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

by

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

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

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

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

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

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

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

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

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<td>Table</td>
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<td>K-4</td>
</tr>
<tr>
<td>K-2</td>
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<td>K-6</td>
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</table>
I. INTRODUCTION

Thermal-hydraulic analysis of light water reactor (LWR) cores is usually performed using a computer code. Thermal-hydraulic 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
Testing 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 between 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, \( h_{\text{gap}} \), 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 \( \beta \), 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>
<thead>
<tr>
<th>Enphasis on MEKIN</th>
<th>COBRA-IIIC/MIT</th>
<th>System</th>
<th>PWR</th>
<th>BAR</th>
<th>S.S.</th>
<th>Transient</th>
<th>Code Used</th>
<th>Information/Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>MEKIN/T.H.</td>
<td>PWR-RIA study, sensitivity study of T-H input parameters on fuel temperatures and coolant density, void fraction. List of most important parameters.</td>
<td>(2)</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
<td>COBRA-IIIC/MIT</td>
<td>Sensitivity of COBRA solution to user input parameters and user selected correlations.</td>
<td>(3)</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td></td>
<td>COBRA-IIIC/MIT</td>
<td>Lumped and mixed lattice approach (single pass method).</td>
<td>(4,7)</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td></td>
<td>COBRA-IIIC/MIT</td>
<td>Verification of the single pass method in transients, discussion of experimental verification of COBRA.</td>
<td>(5,7)</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>COBRA-IIIC/MIT</td>
<td>Transport coefficients to improve results of lumped, mixed lattice approach.</td>
<td>(6,7)</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>COBRA-IIIC/MIT</td>
<td>Sensitivity of COBRA solution to user input parameters.</td>
<td>(8)</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>COBRA-IIIC/MIT</td>
<td>Development of a new solution method based on pressure field, convergence studies.</td>
<td>(9,10)</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td>COBRA-IIIC/MIT &amp; IV-I</td>
<td>Study of different fuel pin models.</td>
<td>(11)</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td>COBRA-IIIC/MIT &amp; IV-I</td>
<td>Assessment and comparison/similar results except for clad temperature predictions.</td>
<td>(12)</td>
</tr>
</tbody>
</table>

Key: + yes
- no
of values used for the transverse momentum parameters, $s/\ell$ and $K_{ij}$, except for cases of large inlet flow upset of blockage. Variation of the turbulent mixing parameter, $\beta$, greatly affected flow and enthalpy predictions under two-phase conditions typical of BWR's.

Work described in Refs. 4-8 was concerned with COBRA-IIIC/MIT development. The major portion of this research 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 transient conditions and to analyze a PWR
### Table II-2

Summary of Cases Analyzed and Results from Ref. 11

<table>
<thead>
<tr>
<th>Case</th>
<th>Steady state or transient initial conditions</th>
<th>Levy sub-cooled Boiling Model Used</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G (Mlb/hr-ft²)</td>
<td>P (psia)</td>
<td>T (°F)</td>
</tr>
<tr>
<td>BWR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet Flow</td>
<td>1.25</td>
<td>1035</td>
<td>527</td>
</tr>
<tr>
<td></td>
<td>1.25</td>
<td>1035</td>
<td>527</td>
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<tr>
<td></td>
<td>1.25</td>
<td>1035</td>
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</tr>
<tr>
<td></td>
<td>1.25</td>
<td>1035</td>
<td>514</td>
</tr>
<tr>
<td>Steady State</td>
<td>1.25</td>
<td>1035</td>
<td>527</td>
</tr>
<tr>
<td>Comparisons</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressurization</td>
<td>1.25</td>
<td>1035</td>
<td>527</td>
</tr>
<tr>
<td>Transient</td>
<td>1.25</td>
<td>1035</td>
<td>527</td>
</tr>
<tr>
<td>PWR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Power</td>
<td>2.48</td>
<td>2100</td>
<td>635</td>
</tr>
<tr>
<td>Transient</td>
<td>2.48</td>
<td>2100</td>
<td>635</td>
</tr>
<tr>
<td></td>
<td>2.48</td>
<td>2100</td>
<td>635</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>2100</td>
<td>635</td>
</tr>
<tr>
<td>Loss of Flow</td>
<td>2.48</td>
<td>2100</td>
<td>541</td>
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<tr>
<td>Transient</td>
<td>2.48</td>
<td>2100</td>
<td>541</td>
</tr>
<tr>
<td></td>
<td>2.48</td>
<td>2100</td>
<td>541</td>
</tr>
<tr>
<td></td>
<td>2.48</td>
<td>2100</td>
<td>570</td>
</tr>
<tr>
<td>Maine Yankee Exit</td>
<td>2.48</td>
<td>2100</td>
<td>532</td>
</tr>
<tr>
<td>Temp. Comparison</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>B&amp;R Crossflow</td>
<td>---</td>
<td>near</td>
<td>ambient</td>
</tr>
<tr>
<td>Experiment</td>
<td></td>
<td>atmos</td>
<td></td>
</tr>
<tr>
<td>EIR Flow Blockage</td>
<td>---</td>
<td>near</td>
<td>ambient</td>
</tr>
<tr>
<td>Experiment</td>
<td></td>
<td>atmos</td>
<td></td>
</tr>
</tbody>
</table>
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 code does not contain the logic or correlations needed to calculate BWR Critical Power Ratio (CPR).

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

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

Application of COBRA-IIIC/MIT to BWR and PWR transient analysis cases indicated that the code had not previously been adequately tested for such cases. One problem encountered was an oscillatory behavior of mass flow rate predictions during iteration, as shown in Figure II-2. This figure shows the variation of mass flow rate with iteration number at the point where boiling starts during analysis of PWR power transient. The oscillatory behavior was eliminated by a correction which prevented the quality from oscillating unrealistically between positive and negative values once it becomes positive in a particular node. Elimination of this and similar problems subsequently allowed COBRA-IIIC/MIT to analyze and make reasonable predictions for several PWR and BWR transients, as mentioned in Table II-2.
Figure II-1 (FIGURE 2.7 of Ref. 12)
CLAD TEMPERATURE VERSUS AXIAL LENGTH
RESULTS FOR STEADY STATE BWR CASE
Figure II-2 (Fig. 3.4 of Ref. 12)

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

Finally, despite the need for improvements in the COBRA-IIIC/MIT heat transfer logic and the procedure for calculating the rod-to-coolant heat transfer coefficient, the code appears to provide adequate PWR DNBR predictions. As dicussed in Ref. 12, with the exception of clad temperature predictions, COBRA-IIIC/MIT and COBRA-IV-I predictions were in good agreement with each other and experimental measurements; and the DNBR was not affected by the clad temperature discrepancies. However, COBRA-IIIC/MIT does not contain the logic or correlations needed to calculate Critical Power Ratio (CPR), a figure-of-merit for BWR thermal margin.
Figure II-3 (Fig. 5.2 of Ref. 12)

Schematic of B&W Apparatus
Figure II-4 (FIGURE 3.18 of Ref. 11)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
COBRA-IIIC/MIT RESULTS FOR B&W CROSSFLOW EXPERIMENT
Figure II-5 (FIGURE 3.19 of Ref. 12)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
COBRA-IV-I RESULTS FOR B&W CROSSFLOW EXPERIMENT
Figure II-6 (FIGURE 3.20 of Ref. 12)
NORMALIZED CROSSFLOW VERSUS AXIAL POSITION
THERMIT RESULTS FOR B&W CROSSFLOW EXPERIMENT (Ref. App. H)
D. Summary of Major Conclusions Leading to Present Research

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

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

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

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

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

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

5b) Overall thermal results are not dependent on the cross-flow parameters \( s/\ell \) 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>
<thead>
<tr>
<th>IMPROVEMENT</th>
<th>PREVIOUS STATUS</th>
<th>DESCRIPTION OF IMPROVEMENT</th>
<th>ADVANTAGES/DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) New Fuel Rod Model</td>
<td>No temperature dependence, constant value of fuel-clad gap heat transfer coefficient used for entire core</td>
<td>New model with temperature dependent properties, higher numerical accuracy and burnup-dependent fuel-clad gap heat transfer coefficient</td>
<td>Better modeling, higher accuracy improved heat transfer prediction/slightly increased computation time</td>
</tr>
<tr>
<td>b) New Rod-to-Coolant Heat Transfer Model</td>
<td>Inconsistent logic causes poor clad temperature predictions</td>
<td>New heat transfer model with greater capabilities in the high quality regime and more consistent logic</td>
<td>Improved heat transfer predictions/Increased computation time</td>
</tr>
<tr>
<td>c) New Mixing Model</td>
<td>Cannot account for quality dependence</td>
<td>Added option enabling use of quality dependent mixing model</td>
<td>Improved capability for BWR subchannel analysis/Slightly increased computation time</td>
</tr>
<tr>
<td>d) Critical Power Ratio (CPR) and Critical Heat Flux Ratio (CHFR) Calculation Options</td>
<td>No CPR or CHFR calculation options available for BWR analysis</td>
<td>Added options calculate CPR and CHFR</td>
<td>CPR and CHFR can be calculated/No disadvantage expected</td>
</tr>
<tr>
<td>e) New Transverse Momentum Coupling Parameters for the Single-Pass Method</td>
<td>Only one value of s/l and K used for all gap interconnections of a case</td>
<td>s/l and K are, in effect, varied from one gap interconnection to another by coupling parameters</td>
<td>May slightly improve accuracy of predictions under some conditions/Extra input preparation effort, no axial variation of coupling parameters</td>
</tr>
</tbody>
</table>
Figure III-1 (Based on Fig. A-2.1 of Ref. 15)

Thermal Conductivity of $\text{UO}_2$
Specific Heat Capacity of $\text{UO}_2$ and $\text{UO}_2$-$\text{PuO}_2$

Figure III-2 (Fig. A-1.1 of Ref. 15)
The methods used by the new fuel rod model to represent temperature dependent properties and h gap are described in Appendix B. The old and new fuel rod model is called by subroutine HEAT and used in the calculation of fuel rod temperatures and surface heat fluxes as described in Appendix C.

C. New Rod-to-Coolant Heat Transfer Model

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

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

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

The new heat transfer model is further described in Appendix D. The equations and data bases of the pre-CHF correlations used in the old and new heat transfer models are given in Appendix E. The new heat transfer model is similar to the COBRA-IV-I heat transfer model in that it constructs a complete boiling curve. The COBRA-IV heat transfer model is briefly described in Appendix F for purposes of comparison.
Figure III-3

A Typical Boiling Curve of New Heat Transfer Model

$T_w$ - wall temperature

$T_f$ - coolant temperature
D. New Mixing Model

1. Description of Model

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

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

- **System Pressure**: \( 50 \leq P \leq 775 \) psia
- **Mass Velocity**: \( 7.3 \times 10^4 \leq G \leq 3 \times 10^6 \) lb/hr-ft\(^2\)
- **Quality**: \( 0 \leq x \leq 0.80 \)
- **Gap Width**: \( 0.2 \leq s \leq 0.10 \) in.

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

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

1. Critical Power Ratio (CPR) Correlation
   
   a. Introduction

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

*It should be noted that the pressure range of interest for BWR's (and PWR's) exceeds the range of data upon which the Beus model is based. Thus, use of the model for analysis of reactor conditions assumes that it accounts for the pressure dependence sufficiently well to allow extrapolation to higher pressures.*
Figure III-4 (Fig. 8 of Ref. 16)

Mixing Rate Variation with Quality
Figure III-5 (Fig. 9 of Ref. 16)

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

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

\[ X_C = X_C(L_B, D_Q, G, L, P, R) \]

where:

- \( X_C \) = bundle average critical quality;
- \( L_B \) = boiling length;
- \( D_Q \) = thermal diameter (i.e., four times the ratio of total flow area to total rod perimeter);
- \( L \) = heated length;
- \( P \) = system pressure;
- \( R \) = a parameter which characterizes the local peaking pattern with respect to the most limiting rod; and
- \( G \) = mass flux.

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

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

- Pressure: 800 to 1400 psia
- Mass Flux: 0.10x10^6 to 1.25x10^6 lb/hr-ft^2
- Inlet Subcooling: 0 to 100 BTU/lb.

As shown in Figure III-6, the heat balance curve which touches the GEXL correlation determines the critical power. The calculation of critical power involves an iterative procedure. The critical power curve is associated with a minimum critical power ratio (MCPR) of one which reduces the critical quality difference, \( \Delta X_{eq} \), 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, $\lambda$, the critical boiling length, $L_{Bo}$, and critical quality, $<x_e>$. Data from experiments with uniform and non-uniform axial heat flux profiles are collapsed onto curves of $<x_e>$ vs. $L_{Bo}$ 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:

$$<x_e>^c = \frac{D_h}{D_e} \frac{a(P,G)L_{Bo}^c}{[L_{Bo}^c + b(P,G,D_e)]}$$  \hspace{1cm} \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:

$$\text{CPR} \approx 1 + \frac{<x_e(L_{Bo}^c)> - <x_e(L_{Bo})>}{<x_e(L_{Bo})> + \frac{h_f - h_{in}}{h_{fg}}}$$  \hspace{1cm} \text{(Eqn. III-2)}

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

* Ref. page H-9 of Appendix H for definition of nomenclature used in this section.
Figure III-7 (Fig. 4-27 of Ref. 19)

Schematic Showing Relationship

Between $L_{Bc}$, $\langle x \rangle_c$ 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:

\[ (q''_{\text{CHF}})_{\text{Biasi}} = f(D_e, G, P, x) \]  \hspace{1cm} (Eqn. III-3)

\[ (q''_{\text{CHF}})_{\text{Void-CHF}} = f(\alpha, \sigma, \rho_f, \rho_g, H_{fg}) \]  \hspace{1cm} (Eqn. III-4)

where,

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

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

Eqn. (III-4) is used for \( G \leq G_0 \).
Figure III-9

Hench-Levy Limit Lines
(Ref. 18)
Figure III-10
Experimentally Observed Trend in CHF Data Compared to the Hench-Levy Limit Line
(Boiling Transition)
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, $s/\lambda$ and $K$, should be modified when the code is used for analysis cases involving interconnected regions of different size.* This suggestion has also been made by Chiu (Ref. 11). The old COBRA-IIIC/MIT approach is compared with the modified approaches suggested by Weisman and Chiu in Appendix I. COBRA-IIIC/MIT has been modified to provide the option of using the Weisman and Chiu approaches in addition to the old COBRA approach for transverse momentum modeling.

2. **Description of Code Modification**

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

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

$$F_{ij} = \frac{K|W_{ij}|W_{ij}/S_{ij}}{2(S_{ij})^2 \rho^* \lambda} (f_{slk})_{ij} \quad \text{(Eqn. III-6)}$$

---

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

\[ (f_{s1})_{ij} = \left( \frac{N}{N_r} \right)_{ij} \]  
(Eqn. III-7)

\[ (f_{s1k})_{ij} = (N_g')_{ij} \]  
(Eqn. III-8)

For the Chiu approach,

\[ (f_{s1})_{ij} = \left( \frac{(N_g)_{ij}}{(N_r')_{ij}} \right) \]  
(Eqn. III-9)

\[ (f_{s1k})_{ij} = (N_g')_{ij} \]  
(Eqn. III-10)

When a user does not select the new transverse momentum option, the \( f_{s1} \) and \( f_{s1k} \) factors are set to unity.
IV. TESTING AND APPLICATION

A. Introduction

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

B. Individual Testing of New Models

1. Testing of New Fuel Rod Model

The new fuel rod model has been tested using steady state and transient test cases. Some test cases were run to test the solution method for numerical stability and energy conservation. Further tests compare predictions of new fuel rod model options with predictions of the old fuel rod model. The following sub-sections 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 distributions 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 separate 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-
IV-2

Data

Fluid temperature  532°F
Rod-to-coolant heat transfer coefficient
Rod surface heat flux
Gap heat transfer coefficient

Properties

<table>
<thead>
<tr>
<th></th>
<th>Fuel</th>
<th>Clad</th>
</tr>
</thead>
<tbody>
<tr>
<td>conductivity</td>
<td>1.4</td>
<td>8.8</td>
</tr>
<tr>
<td>density</td>
<td>650</td>
<td>410</td>
</tr>
<tr>
<td>specific heat</td>
<td>.08</td>
<td>.078</td>
</tr>
</tbody>
</table>

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, $h_{\text{gap}}$.
2) Fuel and clad properties calculated, user input value of $h_{\text{gap}}$.
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 temperature 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  
Fluid temperature  
Rod-to-coolant heat transfer coefficient  
Linear heat generation rate  

- 0.2  
RADIAL DISTANCE(IN)  

Fuel and clad properties calculated,  
\[ h_{gap} = 2120 \text{ Btu/hr-ft}^2\text{-°F} \]

All properties including \( h_{gap} \) calculated,  
\[ h_{gap} = 2377 \text{ Btu/hr-ft}^2\text{-°F} \]

Constant properties,  
\[ h_{gap} = 2120 \text{ Btu/hr-ft}^2\text{-°F} \]

Figure IV-2  
Predictions of the Three Options of New Fuel Rod Model
IV-5

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

Calculated $h_{\text{gap}} = 3020.$ at $t=0$

Calculated $h_{\text{gap}} = 4110.$ at $t=\infty$

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 \( h_{\text{gap}} \).

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

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

   a. Steady State Predictions

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

   b. Transient Predictions

   A transient case was analyzed which considered adjacent PWR channels. These channels were assumed to be initially at nearly zero power and then subjected to a short burst of power sufficient to cause some voiding. This case was run previously as part of the comparison of COBRA-IIIC/MIT and COBRA-IV-I described in Ref. 12.
Figure IV-4

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

c. Conclusions

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

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

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

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

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

3. Testing of New Mixing Model

The new mixing model was tested by comparing COBRA-IIIC/MIT predictions with data from the GE 9-Rod Mixing 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 $\beta=0.02$. 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 mixing 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 analyzed with COBRA-IIIC/MIT using the old and new mixing models. The analysis was done for one-fourth of an assembly, assuming quarter-assembly symmetry. The cases analyzed are listed in Table IV-1.

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

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

\[ f = a(Re)^b \]  
(Eqn. IV-1)

The "b" coefficient was given the smooth-tube friction correlation value of -0.2. The "a" coefficient was adjusted to a value of 0.286 to make predictions agree with experiment. Comparisons of the resulting predicted and experimental pressure drops are shown in Table IV-2. COBRA exit mass flow distribution predictions are compared with experimental data in Figure IV-7. Each curve in the figure is based on three calculated values of data points. These are the values of the normalized mass flux for the corner, side and center subchannels. The COBRA predictions for each subchannel are within 1% of one another for all four isothermal cases. The COBRA predictions are within the spread of data in the corner subchannel and near the spread of data in the side and corner subchannels.
Figure IV-6

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

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Rods</td>
<td>9</td>
</tr>
<tr>
<td>Rod Diameter</td>
<td>0.570 inch</td>
</tr>
<tr>
<td>Radius of Corner Subchannel</td>
<td>0.420 inch</td>
</tr>
<tr>
<td>Rod Rod Clearance</td>
<td>0.168 inch</td>
</tr>
<tr>
<td>Rod Wall Clearance</td>
<td>0.135 inch</td>
</tr>
<tr>
<td>Hydraulic Diameter</td>
<td>0.474 inch</td>
</tr>
<tr>
<td>Heated Length</td>
<td>72 inch</td>
</tr>
<tr>
<td>Pressure</td>
<td>1000 psia</td>
</tr>
<tr>
<td>Average Bundle Mass Flux</td>
<td>0.48 to 1.970 \text{ Mlbm/hr-ft}^2</td>
</tr>
<tr>
<td>Average Heat Flux</td>
<td>0.225 to 0.675 \text{ MBtu/hr-ft}^2</td>
</tr>
<tr>
<td>Inlet Subcooling</td>
<td>29.1 to 504.6 \text{ Btu/lbm}</td>
</tr>
</tbody>
</table>

![Diagram of 9-rod mixing tests](image-url)
Table IV-1

GE 9-Rod Mixing Test Cases Analyzed

<table>
<thead>
<tr>
<th>Test Case Number</th>
<th>Mass Flux (Mlb/hr ft²)</th>
<th>Average Heat Flux (MBTU/hr ft²)</th>
<th>Power Distribution</th>
<th>Inlet Subcooling (BTU/lb)</th>
<th>Average Exit Quality</th>
<th>Boiling Length LB/L</th>
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</thead>
<tbody>
<tr>
<td>1B</td>
<td>0.48</td>
<td>0.0</td>
<td>-</td>
<td>504.6</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>1C</td>
<td>0.99</td>
<td>0.0</td>
<td>-</td>
<td>504.6</td>
<td>0.0</td>
<td>0.00</td>
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<tr>
<td>1D</td>
<td>1.51</td>
<td>0.0</td>
<td>-</td>
<td>504.6</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>1E</td>
<td>1.97</td>
<td>0.0</td>
<td>-</td>
<td>504.6</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>2G1</td>
<td>1.070</td>
<td>0.675</td>
<td>uniform</td>
<td>225.9</td>
<td>0.038</td>
<td>0.10</td>
</tr>
<tr>
<td>2G2</td>
<td>1.080</td>
<td>0.675</td>
<td>uniform</td>
<td>189.8</td>
<td>0.090</td>
<td>0.24</td>
</tr>
<tr>
<td>2G3</td>
<td>1.070</td>
<td>0.675</td>
<td>uniform</td>
<td>146.7</td>
<td>0.160</td>
<td>0.41</td>
</tr>
</tbody>
</table>

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

- System Pressure: $50 \leq P \leq 775$ psia
- Mass Flux: $0.073 \leq G \leq 3.$ Mlb/hr ft²
- Quality: $-0.2 \leq X \leq 0.80$
- Gap Width Between Subchannels: $0.02 \leq S \leq 0.10$ in.
Table IV-2

Measured and Predicted Axial Friction Pressure Drop

<table>
<thead>
<tr>
<th>Test Case</th>
<th>(ΔP_f) measured (psia)</th>
<th>(ΔP_f) predicted* (psia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB</td>
<td>0.2128</td>
<td>0.21</td>
</tr>
<tr>
<td>IC</td>
<td>0.7130</td>
<td>0.75</td>
</tr>
<tr>
<td>ID</td>
<td>1.596</td>
<td>1.60</td>
</tr>
<tr>
<td>IE</td>
<td>2.540</td>
<td>2.58</td>
</tr>
<tr>
<td>ID (repeated)</td>
<td>1.610</td>
<td>1.60</td>
</tr>
</tbody>
</table>

*Frictional pressure drop with COBRA-IIIC/MIT using the single-phase friction correlation $f = a(Re)^{-0.2}$ with $a = 0.286$. 
Figure IV-7
GE Mixing Test Cases 1B, 1C, 1D and 1E
Normalized Exit Mass Flux Distributions
Three adiabatic test cases (2G1, 2G2 and 2G3) were analyzed with COBRA-IIIC/MIT using the old and new mixing models. The analyses with the old model used $\beta = 0.02$ (the standard value of $\beta$ in COBRA-IIIC/MIT's input). The new mixing model is the Beus model. COBRA exit mass flux and enthalpy predictions are compared to data in Figures IV-8 through IV-11 and IV-13 through IV-15.

Figures IV-8 through IV-10 compare predicted and measured enthalpy distributions. Enthalpy becomes increasingly over-predicted as exit quality increases, going from case 2G1 to 2G2 and on to case 2G3. The enthalpy distribution predictions using $\beta = 0.02$ 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 $\beta$ less than 0.02. However, the Beus predictions do follow the quality dependence of the model's mixing predictions (i.e. increasing mixing rate at low quality and then decreasing mixing rate at high quality). This can be seen by comparing Figure IV-11, where corner subchannel enthalpy predictions and data are compared for cases 2G1, 2G2 and 2G3 with Figure IV-12.

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

In going from an exit quality of 0.038 to 0.16, the Beus corner subchannel enthalpy prediction falls and rises. The behavior is due to the increased turbulent interchange of enthalpy from the corner subchannel for case 2G2, where exit quality is 9%. For a given geometry, mass flow rate and pressure, Beus mixing predictions are a function of quality, as shown in Figure IV-12. The mixing rate starts at a single-phase liquid value and increases 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,
\[ \bar{G} = 1.07 \text{ Mlb/hr ft}^2 \]
\[ q'' = 0.675 \text{ MBTU/hr ft}^2 \]
\[ \bar{X}_{\text{exit}} = 0.038 \]

*Figure IV-8*

GE Mixing Test Case 2G1
Normalized Exit Enthalpy Distribution
$G = 1.08 \text{ Mlb/hr ft}^2$
$q'' = 0.675 \text{ MBTU/hr ft}^2$
$\bar{X}_{\text{exit}} = 0.09$

**Figure IV-9**

GE Mixing Test Case 2G2
Normalized Exit Enthalpy Distribution
\[ \bar{G} = 1.07 \text{ Mlb/hr ft}^2 \]
\[ q'' = 0.675 \text{ MBTU/hr ft}^2 \]
\[ \bar{X}_{\text{exit}} = 0.16 \]

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)
$\bar{G} = 1.07 \text{ Mlb/hr ft}^2$
$q'' = 0.675 \text{ MBTU/hr ft}^2$
$\bar{X}_{exit} = 0.038$

Figure IV-13
GE Mixing Test Case 2G1
Normalized Exit Mass Flux Distribution
\( \bar{G} = 1.08 \text{ Mlb/hr ft}^2 \)
\( q'' = 0.675 \text{ MBTU/hr ft}^2 \)
\( \bar{X}_{\text{exit}} = 0.09 \)

**Figure IV-14**

GE Mixing Test Case 2G2

Normalized Exit Mass Flux Distribution
\[ G = 1.07 \text{ Mlb/hr ft}^2 \]
\[ q'' = 0.675 \text{ MBTU/hr ft}^2 \]
\[ \bar{x}_{\text{exit}} = 0.16 \]

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

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

b. **Comparison with Columbia 16-Rod Mixing Tests**

1) **Description of Tests**

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

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

Nine test cases were analyzed with COBRA-IIIC/MIT using the old and new mixing models. The analyses were made for one-half of an assembly, assuming half-assembly symmetry. The cases analyzed are listed in Table IV-3. COBRA-IIIC/MIT predictions for channel 5 and 11 exit mass flux and enthalpy are compared with experimental measurements for cases 22, 25, 27, 29 and 30 in Figures IV-17 through IV-20.
**Figure IV-16**

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rod Outside Diameter</td>
<td>0.422 in.</td>
</tr>
<tr>
<td>Rod Pitch</td>
<td>0.555 in.</td>
</tr>
<tr>
<td>Rod to Wall Spacing</td>
<td>0.143 in.</td>
</tr>
<tr>
<td>Total Flow Area</td>
<td>0.02389 ft²</td>
</tr>
<tr>
<td>Radial Heat Flux</td>
<td></td>
</tr>
<tr>
<td>Hot Rods (H)</td>
<td>100%</td>
</tr>
<tr>
<td>Cold Rods (C)</td>
<td>86%</td>
</tr>
<tr>
<td>Heated Length</td>
<td>60 in.</td>
</tr>
<tr>
<td>Pressure</td>
<td>500 and 1200 psia</td>
</tr>
<tr>
<td>Average Bundle Mass Flux</td>
<td>1 x 10⁶; 2 x 10⁶; 3 x 10⁶ lbm/hr ft²</td>
</tr>
<tr>
<td>Inlet Temperature</td>
<td>172°F to 484°F</td>
</tr>
<tr>
<td>Average Heat Flux</td>
<td>0.384 x 10⁶; 0.56 x 10⁶; 0.967 x 10⁶ BTU/hr ft²</td>
</tr>
<tr>
<td>Traverse Heating Ratio</td>
<td>Colder/Hotter: 0.86; Colder/Average: 1.02; Hotter/Average: 1.08</td>
</tr>
</tbody>
</table>

![Diagram of subchannel configuration](image)
Table IV-3
Columbia 16-Rod Mixing Test Case Analyzed

System Pressure, \( P = 1200 \text{ psia} \) for all cases listed.

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

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

System Pressure \( 50 \leq P \leq 775 \text{ psia} \)
Mass Flux \(.073 \leq G \leq 3. \text{ Mlb/hr ft}^2\)
Quality \(-0.2 \leq X \leq 0.80 \)
Gap Width Between Subchannels \(.02 \leq S \leq 0.10 \text{ in.} \)
\( \bar{\bar{G}} = 1 \cdot \frac{\text{Mlb}}{\text{hr ft}^2} \)

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

\( P = 1200 \text{ psia} \)

---

**Figure IV-17**

Columbia Test Cases 22, 25, 27, 29 and 30

Normalized Channel 5 Exit Enthalpy vs. Quality
IV-28

\[ G = 1 \text{ Mlb} \frac{\text{hr ft}^2}{\text{hr ft}^2} \]

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

\[ P = 1200 \text{ psia} \]

Figure IV-18

Columbia Test Cases 22, 25, 27, 29 and 30
Normalized Channel 11 Exit Enthalpy vs. Quality
\[ G = \frac{1. \text{ Mlb}}{	ext{hr ft}^2} \]

\[ q'' = 0.38 \frac{\text{MBTU}}{	ext{hr ft}^2} \]

\[ P = 1200. \text{ psia} \]

Figure IV-19

Columbia Test Cases 22, 25, 27, 29 and 30

Normalized Channel 5 Exit Mass Flux vs. Quality
$\bar{G} = 1. \frac{\text{Mlb}}{\text{hr ft}^2}$

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

$P = 1200. \text{ psia}$

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


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.
\[ \bar{G} = 1.5 \frac{\text{Mlb}}{\text{hr ft}^2} \]

\[ q'' = 0.53 \frac{\text{MBTU}}{\text{hr ft}^2} \]

\[ P = 1200 \text{ psia} \]

Figure IV-21

Columbia Test Cases 35, 39, 42, and 90

Normalized Channel 5 Exit Enthalpy vs. Quality
IV-33

\[ \dot{G} = 1.5 \text{ Mlb/hr ft}^2 \]

\[ q'' = 0.58 \text{ MBTU/hr ft}^2 \]

\[ P = 1200 \text{ psia} \]

Figure IV-22

Columbia Test Cases 35, 39, 42, and 90

Normalized Channel 11 Exit Enthalpy vs. Quality
\[ \bar{G} = 1.5 \frac{\text{Mlb}}{\text{hr ft}^2} \]

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

\[ P = 1200 \text{ psia} \]

Figure IV-23
Columbia Test Cases 35, 39, 42, and 90
Normalized Channel 5 Exit Mass Flux vs. Ouality
$\bar{G} = 1.5 \frac{\text{Mlb}}{\text{hr ft}^2}$

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

$P = 1200 \text{ psia}$

Figure IV-24
Columbia Test Cases 35, 39, 42, and 90
Normalized Channel 11 Exit Mass Flux vs. Quality
a. Description of GE 9-Rod CHF Tests

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

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

Channel 3 and 4 test cases listed in Table IV-4 were analyzed using COBRA. CISE-4 critical power ratio (CPR) and Hench-Levy CHF 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 CHF 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)**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Rods</td>
<td>9</td>
</tr>
<tr>
<td>Rod Diameter</td>
<td>0.570 inch</td>
</tr>
<tr>
<td>Radius of Corner Subchannel</td>
<td>0.420 inch</td>
</tr>
<tr>
<td>Rod Rod Clearance</td>
<td>0.168 inch</td>
</tr>
<tr>
<td>Rod Wall Clearance</td>
<td>0.135 inch</td>
</tr>
<tr>
<td>Hydraulic Diameter</td>
<td>0.474 inch</td>
</tr>
<tr>
<td>Heated Length</td>
<td>72 inch</td>
</tr>
<tr>
<td>Pressure</td>
<td>800 to 1000 psia</td>
</tr>
<tr>
<td>Average Bundle Mass Flow</td>
<td>0.5 to 1.25 mlb/hr ft$^2$</td>
</tr>
<tr>
<td>Inlet Subcooling</td>
<td>35 to 200 BTU/lb</td>
</tr>
</tbody>
</table>

**Diagram: Uniform Radial Heat Flux Distribution**

- Rod Diameter: 0.570 inch (Typical)
- Rod Radius: 0.420 inch (Typical)
- Hydraulic Diameter: 0.738 inch (Typical)
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

<table>
<thead>
<tr>
<th>Test Channel Case</th>
<th>Test Case No.</th>
<th>p (psia)</th>
<th>Moss Flux (Mlb/hr ft²)</th>
<th>Inlet Subcooling (BTU/lb)</th>
<th>q&quot; (MBTU/hr ft²)</th>
<th>COBRA Single Channel Analysis Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CISE-4 MCPR</td>
</tr>
<tr>
<td>3</td>
<td>266</td>
<td>1005.</td>
<td>1.008</td>
<td>7.1</td>
<td>0.510</td>
<td>0.9320</td>
</tr>
<tr>
<td></td>
<td>268</td>
<td>1015.</td>
<td>1.004</td>
<td>96.5</td>
<td>0.633</td>
<td>0.9950</td>
</tr>
<tr>
<td></td>
<td>270</td>
<td>1000.</td>
<td>1.000</td>
<td>191.8</td>
<td>0.785</td>
<td>0.9936</td>
</tr>
<tr>
<td></td>
<td>279</td>
<td>1000.</td>
<td>0.500</td>
<td>70.7</td>
<td>0.474</td>
<td>0.8634</td>
</tr>
<tr>
<td></td>
<td>286</td>
<td>997.</td>
<td>0.249</td>
<td>42.0</td>
<td>0.289</td>
<td>0.8028</td>
</tr>
<tr>
<td></td>
<td>296</td>
<td>1000.</td>
<td>1.248</td>
<td>12.8</td>
<td>0.522</td>
<td>1.0198</td>
</tr>
<tr>
<td>4</td>
<td>301</td>
<td>1019.</td>
<td>1.051</td>
<td>29.4</td>
<td>0.518</td>
<td>1.0013</td>
</tr>
<tr>
<td></td>
<td>302</td>
<td>1007.</td>
<td>1.075</td>
<td>54.6</td>
<td>0.560</td>
<td>1.0074</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>1018.</td>
<td>1.134</td>
<td>110.2</td>
<td>0.665</td>
<td>1.0289</td>
</tr>
<tr>
<td></td>
<td>320</td>
<td>1027.</td>
<td>0.306</td>
<td>197.4</td>
<td>0.410</td>
<td>0.9170</td>
</tr>
</tbody>
</table>

Note: Ranges of data base for CISE-4 and Hench-Levy correlations are given in Table H-2 of Appendix H.
<table>
<thead>
<tr>
<th>Test Case No.</th>
<th>Analysis Method</th>
<th>CISE-4 MCPR</th>
<th>Hench-Levy MCHFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>266</td>
<td>Single channel</td>
<td>0.9320</td>
<td>0.6017</td>
</tr>
<tr>
<td></td>
<td>Subchannel</td>
<td>0.7657</td>
<td>0.5955</td>
</tr>
<tr>
<td>268</td>
<td>Single channel</td>
<td>0.9950</td>
<td>0.6665</td>
</tr>
<tr>
<td></td>
<td>Subchannel</td>
<td>0.9126</td>
<td>0.6241</td>
</tr>
</tbody>
</table>
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 closely 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. Figure IV-35 shows the axial crossflow predictions of the two analysis methods for the gap connecting channels 7 and 11. The profile shapes are different; however, the net crossflow, represented by the area under each curve, appears to be similar.
Figure IV-29

1/8 Section of PWR Core Used for Test Case
Note: Rod 12 is the hot rod and channel 9 is the hot subchannel.

Figure IV-30

Layout Used for 1/8 Core Single-Pass Case
Note: Ref. Appendix J for other thermal hydraulic data used.

Figure IV-31
Top-Peaked Axial Heat Flux Profile Used for 1/8 Core Single-Pass Analysis
Figure IV-32
1/8 Core Single-Pass Analysis Case
Enthalpy in Channel 9 (Hot Subchannel) vs. Relative Axial Position
Figure IV-33

1/8 Core Single-Pass Analysis Case

Net Crossflow Out of Channel 9 (Hot Subchannel) vs. Relative Axial Position
Figure IV-34
1/8 Core Single-Pass Analysis Case
MDNBR vs. Axial Position
Weisman Approach

Standard Approach

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 approaches might not give the same results for more off normal conditions such as a case involving flow blockage, for example. In this case, however, it may be questionable whether COBRA-IIIC/MIT should be used for the analysis.

C. Application to Transient Test Cases

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

1. PWR Transient Test Case - Loss of Flow Transient

a. Description of Loss of Flow Transient

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

b. Description of Modeling

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

* The "standard" approach used the old transverse momentum option ($f_{sk}$ and $f_{slk}$ equal to unity). The "Weisman approach used coupling factors as defined by Eqns. (III-7) and (III-8).
Figure IV-37
Schematic of Layout Used for Loss of Flow Analysis
Fine radial nodalization (subchannel size coolant and nodes) is used in the vicinity of rods 5 and 15. Coarser radial nodalization is used outside the fine mesh region. Regions one to eight represent one 14x14 fuel rod assembly. Region nine represents the remaining assemblies in the 1/8 section of core.

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

c. Analysis of Results

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

Since DNBR is usually the limiting parameter for a loss of flow accident, comparison of analysis case predictions will begin with this parameter. Predicted MDNBR is shown as a function of time for the four analysis cases in Figure IV-39. The predictions are close. The maximum difference between MDNBR predictions is less than 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

<table>
<thead>
<tr>
<th>Analysis Case Number</th>
<th>Fuel Rod Model</th>
<th>Fuel &amp; Clad Material Properties</th>
<th>Heat Transfer Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>old</td>
<td>constant</td>
<td>old</td>
</tr>
<tr>
<td>3</td>
<td>new</td>
<td>temperature-dependent</td>
<td>new</td>
</tr>
<tr>
<td>4</td>
<td>old</td>
<td>constant</td>
<td>new</td>
</tr>
</tbody>
</table>
Figure IV-38
Transient Forcing Functions
PWR Loss of Flow Transient Test Case
Figure IV-39

Predicted MDNBR vs. Time

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

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

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

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

Although heat flux predictions of the analysis cases were close, differences between the old and new rod-to-coolant heat transfer models caused differences in clad surfact temperature
Figure IV-40

Maximum Heat Flux vs. Time
PWR Loss of Flow Transient Test Case
Figure IV-41

Exit Void Fraction vs. Time

Channel 3

PWR Loss of Flow Transient Test Case
All Cases (time = 0. sec.)

All Cases (time = 2.5 sec.)

Figure IV-42

Axial Heat Flux Profile

Rod 15

PWR Loss of Flow Transient Test Case
Figure IV-43

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

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

d. Summary

The loss of flow transient was analyzed by four analysis cases which all used the one-pass method. One analysis case did not use a fuel rod model. The other three cases used old and new fuel rod and heat transfer models. MDNBR and heat flux predictions of the analysis cases were close. Clad temperature predictions differed according to the rod-to-coolant heat transfer model used.
Figure IV-44

Axial Clad Temperature Profile
Rod 15, Time = 0
PWR Loss of Flow Transient Test Case
Figure IV-45

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

Figure IV-46

Axial Clad Temperature Profile
Rod 15
Analysis Case 4 (New HT)
PWR Loss of Flow Transient Test Case
2. BWR Transient Test Case - Turbine Trip Without Bypass

a. Description of Turbine Trip Transient

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

b. Description of Modeling

The turbine trip transient was analyzed using two channels to represent the central hot and central average assemblies of the Shoreham Nuclear Power Station Unit One (SNPS-1) reactor. Data from the SNPS-1 FSAR (Ref. 30) was used in the analysis. Four COBRA-IIIC/MIT analyses were made using fuel rod and rod-to-coolant heat transfer model options as listed in the Table IV-7. Transient forcing functions used by the analyses are contained in Figure IV-47. The transient was analyzed 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. Although the MCPR and MCHFR predictions may be unreliable, they are based on calculated predictions of COBRA-IIIC/MIT models and can indicate differences in these predictions.
Figure IV-47

Transient Forcing Functions
BWR Turbine Trip Transient Test Case
### Table IV-7

Models Used for Turbine Trip Analysis Cases

<table>
<thead>
<tr>
<th>Analysis Case Number</th>
<th>Fuel Rod Model</th>
<th>Fuel &amp; Clad Material Properties</th>
<th>Heat Transfer Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>old</td>
<td>constant</td>
<td>old</td>
</tr>
<tr>
<td>2</td>
<td>new</td>
<td>temp.-dependent</td>
<td>old</td>
</tr>
<tr>
<td>3</td>
<td>old</td>
<td>constant</td>
<td>new</td>
</tr>
<tr>
<td>4</td>
<td>new</td>
<td>temp.-dependent</td>
<td>new</td>
</tr>
</tbody>
</table>
Analysis case predictions of MCPR version time are contained in Figure IV-48. MCPR predictions are within 3% of one another. Analysis Case 3 predictions are lowest. Analysis Case 1 MCPR predictions end at 2.0 seconds. The Case 1 flow solution failed to converge one time step after 2.0 seconds. This problem will be discussed later. The predictions shown a general downward trend which appears to level off near 2.5 seconds. The lowest MCPR value is 1.017.

MCHFR predictions are shown in Figure IV-49. MCHFR predictions are within 6% of one another. Analysis Case 3 predictions are lowest. The minimum predicted MCHFR value, 1.060 occurs at 2.25 seconds. MCHFR predictions at 2.5 seconds are larger than at 2.25 seconds. The Analysis Case 1 flow solution failed to converge at 2.05 seconds, one time step after 2.0 seconds, as mentioned earlier. None of the other analysis cases had this problem. Instability of the solution is caused by coupling between the heat transfer and hydraulic calculations. Symptoms of a stability problem appear in Analysis Case 1 predictions near 2.0 seconds. Flow rate predictions in channel 2 at 1.75 and 2.0 seconds are shown in Figures IV-50 and IV-51, respectively. Flow rate predictions are close and follow the same smooth trend at 1.75 seconds. Flow rate predictions of Analysis Case 1 and 4 are not as smooth at 2.0 seconds. Analysis Case 1 shows much larger variations in flow rate than the other cases at 2.0 seconds.

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

The sharp dip is caused by large changes in rod-to-coolant heat transfer predictions of the old heat transfer model which accompany diminishing void fractions. Axial void fraction profiles in channel 2 are shown in Figures IV-53 and IV-54. Void fraction profiles at 0.0 and 2.0 seconds are shown in Figure IV-52. All analysis cases start with the same void fraction
Figure IV-48

CISE-4 MCPR vs. Time
BWR Turbine Trip Transient Test Case
Figure IV-49
Hench-Levy MCHFR vs. Time
BWR Turbine Trip Transient Test Case
Flow Rate vs. Axial Position
Channel 2, time = 1.75
BWR Turbine Trip Transient Test Case
Figure IV-51

Flow Rate vs. Axial Position
Channel 2, time = 2.0 sec.
BWR Turbine Trip Transient Test Case
Figure IV-52
Axial Heat Flux Profile
Rod 2
BWR Turbine Trip Transient Test Case
Figure IV-53

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

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

Radial fuel pellet temperature distributions predicted by the old and new fuel rod models at 0.0 seconds are shown in Figure IV-58 for two fuel nodes of rod 1, the hot rod. Predictions for axial fuel nodes 5 and 10 are shown. Axial fuel node 5 is between the core inlet and midplane. The fuel pellet is
Figure IV-55

Axial Clad Temperature Profile
Rod 2, time = 0.0 sec.
BWR Turbine Trip Transient Test Case
Figure IV-56

Axial Clad Temperature Profile

Rod 2, time = 2.0 sec.

BWR Turbine Trip Transient Test Case
Figure IV-57

Axial Clad Temperature Profile
Rod 2
Analysis Case 1 (Old FR&HT)
BWR Turbine Trip Transient Test Case
Radial Fuel Pellet Temperature Distribution
Rod 1, Time = 0.0 sec.
BWR Turbine Trip Transient Test Case

Figure IV-58

Axial Fuel Node 10
Case 2 (New FR)

Axial Fuel Node 10
Case 2 (New FR)

Axial Fuel Node 10
Case 1 (Old FR)

Axial Fuel Node 5
Case 2 (New FR)

Axial Fuel Node 5
Case 1 (Old FR)
divided radially into four regions. Fuel centerline temperature predictions are at the left edge of the Figure IV-58 graph. Fuel pellet surface temperature predictions at the right edge are nearly the same for both axial fuel nodes. The old and new fuel rod model predictions are close for axial fuel node 5. The predictions are much farther apart for axial node 10, where fuel temperatures are higher than node 5. Higher temperatures are predicted by the new fuel rod model because fuel conductivity is calculated to be lower than the constant value used by the old fuel rod model.

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

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

d. Summary

The turbine trip without bypass transient was analyzed using four combinations of old and new COBRA-IIIC/MIT rod-to-coolant heat transfers and fuel rod models. Predictions for MCPR and MCHFR were close. Analysis Case 1, which used the old heat transfer and fuel rod models, had a convergence failure at 2.05 seconds. Coupling of the heat transfer and hydraulic calculations allowed sudden changes in heat transfer to cause instability in the flow solution. Analysis Cases 2, 3, and 4, which used the new heat transfer and/or new fuel rod model, did not have flow convergence problems. Differences
Figure IV-59

Centerline Temperature vs. Axial Position
Rod 1, Time = 0.0 sec.
BWR Turbine Trip Transient Test Case
Figure IV-60

Centerline Temperature vs. Axial Position
Rod 2, Time - 0.0 sec.
BWR Turbine Trip Transient Test Case
exist between the predictions of the old fuel rod model, using constant fuel and clad properties, and the new fuel rod model, using temperature-dependent fuel and clad properties.

D. Summary of Testing and Application Results

The results of testing and application are summarized as follows:

- MDNBR, MCPR, and MCHFR predictions were nearly the same for each case, even though various modeling options were used.

- Rod-to-coolant heat transfer predictions of the new heat transfer model vary smoothly in space and time. Discontinuous changes in predictions of the old heat transfer model can cause code failures during transient analysis of BWRs.

- Differences in fuel rod temperature predictions of the old and new fuel rod models made only small differences in fuel rod surface heat flux predictions.

- The new mixing model does not appear to significantly improve subchannel flow and enthalpy predictions for BWR conditions. A better physical model such as the drift flux model (Ref. 45) is needed rather than only an improved mixing model, in order to predict the void drift experimentation observed in BWR subchannels.

- CISE-4 MCPR predictions are 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.
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>
<thead>
<tr>
<th>Input Data Method</th>
<th>New Options Allowed</th>
<th>IPILE Options Allowed</th>
<th>Reference of Description for Input Data Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Data Representation Based on that of COBRA-IIIC</td>
<td>New mixing model. Calculation of CPR using CISE correlation. Calculation of CHFR using Hench-Levy correlation.</td>
<td>IPILE = 0</td>
<td>App. 10 of Ref. 1</td>
</tr>
<tr>
<td>Simplified COBRA-IIIC Input Data Presentation to be Used for Assembly-to-Assembly Analysis of LWR</td>
<td>Same as above.</td>
<td>IPILE = 1 or 2</td>
<td>App. 11 of Ref. 1</td>
</tr>
<tr>
<td>New INPUT DATA Presentation</td>
<td>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.</td>
<td>IPILE = 0,1 or 2</td>
<td>App. 12 of Ref. 1</td>
</tr>
</tbody>
</table>
Table V-2
Features and Uses of IPILE Options

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

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

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

COBRA-IIIC/MIT Code Modifications

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

Figure A-1

New COBRA-IIIC/MIT Subroutine Structure
# Table A-1

**New Subroutines**

<table>
<thead>
<tr>
<th>Subroutine (or Function)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHF3</td>
<td>calculation of critical heat flux using the Hench-Levy correlation</td>
</tr>
<tr>
<td>CHF4</td>
<td>calculation of critical power ratio using the CISE-4 correlation</td>
</tr>
<tr>
<td>HTRAN</td>
<td>oversees old and new rod-to-coolant heat transfer models</td>
</tr>
<tr>
<td>STATE</td>
<td>evaluates thermodynamics equations of state and their derivatives</td>
</tr>
<tr>
<td>TEMFR</td>
<td>oversees old and new fuel rod model calculations</td>
</tr>
<tr>
<td>INITRC</td>
<td>Initializes variables and arrays for new fuel rod model. Called by CALC before calculation of steady state.</td>
</tr>
<tr>
<td>RTEMPF</td>
<td>solves radial rod heat conduction for new fuel rod model</td>
</tr>
<tr>
<td>RPROP</td>
<td>finds fuel rod material and gap properties for new fuel rod model</td>
</tr>
<tr>
<td>MPF</td>
<td>material properties of fuel</td>
</tr>
<tr>
<td>MPG</td>
<td>gap conductance</td>
</tr>
<tr>
<td>MPC</td>
<td>material properties of clad</td>
</tr>
<tr>
<td>HTCOR</td>
<td>calculates rod-to-coolant heat transfer coefficient for new heat transfer model</td>
</tr>
<tr>
<td>FILM</td>
<td>calculates film boiling heat transfer coefficients for new heat transfer model</td>
</tr>
<tr>
<td>CHF5</td>
<td>calculation of critical heat flux using Biasi/CHF-Void correlation</td>
</tr>
<tr>
<td>POW</td>
<td>A function which evaluates $a^{**b}$. It may be replaced by a fast, engineering accuracy exponentiation routine.</td>
</tr>
<tr>
<td>CONDL</td>
<td>liquid thermal conductivity</td>
</tr>
<tr>
<td>CONDV</td>
<td>steam thermal conductivity</td>
</tr>
<tr>
<td>Subtoutine (or Function)</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>VISLQ</td>
<td>liquid water viscosity</td>
</tr>
<tr>
<td>VISVP</td>
<td>steam viscosity</td>
</tr>
<tr>
<td>TCON</td>
<td>converts temperature from F to K</td>
</tr>
<tr>
<td>DCON</td>
<td>converts density from lb/ft<strong>3 to kg/m</strong>3</td>
</tr>
<tr>
<td>SURTT</td>
<td>surface tension of water</td>
</tr>
</tbody>
</table>
### Table A-2

**Modifications of Old Subroutines**

<table>
<thead>
<tr>
<th>Subroutine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAROC</td>
<td>COMMON COSAVE added to save CORAB array</td>
</tr>
<tr>
<td>CALC</td>
<td>Call to INITRC added. COMMONS LINK4, PPSV, REFP, and TIMEST added.</td>
</tr>
<tr>
<td>CURVE</td>
<td>COMMON INDSAV added to save index</td>
</tr>
<tr>
<td>INPRIN</td>
<td>New models indicated in printout. COMMONS FRDATA and LINK4 added.</td>
</tr>
<tr>
<td>EXPRIN</td>
<td>Type of CHF calculation indicated in printout.</td>
</tr>
<tr>
<td>MIX</td>
<td>New mixing model calculational option added.</td>
</tr>
<tr>
<td>PROP</td>
<td>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.</td>
</tr>
<tr>
<td>CARDS4</td>
<td>MC added to argument list. NK set to zero if IPILE=2.</td>
</tr>
<tr>
<td>CHAN</td>
<td>Modified to read in and print information regarding new models. COMMON FRDATA, GAPFAC, ITPSV, and LINK4 added.</td>
</tr>
<tr>
<td>CHF</td>
<td>Modified to call CHF3 and CHF4. CHF predictions made by CHF5 are obtained from the CHSAVE array. COMMON CHF SV added.</td>
</tr>
<tr>
<td>DIVERT</td>
<td>New transverse momentum parameters used in equations. COMMON GAPFAC added.</td>
</tr>
<tr>
<td>INDAT</td>
<td>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.</td>
</tr>
<tr>
<td>MODEL</td>
<td>IPILE added to argument list. Mixing model options are made available.</td>
</tr>
<tr>
<td>CORE</td>
<td>KS=1 and KMAX=80000 since DATA array set in MAIN program.</td>
</tr>
<tr>
<td>HEAT</td>
<td>Calls HTRAN rather than HCOOL. Calls TEMFR rather than TEMP. Iteration loop added. COMMON LINK4 and TIMEST added.</td>
</tr>
<tr>
<td>SEPRAT</td>
<td>COMMON REFP added.</td>
</tr>
<tr>
<td>VOID</td>
<td>COMMON PPSV added.</td>
</tr>
</tbody>
</table>
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 $\rho c_p$ 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 $\rho c_p$ 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

$$h_{gap} = h_{\text{cond}} + h_{\text{contact}} + h_{\text{rad}} + h_{\text{press}}$$
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 $h_{\text{press}} = C P_f^n$, 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>
<thead>
<tr>
<th>Option Indicator</th>
<th>Fuel Rod Model</th>
<th>Property Option</th>
<th>Heat Transfer Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFRM</td>
<td>IPROP</td>
<td>IHTM</td>
<td>Model</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Old</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>New</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

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

Heat Transfer Regime: IHTR

- $x < 99\%$
  - no: forced/natural convection to single-phase vapor
  - yes: $T_w < T_s$
    - yes: forced/natural convection to single-phase liquid
    - no: $IHTM < 2$
      - no: compute $T_{MSFB}$
      - yes: $T_w < T_{MSFB}$
        - no: low flow
        - yes: compute $T_{CHF}$
          - $T_w < T_{CHF}$
            - yes: transition boiling
            - no: no
          - low flow
            - yes: high flow film boiling
            - no: low flow film boiling

Figure D-1
# Heat Transfer Summary

<table>
<thead>
<tr>
<th>IHTR</th>
<th>Regime</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>forced convection to single-phase liquid</td>
<td>Sieder-Tate</td>
</tr>
<tr>
<td>2</td>
<td>natural convection to single-phase liquid</td>
<td>McAdams</td>
</tr>
<tr>
<td>3</td>
<td>subcooled boiling</td>
<td>Chen</td>
</tr>
<tr>
<td>4</td>
<td>nucleate boiling</td>
<td>Chen</td>
</tr>
<tr>
<td>5</td>
<td>transition</td>
<td>Interpolation between $q_{CHF}$ and $q_{MSFB}$</td>
</tr>
<tr>
<td>6</td>
<td>high P, high G film boiling</td>
<td>Groeneveld</td>
</tr>
<tr>
<td>7</td>
<td>low P, high G film boiling</td>
<td>modified Dittus-Boelter</td>
</tr>
<tr>
<td>8</td>
<td>low G film boiling</td>
<td>modified Bromley plus either McAdams vapor or high flow film boiling</td>
</tr>
<tr>
<td>9</td>
<td>forced convection to single-phase vapor</td>
<td>Sieder-Tate</td>
</tr>
<tr>
<td>10</td>
<td>natural convection to single-phase vapor</td>
<td>McAdams</td>
</tr>
</tbody>
</table>
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 models 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>
<thead>
<tr>
<th>Regime</th>
<th>Correlation Used</th>
<th>Selection Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced convection to single phase liquid</td>
<td>Sieder Tate</td>
<td>x ≤ 0 (Levy model not used)</td>
</tr>
<tr>
<td></td>
<td>Forced convection</td>
<td>x &lt; xₐ (Levy model used)</td>
</tr>
<tr>
<td></td>
<td>x &lt; 99%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T_w ≤ T_s</td>
<td></td>
</tr>
<tr>
<td>Natural convection to single phase liquid</td>
<td>McAdams</td>
<td>Not considered</td>
</tr>
<tr>
<td></td>
<td>Natural convection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>x &lt; 99%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T_w ≤ T_s</td>
<td></td>
</tr>
<tr>
<td>Local boiling or bulk boiling</td>
<td>Chen</td>
<td>Thom modified Jens-Lottes</td>
</tr>
<tr>
<td></td>
<td>x &lt; 99%</td>
<td>x &gt; 0 (Levy model not used)</td>
</tr>
<tr>
<td></td>
<td>T_s &lt; T_w &lt; T_MSFB</td>
<td>x ≥ xₐ (Levy model used)</td>
</tr>
</tbody>
</table>

*See list of nomenclature on page E-5.*
<table>
<thead>
<tr>
<th>Correlation</th>
<th>Ref.</th>
<th>Equation</th>
<th>Range of Data Base</th>
</tr>
</thead>
</table>
| Sieder Tate      | 31   | $h = 0.023 \frac{k}{D} \Re^{0.8} \Pr^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}$ | Flow of water through tubes  
$10^2 < \Re < 10^5$ |
|                  |      | Fluid properties at bulk fluid temperature, except $\mu_w$ at $T_w$        |                                                                                  |
|                  |      | $\Re = \frac{GD}{\mu} \quad \Pr = \frac{\mu C_p}{k}$                    |                                                                                  |
| McAdams          | 32   | $h = 0.13k[Gr \cdot Pr]^{0.33}$                                           | $10^9 < Gr \cdot Pr < 10^{12}$                                                  |
|                  |      | Fluid properties should be at fluid film temperature                      |                                                                                  |
|                  |      | $G_r = \frac{\rho^2 g \beta (T_w - T)}{\mu^2}$                           |                                                                                  |
| Chen             | 33   | $q'' = h_{FC}(T_w - T_f) + h_{NB}(T_w - T_s)$                              | 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). |
|                  |      | $h_{FC} = 0.023 \frac{k_f}{D_f} \Re_f^{0.8} \Pr_f^{0.4}$                 |                                                                                  |
|                  |      | $h_{NB} = 0.00122 S \left[\frac{k_f C_p}{\sigma}\right]^{0.5} \Pr_f^{-0.29}$ |                                                                                  |
|                  |      | $\rho_f 0.25 (P_w - P) 0.75$                                              |                                                                                  |
|                  |      | $C_p (T_w - T_s) \rho_f$                                                   |                                                                                  |
|                  |      | $* \left[\frac{h_f g \rho_g}{C_p(T_w - T_s) \rho_f}\right]^{0.24}$       |                                                                                  |

Note: This eqn. is in SI units. All other eqns. in Table are in English units.
<table>
<thead>
<tr>
<th>Correlation</th>
<th>Ref.</th>
<th>Equation</th>
<th>Range of Data Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Chen cont.)</td>
<td></td>
<td>( F = \begin{cases} 1 \text{ for } X_{tt}^{-1} &lt; 0.1 \ 2.35(X_{tt}^{-1} + 0.213)^{0.736} \text{ for } X_{tt}^{-1} &gt; 0.1 \end{cases} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( X_{tt}^{-1} = \left[ x/(1 - x) \right]^{0.9} \left( \rho_f/\rho_g \right)^{0.5} ) ( \times \left( \mu_g/\mu_f \right)^{0.1} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \left[ 1 + 0.12 \text{Re}<em>{TP} \right]^{1.14} - 1.0 ) ( \text{for } \text{Re}</em>{TP} &lt; 32.5 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( S = \left[ 1 + 0.42 \text{Re}<em>{TP} \right]^{0.78} - 1.0 ) ( \text{for } 32.5 \leq \text{Re}</em>{TP} \leq 70 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 0.1 ) ( \text{for } \text{Re}_{TP} &gt; 70 )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \text{Re}_{TP} = 10^{-4} F^{1.25} (1 - \alpha)(Re)_f )</td>
<td></td>
</tr>
<tr>
<td>Thom modified Dittus-Boeltes and Jens-Loettes</td>
<td>34</td>
<td>( h = 0.134 \frac{k}{D} \text{Re}^{0.65} \text{Pr}^{0.4} ) ( \text{for forced convection to liquid} )</td>
<td>Based on upflow through heated tubes and annuli. Developed as a forced convective and subcooled boiling correlation. ( P = 750 \text{ to } 2000 \text{ psia} ) ( V_{f, in} = 5 \text{ to } 20 \text{ ft/sec} ) ( q'' = 0 \text{ to } 0.5 \frac{\text{MBTU}}{\text{hr-ft}^2} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( T_w = T_{\text{sat}} + \frac{0.072(q'')^{0.5}}{e^{P/1260}} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( h = \frac{T_w - T_b}{q''} ) ( \text{for local boiling} )</td>
<td></td>
</tr>
</tbody>
</table>
### Nomenclature for Tables E-1 and E-2

#### Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(c_p)</td>
<td>heat capacity</td>
<td>BTU/lb(\cdot)(\circ)F</td>
</tr>
<tr>
<td>(D)</td>
<td>diameter</td>
<td>ft</td>
</tr>
<tr>
<td>(g)</td>
<td>gravitational acceleration</td>
<td>ft/hr(^2)</td>
</tr>
<tr>
<td>(G)</td>
<td>mass flow rate</td>
<td>lbm/ft(^2)hr</td>
</tr>
<tr>
<td>(Gr)</td>
<td>Grashof number (= \frac{\rho^2g\beta(T_w - T)}{\mu^2})</td>
<td>-</td>
</tr>
<tr>
<td>(h)</td>
<td>heat transfer coefficient</td>
<td>BTU/hr ft(^2)(\circ)F</td>
</tr>
<tr>
<td>(h_{fg})</td>
<td>latent heat of vaporization</td>
<td>BTU/lb</td>
</tr>
<tr>
<td>(k)</td>
<td>thermal conductivity</td>
<td>BTU/hr ft(^2)(\circ)F</td>
</tr>
<tr>
<td>(P)</td>
<td>pressure</td>
<td>psia</td>
</tr>
<tr>
<td>(Pr)</td>
<td>Prandtl number (= \frac{\mu c_p}{k})</td>
<td>-</td>
</tr>
<tr>
<td>(q'')</td>
<td>heat flux</td>
<td>BTU/hr ft(^2)</td>
</tr>
<tr>
<td>(Re)</td>
<td>Reynolds number (= \frac{GD_h}{\mu})</td>
<td>-</td>
</tr>
<tr>
<td>(T)</td>
<td>temperature</td>
<td>(\circ)F</td>
</tr>
<tr>
<td>(V)</td>
<td>velocity</td>
<td>ft/sec</td>
</tr>
<tr>
<td>(x)</td>
<td>quality</td>
<td>-</td>
</tr>
<tr>
<td>(x_d)</td>
<td>quality at which bubble departure starts</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>according to Levy model</td>
<td>-</td>
</tr>
<tr>
<td>(X_{tt})</td>
<td>Martinelli parameter</td>
<td>-</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>void fraction</td>
<td>-</td>
</tr>
<tr>
<td>(\beta)</td>
<td>thermal expansion coefficient</td>
<td>(\circ)F(^{-1})</td>
</tr>
<tr>
<td>(\mu)</td>
<td>viscosity</td>
<td>lbm/ft hr</td>
</tr>
<tr>
<td>(\rho)</td>
<td>density</td>
<td>lbm/ft(^3)</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>surface tension</td>
<td>lbf/ft</td>
</tr>
</tbody>
</table>
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.

