0                                          COB30880
      DATA($DIST+I+MC*(L-1)) = 0.0                                      COB30890
      DATA($GAPS+I+MG*(L-1)) = 0.0                                      COB30900
    4 CONTINUE                                                          COB30910
C                                                                       COB30920
      IF (NK.EQ.0) RETURN                                               COB30930
      DO 12 K=1,NK                                                      COB30940
      I = IDAT($IK+K)                                                   COB30950
      J = IDAT($JK+K)                                                   COB30960
      DO 8 L=1,4                                                        COB30970
      IF (IDAT($LC+I+MC*(L-1)).EQ.0) GO TO 10                           COB30980
    8 CONTINUE                                                          COB30990
      WRITE (6,2004) K,J,I                                              COB31000
   10 IDAT($LC+I+MC*(L-1)) = J                                          COB31010
      DATA($DIST+I+MC*(L-1)) = DATA($LENGT+K)*12.0                      COB31020
   12 DATA($GAPS+I+MG*(L-1)) = DATA($GAP+K)*12.0                        COB31030
C                                                                       COB31040
      RETURN                                                            COB31050
 2004 FORMAT(' CARDS4  GAP CONNECTION ', I3, '  CHANNEL ', I3,          COB31060
     1 ' IS 5TH ADJACENT TO ', I3)                                      COB31070
      END                                                               COB31080
      SUBROUTINE TOD(A)                                                 COB31090
      DIMENSION A(3),DATIM(5)                                           COB31100
      CALL WHEN(DATIM)                                                  COB31110
      A(1)=DATIM(3)                                                     COB31120
      A(2)=DATIM(4)                                                     COB31130
      A(3)=DATIM(5)                                                     COB31140
      RETURN                                                            COB31150
      END                                                               COB31160
      SUBROUTINE ACOL(IFROM,IK,JK,KMAX,LOCA,MA,MS,NK,MG,IPILE)          COB31170
      DIMENSION  IK(1),JK(1),LOCA(MG,14)                                COB31180
C     SET LOCA, DEFINING INTERACTING BOUNDARIES                         COB31190
C     IFROM = 1, CALLED FROM CARDS4,      = 2, FROM MAIN (OLD COBRA)    COB31200
C     LOCA(K,1)=K.    LOCA(K,L),L=2,7 SPECIFIES UP TO  LOCA(K,8)  .     COB31210
C     BOUNDARIES ADJACENT TO CHANNELS DEFINING BOUNDARY K.              COB31220
      DO 8 K=1,NK                                                       COB31230
      IF (IPILE.GT.0) GO TO 107                                         COB31240
      DO 103 L=2,13                                                     COB31250
  103 LOCA(K,L)=0                                                       COB31260
      GO TO 110                                                         COB31270
  107 DO 3 L=2,7                                                        COB31280
    3 LOCA(K,L)=0                                                       COB31290
  110 N=1                                                               COB31300
      LOCA(K,1) = K                                                     COB31310
      II = IK(K)                                                        COB31320
      JJ = JK(K)                                                        COB31330
    4 DO 7 KK=1,NK                                                      COB31340
      III = IK(KK)                                                      COB31350
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      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,PHIOT,PRINT,FW,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  ,$DHYDN,SDIST  ,SDPDX  ,$DPK   ,$DUR   ,$DR    ,$F    ,COB32090
     3   $FACTO,$FDIV  ,$FINLE,$FLUX  ,SFMULT,$FOLD  ,$FSP   ,SFSPLI,$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,$PRNTR,SPRNIN,$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 (12,1001) 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 (12,1005) TEXT                                                    COB32440
    2 WRITE(I3,1005) TEXT                                                    COB32450
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    3 NCHANL = N2                                                       COB32460
      NROD = N2                                                         COB32470
      J6 = 2                                                            COB32480
      NRAMP = 1                                                         COB32490
      GRID = .FALSE.                                                    COB32500
      NGRT = MAXO(NGRIDT,1)                                             COB32510
      IPILE = J7                                                        COB32520
      DO 4 I=1,NCHANL                                                   COB32530
      DO 4 L=1,6                                                        COB32540
      IDAT($LR+I+MR*(L-1))=0                                            COB32550
      DATA($PHI+I+MR*(L-1))=0.                                          COB32560
      IF (L.GT.4) GO TO 4                                               COB32570
      LC(I,L) = 0                                                       COB32580
      GAPS(I,L) = 0.0                                                   COB32590
      DIST(I,L) = 0.0                                                   COB32600
    4 CONTINUE                                                          COB32610
C                                                                       COB32620
C     READ GEOM AND SPACER DATA FOR EACH CHANNEL GROUP. SET GROUP 1     COB32630
      DO 10 J=1,N1                                                      COB32640
      READ (I2,1002) N,I,FRAC,AC(I),PW(I),PH(I),GAPS(I,1),DIST(I,1),    COB32650
     1    DR(I),DATA($PHI+I),M                                          COB32660
      DATA($CD+I)=0.                                                    COB32670
      FXF(1) = 0.0                                                      COB32680
      IF (FRAC.LE.0.0) FRAC = 1.0                                       COB32690
      AC(I) = FRAC*AC(I)                                                COB32700
      PW(I) = FRAC*PW(I)                                                COB32710
      PH(I) = FRAC*PH(I)                                                COB32720
      DATA($PHI+I)=FRAC*DATA($PHI+I)                                    COB32730
      IF (NGRID.EQ.0) GO TO 6                                           COB32740
      READ(I2,1003) (DATA($CD+I+MC*(L-1)),L=1,NGRIDT),(FXF(L),L=1,NGRIDTCOB32750
     1    )                                                             COB32760
    6 IDAT($NTYPE+I)=J                                                  COB32770
      IFRIC(J) = MAXO(N,1)                                              COB32780
      IDAT($IDFUE+I)=MAXO(M,1)                                          COB32790
      IGROUP(J) = 1                                                     COB32800
      IF (J.GT.1) GO TO 10                                              COB32810
C     SET ALL CHANNELS TEMPORARILY TO GROUP 1 VALUES.                   COB32820
      DO 8 K=1,NCHANL                                                   COB32830
      AC(K) = AC(I)                                                     COB32840
      PW(K) = PW(I)                                                     COB32850
      PH(K) = PH(I)                                                     COB32860
      GAPS(K,1) = GAPS(I,1)                                             COB32870
      DIST(K,1) = DIST(I,1)                                             COB32880
      DR(K) = DR(I)                                                     COB32890
      DATA($PHI  +K)=DATA($PHI  +I)                                     COB32900
      IDAT($NTYPE+K)=1                                                  COB32910
      IDAT($IDFUE+K)=IDAT($IDFUE+I)                                     COB32920
      DO 8 L=1,NGRT                                                     COB32930
      DATA($CD+K+MC*(L-1))=                                             COB32940
     1DATA($CD+I+MC*(L-1))                                              COB32950
    8 CONTINUE                                                          COB32960
   10 CONTINUE                                                          COB32970
      DO 12 K=1,MG                                                      COB32980
      DO 12 L=1,NGRT                                                    COB32990
   12 DATA($FXFLO+K+MG*(L-1))=FXF(L)                                    COB33000
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C                                                                       COB33010
C     READ ROD POWER FACTORS AND SPACER LOCATIONS.                      COB33020
      II = MINO(NROD,16)                                                COB33030
      READ(I2,1003) (DATA($RADIA+I),I=1,II)                             COB33040
      IF             (DATA($RADIA+1).GE.0.0)  GO TO 16                  COB33050
      DO 14 I=1,NROD                                                    COB33060
 14                   DATA($RADIA+I)=1.0                                COB33070
      GO TO 18                                                          COB33080
 16   IF(NROD.GT.16) READ(I2,1003) (DATA($RADIA+I),I=17,NROD)           COB33090
 18   IF (NGRID.GT.0) READ (I2,1004) (GRIDXL(I),IGRID(I),I=1,NGRID)     COB33100
C                                                                       COB33110
C     READ CHANNEL NUMBERS NOT IN GROUP 1, SET DATA                     COB33120
      JCHECK = 1                                                        COB33130
      IF (N1.EQ.1) GO TO 28                                             COB33140
      DO 26 J=2,N1                                                      COB33150
      ICHECK = 0                                                        COB33160
 20   READ(I2,1001) (JB(I),I=1,20)                                      COB33170
      DO 22 JJ=1,20                                                     COB33180
      K = JB(JJ)                                                        COB33190
      IF (K.LE.0) GO TO 24                                              COB33200
      I = IGROUP(J)                                                     COB33210
      AC(K) = AC(I)                                                     COB33220
      PW(K) = PW(I)                                                     COB33230
      PH(K) = PH(I)                                                     COB33240
      GAPS(K,1) = GAPS(I,1)                                             COB33250
      DIST(K,1) = DIST(I,1)                                             COB33260
      DR(K) = DR(I)                                                     COB33270
      DATA($PHI+K)=DATA($PHI+I)                                         COB33280
      IDAT($NTYPE+K)=J                                                  COB33290
      IDAT($IDFUE+K)=IDAT($IDFUE+I)                                     COB33300
      IF (K.EQ.I) ICHECK=1                                              COB33310
      IF (K.EQ.IGROUP(1) ) JCHECK=0                                     COB33320
      DO 22 L=1,NGRT ,                                                  COB33330
      DATA($CD+K+MC*(L-1))=                                             COB33340
     1DATA($CD+I+MC*(L-1))                                              COB33350
 22   CONTINUE                                                          COB33360
      GO TO 20                                                          COB33370
 24   IF (ICHECK.EQ.1) GO TO 26                                         COB33380
      WRITE(I3,2002) J, IGROUP(J)                                       COB33390
      IERROR = 1                                                        COB33400
      RETURN                                                            COB33410
 26   CONTINUE                                                          COB33420
      IF (JCHECK.EQ.1) GO TO 28                                         COB33430
      J = 1                                                             COB33440
      WRITE(I3,2002) J, IGROUP(J)                                       COB33450
      IERROR = 1                                                        COB33460
      RETURN                                                            COB33470
C                                                                       COB33480
C     SET ROD POWER FRACTIONS AND CHANNEL PARAMETERS                    COB33490
 28   PHTOT = 0.0                                                       COB33500
      ATOTAL = 0.0                                                      COB33510
      DO 32 I = 1,NCHANL                                                COB33520
      DO 30 J=1,NROD                                                    COB33530
 30   DATA($PWRF+I+MC*(J-1))=0                                          COB33540
      DATA($PWRF+I+MC*(I-1))=DATA($PHI +I)                              COB33550
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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 = MAXO(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 (13,3002) (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(12,1001) ISTART, IEND                                        COB34260
   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(12,1001) (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 (13,3002) (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($RADIA+L)                          COB34560
   65 CONTINUE                                                          COB34570
      IF (JUMP.EQ.1) GO TO 51                                           COB34580
   66 CONTINUE                                                          COB34590
   68 CONTINUE                                                          COB34600
C     PRINT RADIAL POWER MAP                                            COB34610
      WRITE (13,3010)                                                   COB34620
      DO 69 I=1,IRAD                                                    COB34630
      JMAX = JB(I)                                                      COB34640
   69 WRITE(13,3011)  (DATA($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                                                                       COB36310
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB36320
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),   COB36330
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB36340
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB36350
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB36360
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                     COB36370
C                                                                       COB36380
C                                                                       COB36390
      LOGICAL  GRID,PRINT                                               COB36400
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB36410
C                                                                       COB36420
C                                                                       COB36430
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB36440
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB36450
     1    $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB36460
     2    $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB36470
     3    $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB36480
     4    $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB36490
     5    $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB36500
     6    $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB36510
     7    $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB36520
     8    $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB36530
     9    $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB36540
     A    $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD COB36550
C                                                                       COB36560
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,      COB36570
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG                            COB36580
C                                                                       COB36590
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                 COB36600
C                                                                       COB36610
      COMMON/ITPSV/ITMP                                                 COB36620
C                                                                       COB36630
      COMMON  DATA(1)                                                   COB36640
      LOGICAL LDAT(1)                                                   COB36650
      INTEGER IDAT(1)                                                   COB36660
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB36670
C                                                                       COB36680
      COMMON /GAPFAC/ FACSL(70), FACSLK(70)                             COB36690
C                                                                       COB36700
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),  COB36710
     1JM(9),OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30), COB36720
     2YQ(30)                                                            COB36730
      COMMON/LINK3/DXX,ETIME,GIN,HIN,IB,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB36740
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB36750
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB36760
      DIMENSION CARD(20),CDG(5),GP(250),JBSTOR(150),JB(20),             COB36770
     1 NTHBOX(25,25),GAPREC(400)                                        COB36780
C                                                                       COB36790
C     IPART = 1   READ CHANNEL INPUT DATA                               COB36800
C     IPART = 2   PRINT CHANNEL INPUT DATA                              COB36810
C     OWN-ARRAY MAX SIZES. CARD(20), CDG(NGRIDT), GP(NCHANL), JB(MAXRD),COB36820
C       JBSTOR(NCTYP+3+NUMBER OF CHANNELS NOT OF TYPE 1)                COB36830
C     DEFINE JBSTOR(L),L=1,NCTYP+1 = ARRAY POSITIONS STARTING EACH TYPE,COB36840
C     JBSTOR(NCTYP+2) = A CHANNEL NUMBER OF TYPE 1,                     COB36850
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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
   10 READ(12,1001) CARD,(JB(L),L=1,MAXRD)
      IF(IFIRST.EQ.0) WRITE(I3,1008) CARD
      IF (IFIRST.EQ.0) GO TO 12
      WRITE(I3,1007) I,CARD
      IFIRST=0
      M=JB(1)
      IF((M.GT.0).AND.(M.LE.NCHANL)) GO TO 12
      IERROR=1
      WRITE(I3,2001) I,M
      RETURN
   12 DATA($A+M) = CHAR*FRAC/144.0
      DATA($PERIM+M) = CHPW*FRAC/12.0
      DATA($HPERI+M) = CHPH*FRAC/12.0
      DATA($PHI+M) = HRNUM*FRAC
      DATA($DHYD+M) = CHDI/12.0
      DATA($D+M) = HRDI/12.0
      IDAT($NTYPE+M) = MAX0(N,1)
      GP(M)=GAPWV
      DO 18 L=1,NCHANL
      J=L
      IF(I.EQ.1) GO TO 14
      IF(L.GT.MAXRD) GO TO 10
      J=JB(L)
      IF(J.LE.0) GO TO 20
      JBIC=JBIC+1
      JBSTOR(JBIC)=J
      JBSTOR(I+1) = JBIC+1
   14 DATA($A+J) = DATA($A+M)
      DATA($AN+J) = DATA($A+M)
      DATA($PERIM+J) = DATA($PERIM+M)
      DATA($HPERI+J) = DATA($HPERI+M)
      DATA($DHYD+J) = DATA($DHYD+M)
      DATA($DHYDN+J) = DATA($DHYD+M)
      DATA($DR+J) = DATA($D+M)*12.
      DATA($D +J) = DATA($D+M)
      GP(J) = GP(M)
      IDAT($NTYPE+J) = IDAT($NTYPE+M)
      IDAT($IDFUE+J) = 1
      IF(DATA($RADIA+J).EQ.0.0) GO TO 17
      DATA($PHI+J) = DATA($PHI+M)
      DATA($PHI+J+MR*(I-1))=DATA($PHI+M)
      DATA($PWRF+J+MC*(J-1)) = DATA($PHI+M)
      IDAT($LR+J) = J
      IDAT($LR+J+MR*(I-1)) =J
   17 CONTINUE
      DO 16 K=1,NGRT
   16 DATA($CD+J+MC*(K-1)) = CDG(K)
   18 CONTINUE
   20 CONTINUE
C     SET CHANNEL OF TYPE 1 INTO JBSTOR
      L = JBSTOR(2)
      M = JBSTOR(NCTYP+1) - 1
      DO 26 I=1,NCHANL
      DO 24 J=L,M
```

```
      IF (JBSTOR(J).EQ.I) GO TO 26                                      COB37960
   24 CONTINUE                                                          COB37970
      JBSTOR(NCTYP+2) = I                                               COB37980
      GO TO 28                                                          COB37990
   26 CONTINUE                                                          COB38000
C                                                                       COB38010
   28 IF (NGRID.EQ.0) GO TO 30                                          COB38020
C     READ GRID POSITIONS                                               COB38030
      READ (I2,1009) CARD,(GRIDXL(I),IGRID(I),I=1,7)                    COB38040
      WRITE (I3,1010) CARD                                              COB38050
      IF (NGRID.LE.10) GO TO 29                                         COB38060
      WRITE (I3,2007) NGRID                                             COB38070
      STOP                                                              COB38080
   29 IF (NGRID.LE.7) GO TO 30                                          COB38090
      READ (I2,1009) CARD,(GRIDXL(I),IGRID(I),I=8,NGRID)                COB38100
      WRITE (I3,1010) CARD                                              COB38110
C     READ ROD LAYOUT                                                   COB38120
   30 IF(IPILE) 2031,2031,2032                                          COB38130
 2031 READ(I2,2033) CARD,NN11,NN22,NN33,NN44,ITMP                       COB38140
 2033 FORMAT(20A4,T1,5I5)                                               COB38150
      WRITE(I3,2034) CARD                                               COB38160
 2034 FORMAT('  INDICATORS    ',14X,'***',20A4,'*** CHAN')              COB38170
      IF (IFRM.EQ.1.AND.NN44.NE.1) GO TO 146                            COB38180
      NROD=NN22                                                         COB38190
      IF (NN11.EQ.0) GO TO 2182                                         COB38200
      DO 2181 J=1,NN11                                                  COB38210
      READ (I2,2035) CARD,N,I,DATA($DR+I),DATA($RADIA+I),(IDAT($LR+I+   COB38220
     1MR*(L-1)),DATA($PHI+I+MR*(L-1)),L=1,6)                            COB38230
 2035 FORMAT(20A4,T1,I1,I4,2E5.0,6(I3,E7.0))                            COB38240
      WRITE (I3,2047) CARD                                              COB38250
 2047 FORMAT('  ROD DATA',20X,'***',20A4,'*** CHAN')                    COB38260
      IDAT($IDFUE+I)=N                                                  COB38270
      IF(N.LT.1) IDAT($IDFUE+I)=1                                       COB38280
 2181 CONTINUE                                                          COB38290
 2182 DO 2185 I=1,NROD                                                  COB38300
      DO 2184 L=1,6                                                     COB38310
      IF(IDAT($LR+I+MR*(L-1))) 2184,2184,2183                           COB38320
 2183 K=IDAT($LR+I+MR*(L-1))                                            COB38330
      DATA ($PWRF+K+MC*(I-1))=DATA($PHI+I+MR*(L-1))                     COB38340
 2184 CONTINUE                                                          COB38350
 2185 DATA($D+I)=DATA($DR+I)/12.                                        COB38360
      IF(J1.LE.1) PRINT(8)=.TRUE.                                       COB38370
      NODESF=NN33                                                       COB38380
      NFUELT=NN44                                                       COB38390
 2032 IF(NODESF.EQ.0) GO TO 34                                          COB38400
C     READ FUEL THERMAL DATA                                            COB38410
      READ(I2,1005) CARD, (KFUEL(I),CFUEL(I),RFUEL(I),DFUEL(I),         COB38420
     1 KCLAD(I), CCLAD(I), RCLAD(I), TCLAD(I), HGAP(I),I=1,NFUELT)      COB38430
      WRITE (I3,1011) CARD                                              COB38440
      IF(IFRM.EQ.0) GO TO 31                                            COB38450
      READ(I2,1003)CARD,NCF,NCC,THG                                     COB38460
      WRITE(I3,2010)CARD                                                COB38470
      THG=THG/12.                                                       COB38480
      IF ((NCF+NCC+1).NE.NODESF) GO TO 146                              COB38490
      IF(NODESF.GT.21) GO TO 146                                        COB38500
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      IF (IPROP.EQ.0) GO TO 31                                          COB38510
      READ(I2,1005)CARD,FTD,FPUD2                                       COB38520
      WRITE(I3,2012)CARD                                                COB38530
      IF(IPROP.LE.1) GO TO 31                                           COB38540
      READ(I2,1005)CARD,BURN,CPR,EXPR,FPRESS,GRGH,GMIX,PGAS             COB38550
      WRITE(I3,2014)CARD                                                COB38560
      IF((GMIX(1)+GMIX(2)+GMIX(3)+GMIX(4)).GT.1.01) GO TO 146           COB38570
      GRGH=GRGH/12.                                                     COB38580
   31 DO 32 I=1,NFUELT                                                  COB38590
      KFUEL(I) = KFUEL(I)/3600.                                         COB38600
      KCLAD(I) = KCLAD(I)/3600.                                         COB38610
      DFUEL(I) = DFUEL(I)/12.                                           COB38620
      TCLAD(I) = TCLAD(I)/12.                                           COB38630
   32 HGAP(I) = HGAP(I)/3600.                                           COB38640
C                                                                       COB38650
C     SET WHOLE-CHANNEL AREA AND PH                                     COB38660
   34 ATOTAL = 0.0                                                      COB38670
      PHTOT = 0.0                                                       COB38680
      DO 36 I=1,NCHANL                                                  COB38690
      ATOTAL = ATOTAL + DATA($A+I)                                      COB38700
   36 PHTOT = PHTOT + DATA($HPERI+I)                                    COB38710
      NK = 0                                                            COB38720
      IF (IPILE.EQ.2) GO TO 99                                          COB38730
C                                                                       COB38740
C     SET GAP BOUNDARY NUMBERING SYSTEM (PWR ONLY)                      COB38750
      IF(IPILE.GT.0) GO TO 3010                                         COB38760
      DO 242 ND2=1,ND2X                                                 COB38770
      DO 238 ND1=2,ND1X                                                 COB38780
      I=NTHBOX(ND1-1,ND2)                                               COB38790
      J=NTHBOX(ND1,ND2)                                                 COB38800
      IF((I.LE.0).OR.(J.LE.0)) GO TO  238                               COB38810
      IF((I-J).EQ.0) GO TO  238                                         COB38820
      DO 5216 K=1,NK                                                    COB38830
      IF((I.EQ.IDAT($IK+K)).OR.(I.EQ.IDAT($JK+K))) GO TO 5215           COB38840
      GO TO 5216                                                        COB38850
 5215 IF((J.EQ.IDAT($JK+K)).OR.(J.EQ.IDAT($IK+K))) GO TO 238            COB38860
 5216 CONTINUE                                                          COB38870
      NK=NK+1                                                           COB38880
      IDAT($IK+NK) = I                                                  COB38890
      IDAT($JK+NK) = J                                                  COB38900
  238 CONTINUE                                                          COB38910
      IF(ND2.EQ.ND2X) GO TO  242                                        COB38920
      DO 240 ND1=1,ND1X                                                 COB38930
      J=NTHBOX(ND1,ND2)                                                 COB38940
      I=NTHBOX(ND1,ND2+1)                                               COB38950
      IF((I.LE.0).OR.(J.LE.0)) GO TO  240                               COB38960
      IF((I-J).EQ.0) GO TO  240                                         COB38970
      DO 6216 K=1,NK                                                    COB38980
      IF((I.EQ.IDAT($IK+K)).OR.(I.EQ.IDAT($JK+K))) GO TO 6215           COB38990
      GO TO 6216                                                        COB39000
 6215 IF((J.EQ.IDAT($JK+K)).OR.(J.EQ.IDAT($IK+K))) GO TO 240            COB39010
 6216 CONTINUE                                                          COB39020
      NK=NK+1                                                           COB39030
      IDAT($IK+NK) = I                                                  COB39040
      IDAT($JK+NK) = J                                                  COB39050
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  240 CONTINUE
  242 CONTINUE
      GO TO 3020
 3010 DO 42 ND2=1,ND2X
      DO 38 ND1=2,ND1X
      I=NTHBOX(ND1-1,ND2)
      J=NTHBOX(ND1,ND2)
      IF((I.LE.0).OR.(J.LE.0)) GO TO 38
      NK=NK+1
      IDAT($IK+NK) = I
      IDAT($JK+NK) = J
   38 CONTINUE
      IF(ND2.EQ.ND2X) GO TO 42
      DO 40 ND1=1,ND1X
      J=NTHBOX(ND1,ND2)
      I=NTHBOX(ND1,ND2+1)
      IF((I.LE.0).OR.(J.LE.0)) GO TO 40
      NK=NK+1
      IDAT($IK+NK) = I
      IDAT($JK+NK) = J
   40 CONTINUE
   42 CONTINUE
C
C     SET GAP BOUNDARY PARAMETERS
 3020 IF(IPILE.GT.0) GO TO 9006
      M=1
 9014 MM=MIN0((M+13),NK)
      READ (12,9007) CARD,(GAPREC(I),I=M,MM)
 9007 FORMAT(20A4,T1,14E5.0)
      WRITE(13,9107) CARD
 9107 FORMAT('  GAP INTERCONNECTIONS',8X,'***',20A4,'*** CHAN')
      M=MM+1
      IF(M.LE.NK) GO TO 9014
      IF (ITMP.EQ.0) GO TO 9076
      IF (NK.LE.70) GO TO 9012
      WRITE(13,9010)
 9010 FORMAT(1H ,' ERROR DETECTED IN CHAN - TRANSVERSE ',
     1  'COUPLING PARAMETER ARRAYS NOT LARGE ENOUGH FOR GREATER THAN',
     2  /,' 70 GAP INTERCONNECTIONS.')
      GO TO 146
C
C  READ TRANSVERSE MOMENTUM COUPLING PARAMTERS
 9012 M=1
 9020 MM=MIN0((M+6),NK)
      READ(12,9007) CARD,(FACSL(I),FACSLK(I),I=M,MM)
      WRITE(13,9025) CARD
 9025 FORMAT('  GAP FACTOR PAIRS',12X,'***',20A4,'*** CHAN')
      M=MM+1
      IF(M.LE.NK) GO TO 9020
 9076 DO 9008 K=1,NK
 9078 I=IDAT($IK+K)
      IF (I-IDAT($JK+K)) 9084,9080,9082
 9080 WRITE(13,2003) K,I,IDAT($JK+K)
      IERROR=1
      RETURN
```

```
 9082 IDAT($IK+K)=IDAT($JK+K)                                              COB39610
      IDAT($JK+K)=I                                                        COB39620
      GO TO 9078                                                           COB39630
 9084 M=IDAT($JK+K)                                                        COB39640
      DATA($GAPN+K)=GAPREC(K)/12.                                          COB39650
      DATA($GAP+K)=DATA($GAPN+K)                                           COB39660
      DATA($LENGT+K)=0.0                                                   COB39670
      DATA($FACTO+K)=1.0                                                   COB39680
 9008 CONTINUE                                                             COB39690
      GO TO 9009                                                           COB39700
 9006 DO 90 K=1,NK                                                         COB39710
   78 I =  IDAT($IK+K)                                                     COB39720
      IF (I-IDAT($JK+K)) 84,80,82                                          COB39730
   80 WRITE (13,2003) K,I,IDAT($JK+K)                                      COB39740
      IERROR = 1                                                           COB39750
      RETURN                                                               COB39760
   82 IDAT($IK+K) = IDAT($JK+K)                                            COB39770
      IDAT($JK+K) = I                                                      COB39780
      GO TO 78                                                             COB39790
   84 M = IDAT($JK+K)                                                      COB39800
      DATA($GAPN+K) = 0.5*(GP(I)+GP(M))/12.0                               COB39810
      DATA($GAP+K) = DATA($GAPN+K)                                         COB39820
      DATA($LENGT+K) = 0.0                                                 COB39830
      DATA($FACTO+K) = 1.0                                                 COB39840
   90 CONTINUE                                                             COB39850
 9009 CONTINUE                                                             COB39860
C                                                                          COB39870
C     SET LOCA ARRAY                                                       COB39880
C     DYNAMIC STORAGE CALL TO CORE2 FROM ACOL TO SET MA, MS IF GAPS.       COB39890
      CALL ACOL(1,IDAT($IK+1),IDAT($JK+1),KMAX,IDAT($LOCA+1),MA,MS,NK,     COB39900
     1MG,IPILE)                                                            COB39910
C                                                                          COB39920
      IF (IPILE.EQ.0) GO TO 99                                             COB39930
C     READ HALF-BOUNDARIES AND SET FACTOR(K)=0.5                           COB39940
      MMAX=MAXRD/2                                                         COB39950
   92 READ(12,1001) CARD, (JB(L),L=1,MAXRD)                                COB39960
      WRITE(13,1012) CARD                                                  COB39970
      MM = 0                                                               COB39980
      DO 98 M=1,MMAX                                                       COB39990
      MM = MM+1                                                            COB40000
      L=2*M-1                                                              COB40010
      IF(JB(L).LE.0) GO TO 99                                              COB40020
      I=MINO(JB(L),JB(L+1))                                                COB40030
      J=MAXO(JB(L),JB(L+1))                                                COB40040
      DO 94 K=1,NK                                                         COB40050
      IF ( (I.EQ.IDAT($IK+K)) .AND. (J.EQ.IDAT($JK+K)) ) GO TO 96          COB40060
   94 CONTINUE                                                             COB40070
      IERROR=1                                                             COB40080
      WRITE(13,2005) MM,I,J                                                COB40090
      RETURN                                                               COB40100
   96 DATA($FACTO+K) = 0.5                                                 COB40110
   98 CONTINUE                                                             COB40120
      GO TO 92                                                             COB40130
C                                                                          COB40140
C     READ FORCED FLOW BOUNDARIES HERE IF PROGRAMMED LATER                 COB40150
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```
   99 DO 100 K=1,NK                                                      COB40160
      DO 100 L=1,5                                                       COB40170
  100 DATA($FXFLO+K+MG*(L-1)) = 0.0                                      COB40180
      IF (NFXF.EQ.0) GO TO 101                                           COB40190
      WRITE (I3,1013)                                                    COB40200
      IERROR = 1                                                         COB40210
  101 CONTINUE                                                           COB40220
      RETURN                                                             COB40230
C                                                                        COB40240
C     IPART = 2.   PRINT CHANNEL DATA                                    COB40250
  102 IPILE=J7                                                           COB40260
      WRITE(I3,1040) IPILE,NCHANL,NCTYP,NGRID,NGRIDT,NODESF,NFXF         COB40270
      IF(NODESF.GT.0) WRITE(I3,1045) IFRM,IHTM,IPROP                     COB40280
      WRITE(I3,1050)                                                     COB40290
C                                                                        COB40300
C     DRAW MAP OF CHANNELS AND CHECK TOTAL                               COB40310
      NUMCH=0                                                            COB40320
      DO 106 ND2=1,ND2X                                                  COB40330
      IMAX=0                                                             COB40340
      DO 104 ND1=1,ND1X                                                  COB40350
      NUMCH=MAX0(NUMCH,NTHBOX(ND1,ND2))                                  COB40360
      IF(NTHBOX(ND1,ND2).GT.0) IMAX=ND1                                  COB40370
  104 CONTINUE                                                           COB40380
      IF(IMAX.EQ.0) GO TO 108                                            COB40390
      WRITE(I3,1052) (NTHBOX(I,ND2),I=1,IMAX)                            COB40400
  106 CONTINUE                                                           COB40410
  108 IF(NUMCH.EQ.NCHANL) GO TO 110                                      COB40420
      IERROR=1                                                           COB40430
      WRITE(I3,2006) NUMCH,NCHANL                                        COB40440
      RETURN                                                             COB40450
C                                                                        COB40460
C      PRINT CHANNEL NUMBER IN EACH TYPE                                 COB40470
  110 IF (NCTYP.EQ.1) GO TO 115                                          COB40480
      WRITE (I3,1053)                                                    COB40490
      DO 114 I=2,NCTYP                                                   COB40500
      L=JBSTOR(I)                                                        COB40510
      M=JBSTOR(I+1) - 1                                                  COB40520
      WRITE(I3,1054) I,(JBSTOR(K),K=L,M)                                 COB40530
  114 CONTINUE                                                           COB40540
C                                                                        COB40550
C     PRINT CHANNEL DATA FOR EACH TYPE                                   COB40560
  115 WRITE(I3,1055)                                                     COB40570
      DO 116 I=1,NCTYP                                                   COB40580
      L=JBSTOR(I)                                                        COB40590
      J=JBSTOR(L)                                                        COB40600
      DROD = DATA($D+J)+12.0                                             COB40610
  116 WRITE(I3,1056) I,IDAT($NTYPE+J),DATA($A+J),DATA($PERIM+J),         COB40620
     1 DATA($HPERI+J), DATA($PHI+J), DROD, GP(J)                         COB40630
C                                                                        COB40640
C     PRINT GRID DATA                                                    COB40650
      IF(NGRID.GT.0) GO TO 118                                           COB40660
      WRITE(I3,1057)                                                     COB40670
      GO TO 124                                                          COB40680
  118 WRITE(I3,1058) NGRID,NGRIDT,(IGRID(I),GRIDXL(I),I=1,NGRID)         COB40690
      WRITE(I3,1059) NGRIDT                                              COB40700
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      ITMAX = 1                                                         COB40710
      IF (NFXF.GT.0) ITMAX = 2                                          COB40720
      DO 122 ITTR=1,ITMAX                                               COB40730
      DO 120 I=1,NCTYP                                                  COB40740
      L=JBSTOR(I)                                                       COB40750
      J=JBSTOR(L)                                                       COB40760
      IF(ITTR.EQ.1) WRITE(I3,1060) I,(DATA($CD+J+MC*(K-1)),K=1,NGRIDT)  COB40770
      IF(ITTR.EQ.2) WRITE(I3,1060) I,(DATA($FXFLO+J+MG*(K-1)),K=1,      COB40780
     1 NGRIDT)                                                          COB40790
  120 CONTINUE                                                          COB40800
      IF(ITTR.LT.ITMAX) WRITE(I3,1061) NGRIDT                           COB40810
  122 CONTINUE                                                          COB40820
C                                                                       COB40830
  124 IF(IPILE.GT.0) GO TO 125                                          COB40840
      WRITE(I3,2008) (I,IDAT($IDFUE+I),DATA($DR+I),DATA($RADIA+I),      COB40850
     1(DATA($PHI+I+MR*(L-1)),IDAT($LR+I+MR*(L-1)),L=1,6),I=1,NROD)      COB40860
C     PRINT FUEL THERMAL DATA                                           COB40870
  125 IF(NODESF.EQ.0) GO TO 130                                         COB40880
      WRITE (I3,1062) NODESF                                            COB40890
      DO 126 J=1,NFUELT                                                 COB40900
      WV1 = KFUEL(J)*3600.0                                             COB40910
      WV2 = DFUEL(J)*12.0                                               COB40920
      WV3 = KCLAD(J)*3600.0                                             COB40930
      WV4 = TCLAD(J)*12.0                                               COB40940
      WV5 = HGAP(J)*3600.0                                              COB40950
  126 WRITE(I3,1063) J,WV1,CFUEL(J),RFUEL(J),WV2,WV3,CCLAD(J),RCLAD(J), COB40960
     1 WV4,WV5                                                          COB40970
      WV6=THG*12.                                                       COB40980
      IF(IFRM.EQ.1) WRITE(I3,1080) NCF,NCC,WV6                          COB40990
      IF(IPROP.GE.1) WRITE(I3,1082) FTD,FPUO2                           COB41000
      IF(IPROP.EQ.2) WRITE(I3,1084) BURN,CPR,EXPR,FPRESS,GRGH,GMIX,PGAS COB41010
      IF(IHTM.EQ.1) WRITE(I3,1090)                                      COB41020
      IF(IHTM.EQ.2) WRITE(I3,1092)                                      COB41030
C                                                                       COB41040
  130 IF (IPILE.EQ.2) GO TO 144                                         COB41050
      IF(IPILE.EQ.0) GO TO 132                                          COB41060
      DO 131 K=1,NK                                                     COB41070
  131 GAPREC(K)=DATA($GAPN+K)*12.0                                      COB41080
C     PRINT ARRAYS IK, JK AND LOCA                                      COB41090
  132 WRITE (I3,1064)                                                   COB41100
      WRITE (I3,1065) NK                                                COB41110
      M = 1                                                             COB41120
  134 MM=MINO((M+5),NK)                                                 COB41130
      WRITE (I3,1066) M,(IDAT($IK+K),IDAT($JK+K),GAPREC(K),K=M,MM)      COB41140
      M = MM+1                                                          COB41150
      IF (M.LE.NK) GO TO 134                                            COB41160
      WRITE (I3,1067) NK                                                COB41170
      M = 1                                                             COB41180
  136 MM = MINO( (M+24),NK)                                             COB41190
      IF (IPILE.GT.0) GO TO 4207                                        COB41200
      DO 8138 L=1,14                                                    COB41210
 8138 WRITE(I3,1068) L,(IDAT($LOCA+K+MG*(L-1)),K=M,MM)                  COB41220
      GO TO 4208                                                        COB41230
 4207 DO 138 L=1,8                                                      COB41240
  138 WRITE (I3,1068) L, (IDAT($LOCA+K+MG*(L-1)),K=M,MM)                COB41250
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```
 4208 M=MM+1                                                             COB41260
      WRITE (I3,1069)                                                    COB41270
      IF (M.LE.NK) GO TO 136                                             COB41280
      L = MS+NK                                                          COB41290
      WRITE (I3,1070) MS,KMAX,L,MA                                       COB41300
      IF (ITMP.EQ.0) GO TO 139                                           COB41310
C                                                                        COB41320
C  PRINT TRANSVERSE MOMENTUM COUPLING PARAMTERS                          COB41330
      WRITE(I3,1076)                                                     COB41340
      WRITE(I3,1078) (K,FACSL(K),FACSLK(K),K=1,NK)                       COB41350
C                                                                        COB41360
C     PRINT HALF-BOUNDARIES                                              COB41370
  139 IC = 0                                                             COB41380
      DO 140 K=1,NK                                                      COB41390
      IF (DATA($FACTO+K).EQ.1.0) GO TO 140                               COB41400
      IC = IC+1                                                          COB41410
      JBSTOR(IC) = K                                                     COB41420
  140 CONTINUE                                                           COB41430
      IF (IC.GT.1) GO TO 142                                             COB41440
      WRITE (I3,1072)                                                    COB41450
      GO TO 144                                                          COB41460
  142 WRITE (I3,1073) (JBSTOR(K),K=1,IC)                                 COB41470
  144 CONTINUE                                                           COB41480
      WRITE (I3,1074)                                                    COB41490
      RETURN                                                             COB41500
C                                                                        COB41510
  146 WRITE(I3,1000)                                                     COB41520
      IERROR=1                                                           COB41530
      RETURN                                                             COB41540
C                                                                        COB41550
 1000 FORMAT(1H ,' INPUT ERROR DETECTED BY CHAN.')                       COB41560
 1001 FORMAT(20A4, T1, 14I5)                                             COB41570
 1002 FORMAT('  INDICATORS', 18X, '***', 20A4, '*** CHAN')               COB41580
 1003 FORMAT(20A4, T1, 2I5, 8E5.0)                                       COB41590
 1004 FORMAT('  CHANNEL DATA, TYPE', I3, 7X, '***', 20A4, '*** CHAN')    COB41600
 1005 FORMAT(20A4, T1, 14E5.0)                                           COB41610
 1006 FORMAT('  GRID DATA, TYPE', I3, 10X, '***' ,20A4, '*** CHAN')      COB41620
 1007 FORMAT('  CHANNELS OF TYPE', I3, 9X, '***', 20A4, '*** CHAN')      COB41630
 1008 FORMAT(30X, '***', 20A4, '*** CHAN')                               COB41640
 1009 FORMAT(20A4, T1, 7(E5.0,I5))                                       COB41650
 1010 FORMAT('  GRID POSITIONS', 14X, '***', 20A4, '*** CHAN')           COB41660
 1011 FORMAT('  FUEL THERMAL DATA', 11X, '***', 20A4, '*** CHAN')        COB41670
 1012 FORMAT('  HALF-BOUNDARY CHANNEL PAIRS',1X, '***',20A4, '*** CHAN')COB41680
 1013 FORMAT('  FORCED FLOW NOT PROGRAMMED. STOP CALCULATION IN CHAN')  COB41690
 1040 FORMAT(///, 43X, 'CHANNEL, ROD AND GRID DATA', /, 43X,            COB41700
     1 '-------  --- --- ---- ----', //, '  REACTOR TYPE', 8X,           COB41710
     2 '=', I3, 5X, '(1=PWR,  2=BWR)', /, ' *NO. FUEL ASSEMBLIES =', I3,COB41720
     3 /, '  NO. ASSEMBLY TYPES  =', I3, /, '  NO. GRIDS', 11X, '=',    COB41730
     4 I3, /, '  NO. GRID TYPES', 6X, '=', I3,/, '  NO. FUEL NODES', 6X,COB41740
     5 '=', I3, /, '  NO. FCD FLOW TYPES', 2X, '=', I3, /)              COB41750
 1045 FORMAT(1H ,' FUEL ROD MODEL IND. =',I3,/,                          COB41760
     1  '  HEAT TRANSFER MODEL IND.=',I3,/,                              COB41770
     2  '  FUEL ROD PROP. IND. =',I3,//)                                 COB41780
 1050 FORMAT(///,'  CHANNEL DATA', /, ' ------- ----',15X,               COB41790
     1  '*CHANNEL NUMBERING MAP', /)                                     COB41800
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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              COD41970
    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,'FID, 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         $SS   ,$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,$SA   ,$SB   ,$XPOLD COB43230
C                                                                       COB43240
      COMMON/CHFSV/CHSAVE(20,20,31)                                     COB43250
C                                                                       COB43260
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP                 COB43270
C                                                                       COB43280
      COMMON  DATA(1)                                                   COB43290
      LOGICAL LDAT(1)                                                   COB43300
      INTEGER IDAT(1)                                                   COB43310
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB43320
C                                                                       COB43330
C                                                                       COB43340
      NDXP1 = NDX + 1                                                   COB43350
      DO 100 J=1,NDXP1                                                  COB43360
      DATA($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), COB44010
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),      COB44020
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB44030
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)'                    COB44040
C                                                                       COB44050
C                                                                       COB44060
      LOGICAL  GRID                                                     COB44070
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB44080
C                                                                       COB44090
C                                                                       COB44100
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB44110
     1            $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$D    ,COB44120
     1   $CCHAN,$CD    ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB44130
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,CO944140
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB44150
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB44160
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB44170
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB44180
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB44190
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB44200
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB44210
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA  ,$SB  ,$XPOLD   COB44220
C                                                                       COB44230
      COMMON  DATA(1)                                                   COB44240
      LOGICAL LDAT(1)                                                   COB44250
      INTEGER IDAT(1)                                                   COB44260
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB44270
C                                                                       COB44280
C                                                                       COB44290
C  W-3 CORRELATION INCLUDING, SPACER FACTOR, UNHEATED WALL CORRECTION,  COB44300
C AXIAL FLUX FACTOR                                                     COB44310
C  REFERENCE, LS TONG, BOILING CRISIS AND CRITICAL HEAT FLUX            COB44320
C   AEC CRITICAL REVIEW SERISS,TID-25887(1972).                         COB44330
      DE=4.*DATA($A+I)/DATA($PERIM+I)                                   COB44340
      DH=4.*DATA($A+I)/DATA($HPERI+I)                                   COB44350
      RU = 1.-DE/DH                                                     COB44360
      XX=(DATA($H+I+MC*(J-1))-HF)/HFG                                   COB44370
C  W-3 CORRELATION USING EQUILIBRIUM STEAM QUALITY                      COB44380
      CHF2     = ((2.022 - 0.0004302*PREF) + (0.1722 - 0.0000984*PREF)  COB44390
     1 *EXP((18.2 - 0.004129*PREF)*XX))                                 COB44400
     2 *((0.1484-1.596*XX+.1729*XX*ABS(XX))*DATA($F+I+MC*(J-1))/        COB44410
     2                                       DATA($A+I)                 COB44420
     3 *.0036 + 1.037)                                                  COB44430
     4 *(1.157 - 0.869*XX)                                              COB44440
     5 *(0.2664 + 0.8357*EXP(-37.812*DH))                               COB44450
     6 *(0.8258+0.000794*(HF-DATA($HINLE+I)))/.0036                     COB44460
C  UNHEATED WALL CORRECTION                                             COB44470
      IF(RU.GT.0.) CHF2 = CHF2*(1. - RU*(13.76-1.372*EXP(1.78*XX)       COB44480
     1 -4.732/(DATA($F+I+MC*(J-1))/DATA($A+I)*0.0036)**.0535            COB44490
     1 -0.0619*(PREF*0.001)**.14                                        COB44500
     2-11.101*DH**.1077))                                               COB44510
C  SPACER FACTOR CORRECTION                                             COB44520
C  USER SHOULD SELECT PROPER VALUE OF TDC                               COB44530
      TDC = .019                                                        COB44540
      IF(NGRID.GT.0) CHF2 = CHF2                                        COB44550
```