![Boiling Curve Diagram]

- 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 that the mixing rate increases steadily with quality and is given by the following equation:

$$W' = W_s + \beta_1 \left( \frac{A_G}{D_h} \frac{\rho_l}{\rho_g} \frac{\gamma - 1}{\gamma} \right) x$$

where the slip ratio, $\gamma$, is obtained from the Smith correlation (Ref. 35). $W_L$ and $\beta_1$ are calculated using the following equations:

$$W_L = 0.0035 \mu \rho \Re^{0.9}$$

$$\beta_1 = 0.04 \left( \frac{S}{D_h} \right)^{\lambda} , \lambda = 1.5 .$$

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

* 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
\[ x_c = \frac{A_1}{G} \left[ g \rho_l D_h (\rho_l - \rho_g) \right]^{1/2} \]

\[ \frac{\rho_l}{\rho_g}^{1/2} + A_2 \]

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:

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

\[ \frac{x}{x_c} - \frac{x_o}{x_c} \]

where,

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

\[ W_G = 0.0035 u_g Re_g^{0.9} \]

and

\[ \frac{x_o}{x_c} = 0.57 Re^{0.0417}. \]

The values of \( \beta_I, \frac{x_o}{x_c}, W_L \) and \( W_G \) were obtained by least square fits to the studied data.
Nomenclature

A = subchannel flow area (ft²)

\(D_h\) = hydraulic diameter (ft)

G = mass flux (lbm/hr-ft²)

L = channel length (ft)

T = temperature (°F)

W = mixing rate (lbm/hr-ft)

\(\mu\) = viscosity (lbm/hr-ft)

\(\rho\) = density (lbm/hr-ft³)

x = quality

\(\text{Re}_k = \frac{(G \cdot D_h)}{\mu_k}\)

\(\text{Re}_g = \frac{(G \cdot D_h)}{\mu_g}\)
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

<table>
<thead>
<tr>
<th>Option Indicator (NCHF)</th>
<th>Correlation</th>
<th>Quantity Calculated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DNBR</td>
</tr>
<tr>
<td>1</td>
<td>B&amp;W-2</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>W-3</td>
<td>✓</td>
</tr>
<tr>
<td>3</td>
<td>Hench-Levy</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>CISE-4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Biasi/Void-CHF</td>
<td></td>
</tr>
</tbody>
</table>

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 modified 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>
<thead>
<tr>
<th>Correlation</th>
<th>Ref.</th>
<th>Equation</th>
<th>Range of Data Base</th>
</tr>
</thead>
</table>
| B&W-2       | 36   | \[
\frac{q''_{CHF,EU}}{10^6} = \left\{ (1.155 - 0.407D_e) \left[ 0.37 \times 10^8 \right.
\times (0.591G/10^6) \left[ 0.83 + 0.685(p/10^3 - 2) \right] \\
- 0.1521G \left[ x_{CHF,fg} \right] / \left\{ 12.71 \right\}
\times (3.054G/10^6) \left[ 0.712 + 0.2073(p/10^3 - 2) \right] \}
\]
where \( q''_{CHF,EU} \) is in BTU hr\(^{-1}\)ft\(^{-2}\) | \( p = 2000 \) to \( 2400 \) psia \( G = 0.75 \times 10^6 \) to \( 4.0 \times 10^6 \) 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          | \( F = \frac{q''_{CHF,EU}}{q''_{CHF,NU}} \) \( F = \frac{1.025C \int_{0}^{\ell_{CHF}} q''(z) \exp \left[ -C(\ell_{CHF} - z) \right] dz}{q''_{loc} \left[ 1 - \exp \left( -C(\ell_{CHF,EU}) \right) \right]} \) \( C = \frac{0.249(1 - X_{CHF})^{7.82}}{(G/10^6)^{0.457}} \) | \( p = 2000 \) to \( 2400 \) psia \( G = 1 \times 10^6 \) to \( 3.5 \times 10^6 \) 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>
<thead>
<tr>
<th>Correlation</th>
<th>Ref.</th>
<th>Equation</th>
<th>Range of Data Base</th>
</tr>
</thead>
</table>
| W-3         | 38   | \[ \frac{q''_{crit,EU}}{10^6} = (2.02 - 0.0004302p) 
+ (0.1722 - 0.0000984p) \]
+ \[ \exp[(18.177 - 0.004129p)X]\]
+ \[ (0.1484 - 1.596X) \]
+ \[ 0.1729X|X|(G/10^6) + 1.037 \]
+ \[ (1.157 - 0.869X)[0.2564] \]
+ \[ 0.8357\exp(-3.151D_e)][0.8258 \]
+ \[ 0.000794(H_{sat} - H_{in}) \]
where \( q''_{CHF,EU} \) is in BTU \( hr^{-1} ft^{-2} \). | \( p = 1000 \) to \( 2400 \) psia  
\( G = 1.0 \times 10^6 \) to \( 5.0 \times 10^6 \) lb \( hr^{-1} ft^{-2} \)  
\( D_e = 0.2 \) to \( 0.7 \)  
\( X_{loc} = -0.25 \) to \( +0.15 \)  
\( L = 10 \) to \( 144 \) in.  
Heated perimeter = \( 0.88 \) to \( 1.00 \)  
Wetted perimeter = \( 0.88 \) to \( 1.00 \)  
Geometries = circular tube, rectangular channel, and bare rod-bundle |

| 39 | Non-uniform flux shape factor:  
\[ F_c = \frac{q''_{DNB,EU}}{q''_{CHF,NU}q''_{crit,NU}(1 - e^{-C^2_{crit}})} \]
\[ = \frac{1}{C} \int_{0}^{l_{crit}} q''(z)e^{-C(l_{crit} - z)}dz \]
where \( l \) is measured from start of local boiling.  
\[ C = 0.15 \frac{(1 - X_{crit})^{4.31}}{(G/10^6)^{0.478}} \text{ in.}^{-1} \] | \( p = 1000 \) to \( 2400 \) psia  
\( G = 1.0 \times 10^6 \) to \( 3.0 \times 10^6 \) 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.)

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Ref.</th>
<th>Equation</th>
<th>Range of Data Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-3 (cont.)</td>
<td>40</td>
<td><strong>Spacer-grid effect</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ F_S = \frac{q''<em>{\text{crit, spacer}}}{q''</em>{\text{crit, bare rod bundle}}} ]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ F_S = 1.0 + 0.03 \left( \frac{G}{10^6} \right) \left( \frac{\text{TDC}}{0.019} \right)^{0.35} ]</td>
<td>rod bundles 8 to 14 ft. long</td>
</tr>
<tr>
<td></td>
<td></td>
<td>where TDC is thermal diffusion coefficient denoting the mixing caused by the spacer. Further, TDC = ( \frac{e}{(V_{a})} ), where ( e ) is the eddy diffusivity, ( V ) is the axial velocity, and ( a ) is the gap between two adjacent fuel rods.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>41</td>
<td>[ \frac{\text{CHF}<em>{\text{cold wall}}}{\text{CHF}</em>{W-3,D_h}} = 1.0 - Ru \left[ 13.76 - 1.372e^{1.78X} - 4.732 \right. ]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ \left. \times \left( \frac{G}{10^6} \right)^{0.0535} - 0.0619 \right] ]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ \times \left( \frac{P}{10^3} \right)^{0.14} - 8.509D_h^{0.107} ]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>where, Ru = 1 - (D_e/D_h) and D_e and D_h are the equivalent diameters based on wetted and heated perimeters, respectively.</td>
<td>X_{\text{DNB}} \leq 0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0 \leq G/10^6 lb hr^{-1} ft^{-2} \leq 5.0</td>
<td>Gap \geq 0.10 in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L \geq 10 in.</td>
<td></td>
</tr>
<tr>
<td>Hench-Levy</td>
<td>19</td>
<td>( \frac{\left( q''_{c} / 10^6 \right)}{\text{BTU}} = \frac{F}{P} \frac{\text{hr-ft}^2}{\text{lb}} )</td>
<td>P = 600 to 1450 psia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for ( (\langle x_e \rangle) \leq 0.273 - 0.212 \text{TANH}^2(3G/10^6) )</td>
<td>G = 0.2 \times 10^6 to 1.6 \times 10^6 lb/h-ft^2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D_e = 0.324 to 0.485 in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>rod to rod and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>rod to wall spacings greater than 0.060 in.</td>
</tr>
<tr>
<td>Correlation</td>
<td>Ref.</td>
<td>Equation</td>
<td>Range of Data Base</td>
</tr>
<tr>
<td>-------------------</td>
<td>------</td>
<td>--------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Hench-Levy (cont.)</td>
<td></td>
<td>( \left( \frac{q''}{10^6} \right) = F_p \left[ 1.9 - 3.3 \langle x_e \rangle - 0.7 \sinh^2 \left( \frac{3G}{10^6} \right) \right] \times \left( \frac{3G}{10^6} \right) ), BTU hr(^{-1})ft(^{-2}) for ( 0.273 - 0.212 \sinh^2 \left( \frac{3G}{10^6} \right) \leq \langle x_e \rangle ) ( \leq 0.5 - 0.269 \sinh^2 \left( \frac{3G}{10^6} \right) + 0.0346 \times \sinh^2 \left( \frac{2G}{10^6} \right) )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>( \left( \frac{q''}{10^6} \right) = F_p \left[ 0.6 - 0.7 \langle x_e \rangle - 0.09 \right] \times \left( \frac{2G}{10^6} \right) ), BTU hr(^{-1})ft(^{-2}) for ( \langle x_e \rangle \geq 0.5 - 0.269 \sinh^2 \left( \frac{3G}{10^6} \right) + 0.0346 \sinh^2 \left( \frac{2G}{10^6} \right) )</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>where ( F_p = [1.1 - 0.1 \left( \frac{P - 600}{400} \right)^{1.25}] )</td>
<td></td>
</tr>
<tr>
<td>CISE-4</td>
<td>21</td>
<td>( \langle x_e \rangle = \frac{D_h}{D_e} \left[ a \frac{L}{B_c} + b \right] )</td>
<td>( P = 720 ) to ( 1000 ) psia ( G = 0.8 ) to ( 3.0 \times 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</td>
</tr>
<tr>
<td></td>
<td></td>
<td>where ( a = \frac{1}{1 + 0.20(1 - P/P_{CR})^{-3}} ) for ( G &lt; G^* ) ( 10^6 )</td>
<td></td>
</tr>
<tr>
<td>Correlation</td>
<td>Ref.</td>
<td>Equation</td>
<td>Range of Data Base</td>
</tr>
<tr>
<td>---------------------</td>
<td>------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>CISE-4 (cont.)</td>
<td></td>
<td>$a = \frac{1 - P/P_{CR}}{(1.35G/10^6)^{1/3}}$ for $G &gt; G^*$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>where $G^* = 2.5 \times 10^6(1 - P/P_{CR})^3$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$b = 168(P_{CR}/P - 1)^{0.4}G/10^6D_{e}^{1.4}$</td>
<td></td>
</tr>
<tr>
<td>Biasi/Void-CHF</td>
<td>16</td>
<td>For $</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1) $q''_{CHF} = 2.633(10^7)(30.48D)^{-n}G^{-1/6}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>* $[4.412F(p)G^{-1/6} - x]$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2) $q''_{CHF} = 1.181(10^9)H(p)(30.48D)^{-n}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>* $G^{-0.6}(1.0 - x)$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>where</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F(p) = 0.7249 + 0.00683p \exp(-0.0021p)$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$H(p) = -1.159 + 0.01029p \exp(-0.00131p)$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$+ 130.4p(2103 + p^2)^{-1}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$n = {0.4 \text{ for } D \geq 0.0328 \text{ ft.} }$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$0.6 \text{ for } D &lt; 0.0328 \text{ ft}$</td>
<td></td>
</tr>
</tbody>
</table>

Eqns. 1 & 2 are based on the Biasi correlation (Ref. 23). The range of data for this correlation is:

- $P = 39$ to $2058$ psia
- $G/10^6 = 0.074$ to $4.4$ lb hr$^{-1}$ ft$^{-2}$
- $D = 0.01$ to $0.12$ ft.
- $L = 0.66$ to $19.7$ ft.
- $X = (\frac{1}{1 + \rho_f/\rho_g})$ to $1.0$

Note: Data base is for water in flow through vertical, uniformly heated tubes. The correlation is principally a dryout correlation and consequently is not expected to work well for low qualities and low flows.

Eqn. 3 is based on the Void–CHF correlation (Ref. 24). This correlation contains the physically based pool boiling CHF relationship of Zuber (Ref 42). Data base covers low flow upflow, downflow and counter-current flow conditions in Freon. Extension to water is justified on the basis of the proven wide range of applicability of the Zuber correlation.
<table>
<thead>
<tr>
<th>Correlation</th>
<th>Ref.</th>
<th>Equation</th>
<th>Range of Data Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biasi/Void-CHF</td>
<td></td>
<td>For $10^6 &gt;</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3) $q''_{\text{CHF}} = (1 - \alpha)0.9\pi24^{-1}H_f \rho_g^{0.5}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\times [g \sigma (\rho_f - \rho_g)]^{0.25}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>For $2 \times 10^4 &gt;</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exception:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- For $P &gt; 1200$ psia and $x &gt; 0.5$, use Eqns. 1 and 2 for $</td>
<td>G</td>
</tr>
</tbody>
</table>
## Nomenclature for Table H.2

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Gap between two adjacent fuel rods</td>
<td>ft</td>
</tr>
<tr>
<td>C</td>
<td>Function of G and $X_{\text{CHF}}$ or $X_{\text{crit}}$</td>
<td>ft$^{-1}$</td>
</tr>
<tr>
<td>CHF</td>
<td>Critical heat flux</td>
<td>BTU hr$^{-1}$ft$^{-2}$</td>
</tr>
<tr>
<td>D</td>
<td>Diameter of tube</td>
<td>ft</td>
</tr>
<tr>
<td>$D_e$</td>
<td>Equivalent diameter based on wetted perimeter</td>
<td>ft</td>
</tr>
<tr>
<td>$D_h$</td>
<td>Equivalent diameter based on heated perimeter</td>
<td>ft</td>
</tr>
<tr>
<td>$F_c$</td>
<td>Flux shape factor</td>
<td>-</td>
</tr>
<tr>
<td>$F_p$</td>
<td>Function of P</td>
<td>-</td>
</tr>
<tr>
<td>$F_s$</td>
<td>Spacer grid factor</td>
<td>-</td>
</tr>
<tr>
<td>G</td>
<td>Mass velocity</td>
<td>lb hr$^{-1}$ft$^{-2}$</td>
</tr>
<tr>
<td>g</td>
<td>Acceleration of gravity</td>
<td>ft/sec$^2$</td>
</tr>
<tr>
<td>$q_c$</td>
<td>Conversion factor</td>
<td>ft/sec$^2$</td>
</tr>
<tr>
<td>H</td>
<td>Enthalpy</td>
<td>BTU/lb</td>
</tr>
<tr>
<td>$H_{fg}$</td>
<td>Latent heat of evaporation</td>
<td>BTU/lb</td>
</tr>
<tr>
<td>L</td>
<td>Length of heated channel</td>
<td>ft</td>
</tr>
<tr>
<td>$L_B$</td>
<td>Boiling length</td>
<td>ft</td>
</tr>
<tr>
<td>$L_{BC}$</td>
<td>Critical boiling length</td>
<td>ft</td>
</tr>
<tr>
<td>$l_{\text{CHF}}$</td>
<td>Distance from start of local boiling to CHF location (W-3)</td>
<td>ft</td>
</tr>
<tr>
<td>$l_{\text{crit}}$</td>
<td>Distance from channel inlet to critical heat flux location (B&amp;W-2)</td>
<td>ft</td>
</tr>
<tr>
<td>$l_{\text{CHF,EU}}$</td>
<td>Distance from start of local boiling to CHF location for equivalent uniform heat flux condition (W-3)</td>
<td>ft</td>
</tr>
<tr>
<td>p</td>
<td>Pressure</td>
<td>psia</td>
</tr>
</tbody>
</table>
\begin{align*}
\text{\(p_c\)} & \quad \text{Critical pressure} & \text{psia} \\
\text{\(q_{\text{crit}}\)} & \quad \text{Critical heat flux} & \text{BTU hr}^{-1}\text{ft}^{-2} \\
\text{\(q'_{\text{crit}, EU}\)} & \quad \text{Critical heat flux for equivalent uniform heat flux} & \text{BTU hr}^{-1}\text{ft}^{-2} \\
\text{\(q_{\text{crit}, DNB, EU}\)} & \quad \text{Critical heat flux for non-uniform heat flux distribution} & \text{BTU hr}^{-1}\text{ft}^{-2} \\
\text{\(q'_{\text{loc}}\)} & \quad \text{Local heat flux} & \text{BTU hr}^{-1}\text{ft}^{-2} \\
\text{\(v\)} & \quad \text{velocity} & \text{ft/hr} \\
\langle \text{x}_{e} \rangle & \quad \text{Bundle average quality} & - \\
\langle \text{x}_{c} \rangle & \quad \text{Bundle average critical quality} & - \\
\text{x}_{\text{CHF}} & \quad \text{Quality at the critical heat flux location} & - \\
\text{x}_{\text{DNB}} & \quad \text{Quality of channel exit} & - \\
\text{x}_{\text{loc}} & \quad \text{Local quality} & - \\
\text{z} & \quad \text{Axial length} & \text{ft} \\
\text{\(\alpha\)} & \quad \text{Void fraction} & - \\
\text{\(\varepsilon\)} & \quad \text{Eddy diffusivity or Reynolds flux} & \text{ft}^{2}/\text{hr} \\
\text{\(\rho_{f}\)} & \quad \text{Density of saturated liquid} & \text{lb}_{m}/\text{ft}^{3} \\
\text{\(\rho_{g}\)} & \quad \text{Density of saturated vapor} & \text{lb}_{m}/\text{ft}^{3} \\
\text{\(\sigma\)} & \quad \text{Surface tension} & \text{lb/ft}
\end{align*}
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:

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

where

\[
F_{ij} = \frac{K|W_{ij}|W_{ij}}{2(S_{ij})^2 \rho^* \lambda} \quad \text{(Eqn. I-2)}
\]

and

\[
W_{ij} = \text{diversion crossflow between subchannels } i \text{ and } j \quad \text{(lb}_m/\text{hr ft)}
\]

\[
u^* = \text{effective velocity carried by diversion crossflow} \quad \text{(ft/sec)}
\]

\[
x = \text{axial distance (ft)}
\]

\[
s = \text{width of gap between rods (ft)}
\]

\[
\lambda = \text{effective length of connection between subchannels (ft)}
\]

\[
P_i = \text{pressure in channel } i \quad \text{(lb}_f/\text{ft}^2)
\]

\[
P_j = \text{pressure in channel } j \quad \text{(lb}_f/\text{ft}^2)
\]

\[
K = \text{crossflow resistance coefficient (dimensionless)}
\]

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

\[
\rho^* = \text{density of the diversion crossflow} \quad \text{(lb}_m/\text{ft}^3)
\]
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.

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

where

\[
F_{ij} = \frac{K|W_{ij}|W_{ij}}{2(S_{ij})^2 \rho^*} \left(\frac{S}{L}\right)_{ij}(N_r)_{ij} \tag{Eqn. I-4}
\]

and

\[
S_{ij} = (N_g)_{ij} \tag{Eqn. I-5}
\]

\[
L_{ij} = (N_r)_{ij} \tag{Eqn. I-6}
\]

where

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

\[(N_r) = \text{number of rods between centers of channels } i \text{ and } j . \]

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
\[ \frac{\partial}{\partial t}[W_{ij}] + \frac{\partial (u*W_{ij})}{\partial x} = \frac{S_{ij}}{\ell} \frac{(P_i - P_j)}{(N'_{p})_{ij}} - F_{ij} \]  

(Eqn. I-7)

where

\[ F_{ij} = \frac{K|W_{ij}|W_{ij}S_{ij}}{2(S_{ij})^2 \rho^* \ell} \]  

(Eqn. I-8)

and

\[ (N'_{p})_{ij} = \frac{(P_i - P_j)}{(P_i - P_j)} \]  

(Eqn. I-9)

where

\[ (N'_{p})_{ij} = \text{the pressure transport coefficient for subchannels adjacent to the boundary between subchannels } i \text{ and } j. \]

\[ p_i = \text{pressure in interacting subchannel(s) of channel } i \text{ adjacent to gap interconnection } ij \text{ (lb}_f/\text{ft}^2). \]

\[ p_j = \text{pressure in interacting subchannel(s) of channel } j \text{ adjacent to gap interconnection } ij \text{ (lb}_f/\text{ft}^2). \]

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 ft²
Average heat flux 0.1695 MBTU/hr ft²
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.

<table>
<thead>
<tr>
<th>X/L</th>
<th>Drag Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1.105</td>
</tr>
<tr>
<td>0.090</td>
<td>0.461</td>
</tr>
<tr>
<td>0.228</td>
<td>0.461</td>
</tr>
<tr>
<td>0.366</td>
<td>0.461</td>
</tr>
<tr>
<td>0.504</td>
<td>0.461</td>
</tr>
<tr>
<td>0.642</td>
<td>0.461</td>
</tr>
<tr>
<td>0.780</td>
<td>0.461</td>
</tr>
<tr>
<td>0.918</td>
<td>0.461</td>
</tr>
<tr>
<td>1.0</td>
<td>1.015</td>
</tr>
</tbody>
</table>

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

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 ft²°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 - \( f = 0.184 \, \text{Re}^{-0.2} \)
- Two-Phase Friction - Homogeneous Model
- Two-Phase Slip - Equal to 1
- Subcooled Void Fraction - Levy Model
- Mixing \( \beta = 0.02 \)
- K factor - 0.5
- s/\( \lambda \) 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 x 10^6 lb/hr-ft^2
c) Average Heat Flux - 0.1821 x 10^6 Btu/hr-ft^2
d) Inlet Coolant Temperature - 546. °F

Dimension of Channels

<table>
<thead>
<tr>
<th>Channel</th>
<th>Flow Area(in^2)</th>
<th>Wetted Perimeter(in)</th>
<th>Heated Perimeter(in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 3, 5, &amp; 7</td>
<td>0.1843</td>
<td>1.382</td>
<td>1.382</td>
</tr>
<tr>
<td>2 &amp; 6</td>
<td>0.2309</td>
<td>1.695</td>
<td>1.178</td>
</tr>
<tr>
<td>4</td>
<td>0.0918</td>
<td>0.9083</td>
<td>0.5496</td>
</tr>
<tr>
<td>8</td>
<td>33.00</td>
<td>251.0</td>
<td>210.1</td>
</tr>
<tr>
<td>9</td>
<td>895.80</td>
<td>6813.0</td>
<td>6107.0</td>
</tr>
</tbody>
</table>

Channel Length = 136.7 in.

Channel Numbering Map

```
<table>
<thead>
<tr>
<th>0</th>
<th>8</th>
<th>8</th>
<th>8</th>
<th>8</th>
<th>8</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>6</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>
```
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

<table>
<thead>
<tr>
<th>Rod</th>
<th>Radial Power Factor</th>
<th>Fraction of Power(Channel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.475</td>
<td>.2564(1)</td>
</tr>
<tr>
<td>2</td>
<td>1.475</td>
<td>.2564(1)</td>
</tr>
<tr>
<td>3</td>
<td>1.475</td>
<td>.3089(2)</td>
</tr>
<tr>
<td>4</td>
<td>1.475</td>
<td>.2564(1)</td>
</tr>
<tr>
<td>5</td>
<td>1.611</td>
<td>.2442(1)</td>
</tr>
<tr>
<td>6</td>
<td>1.475</td>
<td>.2867(3)</td>
</tr>
<tr>
<td>7</td>
<td>1.475</td>
<td>.2867(3)</td>
</tr>
<tr>
<td>8</td>
<td>1.475</td>
<td>.2564(5)</td>
</tr>
<tr>
<td>9</td>
<td>1.475</td>
<td>.2564(5)</td>
</tr>
<tr>
<td>10</td>
<td>1.475</td>
<td>.3089(6)</td>
</tr>
<tr>
<td>11</td>
<td>1.475</td>
<td>.2564(7)</td>
</tr>
<tr>
<td>12</td>
<td>1.475</td>
<td>.2564(7)</td>
</tr>
<tr>
<td>13</td>
<td>1.264</td>
<td>168.2(8)</td>
</tr>
<tr>
<td>14</td>
<td>0.9495</td>
<td>4716.9</td>
</tr>
<tr>
<td>15</td>
<td>1.711</td>
<td>.1943(4)</td>
</tr>
</tbody>
</table>
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 Homogeneous 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

<table>
<thead>
<tr>
<th>$x/L$</th>
<th>Drag Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0050</td>
<td>1.105</td>
</tr>
<tr>
<td>0.0877</td>
<td>0.4605</td>
</tr>
<tr>
<td>0.2194</td>
<td>0.4605</td>
</tr>
<tr>
<td>0.3511</td>
<td>0.4605</td>
</tr>
<tr>
<td>0.4828</td>
<td>0.4605</td>
</tr>
<tr>
<td>0.6144</td>
<td>0.4605</td>
</tr>
<tr>
<td>0.7461</td>
<td>0.4605</td>
</tr>
<tr>
<td>0.8778</td>
<td>0.4605</td>
</tr>
<tr>
<td>0.995</td>
<td>1.015</td>
</tr>
</tbody>
</table>
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 - $1.10 \times 10^6 \text{ lb/hr-ft}^2$

c) Average Heat Flux - $0.1512 \times 10^6 \text{ Btu/hr-ft}^2$

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.

*Ref. discussion in section IV.C.2
Figure L-1

Axial Power Distribution

Turbine Trip Transient
Fuel Rod Modeling

Fuel pin geometry is as follows:

Fuel Pellet Diameter - 0.410 in
Clad O.D. - 0.483 in
Clad Thickness - 0.032 in

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

Fuel Density - 640.0 lb/ft³
Fuel Thermal Conductivity - 2.0 Btu/lb-ft-°F
Clad Specific Heat - 0.08 Btu/lb-°F
Clad Density - 405.0 lb/ft³
Clad Thermal Conductivity - 8.8 Btu/hr-ft-°F
Clad Specific Heat - 0.076 Btu/lb-°F
Fuel-clad Gap Conductance - 500 Btu/hr-ft²-°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:
<table>
<thead>
<tr>
<th>Axial Location (x/L)</th>
<th>Grid Type</th>
<th>Grid Coefficient Channel 1</th>
<th>Grid Coefficient Channel 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>1</td>
<td>33.0</td>
<td>33.0</td>
</tr>
<tr>
<td>0.714</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.2143</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>9.3571</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.5000</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.6429</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.7857</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.9289</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0.9900</td>
<td>3</td>
<td>10.0</td>
<td>19.0</td>
</tr>
</tbody>
</table>

**Thermal Hydraulic Models**

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

- Single-Phase Friction - \( f = 0.184 \text{Re}^{-0.2} \)
- 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)
<table>
<thead>
<tr>
<th>Card(s)</th>
<th>Type Cl</th>
<th>Problem Array Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required to be present:</td>
<td>Always</td>
<td></td>
</tr>
<tr>
<td>FORTRAN READ list:</td>
<td>MC MG MN MR MX</td>
<td></td>
</tr>
<tr>
<td>FORTRAN FORMAT:</td>
<td>10I5</td>
<td></td>
</tr>
<tr>
<td>Read from Subroutine:</td>
<td>INDAT</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC</td>
<td>1-5</td>
<td>I5</td>
<td>&gt; 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.</td>
</tr>
<tr>
<td>MG</td>
<td>6-10</td>
<td>I5</td>
<td>&gt; 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.</td>
</tr>
<tr>
<td>MN</td>
<td>11-15</td>
<td>I5</td>
<td>&gt; No. of fuel nodal points in problem. This should be &gt; (NODESF+1) on Card T1. If MN is given as zero, it is reset to 1 in CORE.</td>
</tr>
<tr>
<td>MR</td>
<td>16-20</td>
<td>I5</td>
<td>&gt; No. of rods (NROD) in problem. For PWR and BWR, NROD=NCHANL, hence MR may be given=MC.</td>
</tr>
<tr>
<td>MX</td>
<td>21-25</td>
<td>I5</td>
<td>&gt; No. of axial stations in problem. It may be given as NDX (Card Cl1) as it is increased by 1 immediately after reading in.</td>
</tr>
</tbody>
</table>

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
Required to be present: Always
FORTRAN READ list: MAXT
FORTRAN FORMAT: IS, 6E12.6
Read from Subroutine: INDAT

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXT</td>
<td>1-5</td>
<td>IS</td>
<td>Maximum Running Time, Nominal value is 2000.</td>
<td>CONTROL</td>
</tr>
</tbody>
</table>
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  IPOLE, KASE, J1, TEXT
FORTRAN FORMAT  I1, I4, I5, 17A4
Read from subroutines  INDAT

<table>
<thead>
<tr>
<th>Variables</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPOLE</td>
<td>I1</td>
<td>1</td>
<td>= 0</td>
</tr>
<tr>
<td>KASE</td>
<td>I4</td>
<td>2 - 5</td>
<td>Run identification number. If &gt; 0, calculation continues. If ≤ 0, calculation stops.</td>
</tr>
<tr>
<td>J1</td>
<td>I5</td>
<td>6 - 10</td>
<td>Printing option for standard COBRA output - as in COBR/III-C.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>= 1 print entire output</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>= 2 print only operation conditions</td>
</tr>
<tr>
<td>TEXT</td>
<td>I7A4</td>
<td>11 - 78</td>
<td>Alphanumeric information to identify case</td>
</tr>
</tbody>
</table>
Card Group 1
Required to be present
FORTRAN READ list
FORTRAN FORMAT
Read from subroutine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGROUP</td>
<td>1-5</td>
<td>I-5</td>
<td>= 1 (to select Card Group 1)</td>
</tr>
</tbody>
</table>
| N1       | 6-10    | I-5    | \( \leq 0 \) : calculate physical properties from polynomials  
|          |         |        | \( > 1 \) : the physical properties are given in the next \( N_1 \) Cards as in the original COBRA. |
### Physical Properties

Required to be present when \( N1(\text{in Card Group 1}) \leq 0 \)

FORTRAN READ list

\[
\begin{align*}
N & \quad \text{PH} & \quad P2 & \quad N1 \\
\end{align*}
\]

FORTRAN FORMAT

\[
\begin{align*}
I5 & \quad F10.3 & \quad F10.3 & \quad I5 \\
\end{align*}
\]

READ from subroutine CARDS 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Format</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
</table>
| 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

$$p = 6h^3 \frac{(h-1.35)}{(h - 0.35)}$$

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 \( H \).

<table>
<thead>
<tr>
<th>( H ) (Btu/lb)</th>
<th>181.2</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p ) (psia)</td>
<td>11</td>
<td>101</td>
<td>279</td>
<td>589</td>
<td>1067</td>
<td>1749</td>
</tr>
<tr>
<td>( P_{sat} ) (psia)</td>
<td>15</td>
<td>103</td>
<td>319</td>
<td>745</td>
<td>1409</td>
<td>2236</td>
</tr>
</tbody>
</table>
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.
READ IN \( N_1 \) 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). \( N_1 \) 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 SUBCHANNELS 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 ASSUMED 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 VARIATIONS.
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.


Revised by J. Loomis
May 1980
CARD GROUP 9. CALCULATION VARIABLES

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

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

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

N3 IS A DEBUG PRINT OPTION. IF N3=0, NO DEBUG INFORMATION IS PRINT IF N3=1 A DEBUG PRINT IS MADE FOR EACH STEP OF THE CALCULATION. IT CAN GENERATE A LOT OF PAPER SO IT IS NOT NORMALLY USED.
CARD GROUP 10, TURBULENT MIXING CORRELATIONS

N1 IS THE OPTION FOR SUBCOOLED MIXING CORRELATIONS. FOR ANY N1<4
READ IN THE CONSTANTS A AND B, FORMAT(2F5.3).
THE OPTIONS ARE --
  N1=0, W/GS=A
  N1=1, W/GS=A*RE**B
  N1=2, W/GD=A*RE**B
  N1=3, W/GS=D/IZJ*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).

Revised by J. Loomis
May 1980
CARD GROUP 11, OPERATING CONDITIONS

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

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

N2 IS THE INLET FLOW DISTRIBUTION OPTION. IF N2=0, THE SUBCHANNELS ARE GIVEN THE SAME MASS VELOCITY. IF N2=1, THE INLET FLOW IS DIVIDED 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 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 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 0, 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 II of Ref. 1)
M-23

<table>
<thead>
<tr>
<th>Card(s)</th>
<th>Type Cl</th>
<th>Problem Array Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required to be present:</td>
<td>Always</td>
<td></td>
</tr>
</tbody>
</table>

FORTRAN READ list: MC MG MN MR MX

FORTRAN FORMAT: 1015

Read from Subroutine: INDAT

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC</td>
<td>1-5</td>
<td>I5</td>
<td>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.</td>
</tr>
<tr>
<td>MG</td>
<td>6-10</td>
<td>I5</td>
<td>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.</td>
</tr>
<tr>
<td>MN</td>
<td>11-15</td>
<td>I5</td>
<td>No. of fuel nodal points in problem. This should be &gt; (NODESF+1) on Card T1. If MN is given as zero, it is reset to 1 in CORE.</td>
</tr>
<tr>
<td>MR</td>
<td>16-20</td>
<td>I5</td>
<td>No. of rods (NROD) in problem. For PWR and BWR, NROD=NCHANL, hence MR may be given=MC.</td>
</tr>
<tr>
<td>MX</td>
<td>21-25</td>
<td>I5</td>
<td>No. of axial stations in problem. It may be given as NDX (Card C11) as it is increased by 1 immediately after reading in.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXT</td>
<td>1-5</td>
<td>I5</td>
<td>Maximum Running Time, Nominal value is 2000.</td>
<td></td>
</tr>
</tbody>
</table>
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 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(s) Type C3
Required to be present
FORTRAN READ list
FORTRAN FORMAT:
Read from subroutine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Column</th>
<th>Format</th>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1PILE</td>
<td>1</td>
<td>Il</td>
<td>1: for PWR, with interconnected channels.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>= 2: for BWR, with separated channels.</td>
</tr>
<tr>
<td>KASE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J1</td>
<td></td>
<td></td>
<td>as in Appendix 10</td>
</tr>
<tr>
<td>TEXT</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Case Control Card
Always
1PILE, KASE, J1 TEXT
Il, I4, I5, 17A4
INDAT
Card Group 1

Required to be present
Always

FORTRAN READ list
NGROUP \( \text{N1} \)

FORTRAN FORMAT
I5, I5

Read from Subroutine
INDAT

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGROUP</td>
<td>1-5</td>
<td>I5</td>
<td>= 1 (to select Card Group 1)</td>
</tr>
<tr>
<td>N1</td>
<td>6-10</td>
<td>I5</td>
<td>( \leq 0 ): Calculate physical properties from polynomials.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt; 1: the physical properties are given in the next N1 Cards as in the original COBRA.</td>
</tr>
</tbody>
</table>
### Physical Properties

#### Required to be present when $N_1$ (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**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
</table>
| 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 $N_1 = 1$ or lowest enthalpy (Btu/lb) if $N_1 = 2$ |
| 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 \( P_{\text{sat}} \), the tabled value of pressure corresponding to \( H \).

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</tbody>
</table>
In the original COBRA, the physical properties are read from cards into the arrays (PP(L), TT(L), etc., L = l, N1). In the new version, the values of (PP(L), TT(L), etc., L = l, 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 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

(Channel Data) Card (1)

Required to be present when IPILE=1 or 2

FORTRAN READ list

FORTRAN FORMAT I5

READ from subroutine

INDAT

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGROUP</td>
<td>1-5</td>
<td>= 4 (To select Card Group 4)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>1-4</td>
<td>Number of channel types [(max 15) see below]</td>
</tr>
<tr>
<td>N2</td>
<td>5-8</td>
<td>Total number of channels in problem</td>
</tr>
<tr>
<td>NGRID</td>
<td>9-12</td>
<td>Number of grid positions</td>
</tr>
<tr>
<td>NGRIDT</td>
<td>13-16</td>
<td>Number of types of grid</td>
</tr>
<tr>
<td>NODESF</td>
<td>17-20</td>
<td>Number of radial nodes on the fuel for center temperature calculation</td>
</tr>
<tr>
<td>NFUELT</td>
<td>21-24</td>
<td>Number of fuel types</td>
</tr>
</tbody>
</table>
| NCHF     | 25-28   | = 0 for no CHF calculations  

| 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.
Card (3)

Required to be present when ITEXT > 0

FORTRAN READ list

TEXT

FORTRAN FORMAT

20A4

Read from Subroutine

CARD$4$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEXT</td>
<td>1-80</td>
<td>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.</td>
</tr>
</tbody>
</table>
Card (4)

Required to be present

Always (being $\text{NGROUP}=4$)

FORTRAN READ list

$N, I, \text{FRAC}, AC(I), PW(I), PH(I)$

$\text{GAPS}(I,1), \text{DIST}(I,1), \text{DR}(I), \text{PHI}(I,1), M$

FORTRAN FORMAT

$I1, I4, 8E9.3, I2$

READ from subroutine

CARDS4

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

Required to be present

FORTRAN READ list

FORTRAN FORMAT

Read from subroutine

<table>
<thead>
<tr>
<th>Variable</th>
<th>columns</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD</td>
<td></td>
</tr>
<tr>
<td>FXF</td>
<td></td>
</tr>
</tbody>
</table>

Descriptions

Spacer loss coefficients

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)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADIAL</td>
<td>1-70</td>
<td>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.</td>
</tr>
</tbody>
</table>

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 (1); I=1, NROD) = 1.0
Required to be present

FORTRAN READ list

FORTRAN FORMAT

Read from subroutine

Card (7)

If NGRID > 0

(GRIDXL(L), IGRID(I),
(I=1, :IGRID)

3(E5.3, I5)

CARDS4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRIDXL</td>
<td></td>
<td>Relative location (z/L) where grids are located</td>
</tr>
<tr>
<td>IGRID</td>
<td></td>
<td>Type of grid at GRIDXL</td>
</tr>
</tbody>
</table>
Required to be present: Card (3) if N1 (Card(2)) > 1

**FORTRAN READ list:** JB(I)

**FORTRAN FORMAT:** 2014

Read from subroutine: CARDS4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JB</td>
<td>1-80</td>
<td>List of channels of Type 2</td>
</tr>
</tbody>
</table>

**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.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICROS</td>
<td>1-4</td>
<td>} see notes below</td>
</tr>
<tr>
<td>IDOWN</td>
<td>5-8</td>
<td></td>
</tr>
</tbody>
</table>

**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 order is that used to illustrate the case of IMAP = 4 (Card (9d)).
Figure 1.

Rectangular Matrix of Channels
FIGURE 2
Irregular Pattern of Channels
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISTART</td>
<td>1-4</td>
<td>First channel in each row</td>
</tr>
<tr>
<td>IEND</td>
<td>5-8</td>
<td>Last channel in each row</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>ISTART</th>
<th>IEND</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

For Figure 2 the following cards should be inputed:

<table>
<thead>
<tr>
<th>ISTART</th>
<th>IEND</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Required to be present
FORTRAN READ list
FORTRAN FORMAT
Read from subroutine

Card (9c)

When IPILE = 1 and IMAP = 3
(MAAP(L), L= 1,20)
20 I4
CARD$4$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAAP</td>
<td>1-80</td>
<td>The number of the channels making up a row</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>0</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Card (9d)

Required to be present
When IPILE = 1 and IMAP = 4

FORTRAN READ list
(IN(L), JK(L), L = 1:IK)

FORTRAN FORMAT
20 I4

Read from subroutine
CARDS4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IK</td>
<td></td>
<td>} See notes below</td>
</tr>
<tr>
<td>JK</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

FORTRAN Read list

FORTRAN FORMAT

Read from Subroutine

When IPILE = 1

JB(L), L = 1, 20 I4

CARDS4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JB</td>
<td>1-80</td>
<td>List the identification number of the channels making up each &quot;half-boundary&quot;, i.e. the boundaries that are split by a line of symmetry.</td>
</tr>
</tbody>
</table>

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".
Required to be present

FORTRAN READ list

FORTRAN FORMAT

Read from subroutine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KFUEL</td>
<td>1-5</td>
<td>Fuel thermal conduction ( \frac{BTU}{hrft , ^\circ F} )</td>
</tr>
<tr>
<td>CFUEL</td>
<td>6-10</td>
<td>Fuel specific heat ( \frac{BTU}{lb , ^\circ F} )</td>
</tr>
<tr>
<td>RFUEL</td>
<td>11-15</td>
<td>Fuel Density ((lb/ft^3))</td>
</tr>
<tr>
<td>DFUEL</td>
<td>16-20</td>
<td>Pellet Diameter (in)</td>
</tr>
<tr>
<td>KCLAD</td>
<td>21-25</td>
<td>Cladding thermal conduction ( \frac{BTU}{hrft , ^\circ F} )</td>
</tr>
<tr>
<td>CLAD</td>
<td>26-30</td>
<td>Cladding specific heat ( \frac{BTU}{lb , ^\circ F} )</td>
</tr>
<tr>
<td>RCLAD</td>
<td>31-35</td>
<td>Cladding density ((lb/ft^3))</td>
</tr>
<tr>
<td>TCLAD</td>
<td>36-40</td>
<td>Cladding thickness (in)</td>
</tr>
<tr>
<td>HGAP</td>
<td>41-45</td>
<td>Fuel-cladding heat transfer coefficient ((BTU/ft^2 , hr , ^\circ F))</td>
</tr>
</tbody>
</table>
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 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 VARIATIONS.
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 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 SUCCEEDING CASES.
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/AI*J*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 N1=2, read in the individual subchannel inlet enthalpies, format (12F5.0). If N1=3, read in the individual subchannel inlet temperatures, format (12E5.0).
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 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(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)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC</td>
<td>1-5</td>
<td>I5</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>MG</td>
<td>6-10</td>
<td>I5</td>
<td>No. of gap interconnections[NK] between channels in problem. If this is not known, 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.</td>
<td></td>
</tr>
<tr>
<td>MN</td>
<td>11-15</td>
<td>I5</td>
<td>No. of fuel nodal points in problem. This should be &gt; (NODESF+1) on Card T1. If MN is given as zero, it is reset to 1 in CORE.</td>
<td></td>
</tr>
<tr>
<td>MR</td>
<td>16-20</td>
<td>I5</td>
<td>No. of rods (NROD) in problem. For PWR and BWR, NROD=NCHANL, hence MR may be given=MC.</td>
<td></td>
</tr>
<tr>
<td>MX</td>
<td>21-25</td>
<td>I5</td>
<td>No. of axial stations in problem. It may be given as NDX (Card C11) as it is increased by 1 immediately after reading in.</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXT</td>
<td>1-5</td>
<td>I5</td>
<td>Maximum Running Time, Nominal value is 2000.</td>
</tr>
</tbody>
</table>
### Case Control Card

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
</table>
| 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. |

FORTRAN READ list: IPILE KASE J1 TEXT

FORTRAN FORMAT: I1, I4, I5, 17A4

Read from Subroutine: INDAT
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NGROUP</td>
<td>1-5</td>
<td>I5</td>
<td>= 20</td>
</tr>
<tr>
<td>N1</td>
<td>6-10</td>
<td>I5</td>
<td>Printing trigger, NOPRIN, set to N1. N1=0, standard COBRA IIIC printing obtained as well as &quot;new&quot; printout. N1=1, standard COBRA printing suppressed.</td>
</tr>
<tr>
<td>N2-N6</td>
<td>11-35</td>
<td>I5</td>
<td>Leave blank</td>
</tr>
</tbody>
</table>

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).
### Variable Description

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMAP</td>
<td>1-5</td>
<td>I5</td>
<td>Selects method of reading channel into array NTHBOX (ND1X, ND2X). IMAP=1, 2 or 3</td>
</tr>
<tr>
<td>ND1X</td>
<td>6-10</td>
<td>I5</td>
<td>Size of array NTHBOX, maximum values of each are 25.</td>
</tr>
<tr>
<td>ND2X</td>
<td>11-15</td>
<td>I5</td>
<td></td>
</tr>
</tbody>
</table>

**Card(s) Type** C5 Channel Map parameter

**Required to be present** Always

**FORTRAN READ list:** IMAP ND1X ND2X

**FORTRAN FORMAT:** 1415

**Read from Subroutine:** CARD20

If IMAP = 1 2 3

Go to Card C8 C6 C7
The channel numbering system is contained in the array \( \text{NTHBOX} (\text{ND1X}, \text{ND2X}) \) with a zero for each non-channel. The array is later used to define the interaction between adjacent channels. Thus a channel map:

\[
\begin{array}{cccc}
1 & & & \\
2 & 3 & & \\
4 & 5 & 6 & 7 & 8 \\
& & 9 & & \\
\end{array}
\]

would be represented in \( \text{NTHBOX} (5, 4) \) as

\[
\begin{array}{ccccccc}
0 & 0 & 1 & 0 & 0 & & \\
0 & 2 & 3 & 0 & 0 & & \\
4 & 5 & 6 & 7 & 8 & & \\
0 & 0 & 9 & 0 & 0 & & \\
\end{array}
\]

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

\[
\begin{array}{cccc}
1 & 2 & 3 & 4 \\
5 & 6 & 7 & 8 \\
9 & 10 & 11 & 12 \\
\end{array}
\]

For \( \text{IMAP}=2 \), 3 more complicated channel maps may be specified.
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

\[
\begin{array}{c}
3 \\
3 \\
1 \\
2 \\
\end{array}
\]

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTHBOX</td>
<td>1-70</td>
<td>14I5</td>
<td>Channel identification number</td>
</tr>
</tbody>
</table>

If ND1X>14, the remaining numbers (i.e., 15-ND1X) are read on a continuation 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

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>Variable</td>
<td>Columns</td>
<td>Format</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>--------</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| N1       | 1-5     | IS     | N1=0; trigger to read average nodal fuel powers after rest of data (Cards C12-14). NAX set to 0, IQP3 set to 0.  
N1=1; trigger to read average nodal fuel and coolant powers after rest of data (Cards 12-14). NAX set to 0, IQP3 set to 1.  
N1>2; number of axial points at which heat flux profile will be given on following card C9. Maximum value of N1=30. NAX set to N1, IQP3 set to 2. |
<p>| AFLUX    | 6-10    | E5.0   | Reactor average heat flux in MBtu/ft²·h. If N1=0 or 1, the value of AFLUX is irrelevant and may be given as zero. |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>1-70</td>
<td>E5.0</td>
<td>Normalised axial position along channel ((x/L); 0 \leq Y \leq 1.0)</td>
<td>3</td>
</tr>
<tr>
<td>AXIAL</td>
<td>1-70</td>
<td>E5.0</td>
<td>Relative heat flux (local/average) corresponding to (Y).</td>
<td>3</td>
</tr>
</tbody>
</table>
Card(s)' Type  
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADIAL</td>
<td>1-70</td>
<td>14E5.0</td>
<td>Relative Rod Power (local/average)</td>
<td>8</td>
</tr>
</tbody>
</table>

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 13, 14, 5, 6, 7, 8, 15, 16, and 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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>1-5</td>
<td>E5.0</td>
<td>Channel length (in.)</td>
<td>9</td>
</tr>
<tr>
<td>NDX</td>
<td>6-10</td>
<td>I5</td>
<td>Number of axial intervals</td>
<td>9</td>
</tr>
</tbody>
</table>
| NDT      | 11-15   | I5     | Number of time steps
|          |         |        | NDT=0; steady state only
|          |         |        | NDT>0; steady state + transient |
| 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:**

<table>
<thead>
<tr>
<th>FORTRAN READ list</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPILE NCTYP NGRID NGRIDT NODESF NFXF</td>
</tr>
</tbody>
</table>

**FORTRAN FORMAT:**

<table>
<thead>
<tr>
<th>FORTRAN FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(14I5)</td>
</tr>
</tbody>
</table>

**Read from Subroutine:** CHAN

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPILE</td>
<td>1-5</td>
<td>I5</td>
<td>Iteration trigger=0 for simplified method=1 for PWR, =2 for BWR</td>
<td></td>
</tr>
<tr>
<td>NCTYP</td>
<td>6-10</td>
<td>I5</td>
<td>No. of channel types to be read in; controls reading of cards T2-T4</td>
<td></td>
</tr>
<tr>
<td>NGRID</td>
<td>11-15</td>
<td>I5</td>
<td>No. of grid positions (maximum=10)</td>
<td>7</td>
</tr>
<tr>
<td>NGRIDT</td>
<td>16-20</td>
<td>I5</td>
<td>No. of grid types for each channel (maximum=5)</td>
<td>7</td>
</tr>
<tr>
<td>NODESF</td>
<td>21-25</td>
<td>I5</td>
<td>No. of fuel nodes</td>
<td>8</td>
</tr>
<tr>
<td>NFXF</td>
<td>26-30</td>
<td>I5</td>
<td>No. of &quot;forced flow&quot; types. Not in use; leave blank</td>
<td></td>
</tr>
</tbody>
</table>
| 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 is 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 |  |

Revised by J. Liu  
May 23, 1977  
Revised by J. Loomis  
May 1980
### Card Type: Tla

**Required to be present:** When NODESF > 0 and either IFRM = 1 or IHTM > 0

**FORTRAN READ list:** EPSF

**FORTRAN FORMAT:** (E8.0)

**Read from Subroutine:** CHAN

---

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPSF</td>
<td>1-8</td>
<td>E8.0</td>
<td>Fuel rod temperature convergence criterion. If EPSF is given as zero, it is set to the default value 10^-2.</td>
<td>--</td>
</tr>
</tbody>
</table>

---

*Added by J. Loomis  
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:

(215, 8E5.0)

### Read from Subroutine:

CHAN

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>1-5</td>
<td>I5</td>
<td>Friction Indicator to select friction factor for channel (see T10). Nominal value=1, maximum=4.</td>
<td>4</td>
</tr>
<tr>
<td>J</td>
<td>6-10</td>
<td>I5</td>
<td>Indicator to define A, B, C, D below (=-1 or 2)</td>
<td>--</td>
</tr>
<tr>
<td>FRAC</td>
<td>11-15</td>
<td>E5.0</td>
<td>Amount by which channel area, wetted and heated perimeters and number of heated rods are to be multiplied (see below).</td>
<td>--</td>
</tr>
<tr>
<td>GAP</td>
<td>16-20</td>
<td>E5.0</td>
<td>Effective rod gap for interconnection between channels (in.). If IPILE=0 this may be given as zero.</td>
<td>4</td>
</tr>
<tr>
<td>HNR</td>
<td>21-25</td>
<td>E5.0</td>
<td>No. of heated rods in fuel assembly.</td>
<td>8</td>
</tr>
<tr>
<td>DR</td>
<td>26-30</td>
<td>E5.0</td>
<td>Diameter of heated rods (in.)</td>
<td>8</td>
</tr>
</tbody>
</table>

**If J=1:**

| A        | 31-35   | E5.0   | Channel Flow Area (in^2)                                                   | 4  |
| B        | 36-40   | E5.0   | Channel Wetted perimeter (in.)                                              | 4  |
| C        | 41-45   | E5.0   | Channel heated perimeter (in.)                                              | 4  |
| D        | 46-50   | E5.0   | Not used--leave blank                                                       | -- |

**If J=2:**

| A        | 31-35   | E5.0   | No. of unheated (e.g., control) rods                                        | -- |
| B        | 36-40   | E5.0   | Diameter of unheated rods (in.)                                             | -- |
| C        | 41-45   | E5.0   | Width of square assembly (in.)                                               | -- |
| D        | 46-50   | E5.0   | Radius of channel corners (in.)                                              | -- |

Revised by J. Liu
May 23, 1977
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

Revised by J. Liu
May 23, 1977
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDG</td>
<td>1-70</td>
<td>14E5.0</td>
<td>Single phase grid coefficient for each grid type.</td>
</tr>
</tbody>
</table>
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 

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JB</td>
<td>1-70</td>
<td>I5</td>
<td>Channel Identification Number for Type I</td>
</tr>
</tbody>
</table>

**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:

\[
\begin{align*}
I &= NCTYP & \text{Card T5} \\
I &< NCTYP & \text{Card T2}
\end{align*}
\]
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRIDXL</td>
<td>1-70</td>
<td>E5.0</td>
<td>Fractional distance up channel (x/L) at which each grid is situated, i.e., (0 \leq \text{GRIDXL} \leq 1.0)</td>
</tr>
<tr>
<td>IGGRID</td>
<td>1-70</td>
<td>I5</td>
<td>Grid Type; the coefficients for each type of grid were read by T3.</td>
</tr>
<tr>
<td>Variables</td>
<td>Columns</td>
<td>Format</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>---------</td>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>NN11</td>
<td>1-5</td>
<td>I5</td>
<td>Cards of rod layout data to be read</td>
</tr>
<tr>
<td>NN22</td>
<td>5-10</td>
<td>I5</td>
<td>Total number of rods</td>
</tr>
<tr>
<td>NN33</td>
<td>10-15</td>
<td>I5</td>
<td>Number of radial fuel nodes including the cladding</td>
</tr>
<tr>
<td>NN44</td>
<td>15-20</td>
<td>I5</td>
<td>Total number of fuel types</td>
</tr>
<tr>
<td>ITMP</td>
<td>21-25</td>
<td>I5</td>
<td>Transverse momentum coupling parameter indicator. Parameters read by card(s) T7a if ITMP=1. No parameters read if ITMP=0.</td>
</tr>
</tbody>
</table>

Note:

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

Revised by J. Loomis
May 1980
Card(s) Type: T5b

Required to be present:

FORTRAN READ list:

FORTRAN FORMAT:

Read from Subroutine:

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

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,N;4)

FORTRAN FORMAT: (14E5.0)

Read from Subroutine: CHAN

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>KF</td>
<td>1-5</td>
<td>E5.0</td>
<td>Fuel thermal conductivity (Btu/hr ft°F)</td>
<td>8</td>
</tr>
<tr>
<td>CF</td>
<td>6-10</td>
<td>E5.0</td>
<td>Fuel specific heat (Btu/lb °F)</td>
<td>8</td>
</tr>
<tr>
<td>RF</td>
<td>11-15</td>
<td>E5.0</td>
<td>Fuel density (lb/ft³)</td>
<td>8</td>
</tr>
<tr>
<td>DF</td>
<td>16-20</td>
<td>E5.0</td>
<td>Pellet diameter (inch)</td>
<td>8</td>
</tr>
<tr>
<td>KC</td>
<td>21-25</td>
<td>E5.0</td>
<td>Clad thermal conductivity (Btu/hr ft°F)</td>
<td>8</td>
</tr>
<tr>
<td>CC</td>
<td>26-30</td>
<td>E5.0</td>
<td>Clad specific heat (Btu/lb °F)</td>
<td>8</td>
</tr>
<tr>
<td>RC</td>
<td>31-35</td>
<td>E5.0</td>
<td>Clad density (lb/ft³)</td>
<td>8</td>
</tr>
<tr>
<td>TC</td>
<td>36-40</td>
<td>E5.0</td>
<td>Clad thickness (inch)</td>
<td>8</td>
</tr>
<tr>
<td>HG</td>
<td>41-45</td>
<td>E5.0</td>
<td>Fuel-to-clad heat transfer coefficient (Btu/ft²hr°F)</td>
<td>8</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCF</td>
<td>1-5</td>
<td>I5</td>
<td>Number of radial clad cells</td>
<td>--</td>
</tr>
<tr>
<td>NCC</td>
<td>6-10</td>
<td>I5</td>
<td>Number of radial fuel cells</td>
<td>--</td>
</tr>
<tr>
<td>THG</td>
<td>11-15</td>
<td>I5</td>
<td>Gap thickness(in)</td>
<td>--</td>
</tr>
</tbody>
</table>

Added by J. Loomis
May 1980
Card Type: T6b  
Required to be present: When NODESF>0 and IFRM=1 and IPROP>0  
FOTRAN READ list: FTD, FPUO2  
FOTRAN FORMAT: (14E5.0)  
Read from Subroutine: CHAN  

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTD</td>
<td>1-5</td>
<td>E5.0</td>
<td>Fraction of theoretical density of fuel</td>
<td>--</td>
</tr>
<tr>
<td>EPUO2</td>
<td>6-10</td>
<td>E5.0</td>
<td>PUO2 content, volume fraction</td>
<td>--</td>
</tr>
</tbody>
</table>

Added by J. Loomis  
May 1980
Card Type T6c  
Required to be present: When NODESF>0, IFRM=1, and IPROP=2  
FORTTRAN READ list: BURN, CPR, EXPR, FPRESS, GRGH, GMIX, PGAS  
FORTTRAN FORMAT: (1E5.0)  
Read from Subroutine: CHAN

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

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

Added by J. Loomis  
May 1980
Card(s) Type: T6d  

Effective rod gap for interconnection between channels (in)

Required to be present: Only if IPILE=0

FORMAT READ list: (GAPREC(I),I=1,NK) where NK is the total number of gap interconnections

FORTRAN FORMAT: 14E5.0

Read from Subroutine: CHAN

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAPREC</td>
<td>1-70</td>
<td>Effective rod gap for interconnection between channels (in)</td>
</tr>
</tbody>
</table>

Notes

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

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

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

Pair of channels making up each boundary
1-2 1-3 2-4 2-5 3-4 4-5 5-6 4-7 5-8 3-7 7-8 8-6 7-9 8-

and in general the boundaries are established by going from left to right in each row and from top to bottom between two consecutive rows.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>FACSL(I)</td>
<td>E5.0</td>
<td></td>
<td>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.</td>
<td>--</td>
</tr>
<tr>
<td>FACSLK(I)</td>
<td>E5.0</td>
<td></td>
<td>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.</td>
<td>--</td>
</tr>
</tbody>
</table>

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 approach."