```
     1 *(1.+.03*DATA($F+I+MC*(J-1))/DATA($A+I)*.0036*(TDC/.019)**.35)  COB44560
C  AXIAL FLUX PROFILE CORRECTION                                       COB44570
      FAXIAL = 1.                                                      COB44580
      IF(J.LE.IDAT($JBOIL+I))  GO TO 10                                COB44590
      C=1.8*(1.-XX)**4.31/(DATA($F+I+MC*(J-1))/DATA($A+I)*.0036)**.478 COB44600
      SUM = 0.                                                         COB44610
      JS=IDAT($JBOIL+I)+1                                              COB44620
      CE=C/2.                                                          COB44630
      DO 5 JJ=JS,J                                                     COB44640
    5 SUM=SUM+DATA($FLUX+N+MR*(JJ-1))*(EXP(CE*DATA($X+JJ))+            COB44650
     1EXP(CE*DATA($X+JJ-1)))*(EXP(CE*DATA($X+JJ))-EXP(CE*DATA($X+JJ-1  COB44660
     2)))                                                              COB44670
      FAXIAL=SUM*EXP(-CE*DATA($X+J))/DATA($FLUX+N+MR*(J-1))/           COB44680
     1(1.-EXP(-C*(DATA($X+J)-DATA($X+JS-1))))                          COB44690
      FAXIAL=FAXIAL*EXP(-CE*DATA($X+J))                                COB44700
   10 CHF2 = CHF2/FAXIAL                                               COB44710
      RETURN                                                           COB44720
      END                                                              COB44730
      FUNCTION CHF3(N,I,J)                                             COB44740
C                                                                      COB44750
C                                                                      COB44760
      IMPLICIT INTEGER ($)                                             COB44770
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB44780
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB44790
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB44800
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB44810
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB44820
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB44830
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB44840
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB44850
     8   UF    ,VF    ,VFG   ,VG    ,Z                                 COB44860
C                                                                      COB44870
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),   COB44880
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),  COB44890
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), COB44900
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),     COB44910
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),       COB44920
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                    COB44930
C                                                                      COB44940
C                                                                      COB44950
      LOGICAL  GRID                                                    COB44960
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                              COB44970
C                                                                      COB44980
C                                                                      COB44990
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB45000
     1           $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B   ,COB45010
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB45020
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB45030
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB45040
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB45050
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB45060
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB45070
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB45080
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB45090
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB45100
```

```
     A   SW     ,SWOLD ,SWP   ,SWSAVE,SX    ,SXCROS,SSA  ,SSB  ,SXPOLD   COB45110
C                                                                        COB45120
      COMMON  DATA(1)                                                    COB45130
      LOGICAL LDAT(1)                                                    COB45140
      INTEGER IDAT(1)                                                    COB45150
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                             COB45160
C                                                                        COB45170
C    HENCH-LEVY CORRELATION FOR CRITICAL HEAT FLUX                       COB45180
C                                                                        COB45190
C                                                                        COB45200
      G=DATA($F+I+MC*(J-1))*.0036/DATA($A+I)                             COB45210
      XE=(DATA($H+I+MC*(J-1))-HF)/HFG                                    COB45220
      IF(DATA($FLUX+N+MR*(J-1)).LE.0.) GO TO 10                          COB45230
      XC1=0.273-0.212*(TANH(3.*G))**2                                    COB45240
      XC2=0.5-0.269*(TANH(3.*G))**2+0.0346*(TANH(2.*G))**2               COB45250
      IF(XE.GE.XC2) Q=0.6-0.7*XE-0.09*(TANH(2.*G))**2                    COB45260
      IF(XE.GT.XC1.AND.XE.LT.XC2) Q=1.9-3.3*XE-0.7*(TANH(3.*G))**2       COB45270
      IF(XE.LT.XC1) Q=1.0                                                COB45280
      Q=Q*1.E6                                                           COB45290
      Q=Q*(1.1-0.1*((PREF-600.)/400.)**1.25)                             COB45300
      Q=Q/3600                                                           COB45310
      CHF3=Q                                                             COB45320
      RETURN                                                             COB45330
C                                                                        COB45340
   10 CHF3=10.*DATA($FLUX+N+MR*(J-1))                                    COB45350
      RETURN                                                             COB45360
      END                                                                COB45370
      FUNCTION CHF4(N,I,J)                                               COB45380
C                                                                        COB45390
C                                                                        COB45400
      IMPLICIT INTEGER ($)                                               COB45410
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX     ,COB45420
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF     ,COB45430
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2     ,COB45440
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,        COB45450
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF     ,COB45460
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP  ,COB45470
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF   ,COB45480
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK  ,COB45490
     8   UF    ,VF    ,VFG   ,VG    ,Z                                   COB45500
C                                                                        COB45510
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB45520
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB45530
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB45540
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB45550
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB45560
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB45570
C                                                                        COB45580
C                                                                        COB45590
      LOGICAL  GRID                                                      COB45600
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                COB45610
C                                                                        COB45620
C                                                                        COB45630
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX     ,COB45640
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B      ,COB45650
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     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,SNWRAP,SNWRPS,$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,$SA  ,$SB   ,$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(SF+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
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C                                                                       COB46210
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB46220
     1  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB46230
     2  GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB46240
     3  IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB46250
     4  PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB46260
     5  VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB46270
C                                                                       COB46280
C                                                                       COB46290
      LOGICAL  GRID                                                     COB46300
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                               COB46310
C                                                                       COB46320
C                                                                       COB46330
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB46340
     1          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB46350
     1    $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB46360
     2    $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB46370
     3    $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB46380
     4    $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB46390
     5    $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB46400
     6    $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB46410
     7    $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB46420
     8    $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB46430
     9    $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB46440
     A    $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA  ,$SB   ,$XPOLD  COB46450
C                                                                       COB46460
      COMMON /GAPFAC/ FACSL(70), FACSLK(70)                             COB46470
C                                                                       COB46480
      COMMON  DATA(1)                                                   COB46490
      LOGICAL LDAT(1)                                                   COB46500
      INTEGER IDAT(1)                                                   COB46510
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB46520
C                                                                       COB46530
      EQUIVALENCE (NCHAN,NCHANL)                                        COB46540
C                                                                       COB46550
C                                                                       COB46560
      ABIT(IZ,Z1,Z2,Z3,Z4,Z5,Z6) = IZ*((2.0*Z1 - Z2 + DX/DT)/Z3 +       COB46570
     1 Z4*ABS(Z5+Z6)*DX)                                                COB46580
      IPILE =J7                                                         COB46590
C                                                                       COB46600
      NKK = NK                                                          COB46610
      JM1 = J-1                                                         COB46620
      SLDX = SL*DX                                                      COB46630
      DTGC = DT*GC                                                      COB46640
      DXGC = DX*GC                                                      COB46650
C  CALCULATE USTAR                                                      COB46660
      DO 5 K=1,NKK                                                      COB46670
      II=IDAT($IK+K)                                                    COB46680
      JJ=IDAT($JK+K)                                                    COB46690
      DATA($USAVE+K)=DATA($USTAR+K)                                     COB46700
      DATA($USTAR+K)=0.5*(DATA($U+II)+DATA($U+JJ))                      COB46710
    5 CONTINUE                                                          COB46720
C                                                                       COB46730
C     SET AAA ARRAY USING LOCA (SET IN ACOL BASED ON INPUT DATA)        COB46740
      LMAX = MS                                                         COB46750
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      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($LOCA+K+MG*7)                                         COB46940
 7214 DO 300LL=1,NBOUND                                                 COB46950
      L      =IDAT($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
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      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 = MAXO(1,(L+K-MID))                                            COB47340
      LL=MINO(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(13,2) ((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(13,1)                                                       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          $SS    ,$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,$SA  ,$SB  ,$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
```

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      NGAPS = 0                                                         COB48410
      NAFACT = 0                                                        COB48420
      NSCBC = 0                                                         COB48430
      NBBC = 0                                                          COB48440
      J5 = 0                                                            COB48450
      J6 = 0                                                            COB48460
      NOPRIN=0                                                          COB48470
      J7=0                                                              COB48480
      NGRIDT = 0                                                        COB48490
      JUMP = 0                                                          COB48500
      NJUMP = 0                                                         COB48510
      NROD = 0                                                          COB48520
      NRAMP = 1                                                         COB48530
      NODESF = 0                                                        COB48540
      NFUELT = 0                                                        COB48550
      NOUT = 0                                                          COB48560
      NPCHAN = 0                                                        COB48570
      NPNODE = 0                                                        COB48580
      NARAMP = 1                                                        COB48590
      IG = 0                                                            COB48600
      ISAVE = 0                                                         COB48610
      IN = 0                                                            COB48620
CC  FUEL ROD AND HEAT TRANSFER MODEL INDICATORS INITIALIZED AS ZERO     COB48630
      IFRM=0                                                            COB48640
      IHTM=0                                                            COB48650
      IPROP=0                                                           COB48660
      GRID = .FALSE.                                                    COB48670
      DO 900 I=1,MC                                                     COB48680
      DATA($HINLE+I)=0.                                                 COB48690
      DATA($FINLE+I)=0.                                                 COB48700
  900 DATA($QPRIM+I)=0.                                                 COB48710
      DO 905 K=1,MG                                                     COB48720
      FACSL(K)=1.                                                       COB48730
      FACSLK(K)=1.                                                      COB48740
      DATA($WP    +K)=0.                                                COB48750
  905 LDAT($FDIV +K)=.FALSE.                                            COB48760
      DO 930 J=1,MX                                                     COB48770
      DO 910 I=1,MC                                                     COB48780
      DATA($P     +I+MC*(J-1))=0.                                       COB48790
      DATA($H     +I+MC*(J-1))=0.                                       COB48800
      DATA($F+I+MC*(J-1))=0.                                            COB48810
      DATA($RHO  +I+MC*(J-1))=0.                                        COB48820
      DATA($HOLD +I+MC*(J-1))=0.                                        COB48830
      DATA($FOLD +I+MC*(J-1))=0.                                        COB48840
  910 DATA($RHOOL+I+MC*(J-1))=0.                                        COB48850
      DO 920 N=1,MR                                                     COB48860
      DATA($FLUX +N+MR*(J-1))=0.                                        COB48870
      IDAT($CCHAN+N+MR*(J-1))=0                                         COB48880
      DO 918 L=1,MN                                                     COB48890
  918 DATA($TROD+L+MN*(N-1+MR*(J-1)))=0.                                COB48900
  920 CONTINUE                                                          COB48910
  930 CONTINUE                                                          COB48920
      READ (I2,52) MAXT                                                 COB48930
      IF(MAXT.LT.1) MAXT = 1000                                         COB48940
C                                                                       COB48950
```

```
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
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C  INPUT FOR CARD GROUP 3, AXIAL HEAT FLUX TABLE                       COB49510
  130 IF (N1.GT.1) GO TO 135                                           COB49520
      IQP3 = N1                                                        COB49530
      GO TO 995                                                        COB49540
  135 READ(12,5) (Y(I),AXIAL(I),I=1,N1)                                COB49550
      NAX = N1                                                         COB49560
      IF(J1.LE.1) PRINT(3) = .TRUE.                                    COB49570
      GO TO 995                                                        COB49580
C                                                                      COB49590
C  INPUT FOR CARD GROUP 4, CHANNEL LAYOUT AND DIMENSIONS               COB49600
  140 IF(IPILE.EQ.0) GO TO 1405                                        COB49610
C     COMBINE CARD GROUPS 4, 7, 9 FOR PWR AND BWR.                     COB49620
      CALL CARDS4(DATA($AC+1),DATA($DC+1),DATA($DIST+1),               COB49630
     1  DATA($DR+1),DATA($GAPS+1),                                     COB49640
     1    IDAT($LC+1),MA,MG,N1,N2,NCHF,NFUELT, DATA($PH+1),            COB49650
     2    PHTOT,PRINT,DATA($PW+1),MC)                                  COB49660
      IF (IERROR.GE.1) GO TO 240                                       COB49670
      CALL CORE3                                                       COB49680
      GO TO 995                                                        COB49690
 1405 DO 141 J=1,N1                                                    COB49700
      READ(12,7)  N,I,DATA($AC+I),DATA($PW+I),DATA($PH+I),             COB49710
     1    (IDAT($LC+I+MC*(L-1)),DATA($GAPS+I+MG*(L-1)),                COB49720
     2    DATA($DIST+I+MC*(L-1)),L=1,4)                                COB49730
      IDAT($NTYPE+I)=N                                                 COB49740
      IF(N.LE.1)                                                       COB49750
     1IDAT($NTYPE+I)=1                                                 COB49760
  141 CONTINUE                                                         COB49770
  142 PHTOT = 0.                                                       COB49780
      ATOTAL = 0.                                                      COB49790
      K=0                                                              COB49800
      NCHANL = N2                                                      COB49810
      DO 147 I=1,NCHANL                                                COB49820
      DO 146 L=1,4                                                     COB49830
      IF(IDAT($LC+I+MC*(L-1))) 144,146,143                             COB49840
  143 J= IDAT($LC+I+MC*(L-1))                                          COB49850
      IF(J.LE.I) GO TO 146                                             COB49860
      K=K+1                                                            COB49870
      DATA($FACTO+K)=1.                                                COB49880
      GO TO 145                                                        COB49890
  144 J=-IDAT($LC+I+MC*(L-1))                                          COB49900
      IF(J.LE.I) GO TO 146                                             COB49910
      K=K+1                                                            COB49920
      DATA($FACTO+K)=0.5                                               COB49930
  145 IDAT($JK+K)=J                                                    COB49940
      IDAT($IK+K)=I                                                    COB49950
      DATA($GAPN +K)=DATA($GAPS +I+MG*(L-1))/12.                       COB49960
      DATA($GAP  +K)=DATA($GAPN +K)                                    COB49970
      DATA($LENGT+K)=DATA($DIST +I+MC*(L-1))/12.                       COB49980
  146 CONTINUE                                                         COB49990
      DATA($PERIM+I)=DATA($PW+I)/12.                                   COB50000
      DATA($HPERI+I)=DATA($PH+I)/12.                                   COB50010
      DATA($AN   +I)=DATA($AC+I)/144.                                  COB50020
      DATA($A    +I)=DATA($AN+I)                                       COB50030
      DATA($DC   +I)=DATA($AC+I)*4./DATA($PW+I)                        COB50040
      DATA($DHYD +I)=DATA($DC   +I)/12.                                COB50050
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      DATA($DHYDN+I)=DATA($DHYD +I)                                     COB50060
      PHTOT=PHTOT+DATA($HPERI +I)                                       COB50070
 147  ATOTAL=ATOTAL+DATA($AN+I)                                         COB50080
      NK=K                                                              COB50090
      CALL ACOL(2,IDAT($IK+1),IDAT($JK+1),KMAX,IDAT($LOCA+1),MA,MS,NK,  COB50100
     1   MG,IPILE)                                                      COB50110
      IF(J1.LE.1) PRINT(4) = .TRUE.                                     COB50120
      CALL CORE3                                                        COB50130
      GO TO 995                                                         COB50140
C                                                                       COB50150
C  INPUT FOR CARD GROUP 5, CHANNEL AREA VARIATION TABLE                 COB50160
  150 DO 151 I=1,NCHANL                                                 COB50170
 151  IDAT($IDARE+I)=0                                                  COB50180
      NAXL = N2                                                         COB50190
      NARAMP = N3                                                       COB50200
      IF(NARAMP.LE.0) NARAMP = 1                                        COB50210
      IF(N2.LT.1) GO TO 995                                             COB50220
      READ(I2,5) (AXL(I),I=1,N2)                                        COB50230
      NAFACT=N1                                                         COB50240
      DO 152 J=1,N1                                                     COB50250
      READ(I2,8)  I,(AFACT(J,L),L=1,N2)                                 COB50260
      IDAT($IDARE+I)=J                                                  COB50270
  152 NCH(J)= I                                                         COB50280
      IF(J1.LE.1) PRINT(5) = .TRUE.                                     COB50290
      GO TO 995                                                         COB50300
C                                                                       COB50310
C  INPUT FOR CARD GROUP 6, GAP SIZE VARIATIONS TABLE                    COB50320
  160 DO 161 K=1,NK                                                     COB50330
 161  IDAT($IDGAP+K)=0                                                  COB50340
      NGXL = N2                                                         COB50350
      IF(N2.LT.1) GO TO 995                                             COB50360
      READ(I2,5) (GAPXL(L),L=1,NGXL)                                    COB50370
      NGAPS = N1                                                        COB50380
      DO 162 LL=1,NGAPS                                                 COB50390
      READ(I2,1) K                                                      COB50400
      IDAT($IDGAP+K)=LL                                                 COB50410
      NGAP(LL) = K                                                      COB50420
      READ (I2, 5) (GFACT(LL,L),L=1,NGXL)                               COB50430
  162 CONTINUE                                                          COB50440
      IF(J1.LE.1) PRINT(6) = .TRUE.                                     COB50450
      GO TO 995                                                         COB50460
C                                                                       COB50470
C  INPUT FOR CARD GROUP 7, SPACER DESIGN INFORMATION                    COB50480
  170 IF(IPILE.EQ.0) GO TO 1705                                         COB50490
      WRITE(I3,1704) IPILE,NGROUP                                       COB50500
 1704 FORMAT(' IPILE=',I2,' CARD GROUP',I2,                             COB50510
     1 ' INCORRECTLY ENTERED .CHECK DATA')                              COB50520
      IERROR = 1                                                        COB50530
      GO TO 240                                                         COB50540
 1705 J6 = N1                                                           COB50550
      NRAMP = N4                                                        COB50560
      IF(NRAMP.LT.1) NRAMP = 1                                          COB50570
      GRID = .FALSE.                                                    COB50580
      NGRID = 0                                                         COB50590
      IF(J6.EQ.0) GO TO 995                                             COB50600
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      IF(J6.EQ.1) GO TO 171
      IF(J6.EQ.2) GO TO 176
      GO TO 995
  171 READ(12,42) PITCH,DIA,THICK
      PITCH = PITCH/12.
      DIA = DIA/12.
      THICK = THICK/12.
      NJUMP = N5
      DO 172 M=1,NK
      READ(12,64) K,DUM,CROSS
      DATA($DUR+K)=DUM
      DO 172 L=1,6
 172  DATA($XCROS+K+MG*(L-1))=CROSS(L)
      READ(12,68)  (IDAT($NWRAP+I),I=1,NCHANL)
      DO 173 I=1,NCHANL
 173  IDAT($NWRPS+I)=IDAT($NWRAP+I)
      IF(J1.LE.1) PRINT(7) = .TRUE.
      IF(NJUMP.EQ.3) JUMP = 3
      IF(NJUMP.NE.3) GO TO 995
      REWIND 18
      READ(18) ((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)
      REWIND 18
      GO TO 995
  176 NGRID = N2
      NGRIDT = N3
      READ(12,66) (GRIDXL(I),IGRID(I),I=1,NGRID)
      DO 178 I=1,NGRIDT
      DO 177 K=1,NK
 177  DATA($FXFLO+K+MG*(I-1))=0.
      DO 178 II=1,NCHANL
 178  READ(12,67)  J,DATA($CD+J+MC*(I-1)),K,DATA($FXFLO+K+MG*(I-1))
      IF(J1.LE.1) PRINT(7) = .TRUE.
      GO TO 995
C
C  INPUT FOR CARD GROUP 8, ROD LAYOUT, DIMENSIONS, AND POWER FACTORS
  180 IF(IPILE.EQ.0) GO TO 1805
      WRITE(13,1704) IPILE,NGROUP
      IERROR = 1
      GO TO 240
 1805 NROD = N2
      DO 181 J=1,N1
      READ (12,11) N,I,DATA($DR+I),
     1                     DATA(SRADIA+I),(IDAT($LR+I+MR*(L-1)),
     1    DATA($PHI+I+MR*(L-1)),L=1,6)
      IDAT($IDFUE+I)=N
      IF(N.LT.1)  IDAT($IDFUE+I)=1
  181 CONTINUE
      DO 182 I=1,MC
      DO 182 J=1,MR
 182  DATA($PWRF+I+MC*(J-1))=0.
      DO 185 I=1,NROD
      DO 184 L=1,6
```

```
      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 (12,79) (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(12,14) 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(13,1704) IPILE, NGROUP
      GO TO 995
  205 NSCBC = N1
      IF (NSCBC.NE.4) READ(12,5) ABETA,BBETA
      DO 206I=1,MG
  206 ENEH(I)=1.0
      NBBC =N2
```

```
      J5 = N3                                                           COB51710
      IF(N2.GE.2) READ(I2,5) (XQUAL(I),BX(I),I=1,N2)                    COB51720
      IF(J5.EQ.0) GK = 0.                                               COB51730
      IF(J5.EQ.1) READ(I2,5) GK                                         COB51740
      IF(J1.LE.1) PRINT(10) = .TRUE.                                    COB51750
      GO TO 995                                                         COB51760
C                                                                       COB51770
C  INPUT FOR CARD GROUP 11, OPERATING CONDITIONS AND TRANSIENT FORCING FCOB51780
  210 READ(I2,9) PEXIT,HIN,GIN,AFLUX                                    COB51790
      PREF = PEXIT                                                      COB51800
      CALL PROP(1,1)                                                    COB51810
      IF(IERROR.GT.1) GO TO 240                                         COB51820
      IN = N1                                                           COB51830
C  FOR N1=0, HIN IS THE INLET H.  FOR N1=1, HIN IS THE INLET T.         COB51840
C  FOR N1=2, READ IN CHANNEL H.   FOR N1=3, READ IN CHANNEL T.          COB51850
      IF(N1.GE.2) GO TO 214                                             COB51860
      IF(N1.EQ.1) GO TO 211                                             COB51870
      TIN = TF                                                          COB51880
      IF(HIN.LT.HF) CALL CURVE(TIN,HIN,TT,HHF,NPROP,IERROR,1)           COB51890
      IF(IERROR.GT.1) GO TO 240                                         COB51900
      GO TO 212                                                         COB51910
  211 TIN = HIN                                                         COB51920
      CALL CURVE(HIN,TIN,HHF,TT,NPROP,IERROR,1)                         COB51930
      IF(IERROR.GT.1) GO TO 240                                         COB51940
  212 DO 213 I=1,NCHANL                                                 COB51950
 213  DATA($HINLE+I)=HIN                                                COB51960
      GO TO 216                                                         COB51970
 214  READ(I2,10) (DATA($HINLE+I),I=1,NCHANL)                           COB51980
      IF(N1.LE.2) GO TO 216                                             COB51990
      DO 215 I=1,NCHANL                                                 COB52000
      CALL CURVE(DATA($HINLE+I),DATA($HINLE+I),HHF,TT,NPROP,IERROR,1)   COB52010
      IF(IERROR.GT.1) GO TO 240                                         COB52020
  215 CONTINUE                                                          COB52030
  216 DO 2160 I=1,NCHANL                                                COB52040
      DATA($TINLE+I)=TF                                                 COB52050
      IF(DATA($HINLE+I).LT.HF)                                          COB52060
     1CALL CURVE(DATA($TINLE+I),DATA($HINLE+I),TT,HHF,NPROP,IERROR,1)   COB52070
      IF(IERROR.GT.1) GO TO 240                                         COB52080
 2160 CONTINUE                                                          COB52090
      IG = N2                                                           COB52100
C  FOR N2=0, GIN IS THE INLET G FOR EACH CHANNEL.  FOR N2=1, GIN IS THE COB52110
C  AVERAGE G BUT THE CHANNEL FLOWS ARE SPLIT TO GIVE EQUAL DP/DX,  FOR NCOB52120
C  INDIVIDUAL CHANNEL TOTAL FLOW FRACTION IS READ AS INPUT              COB52130
      FLO = GIN/.0036*ATOTAL                                            COB52140
      DO 217 I=1,NCHANL                                                 COB52150
 217  DATA($FINLE+I)=GIN*DATA($AN+I)/.0036                              COB52160
      IF(N2.EQ.1) CALL SPLIT                                            COB52170
      IF(IERROR.GT.1) GO TO 240                                         COB52180
      IF(N2.LT.2) GO TO 219                                             COB52190
      READ(I2,10)  (DATA($FSPLI+I),I=1,NCHANL)                          COB52200
      DO 218 I=1,NCHANL                                                 COB52210
 218  DATA($FINLE+I)=GIN*DATA($AN+I)*DATA($FSPLI+I)/.0036               COB52220
  219 NP = N3                                                           COB52230
      IF(NP.GT.1) READ(I2,10) (YP(I),FP(I),I=1,NP)                      COB52240
      NH = N4                                                           COB52250
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      IF(NH.GT.1) READ(I2,10) (YH(I),FH(I),I=1,NH)                      COB52260
      NG = N5                                                           COB52270
      IF(NG.GT.1) READ(I2,10) (YG(I),FG(I),I=1,NG)                      COB52280
      NQ = N6                                                           COB52290
      IF(NQ.GT.1) READ(I2,10) (YQ(I),FQ(I),I=1,NQ)                      COB52300
      IF(J1.LE.2) PRINT(11) = .TRUE.                                    COB52310
      GO TO 995                                                         COB52320
C                                                                       COB52330
C  INPUT FOR CARD GROUP 12, OUTPUT OPTIONS FOR CALCULATIONS             COB52340
  220 NOUT = N1                                                         COB52350
      NPCHAN = N2                                                       COB52360
      IF(N2.LT.1) GO TO 221                                             COB52370
      READ(I2,17)  (IDAT($PRNTC+I),I=1,N2)                              COB52380
  221 NPROD = N3                                                        COB52390
      NPNODE = N4                                                       COB52400
      IF(N3.LT.1) GO TO 222                                             COB52410
      READ 17,      (IDAT($PRNTR+I),I=1,N3)                             COB52420
  222 IF(N4.LT.1) GO TO 225                                             COB52430
      READ 17,      (IDAT($PRNTN+I),I=1,N4)                             COB52440
  225 GO TO 995                                                         COB52450
C     CARD GROUP 20  .  READ DATA VIA ITHO                              COB52460
 230  NOPRIN=N1                                                         COB52470
      CALL CARD20(NOPRIN)                                               COB52480
      IF(IERROR.GT.0)  GO TO 240                                        COB52490
      GO TO 995                                                         COB52500
C                                                                       COB52510
C  INPUT DATA ERROR MESSAGE                                             COB52520
  240 WRITE(13,54)                                                      COB52530
      STOP                                                              COB52540
C                                                                       COB52550
C  END OF INPUT                                                         COB52560
C                                                                       COB52570
  250 RETURN                                                            COB52580
C                                                                       COB52590
    1 FORMAT(7I5)                                                       COB52600
    2 FORMAT(I1, I4, I5, 17A4)                                          COB52610
    3 FORMAT(15H1INPUT FOR CASE          I6,5X,16A4,A2,                 COB52620
     19H   DATE  2A4,7H TIME  2A4,A1      )                             COB52630
    5 FORMAT (12F5.3)                                                   COB52640
    7 FORMAT(I1,I4,3E5.2,4(I5,2E5.2))                                   COB52650
    8 FORMAT ( I5/(12F5.3))                                             COB52660
    9 FORMAT (6F10.0)                                                   COB52670
   10 FORMAT(12E5.0)                                                    COB52680
   11 FORMAT(I1,I4,2E5.2,6(I5,E5.2))                                    COB52690
   14 FORMAT(4E5.2,2I5,E5.2,I5,4E5.2)                                   COB52700
   17 FORMAT (36I2)                                                     COB52710
   41 FORMAT (I5,7E10.5)                                                COB52720
   42 FORMAT(8E10.5)                                                    COB52730
   52 FORMAT (I5,6E12.6)                                                COB52740
   54 FORMAT(//' INPUT DATA ERROR, THIS RUN STOPPED, CHECK INPUT')      COB52750
   64 FORMAT(I5,10E5.2)                                                 COB52760
   66 FORMAT (6( E5.2,I5))                                              COB52770
   67 FORMAT (I5,E5.2,I5,E5.2)                                          COB52780
   68 FORMAT(10I5)                                                      COB52790
   79 FORMAT ( 9E5.2)                                                   COB52800
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 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    ,L2    ,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 ,NRCD  ,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,$SA  ,$SB   ,$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
      DATA TAG /4HW/GS, 4HW/GD /
C
C     IPART=1  SET HYDRAULIC MODEL
C     IPART=2  PRINT HYDRAULIC MODEL
C     SAME AS MEKIN CODING
C
C     PRESET MODEL IS CODED FIRST AND IS USED IF ALL N1-N7=0
C     INDIVIDUAL PARTS OF MODEL MAY BE CHANGED BY
C     SETTING ANY OF N1-N7 POSITIVE NON-ZERO
C
      IF(IPART.EQ.2) GO TO 30
C     (N1) MIXING MODEL (CARD GROUP 10)
      NSCBC=1
      NBBC=1
      J5=0
      GK=0.0
      ABETA=0.02
      BBETA=0.0
      IF(IPILE.EQ.2) ABETA=0.0
C     (N2) SINGLE PHASE FRICTION (CARD GROUP 2)
      DO 4 I=1,4
      AA(I)=0.184
      BB(I)=-0.2
    4 CC(I)=0.0
      NVISCW=0
C     (N3) TWO PHASE FRICTION (CARD GROUP 2)
      J4=0