Added by J. Loomis
May 1980
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>1-70</td>
<td>i5</td>
<td>II(l), JJ(l) are the channel identification numbers which define the lth &quot;half-boundary.&quot;</td>
</tr>
<tr>
<td>JJ</td>
<td>1-70</td>
<td>i5</td>
<td></td>
</tr>
</tbody>
</table>

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.

```
  1 2 3
  4 5
  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.

Revised by J. Liu
May 23, 1977
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

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

Notes:

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

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

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

Revised by J.Liu
May 23, 1977
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABETA</td>
<td>1-5</td>
<td>E5.0</td>
<td>( \beta = \frac{W}{G<em>S} = ABETA</em>(RE^{*BBETA}) )</td>
</tr>
<tr>
<td>BBETA</td>
<td>6-10</td>
<td>E5.0</td>
<td>The new mixing model is used if N1=3</td>
</tr>
</tbody>
</table>

Notes:
(1) If N1=0, then ABETA=0.02, BBETA=0.0, and \( \frac{W}{G*S} = ABETA*(RE^{*BBETA}) \)
(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

Revised by J. Loomis
May 1980
**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  

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

**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.
<table>
<thead>
<tr>
<th>Card(s) Type</th>
<th>T11</th>
<th>Two Phase Friction Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required to be present</td>
<td>Only if N3 (on T8)&gt;0</td>
<td></td>
</tr>
</tbody>
</table>

**FORTRAN READ list:** J4

**FORTRAN FORMAT:** (14I5)

Read from Subroutine: MODEL

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>J4</td>
<td>1-5</td>
<td>I5</td>
<td>Two phase friction correlation trigger 2</td>
<td></td>
</tr>
</tbody>
</table>

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

**Note:**

If N3=0, J4 is set to 0.
Card(s) Type | T12 | Two phase friction polynomial
---|---|---
Required to be present | Only if J4 (on T11) = 5
FORTRAN READ list: | NF (AF(L), L=1, NF)
FORTRAN FOPMAT: | (I5, 13E5.0)
Read from Subroutine: | MODEL

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF</td>
<td>1-5</td>
<td>I5</td>
<td>No. of terms in polynomial (max=7)</td>
<td>2</td>
</tr>
<tr>
<td>AF</td>
<td>6-40</td>
<td>E5.0</td>
<td>Polynomial coefficients</td>
<td>2</td>
</tr>
</tbody>
</table>

Notes:
(1) The two phase friction multiplier is calculated as

\[ f = \sum_{j=1}^{NF} \left( AF(j)x^{j-1} \right) \]

where \( x = \text{quality (0} \leq x \leq 1) \)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>J2</td>
<td>1-5</td>
<td>I5</td>
<td>Subcooled Void Indicator</td>
<td>2</td>
</tr>
<tr>
<td>J3</td>
<td>6-10</td>
<td>I5</td>
<td>Slip Ratio Indicator</td>
<td>2</td>
</tr>
</tbody>
</table>

- **J2=0**: no subcooled void
- **J2=1**: Levy subcooled void correlation
- **J3=0**: Slip Ratio=1
- **J3=1**: Armand Slip Ratio Correlation
- **J3=2**: Smith Slip Ratio Correlation
- **J3=3,4**: Not in use
- **J3=5**: Slip ratio given (T14)
- **J3=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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>NV</td>
<td>1-5</td>
<td>IS</td>
<td>No. of terms in polynomial (≤7)</td>
<td>2</td>
</tr>
<tr>
<td>AV</td>
<td>6-40</td>
<td>E5.0</td>
<td>Polynomial coefficients</td>
<td>2</td>
</tr>
</tbody>
</table>

A polynomial
\[
\sum_{\nu=1}^{\nu=NV} (AV(\nu)X) \]

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:
\[
\sum_{\nu=1}^{\nu=NV} (AV(\nu)X^{\nu-1})
\]
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>IG</td>
<td>1-5</td>
<td>I5</td>
<td>Inlet Flow Indicator</td>
<td>11</td>
</tr>
</tbody>
</table>

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.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR</td>
<td>1-70</td>
<td>E5.0</td>
<td>Inlet Mass Velocity Ratio (local/average) for all NCHANL channels</td>
<td>11</td>
</tr>
</tbody>
</table>
### Card(s) Type T17 Parameters

<table>
<thead>
<tr>
<th>Required to be present:</th>
<th>Only if N6 (on T8)&gt;0</th>
</tr>
</thead>
</table>

**FORTRAN READ list:**

NCHF KIJ FTM SL THETA

**FORTRAN FORMAT:**

(I5, 13E5.0)

**Read from Subroutine:**

MODEL

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

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

If NCHF=1 the BAW-2 correlations is used

If NCHF=2 the W-3 correlation is used

If NCHF=3 the Hench-Levy correlation is used

If NCHF=4 the CISE-4 correlation is used

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

**Note:**

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

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

Revised by J. Loomis
May 1980
**Card(s) Type** | **T18** | **Convergence Criteria**
---|---|---
**Required to be present** | Only if N7 (on T8) > 0

**FORTRAN READ list:**
- NTRIES
- FERROR

**FORTRAN FORMAT:**
(I5, 13 E5.0)

**Read from Subroutine:**
MODEL

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTRIES</td>
<td>1-5</td>
<td>I5</td>
<td>Maximum permissable number of hydraulic iterations</td>
<td>9</td>
</tr>
<tr>
<td>FERROR</td>
<td>6-10</td>
<td>E5.0</td>
<td>Flow convergence criterion</td>
<td>9</td>
</tr>
</tbody>
</table>

**Note**
(1) If N7=0, NTRIES set to 20 and FERROR to 0.001.
### Physical Properties

**Card(s) Type:** T19

**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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPROP</td>
<td>1-5</td>
<td>I5</td>
<td>No. of pressure points in physical property table for interpolating between (Minimum=2, Maximum=30).</td>
</tr>
<tr>
<td>N</td>
<td>6-10</td>
<td>I5</td>
<td>1 or 2 (see PH below)</td>
</tr>
<tr>
<td>PH</td>
<td>11-15</td>
<td>E5.0</td>
<td>N=1, PH=lowest pressure (psia) in problem. N=2, PH=lowest enthalpy (Btu/lb) in problem, from which the lowest pressure is calculated (see below).</td>
</tr>
<tr>
<td>P2</td>
<td>16-20</td>
<td>E5.0</td>
<td>Highest pressure in problem (psia)</td>
</tr>
</tbody>
</table>

**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.

Revised by J. Liu
May 23, 1977
Card(s) Type T19a
Required to be present Coupling parameters

FORTRAN READ list:
Only if N9 (on T8) > 0
(ENEH(K), K=1,NK) where NK=total number of boundaries

FORTRAN FORMAT: 14E5.0
Read from Subroutine: MODEL

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENEH</td>
<td>1-70</td>
<td>E5.0</td>
<td>Coupling parameter introduce in the mixing term of the energy conservation equation.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>IH</td>
<td>1-5</td>
<td>I5</td>
<td>Inlet Enthalpy Indicator</td>
<td>11</td>
</tr>
<tr>
<td>HIN</td>
<td>6-10</td>
<td>E5.0</td>
<td>IH=0: Inlet Enthalpy (Btu/lb)</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IH=1: Inlet Temperature (°F)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IH=2,3: HIN not used, set to zero (see T21)</td>
<td></td>
</tr>
<tr>
<td>GIN</td>
<td>11-15</td>
<td>E5.0</td>
<td>Average Inlet Mass Velocity (Mlb/ft²h)</td>
<td>11</td>
</tr>
<tr>
<td>PEXIT</td>
<td>16-20</td>
<td>E5.0</td>
<td>System pressure (psia)</td>
<td>11</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1-70</td>
<td>E5.0</td>
<td>IH=2: Inlet enthalpies for each channel (Btu/lb)</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IH=3: Inlet temperatures for each channel (°F)</td>
<td></td>
</tr>
</tbody>
</table>
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**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>1-5</td>
<td>I5</td>
<td>No. of points at which pressure transient forcing function will be given (T23). Maximum=30</td>
<td>11</td>
</tr>
<tr>
<td>NH</td>
<td>6-10</td>
<td>I5</td>
<td>As NP but inlet enthalpy (T24). Maximum=30</td>
<td>11</td>
</tr>
<tr>
<td>NG</td>
<td>11-15</td>
<td>I5</td>
<td>As NP but inlet flow (T25). Maximum=30</td>
<td>11</td>
</tr>
<tr>
<td>NQ</td>
<td>16-20</td>
<td>I5</td>
<td>As NP but channel power (T25a). Maximum=30</td>
<td>11</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>YP</td>
<td>1-70</td>
<td>E5.0</td>
<td>Time (seconds)</td>
<td>11</td>
</tr>
<tr>
<td>FP</td>
<td>1-70</td>
<td>E5.0</td>
<td>Ratio of transient to steady state pressure at time YP</td>
<td>11</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>YH</td>
<td>1-70</td>
<td>E5.0</td>
<td>Time (seconds)</td>
</tr>
<tr>
<td>FH</td>
<td>1-70</td>
<td>E5.0</td>
<td>Ratio of transient to steady state enthalpy or temperature (depending on IH--card T20) at time Y.H.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>YG</td>
<td>1-70</td>
<td>E5.0</td>
<td>Time (seconds)</td>
<td>11</td>
</tr>
<tr>
<td>FG</td>
<td>1-70</td>
<td>E5.0</td>
<td>Ratio of transient to steady state average mass velocity at time YG</td>
<td>11</td>
</tr>
</tbody>
</table>

Notes
(1) As for card T23, but YG, FG instead of YP, FP.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>YQ</td>
<td>1-70</td>
<td>E5.0</td>
<td>Time (seconds)</td>
<td>11</td>
</tr>
<tr>
<td>FQ</td>
<td>1-70</td>
<td>E5.0</td>
<td>Ratio of transient to steady state channel power at time YQ</td>
<td>11</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>KDEBUG</td>
<td>1-5</td>
<td>I5</td>
<td>&quot;Debug&quot; option</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>=0: normal--no test printing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>=1: &quot;debug&quot;--with test printing</td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>Columns</td>
<td>Format</td>
<td>Description</td>
<td>CG</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>--------</td>
<td>-------------</td>
<td>----</td>
</tr>
<tr>
<td>NSKIPX</td>
<td>1-5</td>
<td>I5</td>
<td>Axial print option</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>=0 or 1: every axial step printed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;1: each (NSKIPX)th step printed</td>
<td></td>
</tr>
<tr>
<td>NSKIPT</td>
<td>6-10</td>
<td>I5</td>
<td>Time step option</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>As for NSKIPX but time (not axial) steps</td>
<td></td>
</tr>
<tr>
<td>NOUT</td>
<td>11-15</td>
<td>I5</td>
<td>=0: print channel results only</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>=1: channel + cross flow tables</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>=2: channel + fuel temperature tables</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>=3: channel + cross flow + fuel temperature tables</td>
<td></td>
</tr>
<tr>
<td>NPCHAN</td>
<td>16-20</td>
<td>I5</td>
<td>=0: all channels printed</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt;1: read in NPCHAN channels to be printed</td>
<td></td>
</tr>
<tr>
<td>NPROD</td>
<td>21-25</td>
<td>I5</td>
<td>As for NPCHAN but rods instead of channels</td>
<td>12</td>
</tr>
<tr>
<td>NPNODE</td>
<td>26-30</td>
<td>I5</td>
<td>As for NPCHAN but radial fuel nodes instead of channels</td>
<td>12</td>
</tr>
</tbody>
</table>
Card(s) Type  T28  Channels to be printed
Required to be present  Only if NPCHAN (T27) \( \geq 1 \)
FORTRAN READ list:  (PRINTC(I), I=1, NPCHAN)
FORTRAN FORMAT:  (14I5)
Read from Subroutine:  TABLES

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRINTC</td>
<td>1-70</td>
<td>I5</td>
<td>Identification Number of channels to be printed.</td>
</tr>
</tbody>
</table>
Card(s) Type: T29
Rods to be printed
Required to be present: Only if NPROD (T27) > 1

FORTRAN READ list: (PRINTR(I), I=1, NPROD)

FORTRAN FORMAT: (14I5)

Read from Subroutine: TABLES

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRINTR</td>
<td>1-70</td>
<td>I5</td>
<td>Identification Number of rods to be printed.</td>
<td>12</td>
</tr>
</tbody>
</table>
Card(s) Type  T30  Fuel nodes to be printed
Required to be present  Only if NPNODE (T27) $\geq 1$
FORTRAN READ list:  (PRINTN(I), I=1, NPNODE)
FORTRAN FORMAT:  (14I5)
Read from Subroutine:  TABLES

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRINTN</td>
<td>1-70</td>
<td>I5</td>
<td>Radial fuel nodes to be printed</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$l=$rod center, $(\text{NODESF} + 1)=$outer clad surface</td>
<td></td>
</tr>
</tbody>
</table>
Card(s) Type C4 End Input Data, start calculation
Required to be present Always
FORTRAN READ list: BLANK CARD
FORTRAN FORMAT: 
Read from Subroutine: INDAT

Variable | Columns | Format | Description | CG
----------|---------|--------|-------------|---

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZM</td>
<td>1-10</td>
<td>E10.0</td>
<td>Nodal Power Multiplier</td>
<td></td>
</tr>
</tbody>
</table>

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.

Revised by J. Liu
May 23, 1977
Card(s) Type  C13  Fuel Nodal Powers
Required to be present  Only if IQP3 (C8) = 0 or 1
FORTRAN READ list:  ((QF(I,J), J=1, NDX), I=1, NCHANL)
FORTRAN FORMAT:  (8E10.0)
Read from Subroutine:  QPR3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>QF</td>
<td>1-80</td>
<td>8E10.0</td>
<td>Average Fuel Nodal Power for Channel I, axial interval J to (J+1)</td>
</tr>
</tbody>
</table>

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.

Revised by J. Liu
May 23, 1977
**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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC(I,J)</td>
<td>1-80</td>
<td>8E10.0</td>
<td>Average Nodal Power deposited in Coolant for channel I, axial interval J to J+1.</td>
</tr>
</tbody>
</table>

As for card C13, but QC instead of QF.

---

Revised by J. Liu  
May 23, 1977
### Card(s) Type

**C13**

**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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

---

Revised by J. Liu
May 23, 1977
<table>
<thead>
<tr>
<th>Card(s) Type</th>
<th>C14</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Transient Coolant Nodal Power</td>
</tr>
<tr>
<td>Required to be present</td>
<td></td>
<td>Only if IQP3= 1 and NDT &gt; 1</td>
</tr>
<tr>
<td>FORTRAN READ list:</td>
<td></td>
<td>((QC(I,J), J=1, NDX), I=1, NCHANL)</td>
</tr>
<tr>
<td>FORTRAN FORMAT:</td>
<td></td>
<td>(8E10.0)</td>
</tr>
<tr>
<td>Read from Subroutine:</td>
<td>QPR3</td>
<td></td>
</tr>
</tbody>
</table>

See last card, "transient" C13.

Revised by J. Liu
May 23, 1977
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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Columns</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(I1, I4, I5, 17A4)</td>
<td></td>
</tr>
</tbody>
</table>

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.
FILE: COBRA3C FORTRAN

CONVERSATIONAL MONITOR SYSTEM

* * * * * * * * *

* * * * * *

COBRA-IIIC/MIT

* * * * *

1980 MIT VERSION

* * * * *

UNIT - ALL COMPUTATIONS ARE DONE USING FT, LB, SEC, BTU AND DEG-F, except for some associated with new fuel rod and heat transfer model.

UNIT CHANGES FOR INPUT AND OUTPUT ARE DONE IN THE PROGRAM.

KMAX IN SUBROUTINE CORE EQUALS

LENGTH OF DATA ARRAY GIVEN BELOW

COMMON DATA(80000)

COMMON /COBRA1/

COMMON /COBRA2/

COMMON /COBRA3/

IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

COMMON /COBRA2/ AA(4), AF(7), AFAC(10, 10), AV(7), AXIAL(30),

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

COMMON /COBRA2/ AA(4), AF(7), AFAC(10, 10), AV(7), AXIAL(30),

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

COMMON /COBRA2/ AA(4), AF(7), AFAC(10, 10), AV(7), AXIAL(30),

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

COMMON /COBRA2/ AA(4), AF(7), AFAC(10, 10), AV(7), AXIAL(30),

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IMPLICIT INTEGER ($)

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IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

COMMON /COBRA2/ AA(4), AF(7), AFAC(10, 10), AV(7), AXIAL(30),

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

IMPLICIT INTEGER ($)
C COMMON DATA(1)  
C LOGICAL LDAT(1)  
C INTEGER IDAT(1)  
C EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))  
C EQUIVALENCE (NCHAN, NCHANL)  
C  
C DIMENSION AFAC(10), GFAC(10)  
C  
C CALCULATE CHANNEL AREA IF REQUIRED.  
DO 5 I=1,NCHANL  
DATA(SA +I)=DATA(SAN +I)  
5  
DATA(SHYD +I)=DATA(SHYDN+I)  
DO 6 K=1,NK  
6  
DATA(SGAP +K)=DATA(SCAPN +K)  
IF(NAXL.EQ.0) GO TO 101  
101 I=1,NCHANL  
JJ=IDAT($IDARE +I)  
IF(JJ.JT.1) GO TO 100  
100  
DO 10 K=1,NAXL  
10  
AFAC(K) = AFAC(JJ,K)  
CALL CURVE(FF,.DATA(SX+J)/Z),AFAC,AXL,NAXL,IERROIR,1)  
IF(IERROIR.GT.1) GO TO 1000  
1000  
IF(DT.LT.100.) GO TO 20  
20  
DUMY = FLOAT(ITERAT)/FLOAT(NARAMP)  
IF(DUMY.GT.1.) DUMY = 1.  
IF(FF.LE.0.) GO TO 1000  
IF(FF.EQ.0.) DUMY = 1.  
FF = 1.-(FF*FF)*DUMY  
10  
DATA(SA +I)=DATA(SAN +I)*FF  
DATA(SHYD +I)=DATA(SHYDN+I)*FF  
100 CONTINUE  
C MODIFY AREA AND HYDRAULIC DIAMETER FOR WIRE WRAPS IN SUBCHANNELS.  
DO 102 I=1,NCHANL  
DATA(SA+I)=DATA(SA+I)-FLOAT(IDAT($WRAP+I))*PI*THICK**2*0.25  
102  
C CALCULATE GAP SPACING IF REQUIRED.  
110 IF(NGX.LT.EQ.0) GO TO 210  
DO 200 K=1,NK  
L=IDAT($DGAP+K)  
IF(L.LT.1) GO TO 200  
200  
DO 120 I=1,NGXL  
120  
GFAC(I) = GFAC(L,1)  
CALL CURVE(FF,.DATA(SX+J)/Z),GFAC,GAPX,NGXL,NGXL,IERROIR,1)  
IF(IERROIR.GT.1) GO TO 1000  
IF(FF.LE.0.) GO TO 1000  
DATA(SGAP +K)=DATA(SGAPN +K)*FF  
C
CONTINUE
RETURN
IERROR = 9
RETURN
END

SUBROUTINE BAROC(IPART,P,Q,GWV,FMULT,PPI)

COMMON/COSAVE/CORAB

DIMENSION A1(4),A2(4),CORAB(14,7),COEF(12,8),DAT(12,5,5),X(5)

DATA 13/6/
DATA ZNN/1.2621,0.6749,0.073,1.9551,1.0043,0.1097,1.4985,0.8408,
20.0971,0.7965,0.5531,0.0673,0.771,0.5638,0.0713,0.4838,0.4793,
10.0657/
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,
1.0971,0.7965,0.5531,0.0673,0.771,0.5638,0.0713,0.4838,0.4793,
10.0657/
DATA COEF/2.2,9.2,26.5,47.0,99.0,163.0,376.0,630.0,
2.15,8.8,22.8,34.2,48.2,70.0,108.0,148.0,240.0,330.0,538.0,
2.08,7.8,16.3,22.8,29.0,36.0,49.5,63.0,86.0,110.0,155.0,
1.59,4.9,9.6,12.4,16.0,20.0,27.0,33.5,43.5,53.0,69.0,85.0,
1.21,3.8,4.5,4.7,6.1,7.9,11.0,13.2,17.3,21.2,26.0,30.0,
1.04,1.22,1.78,2.0,2.2,2.8,3.6,4.2,5.6,5.8,6.0,9.1,
1.01,1.06,1.26,1.36,1.5,1.59,1.77,1.92,2.25,2.48,2.86,3.2,12*
1.0,1.06,1.26,1.36,1.5,1.59,1.77,1.92,2.25,2.48,2.86,3.2,12*
1.0,1.06,1.26,1.36,1.5,1.59,1.77,1.92,2.25,2.48,2.86,3.2,12*
1.0
DATA DAT/1.669,1.669,1.626,1.6,1.59,1.58,1.58,1.58,1.534,
1.534,1.534,1.534,1.534,1.534,1.534,1.534,1.534,
1.534,1.534,1.534,1.534,1.534,1.534,1.534,1.534,
1.534,1.534,1.534,1.534,1.534,1.534,1.534,1.534,
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1.534,1.534,1.534,1.534,1.534,1.534,1.534,1.534,
1.534,1.534,1.534,1.534,1.534,1.534,1.534,1.534,
2 - \((Y_1 - YY) \times (Z_{12} \times (X_2 - XX) + Z_{22} \times (XX - X_1))\)

3 \(/((Y_1 - Y_2) \times (X_1 - X_2))\)

C
ZLINE IS VALUE OF YB AT XB, INTERPOLATED LINEARLY BETWEEN (XA,YA) AND (XC,YC)
ZRECT IS VALUE OF Z AT (XX,YY), LINEARLY INTERPOLATED BETWEEN Z11 AT (X1,Y1), Z12 AT (X1,Y2), Z21 AT (X2,Y1) AND Z22 AT (X2,Y2)

IPART = 1, ENTER WITH PRESSURE AND SET ARRAY CORAB
IPART = 2, ENTER WITH MASS VELOCITY AND QUALITY, INTERPOLATE IN CORAB TO OBTAIN MULTIPLIER.

IF (IPART.EQ.2) GO TO 41
SET PHYSICAL PROPERTY INDEX FROM PRESSURE.
IF((P.LT.11.429).OR.(P.GT.3204.0)) WRITE(I3,1001) P
IF(P.GT.1429.5) GO TO 8
YY=A1(4)
DO 2 I=1,3
   L=4-I
   2 YY=YY*P/3204+A1(L)
   PX = YY
   GO TO 12
8 CONTINUE
   YY=A2(4)
   DO 10 I=1,3
      L=4-I
      10 YY=YY*P/3204+A2(L)
      PX = YY*P/(3204-P+YY*P)
12 PPI = ALOG(PX)
13 CONTINUE
   IMAX=14
   IF((PX.LT.PP(1))) PX = PP(1)
   J=1
14 IF(PX.LE.PP(J)) GO TO 16
      J=J+1
   GO TO 14
16 DO 22 I=1,IMAX
      IF(I.EQ.1) CORAB(1,4)=1.0
      IF(I.EQ.IMAX) CORAB(IMAX,4)=1.0/PX
      IF((I.EQ.1).OR.(I.EQ.IMAX)) GO TO 22
      M=I-1
      IF(J.GT.2) GO TO 15
      WV=ZLINE(ALOG(PP(1)),ALOG(COEF(M,1)),ALOG(COEF(M,2)),ALOG(COEF(M,3)),ALOG(COEF(M,4)),PP(I),PP(I),PP(I),PP(I),PP(I))
      CORAB(I,4)=EXP(WV)
      GO TO 22
15 IF(I.EQ.8) GO TO 17
      IF((J.LT.4).OR.(J.GT.5)) GO TO 17
      ZN=EXP(ZNN(1,M)+ZNN(2,M)+PPI+ZNN(3,M)+PPI+PPI)
      GO TO 19
17 IF(J.LE.7) GO TO 18
      WV = ZLINE(ALOG(PP(7)),ALOG(COEF(M,7)), 0.0,0.0,PPI)
      CORAB(1,4)=EXP(WV)
      GO TO 22
   GO TO 22
FILE: COBRASC FORTRAN A

CONVERSATIONAL MONITOR SYSTEM

18 IF(J.EQ.1) J=2
ZN1 = ALOG((COEF(M,J-1) - 1.0 + QQ(I))*PP(J-1))/ALOG(QQ(I))
ZN2 = ALOG((COEF(M,J) - 1.0 + QQ(I))*PP(J))/ALOG(QQ(I))
ZN = ZLINE(ALOG(PP(J-1)),ALOG(ZN1)),ALOG(PP(J)),ALOG(ZN2),PP1)
ZN = EXP(ZN)
19 CORAB(I,4) = 1.0 - QQ(I) + (QQ(I)**2)*ZN)/PX
22 CONTINUE

C
C SET CORAB MATRIX USING MASS VELOCITY CORRECTION FACTOR.
IND1=1,0
BIT=0.15
30 IF(PPI.LT.X(IND1+1)) GO TO 32
IND1=IND1+1
GO TO 30
32 IND2=0.0
DO 34 K=2,4
34 IF((PPI.GT.(X(K)-BIT)).AND.(PPI.LT.(X(K)+BIT))) IND2=K
DO 38 I=1,IMAX
N=1-1
DO 38 J=1,7
IF(I.EQ.1).AND.(J.LT.7) GO TO 35
IF(I.EQ.IMAX).AND.(J.LT.7) GO TO 35
M=J-1
IF(J.EQ.1) M=J
IF(J.EQ.7) GO TO 37
YY=ZLINE(X(IND1),DAT(N,IND1,M),X(IND1+1),DAT(N,IND1+1,M)
1),PPI)
IF(IND2.EQ.0.0) GO TO 36
X1=X(IND2)-BIT
X2=X(IND2)+BIT
Y1=ZLINE(X(IND2-1),DAT(N,IND2-1,M),X(IND2),DAT(N,IND2,M),X1)
Y2=ZLINE(X(IND2),DAT(N,IND2,M),X(IND2+1),DAT(N,IND2+1,M),X2)
YY=0.5*(ZLINE(X1,Y1,X2,Y2,PPI)+YY)
GO TO 36
35 YY=1.0
36 CORAB(I,J)=YY*CORAB(I,4)
GO TO 38
37 CORAB(I,J)=1.0
38 CONTINUE
RETURN

C
C INTERPOLATE IN CORAB ARRAY TO FIND MULTIPLIER.
G=G+W*1.0E-06
IF(G.GE.1000.0) G = 1000.0
IND1=1
40 IF(Q.LE.QQ(IND1)) GO TO 44
IND1=IND1+1
GO TO 42
42 CONTINUE
IND2=1
46 IF(G.LT.GG(IND2)) GO TO 48
IND2=IND2+1
GO TO 46
48 G1=GG(IND2)
G2=GG(IND2-1)
GO TO 46
50 CONTINUE
RETURN

C
C
G3=G
IF(G.LE.1.0) GO TO 50
G1=1.0/G
G2=1.0/G2
G3=1.0/G3
50 CONTINUE
C
Z11 = CORAB(IND1-1,IND2-1)
Z12 = CORAB(IND1-1,IND2-1)
Z21 = CORAB(IND1-1,IND2-1)
Z22 = CORAB(IND1-1,IND2-1)
X1 = QQ(IND1-1)
X2 = QQ(IND1-1)
XX = Q
FMULT = ZRECT(X1,X2,G1,G2,Z11,Z12,Z21,Z22,XX,G3)
PPI=ALOG10(EXP(PPI))
RETURN
1001 FORMAT(' PRESSURE = ', 1PE15.4, ' OUTSIDE VALID RANGE OF 11.43 TO 3204 PSIA')
END
FUNCTION BVOID(I,J)
BVOID CALCULATES THE BULK VOID FRACTION GIVEN A QUALITY.
IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA,ELEV,EG,FG,FERROR,FLO,GC,GRID,HSURF,HG,IK,JK,JK,KG,
COMMON /COBRA2/ AA(4),AF(7),AF(10,10),AV(7),AXIAL(30),
COMMON /COBRA3/ MA,MC,MG,MN,MR,MS,MX,
LOGICAL KIJC,MH,MN,MR,MS,MX,
COMMON /COBRA4/ AB(4),AX(30),CC(4),CLAD(2),CFUEL(2),DFUEL(2),
COMMON /COBRA5/ GAPX(10),GFACT(10,10),GRIDX(10),HGAP(2),HHF(30),HHG(30),
IH(10),IGRID(10),KCLAD(2),KFUEL(2),KFUEL(30),NCH(10),NGAP(9),
PP(30),RCLAD(2),RFUEL(2),SSIGMA(30),TCLAD(2),UF(30),
VF(30),VVG(30),XQUAL(30),Y(30),Z(30),
XX(30)
FILE: COBRA3C FORTRAN A CONVERSATIONAL MONITOR SYSTEM

$MCFR, $MCFRC, $MCFRR, $NTYPE, $NWRAP, $NWRPS, $SP, $PERIM, $PH, COB03310
$PHI, $PRNTC, $PRNTR, $PRNTN, $PW, $PWRF, $QC, $QF, $OPRIM, COB03320
$QUAL, $RADIA, $RHO, $RHOOl, $SP, $ST, $TDUMY, $TINLE, $TROD, COB03330
$U, $SUH, $USAVE, $USTAR, $SV, $VISC, $VISCW, $VP, $VPA, COB03340
$W, $WOLD, $WP, $WSAVE, $X, $XCROS, $SA, $SB, $XPOLD, COB03350
C COMMON DATA(1), LOGICAL LDAT(1), INTEGER IDAT(1)
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))

XP=$DATA($QUAL+I)
BVOID = 0.
IF(XP.LE.0.) RETURN

DATA($ALPHA+I) =0.
IF(J3.EQ.0) DATA($ALPHA+I) =XP*VG/((1.-XP)*VF+XP*VG)
IF(J3.EQ.1) DATA($ALPHA+I) =(0.833+.167*XP)*XP*VG/((1.-XP)*VF+XP*VG)
IF(J3.EQ.2) GO TO 85
IF(J3.EQ.5) DATA($ALPHA+I) =XP*VG/((1.-XP)*VF+XP*VG)
IF(J3.NE.6) GO TO 90
DATA($ALPHA+I) =AV(1)

XX=$DATA($QUAL+I)
DO 80 K=2,NV
DATA($ALPHA+I) =DATA($ALPHA+I) +AV(K)*XX
80 XX =DATA($QUAL+I)*XX
GO TO 90

SLP = 0.4 + 0.6*((0.4+XP*(VG/VF-0.4))/(0.4+0.6*XP))**0.5
DATA($ALPHA+I) = XP*VG/(SLP*(1.0-XP)*VF+XP*VG)
BVOID = DATA($ALPHA+I)
RETURN
END

SUBROUTINE CALC
C IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX, COB03360
1 ELEV, FERROR, FLO, FTM, GC, GK, GRID, HSURF, HF, COB03370
2 HFG, HG, H2, I3, IERROR, IOP3, ITERAT, J1, J2, COB03380
3 J3, J4, J5, J6, J7, KDEBUG, KF, KIJ, COB03390
4 NAFACT, NARAMP, NAX, NAXL, NBBC, NCHAN, NCHEF, NDX, NF, COB03400
5 NGAPS, NGRID, NGRIDT, NGTYPE, NXL, NK, NODES, NODESF, NPROP, COB03410
6 NRAMP, NRCO, NSCBC, NV, NVISCW, PI, PITCH, POWER, PREF, COB03420
7 QAX, RHOF, RHOG, SIGMA, SL, TF, TFLUID, THETA, THICK, COB03430
8 UF, VF, VFG, VG, Z, COB03440
C COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), COB03450
1 AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), COB03460
2 GAPXL(10), GFACT(9,10), GRIDXL(10), HGRID(2), HGRIDR(2), HGRIDR(2), KFUEL(2), KFUEL(2), KFUEL(2), KFUEL(2), COB03470
3 IGRID(10), KCLAD(2), KCLAD(2), KFUEL(2), KFUEL(2), KFUEL(2), NGRID(10), NGAP(10), COB03480
4 PP(30), RCLAD(2), RFFUEL(2), SIGMA(30), TCLAD(2), UUF(30), COB03490
5 VVF(30), VVG(30), XQUAL(30), Y(30), TT(30), COB03500
C
FILE: COBRA3C FORTRAN A

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LOGICAL GRID
REAL KIJ, KF, KKF, KCLAD, KFUEL

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX
COMMON/LINK4/IFRM, IHTM, IPROP, NCC, NCF, NDM1, NDS, NGP
COMMON/LINK2/CROSS(6), DATE(2), FG(30), FH(30), FP(30), FQ(30), IM(9), JM(9), OUTPUT(10), PRINT(12), TEXT(17), TIME(3), YG(30), YH(30), YP(30)
COMMON/LINK3/DXX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MAXT
COMMON/TSAVER/TSTART

COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1),IDAT(1),LDAT(1))
EQUIVALENCE (NCHAN,NCHANL)

COMMON/LINK2/CROSS(6), DATE(2), FG(30), FH(30), FP(30), FQ(30), IM(9), JM(9), OUTPUT(10), PRINT(12), TEXT(17), TIME(3), YG(30), YH(30), YP(30)
COMMON/LINK3/DXX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MAXT
COMMON/TSAVER/TSTART

START SUBCHANNEL FLOW AND ENTHALPY CALCULATIONS.

400 KT = NSKIPT
IPILE = J7
DT = SAVEDT
DO 401 J=1,NDXP1
DATA($X+J)=DX*FLOAT(J-1)
NDTP1 = NDT+1
CALL PRNTIM (0)

FILE: COBRA3C FORTRAN A
CC TIMING IS EXPECTED TO RETURN CPU TIME
CC (IN HUNDREDTHS OF A SECOND) AS AN INTEGER
CALL TIMING(ICPU)
TSTART=FLOAT(ICPU)/100.
CC INITIALIZE FUEL ROD VARIABLES IF NEW FUEL ROD MODEL USED
IF (IFRM.EQ.0) GO TO 409
CALL INITRC
C
START TRANSIENT DO LOOP
409 DO 500 NT=1,NDTP1
CALL PRNTIM (1)
IERROR = 0
IF (IQP3.GT.1) GO TO 710
CALL QPR3(NCHANL, KASE,TEXT,DATE,TIME,DATA($X+1))
710 CONTINUE
DT = SAVEDT
IF (NT.EQ.1) DT = 1.E+10
ETIME = DT*FLOAT(NT-1)
C ESTABLISH CHANNEL BOUNDARY CONDITIONS AND FORCING FUNCTION VALUES.
C SET TRANSIENT PRESSURE
DUMY = 1.
IF(NP.GT.1)
1CALL CURVE (DUMY,ETIME,FP,YP,NP,IERROR,1)
IF (IFERROR.GT.1) GO TO 505
PREF = DUMY*PEXIT
CALL PROP(1,1)
IF (IERROR.GT.1) GO TO 505
C SET TRANSIENT INLET ENTHALPY
DUMY = 1.
IF(NH.GT.1)
1CALL CURVE (DUMY,ETIME,FH,YH,NH,IERROR,1)
IF (IFERROR.GT.1) GO TO 505
DO 402 I=1,NCHANL
DATA($HOLD+I)=DATA($H+I)
DATA($H+I)=DATA($FINLE+I)*DUMY
IF(IN.EQ.1 .OR. IN.EQ.3)
1CALL CURVE(DATA($H+I),DATA($TINLE+I)*DUMY,HHF,TT,NPROP,IERROR,1)
402 CONTINUE
C SET TRANSIENT INLET FLOW
DUMY = 1.
IF(NG.GT.1)
1CALL CURVE (DUMY,ETIME,FG,YG,NG,IERROR,1)
IF (IFERROR.GT.1) GO TO 505
IF((IPILE.EQ.2) .AND. (NT.GT.1)) GO TO 404
C STEADY STATE AND PWR.
DO 403 I=1,NCHANL
DATA($FOLD+I)=DATA($F+I)
403 DATA($F+I)*DATA($FINLE+I)*DUMY
GO TO 407

C BWR. UPDATE INLET FLOW FOR DUMY AND LAST TRANSIENT.

404 SUMSS = 0.0
SUMTR = 0.0
DO 405 I=1,NCHANL
SUMSS = SUMSS + DATA($FINLE+I)
405 SUMTR = SUMTR + DATA($F+I)
WV = DUMY*SUMSS/SUMTR
DO 406 I=1,NCHANL
DATA($FOLD+I) = DATA($F+I)
406 DATA($F+I) = WV*DATA($F+I)
407 CONTINUE

C SET TRANSIENT POWER
DUMY = 1.
IF(NQ.GT.1)
1 CALL CURVE (DUMMY,ETIME,FQ,YQ,NQ,IERROR,1)
IF(IERROR.GT.1) GO TO 505
POWER = DUMY

C SET BAROCZY PRESSURE DROP ARRAY
IF (U4.EQ.2) CALL BAROCZ(1,PREF,0.0,0.0,RUB,PPI)

C BEGIN ITERATION TO OBTAIN SOLUTION.
DO 430 NN=1,NTRIES
CALL PRNTIM (2)
DO 410 I=1,NCHANL
410 IDAT($NWRAP+I) = IDAT($NWRPS+I)
ITERAT = NN
CALL SCHEME(JUMP,DATA($AAA+1))
CALL PRNTIM (6)
IF(IERROR.GT.1) GO TO 440
CALL TIMING(ICPU)
MTIME = IFIX(FLOAT(ICPU)/100.-TSTART)
IF(MTIME.LT.MAXT) GO TO 429
WRITE(I3,102) GO TO 440
429 IF(JUMP.LT.1 .OR. JUMP.GT.3)
GO TO 505
GO TO (430,440,440),JUMP
430 CONTINUE
WRITE(I3,22) NTRIES
IERROR = 1

C SET CONDITIONS FOR NEXT TIME STEP
440 IF(JUMP.EQ.3) GO TO 441
CALL PRNTIM (7)
IF(NJUMP.GT.0) JUMP = 3
IF(NJUMP.NE.2) GO TO 441
REWIND 18
WRITE(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)
END FILE 18
REWIND 18
DO 445 J=1,NDXP1
   DO 443 K=1,NK
      DATA($WOLD+K+MG*(J-1))=DATA($W +K+MG*(J-1))
      CONTINUE
   DO 444 I=1,NCHANL
      DATA($FOLD +I+MC*(J-1))=DATA($F +I+MC*(J-1))
      DATA($HOLD +I+MC*(J-1))=DATA($H +I+MC*(J-1))
      DATA($RHOOL +I+MC*(J-1))=DATA($RHO +I+MC*(J-1))
      CONTINUE
   CALL EXPRIN
   IF(KT.GE.NSKIPT) KT=0
   IF(ISAVE.GT.0) GO TO 505
   IF(IERROR.GT.0) GO TO 505
   500 CONTINUE
   CALL PRNTIM(8)
END OF PROBLEM, LOOK FOR NEW CASE
GO TO 990
505 WRITE(I3,55) SIGNAL(IERROR)
      WRITE(I3,55) SIGNAL(ISAVE)
990 RETURN
C
END OF PROBLEM, LOOK FOR NEW CASE
GO TO 990
505 WRITE(I3,55) SIGNAL(IERROR)
      WRITE(I3,55) SIGNAL(ISAVE)
990 RETURN
C
22 FORMAT (23HOFAILURE INTEGRATION IN I4,17H ITERATIONS AT X=
1,F8.4,21HO)
55 FORMAT (10H ERROR IN ,A6, ' ** CALCULATION FOR THIS CASE STOPPED')
102 FORMAT (///' * * * ABNORMAL EXIT THROUGH MAXIMUM TIME * * *'//)
C
SUBROUTINE CARDS1(PP,TT,VVF,VVG,HHF,HHG,UUF,KKF,SSIGMA,N1,I2)
DIMENSION PP(1),TT() VF(1),VV(1) VG(1),HHF(1),HHG(1),UUF(1) KKF(1),
    I SSIGMA(1)
REAL KKF
C
12=5
C
MEKIN NEW PHYS PROP FROM CARDS OR POLYNOMIALS
IF (N1.LE.0) GO TO 6
READ(I2,4) (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HHG(I),UUF(I),KKF(I),
1 SSIGMA(I),I=1,N1)
4 FORMAT (I5,2F10.0)
RETURN
C
P2 TO BE HIGHER THAN OPERATING PRESSURE
C
N=1,PH TO BE LOWER THAN P FOR H-IN
C
N=2,PH TO BE LOWER THAN H-IN.
C
N1=NUMBER OF PRESSURE INTERPOLATION STEPS
6 READ(I2,8) N,PH,P2,N1
8 FORMAT(I5,2F10.3,15)
P1=PH
IF(N.EQ.1) GO TO 10
   P1=10.0
   IF(PH.LT.161.3) GO TO 10
   H=0.01*PH;
   P1=6.0*H*H*H*(H-1.35)/(H-0.35)
10 IF(N1.LT.3) N1=3
 A=(P2-P1)/(N1-1)
 DO 12 I=1,-N1
 P=P1+(I-1.0)*A
 PP(I)=P
 TT(I)=SATTEM(P)
 RL=ROLIQ(P)
 VVF(I)=I.0/RL
 RG=ROVAP(P)
 VVG(I)=1.0/RG
 H=HLIQ(P)
 HHF(I)=H
 HHG(I)=HVAP(P)
 CALL HAPROP(P,H,CP,UUF(I),KKF(I))
 CALL SURTEN(P,RL,RG,SSIGMA(I))
 12 CONTINUE
 RETURN
 END

SUBROUTINE CARD20(NOPRIN)
 IMPLICIT INTEGER($)
 COMMON /COBRA1/ ABETA ,AFLUX ,ATOTAL,BBETA ,DIA ,DT ,DX
 COMMON /COBRA2/ AA(4) ,AF(7) ,AFACT(10,10) ,AV(7) ,AXIAL(30)
 COMMON /COBRA3/ MA ,MC ,MG ,MN ,MR ,MS ,MX
 FILE: COBRA3C FORTRAN A
A SW $WOLD $W $WSAVE $X $XCROS $S$A $SB $XPOLD

COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))

COMMON/LINK3/DXX,ETIME,G1N,H1N,I8,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
1 ND,NDXP1,NUELT,NG,NJUMP,NOUT,NP,NPCHAN,NPNODE,HPNOD,NQ,NR,
2 NSKIP,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TIME,ZZ
DIMENSION NTHBOX(25,25)
DIMENSION CARD(20)

SIMULATE NEUTRONIC INPUT TO MEKIN ITH0
WRITE (13,1010)
DO 2 ND1 = 1,20
DO 2 ND2 = 1,20
2 NTHBOX(ND1,ND2) = 0
NTHBXX = 0
READ (12,1001) CARD, IMAP, ND1X, ND2X
WRITE (13,1011) CARD
IF (ND1X.LE.25) .AND. (ND2X.LE.25) ) GO TO 4
WRITE (13,1012) ND1X,ND2X
STOP
IMAP = 1. RECTANGULAR MATRIX
DO 8 ND2 = 1,ND2X
READ (12,1001) CARD, ISTART, IFIN
WRITE (13,1013) ND2,CARD
DO 8 ND1 = 1,ND1X
IF ( (ND1.LT.ISTART) .OR. (ND1.GT.IFIN) ) GO TO 12
NTHBXX = NTHBXX+1
NTHBOX(ND1,ND2) = NTHBXX
12 CONTINUE
GO TO 18
IMAP = 2. GIVE START AND END OF EACH ROW.
10 DO 12 ND2 = 1,ND2X
READ (12,1001) CARD, ISTART, IFIN
WRITE (13,1013) ND2,CARD
DO 12 ND1 = 1,ND1X
IF ( (ND1.LT.ISTART) .OR. (ND1.GT.IFIN) ) GO TO 12
NTHBXX = NTHBXX+1
NTHBOX(ND1,ND2) = NTHBXX
12 CONTINUE
GO TO 18
IMAP = 3. READ NTHBOX
14 MAXRD = 14
MP1 = MAXRD+1
MORE = ND1 - MAXRD
DO 16 ND2 = 1,ND2X
READ (12,1001) CARD, (NTHBOX(ND1,ND2),ND1=1,MAXRD)
WRITE (13,1014) ND2,CARD
IF (MORE.LE.0) GO TO 15
READ (12,1001) CARD, (NTHBOX(ND1,ND2),ND1=MP1,ND1X)
WRITE (13,1014) ND2, CARD
DO 16 ND1=1,ND1X
IF (NTHBOX(ND1,ND2).GT.NTHBXX) NTHBXX=NTHBOX(ND1,ND2)
16 CONTINUE
C
C READ HEAT FLUX PARAMETERS.
C
18 READ (12,1003) CARD, N1, AFLUX
WRITE (13,1015) CARD
IF (N1.GT.1) GO TO 22
IQP3 = N1
DO 20 I=1,NTHBXX
20 DATA($RADIA+I) = 1.0
GO TO 24
22 NAX = N1
CALL READIN(8,NAX,Y,AXIALCARD,2)
CALL READIN(9,NTHBXX,DATA($RADIA+1),CARD,CARD,1)
C
C
24 READ (12,1004) CARD,Z, NDX, NDT, TTIME
WRITE (13,1016) CARD
C
CALL ITHO(NTHBOX,NTHBXX,ND1X,ND2X)
IF (NOPRIN.EQ.O) CALL TIDY
CALL PRECAL
RETURN
C
1001 FORMAT(20A4, T1, 1415)
1003 FORMAT(20A4, T1, I5, 13E5.0)
1004 FORMAT(20A4, T1, E5.0, 215, 10E5.0)
1010 FORMAT(1H1, 42X, 'COBRA INPUT DATA', /, 43X,
'----- ------ ', //, ' NB. DATA READ FROM CARD20 WOULD BE READ',
' 2D OR SET WITH THE NEUTRONICS DATA IN MEKIN', //, ' CARD IMAGES',
'---- ------ ', 32X, '0....*....1....*.......
...... 3..',
'*....4....*
*.... 5...*............7....*....8')
1011 FORMAT(' IMAP ND1X ND2X', 14X, '***', 20A4, '*** CARD20')
1012 FORMAT(' INPUT DATA ERROR IN CARD20. ND1X, ND2X =', 215,
'I IE GREATER THAN 25 FOR EACH ALLOWED')
1013 FORMAT(' ND2=',I3, ' ISTART IFIN', 9X, '***', 20A4, '*** CARD20')
1014 FORMAT(' ND2=',I3, ' NTHBOX', 14X, '***', 20A4, '*** CARD20')
1015 FORMAT(' NAX AFLUX', 19X, '***', 20A4, '*** CARD20')
1016 FORMAT(' Z NDX NOT TTIME', 13X, '***', 20A4, '*** CARD20')
C
END
FUNCTION CHF1(N,I,J)
C
IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX
1 ELEV, FERROR, FLO, FM, GC, 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, NVISCH, PI, PITCH, POWER, PREF
7 QAX, RHOF, RHOG, SIGMA, SL, TF, TFLUID, THETA, THICK
8 UF, V, VFG, VG, Z
C

COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), XQUAL(30), Y(30), TT(30)
COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX, COB07840
LOGICAL GRID
REAL KI, KF, KKF, KCLAD, KFUEL
COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX, COB07840
LOGICAL GRID
REAL KI, KF, KKF, KCLAD, KFUEL
COMMON DATA(1)
LOGICAL IDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))
COMMON DATA(1)
LOGICAL IDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))
DATA A0, B0, A1, A2, A3, A4, A5, A6, A7, A8, A9 / 1.15509, 4.8844, 1.3702E+8, 2.1289E-3, 0.83040, 0.68479E-3, 4.5756E+4, 1.0996E-2, 2.07116, 0.20729E-3, 547.49
REAL KD
DATA A21, A22, A23, KD / 2.9840, 7.82293, 0.457758, 1.02508
QA=DATA($A+1)
QP=DATA($PERIM+1)
QF=DATA($F+1)+MC*(d-1)
SUM=0.
DO 5 JJ=JS, J
SUM=SUM+DATA(SFLUX+N+MR*(dd-1))
XX=(QH-HF)/HFG
1 10)
C AXIAL FLUX CORRECTION FACTOR
FAXIAL = 1.
IF(J, EQ.1) GO TO 10
C=A21*(1.-XX)**A22/(RAT*.0036)**A23
SUM = 0.
JS = 2
DO 5 JU=JS, J
SUM=SUM+DATA($FLUX+N+MR*(JU-1))*(EXP(C*DATA($X+JU))-
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FUNCTION CIJ(K,J)

C THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE MAJOR SUBROUTINES OF COBRA-IIIC.

C COMMON /COBRA1/ ABETA ,AFLUX,ATOTAL,BBETA,DIA,DT,DX
C COMMON /COBRA2/ AA(4),AF(7),FACT(10,10),AV(7),AXIAL(30),
C COMMON /COBRA3/ MA,MC,MG,MN,MR,MS,MX
C COMMON DATA(1)
C FILE: COBRA3C FORTRAN A PAGE 016

1 EXP(C*DATA($X+J-1))) EXP(-C*DATA($X+J))/DATA($FLUX+N+MR*(J-1))/
1 (1-EXP(-C*(DATA($X+J)-DATA($X+J-1))))*KD
10 CHF1 = CHF1/FAXIAL
RETURN
END

FUNCTION CIJ(K,J)

C THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE MAJOR SUBROUTINES OF COBRA-IIIC.

C COMMON /COBRA1/ ABETA ,AFLUX,ATOTAL,BBETA,DIA,DT,DX
C COMMON /COBRA2/ AA(4),AF(7),FACT(10,10),AV(7),AXIAL(30),
C COMMON /COBRA3/ MA,MC,MG,MN,MR,MS,MX
C COMMON DATA(1)
C FILE: COBRA3C FORTRAN A PAGE 016
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($RHO+JJ+MC*(-1))
WMIN=ABS(DATA($W+K+MG*(J-1)))
IF(WMIN.LT..001) WMIN=.001
CIJ=KI*W*MIN*O.5/GC/RSTAR/GGG/GGG
CIJ=CIJ/FACTO**2
RETURN
1000 IERROR = 18
RETURN
END

SUBROUTINE CURVE(FX,X,F,Y,N,J,ISAVE)
DIMENSION F(30), Y(30)
FX - QUANTITY TO BE FOUND
X - INDEPENDENT VARIABLE
F - INPUT ARRAY FOR THE ORDI外

COMMON/INDSAV/I
DATA 13/6/
1 FORMAT(49H TABULAR LOOKUP FAILED IN SUBROUTINE CURVE, FX = E12.6, COB09020
1 6H X = E12.6 / (10E12.4))
IF(ISAVE.LT.1 .OR. ISAVE.GT.2) GO TO 70
GO TO (10,50),ISAVE
DO 20 I=1,N
IF(I.EQ.N) GO TO 40
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,IERROLR,LMAX,MID,UL,X,B,NK)
DIMENSION UL(NK,1),X(),B(1)
SIMPLIFIED VERSION OF DECOMP WITH NO PIVOTING.
STORE DIAGONAL BAND OF AAA MATRIX. POSITION (K,L) IN SQUARE
ARRAY BECOMES (K,(MID-K+L)) IN NEW ARRAY.
N = NN
IF(N.EQ.1) RETURN
DATA 13/6/
NM1 = N-1
DO 17 K = 1,NM1
PIVOT = UL(K,MID)
KP1 = K+1
LIMIT = MINO(N,(K+MID-1))
DO 16 I = KP1,LIMIT
KK = MID+K-1
EM = -UL(I,KK)/PIVOT
UL(I,KK) = EM
IF (EM) 20,16,20
20 DO 21 J=KP1,LIMIT
 d1 = MID-I+J
 JK = MID-J+I
 21 UL(I,JI) = UL(I,JI) + EM*UL(K,JK)
16 CONTINUE
17 CONTINUE
C IF (UL(N,MID)) 19,18,19
18 WRITE((I3,112)) ((UL(K,L),L=1,NN),K=1,NN)
100 FORMAT(/E14.8)
113 FORMAT(54'HOSINGULAR MATRIX IN DECOMPOSE. ZERO DIVIDE IN SOLVE. )
 IERROR = 12
19 RETURN
END
SUBROUTINE DOY(A)
DIMENSION A(2),DATIM(5)
CALL WHEN(DATIM)
A(1)=DATIM(1)
A(2)=DATIM(2)
RETURN
END
SUBROUTINE EXPRIN
IMPLICIT INTEGER
COMMON /COBRA1/ ABETA,ELEV,HFG,HF,HSURF,ICLAD,ID2,IN, IERROR,IPQ3,IJP2,J1,J7, KSURF,KDEBUG,KF,KIJ, NBBC, NCH, NCHF,NCHXL, NK, NODES,NODESF,NPROP, NCBC, NCNL, NCX, NCH(10), NGAP(9), NSIGMA, NTYPE, NP, RX(2), TAX, TFLUID, THETA, THICK
COMMON /COBRA2/ AA(4), AF(7), AFAC(10,10), AV(7), AXIAL(30),
 AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
 GAPXL(10), GRIDXL(10), HGA(2), HHF(30), HG(30),
 IGRID(10), KCLAD(2), KFUEL(2), KHF(30), NCH(10), NGAP(9),
 PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TCLAD(2), UF(30),
 VVF(30), XQUAL(30), Y(30), TT(30)
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LOGICAL GRID
REAL KIJ, KF, KKF, KCLAD, KFUEL

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX
1 $SS $A $SAA $SAC $SALPHA $SAN $SANSE $SB
1 $SCHA, $SCHF, $SCON, $SCOND, $SCP, $SD, $SDC, $SDFX
2 $SDHX, $SHDYD, $SHDYN, $SDIST, $SDPDX, $SDPK, $SDFUR, $SDR, $SF
3 $FACTO, $SFDIV, $SFINL, $SFLUX, $SFMULT, $SFOLD, $FSPL, $FXFLO
4 $GAFF, $GAFFN, $GAP, $SHFILM, $SHINLE, $SHOLD, $SHPERI, $SIDARE
5 $SIDUE, $SIRDAP, $SIK, $SJBOIL, $SK, $SLC, $SLENGT, $SLOCA, $SLR
6 $SMCHFR, $SMCFRC, $SMCFR, $STYE, $SNR, $SNWRP, $SP
7 $SFI, $SPRNTC, $SPRNTI, $SPRN, $SPW, $SPRF, $SQC, $SF
8 $SQUAL, $SRADIA, $SRAD, $SRH, $SRHOLD, $ST, $STDUMY, $STINLE, $STRAD
9 D $SUH, $SUAVE, $SUAVE, $SUAVE, $SUAVE, $SUAVE, $SUAVE, $SUAVE, $SUAVE, $SUAVE
A $SW $SWOLD, $SWAVE, $SX $SACROS, $SSA, $SSB, $SXPLOD
B
C
COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))

EQUIVALENCE (NCHAN, NCHANL)

COMMON/LINK2/CROSS(6), DATE(2), FG(30), FH(30), FP(30), FQ(30), IM(9),
1 JM(9), OUTPUT(10), PRINT(12), TEXT(17), TIME(3), YG(30), YH(30), YP(30),
2 YQ(30)

COMMON/LINK3/DDX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MAXT,
1 NDT, NDXP1, NFUEL, NG, NH, NJUMP, NOUT, NP, NPCHAN, NPNODE, NQ, NR,
2 NSKIP, NSKIPX, NTRIES, PEXIT, PHTOT, SAVEDT, TIN, TTIME, ZZ

DIMENSION CHFCOR(5), CHFLBL(5)
DATA CHFCOR /4HAW2, 4HW-3, 4HC-4, 4HB-VC/
DATA CHFLBL /4HDNBR, 4HDNBR, 4HCHFR, 4HCHFR, 4HCHFR/
DATA H1, H2, H3, H4, H5, /1H, 1H, 1H, 1H, 1H/, H6, H7, H8 /1H, 1H, 2HT/

C
PRINT OUTPUT (COBRA CARDS MAIN1822 - MAIN2331)
ISAVE = IERROR
IERROR = 0
IF(NCHF.GT.0 .AND. ISAVE.EQ.0) CALL CHF(3,NDXP1)
KT = KT+1
IF(KT.LT.NSKIP) GO TO 500
CALL TOD(TIME)

C
PRINT RESULTS
IF(ETIME.GT.0) GO TO 457

C
COMPUTE MASS AND ENERGY BALANCE
FLOIN = 0.
FLOUT = 0.
ENGINE = 0.
ENGOUT = 0.
NDXP1 = NDX+1
DO 448 I=1, NCHANL
FLOIN = FLOIN + DATA($F +I)
FLOUT = FLOUT + DATA($F +I+MC*(NDXP1-1))
ENGINE = ENGINE + DATA($F +I)*DATA($H+I)

!
ENROUT = ENROUT + DATA($F + I + MC*(NDXP1-1))* COB10460
1 DATA($H + I + MC*(NDXP1-1)) COB10470
FLOERR = FLOOUT - FLOIN COB10480
ENGADD = AFLUX*Z*PHIOT/.0036 COB10490
ENGERR = ENROUT - ENGIN - ENGADD COB10500
WRITE(13,99) KASE, TEXT, DATE, TIME, FLOIN, ENGIN, FLOOUT, ENGADD, FLOERR, COB10510
ENGOUT, ENGERR COB10520

C PREPARE CHANNEL EXIT SUMMARY
J = NDXP1
DO 450 I=1, NCHANL
OUTPUT(1) = TF
IF(DATA($H+I+MC*(J-1)).LT.HF) CALL CURVE(OUTPUT(1), COB10570
1 DATA($H+I+MC*(J-1)), TT, HMF, NPROP, IERROR, 1)
OUTPUT(2) = (DATA($H+I+MC*(J-1))-HF)/HFG COB10580
IF(OUTPUT(2).LT.0.) OUTPUT(2) = 0.
OUTPUT(3) = (RHOF-DATA($RHO+I+MC*(J-1)))/(RHOF-RHOG) COB10610
IF(OUTPUT(3).LT.0.) OUTPUT(3) = 0.
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+
1 OUTPUT(2), OUTPUT(3), DATA($F + I + MC*(J-1)), COB10650
2 OUTPUT(4) COB10660
450 CONTINUE COB10670
IF(IERROR.GT.1) GO TO 505 COB10680
C COMPUTE BUNDLE AVERAGED RESULTS
452 WRITE(13,25) KASE, TEXT, DATE, TIME
WRITE(13,101)
WRITE(13,82)
DO 456 J=1, NDXP1, NSkipX
SAVE1 = 0.
SAVE2 = 0.
SAVE3 = 0.
SAVE4 = 0.
DO 454 I=1, NCHANL
SAVE1 = SAVE1 + DATA($P+I+MC*(J-1))*DATA($AN+I) COB10700
SAVE2 = SAVE2 + DATA($H+I+MC*(J-1))*DATA($F+I+MC*(J-1)) COB10720
SAVE3 = SAVE3 + DATA($F+I+MC*(J-1))
SAVE4 = SAVE4 + DATA($RHO+I+MC*(J-1))*DATA($AN+I) COB10740
OUTPUT(1) = DATA($X+J)*12.
OUTPUT(2) = SAVE1/ATOTAL/144.
OUTPUT(3) = SAVE2/SAVE3 COB10760
OUTPUT(4) = TF
IF(OUTPUT(3).LT.HF) CALL CURVE(OUTPUT(4), OUTPUT(3), TT, HMF, NPROP, COB10780
1 IERROR, 1)
IF(IERROR.GT.1) GO TO 505 COB10790
OUTPUT(5) = SAVE4/ATOTAL COB10800
OUTPUT(6) = 0.
IF(OUTPUT(6).LT.0.) OUTPUT(6) = (OUTPUT(6)-HF)/HFG COB10820
OUTPUT(7) = 0.
OUTPUT(8) = SAVE3 COB10840
OUTPUT(9) = SAVE3/ATOTAL/.0036 COB10860
WRITE(13,81) (OUTPUT(II);II=1,9) COB10870
456 CONTINUE COB10880
IF(IERROR.GT.1) GO TO 505 COB10890
C PRINT CHANNEL AND ROD RESULTS AS DEFINED BY OUTPUT OPTIONS COB11000
DO 460 JJ=1,NPCHAN
   I=IDAT($PRNTC+JJ)
   WRITE(I3,25) KASE, TEXT, DATE, TIME
   WRITE(I3,80) ETIME, I
   WRITE(I3,82)
   DO 458 J=I,NDXP1,NSKIPX
      OUTPUT(1)=DATA($X+J)*12.
      OUTPUT(3)=DATA($H+I+MC*(J-1))/144.
      OUTPUT(4) = TF
      IF(DA
      DATA($H+I+MC*(J-1)).LT.HF)CALL CURVE(OUTPUT(4),
      1 DATA($H+I+MC*(J-1)),TT,HHF,NPROP,IERROR,1)
      IF(IERROR.GT.1) GO TO 505
      OUTPUT(5)=DATA($RHO+I+MC*(J-1))
      OUTPUT(6) = 0.
      IF(DATA($H+I+MC*(J-1)).LT.HF) OUTPUT(6)=
      1 DATA($H+I+MC*(J-1))-HF)/HFG
      OUTPUT(7) = 0.
      IF(DATA($RHO+I+MC*(J-1)).LT.RHOF) OUTPUT(7)=(RHOF-
      1 DATA($H+I+MC*(J-1)).LT.RHOF) /DATA($X+J)*.0036
      WRITE(I3,81) (OUTPUT(II),II=1,9)
   CONTINUE
   CONTINUE
   IF(NOUT.LT.1) GO TO 499
   IF(NOUT.EQ.2) GO TO 470
   DO 465 M=1,NK,10
      MM = M+9
      IF(NK.LE.MM) MM=NK
      WRITE(I3,31)KASE, TEXT, DATE, TIME, H7, (H6,H1,IDAT($IK+K),H2.IDAT($JK+K)),K=M,MM).
      DO 465 J=1,NDXP1,NSKIPX
         XDUMY=DATA($X+J)*12.
         DO 460 II=1,NPNOOE
            I=IDAT($PRNTN+II)
            DATA($TDUMY+II)=
            1 DATA($TROD+I+MN*(N-1+MR*(J-1)))
            DFLUX=DATA($FLUX+N+MR*(J-1))*.0036
            IF(IDAT($CCHAN+N+MR*(J-1)).EQ.0)
            1 DATA($CHFR+N+MR*(J-1)),I
            IDAT($CCHAN+N+MR*(J-1)),(DATA(STDUMY+I),I=1,NPNODE)
      CONTINUE
      IF(NOUT.EQ.1) GO TO 499
      IF(NPROD.LT.1) GO TO 4990
      DO 485 NN=1,NPROD
         N=IDAT($PRNTR+NN)
         NDUMY=IDAT($IDFUE+N)
         IF(NCHF.GT.0) II=NCHF
         WRITE(I3,94) KASE, TEXT, DATE, TIME, ETIME, N, NDUMY, CHFLBL(II),
            1 (H8,IDAT($PRNTN+I),H3,I=1,NPNODE)
      CONTINUE
      IF(NCHF.GT.0)II=NCHF
      WRITE(I3,94) KASE, TEXT, DATE, TIME, ETIME, N, NDUMY, CHFLBL(II),
      1 (H8,IDAT($PRNTN+I),H3,I=1,NPNODE)
      DO 483 J=1,NDXP1,NSKIPX
         XDUMY=DATA($X+J)*12.
         DO 480 II=1,NPNODE
            I=IDAT($PRNTN+II)
            DATA($TDUMY+II)=
            1 DATA($TROD+I+MN*(N-1+MR*(J-1)))
            DFLUX=DATA($FLUX+N+MR*(J-1))*.0036
            IF(IDAT($CCHAN+N+MR*(J-1)).EQ.0)
            1 DATA($CHFR+N+MR*(J-1)),I
            IDAT($CCHAN+N+MR*(J-1)),(DATA(STDUMY+I),I=1,NPNODE)
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IF(NODES.LT.1) WRITE(13,95) XDUMY,DFLUX,DATA($CHFR+N+MR*(J-1),COB11560
1 IDAT($SCCHAN+N+MR*(J-1)),COB11570
483 CONTINUE COB11580
485 CONTINUE COB11590
4990 IF(NCHF.LT.1) GO TO 499 COB11600
1 WRITE(I3,96) KASE,TEXT,DATE,TIME,ETIME,CHFCOR(NCHF),CHFLBL(NCHF) COB11610
3 DO 4995 J=1,NDXP1,NSKIPX COB11620
2 XDUMY=DATA($X+J)*12. COB11630
3 N= IDAT($MCFRR+J) COB11640
4 DFLUX = 0. COB11650
5 IF(N.NE.0) DFLUX=DATA($FLUX+N+MR*(J-1))*.0036 COB11660
6 IF(N.EQ.0) DATA($MCHFR+J)=0. COB11670
7 WRITE(13,97) XDUMY,DFLUX,DATA($MCHFR+J),IDAT($MCFRR+J), COB11680
2 IDAT($MCFRC+J) COB11690
6995 CONTINUE COB11700
499 WRITE(I3,75) ITERAT COB11710
500 CONTINUE COB11720
505 CONTINUE COB11730
RETURN COB11740
C
25 FORMAT(17H1CHANNEL RESULTS / COB11750
1 5H CASEI5,5X17A4, 9H DATE 2A4,7H TIME 2A4,A1/) COB11760
30 FORMAT(F7.1,10F10.5) COB11770
31 FORMAT (6BH1DIVERSION CROSSFLOW BETWEEN ADJACENT CHANNELS, W(I,J),COB11780
1 (LB/SEC-FT). COB11790
1 29H DATE 2A4,7H TIME 2A4,A1) COB11800
75 FORMAT (// 14H ITERATIONS = 14) COB11810
80 FORMAT(F8.5, 9H SECONDS COB11820
1 29H DATA FOR CHANNEL I3/) COB11830
81 FORMAT(F6.1,F12.2,2F12.2,F10.2,2F9.3,F11.4,F12.4) COB11840
82 FORMAT (6H DISTANCE DELTA-P ENTHALPY TEMPERATURE DENSITY COB11850
1 EQUIL VOID FLOW ' (IN.) (PSI) (BTU/LB) (DEG-F) (LB/CU-FT) QUALITY FRACTION (LB/SEC) (MLB/HCOB11860
1 R-FT2)') COB11870
94 FORMAT(17H1CHANNEL RESULTS / COB11880
1 5H CASEI5,5X17A4, 9H DATE 2A4,7H TIME 2A4,A1/) COB11890
96 FORMAT(5H1CASEI5,5X17A4,9H DATE 2A4,7H TIME 2A4,A1// COR11900
1 8H TIVE = F8.5,9H SECONDS COB11910
3 12H, FUEL TYPE 12// COB11920
95 FORMAT(6H DISTANCE FLUX M',A4,' ROD CHANNEL') COB12000
97 FORMAT(8H TIME = F8.5,9H SECONDS COB12010
3 DISTANCE FLUX M',A4,' ROD CHANNEL') COB12020
98 FORMAT('1CHANNEL EXIT SUMMARY RESULTS'/ 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 = ' ,17X, 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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100 FORMAT(16,2F10.2,F10.2,2F9.3,F10.4,F12.4)
101 FORMAT(10B4, 'BUNDLE AVERAGED RESULTS')
END

SUBROUTINE FIZPRP(IPART,NPROP)

COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
   AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
   GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
   IGRID(10), KCLAD(2), KFACT(2), KKF(30), NCH(10), NGAP(9),
   PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TCLAD(2), UUF(30),
   VVF(30), VG(30), XQUAL(30), Y(30), TT(30)

REAL KKF

IF (IPART.EQ.2) GO TO 10

ENTER WITH NPROP PMAX (=PP(1)) PMIN (=PP(2)) SET IN OPERA OR MODEL

PI = PP(1)
P2 = PP(2)

A = (P2-PI)/FLOAT(NPROP-1)

DO 8 I=1,NPROP
   PI+I*(1.0)*A
   PP(I)=PI
   TT(I)=SATTEM(P)
   RL=ROLIQ(P)
   VVF(I)=1.0/RL
   VVG(I)=1.0/RG
   HHF(I)=H
   HHG(I)=HVAP(P)
   CALL HAPROP(P,H,CP,UUF(I),KKF(I))
   CALL SURTEN(P,RL,RG,SSIGMA(I))
8 CONTINUE

WRITE (6,1003)
   WRITE (6,1004) (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HHG(I),UUF(I),
                     KKF(I),SSIGMA(I),I=1,NPROP)
   RETURN

1003 FORMAT(///, 'PHYSICAL PROPERTIES', //, 2X,'------- ------- -------', COB1260)
1 //, 4X,'P', 9X,'T', 8X,'VF', 8X,'VG', 8X,'HF', 8X,'HG',
2 7X,'VISC', 8X,'KF', 6X,'SIGMA', //)
COB1260
END

SUBROUTINE FORCE(J)

C
C THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE MAJOR SUBROUTINES OF COBRA-IIIC.

C
C IMPLICIT INTEGER (*)

COMMON /COBRA1/ ABETA ,AFLUX ,ATOTAL,BBETA ,DIA ,DT ,DX

COMMON /COBRA2/ AA(4), AF(7), AFAC(10,10), AV(7), AXIAL(30),

COMMON /COBRA3/ AM ,MC ,MG ,MN ,MR ,MS ,MX

COMMON DATA(1) LDAT(1) IDAT(1)

EQUIVALENCE (DATA(1),IDAT(1),LDAT(1))

NKK = NK

DO 10 K=1,NKK

LDAT($FDIV+K)=.FALSE.

10 CONTINUE

IF(J6.Z.O) RETURN

JM1 = -1

CONTINUE
C FORCED DIVERSION CROSSFLOW FROM WIRE WRAPS
100 IF(PITCH.LE.0.) GO TO 1000
     NN = Z/PITCH
     NN = NN+1
     DO 115 K=1,NN
       IF(DATA($X+J).LE.PITCH+FLOAT(K)) GO TO 118
115 CONTINUE
118 PL = K-1
C PL IS THE PITCH LENGTH CONTAINING X(J).
C FIND THE WRAP CROSSINGS IN DX.
     DO 130 K=1,NK
       II=IDAT($IK+K)
       JJ=IDAT($JK+K)
       DO 130 L=1,6
         IFDATA($XR(K+MG*($L-1))) 119,130,119
       119 XC = (ABS(DATA($X+J)+REG(*$L)).+PITCH)
         IF(XC.GT.DATA($X+J)).OR.
         1 XC.LE.DATA($X+J)) GO TO 130
         LDAT($FDIV+K) = .TRUE.
C ADD AND SUBTRACT WIRE WRAPS FROM SUBCHANNEL AT EACH WRAP CROSSING.
     120 IFDATA($XR(K+MG*($L-1))) 120,130,121
       IDAT($NRAP+II)=IDAT($NRAP+II)+1
       IDAT($NRAP+JJ)=IDAT($NRAP+JJ)-1
       GO TO 123
121 IDAT($NRAP+II)=IDAT($NRAP+II)-1
       IDAT($NRAP+JJ)=IDAT($NRAP+JJ)+1
123 IF(NRAMP.LE.0.) GO TO 1000
DUMMY = FLOAT(I)/FLOAT(NRAMP)
     IF(DUMY.GT.1.) DUMY = 1.
     DATA($W+K+MG*(J-1))=DATA($GAP+K)*PI*(DIAM+THICK)*DATA($DUR+K)/DX
     1 *DUMY
     IFDATA($XR(K+MG*($L-1))) 124,130,125
       DATAS($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($F+J+MC*(J-1))/
         1DATA($A+J)
       DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($FACTOR+K)
       GO TO 130
125 DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($F+II+MC*(J-1))/
         1DATA($A+II)
       DATA($W+K+MG*(J-1))=DATA($W+K+MG*(J-1))*DATA($FACTOR+K)
130 CONTINUE
RETURN
200 IF(NOT.GRID) RETURN
     DO 230 K=1,NK
     IFABS(DATA($FX+K+MG*(NGT-1))).LT.1.0E-10) GO TO 230
C ZERO FORCED FLOW FRACTION DOES NOT BLOCK THE NATURAL DIVERSION CROSSFLOW
     II=IDAT($IK+K)
     JJ=IDAT($JK+K)
     LDAT($FDIV+K) = .TRUE.
     IF(NRAMP.LE.0.) GO TO 1000
DUMMY = FLOAT(I)/FLOAT(NRAMP)
     IF(DUMY.GT.1.) DUMY = 1.
     DUMMY*DUMY*DATA($FX+K+MG*(NGT-1))/DX
     IF(DUMY.GT.0.) DATA($W+K+MG*(J-1))=DUMY*DATA($F+II+MC*(J-1))
     IF(DUMY.LT.0.) DATA($W+K+MG*(J-1))=DUMY*DATA($F+J+MC*(J-1))
DATA($W+K+M*J-1$) = DATA($W+K+M*J-1$) * DATA($FACTO+K$)

CONTINUE
RETURN

1000 IERROR = 6
RETURN
END

SUBROUTINE GAUSS (N,M,A,B,T)

DIMENSION A(3,1), B(1), T(1)

M = M-1
DO 10 K = N, MM

AK = A(1,K+1)/A(2,K)
A(2,K+1) = A(2,K+1)-A(3,K)*AK

10 B(K+1) = B(K+1)-B(K)*AK

DO 20 K = N, MM

L = MM-K+N

20 T(L) = (B(L)-A(3,L)*T(L+1))/A(2,L)
RETURN
END

SUBROUTINE HAPROP(P,H,CP,XMU,XK)

X=0.001*H
X3=X*X*X

CP=0.864+1.66*X-7.0*X*X+10.6*X 3-7.0*X*X3
CP=1.0/CP
XMU=0.008+118.0/H

IF(H-90.0)1,2,2

1 XMU=0.008+118.0/(H+0.25*(90.0-H))

X=H-90.0

2 X=X-0.25

XK=0.47-0.45*X-0.072/EXP(6.25*X)
RETURN
END

FUNCTION HCOOL(N,I,JJ)

C COMPUTES THE HEAT TRANSFER COEFFICIENT FOR ROD N FACING SUBCHANNEL I
C AT AXIAL LOCATION J.
C USING THOM/JENS/LOTTES SUBCOOLED BOILING HEAT TRANSFER COEFF.
C PROCO.IME. VOL 180, PART 3C. PAGES 226-246 (1965-6)
HCOOL CALC BY FWD DIFFERENCING, IE FROM CONDITIONS IN LAST INTVL.

JJ = J-1 WHEN CALLED FROM HEAT AND J FROM PROPC.

IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA , AFLUX , ATOTAL , BBETA , DIA , DT , DX
COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), AXLP(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), UF, VF, VFG, VG, Z
COMMON /COBRA3/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), AXLP(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), UF, VF, VFG, VG, Z
FILE: COBRA3C FORTRAN A

COMMON /CDRA3/ MA ,MC ,MG ,MN ,MR ,MS ,MX
1 $CCHAN,$A ,CASH ,$$ALPHA,$AN ,$$ANSW,$B
2 $CDFR ,$SCOND ,SCP ,$$SD ,$$SDC ,$$DFDX
3 $$DHDX ,$$DHYD ,$$DHYN ,$$DIST ,$$DPDX ,$$DPK ,$$DUR ,$$DR ,$$F
4 $FACTO ,$$DIV ,$$FINLE ,$$FLUX ,$$FMUL ,$$FOLD ,$$FSP ,$$FSPLI ,$$FXFLD
5 $GAP ,$$GAPN ,$$GAPS ,$$G ,$$H ,$$HFILM ,$$HINLE ,$$HOLD ,$$HPERI ,$$IDARE
6 $$INFUE ,$$IDGAP ,$$IK ,$$JBOIL ,$$JK
7 $MCHFR ,$$MCFRC ,$$MCFRR ,$$MCFR ,$$MCFR ,$$MCFRR
8 $$MCFR ,$$MCFRR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFR ,$$MCFR
9 $$MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
A $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
B $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
C $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
D $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
E $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
F $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
G $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
H $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
I $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
J $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
K $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
L $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
M $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
N $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
O $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
P $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
Q $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
R $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
S $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
T $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
U $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
V $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
W $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
X $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
Y $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR
Z $MCFR ,$$MCFRR ,$$MPH ,$$MCFR ,$$MCFRR

C SINGLE PHASE AND ENTRY FROM PROP (N=-1)
4 RE = DATA($F+I+MC*(JJ-1))/DATA($A+I)*DATA($DHYD+I)/DATA($VISC+I)
PR = DATA($CP+I)*DATA($VISC+I)/DATA($CON+I)
HCOOL = 0.023*DATA($CON+I)/DATA($DHYD+I)*RE**.8*PR**.4
RETURN

C TWO PHASE AND ENTRY FROM PROP (N=-2)
6 FI = 3600.0*DATA($OPRIM+I)/DATA($HPERI+I)
IF(FI.LT.0.) FI = ABS(FI)
DTSAT = 0.072*(FI**0.5)*EXP((-PREF/1260.0))
IF (N.E.0.) GO TO 8
HCOOL = DTSAT
RETURN

C MEKIN NEW.  AUGUST 1974
U = ALOG(P)
IF(P.LE.265.) GO TO 2
U = U-7.0
RETURN
HLIQ = (((((-0.58728711D00*U+0.11490811D01)*U+0.74153448D01)*U
+0.1080109D02)*U+0.13891584D02)*U+0.37492429D02) *U
2+0.16078158D03+U+0.56715373D0
RETURN

2
HLIQ = ((((((-0.4771D-04*U+0.84618D-03)*U-0.533926D-02)*U
1+0.12037370D-01)*U+0.908507D-02)*U-0.6628012D-01
2+0.41031089D0)*U+0.33320422D02)*U+0.69795537D02
RETURN

FUNCTION HVAP(P)
C
MEKIN NEW. AUGUST 1974
U=ALOG(P)
IF(P.LE.450.0) GO TO 2
U=U-7.0
HVAP = (((((0.37170416D01*U-0.91118126D001)*U-0.2444781D02)*U
1-0.27217176D02)*U-0.44206896D02)*U-0.46351642D02)*U
2+0.11876082D04
RETURN
2 HVAP = (((((-0.3674D-04*U-0.5862D-03)*U+0.43507598D-02)*U
1-0.14535040D-01)*U+0.227759!9D-01)*U+0.85550917D0)*U+0.14228318D02)*U+0.11059625D04
RETURN
END

SUBROUTINE INPRIN
IMPLICIT INTEGER
COMMON /COBRA1/
ELEV ,FERROR
HFG ,HG
S 3 ,J4
NAFACT,NARAMP
NGAPS
,NGRID
NRAMP ,NROD
QAX ,RHOF
UF
VF ,VF
,AV(7), AFACT(10,10), AFACT(10,10),
AGM ,AGM ,AGM ,AGM ,AGM ,AGM ,AGM ,AGM ,AGM
AA(4), AF(7), AF(7), AF(7)

COMMON /COBRA2/
AA(4), AF(7), AFACT(10,10), AFACT(10,10), AFACT(10,10), AFACT(10,10), AFACT(10,10), AFACT(10,10), AFACT(10,10), AFACT(10,10),

COMMON /COBRA3/

REAL KIU, KF, KKF, KCLAD, KFUEL

COMMON /COBRA3/ MA , MC , MG , MN , MR , MS , MX ,

C

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COMMON DATA(1)

LOGICAL LDAT(1)

INTEGER IDAT(1)

EQUIVALENCE (DATA(1),IDAT(1),LDAT(1))

EQUIVALENCE (NCHAN,NCHANL)

LOGICAL PRINT

COMMON/LINK2/CROSS(6),DATE(2),FG(30),FH(30),FP(30),FQ(30),IM(9),
  M(9),OUTPUTPUT(10),PRINT(12),TEXT(17),TIME(3),YG(30),YH(30),YP(30),
  YQ(30)

COMMON/LINK3/DXX,ETIME,GIN,HIN,18,IG,IN,ISAVE,JUMP,KASE,KT,MAXT,
  NDT,NDXP1,NFUELT,NG,NH,NJUMP,NOUT,NP,NPCHAN,NPNODE,NPROD,NQNR,
  NSKIPT,NSKIPX,NTRIES,PEXIT,PHTOT,SAVEDT,TIN,TTIME,ZZ

COMMON/LINK4/IFRM,IHTM,IPROP,NCC,NCF,NDM1,NDS,

DATA H1,H2,H3,H4,H5 /
  1H(, 1H,, 1H), 4H W(, 4H)WP( /

DATA H6, H7, H8 /
  1HW, 1HX, 2HT( /

PRINT INPUT DATA (COBRA CARDS MAIN8840 - MAIN0350)

SET UP VARIABLES FOR OUTPUT PRINTOUT

DO 251 I=1,NCHANL
  DATA($A +I)=DATA($AN +I)
  DATA($DHYD +I)=DATA($DHYDN+I)
DO 252 K=1,NK

DO 255 K=1,NN

DO 256 I=1,NCHANL

IDAT($PRNTC+I)=I

IF(NPNODE.GT.0) GO TO 261

IDAT($PRNTR+N)=N

IDAT($PRNTN+I)=I

OUTPUT OF INPUT DATA

WRITE(I3,I3) (PP(I),TT(I),VVF(I),VVG(I),HHF(I),HFG(I),UUF(I),
  )
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1KKF(I),SSIGMA(I),I=1,NPROP

265 IF(.NOT.PRINT(2)) GO TO 270
WRITE(13,28)
DO 266 J=1,4
IF(AA(J).GT.0 .OR. CC(J).GT.0.) WRITE(I3,29) J,AA(J),BB(J),CC(J)
266 CONTINUE
IF(NVISCW.EQ.0) WRITE(I3,61)
IF(NVISCW.EQ.1) WRITE(I3,62)
WRITE (13,44)
IF(J2.EQ.0) WRITE(I3,45)
IF(J2.EQ.1) WRITE(I3,46)
IF(J3.EQ.0) WRITE(I3,47)
IF(J3.EQ.1) WRITE(I3,48)
IF(J3.EQ.5) WRITE(I3,49)
IF(J3.EQ.6) WRITE(13,57) NV,(AV(I),I=1,NV)
IF(J4.EQ.0) WRITE(I3,58)
IF(J4.EQ.1) WRITE(I3,59)
IF(J4.EQ.5) WRITE(I3,60)
WRITE(I3,6) (Y(I),AXIAL(I),I=1,NAX)
WRITE(I3,12)
DO 277 I=1,NCHANL
WRITE(13,1003) I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),
DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),
DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)
GO TO 277
WRITE(13,1004) I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),
DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),
DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)
277 CONTINUE
276 IF(.NOT.PRINT(3)) GO TO 285
WRITE(I3,38) AXL(I), (AFACT(J,I),J=N,NN)
270 IF(.NOT.PRINT(3)) GO TO 275
WRITE(I3,6) (Y(I),AXIAL(I),I=1,NAX)
275 IF(.NOT.PRINT(4)) GO TO 280
WRITE(I3,12)
DO 277 I=1,NCHANL
WRITE(13,1003) I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),
DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),
DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)
GO TO 277
WRITE(13,1004) I,IDAT($NTYPE+I),DATA($AC+I),DATA($PW+I),
DATA($PH+I),DATA($DC+I),(IDAT($LC+I+MC*(L-1)),
DATA($GAPS+I+MG*(L-1)),DATA($DIST+I+MC*(L-1)),L=1,4)
277 CONTINUE
280 IF(NAXL .LT.1) GO TO 285
IF(.NOT.PRINT(5)) GO TO 285
WRITE(I3,38) AXL(I), (AFACT(J,I),J=N,NN)
285 IF(.NOT.PRINT(6)) GO TO 290
WRITE(I3,38) AXL(I), (AFACT(J,I),J=N,NN)
280 IF(NAXL .LT.1) GO TO 285
IF(.NOT.PRINT(5)) GO TO 285
WRITE(I3,38) AXL(I), (AFACT(J,I),J=N,NN)
285 IF(.NOT.PRINT(6)) GO TO 290
WRITE(I3,38) AXL(I), (AFACT(J,I),J=N,NN)
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286  JM(M)=IDAT($JK+K)
WRITE (I3,20) (H1,IM(M),H2,JM(M),H3,M=N,NN)
DO 287 L=1,NGXL
287  WRITE (13,20) (H1,IM(M),H2,JM(M),H3,M=N,NN)
N=N+10
NN=NN+10
IF(N.GE.NGAPS) GO TO 290
CONTINUE
289  IF(.NOT.PRINT(7)) GO TO 300
IF(J6.EQ.0) GO TO 300
IF(J6.GT.1) GO TO 296
PITCH = PITCH*12.
DIA = DIA*12.
THICK = THICK*12.
WRITE(I3,69) PITCH, THICK,DIA
PITCH = PITCH/12.
DIA = DIA/12.
THICK = THICK/12.
WRITE(13,70) (K,H1I,IDAT(tIK+K),H2,IDAT($JK+K),H3,DATA($DUR+K),
1 (DATA($XCROS+K+MG*(L-1)),L=1,6),K=1,NK)
WRITE(I3,71) (IGRID(I),I=I,NGRID)
WRITE(I3,72) (GRIDXL(I),I=1,NGRID)
DO 297 L=1,NGRIDT
297  WRITE(I3,73) L,(I,DATA($CD+I+MC*(L-1)),I=1,NCHANL)
II = 0
DO 298 K=1,NK
IF(ABS(DATA($FXFLO+K+MG*(I-1))).GT.0) II=1
CONTINUE
299  IF(.NOT.PRINT(8)) GO TO 305
WRITE(I3,74) (I,IDAT($IDFUE+I),DATA($DR+I),
1 DATA($RADIA+I),(DATA($PHI+I+MR*(L-1)),IDAT($LR+I+MR*(L-1)),L=1,6),I=1,NROD)
DO 301 I = 1,NFUELT
KFUEL(I) = KFUEL(I)*3600.
KCLAD(I) = KCLAD(I)*3600.
DFUEL(I) = DFUEL(I)*12.
TCLAD(I) = TCLAD(I)*12.
HGAP(I) = HGAP(I)*3600.
CONTINUE
301  WRITE(I3,77) NODESF
WRITE(I3,78) (J,KFUEL(J),CFUEL(J),RFUEL(J),DFUEL(J),KCLAD(J),
1 CCLAD(J),TCLAD(J),HGAP(J),J=1,NFUELT)
DO 302 I = 1,NFUELT
KFUEL(I) = KFUEL(I)/3600.
KCLAD(I) = KCLAD(I)/3600.
DFUEL(I) = DFUEL(I)/12.
TCLAD(I) = TCLAD(I)/12.
CONTINUE
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302 CONTINUE
305 IF(.NOT.PRINT(9)) GO TO 310
WRITE(I3,18) KIJ,FTM,SL,ZZ,THETA,NDX,DX,NOT,TIME,DT,NTRIES,
1 FERROR
310 IF(IFRM.EQ.0.AND.IHTM.EQ.0) GO TO 307
WRITE(I3,17) EPSF
307 IF(.NOT.PRINT(10)) GO TO 315
WRITE(I3,35)
IF(NSCBC.LT.1) WRITE(I3,32) ABETA
IF(NSCBC.EQ.1) WRITE(I3,33) ABETA, BBETA
IF(NSCBC.EQ.2) WRITE(I3,34) ABETA, BBETA
IF(NSCBC.EQ.3) WRITE(I3,39) ABETA, BBETA
IF(NSCBC.EQ.4) WRITE(I3,41)
IF(NBBC=1) 311,311,312
311 IF (NSCBC.NE.4) WRITE(I3,36) GO TO 314
312 WRITE (I3,37) (XQUAL(I),BX(I),I=1,NBBC)
314 IF(J5.EQ.1) WRITE(I3,65) GKD
315 IF(.NOT.PRINT(11)) GO TO 318
WRITE(I3,21) PEXIT,H1N,G1N,TIN,AFUX
IF(IN.EQ.0) WRITE(I3,87)
IF(IN.EQ.2) WRITE(I3,89)
IF(IN.EQ.3) WRITE(I3,90)
IF(IN.EQ.0) WRITE(I3,91)
IF(IN.EQ.0) WRITE(I3,92)
IF(IN.EQ.0) WRITE(I3,93)
IF(NP.GT.1) WRITE(I3,83) (YP(I),FP(I),I=1,NP)
IF(NH.GT.1) WRITE(I3,84) (YH(I),FH(I),I=1,NH)
IF(NG.GT.1) WRITE(I3,85) (YG(I),FG(I),I=1,NG)
IF(NQ.GT.1) WRITE(I3,86) (YQ(I),FQ(I),I=1,NQ)
318 IF(KDEBUG) 400,400,319
319 WRITE(I3,50) ((IDAT($LC+I+MC*L-1),I=1,NCHANL),L=1,4)
WRITE(I3,50) ((IDAT($K+K),IDAT($K+K),K=1,NK)
WRITE(I3,51) ( DATA($FACTO),K=1,NK)
WRITE(I3,50) ((IDAT($LR+NR+MR*L-1),NR=1,NROD),L=1,8)
WRITE(I3,51) (DATA($PWRF+I+MC*(N-1),NR=1,NROD),I=1,NCHANL)
WRITE(I3,51) (DATA($D+NR) ,NR=1,NROD),
1  (DATA($RADIA+NR),NR=1,NROD)
400 CONTINUE
RETURN
C
6 FORMAT (23H0HEAT FLUX DISTRIBUTION /23H X/L RELATIVE FLUX / COB17500)
1(F7.3,F12.3)
12 FORMAT(22H0SUBCHANNEL INPUT DATA / COB17510)
110H CHANNEL TYPE AREA WETTED HEATED HYDRAULIC (ADD) COB17520
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)
<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fraction of power to adjacent channels (adj. channel no.)</td>
</tr>
<tr>
<td>2</td>
<td>No. no. (in) factor / (215, F8.4, F9.4, F11.4, F12.1, F14.1)</td>
</tr>
<tr>
<td>11</td>
<td>(F9.4, 1H(1,2,1H)F9.4, 1H(1,2,1H)F9.4, 1H(1,2,1H)F9.4, 1H(1,2,1H)F9.4, 1H(1,2,1H)F9.4, 1H(1,2,1H)</td>
</tr>
<tr>
<td>11</td>
<td>(1H(1,2,1H))</td>
</tr>
<tr>
<td>17</td>
<td>Format (/, fuel rod temp. convergence criteria = 1, E10.5)</td>
</tr>
</tbody>
</table>
| 18     | Format (23,h calculation parameters) /
| 4      | Channel length F8.2, 8 inches |
| 2      | Channel orientation F8.1, 8 degrees/ |
| 5      | Number of axial nodes IB |
| 6      | Node length F8.3, 7 inches/ |
| 7      | Number of time steps IB |
| 8      | Total transient time F8.3, 8 second |
| X      | Time step F8.4, 8 second |
| 11     | Allowable iterations IB |
| 19     | Format (50, h x/l area variation factors for subchannel) /
| 20     | Format (60, h x/l gap spacing variation factors for adjacent subchannel) |
| 25     | System pressure F8.1, 5 psia/ |
| 25     | Inlet enthalpy F8.1, 7 lb |
| 25     | Avg. mass velocity F8.3, 21 lb/ |
| 25     | Inlet temperature F8.1, 10 degrees |
| 25     | Avg. heat flux F8.6, 22 lb |
| 28     | Format (29, h friction factor correlation) |
| 29     | Format (16, h channel type I3, 111) frict = F5.3, 6H*RE*(F5.3) |
| 14     | (F6.4) |
| 32     | Format (31, h subcooled mixing, beta = F6.4) |
| 33     | Format (31, h subcooled mixing, beta = F6.4, 6H*RE*(F6.4, 1H) |
| 34     | Format (31, h subcooled mixing, beta = F6.4, 1H*RE*(F6.4, 1H) |
| 1      | (1H) |
| 35     | Format (20, h mixing correlations) |
| 36     | Format (54, h boiling mixing, beta is assumed same as subcooled) |
| 37     | Format (55, h boiling mixing, beta is a function of steam quality) |
| 1      | (25, h) x betax / (F12.3, F13.6) |
| 38     | Format (F6.3, 10F8.3) |
| 39     | Format (31, h subcooled mixing, beta = F6.4, 12H*(D/L)*RE*(F6.4) |
| 1      | (F6.4, 1H) |
| 41     | Format (1H, new (beus) mixing model used) |
| 44     | Format (20, h two-phase flow correlations) |
| 45     | Format (33, h no subcooled void correlation) |
| 46     | Format (31, h Levy subcooled void correlation) |
| 48     | Format (41, h modified arm and bulk void correlation) |
| 49     | Format (50, h homogeneous bulk void model with slip ratio of) |
| 1      | (F6.2) |
| 50     | Format (205) |
| 51     | Format (BE12.3) |
| 57     | Format (33, h bulk void fraction given as a 12.56H term poly) |
| 1MIAL  | Function of quality with coefficients of/ 10(7.610.4) |
| 58     | Format (41, h homogeneous model friction multiplier) |
1003 FORMAT(15,17,4F10.4,4X,4(1H(I3,1H,F5.3,1H,F5.3,1H))) COB18710
1004 FORMAT(15,17,4F10.6,4X,4(1H(I3,1H,F5.3,1H,F5.3,1H))) COB18720
END COB18730
SUBROUTINE ITHO(NTHBOX,NTHBXX,ND1X,ND2X) COB18740
   IMPLICIT INTEGER ($) COB18750
   COMMON /COBRA1/ ABETA ,AFLUX ,ATOTAL,BBETA ,DIA ,DT
   ,DX ,ELEV
   ,FERROR,FLO
   ,FTM
   ,GRID ,HSURF ,HF
   ,J3 ,J4
   ,J5 ,J6
   ,J7
   ,KDEBUG,KF
   ,KIJ
   ,NAFACT,NRAMP,NAX
   ,NBBC
   ,NCHANL,NCHF
   ,NDX
   ,NF
   ,NGAPS ,NGRID
   ,NGRIDT
   ,NGTYPE
   ,NGXL
   ,NK
   ,NODES
   ,NODESF
   ,NPROP
   ,NRAMP
   ,NSCBC
   ,NV
   ,NVISCW
   ,PI
   ,PITCH
   ,POWER
   ,PREF
   ,QAX
   ,RHOF
   ,RHOG
   ,SIGMA
   ,SL
   ,TF
   ,TFLUID
   ,THETA
   ,THICK
   ,UF
   ,VF
   ,VFG
   ,VG
   ,Z
   LOGICAL GRID COB18780
REAL KIJ, KF, KKF, KCLAD, KFUEL
DIMENSION NTHBOX(25,25) COB18790
DIMENSION CARD(20) COB18800
CONTROL FOR THERMAL-HYDRAULIC INPUT DATA COB18810
WRITE (I3,1001) COB18820
WRITE(I3,1002) COB18830
CALL CHAN(1,NTHBOX,NTHBXX,NDIXND2X,N CARD) COB18840
CALL MODEL(1 ,CARD,IPILE) COB18850
CALL OPERA(1,CARD) COB18860
CALL FIZPRP(1,NPROP) COB18870
CALL TABLES(CARD) COB18880
WRITE(I3,1002) COB18890
CALL CORE3 COB18900
IF (IERROR.EQ.0) GO TO 2 COD;3050
WRITE (13,1004) COB18910
RETURN COB18920
2 CONTINUE COB18930
WRITE (I3,1003) COB18940
WRITE(I3,1004) COB18950
RETURN COB18960
1001 FORMAT(1H1, 42X, 'THERMAL - HYDRAULIC INPUT DATA', /, 43X,
   1 '-----------------------------', ///, ' CARD IMAGES', /, 2X, COB18970
   2 '---- ----- ----') COB18980
1002 FORMAT(32X, '0....*...1....*...2....*...3....*...4....*...5') COB18990
   , '....*...6....*...7....*...8') COB19000
1003 FORMAT(1H1, 42X, 'PROCESSED INPUT DATA', /, 43X,
   1 '-----------------------------', ///, ' = SET IN NEUTRONICS (CARD20)', COB19010
   2 '------------') COB19020
1004 FORMAT(' ERROR SIGNAL IN ITHO') COB19030
END
SUBROUTINE MIX(J)
IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA, ELEV, FERROR, FLO, HG, HFG, HG, I3, J3, J4, J5, J6, J7, KDEBUG, KF, KIJ
COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9), PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TCLAD(2), UUF(30), VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)
COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX
COMMON DATA(1)
LOGICAL GRID
REAL KIJ, KF, KKF, KCLAD, KFUEL
COMMON /COBRA4/ MA, MC, MG, MN, MR, MS, MX
COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))
NKK = NK
DO 240 K = 1, NKK
DATA($COND+K) = 0.
II = IDAT($IK+K)
J = IDAT($JK+K)
ABAR = DATA($A+II) + DATA($A+J)
FBAR = DATA($F+II+MC*(-1)) + DATA($F+J+MC*(J-1))
PBAR = DATA(SPERIM+II) + DATA(SPERIM+J)
QBAR = DATA($QUAL +II) + DATA($QUAL +J)
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VBAR = DATA($)VISC +II) + DATA($)VISC +JU)
DAVG = 4. * ABAR / PBAR
GAVG = FBAR / ABAR
XAVG = 0.
IF (AMAX1(DATA($)SQUAL +II), DATA($)SQUAL +JU)).GT.0.) XAVG = 0.5 * QBAR
IF (XAVG.GT.0. AND. NBBC.GE.2) GO TO 80
UAVG = 0.5 * VBAR
IF (NSCBC.GE.1) RE = GAVG + DAVG / UAVG
IF (NSCBC.EQ.0) DATA($)WP +K) = DATA($)S GAP +K) * GAVG + ABETA
IF (NSCBC.EQ.1) DATA($)WP +K) = DATA($)S GAP +K) * GAVG + ABETA * RE +*BBETA
IF (NSCBC.EQ.2) DATA($)WP +K) = DAVG
* GAVG + ABETA * RE +*BBETA
IF (NSCBC.EQ.3 AND. DATA($)LEN +K). LE. 0.) GO TO 1000
IF (NSCBC.EQ.3) DATA($)WP +K) = DATA($)S GAP +K) / DATA($)LEN +K) * DAVG + GAVG
1 * ABETA + RE +*BBETA
IF (NSCBC.EQ.4) GO TO 50
DATA($)WP +K) = DATA($)WP +K) - DATA($)FACTO +K)
GO TO 100
CC BEUS MIXING MODEL USED WHEN NSCBC = 4
50 WL = 0.0035 * UAVG + RE +*0.9
ARBAR = ABAR + 0.5
BI = 0.04 * (DATA($)S GAP +K) / DAVG) *** 1.5
XC = (0.4 / GAVG + SQRT(32.2 * RHOF * DAVG * (RHOF - RHOD)) + 0.6) / (SQRT(RHOF
1 / RHOD) + 0.6)
CC SLIP RATIO, GAM, BASED ON SMITH CORRELATION
GAM = 1.
IF (XAVG.LE.0.) GO TO 52
ALP = 1. / (XAVG - 1.0) + 0.4 * RHOD / RHOF + 0.4 * RHOF / RHOD + 0.4 *
1 / XAVG - 1.) *** SQRT((1. / XAVG - 1.) *** SQRT((1. / XAVG - 1.) *** SQRT((1. / XAVG
2 - 1.)))
GAM = XAVG / (1. - XAVG) * (1. - ALP) / ALP * RHOF / RHOG
IF (XAVG.GT. XC) GO TO 55
DATA($)WP +K) = WL * BI + ARBAR + GAVG + DAVG + RHOF / RHOG + (GAM - 1.) / GAM * XAVG
GO TO 100
55 XOXC = 0.57 * RE +*0.0417
TK = 0.5556 * (TF + 459.67)
VISCG = 0.672 * VISVP(TK)
WG = 0.0035 * VISCG * (GAVG + GAM + DAVG / VISCG) + 0.9
WC = W + B1 * ARBAR + GAVG + DAVG + RHOF / RHOG + (GAM - 1.) / GAM * XC
DATA($)WP +K) = (WG / (WC - WG)) * ((1. - XOXC) / (XAVG / XC - XOXC)) * DATA($)FACTO +K)
GO TO 100
80 CALL CURVE (XBETA, XAVG, BX, SQUAL, NBBC, IERROR, 1)
IF (IERROR.GT.1) GO TO 1000
DATA($)WP +K) = GAVG + DAVG * XBETA * DATA($)FACTO +K)
GO TO 100
100 IF (JS.EQ.0) GO TO 240
CAVG = 0.5 * (DATA($)CON +II) + DATA($)CON +JU))
IF (DATA($)LEN +K). LE. 0.) GO TO 1000
DATA($)COND +K) = CAVG + DATA($)S GAP +K) / DATA($)LEN +K) * G + DATA($)FACTO +K)
240 CONTINUE
RETURN
IERROR = 4
RETURN
END

SUBROUTINE OPERA(IPART, CARD)
C
C
C
C
FILE: COBRA3C FORTRAN A

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IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

COMMON DATA(1)

LOGICAL GRID

REAL KIU, KF, KKF, KCLAD, KFUEL

LOGICAL GRID

READ OPERATING CONDITIONS

COBRA AN. MEKIN SAME CODING EXCEPT IMEKIN = 0

COMMON LINK2/CROSS (6), DATE(2), FG(30), FH(30), FP(30), FQ(30), IM(9),

COMMON LINK3/OXX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MAXT,

DIMENSION CARD(20)

IPART = 1 READ OPERATING CONDITIONS

IPART = 2 PRINT OPERATING CONDITIONS

COBRA AND MEKIN SAME CODING EXCEPT IMEKIN = 0
IMEKin = 0
IF(IPART.EQ.2) GO TO 10
READ (I2,1001) CARD, IN, HIN, GIN, PEXIT
WRITE(I3,1011) CARD
IF( (NDX.LE.0) .OR. (Z.LE.0.0) ) GO TO 30
PREF = PEXIT
IF(IN.LT.2) GO TO 2
IF(IN.EQ.2) CALL READIN(2,NCHANL,DATA($HINLE+1),CARD,CARD,1)
READ(I2,1002) CARD,NP,NH,NG,NQ
WRITE(I3,1012) CARD
IF(NP.GT.1) CALL READIN(4,NP,YP,FP,CARD,2)
IF(NH.GT.1) CALL READIN(5,NH,YH,FH,CARD,2)
IF(NG.GT.1) CALL READIN(6,NG,YG,FG,CARD,2)
IF(NO.GT.1) CALL READIN(7,NQ,YQ,FQ,CARD,2)
IF(NPROP.GT.0) GO TO 9
SET MAX AND MIN PRESSURES FOR PHYSICAL PROPERTIES IN FIZPRP.
ZMIN = 1.0
IF(NH.LE.1) GO TO 4
DO 3 I=1,NH
IF(FH(I).LT.ZMIN) ZMIN = FH(I)
3 CONTINUE
WV = HIN
IF(IN.LT.2) GO TO 6
WV = 1000.0
DO 5 I=1,NCHANL
IF(DATA($HINLE+I).LT.WV) WV=DATA($HINLE+I)
5 CONTINUE
WV CORRESPONDS TO MIN HIN OR TIN AT STEADY STATE
R = 0.01*WV*ZMIN
IF(R.LT.4.5) R = R*(1.0-0.1*(4.5-R))
SET PP(1) TO PRESSURE LOWER THAN MIN IN PROBLEM FOR FIZPRP
PP(1) = 10.0
IF(R.GT.2.0) PP(1) = 6.0*R*R*R*(R-1.35)/(R-0.35)
ZMAX = 1.0
IF(NP.LE.1) GO TO 8
ZMIN = 1.0E06
DO 7 I=1,NP
IF(FP(I).GT.ZMAX) ZMAX = FP(I)
IF(FP(I).LT.ZMIN) ZMIN = FP(I)
7 CONTINUE
IF(ZMIN*PREF.LT.PP(1)) PP(1) = ZMIN*PREF
SET PP(2) TO HIGHEST PRESSURE DURING TRANSIENT
PP(2) = ZMAX*PREF + 0.01
NPROP = 30
CONTINUE
SET TTIME AND NDT FOR MEKIN ONLY
IF(IMEKin.EQ.0) RETURN
TTIME = 1.0
NDT = 1
IF((NP+NH+NG+NQ).LE.0) NDT=0
RETURN
WRITE (I3,1020) PEXIT,GIN
C     SET HINLET = H OR T ACCORDING TO IN
  12    IF (IN=1) 12,14,20
  14    WRITE (13,1021) IN,HIN
  16    GO TO 16
  18    WRITE (13,1022) IN,HIN
  20    DO 18 I=1,NCHANL
  22    DATA(HINLET+1) = HIN
  24    GO TO 22
  26    IF (IN.EQ.2) WRITE (13,1023) IN,(I,DATA(HINLET+1),I=1,NCHANL)
  28    IF (IN.EQ.3) WRITE (13,1024) IN,(I,DATA(HINLET+1),I=1,NCHANL)
  30    WRITE (13,1025) Z,NOX
        Z = Z/12.0
  32    IF (NOT.GT.0) GO TO 24
  34    WRITE (13,1026)
  36    GO TO 26
  38    IF (INEQIN.EQ.0) WRITE (13,1027) NDT,TIME
  40    IF (NP.GT.1) WRITE(13,1028) (YP(I),FP(I),I=1,NP)
  42    IF (NH.GT.1) WRITE(13,1029) (YH(I),FH(I),I=1,NH)
  44    IF (NG.GT.1) WRITE(13,1030) (YG(I),FG(I),I=1,NG)
  46    IF (NG.GT.1) WRITE(13,1031) (YQ(I),FQ(I),I=1,NQ)
  48    RETURN
  50    WRITE (13,1040)
  52    STOP
C
1001 FORMAT(20A4, T1, I5, 13E5.0)
1002 FORMAT(20A4, T1, 14I5)
C
1011 FORMAT( ' IN H OR T)IN G P EXIT', 6X, '***', 20A4, '*** OPERA')
1012 FORMAT( ' TRANS INDIC FOR PH G Q', 5X, '***', 20A4, '*** OPERA')
C
1020 FORMAT(43X, 'OPERATING CONDITIONS', /, 43X,
  1                                   ' '---------------------', // ', PRESSURE', 20X, '(PSIA)', 9X, 'w', C0B21770)
  2 F10.2, '/', ' AV. INLET MASS VELOCITY', 9X, 'MLB/SQFT.HR', 2X,
  3 ' =', FI2.4)
1021 FORMAT(' IN=', I2, ' INLET ENTHALPY', 7X, '(BTU/LB)', 7X, 'w', C0B21800)
  1 F11.3)
1022 FORMAT(' IN=', I2, ' INLET TEMPERATURE', 4X, '(DEG F)', 8X, 'w', C0B21820)
  1 F11.3)
1023 FORMAT(' IN=', I2, ' INLET ENTHALPIES', 5X, '(BTU/LB)', 7X, 'w', C0B21840)
  1/(5X, 6(15,5X, F10.3)/)
1024 FORMAT(' IN=', I2, ' INLET TEMPERATURES', 3X, '(DEG F)', 8X, 'w', C0B21860)
  1/(5X, 6(15,5X, F10.3)/)
1025 FORMAT(' CHANL LENGTH', 14X, '(IN)', 11X, 'w', F10.2, 'w',
  1 ' NO. OF AXIAL INTERVALS', 21X, 'w', I7)
1026 FORMAT( ' NO TRANSIENT CALCULATION')
1027 FORMAT( ' NO. OF TIME STEPS', 26X, 'w', I7, 'w',
  1 ' TOTAL TIME OF TRANSIENT', 5X, '(SEC)', 10X, 'w', F10.2)
1028 FORMAT( ' FORCING FUNCTION FOR PRESSURE', /, 33H
  1 ' TIME PRESSURE', /, 23H
  2 ' FORCING FUNCTION FOR INLET ENTHALPY',
  1 ' TIME INLET ENTHALPY', /, 12H
  2 ' FORCING FUNCTION FOR INLET FLOW', /, 28H
  1 ' TIME INLET FLOW', /, 28H
C
C
C
C
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2 23H  (SEC)  FACTOR / (F10.4,F13.4))
1031 FORMAT (/, 3BH FORCING FUNCTION FOR HEAT FLUX : /)
C 3BH TIME HEAT FLUX /
C
2 23H (SEC)  FACTOR / (F10.4,F13.4))
1040 FORMAT (" INPUT DATA ERROR. NDX OR Z .LT.0. STOP (OPERA)"
END

SUBROUTINE PRECAL

IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX
ELEV, FERROR, FLO, FTM, GC, GR, GRID, HSURF, HF
HFG, HG, I2, I3, IERROR, IQP3, ITER, J1, J2
J3, J4, J5, J6, J7, KDEBUG, KF, KIJ
NAFACT, NARAMP, NAX, NAXL, NBBC, NCHAN, NCHF, NDX, NF
NGAPS, NGRID, NGRIDT, NNODES, NODENF, NPRED, NPROD, NQ, NR
NRAMP, NROD, NSCBC, NV, NVISCW, PI, PITCH, POWER, PSEL
QAX, RHOF, RHOG, SV, SL, TF, TFLUID, THETA, THICK
UF, VF, VFG, VG, Z

COMMON /COBRA2/ AA(4), AF(7), AFAC(10,30), AV(7), AXIAL(30),
AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(5), DFUEL(2),
GAPX(10), GFAC(9,10), GRIDX(10), HGF(2), HHF(30), HIG(30),
HIGR(10), KCLAD(2), KFUEL(2), KKF(30), KCH(10), NGAP(9),
PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30),
VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

C COMMON /COBRA/ MA, MC, MG, MN, MR, MS, MX

C COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1),IDAT(1),LDAT(1))

COMMON/LINK3/DXX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MAXT,
NDT, NDXP1, NFUEL, NG, NH, NJUMP, NOUT, NP, NPCHAN, NPNODE, NPROP, NQ, NR,
NSKIP, NSKIPX, NTRIES, PEXIT, PHTOT, SAVEDT, TIN, TIME, ZZ

C COMMON LINK3/DXX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MAXT,
CONVERSATIONAL MONITOR SYSTEM

PREPARE TO START CALCULATION (IN CALC)

CALL PROP(1,1)

IF (IERROR.GT.0) GO TO 20

NDXP1 = NDX + 1

DX = Z/FLOAT(NDX)

DXX = DX*12.0

DT = 0.0

IF (NDT.GT.0 .AND. (TTIME.LE.0.0)) NDT=0

IF (NDT.GT.0) DT = TTIME/FLOAT(NDT)

SAVEDT = DT

SET HINLET

HIN = DATA($HINLE+1)

CALL CURVE(HIN,TIN,HHF,TT,NPROP,IERROR,1)

IF (IERROR.GT.0) GO TO 20

DO 4 I=1,NCHANL

DATA($TINLE+'I = TIN

4 DATA($HINLE+I)

GO TO 10

IF (IN.GE.3) GO TO 6

:TIN = HIN

CALL CURVE(DATA($HINLE+I),DATA($TINLE+I),HHF,TT,NPROP,IERROR,1)

IF (IERROR.GT.0) GO TO 20

CONTINUE

SET FINLET

10 WV = GIN/0.0036

FLO = WV*ATOTAL

WV1 = 1.0

DO 12 I=1,NCHANL

IF (IG.EQ.2) WV1 = DATA($FINLE+I)

12 DATA($FINLE+I)

RETURN

WRITE (13,1001)

RETURN

1001 FORMAT(' PRECAL ERROR SIGNAL AFTER CALLING CURVE OR PROP')

SUBROUTINE PROP(IPART,J)

C THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE MAJOR SUBROUTINES OF COBRA-IIIC.