C     (N4) VOID FRACTION (CARD GROUP 2)
      J2=0
      J3=0
C     (N5) FLOW DIVISION AT INLET (CARD GROUP 11)
      IG = 0
C     (N6) CONSTANTS (CARD GROUP 9)
      NCHF = 0
      KIJ=0.5
      FTM=0.0
      SL=0.5
      THETA=0.0
      ELEV=1.0
C     (N7) ITERATION (CARD GROUP 9)
      NTRIES=20
      FERROR=0.001
C     (N8) PHYSICAL PROPERTIES (CARD GROUP 1)
      NPROP=0
C     (N9) COUPLING PARAMETER FOR ENTHALPY EXCHANGE
      DO 3201 K=1,NK
 3201 ENEH(K)=1.0
C
      READ(I2,1001) CARD,N1,N2,N3,N4,N5,N6,N7,NPROP,N9
      WRITE(I3,1009) CARD
      IF((N1+N2+N3+N4+N5+N6+N7+NPROP+N9).EQ.0) RETURN
C
      IF(N1.EQ.0) GO TO 6
      IF (N1.EQ.2) NSCBC=2
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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?', /)                                                 COB54700
 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')       COB54670
 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)' )               C0655080
 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          $$S    ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB55500
     1   $CCHAN,$CD   ,$CHFR ,SCON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB55510
     2   $DHDX ,$DHYD ,SDHYDN,$DIST ,$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,$MCFRR,$NTYPF,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB55560
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB55570
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB55580
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB55590
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA   ,$SB   ,$XPOLD COB55600
C                                                                       COB55610
      COMMON  DATA(1)                                                   COB55620
      LOGICAL LDAT(1)                                                   COB55630
      INTEGER IDAT(1)                                                   COB55640
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB55650
C                                                                       COB55660
C                                                                       COB55670
      COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),  COB55680
     1 JM(9),,OUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),COB55690
     2 YQ(30)                                                           COB55700
      COMMON/LINK3/DXX,ETIME,GIN,HIN,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,  COB55710
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,  COB55720
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ             COB55730
      DIMENSION CARD(20)                                                COB55740
C                                                                       COB55750
C     SET PRINTING PARAMETERS                                           COB55760
C     FOR INPRIN                                                        COB55770
      IF (J1.GT.1) GO TO 4                                              COB55780
      DO 2 I=1,11                                                       COB55790
    2 PRINT(I) = .TRUE.                                                 COB55800
      PRINT(5) = .FALSE.                                                COB55810
      PRINT(6) = .FALSE.                                                COB55820
C                                                                       COB55830
C     FOR CALC (CARD GROUP 9)                                           COB55840
    4 READ (I2,1001) CARD, KDEBUG                                       COB55850
      WRITE (I3,1002) CARD                                              COB55860
C                                                                       COB55870
C     FOR EXPRIN (CARD GROUPS 9, 12)                                    COB55880
      READ (I2,1001) CARD,NSKIPX, NSKIPT, NOUT, NPCHAN, NPROD, NPNODE   COB55890
      WRITE (I3,1003) CARD                                              COB55900
C     NSKIPX.   EVERY NSKIPX AXIAL STEP PRINTED.      (0 = 1)           COB55910
C     NSKIPT.   EVERY NSKIPT TIME  STEP PRINTED.      (0 = 1)           COB55920
C     NOUT = 0-3 FOR PRINTING (0) CHANNEL ONLY, (1) CHAN + CROSS FLOWS, COB55930
C     (2) CHAN + FUEL TEMP,  (3) CHAN + C-F + FUEL TEMP                 COB55940
C     NPCHAN = 0, ALL CHAN PRINTED.   .GT.0 READ CHANS REQD.            COB55950
C     NPROD, NPNODE AS NPCHAN BUT FOR RODS AND NODES.                   COB55960
      IF (NSKIPX.LT.1) NSKIPX = 1                                       COB55970
      IF (NSKIPT.LT.1) NSKIPT = 1                                       COB55980
      IF (NPCHAN.LT.1) GO TO 6                                          COB55990
      MROSI=1                                                           COB56000
 7209 MMJAVI=MIN0((MROSI+13),NPCHAN)                                    COB56010
      READ(I2,1001) CARD,(IDAT($PRNTC+I),I=MROSI,MMJAVI)                COB56020
      WRITE(I3,1004) CARD                                               COB56030
      MROSI=MMJAVI+1                                                    COB56040
      IF(MROSI.LE.NPCHAN) GO TO 7209                                    COB56050
    6 IF(NPROD.LT.1) GO TO 8                                            COB56060
      MROSI=1                                                           COB56070
 8209 MMJAVI=MIN0 ((MROSI+13),NPROD)                                    COB56080
      READ (I2,1001)CARD,(IDAT($PRNTR+I),I=MROSI,MMJAVI)                COB56090
      WRITE (I3,1006) CARD                                              COB56100
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      MROSI=MMJAVI+1                                                    COB56110
      IF (MROSI.LE.NPROD) GO TO  8209                                   COB56120
    8 IF(NPNODE.LT.1) GO TO 10                                          COB56130
      MROSI=1                                                           COB56140
 6209 MMJAVI=MINO((MROSI+13),NPNODE)                                    COB56150
      READ(12,1001) CARD,(IDAT($PRNTN+I),I=MROSI,MMJAVI)                COB56160
      WRITE(13,1007)CARD                                                COB56170
      MROSI=MMJAVI+1                                                    COB56180
      IF (MROSI.LE.NPNODE) GO TO 6209                                   COB56190
C                                                                       COB56200
   10 IF (NPCHAN.GT.0) GO TO 14                                         COB56210
      NPCHAN = NCHANL                                                   COB56220
      DO 12 I=1,NCHANL                                                  COB56230
   12 IDAT($PRNTC+I) = I                                                COB56240
   14 IF (NPROD.GT.0) GO TO 18                                          COB56250
      NPROD = NROD                                                      COB56260
      DO 16 I=1,NROD                                                    COB56270
   16 IDAT($PRNTR+I) = I                                                COB56280
   18 IF (NPNODE.GT.0) GO TO 22                                         COB56290
      NPNODE = NODESF+1                                                 COB56300
      DO 20 I=1,NPNODE                                                  COB56310
   20 IDAT($PRNTN+I) = I                                                COB56320
   22 CONTINUE                                                          COB56330
C                                                                       COB56340
      RETURN                                                            COB56350
C                                                                       COB56360
 1001 FORMAT(20A4, T1, 14I5)                                            COB56370
 1002 FORMAT('  KDEBUG', 22X, '***', 20A4, '*** TABLES')                COB56380
 1003 FORMAT('  PRINTING', 20X, '***', 20A4, '*** TABLES')              COB56390
 1004 FORMAT('  PRINT CHANNELS   ', 11X, '***', 20A4, '*** TABLES')     COB56400
 1005 FORMAT('  PLUS REMAINDER')                                        COB56410
 1006 FORMAT('  PRINT RODS       ', 11X, '***', 20A4, '*** TABLES')     COB56420
 1007 FORMAT('  PRINT NODES      ', 11X, '***', 20A4, '*** TABLES')     COB56430
      END                                                               COB56440
        BLOCK DATA                                                      COB56450
        IMPLICIT INTEGER*4 ($)                                          COB56460
        REAL*8 $NAMES,$NAME1,$NAME2                                     COB56470
        DIMENSION $LX(97),$NAME1(46),$NAME2(51),$NAMES(97)              COB56480
        COMMON /COBRA5/  $NAMES,$LX,$TYPE                               COB56490
        EQUIVALENCE  ($NAMES(1),$NAME1(1)),($NAMES(47),$NAME2(1))       COB56500
         DATA $NAME1 /8HA        ,8HAAA     ,8HAC      ,                COB56510
     1 8HALPHA   ,                                                      COB56520
     18HAN      ,8HANSWER ,8HB       ,8HCCHANL ,8HCD      ,8HCHFR    ,COB56530
     28HCON     ,8HCOND   ,8HCP      ,8HD      ,8HDC      ,8HDFDX    ,COB56540
     38HDHDX    ,8HDHYD   ,8HDHYDN   ,8HDIST   ,8HDPDX    ,8HDPK     ,COB56550
     48HDUR     ,8HDR     ,8HF       ,8HFACTOR ,8HFDIV    ,8HFINLET  ,COB56560
     58HFLUX    ,8HFMULT  ,8HFOLD    ,8HFSP    ,8HFSPLIT  ,8HFXFLOW  ,COB56570
     68HGAP     ,8HGAPN   ,8HGAPS    ,8HH      ,8HHFILM   ,8HHINLET  ,COB56580
     78HHOLD    ,8HHPERIM ,8HIDAREA  ,8HIDFUEL ,8HIDGAP   ,8HIK      /COB56590
         DATA $NAME2/                                                   COB56600
     88HJ8DIL   ,8HJK     ,8HLC      ,8HLENGTH ,8HLOCA    ,8HLR      ,COB56610
     98HMCHFR   ,8HMCHFRC ,8HMCHFRR  ,8HNTYPE  ,8HNWRAP   ,8HNWRAPS  ,COB56620
     A8HP       ,8HPERIM  ,8HPH      ,8HPHI    ,8HPRINTC  ,8HPRINTR  ,COB56630
     B8HPRINTN  ,8HPW     ,8HPWRF    ,8HQC     ,8HQF      ,8HQPRIM   ,COB56640
     C8HQUAL    ,8HRADIAL ,8HRHO     ,8HRHOOLD ,8HSP      ,8HT       ,COB56650
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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                                                        COB57210
      $LX(59)=MC*MX                                                     COB57220
      $LX(62)=MR*6                                                      COB57230
      $LX(64)=MR                                                        COB57240
      $LX(65)=MN                                                        COB57250
      $LX(67)=MC*MR                                                     COB57260
      $LX(68)=MC*MX                                                     COB57270
      $LX(69)=MC*MX                                                     COB57280
      $LX(72)=MR                                                        COB57290
      $LX(73)=MC*MX                                                     COB57300
      $LX(74)=MC*MX                                                     COB57310
      $LX(75)=MG*MX                                                     COB57320
C     PROVIDE SPACE FOR SP IN BWR ITERATION.                            COB57330
      IF ($LX(75) .LT.3*MC) $LX(75) = 3*MC                              COB57340
      $LX(77)=MN                                                        COB57350
      $LX(79)=MN*MR*MX                                                  COB57360
      $LX(82)=MG                                                        COB57370
      $LX(83)=MG                                                        COB57380
      $LX(89)=MG*MX                                                     COB57390
      $LX(90)=MG*MX                                                     COB57400
      $LX(91)=MG                                                        COB57410
      $LX(92)=MG                                                        COB57420
      $LX(93)=MX                                                        COB57430
      $LX(94)=MG*6                                                      COB57440
      $LX(95)=3*MN                                                      COB57450
      $LX(96)=MN                                                        COB57460
C   *******                                                             COB57470
      $LX(97)=MC*MX                                                     COB57480
      $ORG(1)=1                                                         COB57490
      $LXX=0                                                            COB57500
      DO 110  I=1,$$$                                                   COB57510
      $LXX=$LXX+$LX(I)                                                  COB57520
      IF(I.GT.1)  $ORG(I)=$ORG(I-1)+$LX(I-1)                            COB57530
  110 CONTINUE                                                          COB57540
      KS=1                                                              COB57550
CC                                                                      COB57560
CC   KMAX IN SUBROUTINE CORE EQUALS                                     COB57570
CC   LENGTH OF DATA ARRAY GIVEN BELOW                                   COB57580
CC                                                                      COB57590
      KMAX=80000                                                        COB57600
      KFREE=KS                                                          COB57610
      KTOP = KS + KMAX - 1                                              COB57620
      KS=KS+MOD(KS+1,2)                                                 COB57630
      IF(KMAX.LT.$LXX) GO TO 902                                        COB57640
      DO 300 K=KS,KTOP                                                  COB57650
  300 DATA(K) = 0.0                                                     COB57660
      DO 400  N=1,$$$                                                   COB57670
  400 $ORG(N)=$ORG(N)+KS-1                                              COB57680
      RETURN                                                            COB57690
C                                                                       COB57700
      ENTRY CORE2(MSP,NKP)                                              COB57710
      NK=NKP                                                            COB57720
      MS=MSP                                                            COB57730
      MA=NK*MS                                                          COB57740
      $LX(2)=MA                                                         COB57750
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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('ODYNAMIC ALLOCATION OF CORE GOT ',I10,' WORDS'/)          COB58020
 3001 FORMAT('ODYNAMIC ALLOCATION OF CORE FAILED'///)                   COB58030
 3002 FORMAT('ODYNAMIC 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
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     7   QAX    ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB58310
     8   UF     ,VF    ,VFG   ,VG    ,Z                                  COB58320
C                                                                        COB58330
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB58340
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB58350
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB58360
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB58370
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB58380
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB58390
C                                                                        COB58400
C                                                                        COB58410
      LOGICAL  GRID                                                      COB58420
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                COB58430
C                                                                        COB58440
C                                                                        COB58450
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX    ,COB58460
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B     ,COB58470
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB58480
     2   $DHDX ,$DH/D ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB58490
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB58500
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB58510
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB58520
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB58530
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB58540
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB58550
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB58560
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD  COB58570
      COMMON/LINK9/ENEH(400)                                             COB58580
C                                                                        COB58590
      COMMON  DATA(1)                                                    COB58600
      LOGICAL LDAT(1)                                                    COB58610
      INTEGER IDAT(1)                                                    COB58620
      EQUIVALENCE   (DATA(1),IDAT(1),LDAT(1))                            COB58630
C                                                                        COB58640
      EQUIVALENCE (NCHAN,NCHANL)                                         COB58650
C                                                                        COB58660
      IPILE = J7                                                         COB58670
      JM1 = J-1                                                          COB58680
      IF(IPART.LT.1 .OR. IPART.GT.4) GO TO 1000                          COB58690
      GO TO (100,200,300,400),IPART                                      COB58700
C                                                                        COB58710
C  PART 1, CALCULATE DH/DX FOR STEADY STATE AT X AND T.                  COB58720
  100 DO 120 I=1,NCHANL                                                  COB58730
  120 DATA($DHDX+I)=0.                                                   COB58740
      IF (IPILE.EQ.2) GO TO 185                                          COB58750
      DO 180 K=1,NK                                                      COB58760
      I=IDAT($IK+K)                                                      COB58770
      L=IDAT($JK+K)                                                      COB58780
      WV=(DATA($H+I+MC*(J-1))-DATA($H+L+MC*(J-1)))                       COB58790
      IF(DATA($W+K+MG*(J-1)).LT.0.)  GO TO 140                           COB58800
      HWI = 0.0                                                          COB58810
      HWL=  DATA($W+K+MG*(J-1)) * WV                                     COB58820
      GO TO 160                                                          COB58830
  140 HWI=  DATA($W+K+MG*(J-1)) * WV                                     COB58840
      HWL = 0.0                                                          COB58850
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  160  CONTINUE                                                                COB58860
       DATA($DHDX+I)=DATA($DHDX+I)+HWI-WV*DATA($WP+K)/ENEH(K)-(DATA($T+I)COB58870
      1     -DATA($T+L))*DATA($COND+K)                                         COB58880
       DATA($DHDX+L)=DATA($DHDX+L)+HWL+WV*DATA($WP+K)/ENEH(K)+(DATA($T+I)COB58890
      1     -DATA($T+L))*DATA($COND+K)                                         COB58900
  180 CONTINUE                                                                 COB58910
  185 DO 190 I=1,NCHANL                                                        COB58920
  190  DATA($DHDX+I)=(DATA($DHDX+I)+DATA($QPRIM+I)+DATA($QC+I+MC*J)/DX)        COB58930
      1                   /DATA($F+I+MC*(J-1))                                 COB58940
       GO TO 500                                                               COB58950
C                                                                              COB58960
C  PART 2, CALCULATE DF/DX FOR STEADY STATE AT X AND T                         COB58970
  200 DO 220 I=1,NCHANL                                                        COB58980
  220  DATA($DFDX+I)=0.                                                        COB58990
       IF (IPILE.EQ.2) GO TO 500                                               COB59000
       DO 240 K=1,NK                                                           COB59010
       I =IDAT($IK+K)                                                          COB59020
       L =IDAT($JK+K)                                                          COB59030
       DATA($DFDX+I)=DATA($DFDX+I)-DATA($W+K+MG*(J-1))                         COB59040
  240  DATA($DFDX+L)=DATA($DFDX+L)+DATA($W+K+MG*(J-1))                         COB59050
       GO TO 500                                                               COB59060
C                                                                              COB59070
C  PART 3, CALCULATE DP/DX WITHOUT W                                           COB59080
  300 DO 302 I=1,NCHANL                                                        COB59090
  302  DATA($DPDX+I)=0.                                                        COB59100
       IF (FTM.LE.0.0) GO TO 306                                               COB59110
       IF (IPILE.EQ.2) GO TO 306                                               COB59120
       DO 304 K=1,NK                                                           COB59130
       I=IDAT($IK+K)                                                           COB59140
       L=IDAT($JK+K)                                                           COB59150
       WV=(DATA($U+I)-DATA($U+L))*DATA($WP+K)                                  COB59160
       DATA($DPDX+I)=DATA($DPDX+I)+WV                                          COB59170
       DATA($DPDX+L)=DATA($DPDX+L)-WV                                          COB59180
  304 CONTINUE                                                                 COB59190
  306 DO 390 I=1,NCHANL                                                        COB59200
       SAVE=0.5*DATA($FSP+I)*DATA($FMULT+I)*DATA($V+I)/DATA($DHYD+I)           COB59210
      1     +(DATA($VP+I)/DATA($A+I)-DATA($VPA+I))*DATA($A+I)/DX               COB59220
       IF(.NOT.GRID) GO TO 310                                                 COB59230
       IF(NRAMP.LE.0) GO TO 1000                                               COB59240
       DUMY = FLOAT(ITERAT)/FLOAT(NRAMP)                                       COB59250
       IF(DUMY.GT.1.) DUMY = 1.                                                COB59260
       SAVE=SAVE+.5*DUMY*DATA($CD+I+MC*(NGTYPE-1))*DATA($VP+I)/DX              COB59270
  310  DATA($DPK+I)=SAVE/(DATA($A+I)*DATA($A+I))                               COB59280
       JJ = JM1                                                                COB59290
       IF (J.GT.1) GO TO 382                                                   COB59300
       JJ = 1                                                                  COB59310
  382  FLOWSQ=ABS(DATA($F+I+MC*(JJ-1)))*                                       COB59320
      1             DATA($F+I+MC*(JJ-1))                                       COB59330
C      JK INSERT                                                               COB59340
        IF(IPILE.EQ.2)  FLOWSQ= DATA($F+I+MC*(J-1))**2                         COB59350
       DATA($DPDX+I)=-DATA($DPK+I)*FLOWSQ/GC-DATA($RHO+I+MC*(J-1))*            COB59360
      1     ELEV-DATA($DPDX+I)*FTM/(DATA($A+I)*GC)                             COB59370
       IF(DT.GT.100.) GO TO 390                                                COB59380
C         T R INSERT                                                           COB59390
       RHODIF=DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))                    COB59400
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      RHODOT=RHODIF/DT                                                  COB59410
C     JK INSERT                                                         COB59420
       IF(IPILE.NE.2)  GO TO 385                                        COB59430
      DATA($DPDX+I)=DATA($DPDX+I)+RHODOT/GC*2.*DATA($U+I)               COB59440
     1   +(DATA($FOLD+I+MC*(J-1))-DATA($F+I+MC*(J-1)))/DATA($A+I)/DT/GC COB59450
       GO TO 390                                                        COB59460
 385  DATA($DPDX+I)=DATA($DPDX+I)+RHODOT/GC*(2.*DATA($U+I)+DX/DT        COB59470
     1     +DATA($DPK+I)*ABS(DATA($F+I+MC*(JM1-1))+DATA($F+I+MC*(J-1)))* COB59480
     2     DATA($A+I)*DX)+       (DATA($FOLD+I+MC*(J-1))-DATA($F+I+MC*(JM1COB59490
     3     -1)))/DATA($A+I)/DT/GC                                       COB59500
  390 CONTINUE                                                          COB59510
      GO TO 500                                                         COB59520
C                                                                       COB59530
C  PART 4, CALCULATE DP/DX WITH W                                       COB59540
  400 IF (J.EQ.1) GO TO 500                                             COB59550
      DO 410  I=1,NCHANL                                                COB59560
 410  DATA($DHDX+I)=0.                                                  COB59570
      IF (IPILE.EQ.2) GO TO 425                                         COB59580
      DO 420  K=1,NK                                                    COB59590
      I=IDAT($IK+K)                                                     COB59600
      L=IDAT($JK+K)                                                     COB59610
      DATA($DHDX+I)=DATA($DHDX+I)+((2.*DATA($U+I)-DATA($USTAR+K)+DX/DT) COB59620
     1     /DATA($A+I)+DATA($DPK+I)*ABS(DATA($F+I+MC*(JM1-1))+          COB59630
     2     DATA($F+I+MC*(J-1)))*DX)*DATA($W+K+MG*(J-1))                 COB59640
      DATA($DHDX+L)=DATA($DHDX+L)-((2.*DATA($U+L)-DATA($USTAR+K)+DX/DT) COB59650
     1     /DATA($A+L)+DATA($DPK+L)*ABS(DATA($F+L+MC*(JM1-1))+          COB59660
     2     DATA($F+L+MC*(J-1)))*DX)*DATA($W+K+MG*(J-1))                 COB59670
  420 CONTINUE                                                          COB59680
  425 DO 430  I=1,NCHANL                                                COB59690
 430  DATA($DPDX+I)=DATA($DPDX+I)+DATA($DHDX+I)/GC                      COB59700
C                                                                       COB59710
  500 CONTINUE                                                          COB59720
      RETURN                                                            COB59730
 1000 IERROR = 2                                                        COB59740
      RETURN                                                            COB59750
      END                                                               COB59760
      SUBROUTINE HEAT(J)                                                COB59770
C     CALCULATE THE HEAT INPUT TO EACH SUBCHANNEL AT POSITION J.        COB59780
C     IF NODES GREATER THAN ZERO, CALCULATE HEAT INPUT USING THERMAL    COB59790
C     CONDUCTION. OTHERWISE HEAT INPUT IS DEFINED BY HEAT GENERATION.   COB59800
C     POWER = AVERAGE INTERNAL HEAT GENERATION.                         COB59810
C                                                                       COB59820
C                                                                       COB59830
      IMPLICIT INTEGER ($)                                              COB59840
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX    ,COB59850
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF    ,COB59860
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2    ,COB59870
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,       COB59880
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBBC  ,NCHAN ,NCHF  ,NDX   ,NF    ,COB59890
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP ,COB59900
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF  ,COB59910
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK ,COB59920
     8   UF    ,VF    ,VFG   ,VG    ,Z                                  COB59930
C                                                                       COB59940
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),    COB59950
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     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          $$S    ,$A     ,$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   ,$XPOLD
C
      COMMON/LINK3/DXX,ETIME,GIN,HIN,IB,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
     1 NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQ,NR,
     2 NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ
C
      COMMON/FRDATA/BURN,CPR,EFFB,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,
     1  GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG
C
      COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,NGP
C
      COMMON /TIMEST/ NT
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
      EQUIVALENCE (NCHAN,NCHANL)
C
      IPILE = J7
      NP1 = NODESF+1
C  BYPASS THE HEAT FLUX CALCULATION IF BEYOND THE FIRST ITERATION AND
C  IF FUEL TEMPERATURES ARE NOT TO BE CALCULATED.
      IF(ITERAT.GT.1 .AND. NODESF.LT.1) GO TO 60
C  BYPASS THE HEAT FLUX CALCULATION USING THE FUEL TEMPERATURE MODEL
C  IF BEYOND THE FIRST ITERATION, AND IF FUEL TEMPERATURES HAVE BEEN
C  CALCULATED AND IF A TRANSIENT CALCULATION IS BEING PERFORMED.
      IF(ITERAT.GT.1 .AND. NODESF.GT.0 .AND. DT.LT.100.) GO TO 60
      IF(IQP3.LE.1) GO TO 170
      CALL CURVE(QAX,(DATA($X+J)-DX*0.5)/Z,AXIAL,Y,NAX,IERROR,1)
  170 CONTINUE
C  DETERMINE THE HEAT FLUX FROM EACH ROD.
```

```
      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($TDUMY+1),DT,N,J,DATA($SA+1),DATA($SB+1))
      IF(IERROR.GT.1) RETURN
   22 DO 24 I=1,NP1
   24 DATA($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
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      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         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B    ,COB61610
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,COB61620
     2   $DHDX ,$DHYD ,$CHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,COB61630
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB61640
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB61650
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB61660
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB61670
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB61680
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB61690
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB61700
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$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
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```
     1  ROV,ROL,VV,VL,HD,NHTM,CHFR,TSAT,DATA($FLUX+N+MR*(JJ)),          COB62160
     2  NCHF,N,I,JJ,I3)                                                  COB62170
C                                                                        COB62180
      HTC=4.896E-5*(HVFC+HLFC)                                           COB62190
CC ONLY CONSIDER FORCED CONVECTION WHEN TW VERY CLOSE TO TL             COB62200
      IF (ABS(TW-TL).LT..0001) RETURN                                    COB62210
      HTC=HTC+4.896E-5*(QV+QL+HLNB*(TW-TSAT))/(TW-TL)                    COB62220
      IF (NT.GT.1) RETURN                                                COB62230
C                                                                        COB62240
C  LARGE CHANGES IN PREDICTED HEAT TRANSFER COEFF. ARE DAMPED FOR        COB62250
C  STEADY STATE CALCULATIONS                                             COB62260
C                                                                        COB62270
      HTCOLD=DATA($FLUX+N+MR*(JJ))/(DATA($TROD+NP1+MN*(N-1               COB62280
     1  +MR*(JJ)))-TLIQ)                                                 COB62290
      IF ((ABS(HTC-HTCOLD)/HTCOLD).LT..001) RETURN                       COB62300
      HTC=0.8*HTC+0.2*HTCOLD                                             COB62310
      RETURN                                                             COB62320
C                                                                        COB62330
  300 HTC=HCOOL(N,I,JJ)                                                  COB62340
      RETURN                                                             COB62350
      END                                                                COB62360
      SUBROUTINE SCHEME(JUMP,AAA)                                        COB62370
C                                                                        COB62380
C  THIS SUBROUTINE SETS UP AND PERFORMS THE SOLUTION OF THE FINITE       COB62390
C  DIFFERENCE SCHEME AT EACH SPATIAL LOCATION X AT A SELECTED TIME T.    COB62400
C                                                                        COB62410
C                                                                        COB62420
C                                                                        COB62430
      IMPLICIT INTEGER ($)                                               COB62440
      COMMON /COBRA1/  ABETA ,AFLUX ,ATOTAL,BBETA ,DIA   ,DT    ,DX     ,COB62450
     1   ELEV  ,FERROR,FLO   ,FTM   ,GC    ,GK    ,GRID  ,HSURF ,HF     ,COB62460
     2   HFG   ,HG    ,I2    ,I3    ,IERROR,IQP3  ,ITERAT,J1    ,J2     ,COB62470
     3   J3    ,J4    ,J5    ,J6    ,J7    ,KDEBUG,KF    ,KIJ   ,        COB62480
     4   NAFACT,NARAMP,NAX   ,NAXL  ,NBDC  ,NCHAN ,NCHF  ,NDX   ,NF     ,COB62490
     5   NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL  ,NK    ,NODES ,NODESF,NPROP  ,COB62500
     6   NRAMP ,NROD  ,NSCBC ,NV    ,NVISCW,PI    ,PITCH ,POWER ,PREF   ,COB62510
     7   QAX   ,RHOF  ,RHOG  ,SIGMA ,SL    ,TF    ,TFLUID,THETA ,THICK  ,COB62520
     8   UF    ,VF    ,VFG   ,VG    ,Z                                   COB62530
C                                                                        COB62540
      COMMON /COBRA2/  AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),     COB62550
     1   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),    COB62560
     2   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),  COB62570
     3   IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),       COB62580
     4   PP(30), RCLAD(2),RFUEL(2),SSIGMA(30), TCLAD(2), UUF(30),        COB62590
     5   VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)                      COB62600
C                                                                        COB62610
C                                                                        COB62620
      LOGICAL  GRID                                                      COB62630
      REAL     KIJ, KF, KKF, KCLAD, KFUEL                                COB62640
C                                                                        COB62650
C                                                                        COB62660
      COMMON /COBRA3/  MA    ,MC    ,MG    ,MN    ,MR    ,MS    ,MX     ,COB62670
     1         $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,$AN   ,$ANSWE,$B      ,COB62680
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX  ,COB62690
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F     ,COB62700
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     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,COB62710
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,COB62720
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,COB62730
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,COB62740
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,COB62750
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,COB62760
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,COB62770
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$SA  ,$SB  ,$XPOLD  COB62780
C                                                                       COB62790
      COMMON  DATA(1)                                                   COB62800
      LOGICAL LDAT(1)                                                   COB62810
      INTEGER IDAT(1)                                                   COB62820
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB62830
C                                                                       COB62840
      EQUIVALENCE  (NCHAN,NCHANL)                                       COB62850
C                                                                       COB62860
      DIMENSION AAA(1)                                                  COB62870
    1 FORMAT('1ERROR DETECTED IN SUBROUTINE SCHEME AT NODE',I3,         COB62880
     1 '   X =',E10.5,' FEET'/' CALCULATION FOR THIS CASE STOPPED')     COB62890
    2 FORMAT(' NODE',I3,'   X =',E10.5)                                 COB62900
    3 FORMAT('     I       H(I,J)       F(I,J)       P(I,J)    H(I,J-1)    FCOB62910
     1(I,J-1)    P(I,J-1)')                                             COB62920
    4 FORMAT('     I     QUAL(I)    ALPHA(I)    RHO(I,J)      VP(I)     COB62930
     1 V(I)    FMULT(I)')                                               COB62940
    5 FORMAT('     K    W(K,J-1)       W(K,J)        WP(K)    USTAR(K)   SPCOB62950
     1(K,J-1)      SP(K,J)')                                            COB62960
    6 FORMAT('     I     DHDX(I)        UH(I)      DPDX(I)    QPRIM(I)   FQCOB62970
     1LD(I,J) RHOOLD(I,J)')                                             COB62980
   16 FORMAT(3I5,4E12.6)                                                COB62990
   52 FORMAT( I5,6E12.6)                                                COB63000
C     MEKIN.   IPILE = 0,1,2 FOR STANDARD COBRA, PWR, BWR               COB63010
      IPILE = J7                                                        COB63020
      NCHANL = NCHANL                                                   COB63030
      FMIN = .0001                                                      COB63040
      NDXP1 = NDX+1                                                     COB63050
      IF(JUMP.EQ.3) GO TO 400                                           COB63060
      JUMP = 2                                                          COB63070
C                                                                       COB63080
C  BEGIN STEPPING THROUGH CHANNEL                                       COB63090
  400 DO 450 J=1,NDXP1                                                  COB63100
      CALL PRNTIM (3)                                                   COB63110
      JP1 = J+1                                                         COB63120
      JM1 = J-1                                                         COB63130
      IF(J.GT.1) GO TO 405                                              COB63140
C  SET CONDITIONS AT START OF CHANNEL                                   COB63150
      DO 401 I=1,NCHANL                                                 COB63160
  401 DATA($QPRIM+I)=0.                                                 COB63170
      CALL FORCE(1)                                                     COB63180
      IF(IERROR.GT.1) GO TO 440                                         COB63190
      CALL AREA(1)                                                      COB63200
      IF(IERROR.GT.1) GO TO 440                                         COB63210
      CALL PROP(2,1)                                                    COB63220
      IF(IERROR.GT.1) GO TO 440                                         COB63230
      CALL VOID(1)                                                      COB63240
      IF(IERROR.GT.1) GO TO 440                                         COB63250
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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($VFA+I)=DATA($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($DPDX+I)
  428 CONTINUE
      IF(KDEBUG.LT.1) GO TO 450
      GO TO 445
 440  WRITE(13,1) J,DATA($X+J)
      GO TO 446
 445  WRITE(13,2)J,DATA($X+J)
  446 WRITE(13,3)
      WRITE(13,52) (I,DATA($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($P    +I+MC*(JM1-1)),
     1 I=1,NCHANL)
      WRITE(13,4)
      WRITE(13,52) (I,DATA($QUAL +I          ),DATA($ALPHA+I          ),
     1              DATA($RHO  +I+MC*(J  -1)),DATA($VP   +I           ),
     2              DATA($V    +I            ),DATA($FMULT+I           ),
     1 I=1,NCHANL)
      WRITE(13,5)
      WRITE(13,52) (K,DATA($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($SP   +K+MG*(J  -1)),
     1 K=1,NK)
      WRITE(13,6)
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      WRITE(13,52) (I,DATA($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,$SA  ,$SB  ,$XPOLD  COB64920
C                                                                       COB64930
      COMMON  DATA(1)                                                   COB64940
      LOGICAL LDAT(1)                                                   COB64950
      INTEGER IDAT(1)                                                   COB64960
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))                            COB64970
C                                                                       COB64980
C                                                                       COB64990
      XP=DATA($QUAL+I)
       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
```

```
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  ,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          $$$   ,$A    ,$AAA  ,$AC   ,$ALPHA,SAN   ,$ANSWE,$B    ,
     1   $CCHAN,$CD   ,$CHFR ,$CON  ,$COND ,$CP   ,$D    ,$DC   ,$DFDX ,
     2   $DHDX ,$DHYD ,$DHYDN,$DIST ,$DPDX ,$DPK  ,$DUR  ,$DR   ,$F    ,
     3   $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP  ,$FSPLI,$FXFLO,
     4   $GAP  ,$GAPN ,$GAPS ,$H    ,$HFILM,$HINLE,$HOLD ,$HPERI,$IDARE,
     5   $IDFUE,$IDGAP,$IK   ,$JBOIL,$JK   ,$LC   ,$LENGT,$LOCA ,$LR   ,
     6   $MCHFR,$MCFRC,$MCFRR,$NTYPE,$NWRAP,$NWRPS,$P    ,$PERIM,$PH   ,
     7   $PHI  ,$PRNTC,$PRNTR,$PRNTN,$PW   ,$PWRF ,$QC   ,$QF   ,$QPRIM,
     8   $QUAL ,$RADIA,$RHO  ,$RHOOL,$SP   ,$T    ,$TDUMY,$TINLE,$TROD ,
     9   $U    ,$UH   ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP   ,$VPA  ,
     A   $W    ,$WOLD ,$WP   ,$WSAVE,$X    ,$XCROS,$$A   ,$$B   ,$XPOLD
C
      COMMON /REFP/ PO
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
      IF (IPART.EQ.2) GO TO 10
C     DO 2 I=1,NCHANL
C     DATA($DFDX+I)=0.0
C2    DATA($F+I+MC*(J-1))=DATA($F+I+MC*(J-2))-DX/DT*(DATA($RHO+I+MC*(J-1
C    1     ))-DATA($RHOOL+I+MC*(J-1)))*DATA($A+I)
C     CALL DIFFER(3,J)
      RETURN
C
```

```
   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($SP+I).GT.0.0) GO TO 14                                  COB66140
       DATA( SSP+I)=0.7*DATA($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
```

```
     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,$B     ,
     1    SCCHAN,$CD    ,$CHFR ,$CON   ,$COND ,$CP    ,$D     ,$DC    ,$DFDX ,
     2    $DHDX ,$DHYD ,$DHYDN,SDIST ,$DPDX ,$DPK   ,$DUR   ,$DR    ,$F     ,
     3    $FACTO,$FDIV ,$FINLE,$FLUX ,$FMULT,$FOLD ,$FSP   ,$FSPLI,$FXFLO,
     4    $GAP  ,$GAPN ,SGAPS ,$H     ,SHFILM.$HINLE,$HOLD .SHPERI,$IDARE,
     5    $IDFUE,$IDGAP,$IK    ,$JBOIL,$JK    ,$LC    ,$LENGT,$LOCA ,$LR    ,
     6    $MCHFR,$MCFRC,SMCFRR,SNTYPE,SNWRAP,SNWRPS,$P     ,$PERIM,SPH    ,
     7    $DUM  ,$PRNTC,SPRNTR,SPRNTN,SPW   ,$PWRF ,$QC    ,$QF    ,$QPRIM,
     8    $QUAL ,$RADIA,SRHO  ,$RHOOL,SSP   ,$T     ,$TDUMY,$TINLE,$TROD ,
     9    $U    ,$UH    ,$USAVE,$USTAR,$V    ,$VISC ,$VISCW,$VP    ,$VPA  ,
     A    $W    ,$WOLD ,$WP    ,$WSAVE,$X    ,$XCROS,$SA   ,$SB   ,$XPOLD
C
      COMMON /PPSV/ PPI
C
      COMMON  DATA(1)
      LOGICAL LDAT(1)
      INTEGER IDAT(1)
      EQUIVALENCE  (DATA(1),IDAT(1),LDAT(1))
C
C
      EQUIVALENCE (NCHAN,NCHANL)
      $PHI=$FMULT
      DO 200 I=1,NCHAN
      PSI = 0.
      DPSIDH = 0.
      IF(J3.EQ.0) GO TO 40
      DATA($H+I+MC*(J-1))=DATA(SH+I+MC*(J-1))-.1
      DATA($QUAL+I)       =(DATA(SH+I+MC*(J-1))-HF)/HFG
      IF(J2.EQ.1)           DATA($QUAL+I)=SCQUAL(I,J)
      IF(DATA($QUAL+I).LE.0.)  DATA( SQUAL+I)=0.
      DATA($ALPHA+I) = BVOID(I,J)
      PSI=RHOF*DATA(SQUAL+I)*(1.-DATA($ALPHA+I))-RHOG*DATA($ALPHA+I)*
     1    (1.-DATA(SQUAL+I))
      DATA($H+I+MC*(J-1))=DATA($H+I+MC*(J-1))+.1
   40 DATA($QUAL+I)       =(DATA(SH+I+MC*(J-1))-HF)/HFG
      IF(J2.EQ.1)  DATA($QUAL+I)=SCQUAL(I,J)
      IF           (DATA($QUAL+I).LE.0.)  GO TO 150
      XP=          DATA($QUAL+I)
      DATA($ALPHA+I)=BVOID(I,J)
```

```
C  CALCULATE TWO-PHASE DENSITY.                                         COB67110
C  *******    THE FOLLOWING CARDS CORRECT THE CALCULATION OF RHO AND VP COB67120
      DATA($RHO+I+MC*(J-1))=RHOG*DATA($ALPHA+I)+1./DATA($V+I)*(1.-      COB67130
     1    DATA($ALPHA+I))                                               COB67140
C  CALCULATE TWO-PHASE SPECIFIC VOLUME FOR MOMENTUM.                    COB67150
      DATA($VP+I)=DATA($V+I)*(1.-XP)**2/(1.-DATA($ALPHA+I))+VG*XP**2/   COB67160
     1    DATA($ALPHA+I)                                                COB67170
C     JK INSERT                                                         COB67180
       IF(J7.NE.2)  GO TO 3                                             COB67190
       IF(J.EQ.1)  GO TO 3                                              COB67200
      RHODIF = DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))            COB67210
       DATA($F+I+MC*(J-1))= DATA($F+I+MC*(J-2))-DX/DT*RHODIF*DATA($A+I) COB67220
 3     CONTINUE                                                         COB67230
C  TWO-PHASE FRICTIONAL PRESSURE GRADIENT MULTIPLIERS.                  COB67240
      DATA($PHI+I)=1.                                                   COB67250
      IF(J4.EQ.0)    DATA($PHI+I)=RHOF/DATA($RHO+I+MC*(J-1))            COB67260
      GWV = 3600.0*DATA($F+I+MC*(J-1))/DATA($A+I)                       COB67270
      IF (J4.EQ.2) CALL BAROC(2,PREF,XP,GWV,DATA($PHI+I),PPI)           COB67280
      IF(J4.NE.1) GO TO 50                                              COB67290
      DATA($PHI+I)=1.                                                   COB67300
      XA=DATA($ALPHA+I)                                                 COB67310
      IF(XA.GT.0.0.AND.XA.LE.0.6)XXX=(1.-XP)**2/(1.-XA)**1.42           COB67320
      IF(XA.GT.0.6.AND.XA.LE.0.9)XXX=.478*(1.-XP)**2/(1.-XA)**2.2       COB67330
      IF(XA.GT.0.9.AND.XA.LE.1.0)XXX=1.73*(1.-XP)**2/(1.-XA)**1.64      COB67340
      DATA($PHI+I)=XXX                                                  COB67350
   50 IF(J4.NE.5) GO TO 140                                             COB67360
      DATA($PHI+I)=AF(1)                                                COB67370
      XX            =DATA($QUAL+I)                                      COB67380
      DO 130 K=2,NF                                                     COB67390
      DATA($PHI+I)=DATA($PHI +I)+AF(K)*XX                               COB67400
  130 XX            =DATA($QUAL+I)*XX                                   COB67410
  140 DATA($U  +I)=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($VP+I)           COB67420
      IF(J3.EQ.0) GO TO 145                                             COB67430
      DPSIDH=-10.*(PSI-RHOF*DATA($QUAL+I)*(1.-DATA($ALPHA+I))+RHOG*     COB67440
     1    DATA($ALPHA+I)*(1.-DATA($QUAL+I)))                            COB67450
  145 DATA($UH+I)=DATA($F+I+MC*(J-1))/DATA($A+I)/(DATA($RHO+I+MC*(J-1)) COB67460
     1    -HFG*DPSIDH)                                                  COB67470
      GO TO 200                                                         COB67480
C  TWO-PHASE FLOW PARAMETERS WITHOUT BOILING.                           COB67490
  150 DATA($ALPHA+I)=0.0                                                COB67500
      DATA($RHO  +I+MC*(J-1))=1.0/DATA($V+I)                            COB67510
C     JK INSERT                                                         COB67520
       IF(J7.NE.2)  GO TO 4                                             COB67530
       IF(J.EQ.1)  GO TO 4                                              COB67540
      RHODIF = DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))            COB67550
       DATA($F+I+MC*(J-1))= DATA($F+I+MC*(J-2))-DX/DT*RHODIF*DATA($A+I) COB67560
 4     CONTINUE                                                         COB67570
      DATA($VP   +I)=DATA($V+I)                                         COB67580
      DATA($U    +I)=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($VP+I)         COB67590
      DATA($UH   +I)=DATA($U+I)                                         COB67600
      DATA($PHI  +I)=1.0                                                COB67610
      DATA($QUAL +I)=0.0                                                COB67620
  200 CONTINUE                                                          COB67630
      RETURN                                                            COB67640
      END                                                               COB67650
```

```
      SUBROUTINE STATE(P,TV,TL,ROV,ROL,EV,EL,TSAT,DTSDP,                COB67660
     1   DELDP,DEVDP,DELDT,DEVDT,DRLDP,DRVDP,DRLDT,DRVDT,IOP,IERR)      COB67670
C                                                                       COB67680
C                                                                       COB67690
C     SUBROUTINE STATE CALCULATES THE STATE DYNAMIC PROPERTIES OF       COB67700
C     WATER. THE PRESENT VERSION USES FITS DUE TO BILL RIVARD OF        COB67710
C     GROUP T-3 OF THE LASL THEORETICAL DIVISION.                       COB67720
C     TAKEN FROM TRAC AND RECODED TO IMPROVE EFFICIENCY.                COB67730
C     SI UNITS ARE USED                                                 COB67740
C                                                                       COB67750
C     INPUT VARIABLES                                                   COB67760
C        1. P    PRESSURE                                               COB67770
C        2. TL   TEMPERATURE OF THE LIQUID                              COB67780
C        3. TV   TEMPERATURE OF THE VAPOR                               COB67790
C        4. IOP OPTION SELECTOR - NOT IN PRESENT VERSION                COB67800
C                                                                       COB67810
C     OUTPUT VARIABLES                                                  COB67820
C        1. EV      INTERNAL ENERGY OF THE VAPOR                        COB67830
C        2. EL      INTERNAL ENERGY OF THE LIQUID                       COB67840
C        3. TSAT    SATURATION TEMPERATURE                              COB67850
C        4. ROL     DENSITY OF THE LIQUID                               COB67860
C        5. ROV     DENSITY OF THE VAPOR                                COB67870
C        6. DTSDP   DERIVATIVE OF TSAT WRT PRESSURE                     COB67880
C        7. DELDP   DERIVATIVE OF TL WRT PRESSURE                       COB67890
C        8. DEVDP   DERIVATIVE OF TV WRT PRESSURE                       COB67900
C        9. DELDT   DERIVATIVE OF EL WRT TL                             COB67910
C       10. DEVDT   DERIVATIVE OF EV WRT TV                             COB67920
C       11. DRLDP   DERIVATIVE OF ROL WRT PRESSURE                      COB67930
C       12. DRVDP   DERIVATIVE OF ROV WRT PRESSURE                      COB67940
C       13. DRLDT   DERIVATIVE OF ROL WRT TL                            COB67950
C       14. DRVDT   DERIVATIVE OF ROV WRT TV                            COB67960
C       15. IERR    ERROR FLAG (INPUT VARIABLE OUT OF RANGE)            COB67970
C                                                                       COB67980
C     CONSTANTS USED IN FITS                                            COB67990
C                                                                       COB68000
C     FOR TSAT, CPS                                                     COB68010
       DATA TSC1,TSC2, TSEXP  /9.0395, 255.2, 0.223/                    COB68020
       DATA CPS1,CPS2, CPSEXP  /9.5875E2, .00132334, -0.8566/           COB68030
C        CPS2 = -CPSEXP * TCRINV                                        COB68040
C     FOR ES, GAMS  IF P < 20 BARS                                      COB68050
       DATA G11,G12,G13  /2.6134106E6, -4.995E10, 3.403E5/              COB68060
       DATA G14,G15,G16  /1.0665544, 1.02E-8, -2.548E-15/               COB68070
C          G11,G14 ARE ADJUSTED SO THAT ES RESP. GAMS JUMPS LESS THAN   COB68080
C             1 PART IN 1.E-8 ACROSS P = 20 BARS.                       COB68090
       DATA G17 /-5.096E-15/                                            COB68100
C        G17 = 2.* G16                                                  COB68110
C     FOR ES, GAMS  IF P > 20 BARS                                      COB68120
       DATA G21,G22,G23  /2.5896E6, 6.350E-3, -1.0582E-9/               COB68130
       DATA G24,G25,G26  /1.0764, 3.625E-10, -9.063E-17/                COB68140
       DATA G27,G28  /-2.1164E-9, -18.126E-17/                          COB68150
C        G27 = 2.* G23,    G28 = 2.* G26                                COB68160
C                                                                       COB68170
       DATA P20B /2.0E6/                                                COB68180
       DATA TCRIT /647.3/                                               COB68190
       DATA TCRINV /.00154488/                                          COB68200
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```
      DATA CC,CCI,CCM  /1.3, .76923, 0.3/                               COB68210
C                                                                       COB68220
      DATA RLO,RL1,RL2  /1.E3, -2.E-5, -.15E-9/                         COB68230
      DATA RL22  /-.3E-9/                                               COB68240
C       RL22 = 2.*RL2                                                   COB68250
      DATA CL2I  /0.657E-6/                                             COB68260
C                                                                       COB68270
C    FOR EL  IF TL < 300 DEG C                                          COB68280
      DATA SLO,SL1,SL2,SL3  /-1.4655677D+06, 6.9269554D+03,             COB68290
     1  -7.7423067E0, 7.2803006D-03/                                    COB68300
C          SLO IS CHOSEN SO THE JUMP IN EL AT 300 DEG C IS AS           COB68310
C             SMALL AS POSSIBLE                                         COB68320
      DATA SL22,SL33 /-15.484613, 2.1840901E-2/                         COB68330
C       SL22 = 2.* SL2,    SL33 = 3.* SL3                               COB68340
C    FOR EL  IF TL > 300 DEG C                                          COB68350
      DATA SHO,SH1,SH2,SH3  /-8.9, 2.3639439E+04,                       COB68360
     1  -7.7434017E+01, 7.0215574E-02/                                  COB68370
      DATA SH22,SH33 /-1.5486803E2, 2.1064672E-1/                       COB68380
C       SH22 = 2.* SH2,    SH33 = 3.* SH3                               COB68390
C                                                                       COB68400
C    FOR VAPOR                                                          COB68410
      DATA A11,A12,A13  /1.2959E-3, 593.59, 1.6847E-3/                  COB68420
C                                                                       COB68430
      DATA  HALF,ZERO,ONE,TWO  /0.5, 0., 1., 2./                        COB68440
C                                                                       COB68450
C  ---------------------------------------                              COB68460
C                                                                       COB68470
C     CHECK THAT P, TL, TV, ARE WITHIN RANGE OF FITS                    COB68480
C                                                                       COB68490
      IF (P.GE.1.0E+3.AND.P.LE.190.0E+5) GO TO 5                        COB68500
        IERR = 1                                                        COB68510
        RETURN                                                          COB68520
    5 IF (TL.GE.280.0.AND.TL.LE.647.0) GO TO 10                         COB68530
        IERR = 2                                                        COB68540
        RETURN                                                          COB68550
   10 IF(TV.GE.280.0) GO TO 20                                          COB68560
        IERR = 3                                                        COB68570
        RETURN                                                          COB68580
   20 IERR = 0                                                          COB68590
C                                                                       COB68600
C    CALCULATE SATURATION PROPERTIES                                    COB68610
C                                                                       COB68620
C       1. TSAT     SATURATION TEMPERATURE                              COB68630
C       2. DTSDP     DERIVATIVE OF TSAT WRT PRESSURE                    COB68640
C       3. ES       SATURATION INTERNAL ENERGY                          COB68650
C       4. DPES     DERIVATIVE OF ES WRT PRESSURE                       COB68660
C       5. GAMS     GAMMA SUB S                                         COB68670
C       6. DPGAMS   DERIVATIVE OF GAMS WRT PRESSURE                     COB68680
C       7. CPS      C SUB PS                                            COB68690
C       8. DPCPS    DERIVATIVE OF CPS WRT PRESSURE                      COB68700
C       9. GAMSM    GAMS-ONE                                            COB68710
C                                                                       COB68720
      TSAT = TSC1* P**TSEXP                                             COB68730
      PINV = ONE/ P                                                     COB68740
      DTSDP = TSAT*TSEXP*PINV                                           COB68750
```

```
      TSAT = TSAT + TSC2                                                COB68760
C                                                                       COB68770
      T1 = ONE - TSAT*TCRINV                                            COB68780
      CPS = CPS1* T1**CPSEXP                                            COB68790
      DPCPS = CPS2*CPS/T1 *DTSDP                                        COB68800
C                                                                       COB68810
      IF (P.GT.P20B) GO TO 150                                          COB68820
        T2 = ONE/ (G13+P)                                               COB68830
        T1 = T2*G12                                                     COB68840
        ES = G11 + T1                                                   COB68850
        DPES = -T1*T2                                                   COB68860
        GAMS = G14 + P*(G15 + P*G16)                                    COB68870
        DPGAMS = G15+G17*P                                              COB68880
        GO TO 200                                                       COB68890
  150 CONTINUE                                                          COB68900
        ES = G21+(G23*P+G22)*P                                          COB68910
        DPES = G22+G27*P                                                COB68920
        GAMS = G24+(G26*P+G25)*P                                        COB68930
        DPGAMS = G25 + G28*P                                            COB68940
  200 GAMSM = GAMS - ONE                                                COB68950
C                                                                       COB68960
C                                                                       COB68970
C     CALCULATE LIQUID PROPERTIES                                       COB68980
C                                                                       COB68990
C                                                                       COB69000
C        1. INTERNAL ENERGY AND ITS DERIVATIVES                         COB69010
C                                                                       COB69020
      DELDP = 0.                                                        COB69030
      IF (TL.GE.573.15) GO TO 220                                       COB69040
        EL = SLO + TL*(SL1 + TL*(SL2 + TL*SL3))                         COB69050
        DELDT = SL1 + TL*(SL22 + TL*SL33)                               COB69060
        GO TO 240                                                       COB69070
  220 CONTINUE                                                          COB69080
        EL = SHO + TL*(SH1 + TL*(SH2 + TL*SH3))                         COB69090
        DELDT = SH1 + TL*(SH22 + TL*SH33)                               COB69100
  240 CONTINUE                                                          COB69110
C                                                                       COB69120
C        2. DENSITY AND ITS DERIVATIVES                                 COB69130
C                                                                       COB69140
      ROL = RLO + EL*(RL1 + EL*RL2)  + P*CL2I                           COB69150
      DRLDP = CL2I                                                      COB69160
      DRLDE = RL1 + EL*RL22                                             COB69170
      DRLDT = DRLDE*DELDT                                               COB69180
C                                                                       COB69190
C     CALCULATE VAPOR PROPERTIES                                        COB69200
C                                                                       COB69210
      DT = TV-TSAT                                                      COB69220
      IF (DT.LE.ZERO) GO TO 250                                         COB69230
C                                                                       COB69240
C     SUPERHEATED VAPOR                                                 COB69250
C                                                                       COB69260
C        1. BETA A WORKING PARAMETER                                    COB69270
C        2. CAPK A WORKING PARAMETER                                    COB69280
C        3. DBETAP  DERIVATIVE OF BETA WRT PRESSURE                     COB69290
C        4. DCAPKP  DERIVATIVE OF CAPK WRT PRESSURE                     COB69300
```

```
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($)
```

```
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,$SA   ,$SB   ,$XPOLD COB70400
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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(SD+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
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      DO 120 K=1,NCC                                                    COB70960
        CND(NGP+K)=KCLAD(1)                                             COB70970
  120   RCP(NGP+K)=CCLAD(1)*RCLAD(1)                                    COB70980
C                                                                       COB70990
C  INITIALIZE GAP CONDUCTANCE DATA                                      COB71000
C                                                                       COB71010
      IF(IPROP.LT.2)GO TO 205                                           COB71020
      CALL MPG(.TRUE.,BURN,EFFB,FRAC,D3,D4,D5,GRGH,THG,RAD(NGP),        COB71030
     1 D6,D7,D8,D9,D10,D11)                                             COB71040
  205 CONTINUE                                                          COB71050
      RETURN                                                            COB71060
      END                                                               COB71070
      SUBROUTINE RTEMPF (TR,RDT,RADR,HSURF,TFLUID,NODES,NDM1)           COB71080
C                                                                       COB71090
C  GAUSSIAN SOLUTION OF TRIDIAGONAL TEMPERATURE PROBLEM IN FUEL ROD     COB71100
C                                                                       COB71110
      COMMON /MCOND/ CND(22),RCP(22),RAD(22),RRDR(22),                  COB71120
     1  VM(22),VP(22),QPPP(22)                                          COB71130
C                                                                       COB71140
      DIMENSION A1(23),A2(22),A3(22),B(22),TR(1)                        COB71150
      FSS=1.                                                            COB71160
      FTR=1.-FSS                                                        COB71170
      RDELT=RDT                                                         COB71180
C                                                                       COB71190
C  SET UP COEFFICIENTS OF TRIDIAGONAL MATRIX                            COB71200
C                                                                       COB71210
      A1(1)=0.0                                                         COB71220
      A2(1)=RRDR(1)*CND(1)+RDELT*VP(1)*RCP(1)                           COB71230
      B(1)=VP(1)*QPPP(1)+RDELT*VP(1)*RCP(1)*TR(1)                       COB71240
      DO 100 K=2,NDM1                                                   COB71250
        A1(K)=-RRDR(K-1)*CND(K-1)                                       COB71260
        A2(K)=-A1(K)+RRDR(K)*CND(K)+RDELT*(VP(K)*RCP(K)+VM(K)*RCP(K-1)) COB71270
        B(K)=VP(K)*QPPP(K)+VM(K)*QPPP(K-1)+RDELT*(VP(K)*RCP(K)+VM(K)*   COB71280
     1   RCP(K-1))*TR(K)                                                COB71290
  100   CONTINUE                                                        COB71300
      A1(NODES)=-RRDR(NDM1)*CND(NDM1)                                   COB71310
      A2(NODES) = -A1(NODES) + RDELT*VM(NODES)*RCP(NDM1) +              COB71320
     +  RADR*FSS*HSURF                                                  COB71330
      B(NODES) = VM(NODES)*QPPP(NDM1) +                                 COB71340
     +  RDELT*VM(NODES)*RCP(NDM1)*TR(NODES) +                           COB71350
     +  RADR*HSURF*(TFLUID-FTR*TR(NODES))                               COB71360
      A1(NODES+1)=0.0                                                   COB71370
C                                                                       COB71380
C  FORWARD ELIMINATION                                                  COB71390
C                                                                       COB71400
      A2(1)=1./A2(1)                                                    COB71410
      A3(1)=A1(2)*A2(1)                                                 COB71420
      B(1)=B(1)*A2(1)                                                   COB71430
      DO 200 K=2,NODES                                                  COB71440
        A2(K)=1./(A2(K)-A1(K)*A3(K-1))                                  COB71450
        A3(K)=A1(K+1)*A2(K)                                             COB71460
        B(K)=(B(K)-A1(K)*B(K-1))*A2(K)                                  COB71470
  200   CONTINUE                                                        COB71480
CC                                                                      COB71490
CC  BACKWARD SUBSTITUTION                                               COB71500
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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               COB72060
C             FPUO2    PLUTONIUM FRACTION BY VOLUME                  COB72070
C    RETURN   RCP     HEAT CAPACITY (BTU/FT**3-DEG F)                COB72080
C             COND    CONDUCTIVITY (BTU/SEC-FT-DEG F)                COB72090
C                                                                    COB72100
C  THIS SUBROUTINE IS BASED ON EXPRESSIONS USED IN MATPRO; SEE       COB72110
C    TREE-NUREG-1005, APPENDIX A. THOSE EXPRESSIONS HAVE BEEN APPROXI-COB72120
C    MATED BY POLYNOMIAL FITS WHOSE MAXIMUM ERRORS ARE ABOUT ONE     COB72130
C    STANDARD DEVIATION IN EXPERIMENTAL DATA.                        COB72140
C       RCP ERROR =  2 PER CENT       300 < TEM < 3000 DEG K         COB72150
C       COND ERROR = 10 PER CENT      400 < TEM < 2500 DEG K         COB72160
C                                                                    COB72170
      DIMENSION RC(4), RCM(4), CN(3), CNM(3)                         COB72180
      DATA  RC /1.78E6, 3.62E3, -2.61, 6.59E-4/                      COB72190
      DATA RCM /1.81E6, 3.72E3, -2.57, 6.13E-4/                      COB72200
      DATA  CN /10.8, -8.84E-3, 2.25E-6/                             COB72210
      DATA CNM /9.88, -8.44E-3, 2.25E-6/                             COB72220
      DATA CVTC,CVTRC/1.61E-4, 1.49E-5/                              COB72230
C                                                                    COB72240
C-----------------------------------------------                     COB72250
C                                                                    COB72260
      TEM=.5556*(TFUEL+459.7)                                        COB72270
      IF (FPUO2.GT.1.E-7)  GO TO 20                                  COB72280
C                                                                    COB72290
C  UO2 FUEL                                                          COB72300
C                                                                    COB72310
   10 RCP = FTD*( RC(1)+ TEM*(RC(2) +TEM*(RC(3) +TEM*RC(4))) )       COB72320
      BT = 2.74 - TEM * 5.8E-4                                       COB72330
      POR = 1.- BT*(1.- FTD)                                         COB72340
C--THE FACTOR  /(1.-BT*(1.-.95)) IS INCORPORATED IN THE FIT CN(3)    COB72350
      COND = POR*( CN(1)+ TEM*(CN(2)+ TEM*CN(3)) )                   COB72360
      GO TO 100                                                      COB72370
C                                                                    COB72380