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,IQPS ,ITERAT,J1 ,J2 ,.

3 J3 ,J4 ,J5 ,J6 ,J7 ,KDEBUG,KE ,KIJ ,.

4 NFACT,NARAMP,NAX ,NAXL ,NBBC ,NCHAN ,NCHF ,NDX ,NF ,.

5 NGAPS ,NGRID ,NGRIDT ,NGTYPE ,NGXL ,NK ,NODES ,NODESH,NPROP ,.

6 NROD ,NSCBC ,NV ,NVISCW,PI ,PITCH ,POWER ,PREF ,.

7 QAX ,RHOF ,RHOG ,SIGMA ,SL ,TF ,TFLUID,THETA ,THICK ,.

8 UF ,VF ,VFG ,VG ,Z ,.

IMPLICIT INTEGER (*)

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C PART 2. CALCULATE LIQUID PROPERTIES AND PARAMETERS

100 NCHAN = NCHANL
   IF(J.GT.1) GO TO 102
   DO 101 I=1,NCHAN
   DATA($VISC W-I)=VF
   DATA($VISC +I)=VF
   DATA($CON +I)=KF
   DATA($V +I)=VFI
   HH=DATA($H+I+MC*(J-1))
   IF(HH.GT.HF) GO TO 105
   CALL CURVE(DA(TA($VISC +I)),HH,UUF,HFF,NPROP,IERROA,1)
   IF(IERROR.GT.1) GO TO 1000
   CALL CURVE(DA($V +I),HH,VVF,HFF,NPROP,IERROA,2)
   CALL CURVE(DA($ST +I),HH,TT,HFF,NPROP,IERROA,2)
   CALL CURVE(DA($CON +I),HH,KKF,HFF,NPROP,IERROA,2)

105 TM=DATA($T +I)-1.
   CALL CURVE (TM,TM,HFF,TT,NPROP,IERROA,1)
   IF(IERROR.GT.1) GO TO 1000
   DATA($SCP+I)=HH-HM
   IF(HH.GT.HF) DATA($SCP+I)=HF-HM
   DATA($VISC -I)=DATA($VISC +I)/3600.
   DATA($CON -I)=DATA($CON +I)/3600.
   DATA($V -I)=DATA($V +I)/3600.
   RE=DATA($F+I+MC*(J-1))/DATA($H+I+MC*(J-1))
   IF(RE.LT.0.5) WRITE(13,1) I,J,RE,DATA($F+I+MC*(J-1)),DATA($VISC +I)
   IF(RE.LT.0.2) RE = 2000.
   PR=DATA($SCP+I)*DATA($VISC +I)/DATA($CON +I)
   IF(DA(TA($H+I+MC*(J-1)))/DATA($VISC +I),DATA($H+I+MC*(J-1))=J)
   DATA($SHFILM+I)=0.023*DATA($CON +I)/DATA($H+I+MC*(J-1))
   DATA($SHFILM +I) = HC0OL(-1,I,J)
   DTWALL=DATA($QPRIM+I)/DATA($HPERI +I)/DATA($SHFILM +I)
   DTWALL = DATA($QPRIM +I)/DATA($HPER +I)/DATA($SHFILM +I)
   C DETERMINE THE START OF NUCLEATE BOILING
   IF(DAT(A($BOIL+I).GT.0) GO TO 106
   IF(DAT(A($QPRIM+I).LT.0.0) GO TO 106
   C TLBOIL=TF-DT WALL+60.*EXP(-PREF/900.)*DATA($QPRIM +I)
   IF(TLBOIL GT0.1) GO TO 106
   IF(DAT(A($T+I),GE.TLBOIL AND.NCHF,NE.4) IDAT($BOIL+I)=J
   IF(NCHF.EQ.4 AND DATA($H+I+MC*(J-1)),GE.HF) IDAT($BOIL+I)=J
   C CALCULATE...
106 Twall = Data($T+I)+DTwall
GO TO 110

C

108 SAVE = 0.
SUM = 0.
DO 109 NN = 1, NROD
DUMY = Data($SPRF+I+MC*(NN-1))
IF (DUMY .LE. 0.) GO TO 109
SUM = SUM + DUMY * Data($TROD+NODESF+1+MN*(NN-1+MR*(J-1)))
SAVE = SAVE + Data($SPRF+I+MC*(NN-1))
109 CONTINUE
GO TO 110

TWALL = Data($T+I)+DTWALL COB24210
GO COB24220
C
COB24230
108 SAVE = 0.
109 CONTINUE
GO TO 120

CC

110 CONTINUE
112 IF (TWALL .LT. TF) CALL CURVE(Data($VISCW+I), TWALL, UUF, TT, NPROP, 1, IERROR, 1)
GO TO 1000
120 L = IDAT($JBOIL+I).NE.0 GO TO 112
IF (TWALL .GE. TF AND .AND. NCHF .NE. 4) IDAT($JBOIL+I) = J COB24350
IF (DATA ($.+I+MC*(J-1)).GE.HF .AND. NCHF .EQ. 4) IDAT($JBOIL+I) = J
CC

RETURN COB24380

RETURN COB24490

200 WRITE (13, 6) PREF, PP
GO TO 1001
210 WRITE (13, 5) PREF, PP
GO TO 1001
1000 WRITE (13, 7)
1001 IERROR = 11
RETURN COB24540
END

SUBROUTINE QPR3(NCHANL, IKASE, TEXT, DATE, TIME, X)
C
C
IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX, COB24620
1 ELEV, FERROR, FLO, FTM, GC, GK, GRID, Hsurf, HF, COB24630
2 MFG, HG, I2, I3, IERROR, IQP3, ITERAT, J1, J2, COB24640
3 J3, J4, J5, J6, J7, KDEBUG, KF, KIJ, COB24650
4 NFACT, NRAMP, NAX, NAXL, NBBCC, NCHAN, NCHF, ND, NF, COB24660
5 NGAPS, NGCP, NGF, NGHY, NGTH, NX, NY, NZ, NODES, NPROP, COB24670
6 NRAMP, NRD, NSCBC, NV, NISCW, PI, PITCH, POWER, PREF, COB24680
7 QAX, RHOF, VGA, SL, TF, TFLUID, THERM, THICK, COB24690
8 UF, VF, VFG, VG, Z COB24700
C
COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), COB24720
1 AXL(10), BB(4), B(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), COB24730
2 GAPXL(10), GFAC(9,10), GRIDX(10), HGAP(2), HFF(30), HHG(30), COB24740
3 IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9), COB24750
FILE: COBRA3C FORTRAN A

LOGICAL GRID
REAL KIJ, KF, KKF, KCLAD, KFUEL

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX 
1 $S$SA, $AAA, $AC, $ALPHA, $SAN, $SANSWE, $B, COB24850
1 $CCHAN$, $CD, $CHFR, $CON, $COND, $CP, $D, $DC, $DFDX, COB24860
2 $DHDX, $DHYD, $DHYN, $DIST, $DPDX, $DPK, $DUR, $SR, $F, COB24870
3 $FACTO, $FDIV, $FINLE, $FLEX, $FOLD, $FS, $FSPLI, $FXFLO, COB24880
4 $GAP, $GAPN, $GAPS, $H, $HFLM, $HFLN, $HOLD, $HMERI, $HFERI, COB24890
5 $IDFUE, $IDGAP, $IK, $JBOIL, $JK, $MCHFR, $MCFRC, $MCFRR, COB24900
6 $NTYPE, $NWRES, $NR, $SP, $U, $UH, $USAVE, $USTAR, $V, COB24910
7 $W, $WOLD, $WP, $XP0LD, $X4ROS, $X5, COB24920
C
COMMON /LINK3/DXX, ETIME, GIN, HIN, I8, IG, IN, ISAVE, JUMP, KASE, KT, MAXT, COB24930
1 NDT, NDXP1, NFUEL, NG, NH, NJUMP, NOUT, NP, NCHANL, NPNODE, NPROD, NQ, NR, COB24940
2 NSKUPT, NSKIPX, NTRIES, PEXIT, PHTOT, SAVEDT, TIN, TTIME, ZZ COB24950
COMMON DATA(1) COB25000
LOGICAL LDAT(1) COB25010
INTEGER IDAT(1) COB25020
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1)) COB25030
C
DIMENSION JB(10), TEXT(17), DATE(2), TIME(3), $X(1) COB25040
C
READ (12, 700) ZM
WRITE (13, 1000) ZM
IF (ZM.GE.0.0) GO TO 505
IF (ZM.LT.-1.01) GO TO 500
ZM = 3.4313.0/3.6
GO TO 505
ZM = 1000.0/3.6
500 WRITE (13, 1001) ZM
NDXP1 = NDXI + 1
DO 601 I=1, NCHANL
601 READ(12, 700) (DATA($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($QC+I+MC*(J-1)), J=2, NDXP1)
705 CONTINUE
C
PRINT INPUT FUEL NODAL POWERS
WRITE(13, 1000) ZM
NDXP1 = NDXI + 1
DO 601 I=1, NCHANL, 10
601 READ(12, 700) (DATA($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($QC+I+MC*(J-1)), J=2, NDXP1)
705 CONTINUE
C
PRINT INPUT FUEL NODAL POWERS
WRITE(13, 1000) ZM
NDXP1 = NDXI + 1
DO 601 I=1, NCHANL, 10
601 READ(12, 700) (DATA($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
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C

MULTIPLY FUEL POWERS BY ZM
SUMF = 0.0
DO 630 I=1,NCHANL
DATA($RADIA+I) = 0.0
DO 630 J=2,NDXP1
DATA($QF+I+MC*(J-1))=DATA($QF+I+MC*(J-1))*ZM
DATA($RADIA+I) = DATA($RADIA+I) + DATA($QF+I+MC*(J-1))
630 SUMF = SUMF + DATA($QF+I+MC*(J-1))
SUMC = 0.0
IF(IQP3.EQ.0) GO TO 645
C

PRINT INPUT COOLANT NODAL POWERS
WRITE(13,660)
DO 622 I=1,NCHANL,10
DO 6  K=1,10
JB(K)=I+K-1
IF(NCHANL.LE.II) II=NCHANL
L=II-I+1
WRITE(13,655) (JB(K),K=1,L)
DO 621 J=1,NDX
WRITE(13,30) J,(DATA($QF+K+MC*(J ) ),K=I,II)
621 CONTINUE
C

MULTIPLY COOLANT POWERS BY ZM
DO 640 I=1,NCHANL
DO 640 J=2,NDXP1
DATA($QC+I+MC*(J-1))=DATA($QC+I+MC*(J-1))*ZM
DATA($RADIA+I) = DATA($RADIA+I) + DATA($QC+I+MC*(J-1))
640 SUMC = SUMC + DATA($QC+I+MC*(J-1))

PRINT FUEL AND COOLANT SUMMED POWERS.
SUMT = SUMF+SUMC
WV = FLOAT(NCHANL)/SUMT
DO 647 I=1,NCHANL
DATA($RADIA+I) = DATA($RADIA+I)*WV
WRITE (13,1004) (DATA($RADIA+I),I=1,NCHANL)
WV = 3.6/3413.0
SUMF1 = WV*SUMF
SUMC1 = WV*SUMC
SUMT1 = WV*SUMT
SUMF = 0.001*SUMF
SUMC = 0.001*SUMC
SUMT = 0.001*SUMT
WRITE (13,1002) SUMF1,SUMF, SUMC1,SUMC, SUMT1, SUMT
AFLUX = SUMT1*3.413/(PHTOT*Z)
WRITE(13,1003) AFLUX
RETURN
C
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20 FORMAT((5,2X,10F10.5))
650 FORMAT(//,' HEAT GENERATION IN FUEL')
655 FORMAT(//,' NODE ROD',I4,I9,8I10,/) 
660 FORMAT(//,' HEAT GENERATION IN COOLANT')
700 FORMAT(8E10.0)
1000 FORMAT(//,' READ NODAL POWERS IN SUBROUTINE QPR3 AND MULTIPLY 
1 GIVEN VALUES BELOW BY ZM',//,' ZM GIVEN AS',F10.4,
2 '(.GE.0.0 USED AS MULTIPLIER TO CONVERT TO BTU/SEC)',//,' 30X, 
3 '(.EQ.-1.0 TO CONVERT MW TO BTU/SEC)',//,' 30X, 
4 '(.EQ.-2.0 TO CONVERT MBTU/HR TO BTU/SEC)' )
1001 FORMAT(//,' ZM TAKEN TO BE ',F11.5)
1002 FORMAT(//,' POWER IN FUEL = ',F9.2,' MW IE ',F9.2, 
1 ' KBTU/SEC',//,' IN COOLANT = ',F9.2,' MW IE ',F9.2, 
2 ' KBTU/SEC',//,' TOTAL = ',F9.2,' MW IE ',F9.2, 
3 ' KBTU/SEC' )
1003 FORMAT(//,' AVERAGE HEAT FLUX = ',F10.4,' MBTU/SQFT.HR' )
1004 FORMAT(//,' RADIAL POWER FACTORS FOR EACH CHANNEL',//) 
1 (6X,10F10.4,22X)
END
SUBROUTINE READIN(IVAR,N,A,B,CARD,M)
DIMENSION A(1),B(1),CARD(20)
IVAR IDENTIFIES A, B AND THUS PRINTING
IF M=1, READ (A(I),I=1,N). M=2, READ (A(I),B(I),I=1,N)
IDI = 14/M
IVMAX = 9
DO 20 I=1,N,IDI
II = I + IDI-1
IF (II.GT.N) II=N
IF (M.EQ.1) READ (5,1000) CARD, (A(L),L=I,II)
IF (M.EQ.2) READ (5,1000) CARD, (A(L),B(L),L=I,II)
IF (I.IE.1) GO TO 11
IF (((IVAR.LT.1).OR.(IVAR.GT.IVMAX)) GO TO 30
GO TO (1,2,3,4,5,6,7,8,9),IVAR
1 WRITE (6,1001) CARD
GO TO 20
2 WRITE (6,1002) CARD
GO TO 20
3 WRITE (6,1003) CARD
GO TO 20
4 WRITE (6,1004) CARD
GO TO 20
5 WRITE (6,1005) CARD
GO TO 20
6 WRITE (6,1006) CARD
GO TO 20
7 WRITE (6,1007) CARD
GO TO 20
8 WRITE (6,1008) CARD
GO TO 20
9 WRITE (6,1009) CARD
GO TO 20
11 WRITE (6,1011) CARD
CONTINUE
RETURN
WRITE (6,1030) IVAR,IVMAX,CARD
RETURN
C
1000 FORMAT(20A, T1, 14E5.0)
1001 FORMAT(' INLET FLOW SPLIT', 12X, '***', 20A, '*** READIN (MODEL)')
1002 FORMAT(' INLET ENTHALPIES', 12X, '***', 20A, '*** READIN (OPERA)')
1003 FORMAT(' INLET TEMPERATURES', 10X, '***', 20A, '*** READIN (OPERA)')
1004 FORMAT(' PRESSURE TRANSIENT', 10X, '***', 20A, '*** READIN (OPERACARD)')
1005 FORMAT(' INLET ENTHALPY TRANSIENT', 4X, '***', 20A, '*** READIN (OPERACARD)')
1006 FORMAT(' INLET FLOW TRANSIENT', 8X, '***', 20A, '*** READIN (OPERACARD)')
1007 FORMAT(' INLET POWER TRANSIENT', 7X, '***', 20A, '*** READIN (OPERACARD)')
1008 FORMAT(' AXIAL HEAT FLUX', 13X, '***', 20A, '*** READIN(CARD20)')
1009 FORMAT(' RADIAL POWERS', 15X, '***', 20A, '*** READIN(CARD20)')
1010 FORMAT(' *** CONTINUED')
1030 FORMAT(' IVAR = ', I3, ' NOT 0 - ', I3, 6X, '***', 20A, '*** READIN')

FUNCTION ROLIQ(P)
C MEK1N NEW. AUGUST 1974
U=ALOG(P)
IF(P.LE.450.0) GO TO 2
U=U-7.0
VLIQ=(((-0.26381D-03*U+0.142678D-02)*U+0.21252D-02)*U+0.119227D-02)*U+0.197421D-02)*U+0.404696D-02)*U+0.219632D6-1
ROLIQ=1.0/VLIQ
RETURN
2
VLIQ=(((((0.468D-08*U-0.747D-07)*U+0.39696D-06)*U-0.36945D-06)*U-0.204944D-05)*U+0.67462798D-05)*U+0.33132739D-04)*U+0.10394514D-03)*U+0.16140836D-1
ROLIQ=1.0/VLIQ
RETURN
END

FUNCTION ROVAP(P)
C MEK1N NEW. AUGUST 1974
U=ALOG(P)
IF(P.LE.450.0) GO TO 2
U=U-7.0
PVG=((((0.47458752D0*U-0.65913524D0)*U-0.22430605002)*U-0.27967054D0)*U-0.53007282D0)*U-0.61514691D0)*U+0.43997464D03
ROVAP=P/PVG
RETURN
2
PVG=(((((-0.186D-05*U-0.120D0D-03)*U+0.67223D-03)*U-0.307139D0D-02)*U+0.6000629D-01)*U+0.1103915D0D1)*U+0.19257401D0)*U+0.33360056D03
ROVAP=P/PVG
RETURN
END
FUNCTION S(K,I)

IMPLICIT INTEGER ($)

COMMON /COBRA1/
  ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

COMMON /COBRA2/
  AA(4), AF(7), AFAC(10,10), AV(7), AXIAL(30),
  AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
  GAPX(10), GFAC(9,10), GRIDX(10), HGAP(2), HMF(30), HMG(30),
  IGRI(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
  PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30),
  VVF(30), VVG(30), XQAL(30), Y(30), TT(30)

COMMON /COBRA3/
  MA, MC, MG, MN, MR, MS, MX

DATA IDAT(1)
  0

FUNCTION SATTEM(P)

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XX=ALOG(P)
U=DBLE(XX)
IF(P.LE.450.0) GO TO 2
U=U-7.00D
XATTEM=((((-0.16074225D-00*U-0.69678576DO)*U+0.61781119D0)*U
1+0.14867765D0)*U+0.124671119D03)*U+.55599496D03
SATTEM=SNGL(XATTEM)
RETURN

2 XATTEM=(((-0.198D0-05*U+0.1405D-04)*U-3.265D-5)*U+
12.3907D-3)
XATTEM=((XATTEM*U+0.43461BD-02)*U+0.17363004D0)*U+
0.14657783D-002)*U+0.12405875D03)*U+.55599496D03
SATTEM=SNGL(XATTEM)
RETURN

END

SUBROUTINE SOLVE(NN,LMAX,MID,UL,X,B,NK)
DIMENSION UL(NK,1),X(1),B(1)
C
STORE DIAGONAL BAND OF AAA MATRIX. POSITION (K,L) IN SQUARE
ARRAY BECOMES (K,(MID-K+L)) IN NEW ARRAY.
N = NN
IF(N.EQ.1) GO TO 5
NP1 = N+1
C
X(1) = B(1)
DO 2 I = 2,N
IM1 = I-1
SUM = 0.0
JMIN = MAXO(1,(I-MID+1))
DO 1 J = JMIN,IM1
JJ = MID-I+J
1 SUM = SUM + UL(I,JJ)*X(J)
2 X(I) = B(I) - SUM
C
X(N) = X(N)/UL(N,MID)
DO 4 IBACK = 2,N
I = NP1-IBACK
C
I GOES (N-1),...,1
IP1 = I+1
SUM = 0.0
X(N) = X(N)/UL(N,MID)
DO 4 IBACK = 2,N
I = NP1-IBACK
C
I GOES (N-1),...,1
IP1 = I+1
SUM = 0.0
X(N) = X(N)/UL(N,MID)
DO 4 IBACK = 2,N
I = NP1-IBACK
C
I GOES (N-1),...,1
IP1 = I+1
SUM = 0.0
RETURN
END

SUBROUTINE SPLIT
C
THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE
MAJOR SUBROUTINES OF COBRA-IIIC.
C
C
IMPLICIT INTEGER (*)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX, COB28070
1 ELEV, FERROR, FLO, FTM, GC, JK, J3, J4, J5, J6, J7, J9, KDEBUG, KIJ
2 HFG, IERROR, IQP3, ITERAT, U, J2, J3, J4, J5, J6, J7, J8, J9
3 UJ, UJ4, UJ5, UJ6, UJ7, KDEBUG, KIJ

COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), COB28160
1 AXL(10), B(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), COB28180
2 GAPXL(10), GF(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)

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX, COB28290
1 $A, $AA, $ACA, $ALPHA, $AN, $ANSW, $B, COB28300
2 $CCHAN, $CO, $CHFR, $CON, $SCON, $CP, $DC, $DFDX, COB28310
3 $DDXY, $DHYD, $DHYDN, $DIST, $DPDX, $DPK, $DUR, $DR, $F, COB28320
4 $FACTOR, $FDIV, $FINLE, $FLUX, $FMULT, $FOLD, $FSP, $FSPLI, $FXFLO, COB28330
5 $GAP, $GAPN, $GAPS, $H, $SHFILM, $SHINLE, $HOLD, $HPERI, $IDARE, COB28340
6 $IDFUE, $IDGAP, $IJK, $JBOIL, $SLC, $SLENGTH, $SLOCA, $SLR, COB28350
7 $MCFRC, $MCFRR, $SNTYPE, $NWRAP, $NWRPS, $P, $SPERIM, $SPE, COB28360
8 $PHI, $PRNTC, $PRNTF, $PRNTN, $PRNT, $PSP, $PSH, $PSH, COB28370
9 $QUAL, $RADIUS, $RHOD, $SHOOL, $SPP, $ST, $STOXD, $STON, $STROD, COB28380
10 $S, $SUH, $SUSAVE, $USTAR, $V, $VOLF, $VIS, $VISCW, $VP, $VPA, COB28390
A $W, $WOLD, $WP, $WSAVE, $X, $XCR, $XA, $XB, $XPODL, COB28400

COMMON DATA(1), IDAT(1), LDA(1), IDAT(1), COB28410
1 LOGICAL LDAT(1), IDAT(1), NCHAN(1), NCHANL(1), IDAT(1), COB28420
2 $CCHAN, $CCH, $CON, $CON, $CT, $D, $DE, $DF, $DFDS, COB28430
3 $DFDX, $DFL, $DFNL, $DFOL, $DFLP, $DFOL, $DFSP, $DFSP, COB28440
4 $DGAP, $DGAPN, $DGAPS, $H, $SHFILM, $SHINLE, $HOLD, $HPERI, $IDARE, COB28450
5 $IDFUE, $IDGAP, $IJK, $JBOIL, $SLC, $SLENGTH, $SLOCA, $SLR, COB28460
6 $MCFRC, $MCFRR, $SNTYPE, $NWRAP, $NWRPS, $P, $SPERIM, $SPE, COB28470
7 $PHI, $PRNTC, $PRNTF, $PRNTN, $PRNT, $PSP, $PSH, $PSH, COB28480
8 $QUAL, $RADIUS, $RHOD, $SHOOL, $SPP, $ST, $STOXD, $STON, $STROD, COB28490
9 $S, $SUH, $SUSAVE, $USTAR, $V, $VOLF, $VIS, $VISCW, $VP, $VPA, COB28500
A $W, $WOLD, $WP, $WSAVE, $X, $XCR, $XA, $XB, $XPODL, COB28510

COMMON /COBRA4/ MA, MC, MG, MN, MR, MS, MX, COB28520
1 $A, $AA, $ACA, $ALPHA, $AN, $ANSW, $B, COB28530
2 $CCHAN, $CO, $CHFR, $CON, $SCON, $CP, $DC, $DFDX, COB28540
3 $DDXY, $DHYD, $DHYDN, $DIST, $DPDX, $DPK, $DUR, $DR, $F, COB28550
4 $FACTOR, $FDIV, $FINLE, $FLUX, $FMULT, $FOLD, $FSP, $FSPLI, $FXFLO, COB28560
5 $GAP, $GAPN, $GAPS, $H, $SHFILM, $SHINLE, $HOLD, $HPERI, $IDARE, COB28570
6 $IDFUE, $IDGAP, $IJK, $JBOIL, $SLC, $SLENGTH, $SLOCA, $SLR, COB28580
7 $MCFRC, $MCFRR, $SNTYPE, $NWRAP, $NWRPS, $P, $SPERIM, $SPE, COB28590
8 $PHI, $PRNTC, $PRNTF, $PRNTN, $PRNT, $PSP, $PSH, $PSH, COB28600
9 $QUAL, $RADIUS, $RHOD, $SHOOL, $SPP, $ST, $STOXD, $STON, $STROD, COB28610
10 $S, $SUH, $SUSAVE, $USTAR, $V, $VOLF, $VIS, $VISCW, $VP, $VPA, COB28620
A $W, $WOLD, $WP, $WSAVE, $X, $XCR, $XA, $XB, $XPODL, COB28630

COMMON /COBRA5/ MA, MC, MG, MN, MR, MS, MX, COB28640
1 $A, $AA, $ACA, $ALPHA, $AN, $ANSW, $B, COB28650
2 $CCHAN, $CO, $CHFR, $CON, $SCON, $CP, $DC, $DFDX, COB28660
3 $DDXY, $DHYD, $DHYDN, $DIST, $DPDX, $DPK, $DUR, $DR, $F, COB28670
4 $FACTOR, $FDIV, $FINLE, $FLUX, $FMULT, $FOLD, $FSP, $FSPLI, $FXFLO, COB28680
5 $GAP, $GAPN, $GAPS, $H, $SHFILM, $SHINLE, $HOLD, $HPERI, $IDARE, COB28690
6 $IDFUE, $IDGAP, $IJK, $JBOIL, $SLC, $SLENGTH, $SLOCA, $SLR, COB28700
7 $MCFRC, $MCFRR, $SNTYPE, $NWRAP, $NWRPS, $P, $SPERIM, $SPE, COB28710
8 $PHI, $PRNTC, $PRNTF, $PRNTN, $PRNT, $PSP, $PSH, $PSH, COB28720
9 $QUAL, $RADIUS, $RHOD, $SHOOL, $SPP, $ST, $STOXD, $STON, $STROD, COB28730
10 $S, $SUH, $SUSAVE, $USTAR, $V, $VOLF, $VIS, $VISCW, $VP, $VPA, COB28740
A $W, $WOLD, $WP, $WSAVE, $X, $XCR, $XA, $XB, $XPODL, COB28750

Correct flow estimate by iteration. This procedure assumes there is no diversion crossflow.

Convergence tolerance is E.

E=0.005
SAVEDT = DT
DT = 1.0 E-10
DO 10 I=1,NCHANL
DATA($F+I)=DATA(SFINLE+I)
10 DATA($H+I)=DATA($HINLE+I)
DO 100 K=1,200
CALL PROP(2,1)
IF(IERROR.GT.1) GO TO 1000

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CALL VOID(1)
DO 15 I=1,NCHNL
15 DATA($VPA+I)=DATA($VP+I)/DATA($A+I)
IF(IERRROR.GT.1) GO TO 1000
IF(FITM.GT.0.) CALL MIX(I)
IF(IERRROR.GT.1) GO TO 1000
CALL DIFFER(3,I)
IF(IERRROR.GT.1) GO TO 1000
DPAVG = 0.
DO 20 I=1,NCHNL
20 DPAVG=DPAVG+DATA($DPDX+I)*DATA($A+I)
DPAVG = DPAVG/ATOTAL
J=2
FTOT = 0.
DO 30 I=1,NCHNL
30 DELTAF=(DPAVG-DATA($DPDX+I))*0.5/DATA($DPDX+I)*DATA($F+I)
IF(FITM.GT.0.) DELTAF = DELTAF*0.5
FSAVE =DATA($F+I)
DATA($F+I)=DATA($F+I)+DELTAF
IF((DATA($F+I).LT.0.) GO TO 1000
IF(ABS(DATA($F+I)-FSAVE)/FSAVE.GT. E) J=1
FTOT=FTOT+DATA($F+I)
30 CONTINUE
DO 40 I=1,NCHNL
40 DATA($F+I)=DATA($F+I)*FLO/FTOT
100 WRITE(13,1) (I,DATA($F+I),DATA($DPDX+I),I=1,NCHNL)
1 FORMAT(40H FLOW SPLIT TO GIVE EQUAL DP/DX FAILED / (I5,2E14.6))
1ERROR = 8
120 DT = SAVEDT
RETURN
END
SUBROUTINE SURTEN(P,RL,RG,ST)
C MEKN NEW. AUGUST 1974
C SUBROUTINE SURTEN (T,DUM,N,JU,A,B)
C IN A CYLINDRICAL OR PLATE NUCLEAR FUEL ELEMENT WHERE THE LARGEST
C NUMBER NODE IS THE CLADDING. FOR TRANSIENT CALCULATIONS, FLUID
C DATA AT T IS USED TO CALCULATE THE TEMPERATURE AT T+DT BY USING
C A STABLE IMPLICIT NUMERICAL TECHNIQUE.
C SIMULTANEOUS EQUATIONS ARE SOLVED USING A COMPACT ELIMINATION
C SCHEME FOR TRI-DIAGONAL MATRICES.
C THE VALUE OF T UPON ENTRY IS THE TEMPERATURE AT ORIGINAL TIME.
C AT EXIT T IS THE TEMPERATURE DELTA-T LATER IN TIME.
C SUBROUTINE TEMP (T,DUM,N,JU,A,B)
C SUBROUTINE TEM001 CALCIJATES THE TRANSIENT TEMPERATURE DISTRIBUTION
C IN A CYLINDRICAL OR PLATE NUCLEAR FUEL ELEMENT WHERE THE LARGEST
IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

1 ELEV, FERROR, FLO, FTM, GC, GK, GRID, HSURF, HF

2 HFG, J1, J2, J3, J4, J5, J6, J7, KDEBUG, KF, KIJ

4 NFACT, NRAMP, NAXL, NABC, NCH, NCHE, NO, NF

5 NGAPS, NGRID, NGRIDT, NGTYPE, NGXL, NK, NODES, NODESF, NPROP

6 NRA, NRAMP, NROD, NSCBC

7 NAFACT, NARAMP, NAXL, NABC, NCH, NCHE, NO, NF

8 UF, VF, VFG, VG, Z

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), GAPY(9,10), GRIDXL(10), HGAP(2), HFF(30), HG(30),

3 IGRID(10), KCLAD(2), KFUEL(2), KFF(30), NCH(10), NGAP(9),

4 PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TCLAD(2), UUF(30),

5 VVF(30), VGG(30), XQUAL(30), Y(30), TT(30)

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

1 $$$, $A, $AAA, $AC, $ALPHA, $AN, $ANSW, $B, $C,

1 $CCHAN, $CD, $CHFR, $CON, $COND, $CP, $D, $DC, $SDFDX,

2 $DHDX, $DHYD, $DHYN, $DIST, $DPDX, $DPK, $DUR, $DR, $F,

2 $FACTO, $FDIV, $FINLE, $FLUX, $FMULT, $FOLD, $FSP, $FSPLI,

3 $GAP, $GAPN, $GAPS, $H, $HFILM, $HINLE, $HOLD, $HPERI, $IDARE,

3 $IDFUE, $IDGAP, $IK, $UBOIL, $JK, $LC, $LENGT, $LOCA,

6 $MCHFR, $MCFC, $MCFR, $SNTYPE, $SNWRAP, $NWRS, $SP, $SPRIM, $SH,

6 $SPHI, $SPRNTC, $SPRNT, $SPW, $SPWRF, $SQ, $SQF, $SQPRIM,

8 $QUAL, $RADIUS, $RHOO, $RHOOL, $SP, $ST, $TDUMY, $TINLE, $TROD,

8 $U, $UH, $USAVE, $USTAR, $V, $VISC, $VISCW, $VSP, $VPA

A $W, $WOLD, $WSP, $WSAVE, $X, $XCROS, $$$A, $$$B, $WOLD

COMMON DATA(1), LOGICAL LDAT(1), INTEGER IDAT(1)

EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))

DIMENSION A(3,1), B(1), T(1), KFDR2

REAL KF, KKF, KCLAD, KFUEL

SETUP A MATRIX OF THE FORM A*T=B WHERE ONLY THE 3 DIAGONALS OF

A ARE STORED.

NM1 = NODESF-1

NP1 = NODESF+1

IF (NODESF.LE.0) GO TO 1000

J = IDAT($IDFUE+N)

DR = DFUEL(J)*.5/FLOAT(NM1)

DR2 = DR**2

RCFUEL = RFUEL(J)+CFUEL(J)/DT
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KFD2 = KFUEL(J)/DR2
HGA1 = 1./(1./HGA1(J) + TCLAD(J)/KCLAD(J))
QCLAD = 0.

C J IS THE FUEL TYPE CODE. CYLINDRICAL FUEL, J=1. PLATE FUEL, J=2.

IF(J.EQ.2) GO TO 101

C

C THIS SECTION FOR CYLINDRICAL FUEL RODS.

QFUEL = DATA($FLUX+N+MR*(JU-1))/4.*DATA($D+N)/DFUEL(J)**2

DO 100 I=1,NP1

IF(I.GT.1) GO TO 10

IF(J.EQ.2) GO TO 10

10 A(2,1) = RCFUEL + 4.*KFD2
A(3,1) = -4.*KFD2
GO TO 80

10 IF(I.GT.NM1) GO TO 20

A(1,1) = -KFD2*(1.-1./FLOT(2*I-2))
A(2,1) = RCFUEL + 2.*KFD2
A(3,1) = -KFD2*(1.+1./FLOT(2*I-2))
GO TO 80

20 IF(I.EQ.NP1) GO TO 30

A(1,1) = -2.*KFD2
A(2,1) = RCFUEL + 2.*KFD2 + 2.*HGA1/DR + HGA1/DR/FLOT(I-1)
A(3,1) = -(2.*HGA1/DR + HGA1/DR/FLOT(I-1))
GO TO 80

30 A(1,1) = HGA1/TCLAD(J)/DFUEL(J)*DATA($D+N)
A(2,1) = RCLAD(J)*CCLAD(J)/DT*HGA1/TCLAD(J)*DFUEL(J)/DATA($D+N)

1 + SURF/TCLAD(J)

80 IF(I.EQ.NP1) GO TO 90

B(I) = QFUEL + RCFUEL*T(I)
GO TO 100

90 B(I) = QCLAD + RCLAD(J)*CCLAD(J)/DT*T(I) + SURF/TCLAD(J)*TFUID

100 CONTINUE

C

CALL GAUSS(1,NP1,A,B,T)
RETURN

C

C THIS SECTION FOR FLAT PLATE FUEL.

101 QFUEL = DATA($FLUX+N+MR*(JU-1))/2./DFUEL(J)

DO 200 I=1,NP1

IF(I.GT.1) GO TO 110

A(2,1) = RCFUEL + KFD2.*2.
A(3,1) = -2.*KFD2
GO TO 180

110 IF(I.GT.NM1) GO TO 120

A(1,1) = -KFD2
A(2,1) = RCFUEL + 2.*KFD2
A(3,1) = -KFD2
GO TO 180

120 IF(I.EQ.NP1) GO TO 130

A(1,1) = -2.*KFD2
A(2,1) = RCFUEL + 2.*KFD2 + 2.*HGA1/DR
A(3,1) = -2.*HGA1/DR
GO TO 180

130 A(1,1) = -HGA1/TCLAD(J)
A(2,1) = RCLAD(J)*CCLAD(J)/DT + HGA1/TCLAD(J) + HSURF/TCLAD(J)

180 IF(I.EQ.NP1) GO TO 190

C

C
B(I) = QFUEL + RCFUEL*T(I)
GO TO 200

190  B(I) = QCLAD + RCLAD(J)*CCLAD(J)/DT*T(I) + HSURF/TCLAD(J)*TFLUID
CONTINUE

C SOLVE FOR TEMPERATURES
CALL GAUSS(1,NP1,A,B,T)
RETURN

1000 IERROR = 15
RETURN
END

SUBROUTINE TIDY
IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA ,AFLUX ,ATOTAL ,ABETA ,AFLUX ,AFLUX ,AFLUX ,AFLUX ,AFLUX


COMMON DATA(1)
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DO 4 I=1,NCHANL
DATA($AC+I) = 144.0*DATA($A+I)
DATA($PW+I) = 12.0*DATA($PERIM+I)
DATA($PH+I) = 12.0*DATA($HPERI+I)
DATA($DC+I) = 12.0*DATA($DHYD+I)
DATA($DR+I) = 12.0*DATA($D+I)
DO 4 L=1,4
IDAT($LC+I+MC*(L-1)) = 0
DATA($DIST+I+MC*(L-1)) = 0.0
DATA($GAPS+I+MG*(L-1)) = 0.0
CONTINUE
4

IF (NK.EQ.0) RETURN
DO 12 K=I,NK
I = IDAT($IK+K)
J = IDAT($JK+K)
DO 8 L=1,4
IF (IDAT($LC+I+MC*(L-1)).EQ.0) GO TO 10
8 CONTINUE
WRITE (6,2004) K,J,I
0 IDAT($LC+I+MC*(L-1)) = J
DATA($DIST+I+MC*(L-1)) = DATA($LENGT+K)*12.0
DATA($GAPS+I+MG*(L-1)) = DATA($GAP+K)*12.0
RETURN
2004 FORMAT(' CARDS4 GAP CONNECTION ',I3, ' CHANNEL ',I3,
' 1' IS 5TH ADJACENT TO ',I3)
END

SUBROUTINE TOD(A)
DIMENSION A(3),DATIM(5)
CALL WHEN(DATIM)
A(1)=DATIM(3)
A(2)=DATIM(4)
A(3)=DATIM(5)
RETURN
END

SUBROUTINE ACOL(IFROM,IK,JK,KMAX,LOCA,MA,MS,NK,MG,IPILE)
DIMENSION IK(1),JK(1),LOCA(MG,14)
SET LOCA, DEFINING INTERACTING BOUNDARIES
IFROM = 1, CALLED FROM CARDS4, = 2, FROM MAIN (OLD COBRA)
LOCA(K,1)=K.
LOCA(K,L),L=2,7 SPECIFIES UP TO LOCA(K,8) BOUNDARIES ADJACENT TO CHANNELS DEFINING BOUNDARY K.
DO 8 K=1,NK
IF (IPILE.GT.0) GO TO 107
DO 103 L=2,13
103 LOCA(K,L)=0
GO TO 110
107 DO 3 L=2,7
3 LOCA(K,L)=0
110 N=1
LOCA(K,1) = K
II = IK(K)
JJ = JK(K)
DO 7 KK=1,NK
7 III = IK(KK)
RETURN

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CONVERSATIONAL MONITOR SYSTEM
FILE: COBRA3C FORTRAN A

CONVERSATIONAL MONITOR SYSTEM

IF (III.GT.II) GO TO 7
JJJ = JK(KK)

6 IF ( (III.EQ.JII) .OR. (II.EQ.JJJ) ) GO TO 7
GOTO 7

6 IF ( (III+JJJ - II-JU) .EQ. 0) GO TO 7
N = N+1

LL = III

IF (II.EQ.JII) LL = JJJ

WV = FLOAT(II-LL)/FLOAT(II-JU)

7 CONTINUE

IF (IPILE.GT.0) GO TO 108

GO TO 109

108 LOCA(K,8) = N

109 IF (II.GE.JU) GO TO 8

II = JK(K)
JJ = IK(K)

7 CONTINUE

DO 10 K=1,NK

DO 10 L=2,N

10 CONTINUE

C FIND STRIPE WIDTH FOR AAA MATRIX IN DIVERT

MAX = 0

DO 10 K=1,NK

N = LOCA(K,8)

IF (IPILE.GT.0) GO TO 111

N = LOCA(K,14)

111 DO 10 L=2,N

NKL = IABS(LOCA(K,L))

J = IABS(K-NKL)

IF (J.LT.MAX) GO TO 10

MAX = J

KMAX = K

10 CONTINUE

MS = 2*MAX + 1

CALL CORE2(MS,NK)

RETURN

END

SUBROUTINE CARDS4(AC, DC, DIST, DR, GAPS, LC, MA, MG, N1, N2, NCHF, NFUEL, 1 PH, PHTOT, PRINT, PW, MC)

C=====NOTE THAT THESE COMMON AREAS ARE NOT IDENTICAL WITH THOSE

IMPLICIT INTEGER ($)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX

1 ELEV, FERROR, FLO, FTM, GC, GK, GRID, HSURF, HF

2 HG, .HG, J1, J3, J6, J7, KDEBUG, KF, KIJ

3 J3, J4, J5, J6, KMAX, KDEBUG, KF, KIJ

4 NFACT, NARAP, NAXL, NAXL, NBBC, NCHAN, DUM1, DX, NF

5 NGAPS, NGRID, NGRIDT, NGTYPE, NGXL, NK, NODES, NODESF, NPROP

6 NRAMP, NROD, NSCBC, NV, NDISC, PI, PITCH, POWER, PREF
FILE: COBRA3C FORTRAN A CONVERSATIONAL MONITOR SYSTEM

7 QAX ,RHDF ,RHDG ,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),
A KL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
GAPX(30), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
GRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
P(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30),
VFG(30), VVG(30), XQUAL(30), Y(30), Z(30).

LOGICAL GRID, PRINT
REAL KIJ, KF, KKF, KCLAD, KFUEL
COMMON /COBRA3/ DUM2 ,DUMC ,DUM3 ,MN ,MR ,MS ,MX ,NCB32070.
1 $SS ,SA ,SAAA ,SAC ,SALPHA ,SAN ,SANSWE ,SB ,SCB32070.
2 $CCCHAN ,SCD ,SCFR ,SCON ,SCON ,SCP ,SD ,SDC ,SDFX ,SCB32080.
3 $DHDX ,SDHYD ,SDHYD ,SDIST ,SDFDX ,SDFX ,SDR ,SDR ,SF ,SCB32090.
4 $GAP ,SGAP ,SGAPS ,SH ,SHFILM ,SHLINE ,SHOLD ,SHPERI ,SHDARE ,SCB3110.
5 $DFUE ,$DIGAP ,SIK ,$JBOIL ,$UK ,$LC ,$LENGT ,$LOGA ,SLR ,SCB32120.
6 $MCFRC ,$MCFR ,$MCFR ,$NTYPE ,$NSP ,$NSP ,$SP ,$SP ,$SP ,SCB32130.
7 $PHI ,$PRNTC ,$PRNTR ,$PRNTN ,$PW ,$PW ,$PWRF ,SOC ,SOF ,SCB32140.
8 $QUAL ,$RADIA ,$RHO ,$ROOL ,$ST ,$TDUMY ,$TINLE ,$TROD ,SCB32150.
9 $U ,$UH ,SUH ,$SSTAR ,SV ,SVISC ,$VISCW ,$SVP ,$SVPA ,SCB32160.
A $W ,$WOLD ,$WSAVE ,$X ,$X ,$XCROS ,$X ,$XPOLD ,SCB32170.

C

COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1),IDAT(1), IDAT(1))

C

EQUIVALENCE (NCHAN,NCHANL)

C

DIMENSION AC(1),DC(1),DR(1),PH(1),PRINT(12),PW(1),DIST(MC,1),
1 GAPX(1),LC(MC,1),FXF(5),IGROUP(15),JB(20),IFRIC(15),
2 TEXT(20),MAAP(2,20)

C

MEKIN - ENTERED FOR PWR AND BWR SIMPLIFIED INPUT DATA.
COMBINES CARD GROUPS 4, 7, 8 IE CHAN GEOMETRY, SPACERS AND RODS.
READ (A) INDICATORS, (B) CHAN GEOM + SPACERS FOR EACH GROUP,
(C) ROD POWERS, (D) SPACER X/L, (E) CHANNELS IN GROUPS 2,3 ETC,
(F) GAP CONNECTIONS, (G) FUEL DATA

C

READ INDICATORS. INITIALISE
READ (12,1001) N1,N2,NGRID,NGRIDT,NODESF,NFUELT,NCHF,IMAP,ITEXT
IF (N1.LE.15) GO TO 1
WRITE (13,2001)
IERROR = 1
RETURN
1 IF (ITEXT.LE.0) GO TO 3
DO 2 I=1,ITEXT
READ (12,1005) TEXT
2 WRITE(13,1005) TEXT
3 NCHANL = N2
NRod = N2
J6 = 2
NRAMP = 1
GRID = .FALSE.
NGRT = MAX0(NGRIDT,1)
IPILE = U7
DO 4 I=1,NCHANL
DO 4 L=1,6
IDAT(LR+I+MR*(L-1))=O
DATA(PHI+I+MR*(L-1))=O.
IF (L.GT.4) GO TO 4
LC(I,L) = 0
GAPS(I,L) = 0.0
DIST(I,L) = 0.0
4 CONTINUE
C READ GEOM AND SPACER DATA FOR EACH CHANNEL GROUP. SET GROUP 1
DO 10 J=1,N1
READ (12,1002) N,I,FRAC,AC(I),PW(I),PH(I),GAPS(I,1),DIST(I,1),
1 DR(I),DATA(PHI+I),M
DATA(CD+I)=O.
FXF(1) = 0.
IF (FRAC.LE.0.0) FRAC = 1.0
AC(I) = FRAC*AC(I)
PW(I) = FRAC*PW(I)
PH(I) = FRAC*PH(I)
DATA(PHI+I)=FRAC*DATA(PHI+I)
IF (NGRID.EQ.0) GO TO 6
READ(I2,1003) (DATA(CD+I+MC*(L-1)),L=1,NGRIDT),(FXF(L),L=1,NGRIDT)
6 IDAT(NTYPE+I)=J
IFRIC(J) = MAX0(N,1)
IDAT(IDFUE+I)=MAX0(M,1)
IGROUP(J) = I
IF (J.GT.1) GO TO 10
C SET ALL CHANNELS TEMPORARILY TO GROUP 1 VALUES.
DO 8 K=1,NCHANL
AC(K) = AC(I)
PW(K) = PW(I)
PH(K) = PH(I)
GAPS(K,1) = GAPS(I,1)
DIST(K,1) = DIST(I,1)
DF(K) = DR(I)
DATA(PHI+K)=DATA(PHI+I)
DATA(NTYPE+K)=1
IDAT(IDFUE+K)=IDAT(IDFUE+I)
DO 8 L=1,NGRT
DATA(CD+K+MC*(L-1))=DATA(CD+I+MC*(L-1))
8 CONTINUE
10 CONTINUE
DO 12 K=1,MG
DATA(FXFLD+K+MG*(L-1))=FXF(L)
12
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C
C READ ROD POWER FACTORS AND SPACER LOCATIONS.
II = MINO(NROD,16)
READ(12,1003) (DATA($RADIA+I),I=1,II)
IF (DATA($RADIA+I).GE.0.0) GO TO 16
DO 14 I=1,NROD
14 DATA($RADIA+I)=1.0

GO TO 18
16 IF(NROD.GT.16) READ(12,1003) (DATA($RADIA+I),I=17,NROD)
18 IF (NGRID.GT.0) READ (12,1004) (GRIDXL(I),IGRID(I),I=1,NGRID)
C
C READ CHANNEL NUMBERS NOT IN GROUP 1, SET DATA
JCHECK = 1
IF (N1.EQ.1) GO TO 28
DO 26 J=2,N1
ICHECK = 0
20 READ(12,1001) (JB(I),I=1,20)
DO 22 J=1,20
K = JB(J)
IF (K.LE.0) GO TO 24
I = IGROUP(J)
AC(K) = AC(J)
FW(K) = PW(J)
PH(K) = PHI(J)
GAPS(K,1) = GAPS(I,1)
DIST(K,1) = DIST(I,1)
DR(K) = DR(I)
DATA($PH1+K) = DATA($PHI+I)
IDAT($NTYPE+K) = J
IDAT($IDFUE+K) = IDAT($IDFUE+I)
IF (K.EQ.1) ICHECK = 1
IF (K.EQ.IGROUP(1)) JCHECK = 0
DO 22 L=1,NGR
DATA($CD+K+MC*(L-1)) = 1
DATA($CD+1+MC*(L-1)) = 1
22 CONTINUE
24 IF (ICHECK.EQ.1) GO TO 26
WRITE(13,2002) J,IGROUP(J)
IERRO = 1
RETURN
26 CONTINUE
IF (JCHECK.EQ.1) GO TO 28
WRITE(13,2002) J,IGROUP(J)
IERRO = 1
RETURN
C
C SET ROD POWER FRACTIONS AND CHANNEL PARAMETERS
28 PHOT = 0.0
ATOT = 0.0
DO 32 I = 1,NCHANL
DO 30 J=1,NROD
30 DATA($PWRF+I+MC*(J-1)) = 0
DATA($PWRF+I+MC*(I-1)) = DATA($PHI+I)
32 CONTINUE
C
$LR+I=I
DATA(DR+I)=DR(I)/12.0
DATA(DP+I)=DP(I)/12.0
DATA(DP+I)=DP(I)/12.0
DATA(DS+I)=DC(I)
DATA(DH+I)=DC(I)/12.0
DATA(DC+I)=DATA(DS+I)
PHTOT=PHTOT+DATA(DP+I)
ATOTAL=ATOTAL+DATA(DS+I)
32 IF (IPILE.EQ.1) GO TO 34
BWR. NO CHANNEL INTERACTION
NSCBC = 0
NBBC = 1
JS = 0
ABETA = 0.0
BBETA = 0.0
GK = 0.0
NK = 0
GO TO 120
PWR. READ AND SET GAP CONNECTIONS (IE BOUNDARIES)
IMAP=1 FOR RECTANGULAR MAP. SAY HOW MANY CHAN ACROSS AND DOWN.
IMAP=2 FOR PWR MAP. GIVE START AND END OF EACH ROW. LAST ROW ALL 0.
IMAP=3 FOR CHANNEL-NUMBERED MAP. LAST ROW ALL 0.
IMAP=4 FOR SPECIFYING CHANNEL BOUNDARY NUMBERS
34 NK = 0
IRAD = 0
ISIZE = 20
NEXT = 1
WRITE (13,3001) IMAP
IF (IMAP.EQ.4) GO TO 70
IF (IMAP.EQ.2) 40,42,48
40 READ (12,1001) ICROSS, IDOWN
ISTART = 1
IEND = ICROSS
GO TO 44
42 READ (12,1001) ISTART, IEND
44 US = 0
DO 46 J=1,ISIZE
MAAP(2,J) = 0
IF (J.LT.ISTART) .OR. (J.GT.IEND) GO TO 46
JS = JS+1
MAAP(2,J) = JS
CONTINUE
GO TO 49
48 READ (12,1001) (MAAP(2,J),J=1,ISIZE)
C SET BOUNDARIES FOR IMAP = 1,2,3
49 USMAX = 0
WRITE (13,3009)
DO 66 I=1,ISIZE
C SET BOUNDARIES ACROSS
DO 50 J=1,ISIZE
MAAP(1,J) = MAAP(2,J)
JSMAX = MAX0(JSMAX,MAAP(2,J))
IF (MAAP(2,J).NE.0) JMAX=J
IF (J.EQ.ISIZE) GO TO 50
IF ( MAAP(2,J).EQ.0 .OR. (MAAP(2,J+1).EQ.0) ) GO TO 50
NK = NK+1
IDAT($IK+NK) = MAAP(2,J)
IDAT($JK+NK) = MAAP(2,J+1)
50 CONTINUE
IF (I.GT.1) GO TO 51
WRITE (13,3002) (MAAP(1,J),J=1,JMAX)
JUMP = 1
GO TO 64
51 IF (1.EQ.ISIZE) GO TO 66
IF (IMAP-2) 52,54,60
52 IF (I.GE.IDOWN) ISTART = ISIZE+1 GO TO 56
54 READ(I2,1001) ISTART, IEND
56 DO 58 J=1,ISIZE
MAAP(2,J) = 0
IF ( (J.LT.ISTART) .OR. (J.GT.IEND) ) GO TO 58
JS = JS+1
MAAP(2,J) = JS
58 CONTINUE
IF (IC.EQ.NK) GO TO 68
WRITE (13,3002) (MAAP(2,J),J=1,JMAX)
C SET WOLD TO PRINT MAP OF RADIAL POWERS
59 IRAD = IRAD+I
JB(IRAD) = JMAX
DO 65 J=1,JMAX
L = MAAP(JUMP,J)
DATA($WOLD+IRAD+MG*(J-1))=-100.
IF (L.LE.0) GO TO 65
DATA($WOLD+IRAD+MG*(J-1))=DATA($RADIA+L)
65 CONTINUE
IF (JUMP.EQ.1) GO TO 51
WRITE (13,3011) (DATA($WOLD+I+MG*(J-1)),J=1,JMAX)
C PRINT RADIAL POWER MAP
WRITE (13,3010) I=1,IRAD
JMAX = JB(I)
69 WRITE(13,3011) (DATA($WOLD+I+MG*(J-1)),J=1,JMAX)
IF (JSMAX.EQ.NCHANL) GO TO 76
WRITE (13,2006) JSMAX,NCHANL
IERROR = 1
RETURN

C
C SET BOUNDARIES FOR IMAP = 4
C
70 READ (12,1001) (JB(J),J=1,20)
DO 74 I=1,20
IF (JB(I).EQ.0) GO TO 76
IF (NEXT.EQ.0) GO TO 72
NK = NK+1
IDAT($IK+NK) = JB(I)
NEXT = 0
GO TO 74
72 IDAT($JK+NK) = JB(I)
NEXT = 1
74 CONTINUE
GO TO 70
76 DO 90 K=1,NK
78 I=IDAT($IK+K)
IF (IBS(I).EQ.0) GO TO 78
70
80 WRITE (13,2003) K,I,IDAT($JK+K)
IERROR = 1
RETURN
82 IDAT($IK+K) = IDAT($JK+K)
IDAT($JK+K) = I
GO TO 78
84 M = IDAT($JK+K)
DO 86 L=1,4
IF (LC(I,L).EQ.0) GO TO 88
86 CONTINUE
WRITE (13,2004) K,M,I
IERROR = 1
RETURN
88 LC(I,L) = M
NG = IDAT($NTYPE+I)
N = IGROUP(NG)
GAPS(I,L) = AMAX1(GAPS(M,1),GAPS(N,1))
DIST(I,L) = DIST(N,1)
DATA($GAPN+K) = GAPS(I,L)/12.0
DATA($GAP+K) = DATA($GAPN+K)
DATA($LENGT+K) = DIST(I,L)/12.0
DATA($FACTO+K) = 1.0
90 CONTINUE
C
C READ HALF-BOUNDARIES AND SET FACTOR(K) = 0.5
C
92 READ (12,1001) (JB(L),L=1,20)
IF (JB(1).EQ.0) GO TO 110
IEND = 100
MARK = 1
DO 98 M=1,10
98 MARK = 1
L = 2*M - 1
JBL = JB(L)
IF (JBL-JB(L+1)) 98,94,96
94 IEND = M
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IF (JBL.EQ.0) GO TO 100
WRITE (13,2005) JBL,JBL(L+1)
IERROR = 1
RETURN

96 JBL(L) = JBL(L+1)
JBL(L+1) = JBL
98 CONTINUE

100 IC = MARK
DO 102 K=1,NK
IF((IDAT($IK+K).NE.JB(MARK)).OR.
1 (IDAT($JK+K).NE.JB(MARK+1))) GO TO 102
DATA($FACTO+K)=0.5
MARK = MARK+2
IF (MARK.EQ.IEND) GO TO 110
IF (MARK.GE.20) GO TO 92
102 CONTINUE
IF (IC.LT.MARK) GO TO 100
WRITE (13,2005) JB(MARK), JB(MARK+1)
IERROR = 1
RETURN

110 CALL ACOL(1,IDAT($IK+1),IDAT($JK+1),KMAX,IDAT($LOCA+1),MA,MS,NK,
1 MG,IPILE)
112 WRITE (13,3003) NK
M = 1
114 MM = MINO( (M+7),NK)
WRITE(13,3004) M,(IDAT($IK+K),IDAT($JK+K),K=M,MM)
M = MM+1
IF (M.LE.NK) GO TO 114
WRITE (13,3005) NK
M = 1
116 MM = MINO( (M+24),NK)
DO 118 L=1,8
118 WRITE(I3,3006) L,(IDAT($LOCA+K+MG*(L-1)) ,K=M,MM) M = MM+1
WRITE (13,3007)
IF (M.LE.NK) GO TO 116
L = MS*NK
WRITE (13,3009) MS,KMAX,L,MA

C SET NTYYPE BACK TO INDICATE FRICTION TYPE
120 DO 122 I=1,NCHANL
NG=IDAT($NTYPE+I)
IDAT($NTYPE+I)=IFRIC(NG)
IF (LC(I,1).GT.0) GO TO 122
GAPS(I,1) = 0.0
DIST(I,1) = 0.0
122 CONTINUE

READ FUEL DATA
C IF(NODESF.EQ.0) GO TO 126
READ(12,1003) (KFUEL(I),CFUEL(I),RFUEL(I),DFUEL(I),
1 KCLAD(I), CCLAD(I), RCLAD(I), TCLAD(I), HGAP(I),I=1,NFUELT)
DO 124 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.

C SET PRINT REQUIREMENTS
126 IF (J1.GT.1) RETURN
PRINT(4) = .TRUE.
PRINT(7) = .TRUE.
PRINT(8) = .TRUE.
RETURN

C 1001 FORMAT(201)
1002 FORMAT(11,14,9E9.3,12)
1003 FORMAT(16E9.3)
1004 FORMAT(8(E5.3,15))
1005 FORMAT(20A4)
2001 FORMAT(' CARDS4 N1.GT.15')
2002 FORMAT(' CARDS4 CHANNEL GROUP',I3,' CHANNEL',I4,' INCORRECT')
2003 FORMAT(' CARDS4 GAP CONNECTION', I3, ' AND SAME IE ', 213)
2004 FORMAT(' CARDS4 GAP CONNECTION', I3, ' CHANNEL ', I3, 1)
2005 FORMAT(' CARDS4 HALF-BOUNDARY ', I4, ' - ', I4, ' NOT IN BOUNDARY '
1SET')
2006 FORMAT(' CARDS4 HIGHEST NUMBER CHANNEL FOUND TO BE ', I3, 1)
1 ' AND THIS NOT EQUAL TO NUMBER SPECIFIED, IE ', I3)
3001 FORMAT('CH1', ' CHANNEL DATA SET IN SUBROUTINE CARDS4 ( IMAP = ', 1 12, ' )', )
3002 FORMAT( /.2016)
3003 FORMAT(17H1, I5, ' BOUNDARIES AS BELOW (IK(K) - JK(K))', /)
3004 FORMAT( '(', I3, ' ', I3, ') ', 8(6X, I3, ' - ', I3)
3005 FORMAT( '(', I1, ') ', 2515)
3006 FORMAT( '(', Ii, ') ', 2515)
3007 FORMAT( //)
3008 FORMAT( 'CHANNEL NUMBERING MAP', ')
3009 FORMAT( //, ' MAXIMUM OVERALL STRIPE WIDTH FOR ARRAY AAA IN DIVER '
1T = ', I3, ' FOR BOUNDARY NO. ', I3, //, ' REQUIRE ', I6, ' STORES '
2 FOR AAA SIZE AND THIS OK SINCE LESS THAN ', I6, ' PROVIDED', //)
3100 FORMAT(1H1, ' RADIAL POWER MAP (-100 OR *** INDICATES NO CHANNEL '
1EL)', '')
3101 FORMAT( //, 20F6.3)
END

SUBROUTINE CHAN(IPART,NTHBOX,NTHBXX,ND1X,ND2X)

IMPLICIT INTEGER (*)
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, IGP3 , ITERAT, J1 , U2 , COB36240
3 J3 , J5 , J6 , J7 , KDEBUG,KF , KI , COB36250
4 NAFACT, NRAMPP, NAX , NAXL , NBBC , NHANL , NCHF , NDX , NF , COB36260
5 NGAPS , NGRID , NGRITD , NGRIDT, NGTYPE , NGXL , NK , NODES , NODESF , NPROP , COB36270
6 NRAMPP, 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
CONVERSATIONAL MONITOR SYSTEM

COMMON /COBRA2/ AA(4), AF(7), AFAC(10,10), AV(7), AXIAL(30),
1 AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
2 GAPX(10), GFAC(9,10), GRIDX(10), HGAP(2), HHF(30), HHG(30),
3 IGRID(10), KCLAD(2), KFUEL(2), KFF(30), NGAP(9),
4 PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLA(2), UUF(30),
5 VVF(30), VVG(30), XQUAL(30),

COMMON /COBRA3/ MA, MC

LOGICAL GRID, PRINT

REAL KIJ, KF, KKF, KCLAD, KFUEL

COMMON /FRDATA/ BURN, CPR, EFFB, EPSF, EXPR, FPRESS, FPUO2, FRAC, FYD,
1 GMIX(4), GRGH, PGAS, RADR, RDELT, THC, THG

COMMON /LINK4/ IFRM, IHTM, IPRP, NCC, NCF, NDM1, NDS, NGP

COMMON /ITPSV/ ITMP

COMMON DATA(1)

LOGICAL LDAT(1)

INTEGER IDAT(1)

LOGICAL LDAT(1)

COMMON /GAPFAC/ FACSL(70), FACSLK(70)

COMMON /GAPFAC/ FACSL(70), FACSLK(70)

DIMENSION CARD(20), CDG(5), GP(250), JBSTOR(150), JB(20),
1 NTHBOX(25, 25), GAPREC(400)

IPART = 1 READ CHANNEL INPUT DATA

IPART = 2 PRINT CHANNEL INPUT DATA

OWN = ARRAY MAX SIZES. CARD(20), CDG(NGRIDT), GP(NCHANL), JB(MAXRD),

JBSTOR(NCTYP+3+NUMBER OF CHANNELS NOT OF TYPE 1)

DEFINE JBSTOR(L), L1, NCTYP = 1 = ARRAY POSITIONS STARTING EACH TYPE,

JBSTOR(NCTYP+2) = A CHANNEL NUMBER OF TYPE 1,
CHN OF TYPE N IN JBSTOR(L), L=J.K WHERE J=JBSTOR(N), K=JBSTOR(N+1) -1

IF (IPART.EQ.2) GO TO 102

MAXRD = 14

NFUEL = 1

NCHANL = NTHBXX

ITMP = 0

READ (12,1001) CARD, IPILE, NCTYP, NGRID, NGRIDT, NODESF, NFXF, IFRM,

1 IHTM, IPROP

WRITE (I3,1002) CARD

IF (NODESF.EQ.0) GO TO 2

IF (IFRM.EQ.0.AND. IHTM.EQ.0) GO TO 2

READ(I2,2016) CARD, EPSF

WRITE(I3,2009) CARD

CC IF EPSF=0, THEN SET TO DEFAULT VALUE

IF (EPSF.EQ.0.) EPSF=0.01

2 NROD = NCHANL

J6 = 2

NRAMP = 1

GRID = .FALSE.

NGRT = MAX0(NGRIDT, 1)

J7 = IPILE

DO 1109 I=1, MR

DO 1109 J=1, MC

1109 DATA($PWRF+I+MC*(J-1))=0.0

DO 4 L=1, 6

DO 4 I=1, MR

4 DATA($PHI+I+MR*(L-1))=0.0

CONTINUE

READ AND SET CHANNEL DATA. (A) CHANNEL PARAMETERS, (B) GRID DATA.

CC (C) CHANNELS MAKING EACH TYPE (EXCEPT TYPE 1)

JBSTOR(1) = JBTC

JBSTOR(2) = JBTC+1

READ(12,1003) CARD, N, J, FRAC, GAP, TV, HRNUM, HRDI, CRNUM, CRDI, SIDE, CORN

WRITE(I3,1004) I, CARD

IF (FRAC.LE.0.0) FRAC=1.0

IF (J.EQ.2) GO TO 6

CHAR = CRNUM

CHPW = CRDI

CHPH = SIDE

GO TO 8

6 CHAR = SIDE*SIDE - 4.0*CORN*CORN - PI*(0.25*HRNUM*HRDI*HRDI

1 + 0.25*CRNUM*CRDI*CRDI - CORN*CORN)

CHPW=HRNUM*PI*HRDI

CHPH=CHPW+4.0*(SIDE-2.0*CORN)+2.0*PI*CORN+CRNUM*PI*CRDI

8 CHDI = 4.0*CHAR/CHPW

CDG(1)=0.0

IF (NGRID.LE.0) GO TO 9

READ(12,1005) CARD, (CDG(L), L=1, NGRIDT)

WRITE(I3,1006) I, CARD

9 M=1

IF (I.EQ.1) GO TO 12
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IFIRST=1
10 READ(12,1001) CARD,(JB(L),L=1,MAXRD)
   IF(IFIRST.EQ.0) WRITE(13,1008) CARD
   IF (IFIRST.EQ.0) GO TO 12
   WRITE(13,1007) I,CARD
   IFIRST=0
   M=JB(1)
   IF(M.GT.0).AND.(M.LE.NCHANL)) GO TO 12
   IERROR=1
   WRITE(13,2001) I,M
   RETURN
12 DATA($A+M) = CHAR=FRAC/144.0
   DATA($PERIM+M) = CHPW=FRAC/12.0
   DATA($PERI+M) = CHPH=FRAC/12.0
   DATA($PHI+M) = HRNUM=FRAC
   DATA($DHYD+M) = CHDI/12.0
   DATA($D+M) = HDRI/12.0
   IDAT($NTYPE+M) = MAXO(N,1)
   GP(M) = GAPW
   DO 18 L=1,NCHANL
      J=L
      IF(I.EQ.1) GO TO 19
      IF(L.GT.MAXRD) GO TO 10
      JBIC=JBIC+1
      JBSTOR(JBIC)=J
      JBSTOR(JBIC+1) = JBIC+1
      J=J+J
   18 DATA($A+J) = DATA($A+M)
      DATA($AN+J) = DATA($A+M)
      DATA($PERIM+J) = DATA($PERIM+M)
      DATA($PERI+J) = DATA($PERI+M)
      DATA($DHYD+J) = DATA($DHYD+M)
      DATA($D+J) = DATA($D+M)
      GP(J) = GP(M)
      IDAT($NTYPE+J) = IDAT($NTYPE+M)
      IDAT($DIFUE+J) = 1
      IDAT($DIFUE+J) = 1
      IF(DATA($RADIA+J).EQ.O.0) GO TO 17
      DATA($PHI+J) = DATA($PHI+M)
      DATA($PHI+J+MR*(1-1)) = DATA($PHI+M)
      DATA($PWRF+J+MC*(1-1)) = DATA($PHI+M)
      IDAT($LR+J) = J
      IDAT($LR+J+MR*(1-1)) = J
   17 CONTINUE
   DO 16 K=1,NGRT
      16 DATA($CD+J+MC*(K-1)) = CDG(K)
   18 CONTINUE
   CONTINUE
   CONTINUE
   C SET CHANNEL OF TYPE 1 INTO JBSTOR
      L = JBSTOR(2)
      M = JBSTOR(NCTYP+1) - 1
   DO 26 I=1,NCHANL
      DO 24 J=L,M
IF (JBSTOR(J).EQ.1) GO TO 26
24 CONTINUE
JBSTOR (NCYTP+2) = 1
GO TO 28
26 CONTINUE
C
28 IF (GRID.EQ.0) GO TO 30
C READ GRID POSITIONS
READ (12,1000) CARD,(GRIDX(I),GRID(I),I=1,7)
WRITE (13,1010) CARD
IF (GRID.LE.10) GO TO 29
WRITE (13,2007) NGRID
STOP
29 IF (GRID.LE.7) GO TO 30
READ (12,1000) CARD,(GRIDX(I),GRID(I),I=8,NGRID)
WRITE (13,1010) CARD
C READ ROD LAYOUT
30 IF(IPILE) 2031,2031,2032
2031 READ(12,2033) CARD,NN11,NN22,NN33,NN44,ITMP
2033 FORMAT(204A1,T1,45)
WRITE(13,2034) CARD
2034 FORMAT(' INDICATORS '14X,'***',20A4,'*** CHANNEL')
IF (IFRM.EQ.1.AND.NN44.NE.1) GO TO 146
C IF(15,LE.1) IF(IFRM.EQ.1.AND.NN44.NE.1) GO TO 146
IF (NN11.EQ.0) GO TO 2182
DO 2180 J=1,NN11
READ (12,2035) CARD,N,I,DATA($DIR+I),DATA($RADIA+I),(IDAT($LR+I+
1MR*(L-1)),DATA($PHI+I+MR*(L-1)),L=1,6)
2035 FORMAT(204A1,T1,14,25.,6(I3,E7.0))
WRITE (13,2047) CARD
2047 FORMAT(' ROD DATA',20X,'***',20A4,'*** CHANNEL')
IDAT($IDFUE+1)=N
IF(N. LT.1) IDAT($IDFUE+1)=1
2181 CONTINUE
2182 DO 2185 I=1,NGRID
DO 2184 L=1,6
IF(IDAT($LR+I+MR*(L-1))) 2184,2184,2183
2183 K=IDAT($LR+I+MR*(L-1))
DATA ($PRF+K+MC*(L-1))=DATA($PHI+I+MR*(L-1))
2184 CONTINUE
2185 DATA($SD+I)=DATA($DIR+I)/12.
IF(JJ.LE.1) PRINT(8)=.TRUE.
NDESF=NN33
NFUEL=NN44
3023 IF(NODESF.EQ.0) GO TO 34
C READ FUEL THERMAL DATA
READ(12,1005) CARD,(KFUEL(I),CFUEL(I),RFUEL(I),DFUEL(I),
1 KCLAD(I),CCLAD(I),RCLAD(I),TCLAD(I),HGAP(I),I=1,NFUEL)
WRITE (13,1011) CARD
IF(IFRM.EQ.0) GO TO 31
READ(12,1003)CARD,NCF,NCC,THG
WRITE(13,3010)CARD
THG=THG/12.
IF((NCF+NCC+1).NE.NODESF) GO TO 146
IF(NODESF.GT.21) GO TO 146
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IF (IPROP.EQ.0) GO TO 31
READ(12,1005)CARD,FTD,FPUO2
WRITE(13,2012)CARD
IF(IPROP.LE.1) GO TO 31
READ(12,1005)CARD,BURN,CPR,EXPR,FPRESS,GRGH,G MIX,PGAS
WRITE(13,2014)CARD
IF((GMIX(1)+GMIX(2)+GMIX(3)+GMIX(4)).GT.1.01) GO TO 146
GRGH=GRGH/12.
31 DO 32 I=1,NFUEL
KFUEL(I)=KFUEL(I)/3600.
KCLAD(I)=KCLAD(I)/3600.
DFUEL(I)=DFUEL(I)/12.
TCLAD(I)=TCLAD(I)/12.
32 H GAP(I)=H GAP(I)/3600.
C SET WHOLE-CHANNEL AREA AND PH
34 A TOT AL=0.0
PHTOT=0.0
D O 36 I=1,NCH ANL
A TOTAL=ATOTAL+DATA($A+I)
36 PHTOT=PHTOT+DATA($HPEI+I)
N K=0
IF (IPILE.EQ.2) GO TO 99
C SET GAP BOUNDARY NUMBERING SYSTEM (PWR ONLY)
IF(IPILE.GT.0) GO TO 3010
D O 242 ND2=1,ND2X
D O 238 ND1=2,ND1X
I=NTHBOX(ND1-1,ND2)
J=NTHBOX(ND1,ND2)
IF((I.LE.0).OR.(J.LE.0)) GO TO 238
IF((I-J).EQ.0) GO TO 238
D O 5216 K=1,NK
IF((I.EQ.IDAT($IK+K)).OR.(I.EQ.IDAT($JK+K))) GO TO 5215
GO TO 5216
5215 IF((J.EQ.IDAT($JK+K)).OR.(J.EQ.IDAT($IK+K))) GO TO 238
5216 CONTINUE
N K=NK+1
IDAT($IK+N K)=I
IDAT($JK+N K)=J
238 CONTINUE
IF(ND2.EQ.ND2X) GO TO 242
D O 240 ND1=1,ND1X
J=NTHBOX(ND1,ND2)
I=NTHBOX(ND1,ND2+1)
IF((I.LE.0).OR.(J.LE.0)) GO TO 240
IF((I-J).EQ.0) GO TO 240
D O 6216 K=1,NK
IF((I.EQ.IDAT($IK+K)).OR.(I.EQ.IDAT($JK+K))) GO TO 6215
GO TO 6216
6215 IF((J.EQ.IDAT($JK+K)).OR.(J.EQ.IDAT($IK+K))) GO TO 240
6216 CONTINUE
N K=NK+1
IDAT($IK+N K)=I
IDAT($JK+N K)=J
CONTINUE
GO TO 3020
3010 DO 42 ND2=1,ND2X
DO 38 ND1=2,ND1X
I=INTBOX(ND1-1,ND2)
J=INTBOX(ND1,ND2)
IF((I.LE.0).OR.(J.LE.0)) GO TO 38
NK=NK+1
IDAT($IK+NK) = I
IDAT($JK+NK) = J
38 CONTINUE
IF(ND2.EQ.ND2X) GO TO 42
DO 40 ND1=1,ND1X
J=INTBOX(ND1,ND2)
I=INTBOX(ND1,ND2+1)
IF((I.LE.0).OR.(J.LE.0)) GO TO 40
NK=NK+1
IDAT($IK+NK) = I
IDAT($JK+NK) = J
40 CONTINUE
CONTINUE
C SET GAP BOUNDARY PARAMETERS
3020 IF(IPILE.GT.0) GO TO 9006
M=1
9014 MM=MIN0((M+13),NK)
READ (I2,9007) CARD,(GAPREC(I),I=M,MM)
9007 FORMAT(20A4,T1,14E5.0)
WRITE(13,9107) CARD
9107 FORMAT(' GAP INTERCONNECTIONS',8X,'***',20A4,'*** CHAN')
M=MM+1
IF(M.LE.NK) GO TO 9014
IF (IMIT.EQ.0) GO TO 9076
IF (NK.LE.70) GO TO 9012
WRITE(13,9010)
9010 FORMAT(1H , ' ERROR DETECTED IN CHAN - TRANSVERSE ',
1 ' COUPLING PARAMETER ARRAYS NOT LARGE ENOUGH FOR GREATER THAN',
2 '/.
3 70 GAP INTERCONNECTIONS. ')
GO TO 146
C READ TRANSVERSE MOMENTUM COUPLING PARAMETERS
9012 M=1
9020 MM=MIN0((M+6),NK)
READ(I2,9007) CARD,(FACSL(I),FACSLK(I),I=M,MM)
WRITE(13,9025) CARD
9025 FORMAT(' GAP FACTOR PAIRS',12X,'***',20A4,'*** CHAN')
M=MM+1
IF(M.LE.NK) GO TO 9020
9076 DO 9000 K=1,NK
9078 I=IDAT($IK+K)
IF (I-IDAT($JK+K)) 9084,9080,9082
9080 WRITE(13,2003) K,I,IDAT($JK+K)
ERROR =1
RETURN
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9092 IDAT(SIK+K)=IDAT(SJK+K)
IDAT(SJK+K)=I
GO TO 9078

9004 M=IDAT(SJK+K)
DATA($GAPN+K)=GAPREC(K)/12.
DATA($GAP+K)=DATA($GAPN+K)
DATA($LEN+K)=0.0
DATA($FACTO+K)=1.0

9008 CONTINUE
GO TO 9009

9006 DO 90 K=1,NK
78 I = IDAT(SIK+K)
IF (I-IDAT($JK+K)) 84,80,82
80 WRITE (13,2003) K,1,IDAT($JK+K)
IERRO=1
RETURN
82 IDAT($IK+K) = IDAT($JK+K)
IDAT($JK+K) = I
GO TO 78

84 M = IDAT($JK+K)
DATA($GAPN+K) = 0.5*(GP(I)+GF(M))/12.0
DATA($GAP+K) = DATA($GAPN+K)
DATA($LEN+K) = 0.0
DATA($FACTO+K) = 1.0

90 CONTINUE

9009 CONTINUE

C SET LOCA ARRAY
C DYNAMIC STORAGE CALL TO CORE2 FROM ACOL TO SET MA, MS IF GAPS.
CALL ACOL(1,IDAT(SIK+1),IDAT($JK+1),KMAX,IDAT($LOCA+1),MA,MS,NK,
1MG,IPILE)
C
C IF (IPILE.EQ.0) GO TO 99
C READ HALF-BOUNDARIES AND SET FACTOR(K)=0.5
MMAX=MAXRD/2

92 READ(12,1001) CARD, (JB(L),L=1,MAXRD)
WRITE(13,1012) CARD
MM = 0
DO 98 M=1,MMAX
MM = MM+1
L=2*M-1
IF(JB(L).LE.0) GO TO 99
I=MING(JB(L),JB(L+1))
J=MAXD(JB(L),JB(L+1))
FOR 94 K=1,NK
IF ( (I.EQ.1.IDAT(SIK+K)) .AND. (J.EQ.IDAT($JK+K)) ) GO TO 96
C CONTINUE
C READ FORCED FLOW BOUNDARIES HERE IF PROGRAMMED LATER
C
C
99 DO 100 K=1,NK
   DO 100 L=1,5
      DATA(SXFLO+K+MG*(L-1)) = 0.0
      IF (NFXF.EQ.0) GO TO 101
      WRITE (13,1013) IERROR
      ERROR = 1
   101 CONTINUE
      RETURN
   C
      IFPART = 2.
      PRINT CHANNEL DATA
   C
      IPILE=J7
      WRITE(13,1040) IPILE,NCHANL,NCTYP,NGRID,NGRIDT,NODESF,NFXF
      IF(NODESF.GT.0) WRITE(I3,1045) IFRM,IHTM,IPROP
      WRITE(I3,1050)
   C
      DRAW MAP OF CHANNELS AND CHECK TOTAL NUMCH=0
      DO 106 ND2=1,ND2X
         IMAX=0
         DO 104 NI=1,ND1X
            NUMCH=NUMCH+NTHBOX(ND1,ND2)
            IF(NTHBOX(ND1,ND2).GT.0) IMAX=ND1
         104 CONTINUE
         IF(IMAX.EQ.0) GO TO 108
         WRITE(I3,1052) (NTHBOX(I,ND2),I=1,IMAX)
      106 CONTINUE
      IF(NUMCH.EQ.NCHANL) GO TO 110
      IERROR=1
      NUMCH=NCHANL
      RETURN
   C
      PRINT CHANNEL NUMBER IN EACH TYPE
   C
      IF (NCTYP.EQ.1) GO TO 115
      WRITE (13,1053) I,(JBSTOR(K),K=L,M)
   114 CONTINUE
   C
      PRINT CHANNEL DATA FOR EACH TYPE
   115 WRITE(13,1054) I,IDAT($NTYPE+J),DATA($A+J),DATA($PERIM+J),
                              DATA($HPERI+J), DATA($PHI+J), DROD,
                              GP(J)
   116 WRITE(13,1057) I,IDAT($NTYPE+J),DATA($A+J),DATA($PERIM+J),
                              DATA($HPERI+J), DATA($PHI+J), DROD, GP(J)
   C
      PRINT GRID DATA
      IF(NGRID.GT.0) GO TO 118
      WRITE(13,1058) IGRID,NGRIDT,(IGRID(I),GRIDXL(I),I=1,NGRID)
   117 WRITE(13,1059) IGRID
      GO TO 124
   118 WRITE(13,1056) NGRID,NGRIDT,(IGRID(I),GRIDXL(I),I=1,NGRID)
      WRITE(13,1059) NGRID
ITMAX = 1
IF (NFXF.GT.0) ITMAX = 2
DO 122 ITTR=1,ITMAX
DO 120 I=1,NCTYP
L=JBSTOR(I)
J=JBSTOR(L)
IF(1TR.EQ.1) WRITE(I3,1060) I,(DATA($CD+J+MC*(K-1)),K=1,NGRIDT)
IF(1TR.EQ.2) WRITE(I3,1060) I,(DATA($FXFLO+J+MG*(K-1)),K=1,NGRIDT)
1 CONTINUE
120 CONTINUE
IF(1TR.LT.ITMAX) WRITE(I3,1061) NGRIDT
122 CONTINUE
C
124 IF(IPILE.GT.0) GO TO 125
WRITE(I3,2008) (I,IDAT($IDFUE+I),DATA($DR+I),DATA($RADIA+I),I(DATA($PHI+I+MR*(L-1)),IDAT($LR+I+MR*(L-1)),L=1,6),I=,NROD)
C PRINT FUEL THERMAL DATA
126 WRITE(I3,1063) J,WV1,CFUEL(J),RFUEL(J),WV2,WV3,CCLAD(J),RCLAD(J),WV4,WV5
WV6=THG*12.
128 WRITE(I3,1066) NK,M
C PRINT ARRAYS IK, JK AND LOCA
132 WRITE(I3,1064) NK
WRITE(I3,1065) NK
M = 1
134 MM=MINO((M+5),NK)
WRITE(I3,1066) M,(IDAT($IK*K),IDAT($JK+K),GAPREC(K),K=M,MM)
M = MM+1
136 MM = MINO((M+24),NK)
IF (IPILE.GT.0) GO TO 4207
DO B138 L=1,14
8138 WRITE(I3,1068) L,(DATA($LOCA+K+MG*(L-1)),K=M,MM)
GO TO 4208
4207 DO 138 L=1,8
138 WRITE(I3,1068) L, (DATA($LOCA+K+MG*(L-1)),K=M,MM)
4208 M=MM+1
WRITE (I3,1069)
IF (M.LE.NK) GO TO 136
L = MS*NK
WRITE (I3,1070) MS,KMAX,L,MA
IF (ITMP.EQ.0) GO TO 139

C PRINT TRANSVERSE MOMENTUM COUPLING PARAMETERS
WRITE(I3,1076)
WRITE(13,1078) (K,FACSL(K),FACSLK(K),K=1,NK)

C PRINT HALF-BOUNDARIES
IC = 0
DO 140 K=1,NK
IF (DATA($FACTO+K).EQ.1.0) GO TO 140
IC = IC+1
JBSTOR(IC) = K
140 CONTINUE
IF (IC.GT.1) GO TO 142
WRITE (I3,1072)
CONTINUE
WRITE (I3,1074)
RETURN

C C
1000 FORMAT(1H ' INPUT ERROR DETECTED BY CHAN.')
1001 FORMAT(20A4, T1, 1415)
1002 FORMAT (' INDICATORS', 18X, '***', 20A4, '*** CHAN')
1003 FORMAT (20A4, T1, 215, 8E5.0)
1004 FORMAT (' CHANNEL DATA, TYPE', I3, 7X, '***', 20A4, '*** CHAN')
1005 FORMAT (20A4, T1, 14E5.0)
1006 FORMAT (' GRID DATA, TYPE', I3, 10X, '***', 20A4, '*** CHAN')
1007 FORMAT (' CHANNELS OF TYPE', I3, 9X, '***', 20A4, '*** CHAN')
1008 FORMAT (30X, 'GRID POSITIONS', 14X, '***', 20A4, '*** CHAN')
1009 FORMAT (30X, T1, 7(E5.0, 15))
1010 FORMAT (' GRID POSITIONS', 14X, '***', 20A4, '*** CHAN')
1011 FORMAT (' FUEL THERMAL DATA', 11X, '***', 20A4, '*** CHAN')
1012 FORMAT (' FORCED FLOW NOT PROGRAMMED. STOP CALCULATION IN CHAN')
1013 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1014 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1015 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1016 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1017 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1018 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1019 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1020 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1021 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1022 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1023 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1024 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1025 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1026 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1027 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1028 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1029 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1030 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1031 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1032 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1033 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1034 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1035 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1036 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1037 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1038 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1039 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1040 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1041 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1042 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1043 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1044 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1045 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1046 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1047 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1048 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1049 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1050 FORMAT(43X, ' REACTOR TYPE', 8X, ' REACTOR TYPE', 8X)
1052 FORMAT(/, 2515) COB41810
1053 FORMAT(/, ' TYPE', 15X, 'CHANNEL NUMBERS') COB41820
1054 FORMAT(5I5, 3X, 3014) COB41830
2  'SQ FT', 12X, 'FT', 13X, 'IN', 13X, 'IN') COB41860
1056 FORMAT(15, 5X, I5, F15.5, F15.3, F15.0, 2F15.4) COB41870
1057 FORMAT(/, ' NO GRIDS', ') COB41880
1058 FORMAT(/, ' GRID DATA', ') COB41890
1  NO. GRID TYPES', 4X, 'I3', 13X, 'TYPE AT X/L', 7X, 'I3,') COB41900
8((I5, F8.4)) COB41920
1059 FORMAT(/, ' ASSY. TYPE', 10X, 'GRID COEFF FOR GRID TYPES 1 - ', 13) COB41930
1060 FORMAT(8(I8, 7X, 1F10.4)) COB41940
1061 FORMAT(/, ' ASSY. TYPE', 10X, 'FORCED FLOW DIVERSION FACTORS FOR T') COB41950
1YPES 1 - ', 13) COB41960
1062 FORMAT(/, 39H THERMAL PROPERTIES FOR FUEL MATERIAL COB41970
1 1B,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
1  1F9.2) COB42060
1064 FORMAT(/, ' GAP BOUNDARY DATA', ') COB42070
1065 FORMAT((15, ' BOUNDARIES AS BELOW (IK(K)-JK(K))', ' (EFFECTIVE RODDCOB42080
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('(()I12, ','2515) COB42120
1069 FORMAT(/) COB42130
1070 FORMAT(/, ' MAXIMUM OVERALL STRIPE WIDTH FOR ARRAY AAA IN DIVERCOB42140
1 T = ', I3, ' FOR BOUNDARY NO. ', I3, 1, ' REQUIRE ', I6, ' STORES COB42150
2 FOR AAA SIZE AND THIS OK SINCE .LE.', I6, ' PROVIDED', 1) COB42160
1072 FORMAT(/, ' NO HALF BOUNDARIES') COB42170
1073 FORMAT(/, ' GAP BOUNDARIES CROSS BY LINE OF SYMMETRY, IE FACTOR') COB42180
1 1(K) = 0.5 (2515) COB42190
1074 FORMAT(1H1) COB42200
1076 FORMAT(/, ' TRANSVERSE MOMENTUM COUPLING PARAMETERS', 1 COB42210
1  ' ---------------- --------- --------- --------- 1, COB42220
2  ' GAP NO. FACSL FACSLK') COB42230
1078 FORMAT(1H1, 16,5X, E9.2, 3X, E9.2) COB42240
CC COB42250
1080 FORMAT(/, ' NEW FUEL ROD MODEL',/) COB42260
1  ' ---------------- --------- 1, COB42270
2  ' NUMBER OF FUEL PELLET NODES =', I5,/) COB42280
3  ' NUMBER OF CLAD NODES =', I5,/) COB42290
4  ' GAP THICKNESS(IN)' 1X, =', E12.5,/) COB42300
CC COB42310
1082 FORMAT(/, ' FUEL AND CLAD PROPERTIES WILL BE CALCULATED USING', COB42320
1  ' FUEL ROD TEMPERATURES', 1) COB42330
2  ' FRACTION THEORETICAL DEN(FUEL)=', E12.5,/) COB42340
3  ' FRACTION PU02 =', E12.5,/) COB42350
GAP HEAT TRANSFER COEFFICIENTS WILL BE CALCULATED USING FUEL ROD TEMPERATURES.

BURNUP (MWd/MTU) = \(10.5\),

COEFF. OF FUEL PRESSURE = \(10.5\),

EXPOENT OF FUEL PRESSURE = \(10.5\),

FUEL PRESSURE = \(10.5\),

GAP ROUGHNESS, RMS (FT) = \(10.5\),

HELIUM FRACTION = \(10.5\),

ARGON FRACTION = \(10.5\),

KRYPTON FRACTION = \(10.5\),

XENON FRACTION = \(10.5\),

GAP GAS PRESSURE (PSIA) = \(10.5\).

ROD-TO-COOLANT HEAT TRANSFER USING NEW MODEL FOR PRE-CHF CONDITIONS.

ROD-TO-COOLANT HEAT TRANSFER USING NEW MODEL FOR PRE- AND POST-CHF CONDITIONS.

INPUT DATA ERROR IN ITHO. FIRST CHANNEL OF TYPE, IS, I3.

AND THIS NOT EQUAL TO NUMBER SPECIFIED, IE, I3.

NGRID GIVEN AS, I3, THIS TOO LARGE AS MAX ALLOWED.

ROD TYPE DIA RADIAL POWER FRACTION OF POWER TO ADJACENT CHANNELS.

ROD INPUT DATA --- --- --- --- ---.

FUEL PRESSURE (PSIA) = \(10.5\).

CHF SEARCHES COBRA-IIIC OUTPUT AT THE END OF EACH TIME STEP FOR THE OCCURRENCE OF CRITICAL HEAT FLUX. THE SEARCH IS MADE ON EACH ROD AT A SPECIFIED AXIAL LOCATION RANGE BY CONSIDERING EACH ROD AND THE ADJACENT CHANNELS.

ALTHOUGH THE BAW-2 AND W-3 CORRELATIONS ARE INCLUDED, USERS SHOULD PROGRAM OTHER CORRELATIONS OF THEIR CHOICE AS OPTIONS.
FILE: COBRA3C FORTRAN A

CONVERSATIONAL MONITOR SYSTEM

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1 ELEV ,FERROR,FLO ,FTM,GC,GK,GRID,HSURF,HF, C0B42910
2 HFG ,HG ,I2 ,I3 ,ERROR,IP3 ,ITER, J1 ,J2 , C0B42920
3 J3 ,J4 ,J5 ,J6 ,J7 ,KDEBUG,KF,KIJ, C0B42930
4 NFACT,NRAMP,NAX,NAXL,NBC,NCHAN,NCHF,NDX,NF, C0B42940
5 NGAPS,NGRID,NGRIDT,NGTYPE,NXL,NK,NODES,NODESF,NPROP, C0B42950
6 NRAMP,NROD,NSCBC,NV,NVISCW,PI,PITCH,POWER,PREF, C0B42960
7 QAX,RHOF,RHOG,SIGMA,SL,TF,TFLUID,THETA,THICK, C0B42970
8 UF,VF,VFG,VG,Z, C0B42980
9
10 COMMON /COBRA2/ AA(4),AF(7),AFACT(10,10),AV(7),AXIAL(30), C0B43000
11 AXL(10),BB(4),BX(30),CC(4),CCLAD(2),CFUEL(2),DFUEL(2), C0B43010
12 GAPXL(10),GFACT(9,10),GRIDXL(10),HGAP(2),HHF(30),HHG(30), C0B43020
13 IGRID(10),KCLAD(2),KFUEL(2),KKF(30),NCH(10),NGAP(9), C0B43030
14 PP(30),RCLAD(2),RFUEL(2),SSIGMA(30),TCLAD(2),UUF(30), C0B43040
15 VVF(30),VVG(30),XQUAL(30), Y(30), TT(30), C0B43050
16
17 COMMON/CHFSV/CHSAVE(20,20,31) C0B43110
18
19 COMMON /COBRA3/ MA,MC,MG,MN,MR,MS,MX, C0B43120
20 $SS,$A,$AAA,$AC,$ALPHA,$AN,$ANSW,$B, C0B43130
21 $CCAN,$CD,$CFR,$CON,$COND,$CP,$D,$DC, C0B43140
22 $DHD,$DHYD,$DHYDN,$DIST,$DP,$DPK,$DUR,$DR,$F, C0B43150
23 $FACTO,$FDIV,$FINLE,$FLOX,$FMUL,$FSP,$SP, C0B43160
24 $GAP,$GAPN,$GAPS,$H,$HFLM,$INLE,$SHOL,$SHPERI,$SIDARE, C0B43170
25 $IDFUE,$IDGAP,$IK,$SJBOIL,$JK,$SLC,$SLGNT,$SLCA,$SL, C0B43180
26 $MCF,$MCFCF,$MCFCR,$NTYPE,$NWRAP,$SNWRPS,$SP,$PERIM,$P, C0B43190
27 $PHI,$PRNTC,$PRNTR,$PRNTN,$PR,$Q,$QF,$QPRIM, C0B43200
28 $QUAL,$RADIA,$RHQ,$RHOL,$SP,$T,$TDUMY,$TROL,$TROD, C0B43210
FILE: COBRA3C FORTRAN
A CONVERSATIONAL MONITOR SYSTEM

1 ' NCHF=5 AND IHTM DOES NOT = 2."
DO 500 J=JSTART,JEND
CHFROD = 0
DO 300 N=1,NRCD
XMCHFR = 10.
IF(IDATA($FLUX+N+MR*(J-1)).LE.0.0) GO TO 300
DO 290 L=1,6
IF(IDAT($LR+N+MR*(L-1)))
C CALCULATE CHF RATIO FOR ROD N FACING CHANNEL I.
200 I=IDAT($LR+N+MR*(L-1))
XCHFR = 0.
IF(NCHF.EQ.1) XCHFR = CHF1(N,I,J)/DATA($FLUX+N+MR*(J-1))
IF(NCHF.EQ.2) XCHFR = CHF2(N,I,J)/DATA($FLUX+N+MR*(J-1))
IF(NCHF.EQ.3) XCHFR = CHF3(N,I,J)/DATA($FLUX+N+MR*(J-1))
IF(NCHF.EQ.4) XCHFR = CHF4(N,I,J)
CC OPTION NCHF=5 OPERATIONAL ONLY IF IHTM=2
CC BECAUSE CHSAVE CALCULATED IN HTCOR AND SAVED
IF (NCHF.EQ.5.AND.IHTM.EQ.2) 1
XCHFR = CHSAVE(N,I,J)/DATA($FLUX+N+MR*(J-1))
IF(XCHFR.LE.0.) GO TO 1000
C CALCULATE MINIMUM CHF RATIO FOR ROD N FACING CHANNEL I.
IF(XCHFR.GT.DATA($CHFR+N+MR*(J-1)))
DATA($CHFR+N+MR*(J-1))=XCHFR
IDAT($CCHAN+N+MR*(J-1))=I
CHFROD = N
290 CONTINUE
500 CONTINUE
RETURN
1000 PRINT 1
1 FORMAT (' ERROR IN CHF ROUTINE')
RETURN
FUNCTION CHF2(N,I,J)
IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA ,AFLUX ,ATOTAL,BBETA ,DIA ,DT ,DX
1 ELEV ,ERROR,FLO ,FMT GC ,GK ,GRID ,HSURF ,HF
2 HFG ,HG ,I2 ,I3 ERROR,IP3 ,ITERAT,J1 ,J2
3 J3 ,J4 ,J5 ,J6 ,J7 ,KDEBUG,KF ,KI J
4 NAFACT,NARAMP,NAXL ,NBBC ,NCHAN ,NCHF ,NDX ,NF
5 NGAPS ,NGRID ,NGRIDT,NGTYPE,NXGL ,NK ,NODES ,NODESF ,NPROP
6 NRAMP ,NROD ,NSCBC ,NV ,NVISCW,PI ,PITCH ,POWER ,PREF
7 QAX ,RHO ,RMDD ,SIGMA ,SL ,TF ,TFLUID,THETA ,THICK
8 UF ,VF ,VFG ,VG ,Z
COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30)
1 AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
W-3 CORRELATION INCLUDING, SPACER FACTOR, UNHEATED WALL CORRECTION,
AXIAL FLUX FACTOR
REFERENCE, LS TONG, BOILING CRISIS AND CRITICAL HEAT FLUX
AEC CRITICAL REVIEW SERIES.TID-25887(1972).
DE=4.*DATA($A+I)/DATA($PERIM+I)
DH=4.*DATA($A+I)/DATA($HPERI+I)
RU = 1.-DE/DH
XX=(DATA($H+I+MC*(J-1))-HF)/HFG
CHF2 = (((2.022 - 0.0004302*PREF) + (0.1722 - 0.0000984*PREF) *EXP((18.2 - 0.004129*PREF)*XX))
*9.1729*XX*ABS(XX))DATA($F+I+MC*(J-1))/DATA($A+I)
*0.0036 + 1.037)
*1.157 - 0.869*XX)
5 *(0.2664 + 0.8357*EXP(-37.812*DH))
6 *(0.258+0.000794*(HF-DATA($HINLE+I))/0.0036
UNHEATED WALL CORRECTION
IF(RU.GT.0.) CHF2 = CHF2*(1. - RU*(13.76-1.372*EXP(1.78*XX)
1 -4.732/(DATA($F+I+MC*(J-1))/DATA($A+I)+0.0036)+0.8535
1 -0.0619*(PREF+0.001)**.14
2-11.101*(DH**.1077))
SPACER FACTOR CORRECTION
USER SHOULD SELECT PROPER VALUE OF TDC
TDC = .019
IF(NGRID.GT.0) CHF2 = CHF2
CONVERSATIONAL MONITOR SYSTEM

1 *(1.+.03*DATA($F+I+$MC(J-1))/DATA($A+I). 0036*(TDC/.019)**.35)

C AXIAL FLUX PROFILE CORRECTION

FAXIAL = 1.
IF(J.LE.IDAT($JBOIL+I)) GO TO 10
C=1.8*(1.-XX)**4.31/(DATA($F+I+MC*(-1))/(DATA($A+I)*.0036)**.478
SUM=0.
JS=IDAT($JBOIL+I)+I
CE=C/2.
DO 5 JJ=JS,J
5 SUM=SUM+DATA($FLUX+N+MR*(JU-1))*(EXP(CE*DATA($X+JJ))+
1 EXP(CE*DATA($X+J-1)))*(EXP(CE*DATA($X+JJ))-EXP(CE*DATA($X+jJ-1))
2))
FAXIAL=SUM*EXP(-CE*DATA($X+J))/DATA($FLUX+N+MR*(J-1))/
1(1.-EXP(-CE*(DATA($X+J)-DATA($X+JS-1)))
FAXIAL=FAXIAL*EXP(-CE*DATA($X+J))
CHF2 = CHF2/FAXIAL
RETURN
END
FUNCTION CHF3(N,I,J)
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,IXP3 ,ITERAT,J1 ,J2
3 J3 ,J4 ,J5 ,J6 ,J7 ,KDEBUG,KF
4 NFACT,NARMP,NAX ,NAXL ,NBBC ,NCHAN ,NCHF ,NCHG ,NFC
5 NGAP ,NGRID ,NGRIDT,NGTYPE,NGXL ,NX ,NODES ,NODSF,NPROP
6 NRAMP ,NSCBC ,NCH ,NCHF ,NCHG ,NFC
7 QAX ,RHOF ,RHOG ,SIGMA ,SL ,TF ,TFLUID,THETA ,THICK
8 UF ,VF ,VFG ,VG ,Z
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), HBG(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), VVQ(30), XQUAL(30), Y(30), TT(30)
COMMON /COBRA3/ MA ,MC ,MG ,MN ,MR ,MS ,MX
1 $SS ,SA ,$AAA ,SAC ,$ALPHA,SAAN ,SANSWE,$SB
2 $DHDX ,$DHYN ,SDIST ,$DPDX ,$DPK ,SDUR ,$DFX,
3 $FACTO,$FDIV ,FICLUE ,$FMUL ,$FOLD ,FSP ,FSPLI,$FXFLO
4 $GAP ,SGAP ,SGAPS ,SH ,$HFLM ,SHINE ,SHOLD ,$HSPEI ,$HSPR
5 $IDFUE ,SIGAP ,$JK ,$JBOIL ,$LC ,$LENGTH ,SLOCA ,SR
6 $MCRR ,MCRRR ,MCRRRR ,$MNTP ,$SNRP ,SNWPR ,$SP ,SPERIM,SPH
7 $PHI ,SPNTC,SPTRT,SPRTN ,SPW ,SPWRF ,SOC ,$SOPQ ,$SPRIM
8 $QAX ,SRADIA ,$RHOD ,SRMODL ,$SS ,ST ,STDUMY ,STINE ,STROD
9 $SU ,SUH ,$SAVE ,SUSTAR ,SV ,$VIS ,$VISW ,$VP ,$VPA
Hench-Levy Correlation for Critical Heat Flux

\[ G = \text{DATA}(S + I + \text{MC} \times (J-1)) \times 0.0036 / \text{DATA}(A + I) \]

\[ X_E = (\text{DATA}(H + I + \text{MC} \times (J-1)) - H_F) / H_F \]

\[ \text{IF} \left( \text{DATA}(\text{FLUX} + N + \text{MR} \times (J-1)) \leq 0 \right) \text{GO TO 10} \]

\[ X_{C1} = 0.273 - 0.212 \times (\tanh(3 \times G))^{2} \]

\[ X_{C2} = 0.5 - 0.269 \times (\tanh(3 \times G))^{2} + 0.0346 \times (\tanh(2 \times G))^{2} \]

\[ \text{IF} \left( X_E \geq X_{C2} \right) Q = 0.6 - 0.7 \times X_E - 0.09 \times (\tanh(2 \times G))^{2} \]

\[ \text{IF} \left( X_E > X_{C1} \text{ AND } X_E < X_{C2} \right) Q = 1.9 - 3.3 \times X_E - 0.7 \times (\tanh(3 \times G))^{2} \]

\[ \text{IF} \left( X_E < X_{C1} \right) Q = 1.0 \]

\[ Q = Q \times 1 \times 6 \]

\[ Q = Q \times (1.1 - 0.1 \times (\frac{\text{PREF} - 600}{400})^{1.25}) \]

\[ Q = Q / 3600 \]

\[ CHF3 = Q \]

\[ \text{RETURN} \]

\[ 10 \text{ CHF3} = 10 \times \text{DATA}(\text{FLUX} + N + \text{MR} \times (-1)) \]

\[ \text{return} \]

\[ \text{END} \]

\[ \text{FUNCTION CHF4(N,I,J)} \]

\[ \text{IMPLICIT INTEGER ($$)} \]

\[ \text{COMMON} \ /\text{COBRA1/ ABETA, A flu x, ATOTAL, BB ETA, DIA, DT, DX} \]

\[ 1 \text{ ELEV, FERROR, FLO, FTM, GC, GK, GRID, HSFUR, MF} \]

\[ 3 \text{ J4, J5, J6, J7, KDEBUG, KF, KI J} \]

\[ 4 \text{ NFACT, NARAMP, NAXL, NBBC, NCHAN, NCF, NDX, NF} \]

\[ 5 \text{ NGAPS, NGRID, NGRIDT, NGTYPE, NXL, NK, NODER, NODESF, NPROP} \]

\[ 6 \text{ NRAMP, NROD, NBC, NV, NVISCW, PI, PIONT, POWER, PPREP} \]

\[ 7 \text{ QAX, RHOF, RHOG, SIGMA, SL, TF, TF LUID, THETA, THICK} \]

\[ 8 \text{ UF, VF, VFG, VO, Z} \]

\[ \text{COMMON} \ /\text{COBRA2/ AA(4), AF(7), FRACT(10,10), AV(7), AXIAL(30),} \]

\[ 1 \text{ AXL(10), BB(4), BX(30), CC(4), CLAD(2), CFUEL(2), DFU EL(2),} \]

\[ 2 \text{ GAPXL(10), GFAC T(9,9), GRIDXL(10), HGAP(2), HHF(30), HHG(30),} \]

\[ 3 \text{ IG R10(10), KCLAD(2), KFU E(2), KX(30), NCH(10), NGA P(9),} \]

\[ 4 \text{ PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30),} \]

\[ 5 \text{ VF(30), VVG(30), XQUAL(30), Y(30), TT(30)} \]

\[ \text{COMMON} \ /\text{COBRA3/ MA, MC, MG, MN, MR, MS, MX,} \]

\[ 1 \text{ $SSS, S A, SAAA, SAC, SALPHA, SAN, SANSW, SB} \]

\[ \text{COMMON} \ /\text{COBRA4/ ABETA, A flu x, ATOTAL, BB ETA, DIA, DT, DX,} \]

\[ 1 \text{ ELEV, FERROR, FLO, FTM, GC, GK, GRID, HSFUR, MF} \]

\[ 3 \text{ J4, J5, J6, J7, KDEBUG, KF, KI J} \]

\[ 4 \text{ NFACT, NARAMP, NAXL, NBBC, NCHAN, NCF, NDX, NF} \]

\[ 5 \text{ NGAPS, NGRID, NGRIDT, NGTYPE, NXL, NK, NODER, NODESF, NPROP} \]

\[ 6 \text{ NRAMP, NROD, NBC, NV, NVISCW, PI, PIONT, POWER, PPREP} \]

\[ 7 \text{ QAX, RHOF, RHOG, SIGMA, SL, TF, TF LUID, THETA, THICK} \]

\[ 8 \text{ UF, VF, VFG, VO, Z} \]

\[ \text{COMMON} \ /\text{COBRA5/ AA(4), AF(7), FRACT(10,10), AV(7), AXIAL(30),} \]

\[ 1 \text{ AXL(10), BB(4), BX(30), CC(4), CLAD(2), CFUEL(2), DFU EL(2),} \]

\[ 2 \text{ GAPXL(10), GFAC T(9,9), GRIDXL(10), HGAP(2), HHF(30), HHG(30),} \]

\[ 3 \text{ IG R10(10), KCLAD(2), KFU E(2), KX(30), NCH(10), NGA P(9),} \]

\[ 4 \text{ PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30),} \]

\[ 5 \text{ VF(30), VVG(30), XQUAL(30), Y(30), TT(30)} \]

\[ \text{COMMON} \ /\text{COBRA6/ ABETA, A flu x, ATOTAL, BB ETA, DIA, DT, DX,} \]

\[ 1 \text{ ELEV, FERROR, FLO, FTM, GC, GK, GRID, HSFUR, MF} \]

\[ 3 \text{ J4, J5, J6, J7, KDEBUG, KF, KI J} \]

\[ 4 \text{ NFACT, NARAMP, NAXL, NBBC, NCHAN, NCF, NDX, NF} \]

\[ 5 \text{ NGAPS, NGRID, NGRIDT, NGTYPE, NXL, NK, NODER, NODESF, NPROP} \]

\[ 6 \text{ NRAMP, NROD, NBC, NV, NVISCW, PI, PIONT, POWER, PPREP} \]

\[ 7 \text{ QAX, RHOF, RHOG, SIGMA, SL, TF, TF LUID, THETA, THICK} \]

\[ 8 \text{ UF, VF, VFG, VO, Z} \]
COMMON DATA(1) COB45760
LOGICAL LDAT(1) COB45770
INTEGER IDAT(1) COB45780
EQUIVALENCE (DATA(1),IDAT(t),LDAT(1)) COB45790

THE CISE CORRELATION IS USED TO ESTIMATE CRITICAL POWER

IF(J.LE.IDAT($UBOIL+I)) GO TO 100

XLBL=.3048*DX*FLOAT(J-IDAT($JBOIL+I))
G=4.88*DATA($F+I+MC*(J-1))/DATA($A+I)
C1=(1.-PREF/3206.)
GSTAR=3375.*C1**3
DH=.3048*DATA($DHYD+I)
A=C1/(G*.001)**.333

IF(G.LT.GSTAR)
A=1./(1.+1.481E-4*C1**(-3)*G)

B=0.199*(3206./PREF-1)**0.4*G*DH**1.4
XCR=(DATA($PERIM+I)*A*XLBL)/(DATA($PERIM+I)*(XLBL+B))

XE=(DATA($H+I+MC*(J-1))-HF)/HFG
HSUB=HF-DATA($H+I)

CPR=(XCR*HFG+HSUB)/(XE*HFG+HSUB)
CHF4=CPR
RETURN

CHF4=10.
RETURN
END

SUBROUTINE DIVERT(J)
THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE MAJOR SUBROUTINES OF COBRA-IIIC.

IMPLICIT INTEGER ($)
COMMON /COBRAI/ ABETA ,AFLUX ,ATOTAL,BBETA ,DIA ,DT ,DX ,COB46110
1 ELEV ,FERRO,R,FLO ,FTM ,GC ,GK ,GRID ,HDFLUX ,HF ,COB46120
2 HFG ,HG ,I2 ,I3 ,IERRORE,IOPLS ,ITERAT,J1 ,J2 ,COB46130
3 J3 COB46140
J4 ,J5 ,KDEBUG,KF ,KIJ ,COB46150
4 NFACT,NRAMP,NAX ,NAXL ,NBBC ,NC cooks ,NCHF ,NDX ,NF ,COB46160
5 NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL ,NK ,NODDS ,NODESF ,NRO ,NP ,COB46170
6 NRAMP ,NROD ,NSCBC ,NV ,NVISCW,PI ,PITCH ,POWER ,PRE ,COB46180
7 QAX ,RHO ,RHOG ,SIGMA ,SL ,TF ,TFLUID,THETA ,THICK ,COB46190
8 UF ,VF ,VFG ,VG ,Z ,COB46200
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), GFAC(9,10), GRIDXL(10), HGAP(2), HHG(30),
3 IGSAVE(10), KCLAD(2), KFUEL(2), K(30), NCH(10), NGAP(9),
4 VV(30), VVG(30), XQUAL(30), Y(30), TT(30),
5 VVF(30), VG(30), XQUAL(30), Y(30), TT(30),

COMMON /COBRA3/ MA ,MC ,MG ,MN ,MR ,MS ,MX ,
1 $$ $$ ,$$A ,$$A ,$$AC ,$$ALPHA ,$$A ,$$ANSWE ,$$B ,
2 $$ $$ ,$$CCHAN ,$$CD ,$$CHFR ,$$CON ,$$COND ,$$CP ,
3 $$ $$ ,$$DHDX ,$$DHYD ,$$DHYDN ,$$DIST ,$$DPDX ,$$DPK ,$$DUR ,$$DR ,$$F ,
4 $$ $$ ,$$FACTO ,$$FDIV ,$$FINLE ,$$FLEX ,$$FSLAP ,$$FSLAP ,$$FSLP ,$$FXFLO ,
5 $$ $$ ,$$GAP ,$$GAPN ,$$GAPS ,$$H ,$$HFILM ,$$HINLE ,$$HOLD ,$$HPERI ,$$IDARE ,
6 $$ $$ ,$$IDFUE ,$$IDGAP ,$$IDK ,$$JBOIL ,$$JK ,$$LC ,$$LENGT ,$$LOCA ,$$LR ,
7 $$ $$ ,$$MCHFR ,$$MCFRC ,$$MCFRR ,$$MCFRR ,$$NWRAP ,$$NWRAP ,$$NWRAP ,$$SP ,$$PERIM ,$$PH ,
8 $$ $$ ,$$PHI ,$$PRNTC ,$$PRNTR ,$$PRNTN ,$$PW ,$$PWRF ,$$QF ,$$QPRIM ,$$QUAL ,
9 $$ $$ ,$$RADIA ,$$RA ,$$RADIA ,$$RADIA ,$$RHOOL ,$$SP ,$$ST ,$$TDUMY ,$$TINLE ,$$TR ,
A $$ $$ ,$$UH ,$$USAVE ,$$USTAR ,$$V ,$$VISC ,$$VISC ,$$VPA ,$$W ,$$WOLD ,$$WP ,$$WSAVE ,$$X ,$$X ,$$X ,$$X, $$A ,$$B ,$$XPOLD ,

COMMON /GAPFAC/ FACSL(70), FACSLK(70)

LOGICAL GRID

REAL KJ, KF, KKF, KCLAD, KFUEL

COMMON /COBRA3/ MA ,MC ,MG ,MN ,MR ,MS ,MX ,
1 $$ $$ ,$$A ,$$A ,$$AA ,$$AC ,$$ALPHA ,$$A ,$$ANSWE ,$$B ,
2 $$ $$ ,$$CC ,$$CH ,$$CON ,$$COND ,$$CP ,
3 $$ $$ ,$$DH ,$$DHYD ,$$DHYDN ,$$DIST ,$$DP ,$$DPK ,$$DUR ,$$DR ,$$F ,
4 $$ $$ ,$$FACTO ,$$FDIV ,$$FINLE ,$$FLEX ,$$FSLAP ,$$FSLAP ,$$FSLP ,$$FXFLO ,
5 $$ $$ ,$$GAP ,$$GAPN ,$$GAPS ,$$H ,$$HFILM ,$$HINLE ,$$HOLD ,$$HPERI ,$$IDARE ,
6 $$ $$ ,$$IDFUE ,$$IDGAP ,$$IDK ,$$JBOIL ,$$JK ,$$LC ,$$LENGT ,$$LOCA ,$$LR ,
7 $$ $$ ,$$MCHFR ,$$MCFRC ,$$MCFRR ,$$MCFRR ,$$NWRAP ,$$NWRAP ,$$NWRAP ,$$SP ,$$PERIM ,$$PH ,
8 $$ $$ ,$$PHI ,$$PRNTC ,$$PRNTR ,$$PRNTN ,$$PW ,$$PWRF ,$$QF ,$$QPRIM ,$$QUAL ,
9 $$ $$ ,$$RADIA ,$$RA ,$$RADIA ,$$RADIA ,$$RHOOL ,$$SP ,$$ST ,$$TDUMY ,$$TINLE ,$$TR ,
A $$ $$ ,$$UH ,$$USAVE ,$$USTAR ,$$V ,$$VISC ,$$VISC ,$$VPA ,$$W ,$$WOLD ,$$WP ,$$WSAVE ,$$X ,$$X ,$$X, $$A ,$$B ,$$XPOLD ,

LOGICAL LDAT(1)

INTEGER IDAT(1)

EQUIVALENCE (DATA(1),IDAT(1),LDAT(1))

EQUIVALENCE (NCHAN,NCHANL)

ABIT(I2,Z1,Z2,Z3,Z4,Z5,Z6) = I2*(2.0*Z1-Z2+DX/DT)/Z3 +
1 Z4*ABS(Z5+Z6)*DX

IPILE = I7

NKK = NK

JM1 = J-1

SLDX = SL*DX

DTG = DT*GC

DXGC = DX*GC

C CALCULATE USTAR

DO 5 K=1,NKK

II=IDAT(IK+1)

JJ=IDAT(IK+K)

DATA($USTAR+K)=DATA($USTAR+K)

DATA($USTAR+K)=0.5*(DATA($U+II)+DATA($U+JJ))

5 CONTINUE

C SET AAA ARRAY USING LOCA (SET IN ACOL BASED ON INPUT DATA)

LMAX = MS
C TRANSVERSE MOMENTUM PARAMETER IN NEXT EQUATION

DATA($B+K)=DATA($B+K)-(DATA($AAA+K+NK*(L-1))-DATA($AAA+K+NK*1))/GC*DATA($FACTO+K)

C MODIFY SIMULTANEOUS EQUATIONS TO ACCOUNT FOR SPECIFIED VALUES OF CROSSFLOW GIVEN IN SUBROUTINE FORCE

DO 310 K=1,NK
  IF(LDAT($FDIV+K)) GO TO 310
  DO 290 L=1,LMAX
    IF(LL.EQ.1) GO TO 290
    IF(L.LT.0) IZ=-1
    L = IABS(L)
    IJ = LL
    IF( (II.LT.JK) .OR. (II.GT.JK) ) IJ=II
    IF(II.EQ.IJ) GO TO 290
    IF(LL.EQ.MID) GO TO 290
    IF(LL.GT.LMAX) GO TO 310
    IF(LL.LT.1) GO TO 310
  END
  IF(LL.EQ.MID) GO TO 310
  IF(LL.GT.LMAX.OR.LL.LT.1) GO TO 310
  IF(LDAT($FDIV+L)) GO TO 310
  DATA($AAA+K+NK*(MID-1))=SAVE*SLDX*FACSLK(K)*CIJ(J,K)*DATA($FACTO+K)+
    DATA($AAA+K+NK*(MID-1))*DATA($AAA+K+NK*(LL-1))+SL*FACSL(K)*CIJ(J,K)*DATA($FACTO+K)+
    DATA($AAA+K+NK*(MID-1))*DATA($AAA+K+NK*(LL-1))*DATA($AAA+K+NK*(L-1))*DATA($AAA+K+NK*(L-1))

C CROSSFLOW GIVEN IN SUBROUTINE FORCE

C TRANSVERSE MOMENTUM PARAMETER IN NEXT EQUATION

DO 101 L=1,LMAX
  IF(L.LT.1) GO TO 101
  DATA($AAA+K+NL*(L-1))=SAVE*SLDX*FACSL(K)/GC*DATA($FACTO+K)

C MODIFY SIMULTANEOUS EQUATIONS TO ACCOUNT FOR SPECIFIED VALUES OF CROSSFLOW GIVEN IN SUBROUTINE FORCE

DO 290 K=1,NK
  IF(LDAT($FDIV+K)) GO TO 290
  DATA($AAA+K+NL*(L-1))=0.

C TRANSVERSE MOMENTUM PARAMETER IN NEXT EQUATION

DATA($AAA+K+NL*(L-1))=0.
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FILE: COBRA3C FORTRAN

IF(.NOT.LDAT($FDIV+K)) GO TO 100
DO 95 L=1,LMAX
DATA($AAA+K+NK*(L-1)) = 0.0
LL=MAXO(1,(L+K-MID))
MPICU=MID+K-LL
95 DATA($AAA+LL+NK*(MPICU-1))=0.0
DATA($AAA+K+MK*(MID-1)) = 1.0
DATA($B+K)=DATA($W+K+MG*(J-1))
100 CONTINUE
105 IF(KDEBUG.LT.1) GO TO 110
WRITE(13,2) ((DATA($AAA+K+NK*(L-1)),L=1,LMAX),DATA($B+K),K=1,NKK)
2 FORMAT(1HO,1P7E15.4)
110 CALL DECOMP(NK,IERROR,LMAX,MID,DATA($AAA+1),DATA($ANSWE+1),
1 DATA($B+1),NK)
IF(IERROR.GT.1) GO TO 1000
CALL SOLVE(NK,LMAX,MID,DATA($AAA+1),DATA($ANSWE+1),DATA($B+1),NK)
DO 150 K=1,NKK
150 DATA($W+K+MG*(J-1))=DATA($ANSWE+K)
RETURN
1000 WRITE(13,1)
1 FORMAT(24H ERROR IN DECOMP, DIVERT )
IERROR = 3
RETURN
END

SUBROUTINE INDAT(INIT,NOPRIN)
IMPLICIT INTEGER($)
COMMON /COBRA1/
ABETA ,AFLUX ,OTAL,BETA ,DIA ,DT ,DX ,COB47600
ELEV ,FERROR, FLO ,FTM ,GC ,GK ,GRID ,HSURF ,HF ,COB47610
HGF ,HG ,I2 ,I3 ,IERROR,IOP3 ,ITERAT ,J1 ,J2 ,COB47620
J3 ,J4 ,J5 ,J6 ,J7 ,KDEBUG,KF ,KIJ ,COB47630
NAFACT,NRAMP,NAX ,NAXL ,NBBC ,NCHAN ,NCF ,NDX ,NF ,COB47640
NGAPS ,NGRIT ,NGRIDT,NGTYPE ,NGX L ,N ,NODS ,NODSF,NPROP ,COB47650
NRAMP ,NRAD ,NCCB ,NV ,NNSCW,PI ,PITCH ,POWER ,PREF ,COB47660
QAX ,RHDF ,RHOG ,SIGMA ,SL ,TF ,TFLUID,THETA ,THICK ,COB47670
UF ,VF ,VFG ,VG ,Z
COMMON /COBRA2/
AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), COB47700
AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
GAPXL(10), GFAC(9,10), GRIDX(10), HGA(2), HFF(30), HOG(30),
IGRID(10), KCLAD(2), KFUEL(2), KFF(30), MCH(10), NGAP(9),
PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UFF(30),
VF(30), VG(30), QUAL(30), Y(30), T(30)
COMMON /COBRA3/
KCH, KF, KKF, KLAD, KFUEL ,COB47800
MA ,MC ,MG ,MN ,MR ,MS ,MX ,COB47820
$S$ ,SAC ,SAAA ,SAC ,SALPHA ,SAN ,SANSW ,S
$C$ ,SCD ,$CFR$, $CON$, $COND$, $CP$, $D$, $DC$, $DFD$, $D$, $DFX$, COB47840
$HD$, $HDX$, $HYD$, $HYN$, $DIST$, $DPD$, $DPK$, $DUR$, $DR$, $F$, COB47850

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3 $FACTO,$FDIV,$FSLN,$FLUX,$FMULT,$FOLD,$FSPL,$FXFLO,COB47860
4 $GAP,$GAPN,$GAPS,$SH,$SHFIL,$SFINLE,$SHOLD,$SHPERI,$SIDARE,COB47870
5 $IDFUE,$IDGAP,$IK,$JBLOL,$JK,$LCL,$LEN,$LOC,$LR,COB47880
6 $MCHFR,$MCFRC,$MCFRR,$SNYPE,$SNRAPS,$SNRP,$PH,$PERIM,$PH,COB47890
7 $PH,$SPHNC.$SPNTR,$SPRNTN,$SPW,$SPWF,$SRC,$$QF,$$QPRIM,COB47900
8 $SQUAL,$SRADIA,$SHO0,$SMP,$ST,$STUMY,$STINLE,$STROD,COB47910
9 $S,$SUH,$SUSAVE,$SUSTAR,$SV,$VIS,$VISCV,$VSP,$VPA,COB47920
A $W,$WOLD,$WP,$WSAVE,$X,$XCRO,$X$A,$X$B,$X$BOLD,COB47930

COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE ((DATA(1),IDAT(1),LDAT(1))

COMMON (NCHAN,NCHANL)

COMMON /GAPFAC/FACSL(70),FACSLK(70)

READ IN INPUT DATA (MAIN 5365-8830)

IF (INIT.EQ.2) GO TO 990
THE UNIVAC 1108 SETS THE CORE TO ZERO AT THE START OF EACH JOB

THE INITIALIZATION BELOW IS TO INITIALIZED FOR OTHER MACHINES

UNITS 12,13, AND 18 ARE THE INPUT, OUTPUT, AND SAVE TAPE UNITS

BEGINNING OF VARIABLE BLOCK

READ(12,68) MC,MG,MN,MR,MX
WRITE(13,3000) MC,MG,MN,MR,MX
3000 FORMAT('I',T50,'PROBLEM SIZE'/T50,MC=',I5/1T50,GM=',15/T50,'MN=',15/T50,'MR=',15/T50,'MX=',15/)

CALL CORE

All values initialised to zero between here and 930 could probably be left out since now initialised in core. However left in for safety as no time to check.
FILE: COBRA3C FORTRAN A

CONVERSATIONAL MONITOR SYSTEM

NGAPS = 0
NAFACT = 0
NSCBC = 0
NBBC = 0
J5 = 0
J6 = 0
NPRIN = 0
J7 = 0
NGRIDT = 0
JUMP = 0
NJUMP = 0
NRGD = 0
NRAMP = 1
NODESF = 0
NFUEL = 0
NOIT = 0
NPCHAN = 0
NPNODE = 0
NARAMP = 1
IG = 0
ISAVE = 0
IN = 0

CC FUEL ROD AND HEAT TRANSFER MODEL INDICATORS INITIALIZED AS ZERO

IFRM=0
IHTM=0
IPROP=0
GRID = .FALSE.
DO 900 I=1,MC
DATA($HINLE+I)=0.
DATA($FINLE+I)=0.
DATA($QPRIM+I)=0.
900 DATA($QPRIM+I)=0.
DO 905 K=1, MG
FACSL(K)=1.
FACSLK(K)=1.
DATA($WP +K)=0.
905 LDAT($FDIV +K)=.FALSE.
DO 930 J=1, MX
DATA($P +I+MC*(J-1))=0.
DATA($H +I+MC*(J-1))=0.
DATA($F+I+MC*(J-1))=0.
DATA($RHO +I+MC*(J-1))=0.
DATA($FOLD +I+MC*(J-1))=0.
910 DATA($RHODL+I+MC*(J-1))=0.
DO 920 N=1, MR
DATA($FLUX +N+MR*(J-1))=0.
IDAT($CCHAN+N+MR*(J-1))=0.
918 CONTINUE
DO 918 L=1, MN
918 DATA($TROD+L+MN*(N-1+MR*(J-1))=0.
920 CONTINUE
930 CONTINUE
READ (I2,52) MAXT
IF(MAXT.LT.1) MAXT = 1000
C
file: cobrac3 fortran a

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($P +K+MG*(J-1))=0.
914 DATA($NLD+K+MG*(J-1))=0.
DO 915 K=1,MC
DATA($QC +K+MC*(J-1))=0.
DATA($OF +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 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 INPUT FOR CARD GROUP 1, PROPERTY TABLE

110 CALL CARDS1(PP,TT,VVF,VVG,HHF,HHG,UF,KF,SSIGMA,N1,I2)
NPROP = N1
IF(J1.LE.1) PRINT(1) = .TRUE.
GO TO 995
C INPUT FOR CARD GROUP 2, FRICTION FACTOR AND TWO-PHASE FLOW CORRELATION

120 READ(I2,5) (AA(I),BB(I),CC(I),I=1,4)
J2 = N1
J3 = N2
J4 = N3
NVISCW = N4
IF(J3.GT.4) READ(I2,41) NV,AV
IF(J4.GT.4) READ(I2,41) NF,AF
IF(J1.LE.1) PRINT(2) = .TRUE.
GO TO 995
C

C

C
C INPUT FOR CARD GROUP 3, AXIAL HEAT FLUX TABLE

130 IF (N1.GT.1) GO TO 135
10P3 = N1
GO TO 995

135 READ(I2,5) (Y(I),AXIAL(I),I=1,N1)
NAX = N1
IF(J1.LE.1) PRINT(3) = .TRUE.
GO TO 995
C
C INPUT FOR CARD GROUP 4, CHANNEL LAYOUT AND DIMENSIONS

140 IF(IPILE.EQ.0) GO TO 1405
C COMBINE CARD GROUPS 4, 7, 9 FOR PWR AND BWR.
CALL CARDS4(DATA($AC+1),DATA($DC+1),DATA($DIST+1),
1 DATA($DR+I),DATA($GAPS+1),
1 IDAT($LC+1),MA,MG,N1,N2,NCHF,NFUELT, DATA($PH+1),
2 PHTOT,PRINT,DATA($PW+1),MC)
IF (IERROR.GE.1) GO TO 240
CALL CORE3
GO TO 995

1405 DO 141 J=1,N1
READ(I2,7) N,I,DATA($AC+I),DATA($PW+I),DATA($PH+I),
1 (IDAT($LC+I+MC*(L-1)),DATA($GAPS+I+MG*(L-1)),
2 DATA($DIST+I+MC*(L-1)),L=1,4)
IDAT($NTYPE+I)=N
IF(N.LE.1) IDAT($NTYPE+I)=1
141 CONTINUE

142 PHTOT = 0.
ATOTAL = 0.
K=0
NCHANL = N2
DO 147 I=1,NCHANL
146 L=1,4
IF(IDAT($LC+I+MC*(L-1))) 144,146,143
143 J= IDAT($LC+I+MC*(L-1))
IF(J.LE.1) GO TO 146
K=K+1
DATA($FACTO+K)=1.
GO TO 145
144 J=-IDAT($LC+I+MC*(L-1))
IF(J.LE.1) GO TO 146
K=K+1
DATA($FACTO+K)=0.5
145 IDAT($JK+K)=J
IDAT($IK+K)=I
DATA($GAPN +K)=DATA($GAPS +I+MG*(L-1))/12.
DATA($GAP +K)=DATA($GAPN +K)
DATA($LENGT+K)=DATA($DIST +I+MC*(L-1))/12.
146 CONTINUE
DATA($PERIM+I)=DATA($PW+I)/12.
DATA($PERIM+I)=DATA($PH+I)/12.
DATA($AN +I)=DATA($AC+I)/144.
DATA($A +I)=DATA($AN+I)
DATA($DC +I)=DATA($AC+I)*4./DATA($PW+I)
DATA($HYD +I)=DATA($DC +I)/12.
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FILE: COBRA3C FORTRAN A

![COBRA3C FORTRAN A code snippet](image)