C  MIXED OXIDE FUEL                                                  COB72390
C                                                                    COB72400
   20 RCP = FTD *(1.+.045+FPUO2) *                                   COB72410
     *         (RCM(1)+ TEM*(RCM(2)+ TEM*(RCM(3)+ TEM*RCM(4))) )     COB72420
      BT = 2.74 - TEM * 5.8E-4                                       COB72430
      POR = FTD / (1.+ BT*(1.-FTD))                                  COB72440
C          THE FACTOR (1.+BT*(1.-.96))/.96 IS INCORPORATED IN CNM(3) COB72450
      COND = POR*( CNM(1)+ TEM*(CNM(2)+ TEM*CNM(3)) )                COB72460
C                                                                    COB72470
C                                                                    COB72480
  100 CONTINUE                                                       COB72490
CC COND CONVERTED FROM (W/M-DEG K) TO (BTU/SEC-FT-DEG F)             COB72500
      COND=COND*CVTC                                                 COB72510
CC RCP CONVERTED FROM (J/M**3-DEG K) TO (BTU/FT**3-DEG F)            COB72520
      RCP=RCP*CVTRC                                                  COB72530
      RETURN                                                         COB72540
      END                                                            COB72550
      SUBROUTINE  MPG (INIT, BURN, EFFB, FRAC, PRESS, CPR, EXPR, GRGH,  COB72560
     1       THG, RADFU, PG, TG, GMIX, TF, TC, HGAP)                 COB72570
C                                                                    COB72580
C  CALULATES GAP HEAT TRANSFER COEFFICIENT, IN THREE PARTS:          COB72590
C     1. OPEN GAP COMPONENT, BASED ON CONDUCTIVITY OF A MIXTURE OF FOUR COB72600
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C        NOBLE GASES; A SMALL GAP CORRECTION IS APPLIED IF PGAS > 0.    COB72610
C     2. CONTRIBUTION FROM PARTIAL FUEL-CLAD CONTACT                    COB72620
C     3. RADIATION COMPONENT                                            COB72630
C  IF RADFU > (RADFU+THG) - ROUGH, THEN IN ADDITION TO THE ABOVE:       COB72640
C     4. CLOSED GAP LAW = CPR * (PRESS**EXPR)                           COB72650
C                                                                       COB72660
C  PARTS 1 & 2 ARE BASED ON TREE-NUREG-1005, APPENDIX C, WITH CRACKED   COB72670
C    PELLET MODEL; PART 4 IS USER-SUPPLIED.                             COB72680
C                                                                       COB72690
C  MPG IS CALLED WITH INIT = .TRUE. TO PERFORM INITIALIZATION           COB72700
C   NORMAL CALLS HAVE INIT = .FALSE.                                    COB72710
C                                                                       COB72720
C  ARGUMENTS: INIT = .TRUE.                                             COB72730
C    INPUT      BURN     BURNUP (MWD/MTU)                               COB72740
C               GRGH     ROOT MEAN SQUARE OF FUEL PELLET AND CLADDING   COB72750
C                         SURFACE ROUGHNESSES (FT)                      COB72760
C               THG      GAP THICKNESS (FT)                             COB72770
C    RETURN     GRGH     IF GRGH  = 0 ON INPUT, A DEFAULT VALUE OF      COB72780
C                         1.34E-6 FEET IS RETURNED                      COB72790
C               EFFB     FRACTIONAL EFFECT OF BURNUP, USED IN PARTIAL   COB72800
C                         FUEL-CLAD CONTACT MODEL                       COB72810
C               FRAC     FRACTION OF FUEL PERIMETER IN LIGHT CONTACT    COB72820
C                         WITH CLAD                                     COB72830
C                                                                       COB72840
C  ARGUMENTS: INIT = .FALSE. (NORMAL ENTRY)                             COB72850
C    INPUT      FRAC     FRACTION OF FUEL PERIMETER TOUCHING CLAD       COB72860
C               PRESS    PRESSURE OF FUEL AGAINST CLAD FOR CLOSED GAP   COB72870
C               CPR      COEFFICIENT OF PRESS                           COB72880
C               EXPR     EXPONENT OF PRESS                              COB72890
C               GRGH     RMS OF FUEL AND CLAD GRGH NESSES (FT)          COB72900
C               THG      GAP THICKNESS (FT)                             COB72910
C               PG       PRESSURE OF GAS MIXTURE IN GAP, FOR SMALL GAP  COB72920
C                         CORRECTION FACTOR (PSIA)                      COB72930
C               TG       TEMPERATURE OF GAS MIXTURE IN GAP (DEG F)      COB72940
C               GMIX     FOUR MOLE FRACTIONS OF NOBLE GASES             COB72950
C                         1. HELIUM                                     COB72960
C                         2. ARGON                                      COB72970
C                         3. KRYPTON                                    COB72980
C                         4. ZENON                                      COB72990
C                          THE FOUR ELEMENTS OF GMIX MUST SUM TO 1      COB73000
C               TF       TEMPERATURE OF FUEL PELLET SURFACE (DEG F)     COB73010
C               TC       TEMPERATURE OF INNER CLAD SURFACE (DEG F)      COB73020
C    RETURN     HGAP     GAP HEAT TRANSFER COEFFICIENT (BTU/FT**3-DEG F)COB73030
C                                                                       COB73040
      LOGICAL  INIT                                                     COB73050
      DIMENSION  GMIX(4)                                                COB73060
C                                                                       COB73070
      DIMENSION AM(4,4), BM(4,4)                                        COB73080
C       COMBINING FACTORS WHICH ARE FUNCTIONS ONLY OF THE MOLECULAR     COB73090
C       WEIGHTS OF THE FOUR NOBLE GASES                                 COB73100
      DATA AM / 0.,   .295, .232, .194,                                 COB73110
     2          .362, 0.,   .309, .332,                                 COB73120
     3          .413, .235, 0.,   .286,                                 COB73130
     4          .435, .260, .232, 0.    /                               COB73140
      DATA BM / 0.,   1.78, 2.14, 2.39,                                 COB73150
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     2          .563, 0.,   1.20, 1.35,                                    COB73160
     3          .467, .831, 0.,   1.12,                                    COB73170
     4          .418, .743, .894, 0.    /                                  COB73180
      DIMENSION CC(4), EE(4), CON(4), CSR(4)                               COB73190
      DATA CC / 3.366E-3, 3.421E-4, 4.029E-5, 4.726E-5 /                   COB73200
      DATA EE / .668, .701, .872, .923 /                                   COB73210
C                                                                          COB73220
C----------------------------------------------------                      COB73230
C                                                                          COB73240
CC CONVERT TO DGAP(M)                                                      COB73250
      DGAP = THG*.3048                                                     COB73260
CC TEMPERATURES CONVERTED FROM (DEG F) TO (DEG K)                          COB73270
      TCLAD=.5556*(TC+459.67)                                              COB73280
      TGAS=.5556*(TG+459.67)                                               COB73290
      TFUEL=.5556*(TF+459.67)                                              COB73300
      TGAS=.5556*(TG+459.67)                                               COB73310
CC CONVERT TO PGAS(N/M**2)                                                 COB73320
      PGAS=PG*6.893E3                                                      COB73330
CC CONVERT TO ROUGH(M)                                                     COB73340
      ROUGH=GRGH*.3048                                                     COB73350
C                                                                          COB73360
      IF (INIT) GO TO 200                                                  COB73370
C                                                                          COB73380
C  NOBLE GAS CONDUCTIVITIES                                                COB73390
C                                                                          COB73400
      CON(1) = 0.                                                          COB73410
      DO  10  I = 1, 4                                                     COB73420
        IF (GMIX(I).LT.1.E-6)  GO TO 10                                    COB73430
        CON(I) = CC(I) *(TGAS**EE(I))                                      COB73440
        CSR(I) = SQRT(CON(I))                                              COB73450
   10   CONTINUE                                                           COB73460
C  SMALL GAP CORRECTION FOR HELIUM:                                        COB73470
      GAP = AMAX1  (ROUGH, DGAP)                                           COB73480
      FAC = PGAS * GAP                                                     COB73490
      IF (FAC.LT.1.E-9)  GO TO 15                                          COB73500
        CON(1) = CON(1) / (1.+ CON(1)*.2103*SQRT(TGAS)/FAC)                COB73510
        CSR(1) = SQRT(CON(1))                                              COB73520
   15 CONTINUE                                                             COB73530
C                                                                          COB73540
C  MIXTURE CONDUCTIVITY                                                    COB73550
C                                                                          COB73560
      GCOND = 0.                                                           COB73570
      DO  30  I = 1, 4                                                     COB73580
        IF (GMIX(I).LT.1.E-6) GO TO 30                                     COB73590
        XSUM = GMIX(I)                                                     COB73600
        DO  20  J = 1, 4                                                   COB73610
          IF (J.EQ.I) GO TO 20                                             COB73620
          IF (GMIX(J).LT.1.E-6) GO TO 20                                   COB73630
          TS = CSR(J) + CSR(I)*BM(I,J)                                     COB73640
          XSUM = XSUM + GMIX(J)*AM(I,J)*TS*TS/CON(J)                       COB73650
   20     CONTINUE                                                         COB73660
        GCOND = GCOND + CON(I)*GMIX(I)/XSUM                                COB73670
   30 CONTINUE                                                             COB73680
C                                                                          COB73690
      HGAP = GCOND /(DGAP + ROUGH)                                         COB73700
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C                                                                       COB73710
C  PARTIAL FUEL-CLAD CONTACT MODEL                                      COB73720
C                                                                       COB73730
      HGAP = (1.-FRAC)*HGAP + FRAC*GCOND/ROUGH                          COB73740
C                                                                       COB73750
C  RADIATION HEAT TRANSFER CONTRIBUTION                                 COB73760
C                                                                       COB73770
      REMISF = AMAX1(1.1485, AMIN1(2.451, -.154+TFUEL*1.3025E-3 ))      COB73780
      REMISC = 1.33                                                     COB73790
      RFVIEW = REMISF + (REMISC-1.)*RADFU/(RADFU+THG)                   COB73800
C                                                                       COB73810
      HGAP = HGAP +                                                     COB73820
     +   5.279E-8*(TFUEL+TCLAD)*(TFUEL*TFUEL+TCLAD*TCLAD)/RFVIEW        COB73830
CC  CONVERT HGAP FROM (W/M**2-DEG K)) TO (BTU/SEC-FT**2-DEG F)          COB73840
      HGAP=HGAP*4.89E-5                                                 COB73850
CC                                                                      COB73860
C                                                                       COB73870
C  CLOSED GAP CONTACT HEAT TRANSFER                                     COB73880
C                                                                       COB73890
      IF (DGAP .GE. ROUGH)  RETURN                                      COB73900
      HGAP = HGAP +  CPR * (PRESS **EXPR)                               COB73910
C                                                                       COB73920
C                                                                       COB73930
C                                                                       COB73940
      RETURN                                                            COB73950
C                                                                       COB73960
C  INITIALIZATION OF MPG, CALLED ONLY ONCE                              COB73970
C                                                                       COB73980
  200 IF (GRGH.LE.0.)  GRGH = 1.34E-6                                   COB73990
C                                                                       COB74000
C  FRACTION OF FUEL IN LIGHT CONTACT WITH CLAD, A FUNCTION OF BURNUP    COB74010
C                                                                       COB74020
C--FRACTIONAL EFFECT OF BURNUP, INDEPENDENT OF FUEL RADIUS              COB74030
      IF (BURN-600.) 210,210,220                                        COB74040
  210   EFFB = 0.                                                       COB74050
        GO TO 230                                                       COB74060
  220 CONTINUE                                                          COB74070
        TS = .001*BURN - .6                                             COB74080
        TS = TS*TS                                                      COB74090
        EFFB = 1.- 1./(TS*TS + 1.)                                      COB74100
  230 CONTINUE                                                          COB74110
C--FRACTION OF CIRCUMFERENCE OF FUEL IN LIGHT CONTACT WITH CLAD         COB74120
      A1 = 100. - 98.*EFFB                                              COB74130
      A2 = 4. - .5*EFFB                                                 COB74140
      FRAC = 1./ (A1*(100.*DGAP/RADFU)**A2 + 1.42857) + .3              COB74150
      RETURN                                                            COB74160
      END                                                               COB74170
      SUBROUTINE MPC (TCL, RCP, COND)                                   COB74180
C                                                                       COB74190
C  CALCULATES HEAT CAPACITY AND CONDUCTIVITY OF ZIRCALOY AS A FUNCTION  COB74200
C    OF TEMPERATURE                                                     COB74210
C                                                                       COB74220
C  ARGUMENTS                                                            COB74230
C    INPUT      TCL      TEMPERATURE (DEG F)                            COB74240
C    RETURN     RCP      HEAT CAPACITY (BTU/FT**3-DEG F)                COB74250
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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:
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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.
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C  TO PRESSURE P.                                                        COB75360
C                                                                        COB75370
      TSAT1 = 9.0395*POW(P,.223E0) + 255.2                               COB75380
      CALL STATE(P,TSAT1,TSAT1,ROVS,ROLS,EV,EL,TSAT,DTSDP,DELDP,         COB75390
     1 DEVDP,DELDT,DEVDT,DRLDP,DRVDP,DRLDT,DRVDT,2,IERR)                 COB75400
      SPVV = 1./ROVS                                                     COB75410
      SPVL = 1./ROLS                                                     COB75420
      HFG = EV+P*SPVV -EL-P*SPVL                                         COB75430
      BETAV = -DRVDT*SPVV                                                COB75440
      BETAL = -DRLDT*SPVL                                                COB75450
      CPV = DEVDT -P*DRVDT*SPVV*SPVV                                     COB75460
      CPL = DELDT -P*DRLDT*SPVL*SPVL                                     COB75470
    4 CONTINUE                                                           COB75480
      VISV = VISVP(TV)                                                   COB75490
      VISL = VISLQ(TL)                                                   COB75500
      CNDV = CONDV(P,TV)                                                 COB75510
      CNDL = CONDL(P,TL)                                                 COB75520
      SIG = SURTT(TL)                                                    COB75530
C                                                                        COB75540
      GV = ALP*ROV*VVA                                                   COB75550
      GL = (1.-ALP)*ROL*VLA                                              COB75560
      G = GV + GL                                                        COB75570
   10 CONTINUE                                                           COB75580
C                                                                        COB75590
C           ... DETERMINE HEAT TRANSFER REGIME ...                       COB75600
C                                                                        COB75610
C  TEST QUALITY                                                          COB75620
C                                                                        COB75630
      IF(X.GE.0.99)GO TO 300                                             COB75640
C                                                                        COB75650
C  TEST FOR COLD WALL                                                    COB75660
C                                                                        COB75670
      IF(TW.LE.TSAT)GO TO 200                                            COB75680
C                                                                        COB75690
      IF(IHTM.LT.2)GO TO 30                                              COB75700
C                                                                        COB75710
C  COMPUTE MINIMUM STABLE FILM BOILING TEMPERATURE                       COB75720
C                                                                        COB75730
      IF (P.GT.68.96E5) GO TO 20                                         COB75740
      THN = 581.5 + .01876*SQRT( AMAX1(P-1.0345E5,(0.)) )                COB75750
      GO TO 25                                                           COB75760
   20 THN = 630.37 + .00432*SQRT(P-68.96E5)                              COB75770
   25 CONTINUE                                                           COB75780
      PSI=0.0                                                            COB75790
      IF (P.LT.4.827E5) PSI = 127.3 - 26.37E-5*P                         COB75800
C     CALL MPC(TW,RCP,COND)                                              COB75810
C     RRKCPW = 1./(RCP*COND)                                             COB75820
C  INVERSE OF ROCP OF ZIRCALOY TIMES CONDUCTIVITY OF OXIDE               COB75830
      RRKCPW = 3.1E-7 - 1.3E-10*TW                                       COB75840
      RKCPL=ROL*CNDL*CPL                                                 COB75850
C                                                                        COB75860
      TMSFB = THN + (THN-TL)*POW(RKCPL*RRKCPW,.5E0) - PSI                COB75870
C                                                                        COB75880
C  TEST WHETHER TWALL EXCEEDS TMSFB                                      COB75890
C                                                                        COB75900
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      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
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C  SOLVE THE EQUATION                                                   COB76460
C       HLFC*(TCHF-TL) +HLNB*(TCHF-TSAT)**1.24*(PWALL-P)**.75  = QCHF   COB76470
C  FOR TCHF USING NEWTON'S ITERATION                                    COB76480
C                                                                       COB76490
      TCHF=AMAX1(TL,TSAT+.1)                                            COB76500
      DO 35 K=1,10                                                      COB76510
        TCS=AMAX1(TCHF-TSAT,(0.))                                       COB76520
        PWALL=(.11062558*(TCHF-255.2))**4.4843049                       COB76530
        DQ = QCHF-HLF*(TCHF-TL)-HS*POW(TCS,1.24E0)*POW(PWALL-P,.75E0)   COB76540
        DQDT = HLF + HS*POW(TCS,.24E0)*POW(PWALL-P,.75E0) *             COB76550
     *    (1.24 + 3.3632287*TCS*PWALL/((TCHF-255.2)*(PWALL-P)) )        COB76560
        DTCHF = DQ/DQDT                                                 COB76570
        TCHF = TCHF + DTCHF                                             COB76580
        IF(ABS(DTCHF).LE.0.1)GO TO 40                                   COB76590
   35   CONTINUE                                                        COB76600
   40 CONTINUE                                                          COB76610
      GO TO 500                                                         COB76620
C                                                                       COB76630
C           ... INDIVIDUAL CORRELATIONS FOLLOW ...                      COB76640
C                                                                       COB76650
C                                                                       COB76660
C  CONVECTION TO SINGLE PHASE LIQUID                                    COB76670
C  MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS                          COB76680
C                                                                       COB76690
C  NOTE: MCADAMS SHOULD EVALUATE PROPERTIES AT A LIQUID FILM TEMP       COB76700
C                                                                       COB76710
  200 CONTINUE                                                          COB76720
      T1=ROL*ROL*GCON*BETAL*CPL*ABS(TW-TL)/(VISL*CNDL)                  COB76730
      HMA=.13*CNDL*POW(T1,.333333E0)                                    COB76740
      REL=ROL*VLA*HD/VISL                                               COB76750
      PRL=VISL*CPL/CNDL                                                 COB76760
      VISW=VISLQ(TW)                                                    COB76770
       HST=.023*CNDL*RHD*POW(REL,.8E0)*POW(PRL,.33E0)*                  COB76780
     1 POW(VISL/VISW,.14E0)                                             COB76790
      HLFC=AMAX1(HMA,HST)                                               COB76800
      CHFR=100.0                                                        COB76810
      IHTR=1                                                            COB76820
      IF(HMA.GT.HST) IHTR=2                                             COB76830
      GO TO 1000                                                        COB76840
C                                                                       COB76850
C  CONVECTION TO SINGLE PHASE VAPOR                                     COB76860
C  MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS                          COB76870
C                                                                       COB76880
C  NOTE:  MCADAMS SHOULD EVALUATE PROPERTIES AT A VAPOR FILM TEMP       COB76890
C                                                                       COB76900
  300 CONTINUE                                                          COB76910
      T1=ROV*ROV*GCON*BETAV*CPV*ABS(TW-TV)/(VISV*CNDV)                  COB76920
      HMA=.13*CNDV*POW(T1,.333333E0)                                    COB76930
      REV=ROV*VVA*HD/VISV                                               COB76940
      PRV=VISV*CPV/CNDV                                                 COB76950
      VISW=VISVP(TW)                                                    COB76960
      HST=.023*CNDV*RHD*POW(REV,.8E0)*POW(PRV,.33E0)*                   COB76970
     1  POW(VISV/VISW,.14E0)                                            COB76980
      HVFC=AMAX1(HMA,HST)                                               COB76990
      IHTR=9                                                            COB77000
```

```
      IF(HMA.GT.HST) IHTR=10                                            COB77010
      GO TO 1000                                                        COB77020
C                                                                       COB77030
C  SUBCOOLED OR SATURATED NUCLEATE BOILING                              COB77040
C  CHEN CORRELATION                                                     COB77050
C                                                                       COB77060
  400 CONTINUE                                                          COB77070
      HLFC = HLF                                                        COB77080
      HLNB = HLN                                                        COB77090
      IHTR=4                                                            COB77100
      IF(TL.LT.TSAT) IHTR=3                                             COB77110
      GO TO 1000                                                        COB77120
C                                                                       COB77130
C  TRANSITION BOILING                                                   COB77140
C                                                                       COB77150
  500 CONTINUE                                                          COB77160
      CALL FILM(HVTB,ALP,ROV,ROL,VVA,VLA,HD,RHD,TL,TV,TMSFB,TSAT,HFG,   COB77170
     1 CPV,CPL,P,VISV,VISL,BETAV,SIG,IHTR,X)                            COB77180
      RDTMC = 1./(TMSFB-TCHF)                                           COB77190
      EPS = (TMSFB-TW)*RDTMC                                            COB77200
      EPS2 = EPS*EPS                                                    COB77210
      QMSFB=HVTB*(TMSFB-TV)                                             COB77220
      QV=(1.-EPS2)*QMSFB                                                COB77230
      QL=EPS2*QCHF                                                      COB77240
      DQLDTW = -2.*EPS*QCHF*RDTMC                                       COB77250
      DQVDTW = 2.*EPS*QMSFB*RDTMC                                       COB77260
      HLFC = DQLDTW                                                     COB77270
      QL = QL + DQLDTW*(TL-TW)                                          COB77280
      HVFC = DQVDTW                                                     COB77290
      QV = QV + DQVDTW*(TV-TW)                                          COB77300
      IHTR=5                                                            COB77310
C                                                                       COB77320
C                                                                       COB77330
C                                                                       COB77340
 1000 CONTINUE                                                          COB77350
      RETURN                                                            COB77360
 2000 WRITE(I3,2020)                                                    COB77370
 2020 FORMAT(1H ,' ERROR DETECTED IN SUBROUTINE HTCOR.  ATTEMPT TO USE',COB77380
     1  ' NCHF=5 OPTION FOR TOO LARGE A PROBLEM.')                      COB77390
      CALL EXIT                                                         COB77400
      END                                                               COB77410
      SUBROUTINE FILM(H,ALP,ROV,ROL,VVA,VLA,HD,RHD,TL,TV,TW,TSAT,HFG,   COB77420
     1  CPV,CPL,P,VISV,VISL,BETAV,SIG,IHTR,X)                           COB77430
      DATA GCON,PI2/9.8066,6.2831853/                                   COB77440
C                                                                       COB77450
C  NOTE: IN BROMLEY'S AND MCADAMS' CORRELATIONS VAPOR PROPERTIES        COB77460
C        ARE EVALUATED AT BULK VAPOR TEMPERATURE AND NOT                COB77470
C        AT VAPOR FILM TEMPERATURE.                                     COB77480
C        IN GROENEVELD'S CORRELATION THE VAPOR PRANDTL NUMBER           COB77490
C        IS EVALUATED AT BULK VAPOR TEMPERATURE AND NOT                 COB77500
C        AT WALL TEMPERATURE.                                           COB77510
C                                                                       COB77520
C                                                                       COB77530
C   HIGH FLOW FILM BOILING                                              COB77540
C   GROENEVELD 5.7 OR MODIFIED DITTUS-BOELTER (FOR LOW PRESSURE)        COB77550
```

```
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 /2.718281B/                                               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)                                                   COB78110
      Q10=0.0                                                           COB78120
      IF(GT.LT.300.0)GO TO 10                                           COB78130
      F=.7249 + .099*PBAR*POW(EE,-(.032)*PBAR)                          COB78140
      G6=POW(GT,(-.166667))                                             COB78150
      Q10=2.764E7*POW(100.E0*HD,EN)*G6*(1.468*F*G6-X)                   COB78160
   10 CONTINUE                                                          COB78170
      H=-1.159 + .149*PBAR*POW(EE,-.019E0*PBAR) + 8.99*PBAR/            COB78180
     1 (10.+PBAR*PBAR)                                                  COB78190
      Q11=15.048E7*H*POW(100.E0*HD,EN)*POW(GT,(-.6))*(1.0-X)            COB78200
      QB=AMAX1(Q10,Q11)                                                 COB78210
      QCHF=QB                                                           COB78220
C                                                                       COB78230
C                                                                       COB78240
      IF(G.GE.GHI)GO TO 100                                             COB78250
   20 CONTINUE                                                          COB78260
C                                                                       COB78270
C  CHF-VOID CORRELATION FOR LOW FLOW                                    COB78280
C                                                                       COB78290
      T1=SIG*GCON*GCON*(ROL-ROV)*ROV*ROV                                COB78300
      QVC=.1179*(1.-ALP)*HFG*POW(T1,(.25))                              COB78310
      QCHF=QVC                                                          COB78320
C                                                                       COB78330
C                                                                       COB78340
      IF(G.LE.GLO)GO TO 100                                             COB78350
C                                                                       COB78360
C  LINEAR INTERPOLATION BETWEEN BIASI AND CHF-VOID                      COB78370
C                                                                       COB78380
      WT=(G-GLO)/(GHI-GLO)                                              COB78390
      QCHF=WT*QB+(1.-WT)*QVC                                            COB78400
C                                                                       COB78410
  100 CONTINUE                                                          COB78420
      RETURN                                                            COB78430
      END                                                               COB78440
      FUNCTION POW(A,B)                                                 COB78450
C                                                                       COB78460
C  THIS FUNCTION IS CALLED WHENEVER A LOW ACCURACY EXPONENTIATION       COB78470
C   WOULD BE ADEQUATE                                                   COB78480
C                                                                       COB78490
      POW=A**B                                                          COB78500
      RETURN                                                            COB78510
      END                                                               COB78520
      FUNCTION  CONDL (P, TL)                                           COB78530
C                                                                       COB78540
C  THERMAL CONDUCTIVITY OF LIQUID WATER                                 COB78550
C    W/M DEG K     FUNCTION OF     PASCAL,  DEG K                       COB78560
C                                                                       COB78570
C  ERROR OF APPROXIMATION < 5 PERCENT FOR  273 < TL < 573 DEG K         COB78580
C  VALUE AT 150 BAR, 300 DEG C = .55                                    COB78590
C                                                                       COB78600
      TS = TL - 415.                                                    COB78610
      CONDL = .686 - 5.87E-6*TS*TS + 7.3E-10*P                          COB78620
      RETURN                                                            COB78630
      END                                                               COB78640
      FUNCTION  CONDV (P, TV)                                           COB78650
```

```
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                                                                       COB79210
C  SURFACE TENSION OF LIQUID WATER                                      COB79220
C    KG(F)/M    FUNCTION OF    DEG K                                    COB79230
C  ( 1 KG(F)= 9.80665 KG M/SEC**2 )                                     COB79240
C  ALSO EQUAL TO SURFACE TENSION / GRAVITATIONAL ACCELERATION CONSTANT  COB79250
C  IN UNITS OF KG/M                                                     COB79260
C                                                                       COB79270
C  ERROR OF APPROXIMATION = 2 PERCENT FOR 373 < TL < 623 DEG K          COB79280
C  VALUE AT 250 DEG C = .0026                                           COB79290
C                                                                       COB79300
      SURTT = (80.72 - TL*.126) / (5140.+ TL)                           COB79310
      IF(SURTT.LT.0.0)   SURTT=0.0                                      COB79320
      RETURN                                                            COB79330
      END                                                               COB79340
```

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. .48315.82119.394.08
  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   .2857  5   .2564  7   .2564  8   .2564
1   7  .441.475  3   .2867  4   .2039  5   .2554  6   .3069
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  5.00.755  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
```

```
INPUT FOR CASE     1        BWR TURBINE TRIP W/O BYPASS  NEW FUEL ROD MODEL                DATE   9/24/80 TIME   14.46.31
 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 .830           *** 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 .078 405..0320500.0                                  *** 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
                                                            2=INTEGER
```

```
                                                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       928      2
        64     PRINTR        2         3      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)          =      2.80

  FORCING FUNCTION FOR PRESSURE
     TIME      PRESSURE
    (SEC)      FACTOR
   0.0           1.0000
   2.0000        1.1650
   2.5000        1.1650

  FORCING FUNCTION FOR INLET FLOW
     TIME   INLET FLOW
    (SEC)      FACTOR
   0.0           1.0000
   2.0000        0.7000
   5.0000        0.5000

  FORCING FUNCTION FOR HEAT FLUX
     TIME   HEAT FLUX
    (SEC)      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          WT PER         HT PER         NO. RODS       ROD DIA        GAP
                       SQ FT           FT             FT                            IN            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    COND.     SP. HEAT   DENSITY   DIA.       COND.      SP. HEAT    DENSITY  THICK.   GAP COND.
   NO. (B/HR-FT-F) (B/LB-F)   (LB/FT3)  (IN.)  (B/HR-FT-F)  (B/LB-F)   (LB/FT3)  (IN.)  (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   14.48.34

MASS BALANCE - -                                      ENERGY BALANCE - -
    MASS FLOW IN       0.67137E+02 LB/SEC                  FLOW ENERGY IN         0.35489E+05 BTU/SEC
    MASS FLOW OUT      0.67137E+02 LB/SEC                  ENERGY ADDED           0.82320E+04 BTU/SEC
    MASS FLOW ERROR    0.0         LB/SEC                  FLOW ENERGY OUT        0.45523E+05 BTU/SEC
                                                         ENERGY ERROR         0.18027E+04 BTU/SEC

CHANNEL ENTHALPY TEMPERATURE DENSITY   EQUIL     VOID      FLOW     MASS FLUX
 (NO.) (BTU/LB)  (DEG-F)    (LB/FT3) QUALITY  FRACTION  (LB/SEC) (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   DELTA-P     ENTHALPY   TEMPERATURE DENSITY    EQUIL    VOID       FLOW      MASS FLUX
 (IN.)      (PSI)      (BTU/LB)    (DEG-F)   (LB/CU-FT) QUALITY FRACTION  (LB/SEC) (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   DELTA-P    ENTHALPY   TEMPERATURE DENSITY   EQUIL   VOID      FLOW     MASS FLUX
 (IN.)      (PSI)     (BTU/LB)    (DEG-F)  (LB/CU-FT) QUALITY FRACTION (LB/SEC) (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       16.66      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      685.02      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*48*34

TIME =  0.0      SECONDS      DATA FOR CHANNEL  2

DISTANCE  DELTA-P    ENTHALPY   TEMPERATURE DENSITY    EQUIL   VOID       FLOW      MASS FLUX
 (IN.)     (PSI)     (BTU/LB)    (DEG-F)   (LB/CU-FT) QUALITY FRACTION  (LB/SEC)  (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   14.48.34

TIME =  0.0      SECONDS     TEMPERATURE DATA FOR ROD  1,  FUEL TYPE 1

DISTANCE  FLUX       CHFR  CHANNEL                TEMPERATURE(F)
 (IN.)  (MBTU/HR-FT2)                    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   2402.6   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   1740.4   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   14.48.34

TIME =  0.0     SECONDS     TEMPERATURE DATA FOR ROD  2,  FUEL TYPE 1

DISTANCE  FLUX       CHFR  CHANNEL              TEMPERATURE(F)
 (IN.)  (MBTU/HR-FT2)                   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    2107.7    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    1179.7     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•48•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   DELTA-P     ENTHALPY    TEMPERATURE DENSITY    EQUIL    VOID        FLOW      MASS FLUX
 (IN.)      (PSI)      (BTU/LB)     (DEG-F)   (LB/CU-FT) QUALITY FRACTION   (LB/SEC) (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   DELTA-P    ENTHALPY   TEMPERATURE DENSITY   EQUIL    VOID       FLOW     MASS FLUX
 (IN.)      (PSI)     (BTU/LB)    (DEG-F)  (LB/CU-FT) QUALITY FRACTION   (LB/SEC) (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     24.4200     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      685.04      567.41    17.10    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  FLUX        CHFR  CHANNEL              TEMPERATURE(F)
 (IN.)  (MBTU/HR-FT2)                   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    1660.3    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     805.7     574.8
```

```
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  2,  FUEL TYPE 1

DISTANCE  FLUX        CHFR  CHANNEL              TEMPERATURE(F)
 (IN.)  (MBTU/HR-FT2)                    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    1608.4    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    1200.3     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

ITERATIONS =    2
```

APPENDIX P

INPUT FOR BYPASS ANALYSIS

COBRA-IIIC/MIT Nineteen Channel Case One Input

```
   19   38    1   10  200 <---- first "card"
 2000
0   1    1  BWR Bypass Analysis Test Case - No Control Rods Inserted 9-80 1.00 P
    1    0
    1      500.     1500.   20
    2    0    0    0    0
 .184  -.2
    3   21
   0..2653  .05.5491  .10.7268  .15.8541  .20.9363  .25.9814
  .30.9841  .35.9523  .40.9045  .45.8674  .50.8753  .55.9496
  .601.096  .651.302  .701.517  .751.671  .801.674  .851.451
  .90.9867  .95.3899  1.0 0.00
    4   19   19
    12.1795.4385.438    2.3752         5.3752
    23.19510.8810.88    1.3752         3.3752         6.3752
    32.1795.4385.438    2.3752         7.3752
    41.0525.4385.438    5.1870        11.1870
    54.79416.3116.31    1.3752         4.1870         6.3752        10.7520
    64.20721.7521.75    2.3752         5.3752         7.3752         9.3752
    73.19510.8810.88    3.3752         6.3752         8.3752
    82.1795.4385.438    7.3752         9.3752
    94.79416.3116.31    6.3752         8.3752        10.7520        16.1870
   108.40821.7521.75    5.7520         9.7520        11.7520        15.7520
   114.79416.3116.31    4.1870        10.7520        12.3752        14.3752
   122.1795.4385.438   11.3752        13.3752
   133.19510.8810.88   12.3752        14.3752        19.3752
   144.20721.7521.75   11.3752        13.3752        15.3752        18.3752
   154.79416.3116.31   10.7520        14.3752        16.1870        17.3752
   161.0525.4385.438    9.1870        15.1870
   172.1795.4385.438   15.3752        18.3752
   183.19510.8810.88   14.3752        17.3752        19.3752
   192.1795.4385.438   13.3752        18.3752
    7
    8   10   10
    1 6.921.158    1  .33     2  .25     5  .25     6  .17
    2 6.921.174    2  .25     3  .33     6  .17     7  .25
    3 6.92 1.00    4  .17     5  .25    10  .33    11  .25
    4 6.92 1.00    5  .25     6  .17     9  .25    10  .33
    5 6.921.158    6  .17     7  .25     8  .33     9  .25
    6 6.921.158   11  .25    12  .33    13  .25    14  .17
    7 6.92 1.00   10  .33    11  .25    14  .17    15  .25
    8 6.92 1.00    9  .25    10  .33    15  .25    16  .17
    9 6.921.174   13  .25    14  .17    18  .25    19  .33
   10 6.921.158   14  .17    15  .25    17  .33    18  .25
    9    3         0
  0.5   0.167.8   0.   60    0   0.           .094
   10    0    1
  .02
   11    0    1
     1035.     527.1     .1750     .0060
   12    1    7
 1 2 3 4 5 610

/* end of file
```

COBRA-IIIC/MIT Four Channel Case Input

```
    4    3    1    2  200       first "card"
 2000
0   1    1   Four Channel BWR Bypass Test Case 10-80
    1   -1
    1      500.     2000.   30
    2    0    0    0    0
 .184  -.2
    3   21
   0..2653  .05.5491  .10.7268  .15.8541  .20.9363  .25.9814
  .30.9841  .35.9523  .40.9045  .45.8674  .50.8753  .55.9496
  .601.096  .651.302  .701.517  .751.671  .801.674  .851.451
  .90.9867  .95.3899  1.0 0.00
    4    4    4
    11.0902.7192.719    2 .375
    23.19510.8810.88    3 .375          4 .375
    31.0902.7192.719
    41.0525.4385.438
    8    2    2    0    0    0
1   1 6.92   1.    1 .167    2  .25     4 .083
1   2 6.92   1.    2  .25    3 .167     4 .083
    9    3
  0.5   0.167.8   0.   60    0   0.           .094
   10    0    1    0
  .02
   11    0    1
     1035.     527.1     .3290     .0132
   12    1

end of input deck
```

THERMIT Four Channel Case Input

```
   1      first "card"
 BWR Bypass Analysis - Four Channel Case  10-80
 4,2,4,10,1,1
 0,1,0,0,1,2,0,1,1,0,0, 0,0,0,0,0,-9.81,0.03,5.0
 1,3,20,1.e-7,1.e-7
 9.81e4,0.,0.,8.794e-2,1.e-3,1.e-3,1.e6,1.,0.,1.,1.,1.,1.e-4,1.e6,1.,0.,0.,0.,0.
 3 1 $ ncr
 0 1 $ indent
 30(19.350e-3) 10(6.370e-3)$ arx
 2( 10(6.601e-3) 10(19.35e-3) ) $ ary
 11(7.032e-4) 11(2.061e-3) 11(7.032e-4) 11(6.787e-4)$ arz
 10(2.997e-4) 10(8.784e-4) 10(2.997e-4) 10(2.892e-4) $ vol
 1.549e-2 4.540e-2 1.549e-2 4.540e-2 $ dx
 3(4.540e-2) 1.495e-2 $ dy
 12(0.4262) $ dz
 4.073e-2 2.984e-2 4.073e-2 1.965e-2 $ hdz
 3(0.) 0.00953 0.00953 0. 0.00953 0.  0.00953 3(0.)  0. 0.00953 2(0.) $ sij
 11(01) $ ifwz
 48(7.135e6)$p
 48(0.) $ alp
 48(551.11)$ tv
 11(0.3) 11(0.3) 11(0.3) 11(0.3) $ vvz
 1 2 3 4 $ icr
 4.073e-2 2.984e-2 4.073e-2 1.965e-2 $ hdh
 40(551.11)$ tw
 .407 .7905  .9585 .968 .886 .9125  1.199 1.594 1.54625 .6885 $ qz
1.333 1. 1.333 0.666 $ qt
 3(1.) $ qr
 4(1.) $ rn
 0.125 0.5 0.125 0.250 $ fracp
 0,0,0,0
 40.,0.01,0.10,10.,40.,1.0,4
-1
0.......
end of deck
```

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