```
DATA($DHYD+1)=DATA($DHYD +I)
PHPT=PHPT+DATA($PER1 +I)
147 ATOTAL=ATOTAL+DATA($AN+1)
NK=K
CALL ACOL(2, IDAT(ID$1+1), IDAT(ID$2+1), KMAX, IDAT(ID$LA+1), MA, MS, NK,
1 MG, IPILE)
IF(J1.LE.1) PRINT(4) = .TRUE.
GO TO 995
CALL CORE3
GO TO 995
C
C INPUT FOR CARD GROUP 5, CHANNEL AREA VARIATION TABLE
C 150 DO 151 I=1,NCHANL
151 IDAT(IDARE+I)=0
NAXL = N2
NARAMP = N3
IF(NARAMP.LE.0) NARAMP = 1
IF(N2.LT.1) GO TO 995
READ(12,5) (AXL(I),I=1,N2)
NFACT=N1
DO 152 J=1,N1
READ(12,8) I, (AFACT(J),J=1,N2)
IDAT(IDARE+I)=J
152 NCH(J)= I
IF(J1.LE.1) PRINT(5) = .TRUE.
GO TO 995
C
C INPUT FOR CARD GROUP 6, GAP SIZE VARIATIONS TABLE
C 160 DO 161 K=1,NK
161 IDAT(IDGAP+K)=0
NGXL = N2
IF(N2.LT.1) GO TO 995
READ(12,5) (GAPX(L),L=1,NGXL)
NGAP$ = N1
DO 162 LL=1,NGAPS
162 CONTINUE
IF(J1.LE.1) PRINT(6) = .TRUE.
GO TO 995
C
C INPUT FOR CARD GROUP 7, SPACER DESIGN INFORMATION
C 170 IF(IPILE.EQ.0) GO TO 1705
WRITE(13,1704) IPILE, NGROUP
1704 FORMAT(' IPILE=',I2, ' CARD GROUP',I2,
1 ' INCORRECTLY ENTERED .CHECK DATA')
1ERROR = 1
GO TO 240
1705 J6 = N1
NARAMP = N4
IF(NRAMPLT.1) NRAMP = 1
GRID = .FALSE.
NGRID = G
IF(J6.EQ.0) GO TO 995
```

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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=I,NK
READ(12,64)
DATA($DUR+K)=DUM
DO 172 L=1,6
DATA($XCROS+K+MG*(L-1))=CROSS(L)
READ(12,68) (IDAT($NWRAP+I),I=1,NCHANL)
DO 173 I=1,NCHANL
IDAT($NWRPS+I)=IDAT($NWRAP+I)
IF(J1.LE.1) PRINT(7) = .TRUE.
GO TO 995
REWIND 18
READ(18) ((DATA($W+I+MG*(J-1)),I=1,MG),J)
DO 185 I=1,NCHANL
DATA($FXFLO+K+MG*(I-1))=O.
DO 185 I=1,MC
DO 182 J=1,MR
DATA($PWRF+I+MC*(J-1))=O.
DO 185 I=1,NROD
DO 184 L=1,6
C INPUT FOR CARD GROUP B, 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
READ(12,11) N,I,DATA($DR+I),
DATA($SRADIA+I),(IDAT($LR+I+MR*(L-1)),L=1,6)
IDAT($RFUE+I)=N
IF(N.LT.1) IDAT($RFUE+I)=1
CONTINUE
DO 182 I=1,MC
DO 182 J=1,MR
DATA($WRF+I+MC*(J-1))=0.
DO 185 I=1,NROD
DO 184 L=1,6
IF(IDAT($L+I+MR*(L-1))) 184.184.183
183  K = IDAT($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
IF(NODESF.EQ.0) GO TO 995
READ (12,79) (KFUEL(I), CFUEL(I), RFUEL(I), DFUEL(I),
1 KCLAD(I), CCLAD(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.
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.1.E-3) FERROR = 1.E-3
NDXP1 = NDX + 1
NSKIPX = N1
NSKIPT = N2
KDEBUG = N3
IF(NSKIPT.NE.1) NSKIPT = 1
IF(NSKIPT.LT.1) NSKIPT = 1
ZZ = Z
Z = Z/12.
IF(Z.LT.0.) GO TO 240
IF(NDX.LT.1) GO TO 240
DX = Z/FLOAT(NDX)
DT = 0.
IF(NDT.GT.0 .AND. TTIME.LT.0.) NDT = 0
IF(NDT.GT.0) DT = TTIME/FLOAT(NDT)
SAVEDT = DT
DXX = DX*2.
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 206 I=1, MG
ENEH(I)=1.0
NBBC = N2
GO TO 995
206 CONTINUE
GO TO 995
FILE: COBRA3C FORTRAN A
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J5 = N3
IF(N2.GE.2) READ(I2,5) (XQUAL(I),BX(I),I=1,N2) COB51710
IF(J5.EQ.0) GK = 0. COB51720
IF(J5.EQ.1) READ(I2,5) GK COB51730
IF(J1.LE.1) PRINT(10) = .TRUE. COB51740
GO TO 995 COB51750

C INPUT FOR CARD GROUP 11, OPERATING CONDITIONS AND TRANSIENT FORCING COB51760
210 READ(I2,9) PEXIT,HIN,GIN,AFLUX COB51770
PREP = PEXIT CALL PROP(1,1)
IF(IERROR.GT.1) GO TO 240
IN = N1 COB51780
IN = TF IF(HIN.LT.HF) CALL CURVE(HIN,HIN,TH,HHF,NPROP,IERROR,1)
IF(IERROR.GT.1) GO TO 240 COB51790
GO TO 212 COB51800

211 IN = HIN CALL CURVE(HIN,TIN,TH,TH,TH,FNP,S,ERROR,1)
IF(IERROR.GT.1) GO TO 240 COB51810
GO TO 212 COB51820

212 DATA(SHINLE+I)=HIN COB51830
DATA(I)=I1N CHANNEL T.
213 DATA(SHINLE+I)=HIN COB51840
GO TO 216 COB51850

214 READ(I2,10) (DATA($SHINLE+I),I=1,NCHANL) COB51860
IF(N1.LE.2) GO TO 216 COB51870
DO 215 I=1,NCHANL
CALL CURVE(DATA($SHINLE+I),DATA($SHINLE+I),HMF,TT,NPROP,IERROR,1)
IF(IERROR.GT.1) GO TO 240 COB52010
CONTINUE COB52020

215 CONTINUE COB52030
216 DATA($TINLE+I)=TF COB52040
DATA($TINLE+I)=TF IF(DATA($SHINLE+I).LT.HF)
41 CALL CURVE(DATA($TINLE+I),DATA($SHINLE+I),TT,HMF,NPROP,IERROR,1)
IF(IERROR.GT.1) GO TO 240 COB52060
2160 CONTINUE COB52070

217 DATA($FINLE+I)=GIN*DATA($AN+I)/.0036 COB52080
DATA($FINLE+I)=GIN*DATA($AN+I)/.0036
DO 217 I=1,NCHANL COB52090

218 DATA($FINLE+I)=GIN*DATA($AN+I)*DATA($FSPLI+I)/.0036 COB52100
219 NP = N3 COB52110
IF(NP.GT.1) READ(I2,10) (YP(I),FP(I),I=1,NP)
NH = N4 COB52120

C FOR N2=0, GIN IS THE INLET G FOR EACH CHANNEL. FOR N2=1, GIN IS THE COB52130
C AVERAGE G BUT THE CHANNEL FLOWS ARE SPLIT TO GIVE EQUAL DP/DX. FOR NCOB52140
C INDIVIDUAL CHANNEL TOTAL FLOW FRACTION IS READ AS INPUT.
FLO = GIN/.0036*ATOTAL COB52150
DO 217 I=1,NCHANL COB52160

217 DATA($FINLE+I)=GIN*DATA($AN+I)/.0036 COB52170
IF(N2.EQ.1) CALL SPLIT COB52180
IF(IERROR.GT.1) GO TO 240 COB52190
IF(N2.LT.2) GO TO 219 COB52200
READ(I2,10) (DATA($FSPLI+I),I=1,NCHANL)
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)
NH = N4 COB52240

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IF(NH.GT.1) READ(I2,10) (YH(I),FH(I),I=1,NH)
NG = N5
IF(NG.GT.1) READ(I2,10) (YG(I),FG(I),I=1,NG)
NQ = N6
IF(NQ.GT.1) READ(I2,10) (YQ(I),FQ(I),I=1,NQ)
IF(J1.LE.2) PRINT(11) = .TRUE.
GO TO 995
C
C INPUT CARD GROUP 12, OUTPUT OPTIONS FOR CALCULATIONS
220 NOUT = N1
NPCHAN = N2
IF(N2.LT.1) GO TO 221
READ(I2,10) (IDAT($PRNTC+I),I=1,N2)
221 NPROD = N3
NPNODE = N4
IF(N3.LT.1) GO TO 222
READ(I2,10) (IDAT($PRNTR+I),I=1,N3)
222 IF(N4.LT.1) GO TO 225
READ(I2,10) (IDAT($PRNTN+I),I=1,N4)
225 GO TO 995
C
CARD GROUP 20 . READ DATA VIA ITHO
230 NUPRIN=N1
CALL CARD20(NOPRIN)
IF(IERROR.GT.0) GO TO 240
GO TO 995
C
C INPUT DATA ERROR MESSAGE
240 WRITE(13,54)
STOP
C
END OF INPUT
C
250 RETURN
C
1 FORMAT(71S)
2 FORMAT(I1, I4, I5, 17A4)
3 FORMAT(I15H INPUT FOR CASE 16,5X,16A4,A2,
19H DATE 2A4,7H TIME 2A4,A1)
5 FORMAT (12F5.3)
7 FORMAT(I1, I4, 3E5.2,4(I5,2E5.2))
8 FORMAT ( I5/(12F5.3))
9 FORMAT (6F10.0)
10 FORMAT(12E5.0)
11 FORMAT(I1, I4, 2E5.2,6(I5,E5.2))
14 FORMAT (4E5.2,2I5,5E5.2,15,4E5.2)
17 FORMAT (36I2)
41 FORMAT (15,7E10.5)
42 FORMAT(8E10.5)
52 FORMAT (15,6E12.6)
54 FORMAT(/1 INPUT DATA ERROR, THIS RUN STOPPED, CHECK INPUT')
64 FORMAT(I5,10E5.2)
66 FORMAT (6(E5.2,15))
67 FORMAT (15,E5.2,15,E5.2)
68 FORMAT(1015)
79 FORMAT (9E5.2)
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C
DATA TAG /4HW/GS, 4HW/GD /
C
IPART=1 SET HYDRAULIC MODEL
IPART=2 PRINT HYDRAULIC MODEL
SAME AS MEKIN CODING

PRESET MODEL IS CODED FIRST AND IS USED IF ALL N1-N7=0
INDIVIDUAL PARTS OF MODEL MAY BE CHANGED BY
SETTING ANY OF N1-N7 POSITIVE NON-ZERO

IF(IPART.EQ.2) GO TO 30

C (N1) MIXING MODEL (CARD GROUP 10)
NSCBC=1
NBB=1
J5=0
GK=0.0
ABETA=0.0
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
CC(I)=0.0
NVISCW=0
4

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
ERROR=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

READ(12,1001) CARD,N1,N2,N3,N4,N5,N6,N7,NPROP,N9
WRITE(13,1009) CARD
IF(N1+N2+N3+N4+N5+N6+N7+NPROP+N9).EQ.0) RETURN

IF(N1.EQ.0) GO TO 6
IF (N1.EQ.2) NSCBC=2
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IF (N1.EQ.3) NSBC=4
IF(N1.EQ.4) WRITE(I3,1010)
IF(N1.EQ.5) WRITE(I3,1011)
IF(N1.EQ.6) WRITE(I3,1012)

6 IF(N2.EQ.0) GO TO 8
READ(I2,1003) CARD, NVISCW, (AA(I), BB(I), CC(I), I=1,4)
WRITE(I3,1013) CARD

8 IF(N3.EQ.0) GO TO 10
READ(I2,1001) CARD, J4
WRITE(I3,1014) CARD
IF(J4.LE.4) GO TO 8
READ(I2,1003) CARD, MF, AF
WRITE(I3,1015) CARD

10 IF(N4.EQ.0) GO TO 12
READ(I2,1001) CARD, J2, J3
WRITE(I3,1016) CARD
IF(J3.LE.4) GO TO 10
READ(I2,1003) CARD, NV, AV
WRITE(I3,1017) CARD

12 IF(N5.EQ.0) GO TO 16
READ(I2,1001) CARD, IG
WRITE(I3,1018) CARD
IF(IG.LE.1) GO TO 12
CALL READIN(1, NCHANL, DATA($FINL+1), CARD, CARD, 1)

16 IF(N6.EQ.0) GO TO 18
READ(I2,1003) CARD, NCHF, KI, JF, TH, S, T
WRITE(I3,1019) CARD
ELEV=COS(THETA+PI/180.0)

18 IF(N7.EQ.0) GO TO 20
READ(I2,1003) CARD, NTRIES, FERROR
WRITE(I3,1020) CARD

20 IF(NPROP.EQ.0) GO TO 22
READ(I2,1004) CARD, NPROP, N, PH, PP(2)
WRITE(I3,1021) CARD
PP(1) = PH
IF(N.LE.1) GO TO 20
PP(1) = 10.0
IF(PH.LE.200.0) GO TO 22
R = 0.01*PH
PP(1) = 6.0*R*R*(R-1.35)/(R-0.35)

22 CONTINUE
IF(N9.EQ.0) GO TO 3206
M=M+1

3204 MM=MIN0(M+13, N)
READ(I2,3202) CARD, (EHEH(K), K=1,MM)

3202 FORMAT(20A4, T1, 14E5.0)
WRITE(I3,3203) CARD

3203 FORMAT(' COUPLING FACTOR NH', 10X,'***', 20A4,'*** MODEL')
M=M+1
IF(M.LE.NK) GO TO 3204

3206 CONTINUE
RETURN

C
C IPART = 2. PRINT MODEL
WRITE(I3,1061)
IF (MI+NI2+NI3+NI4+NI5+NI6+NI7).EQ.0) WRITE (I3, 1060)

SIG=TAG(1)

IF (NSCBC.EQ.2) SIG=TAG(2)

IF (N1.LT.3) WRITE (I3, 1062) SIG, ABETA, BBETA

IF (N1.EQ.3) WRITE (I3, 1084)

WRITE (I3, 1063) NVISCW, (I, AA(I), BB(I), CC(I), I=1,4)

WRITE (I3, 1064)

J4

IF (J4.GT.4) WRITE (I3, 1065) (AF(I), I=1, NF)

WRITE (13,1066)

d2, J3

IF (J3.GT.4) WRITE (I3, 1065) (AV(I), I=1, NV)

WRITE (13,1067) IG

IF (IG.EQ.2) WRITE (I3, 1068) (DATA($FINLE+I), I=1, NCHANL)

WRITE (13,1069) NCHF, KIJ, FTM, SL, THETA

WRITE (13,1070) NTRIES, FERROR

IF (N9.GT.0) GO TO 40

WRITE (13,1071)

WRITE (I3, 1080)

GO TO 50

40 WRITE (13,1071)

WRITE (I3, 1080)

WRITE (13,1081)(K, ENEH(K), K=1, NK)

50 CONTINUE

RETURN

C

C

C

1001 FORMAT (20A4, T1, 1415)

1002 FORMAT (20A4, T1, 14E5.0)

1003 FORMAT (20A4, T1, 15, 13E5.0)

1004 FORMAT (20A4, T1, 215, 2E5.0)

C

C

1009 FORMAT (' HYDRAULIC MODEL INDICATORS', 2X '***', 20A4, '*** MODEL')

1010 FORMAT (' IS CHANGED MIXING MODEL VALID')

1011 FORMAT (' HYDRAULIC COEFFICIENTS', 9X '***', 20A4, '*** MODEL')

1012 FORMAT (' SINGLE-PHASE FRICTION', 7X '***', 20A4, '*** MODEL')

1013 FORMAT (' TWO-PHASE FRICTION (J4)', 5X '***', 20A4, '*** MODEL')

1014 FORMAT (' POLYNOMIAL COEFFICIENTS', 5X '***', 20A4, '*** MODEL')

1015 FORMAT (' VOID FRACTION (J2, J3)', 6X '***', 20A4, '*** MODEL')

1016 FORMAT (' INLET FLOW DIVISION (IG)', 4X '***', 20A4, '*** MODEL')

1017 FORMAT (' CONSTANTS', 19X '***', 20A4, '*** MODEL')

1018 FORMAT (' ITERATION', 19X '***', 20A4, '*** MODEL')

1019 FORMAT (' NPROP, N, PH, P2', 12X '***', 20A4, '*** MODEL')

1060 FORMAT (///, ' PRESET HYDRAULIC MODEL USED')

1061 FORMAT (43X, 'THERMAL - HYDRAULIC MODEL', 9X '***', 20A4, '*** MODEL')

1062 FORMAT (///, ' (1) MIXING', 9X '***', 20A4, '*** MODEL')

1063 FORMAT (///, ' (2) SINGLE-PHASE FRICTION', 10X, '***', 20A4, '*** MODEL')

1064 FORMAT (///, ' (3) TWO-PHASE FRICTION', 6X, '***', 20A4, '*** MODEL')

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COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)
EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))

COMMON/LINK2/CROSS(6), DATE(2), FG(30), FH(30), FP(30), FQ(30), IM(9), JM(9), OUTPUT, PRINT(12), TEXT(17), TIME(3), YG(30), YH(30), YP(30), YQ(30)
COMMON/LINK3/DXX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MMAX, NDT, NDXP1, NFUEL, NG, NH, NJUMP, NOUT, NP, NPCHAN, NPNODE, NPROD, NQ, NR

DIMENSION CARD(20)

SET PRINTING PARAMETERS
FOR INPRINT
IF (J1.GT.1) GO TO 4
DO 2 I=1,11
PRINT(I) = .TRUE.
PRINT(5) = .FALSE.
PRINT(6) = .FALSE.
FOR CALC (CARD GROUP 9)
READ (I2,1001) CARD, KDEBUG
WRITE (I3,1002) CARD
FOR EXPRN (CARD GROUPS 9, 12)
READ (I2,1001) CARD, NSKIPIX, NSKIPT, NOUT, NPCHAN, NPROD, NPNODE
WRITE (I3,1003) CARD
NSKIPIX = EVERY NSKIPIX AXIAL STEP PRINTED. (0 = 1)
NSKIPT = EVERY NSKIPT TIME STEP PRINTED. (0 = 1)
NOUT = 0-3 FOR PRINTING (0) CHANNEL ONLY, (1) CHANNEL + CROSS FLOWS,
(2) CHANNEL + FUEL TEMP, (3) CHANNEL + C-F + FUEL TEMP
NPCHAN = NSKIPIX = 0, ALL CHANNEL PRINTED. .GT.0 READ CHANS REQD.
NPROD, NPNODE AS NPCHAN BUT FOR RODS AND NODES.
IF (NSKIPIX.LE.1) NSKIPIX = 1
IF (NSKIPT.LE.1) NSKIPT = 1
IF (NPCHAN.LE.1) GO TO 6
MROSI+1
MMJAVI = MINO((MROSI+13), NPCHAN)
READ(12,1001) CARD, (IDAT($PRNTC+I), I=MROSI, MMJAVI)
WRITE(13,1004) CARD
MROSI = MMJAVI+1
IF(MROSI.LE.NPCHAN) GO TO 7209
MROSI+1
MMJAVI = MINO((MROSI+13), NPROD)
READ(12,1001) CARD, (IDAT($PRNTR+I), I=MROSI, MMJAVI)
WRITE(13,1006) CARD
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MPSI=MMJAVI+1
IF (MPSI.LE.NPROD) GO TO 8209
8 IF(NPNode.LE.1) GO TO 10
MPSI=1
6209 MMJAVI=MINC(MPSI+13),NPNode)
READ(12,1001) CARD,(IDAT($PRNTN+I),I=MPSI,MMJAVI)
WRITE(13,1007)CARD
MPSI=MMJAVI+1
IF (MPSI.LE.NPNode) GO TO 6209
C
10 IF (NPCHAN.GT.0) GO TO 14
NPChan = NCHAN
DO 12 I=1,NCHAN
12 IDAT($PRNTC+I) = I
14 IF (NPROD.GT.0) GO TO 18
NPROD = NROD
DO 16 I=1,NROD
16 IDAT($PRNTR+I) = I
18 IF (NPNode.GT.0) GO TO 22
NPNode = NODESF+1
DO 20 I=1,NPNode
20 IDAT($PRNTN+I) = I
22 CONTINUE
C
RETURN

1001 FORMAT (20A4, T1, '1415)
1002 FORMAT (' KDEBUG', 22X, '***', 20A4, '*** TABLES')
1003 FORMAT (' PRINTING', 20X, '***', 20A4, '*** TABLES')
1004 FORMAT (' PRINT CHANNELS', 1, 11X, '***', 20A4, '*** TABLES')
1005 FORMAT (' PLUS REMAINDER')
1006 FORMAT (' PRINT ROOS', 1, 11X, '***', 20A4, '*** TABLES')
1007 FORMAT (' PRINT NODES', 1, 11X, '***', 20A4, '*** TABLES')
END

BLOCK DATA

COMMON COBRA8/ $NAME, $LX, $TYPE
EQUIVALENCE ($NAME(1), $NAME(1)), ($NAME(47), $NAME(2))

DATA $NAME1 /8HA/, $BAAA/, $BAC/,
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DBHTDMY ,BHINLET ,BHTOD ,BHU ,BHUH ,BSAVE ,COB56660
GBHSTUAR ,BV ,BVISC ,BVISCW ,BVHP ,BVPA ,COB56670
FBH ,BHWOLO ,BHWP ,BHWSAVE ,BH ,COB56680
GBH ,BH ,BHXPLOL /

INTEGER $TYPE(97) /7*1,2,18*1,3,15*1,7*2,1,2*2,1,5*2,4*1,3*2,
1 32*1/

END

SUBROUTINE CORE

IMPLICIT INTEGER ($) COB56740
COMMON /COBRA3/ MA,MC,MR,MS,MX,$$$,SORG(97) COB56750
INTEGER $LX(97)
COMMON /COBRA5/ $NAMES,$LX,$TYPE
DIMENSION $TYPE(97)
REAL *8 $NAMES(97)
MA = 1
MS = 1
IF (MG.LE.0) MG=1
IF (MN.LE.0) MN=1

C $*****

DO 100 I=1,$$$

100 $LX(I) = MC

$LX(  1) = MG
$LX(  2) = MG
$LX(  3) = MG
$LX(  4) = MG
$LX(  5) = MG
$LX(  6) = MG
$LX(  7) = MG
$LX(  8) = MG
$LX(  9) = MG
$LX( 10) = MG
$LX( 11) = MG
$LX( 12) = MG
$LX( 13) = MG
$LX( 14) = MG
$LX( 15) = MG
$LX( 16) = MG
$LX( 17) = MG
$LX( 18) = MG
$LX( 19) = MG
$LX( 20) = MG
$LX( 21) = MG
$LX( 22) = MG
$LX( 23) = MG
$LX( 24) = MG
$LX( 25) = MG
$LX( 26) = MG
$LX( 27) = MG
$LX( 28) = MG
$LX( 29) = MG
$LX( 30) = MG
$LX( 31) = MG
$LX( 32) = MG
$LX( 33) = MG
$LX( 34) = MG
$LX( 35) = MG
$LX( 36) = MG
$LX( 37) = MG
$LX( 38) = MG
$LX( 39) = MG
$LX( 40) = MG
$LX( 41) = MG
$LX( 42) = MG
$LX( 43) = MG
$LX( 44) = MG
$LX( 45) = MG
$LX( 46) = MG
$LX( 47) = MG
$LX( 48) = MG
$LX( 49) = MG
$LX( 50) = MG
$LX( 51) = MG
$LX( 52) = MG
$LX( 53) = MG
$LX( 54) = MG

COB56690
COB56700
COB56710
COB56720
COB56730
COB56740
COB56750
COB56760
COB56770
COB56780
COB56790
COB56800
COB56810
COB56820
COB56830
COB56840
COB56850
COB56860
COB56870
COB56880
COB56890
COB56900
COB56910
COB56920
COB56930
COB56940
COB56950
COB56960
COB56970
COB56980
COB56990
COB57000
COB57010
COB57020
COB57030
COB57040
COB57050
COB57060
COB57070
COB57080
COB57090
COB57100
COB57110
COB57120
COB57130
COB57140
COB57150
COB57160
COB57170
COB57180
COB57190
COB57200
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C PROVIDE SPACE FOR SP IN BWR ITERATION.
IF ($LX(75) .LT. 3*MC)$ $LX(75) = 3*MC
$LX(77) = MN
$LX(79) = MN*MR*MX
$LX(82) = MG
$LX(83) = MG
$LX(89) = MG*MX
$LX(90) = MG*MX
$LX(91) = MG
$LX(92) = MG
$LX(93) = MX
$LX(94) = MG*6
$LX(95) = 3*MN
$LX(96) = MN

C - =========
$LX(97) = MC*MX
$ORG(1) = 1
$LXX = 0
DO 110 I = 1, $$$
$LXX = $LXX+$LX(I)
110 CONTINUE
K$ = 1

CC

CC KMAX IN SUBROUTINE CORE EQUALS

CC LENGTH OF DATA ARRAY GIVEN BELOW

CC

KMAX = 80000
KFREE = KS
KTOP = KS + KMAX - 1
KS = KS + MOD(K$ + 1, 2)
IF (KMAX.LT.$LXX) GO TO 902
DO 300 K = KS, KTOP
300 DATA(K) = 0.0
DO 400 N = 1, $$$
400 $ORG(N) = $ORG(N) + KS - 1
RETURN

C

ENTRY CORE2(MSP, NK)
N$ = NK
MS = MSP
MA = NK*MS
$LX(2) = MA
C

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C

```fortran
SORG(2) = SORG(97) + $LX(97)
$LXX = $LXX + $LX(2)
IF(KMAX.LT.$LXX) GO TO 902
RETURN
901 WRITE(6,3001)
   STOP 1
902 WRITE(6,3002) KMAX,$LXX
   STOP 1
C ENTRY CORE3
COB577850
C FROM ITHO FOR PRINTING
WRITE(6,1000) MA, MC, MG, MN, MR, MS, MX
WRITE(6,4500)
WRITE(6,5000) COB57840
WRITE(6,4000) (N,$NAMES(N),$LX(N),$ORG(N),$TYPE(N),N=1,$$$)
C057910
WRITE(6,3000) KMAX
LOWER = 4.0*FLOAT(KMAX-$LXX)/1024.0
WRITE (6,1004) $LXX, LOWER
RETURN
C
1000 FORMAT(///, ' DYNAMIC ARRAY SIZES', /, ' MA = ', I5, /,
   1 ' MC = ', I5, ' MG = ', I5, ' MN = ', I5, /
   2 ' MR = ', I5, ' MS = ', I5, ' MX = ', I5)
1004 FORMAT(/, ' DYNAMIC STORAGE REQUIRED = ', I4, ' WORDS', //)
3000 FORMAT(///, ' DYNAMIC ALLOCATION OF CORE GOT ', I10, ' WORDS'/)
3001 FORMAT(///, ' DYNAMIC ALLOCATION OF CORE FAILED', //)
3002 FORMAT(///, ' DYNAMIC ALLOCATION OF CORE GOT ONLY ', I10, ' WORDS'/)
1200 FORMAT(///, ' NUMBER OF WORDS REQUIRED FOR THIS PROBLEM IS ', I10///)
4000 FORMAT(///, ' MAXIMUM PROBLEM SIZE LIMITED TO ', I10///)
1004 FORMAT(/, ' DYNAMIC STORAGE REQUIRED = ', I4, ' WORDS', //)
4000 FORMAT(///, ' MAXIMUM PROBLEM SIZE LIMITED TO ', I10///)
```

C

```fortran
1 ' DYNAMIC STORAGE.'
5000 FORMAT(///, ' DYNAMIC STORAGE REQUIRED = ', I4, ' WORDS', //)
1 ' DYNAMIC ALLOCATION OF CORE FAILED', //)
2 ' DYNAMIC ALLOCATION OF CORE GOT ONLY ', I10, ' WORDS'/
3 ' DYNAMIC ALLOCATION OF CORE GOT ', I10, ' WORDS'/
1 ' DYNAMIC STORAGE.'
5000 FORMAT(///, ' DYNAMIC STORAGE REQUIRED = ', I4, ' WORDS', //)
1 ' DYNAMIC ALLOCATION OF CORE FAILED', //)
```

C

```fortran
END
```

C

```fortran
SUBROUTINE DIFFER(IPART,J)
C THIS PROCEDURE CONTAINS THE COMMON AND TYPE STATEMENTS SHARED BY THE
C MAJOR SUBROUTINES OF COBRA-III.
C
COMMON /COBRA1/ ABETA ,AFLUX ,ATOTAL,BBETA ,DIA ,DT ,DX, 
ELEV ,FERRO ,FLO ,FTM ,GC ,GK ,GRID ,HSURF ,HF, 
J1 ,J2 ,J3 ,J4 ,J5 ,J6 ,J7 ,KDEBUG ,KF, 
KI ,KIJ, 
NFACT ,NARAMP ,NAX ,NAXL ,N BBC ,NCHAN ,NCHF ,NDX ,NF
NGAPS ,NGRID ,NGRIDT,NGTYPE,NGXL ,NK,
NPROP ,NROD ,NRODCOA ,NV,
NRODF ,NRODST ,NRODG, 
NPDO ,NRODGPP ,NRODQ, 
NPDO ,NRODST ,NRODG, 
```

C

```fortran
IMPLICIT INTEGER ($)
```
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7 QAX ,RHDF ,RHOG ,SIGMA ,SL ,TF ,TFLUID,THETA ,THICK
8 UF ,VF ,VFG ,VG ,Z

COMMON /COBRA2/ AA(4), AF(7), AFAC(10, 10), AV(7), AXIAL(30),
1 AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2),
2 GAPXL(10), GFAC(9, 10), GRDXL(10), HGAP(2), HHF(30), HMG(30),
3 IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
4 PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30),
5 VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)

COMMON /COBRA3/ MA ,MC ,MG ,MN ,MR ,MS ,MX

LOGICAL GRID

REAL KIJ, KF, KKF, KCLAD, KFUEL

COMMON /COBRA3/ 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), GFAC(9, 10), GRDXL(10), HGAP(2), HHF(30), HMG(30),
3 IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9),
4 PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30),
5 VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)

PART 1, CALCULATE DH/DX FOR STEADY STATE AT X AND T.

100 DO 120 I=1,NCHANL
120 DATA($DHDX+I)=0.
121 IF (IPILE.EQ.2) GO TO 185
120 DO 180 K=1,NK
121 I=IDAT($IK+K)
122 L=IDAT($JK+K)
123 WV=(DATA($H+I+MC*(J-1))-DATA($H+L+MC*(J-1)))/NK
124 DATA($W+K+MG*(J-1)) = DATA($W+K+MG*(J-1))
125 IF (DATA($W+K+MG*(J-1)) LT 0.) GO TO 140
126 HWI = DATA($W+K+MG*(J-1)) * WV
127 GO TO 160
128 140 HWL = DATA($W+K+MG*(J-1)) * WV
129 GO TO 160
130 160 IF (IPART.GT.4) GO TO 1000
131 GO TO (100,200,300,400),IPART
CONTINUE
DATA($DHDX+I)=DATA($DHDX+I)+HWI-WV*DATA($WP+K)/ENEH(K)-(DATA($T+I)-DATA($T+L))*DATA($COND+K)

CONTINUE
DATA($DHDX+L)=DATA($DHDX+L)+HWL+WV*DATA($WP+K)/ENEH(K)+(DATA($T+1)-DATA($T+L))*DATA($COND+K)

DO 190 I=1,NCHANL
  DATA($DHDX+I)=(DATA($DHDX+I)+DATA($QPRIM+I)+DATA($QC+I+MC*J)/DX)/DATA($F+I+MC*(J-1))
  GO TO 500
C
C PART 2, CALCULATE DF/DX FOR STEADY STATE AT X AND T
DO 220 I=1,NCHANL
  DATA($DFDX+I)=0.
  IF (IPILE.EQ.2) GO TO 500
  DO 240 K=1,NK
    I=IDAT($IK+K)
    L=IDAT($JK+K)
    DATA($DFDX+I)=DATA($DFDX+I)-DATA($W+K+MG*(J-1))
    DATA($DFDX+L)=DATA($DFDX+L)+DATA($W+K+MG*(J-1))
   240 DATA($DFDX+L)=DATA($DFDX+L)+DATA($W+K+MG*(J-1))
   220 DATA($DFDX+I)=DATA($DFDX+I)-DATA($W+K+MG*(J-1))
C
C PART 3, CALCULATE DP/DX WITHOUT W
DO 302 I=1,NCHANL
  DATA($DPDX+I)=0.
  IF (FTM.LE.0.0) GO TO 310
  IF (IPILE.EQ.2) GO TO 306
  DO 304 K=1,NK
    I=IDAT($IK+K)
    L=IDAT($JK+K)
    WV=(DATA($U+I)-DATA($U+L))*DATA($WP+K)
    DATA($DPDX+I)=DATA($DPDX+I)+WV
    DATA($DPDX+L)=DATA($DPDX+L)-WV
  304 CONTINUE
  302 DATA($DFDX+I)=DATA($DFDX+I)+DATA($QPRIM+I)+DATA($QC+I+MC*J)/DX
  306 DATA($DFDX+I)=DATA($DFDX+I)+DATA($QPRIM+I)+DATA($QC+I+MC*J)/DX
  310 DATA($DFDX+I)=DATA($DFDX+I)+DATA($QPRIM+I)+DATA($QC+I+MC*J)/DX
C
C TR INSERT
DATA($DPK+I)=SAVE/(DATA($A+I)*DATA($A+I))
IF (J.GT.1) GO TO 382
DATA($DPK+I)=-DATA($DPK+I)*FLOWSQ/GC-DATA($RHO+I+MC*(J-1))*ELEV-DATA($PDX+I)*FTM/(DATA($A+I));GC)
IF (DT.GT.100.) GO TO 390
RHODIF=DATA($SRHO+I+MC*(J-1))-DATA($SRHO+I+MC*(J-1))
RHODOT = RHODIF/DT

C JK INSERT
IF(IPILE.NE.2) GO TO 385

DATA(DPDX+C) = DATA(DPDX+C) + RHODOT/GC*2.*DATA(U+C) + (DATA(FOLD+C+MC*(J-1)) - DATA(F+C+MC*(J-1)))/DATA(A+C)/DT/GC
GO TO 390

385 DATA(DPDX+C) = DATA(DPDX+C) + RHODOT/GC*(2.*DATA(U+C) + DX/DT)

1 + (DATA(FOLD+C+MC*(J-1)) - DATA(F+C+MC*(J-1)))/DATA(A+C)/DT/GC

3 -1))/DATA(A+C)/DT/GC

390 CONTINUE
GO TO 500

C C008B59530
C
PART 4, CALCULATE DP/DX WITH W

C0859540
C
400 IF (J.EQ.1) GO TO 500

DO 410 I=1,NCHANL
C0859550
C
DATA(DHDX+I) = 0.

IF (IPILE.EQ.2) GO TO 425

DO 420 K=1,NK
C0859560
C
I=IDAT(IK+K)
L=IDAT(IJ+K)

DATA(DHDX+I) = DATA(DHDX+I) + ((2.*DATA(U+I) - DATA(USTAR+K) + DX/DT)/DATA(A+I) + DATA(DPK+I)*ABS(DATA(F+I+MC*(JM1-1)) + DATA(F+I+MC*(J-1)))*DX)*DATA(W+K+MG*(-1))

DATA(DHDX+L) = DATA(DHDX+L) - ((2.*DATA(U+L) - DATA(USTAR+K) + DX/DT)/DATA(A+L) + DATA(DPK+I)*ABS(DATA(F+L+MC*(JM1-1)) + DATA(F+L+MC*(J-1)))*DX)*DATA(W+K+MG*(J-1))

420 CONTINUE
425 DO 430 I=1,NCHANL
C0859570

DATA(DPDX+I) = DATA(DPDX+I) + DATA(DHDX+I)/GC

430 CONTINUE
500 CONTINUE
RETURN

IERROR = 2
RETURN

END

SUBROUTINE HEAT(J)

IF NODES GREATER THAN ZERO, CALCULATE HEAT INPUT USING THERMAL CONDUCTION. OTHERWISE HEAT INPUT IS DEFINED BY HEAT GENERATION.
POWER = AVERAGE INTERNAL HEAT GENERATION.

IMPLICIT INTEGER (*)
COMMON /COBRA1/ ABETA , AFLUX , ATOTAL, BBETA , DIA , DT , DX , ELEV , FERROR, FLO , FM , GC , GK , GRID , HSURF , HF , KDEBUG , PREF , QAX , RHOF , RHOD , SIGMA , SL , TF , TFLUID , THETA , THICK , UF , VF , VFG , VG , Z

COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30),
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AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2).

PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TCLAD(2), UUF(30).

LOGICAL GRID

REAL KIJ, KF, KKF, KCLAD, KFUEL.

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX.

COMMON /LINK3/ DXX, ETIME, GIN, HIN, IB, IG, IN, ISAVE, JUMP, KASE, KT, MAXT.

COMMON /LINK4/ IFRM, IHTM, IPROP, NCC, NCF, NDM1, NDS, NGP.

COMMON /TIMEST/ NT.

COMMON DATA(1)

LOGICAL LDAT(1)

INTEGER IDAT(1)

EQUIVALENCE (DATA(1), IDAT(1), IERROR)

IPILE = J7

NP1 = NODESF+1

BYPASS THE HEAT FLUX CALCULATION IF BEYOND THE FIRST ITERATION AND

IF FUEL TEMPERATURES ARE NOT TO BE CALCULATED.

IF(ITERAT.GT.1 .AND. NODESF.LT.1) GO TO 60

BYPASS THE HEAT FLUX CALCULATION USING THE FUEL TEMPERATURE MODEL

IF BEYOND THE FIRST ITERATION, AND IF FUEL TEMPERATURES HAVE BEEN

CALCULATED AND IF A TRANSIENT CALCULATION IS BEING PERFORMED.

IF(ITERAT.GT.1 .AND. NODESF.GT.1 .AND. DT.LT.100.) GO TO 60

CALL CURVE(QAX, (DATA($X+J)-DX*$0.5)/Z, AXIAL, Y, NAX, IERROR, 1)

170 CONTINUE

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($QF+N+MC*(J-1))
   1 /(DATA($SHPERI+N)*DX)
   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
      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.O.) GO TO 1000
      TFLUID = TFLUID/SAVE
      HSURF = HSURF/SAVE
   CC CALCULATE FUEL TEMPERATURE
   7 DO 8 I=1,NP1
      DATA($TDUMY+I)=DATA($TROD+I+MN*(N-1+MR*(J-1)))
      IF(IFRM.EQ.0) GO TO 20
      QP=DATA($FLUX+N+MR*(J-1))*4.*DATA($D+N)/(DFUEL(1)**2)
      CALL TEMFR(DATA($TDUMY+1),DT,N,TFLUID,HGAP(1),HSURF,QP,INN,NT)
      GO TO 22
   20 CALL TEMP(DATA($TDUMY+1),DT,N,J,DATA($$A+1),DATA($$B+1))
      IF(IERROR.GT.1) RETURN
   22 DO 24 I=1,NP1
      24 DATA($TROD+I+MN*(N-1+MR*(J-1)))=DATA($TDUMY+I)
      IF (IHTM.EQ.0.AND. IPROP.EQ.0) GO TO 45
      IF (NT.GT.1) GO TO 45
      IF(INN.LT.2) GO TO 40
      IF (ABS(DATA($TDUMY+I)-FTOLD).GT.EPSF) GO TO 40
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GO TO 45

40 FTOLD=DATA($TDUMY+1)
WRITE(I3,55) N,J
WRITE(I3,55) I3, FTOLD=DATA($TDUMY+1) COB61070
55 FORMAT('1H1,' FUEL TEMPERATURES FAILED TO CONVERGE IN FUEL ROD ', 
1 I3, ' AT AXIAL LEVEL ', I3, '. MAXIMUM ITERATIONS = 50. ')
GO TO 1000

45 DATA($ FLUX+N+MR*(J-1))=HSURF*(DATA($TROD+NP1+MN*(N-1+MR*(J-1))))
1 -TFLUID)
GO TO 1000

50 CONTINUE

60 IF (IPILE.EQ.0) GO TO 70
IF (NODESF.LT.1) GO TO 66
DO 65 I=1,NCHANL

C JK INSERT
CALL HTRAN(I,I,J,JJ,HTC,TLIQ,IHTM,NT)

65 DATA($QPRIM+I)= DATA($PWRF+I+MC*(I-1))* PI* DATA($D+I)* 
1 HSURF *(DATA($TROD+NP1+MN*(I-1+MR*(J-1)))- DATA($T+I))
RETURN

66 DO 68 I=1,NCHANL

68 DATA($QPRIM+I)=DATA($PWRF+I+MC*(I-1))*PI*DATA($D+I)* 
1 DATA($FLUX+I+MR*(J-1))
RETURN

C CALCULATE HEAT INPUT TO EACH CHANNEL.

70 DO 100 I=1,NCHANL
SAVE = 0.
DO 90 N=1,NROD
DUMY=DATA($PWRF+I+MC*(N-1))
IF(DUMY.GT.0.) SAVE=SAVE+DUMY*DATA($FLUX+N+MR*(J-1))*PI*DATA($D+N)
90 CONTINUE

100 DATA($QPRIM+I)=SAVE
RETURN

1000 IERROR = 14
RETURN

END

SUBROUTINE HTRAN(N,I,J,JJ,HTC,TLIQ,IHTM,NT)
C C CALCULATES ROD-TO-COOLANT HEAT TRANSFER COEFFICIENT, HTC
C C IMPLICIT INTEGER(S)
COMMON/PSAVE/P,ROV,ROL,TSAT
COMMON /COBRA1/ ABETA, AFLUX ,TOTAL, BBETA ,DIA, DT, DX
COMMON /COBRA2/ ELEV ,FERROR, FLO, FTM, GC, GK, GRID, HSURF, HF
COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX
COMMON /COBRA4/ MC
C
COMMON DATA(1)
LOGICAL LDAT(1)
INTEGER IDAT(1)

C CHOICE BETWEEN OLD AND NEW HEAT TRANSFER MODELS MADE HERE
IF (IHTM.EQ.0) GO TO 300
NP1=NODESF+1

C VALUES CONVERTED TO SI UNITS FOR USE BY HTCOR

C Tw=TCNS(DATA($TROD+NP1+MN*(N-1+MR*(JJ)))

C LOW WALL TEMP. INDICATES THAT ROD TEMP. NOT YET
C CALCULATED - SO OLD HEAT TRANSFER MODEL USED.

C IF (IW.TL.280.) GO TO 300
TL=TCNS(TLIQ)
TV=TL
XX=DATA($QUAL+I)
ALP=DATA($ALPHA+I)

C IF (XX.LE.0.) VL=.3048*DATA($F+I+MC*(JJ-1))/
C (DATA($RHO+I+MC*(JJ-1))*(1.-ALP)*DATA($A+I))
C (XX.GT.0.) VL=.3048*( (DATA($F+I+MC*(JJ-1)) *
C (1.-XX))/(RHOG*(1.-ALP)*DATA($A+I)))

C V=VL
C IF (XX.GT.0.) VV=.3048*DATA($F+I+MC*(JJ-1))*XX/
C (DATA($RHOG+ALP)*DATA($A+I))
C HD=.3048*DATA($DHYD+I)
C (RD=V=DCON(RHOG)
C ROL=DCON(RHOF)

C CONVERT PRESSURE FROM PSI TO N/M**2
P=6.893E3*(PREF)

C NO CHF CHECK IN HTCOR IF NT AND ITERAT BOTH EQUAL ONE
C BECAUSE START OF BOILING INDICATORS WILL NOT
C BE SET YET IN THIS CASE

NHTM=IHTM
C IF (NT.EQ.1.AND.ITERAT.EQ.1) NHTM=1

C CALL HTCOR(IĐUM1,QV,QL,HVFC,HLNB,HLFC,TW,TL,TV,P,ALP,XX.

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FILE: COBRA3C FORTRAN A CONVERSATIONAL MONITOR SYSTEM

1  ROV, ROL, VF, VL, HD, NHTM, CHFR, TSAT, DATA($FLUX + N+MR*(JJ)).
2  NCHF, N,I,JJ,13)

C  HTC=4.896E-5*(HVFC+HLFC)

CC  ONLY CONSIDER FORCED CONVECTION WHEN TW VERY CLOSE TO TL
IF (ABS(TW-TL) LT .0001) RETURN
HTC=HTC+4.896E-5*(QV+QL+HLNB*(TW-TSAT))/(TW-TL)
IF (NT.GT.1) RETURN

C  LARGE CHANGES IN PREDICTED HEAT TRANSFER COEFF. ARE DAMPED FOR
C  STEADY STATE CALCULATIONS
HTCOLD=DATA($FLUX+N+MR*(JJ))/(DATA($TROD+NP1+MN*(N-1))
1  +MR*(JJ)) - TLQ)
IF ((ABS(HTC-HTCOLD)/HTCOLD).LT..001) RETURN
HTC=0.8*HTC+0.2*HTCOLD
RETURN

300 HTC=HCOLD(N,I,JJ)
RETURN
END

SUBROUTINE SCHEME(JUMVP, AAA)

C  THIS SUBROUTINE SETS UP AND PERFORMS THE SOLUTION OF THE FINITE
C  DIFFERENCE SCHEME AT EACH SPATIAL LOCATION X AT A SELECTED TIME T.

C  IMPLICIT INTEGER ($)
COMMON /COBRA1/
  A5 , ABETA, CFLUX, ATOTAL, BBETA, DIA, DT, DX
1  ELEV, FERROR, FLO, FTM, GC, GK, GRID, HSURF, HF
2  HFG, HG, HG, I2, I3, IERROR, IOP3, ITERAT, J1, J2
3  J3, J4, J5, J6, J7, KDEBUG, KF, KIJK
4  NAFACT, NRAMA, NAX, NXAL, NBBC, NCHAN, NCF, NDF, NF
5  NQPS, NGRID, NGRID, NGTYPE, NGX, NL, NODS, NODESF, NPROP
6  NRM, NROD, NNBC, NV, NNSCW, 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  GAPX(10), GFAC(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30),
3  IGRD(10), KCLAD(2), KFUEL(2), KKK(30), MCH(10), NGAP(9),
4  PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TCLAD(2), UUF(30),
5  VFV(30), VG(30), XQUAL(30), Y(30), ZZ(30)

C  COMMON /COBRA3/
  MA, MC, MG, MN, MR, MS, MX
1  SSS, SA, SAAA, SAS, SALPHA, SAN, SANSE, SB
1  $CCHAN, $CD, $CHFR, $CON, $COND, $CP, $D, $DC, $DFX
2  $DHDX, $DHYN, $DIST, $DPX, $DPK, $DUR, $DR, $F
2  $DHDX, $DHYN, $DIST, $DPX, $DPK, $DUR, $DR, $F
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3 $FACTU,$DIV ,$FINL$E , $SFLUX , $FMUL$T , $SFLD , $SFSP
   , $FSPLI , $FXFLD, COB62710
4 $GAP , $GAPN , $GAPS , $SH , $SHFLM, $SHINL, $SHOLD , $SHP$E , $SIDAR$E, COB62720
5 $IDFUE , $IDGAP , $IK , $JBOIL , $JK , $LCL , $LEN$GT, $LOCA , $SLR , COB62730
6 $MGCHR , $MCFIN , $MCFLR , $N$SPE , $SN$RAP , $SW$RP$S , $SP , $SP$E$RM , $SP$H$E , COB62740
7 $PHI , $PRNTC , $PRNTN , $SP$N$T$ , $SPW , $SP$W$F$ , $SOC , $SOF , $SP$R$ME , COB62750
8 $Q$AL$U , $SR$DAC, $SR$HO , $SR$HOL , $SSP , $ST , $ST$DUM$Y , $ST$INL , $STR$O$D , COB62760
9 $SU , $SU$SAV$E , $SU$T$AR , $SV , $SV$ISC , $SV$IS$C$W , $SV$P , $V$P$A , COB62770

C COMMON (DATA(1), IDAT(1), LDAT(1))
C LOGICAL LDAT(1)
C INTEGER IDAT(1)
C EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))
C
C EQUIVALENCE (NCHAN, NCHANL)
C
C DIMENSION AAA(1)
C
1 FORMAT('ERROR DETECTED IN SUBROUTINE SCHEME AT NODE', 'I3,')
1 ' X = ','E10.5,' FEET'/ CALCULATION FOR THIS CASE STOPPED')
1 FORMAT(' NODE', 'I3, ' X = ', 'E10.5')
1 FORMAT(' I H(I,J) F(I,J) P(I,J) H(I,J-1) FCOB62910
1(I,J-1) P(I,J-1)')
1 FORMAT(' I QUAL(I) ALPHA(I) RHO(I,J) VP(I)')
1 V(I) FMULT(I)')
1 FORMAT(' K W(K,J-1) W(K,J) WP(K) USTAR(K) SP$C$OB62950
1(K,J-1) SP(K,J)')
1 FORMAT(' I DHDX(I) UH(I) DPDX(I) QPRIM(I) FCOB62970
1LD(I,J) RHO$H(I,J)')
16 FORMAT(315,4E12.6) COB62990
52 FORMAT(15,6E12.6) COB63000
C MEKIN. IPILE = 0,1,2 FOR STANDARD COBRA, PWR, BWR
C IPILE = J7
C NCHANL = NCHANL
C FM$N$ = .0001
C NDXP$1 = NDX+1
C IF(JUMP.EQ.3) GO TO 400
C JUMP = 2
C BEGIN STEPPING THROUGH CHANNEL
400 DO 450 J=1,NDXP$1
C CALL PRNTIM (3) COB63110
C JP1 = J+1
C JM1 = J-1
C IF(J,J.GT.1) GO TO 405
C SET CONDITIONS AT START OF CHANNEL
C DO 401 I=1,NCHANL
C DATA(SOPRIM+I)=0.
C CALL FORC$E(I)
C IF(IIERROR.GT.1) GO TO 440
C CALL AREA(I)
C IF(IIERROR.GT.1) GO TO 440
C CALL PROP(2.1)
C IF(IIERROR.GT.1) GO TO 440
C CALL VOID(I)
C IF(IIERROR.GT.1) GO TO 440
GO TO 428
405 IF(JUMP.EQ.3) GO TO 420
IF(NGRID.LT.1) GO TO 410
GRID = .FALSE.
DO 410 I=1,NGRID
ZG = GRIDX(I)*Z
IF(ZG.GT.DATA($X+JM1).AND.
1 ZG.LE.DATA($X+J)) GO TO 409
408 CONTINUE
GO TO 410
409 NGTEMP = IGRID(I)
GRID = .TRUE.
C CALCULATE PARAMETERS TO BE SAVED FROM PREVIOUS SPACE
410 DO 411 I=1,NCHANL
DATA($VP+I)=DATA($VP+I)/DATA($A+I)
411 CONTINUE
C CALL HEAT(J)
420 CALL HEAT(J)
IF(IERROR.GT.1) GO TO 440
IF(IPILE.EQ.2) GO TO 423
CALL MIX(JM1)
423 CALL DIFFER(1,JM1)
IF(IERROR.GT.1) GO TO 440
C CALCULATE ENTHALPY AND ESTIMATE FLOW AT X.
DO 425 I=1,NCHANL
C JK INSERT
1 IF(ITERAT.EQ.1.AND.JUMP.NE.3.OR.IPILE.EQ.2) DATA(SF+I+MC*(J-1))*(1)
DATA(SF+I+MC*(JM1-1))
DATA($H+I+MC*(J-1))=(DATA($H+I+MC*(JM1-1))+DX/DT)/DATA($SUH+I)*
1 DATA($HOLD+I+MC*(J-1))+DX*DATA($DHDX+I))/(1.0+DX/DT/
2 DATA($SUH+I)
425 CONTINUE
IF(JUMP.EQ.3) GO TO 450
CALL FORCE(J)
IF(IERROR.GT.1) GO TO 440
CALL AREA(J)
IF(IERROR.GT.1) GO TO 440
CALL PROP(2,J)
IF(IERROR.GT.1) GO TO 440
CALL VOID(J)
IF(IERROR.GT.1) GO TO 440
CALL DIFFER(3,J)
IF(IERROR.GT.1) GO TO 440
IF(IPILE.EQ.2) GO TO 4255
CALL SEPRAT(1,J,JUMP)
IF(IERROR.GT.1) GO TO 440
GO TO 435
4255 DO 426 K=1,NK
DATA($WSAVE+K)=DATA($W+K+MG*(J-1))
426 CONTINUE
C CALCULATE THE DIVERSION CROSSFLOW AT X.
CALL PRNTIM (4)
C CALL DIVERT(J)
CALL PRNTIM (5)
IF (ERROR.R.T.1) GO TO 440
C CALCULATE THE FLOW AT X AND CHECK FOR CONVERGENCE.
CALL DIFFER(2,J)
C  T R INSERT
RHDIF=DATA($RHO+I+MC*(J-1))-DATA($RHO+I+MC*(J-1))
C THE FOLLOWING STATEMENT PROVIDES DAMPING TO ASSIST IN MORE RAPID
C CONVERGENCE, ESPECIALLY WHEN USING THE SUBCOOLED VOID OPTION.
C USERS MAY WISH TO TRY OTHER COMBINATIONS OF CONSTANTS.
C USED FOR THE SAMPLE PROBLEMS. A VALUE OF ZERO WAS
C CONVERGENCE FOR MANY PROBLEMS. USERS MAY WISH TO TRY OTHER VALUES.
C THE FACTOR DAMPING WAS ADDED AFTER PUBLICATION. A VALUE OF ZERO WAS
C CALCULATE SP AT X-DX.
CALL DIFFER(4,J)
IF (ERROR.R.T.1) GO TO 440
C 427 I=1,NCHNL
DO 427 I=1,NCHANL
C 428 CONTINUE
IF (KDEBUG.LT.1) GO TO 450
GO TO 445
GO TO 446
WRITE(13,1) J,DATA($X+J)
GO TO 446
WRITE(13,2) J,DATA($X+J)
WRITE(13,3)
WRITE(13,52) (1,DATA($H+I+MC*(J-1)),DATA($F+I+MC*(J-1))),C086310
1 DATA($P+I+MC*(J-1)),DATA($H+I+MC*(J-1)),DATA($F+I+MC*(J-1)),DATA($P+I+MC*(J-1)),C086310
1 IF (KDEBUG.LT.1) GO TO 450
GO TO 445
GO TO 446
WRITE(13,4)
WRITE(13,52) (1,DATA($RHO+I+MC*(J-1)),DATA($V+I)),C086310
1 DATA($RHO+I+MC*(J-1)),DATA($V+I)),C086310
1 I=1,NCHNL
WRITE(13,5) DATA($W+K+MG*(J-1)),DATA($W+K+MG*(J-1)),C086310
1 DATA($WP+K),DATA($W+K+MG*(J-1)),DATA($WP+K),C086310
1 K=1,NK
WRITE(13,52) (I,DATA(SOHDX +I) ) , DATA($UH +I ), C0B64360
1  DATA(SOPDX +I) ,DATA(SQPRIM +I), C0B64370
2  DATA($FOLD +I+MC*(J -1)),DATA($RHOOL +I+MC*(J -1)), C0B64380
1 I=1,NCHANL)
450 CONTINUE
C CORRECT SUBCHANNEL PRESSURES TO ZERO EXIT PRESSURE.
C PRESSURE P(I,J) IS THE PRESSURE ABOVE THE EXIT REFERENCE PRESSURE.
DO 460 I=1,NCHANL C0B64440
PEXIT=DATA($P+I+MC*(NDXP1-1))
DO 460 J=1,NDXP1
460 DATA(SP+I+MC*(J-1))=DATA($P+I+MC*(J-1)) -PEXIT C0B64470
IF (IPILE.NE.2) RETURN C0B64520
CALL SEPRAT(2,J,JUMP) RETURN C0B64550
END FUNCTION SCQUAL(I,J)
C LEVY SUBCOOLED MODEL. CALCULATES TRUE QUALITY AS
C A CORRECTION TO
C THE EQUILIBRIUM QUALITY.
C IMPLICIT INTEGER ($)
COMMON /COBRA1/ ABETA ,AFLUX ,ATOTAL,BBETA ,DIA ,DT ,DX C0B64580
1 ELEV ,FERROR,FLO ,FTM ,GC ,GK ,GRID ,HSURF ,HF C0B64600
2 HFG ,HG ,I2 ,I3 ,IERROR,IQP3 ,ITERAT,J1 ,J2 C0B64610
3 J3 QAX ,J5 ,J6 ,J7 ,KDEBUG,KF ,KIJ C0B64620
4 NFACT,NARAMP,NAX ,NAXL ,NBB ,NCHANL,NCF ,NDX ,NF C0B64630
5 NGAPS ,NGRID ,NGRIDT,NGTYPE ,NGXL ,NK C0B64640
6 NRAMP ,NROD ,NSCBC ,NV ,NVISCW,PI ,PITCH ,POWER ,PREF C0B64650
7 QAX ,RHOF ,RHOG ,SIGMA ,SL ,TF ,TLFLUID,THETA ,THICK C0B64660
8 UF ,VF ,VFG ,VG ,Z C0B64670
IMPLICIT LOGICAL ($)
COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30) C0B64680
1 AXL(10), BB(4), BX(30), CC(4), CCLAD(2), CFUEL(2), DFUEL(2), C0B64690
2 GAPXL(10), GFAC(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30) C0B64700
3 IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9) C0B64710
4 PP(30), RCLAD(2), RFUEL(2), SIGMA(30), TCLAD(2), UUF(30), C0B64720
5 VVF(30), VVG(30), XQUAL(30), Y(30), TT(30) C0B64730
C LOGICAL GRID
C REAL KI ,KF ,KKF, KCLAD, KFUEL C0B64740
C COMMON /COBRA3/ MA ,MC ,MG ,MN ,MR ,MS ,MX ,C0B64800
1 MACH ,MC ,MG ,MN ,MR ,MS ,MX ,C0B64810
2 SSS ,SA ,SAAA ,SAC ,SALPHA ,SAN ,SANW ,SB ,C0B64820
3 $CCHAN,$CDO ,$CFR ,$CSCN ,COND ,CONDC ,SCP ,C0B64830
4 $DCMX ,DDHYD ,DSHYDN ,SDIST ,SOPDX ,SDPK ,SDFX ,SDFMX ,C0B64840
5 $FACT ,FDIV ,FIND ,FUX ,FMULT ,FSDFX ,FSFLX ,C0B64850
6 $GAP ,$GAPN ,$GAPS ,SH ,SHFILM,SHINEL ,SHOLD ,C0B64860
7 $FUE ,$DGAP ,$IK ,SBOIL ,SUK ,SLOC ,SL ,$FL ,C0B64870
8 $MCFR ,$MCFCR ,$MFRR ,SNTYPE ,SNWRAP ,SNWPS ,$SP ,$PERIM ,SPH C0B64880
7 $PHI ,$PRNTC ,$PNTR ,$PRNTN ,$PW ,$PRWF ,$QOC ,$QF ,C0B64890
8 $QPRIM ,$RADIUS ,$RHO ,$RHOOL ,$SP ,$ST ,$DUMY ,$STINL ,$STROD ,C0B64900
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9 SU ,SUH ,SUSAVE,SUSTAR,SV ,$VISC ,$VISCM ,$VSP ,$VPA ,COB64910
C SW ,SWOLD ,SWP ,$WSAVE,$X ,$XCRON,$$A ,$$B ,$$XPOLD ,COB64920
C
COMMON DATA(1) COB64930
LOGICAL LDAT(1) COB64940
INTEGER IDAT(1) COB64950
EQUIVALENCE (DATA(1),IDAT(1),LDAT(1)) COB64960
C
XP=DATA($QUAL+I)
C
DATA($XPOLD+I)=0.
SCUAL = XP
IF(DATA($QPRIM+I).LE.0.) RETURN
CNC = 0.015
JJ = J
C
*** THE FOLLOWING CARDS CORRECT THE LEVY MODEL ****
YB=CNC/UF *3600. *SQR( SIGMA *GC*DATA($HYD+I)/VF)
TAU=DATA($SP+I)*.125*VF *(DATA($F+MC*(J-1)+I)/
1 DATA($A+I))*2/GC
PR=DATA($CP+I)/UF/KF
Q= DATA($QPRIM+I)/(DATA($HPERI+I)/VF *DATA($CP+I)*
1 SORT(TAUW*GC*VF ))
C
UK INSERT
RE=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($HYD+I)/DATA($VISC+I)
HTC=DATA($CON+I)/DATA($HYD+I)*.023*RE**.8*PR**.4
DELAT=DATA($QPRIM+I)/DATA($HPERI+I)/HTC
C
***
IF(YB,GE.0..AND. YB.LT.5.) DELAT = DELAT - Q*PR*YB
IF(YB,GE.5. AND. YB.LT.30.) DELAT = DELAT - 5.*Q*(PR+ALOG(1.+PR)*(COB65200
1 YB=-2.1.))
IF(YB,GE.30.) DELAT = DELAT - 5.*Q*(PR+ALOG(1.+5.*PR)
1 + .5=ALOG(YB,30.1.)
XD=-DATA($CP+I)*DELAT/HFG
ARG=DATA($QUAL+I)/XD-1.
IF (ARG.LT.-15.0) GO TO 140
IF(ARG.GT.0.) ARG = 0.
XP =DATA($QUAL+I)-XD*EXP(ARG)
C
*** THE FOLLOWING CARDS CORRECT THE LEVY MODEL ****
IF(DATA($QUAL+I),LT.XD) XP=0.
IF(J7.EQ.2) GO TO 130
IF(ITERA.T.EQ.1) DATA($XPOLD+I+MC*(J-1))=XP
DUMY=DATA($XPOLD+I+MC*(J-1))
XP=.99*XP+.1*DUMY
130 IF(JJ.EQ.JJ) JJ=2
XP=MAX1(XP,DATA($XPOLD+I+MC*(J-1)))
140 SCQUAL = XP
END
C
FLOW ITERATION FOR SEPARATED CHANNELS (EG BWR
C CALLED FROM SCHEME
C SP USED FOR (1) DM/DP (2) DM (3) DP
C
SUBROUTINE SEPRAT(IPART,J,JUMP)
C
C
COB65380
COB65390
COB65400
COB65410
COB65420
COB65430
COB65440
COB65450
IMPLICIT INTEGER (S)

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX, ELEV, FERROR, FLO, HFG, HG, I2, I3, IERROR, JOP3, ITERAT, J1, J2, J3, J4, J5, J6, J7, KEBUG, KF, KIJ

COMMON /COBRA2/ AA(4), AF(7), AFACT(10,10), AV(7), AXIAL(30), BX(30), CC(4), CCCLAD(2), CFUEL(2), DFUEL(2), GAPXL(10), GFACT(9,10), GRIDXL(10), HGAP(2), HHF(30), HHG(30), IGRID(10), KCLAD(2), KFUEL(2), KKF(30), NCH(10), NGAP(9), PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TCLAD(2), UUF(30), VVF(30), VVG(30), XQUAL(30), Y(30), TT(30)

COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX

LOGICAL GRID

REAL KIJ, KF, KKF, KCLAD, KFUEL

COMMON /REFP/ PO

LOGICAL DATA(1)

INTEGER IDAT(1)

EQUIVALENCE (DATA(1), IDAT(1), LDAT(1))

IF (IPART.EQ.2) GO TO 10

DO 2 I=1,NCHANL

DATA($DFDX+I)=O.O

DATA($F+I+MC(J-1))=DATA($F+I+MC*(J-2))-DX/DT*(DATA($RHO+I+MC*(J-1))-DATA($RHOOL+I+MC*(J-1)))*DATA($A+I)

CALL DIFFER(3,J)

RETURN

END
10 PMIN=1.00000   0
PMAX=1.00000
DO 12 I=1,NCHANL
WV=DATA($P+I)
IF (WV.LT.PMIN) PMIN=WV
IF (WV.GT.PMAX) PMAX=WV
12 CONTINUE
IF (ABS(1.-PMIN/PMAX).LT.FERROR) RETURN
JUMP=1
IF (ITERAT.GT.1) GO TO 16
FTOT=0.0
DO 14 I=1,NCHANL
FTOT=FTOT+DATA($F+I)
DO 12 I=1,NCHANL
FTOT=FTOT+DATA($F+I)
14 CONTINUE
IF (ABS(FTOT-FTOT).LT.0.001) GO TO 18
DATA($SP+I)=0.7*DATA($F+I)/(DATA($P+I)-DATA($RHO+I+MC*NDX)*
1 ELEV*Z)
18 CONTINUE
20 SUM1=0.0
SUM13=0.0
DO 22 I=1,NCHANL
DATA($SP+I)=DATA($F+I)-DATA($SP+I+MC)/DELTAP
DELTAP=(DATA($P+I)-DATA($SP+I+2*MC))
IF (ABS(DELTAP).LT.0.001) GO TO 18
IF(ABS(DELTAP).LT.0.001) GO TO 18
22 DATA($SP+I+MC)=DATA($F+I)
DATA($SP+I+MC*2)=DATA($P+I)
23 PO=P113
IF (PO.LE.0.0) PO=ABS(PO)
SUMF=0.0
DATA($F+I)=DATA($F+I)+DATA($SP+I)*(PO-DATA($P+I))
SUMF=SUMF+DATA($F+I)
DO 24 I=1,NCHANL
DATA($F+I)=DATA($F+I)*FTOT/SUMF
24 DATA($F+I)=DATA($F+I)*FTOT/SUMF
26 DATA($F+I)=DATA($F+I)*FTOT/SUMF
RETURN
END
SUBROUTINE VOID
IMPLICIT INTEGER ($)
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 ,KI J
4 NFACT ,NAMAX ,NAX ,NBL ,NCHN ,NCHF ,NDX ,NF
5 NGAPS ,NGRID ,NGRDT ,NGTYPE ,NX ,NROD ,NROD ,NROD ,NROD ,NROD
6 NROD ,NPROD ,NSC BC ,NV ,NVISB ,PI ,PITCH ,POW E ,PREF
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C CALCULATE TWO-PHASE DENSITY.
C
C ******** THE FOLLOWING CARDS CORRECT THE CALCULATION OF RHO AND VP
C
DATA($RHO+1+MC*(J-1))=RHOG+DATA($ALPHA+I)+1./DATA($V+I)(1.0-
C
DATA($ALPHA+I))
C
C CALCULATE TWO-PHASE SPECIFIC VOLUME FOR MOMENTUM.
C
DATA($VP+I)=DATA($V+I)*(1.-XY)**2/(1.-DATA($ALPHA+I))+YG*XP**2/
C
DATA($ALPHA+I)
C
C JK INSERT
C
IF(J7.NE.2) GO TO 3
C
IF(J.EQ.1) GO TO 3
C
RHODIF = DATA($RHO+1+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))
C
DATA($F+I+MC*(J-1))= DATA($F+I+MC*(J-2))-DX/DT*RHODIF*DATA($A+I)
C
C CONTINUE
C
C TWO-PHASE FRICTIONAL PRESSURE GRADIENT MULTIPLIERS.
C
DATA($PHI+I)=1.
C
IF(J4.EQ.0) DATA($PHI+I)=RHOF/DATA($RHO+I+MC*(J-1))
C
GWV = 3600.0*DATA($F+I+MC*(J-1))/DATA($A+I)
C
IF(J4.EQ.1) CALL BAROC(2,PREF,XP,GWV,DATA($PHI+I),PPI)
C
IF(J4.NE.1) GO TO 50
C
DATA($PHI+I)=1.
C
IF(XA.GT.0.0.AND.XA.LE.0.6)XXX=(1.-XY)**2/(1.-XA)**1.42
C
IF(XA.GT.0.9.AND.XA.LE.1.0)XXX=1.73,(1.-XY)**2/(1.-XA)**1.64
C
DATA($PHI+I)=XXX
C
50 IF(J4.NE.5) GO TO 140
C
DATA($PHI+I)=AF(I)
C
XX =DATA($QUAL+I)
C
DO 130 K=2,NF
C
DATA($PHI+I)=DATA($PHI+I)+AFK*XX
C
130 XX =DATA($QUAL+I)+XX
C
140 DATA($U +I)=DATA($QUAL+I)+XX
C
DATA($U+1+MC*(J-1))/DATA($A+I)*DATA($VP+I)
C
IF(J3.EQ.0) GO TO 145
C
DPSIDH = 10.* (PSI-RHOF*DATA($QUAL+I)*1.-DATA($ALPHA+I)+RHOG*
C
1 DATA($ALPHA+I)*(1.-DATA($QUAL+I))
C
145 DATA($UH+I) =DATA($F+I+MC*(J-1))/DATA($A+I)/DATA($RHO+I+MC*(J-1))
C
1 -HEG+DPSIDH
C
GO TO 200
C
C TWO-PHASE FLOW PARAMETERS WITHOUT BOILING.
C
150 DATA($ALPHA+I)=0.0
C
DATA($RHO +1+MC*(J-1))=1.0/DATA($V+I)
C
C JK INSERT
C
IF(J7.NE.2) GO TO 4
C
IF(J.EQ.1) GO TO 4
C
RHODIF = DATA($RHO+1+MC*(J-1))-DATA($RHOOL+I+MC*(J-1))
C
DATA($F+I+MC*(J-1))= DATA($F+I+MC*(J-2))-DX/DT*RHODIF*DATA($A+I)
C
4 CONTINUE
C
DATA($VP +I)=DATA($V+I)
C
DATA($U +I)=DATA($F+I+MC*(J-1))/DATA($A+I)*DATA($VP+I)
C
DATA($UH +I)=DATA($U+I)
C
DATA($PHI +I)=1.0
C
DATA($QUAL +I)=0.0
C
200 CONTINUE
C
RETURN
C
END
SUBROUTINE STATE(P,TV,TL,ROV,ROL,EV,EL,TSAT,TSATP,
  DELDP,DEVP,DELDT,DEVDT,DRDP,DRVDP,DRDT,DRVT,IOP,IERR)

SUBROUTINE STATE CALCULATES THE STATE DYNAMIC PROPERTIES OF WATER. THE PRESENT VERSION USES FITS DUE TO BILL RIVARD OF GROUP T-3 OF THE LASL THEORETICAL DIVISION. TAKEN FROM TRAC AND RECODED TO IMPROVE EFFICIENCY.

INPUT VARIABLES
1. P PRESSURE
2. TL TEMPERATURE OF THE LIQUID
3. TV TEMPERATURE OF THE VAPOR
4. IOP OPTION SELECTOR - NOT IN PRESENT VERSION

OUTPUT VARIABLES
1. EV INTERNAL ENERGY OF THE VAPOR
2. EL INTERNAL ENERGY OF THE LIQUID
3. TSAT SATURATION TEMPERATURE
4. ROL DENSITY OF THE LIQUID
5. ROV DENSITY OF THE VAPOR
6. TSATP DERIVATIVE OF TSAT WRT PRESSURE
7. DELDP DERIVATIVE OF TL WRT PRESSURE
8. DEVP DERIVATIVE OF TV WRT PRESSURE
9. DELDT DERIVATIVE OF EL WRT TL
10. DEVDT DERIVATIVE OF EV WRT TV
11. DRDP DERIVATIVE OF ROL WRT PRESSURE
12. DRVDP DERIVATIVE OF ROV WRT PRESSURE
13. DRDT DERIVATIVE OF ROL WRT TL
14. DRVT DERIVATIVE OF ROV WRT TV
15. IERR ERROR FLAG (INPUT VARIABLE OUT OF RANGE)

CONSTANTS USED IN FITS
FOR TSAT, CPS
DATA TSC1,TSC2, TSEXP /9.0395, 255.2, 0.223/
DATA CPS1,CPS2, CPSEXP /9.5875E2, .00132334, -0.8566/
C
C CPS2 = -CPSEXP * TCIRVIN
C
FOR ES, GAMS IF P < 20 BARS
DATA G11,G12,G13 /2.6104106E6, -4.99535, 3.4035E5/
DATA G14,G15,G16 /1.0665544, 1.02E-8, -2.548E-15/C
C C G11,G14 ARE ADJUSTED SO THAT ES RESP. GAMS JUMPS LESS THAN 1 PART IN 1.E-8 ACROSS P = 20 BARS.
DATA G17 /-5.096E-15/
C G17 = 2.* G16
C
FOR ES, GAMS IF P > 20 BARS
DATA G21,G22,G23 /2.5896E6, 6.350E3, -1.0592E-9/
DATA G24,G25,G26 /1.0764, 3.625E-10, -9.063E-17/
DATA G27,G28 /-2.1184E-9, -18.126E-17/
C G27 = 2.* G23, G28 = 2.* G26
C
DATA P20B /2.0E6/
DATA TCIR/647.3/
DATA TCIRVIN /0.00154488/
DATA CC,CCI,CCM /1.3, .76923, 0.3/
C
DATA RLO,RL1,RL2 /1.E3, -2.E-5, -.15E-9/
DATA RL22 /*-.3E-9/ C
DATA SLO,SL1,SL2,SL3 /*-1.4655677D+06,
1 -7.7423067E+03, 1 -7.7423067E+01/ C
SLO IS CHOSEN SO THE JUMP IN EL AT 300 DEG C IS AS SMALL AS POSSIBLE
C
DATA SL22,SL33 /*-15.484613, 2.1840901E-2/ C
SL22 = 2.* SL2, SL33 = 3.* SL3
C
FOR EL IF TL < 300 DEG C
C
DATA SHO,SH1,SH2,SH3 /*-8.9, 2.3639439E+04, 1
1 -7.7434017E+01, 7.0215574E-02/ C
DATA SH22,SH33 /*-1.5486803E2, 2.1064672E-1/ C
SH22 = 2.* SH2, SH33 = 3.* SH3
C
FOR VAPOR
C
DATA A11,A12,A13 /*1.2959E-3, 593.59, 1.6847E-3/
C
DATA HALF,ZERO,ONE,TWO /*0.5, 0., 1., 2./
C
CHECK THAT P, TL, TV, ARE WITHIN RANGE OF FITS
C
IF (P.GE.1.0E+3.AND.P.LE.190.0E+5) GO TO 5
IERR = 1
RETURN
5 IF (TL.GE.280.0.AND.TL.LE.647.0) GO TO 10
IERR = 2
RETURN
10 IF(TV.GE.280.0) GO TO 20
IERR = 3
RETURN
20 IERR = 0
C
CALCULATE SATURATION PROPERTIES
C
1. TSAT SATURATION TEMPERATURE
2. DTSDP DERIVATIVE OF TSAT WRT PRESSURE
3. ES SATURATION INTERNAL ENERGY
4. DPES DERIVATIVE OF ES WRT PRESSURE
5. GAMS GAMMA SUB S
6. DPGAMS DERIVATIVE OF GAMS WRT PRESSURE
7. CPS C SUB PS
8. DPCPS DERIVATIVE OF CPS WRT PRESSURE
9. GAMSM GAMS-ONE
C
TSAT = TSC1* P**TSEXP
PINV = ONE/ P
DTSDP = TSAT*TSEXP*PINV
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TSAT = TSAT + TSC2

C

T1 = ONE - TSAT*TCRINV
CPS = CPS1* T1**CPSEX
DPCPS = CPS2*CPS/T1 +DTSDP

C

IF (P.GT.P208) GO TO 150
T2 = ONE/(G13+P)
T1 = T2*G12
ES = G11 + T1
DPES = -T1*T2
GAMS = G14 + P*(G15 + P*G16)
DPGAMS = G15+G17*P
GO TO 200

150 CONTINUE
ES = G21+(G23+P*G22)*P
DPES = G22+G27*P
GAMS = G24+(G26+P*G25)*P
DPGAMS = G25+G28*P
GO TO 200

200 GAMS = GAMS - ONE

C

CALCULATE LIQUID PROPERTIES

1. INTERNAL ENERGY AND ITS DERIVATIVES

DELDP = 0.
IF (TL.GE.573.15) GO TO 220
EL = SLO + TL*(SL1 + TL*SL2 + TL*SL3))
DELT = SL1 + TL*(SL2 + TL*SL3))
GO TO 240

220 CONTINUE
EL = SHO + TL*(SH1 + TL*SH2 + TL*SH3))
DELT = SH1 + TL*(SH2 + TL*SH3))

240 CONTINUE

C

2. DENSITY AND ITS DERIVATIVES

ROL = RL0 + EL*(RL1 + EL*RL2) + P*CL2I
DRLDP = CL2I
DRLDE = RL1 + EL*RL22
DRLDT = DRLDE+DELT

C

CALCULATE VAPOR PROPERTIES

DT = TV-TSAT
IF (DT.LE.ZERO) GO TO 250

C

SUPERHEATED VAPOR

1. BETA A WORKING PARAMETER
2. CAPK A WORKING PARAMETER
3. DBETAP DERIVATIVE OF BETA WRT PRESSURE
4. DCAPKP DERIVATIVE OF CAPK WRT PRESSURE
5. DEVD
6. DEVD
7. ROV
8. DRVDE
9. DRVDP

\[
T1 = \frac{\text{ONE}}{(A11 \cdot \text{CPS} - \text{ONE})} \\
T1SQ = T1 \cdot T1 \\
BETA = \frac{\text{TSAT} \cdot \text{TSAT} \cdot (\text{ONE} - T1SQ)}{\text{ONE}} \\
T2 = \frac{\text{TSAT} \cdot T1}{\text{ONE}} \\
DE = A12 \cdot (DT + \sqrt{(TV + TV - BETA) - T2}) \\
EV = ES + DE \\
\text{CAPK} = A13 \cdot DE + TSAT + T2 \\
\text{DBETAP} = 2 \cdot (BETA \cdot DTSDP + T2 \cdot T2 \cdot T2 \cdot A11 \cdot DPCPS) / TSAT \\
\text{DCAPKP} = -A13 \cdot \text{DPES} + (\text{ONE} + T1) \cdot DTSDP \\
\text{T3} = \frac{\text{ONE} - \text{BETA}}{(\text{CAPK} + \text{CAPK})} \\
\text{DEVD} = \frac{\text{ONE} / (\text{HALF} \cdot T3 \cdot A13)}{\text{DEVDT} \cdot \text{DEVDP} - \text{HALF} \cdot (T3 \cdot \text{DCAPKP} + \text{DBETAP} / \text{CAPK}) \cdot \text{DEVDT}} \\
\text{T4} = \frac{\text{ONE} / (\text{GAMSM} \cdot \text{ES} + \text{CCM} \cdot \text{DE})}{\text{ROV} = \text{P} \cdot T4} \\
\text{DRVDE} = -\text{ROV} \cdot \text{CCM} \cdot T4 \\
\text{DRVDT} = \text{DRVDE} \cdot \text{DEVDT} \\
\text{DRVDP} = \text{ROV} \cdot (\text{PINV} - (\text{ES} \cdot \text{DPMAMS} + (\text{GAMSM} - \text{CCM}) \cdot \text{DPES}) \cdot T4) / \text{T4} \\
1 + \text{DRVDE} \cdot \text{DEVDP} \\
\text{GO TO 300}
\]

250 \text{CONTINUE}

\[
\text{SUBCOOLED VAPOR}
\]

\[
\text{DEVDT} = \text{CPS} \cdot \text{CCI} \\
\text{DE} = DT \cdot \text{DEVDT} \\
\text{EV} = \text{ES} + \text{DE} \\
\text{T1} = \frac{\text{ONE} / \text{CPS}}{\text{DEVDP} = -(\text{DTSDP} - \text{CC} \cdot T1 \cdot (\text{DPES} + \text{DE} \cdot \text{DPCPS} \cdot T1)) \cdot \text{DEVDT}} \\
\text{T1} = \frac{\text{ONE} / \text{GAMSM}}{\text{T2} = \frac{\text{ONE} / \text{EV}}{\text{ROV} = \text{P} \cdot T1 \cdot T2} \\
\text{DRVDE} = -\text{ROV} \cdot T2 \\
\text{DRVDT} = \text{DRVDE} \cdot \text{DEVDT} \\
\text{DRVDP} = \text{ROV} \cdot (\text{PINV} - (\text{ES} \cdot \text{DPMAMS} + (\text{GAMSM} - \text{CCM}) \cdot \text{DPES}) \cdot T1) + \text{DRVDE} \cdot \text{DEVDP}
\]

300 \text{CONTINUE}

\[
\text{RETURN}
\]

\[
\text{END}
\]

\[
\text{OVERSEES NEW FUEL ROD MODEL CALCULATIONS}
\]

\[
\text{IMPLICIT INTEGER($)} \\
\text{COMMON} / \text{MCND}, \text{CNO}(22), \text{RCP}(22), \text{RAD}(22), \text{RRDR}(22), \text{VM}(22), \text{VP}(22), \text{QPPP}(22)
\]

\[
\text{COMMON} / \text{FRDATA}/ \text{BURN}, \text{CPR}, \text{EFFB}, \text{EPSF}, \text{EXPR}, \text{FRESS}, \text{FPUO2}, \text{FRAC}, \text{FTD}, \text{GMIX}(4), \text{GAMN}, \text{BGAS}, \text{RADR}, \text{RDELT}, \text{THC}, \text{THG}
\]

\[
\text{RETURN}
\]

\[
\text{END}
\]
CONVERSATIONAL MONITOR SYSTEM

COMMON/LINK4/IFRM, IHTM, IPROP, NCC, NCF, NDM1, NDS, NGP

DIMENSION TDUMY(1)

DO 20 JJ=1,NCF
 20 QPPP(jj)=QP
RDELT=1./DT
IF(NT.EQ.1) RDELT=0.
IF(NT.EQ.1.AND.III.EQ.1) GO TO 30
IF (IPROP.EQ.0) GO TO 30
CALL RPROP(TDUMY(1),NCF,NGP,NDM1,HGAP,IPROP)
30 CALL RTEMPF(TDUMY(1),RDELT,RADR,HSURF,TFLUID,NDS,NDM1)
RETURN
END

SUBROUTINE INITRC
  C
  C INITIALIZE ARRAYS FOR NEW FUEL ROD MODEL

COMMON /COBRA1/ ABETA, AFLUX, ATOTAL, BBETA, DIA, DT, DX
1 ELEV, FERROR, FLO, FTM, GC, GGRID, HSURF, HF
2 HFG, HG, J2, J3, J4, J5, J6, J7, KDEBUG, KF, KI
3 NFACT, NCHF, NCHL, NDATA, NICH, NNAME, NF
4 NCHB, NNAME, NH, NNAME
5 NGAPS, NGRID, NGRIDT, NGX, NGZ, NPROP, NQC, NQQ, NQQQ
6 NCHT, NGRID, NGRIDT, NGX, NGZ, NPROP, NQC, NQQ, NQQQ
7 QAX, RHOF, RHOH, SIGMA, SL, TFLUID
8 UF, VF, VFG, VG
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), GAPX, GRIDXL(10), HGAP(2), HHF(30), HHG(30),
3 IGRID(10), KCLAD(2), KFUEL(2), KGRID(10), KGRIDXL(10),
4 PP(30), RCLAD(2), RFUEL(2), SSIGMA(30), TGRID(2), UUF(30),
5 VVF(30), VVG(30), XQUAL(30), Y(30)
C
COMMON /COBRA3/ MA, MC, MG, MN, MR, MS, MX
1 $AAA, $SAAA, $SAC, $SALPHA, $SAN, $SANSWE, $SB
2 $CSCHAN, $SCD, $SCHFR, $SCON, $SCOND, $SCP, $SCL, $SC, $SDFX,
3 $DHD, $DHYD, $DHYD, $DHD, $DHD, $DHD, $DHD, $DHD, $DHD,
4 $FACTO, $FDIV, $FFINL, $FFLU, $FMULT, $FOLD, $FSP, $FSPL, $FXFL,
5 $GAP, $GAPN, $GAPS, $SH, $SHFIL, $SHLINE, $SHOLD, $SHPERI, $SIDARE,
6 $ID, $IFUEL, $IFUEL, $IFUEL, $IFUEL, $IFUEL, $IFUEL,
7 $MAC, $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR,
8 $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR,
9 $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR,
A $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR, $MCFCR,
COMMON /MCOND/ CND(22), RCP(22), RAD(22), RRDR(22),
  VM(22), VP(22), QPPP(22)

COMMON /FRDATA/ BURN, CPR, EFFB, EPSF, EXPR, FPRESS, FPUD2, FRAC, FTD,
  GMIX(4), GRGH, PGAS, RADR, RDELT, THG, THC

COMMON /LINK4/ IFRM, IHMT, IPROP, NCC, NCF, NDM1, NDS, NGP

COMMON DATA(1)

INITIALIZE ROD CONDUCTION ARRAYS
AND MAKE INITIALIZING CALL TO GAP CONDUCTANCE SUBROUTINE

GEOMETRY ARRAYS

RADR = DATA($D+1)/2.
THC = TCLAD(1)
NDM1 = NODESF
NDS = NODESF + 1
NGP = NCF + 1
DRF = 0.5 * DFUEL(1)/NCF
DRC = THC/NCC
RAD(1) = 0.0
DO 10 K = 1, NCF
  10 RAD(K+1) = K * DRF
RAD(NGP+1) = RAD(NCF+1) + THG
DO 20 K = 1, NCC
  20 RAD(NGP+1+K) = RAD(NGP+1) + K * DRC
DO 30 K = 1, NDM1
  30 CONTINUE
VM(1) = 0.0
VP(1) = DRF * DRF / 8.0
DO 40 K = 2, NDM1
  40 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))
  VM(K) = 0.5 * (RAD(K) * RAD(K) - RM * RM)
  VM(NDS) = 0.5 * (RADR * RADR - RM * RM)
  VP(NDS) = 0.0

ASSUME NO HEAT GENERATED IN GAP OR CLADDING
DO 105 K = NGP, NDM1
  105 QPPP(K) = 0.0

MATERIAL PROPERTY ARRAYS

DO 110 K = 1, NCF
  110 RCP(K) = CFUEL(1) * RFUEL(1)
CND(NGP) = HGAP(1)
RCP(NGP) = 0.0
DO 120 K=I,NCC
   CND(NGP+K)=KCLAD(1)*CCLAD(1)*RCLAD(1)
120  RCP(NGP+K)=CCLAD(1)*RCLAD(1)
C
C INITIALIZE GAP CONDUCTANCE DATA
C
IF(IPROP.LT.2)GO TO 205
CALL MPG(.TRUE.,BURN,EFFB,FRAC,D3,D4,D5,GRGH,THG,RAD(NGP),
1 D6,D7,D8,D9,D10,D11)
205 CONTINUE
RETURN
END

SUBROUTINE RTEMPF (TR,RDT,RADR,HSURF,TFLUID,NODES,NOM1)
COMMON /MCOND/ CND(22),RCP(22),RAD(22),RRDR(22),
1 VM(22),VP(22),QPPP(22)
DIMENSION A1(23),A2(22),A3(22),B(22),TR(1)
FSS=.037
FTR=1.-FSS
RDELT=RDT
C
SET UP COEFFICIENTS OF TRIDIAGONAL MATRIX
DO 100 K=2,NDM1
   A1(K)=-RRDR(K-1)*CND(K-1)
   A2(K)=-A1(K)+RRDR(K)*CND(K)+RDELT*(VP(K)*RCP(K)+VM(K)*RCP(K-1))
   B(K)=VP(K)*QPPP(K)+VM(K)*QPPP(K-1)+RDELT*(VP(K)*RCP(K)+VM(K)*RCP(K-1))
100  CONTINUE
   A1(NODES)=-RRDR(NDM1)*CND(NDM1)
   A2(NODES)=-A1(NODES)+RDELT*VM(NDM1)*RCP(NDM1) +
      + RADR*FSS*HSURF
   B(NODES) = VM(NDM1)*QPPP(NDM1) +
     + RDELT*VM(NDM1)*RCP(NDM1)*TR(NODES) +
     + RADR*HSURF*(TFLUID-FTR-TR(NODES))
   A1(NODES+1)=0.0
C
FORWARD ELIMINATION
DO 200 K=2,NODES
   A2(K)=1./A2(1)
   A3(K)=A1(K)*A2(1)
   B(1)=B(1)*A2(1)
200  CONTINUE
C
BACKWARD SUBSTITUTION
CC
TR(NODES)=B(NODES)
DO 250 K=1,NDM1
  KK = NODES-K
  250 TR(KK)=B(KK)-TR(KK+1)*A3(KK)
C
RETURN
END

SUBROUTINE RPROP(TRN,NCF,NGP,NDM1,HGAP,IPROP)
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,EPSF,EXPR,FPRESS,FPUO2,FRAC,FTD,
  1 GMIX(4),GRGH,PGAS,RADR,RDELT,THC,THG
C
DIMENSION TRN(1)
C
DO 100 K=1,NCF
  ATEMP=0.5*(TRN(K)+TRN(K+1))
  CALL MPF(ATEMP,FTD,FPUO2,RCP(K),CND(K))
100 CONTINUE
C
DO 200 K=KSTART,NDM1
  ATEMP=0.5*(TRN(K)+TRN(K+1))
  CALL MPC(ATEMP,RCP(K),CND(K))
200 CONTINUE
C
CALL 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
C
C CALCULATE GAP HEAT TRANSFER COEFFICIENT
C
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
INPUT TFUEL TEMPERATURE (DEG F)
CONVERSATIONAL MONITOR SYSTEM

FILE: COBRA3C FORTRAN A

C FTD FRACTION OF THEORETICAL DENSITY
C FP02 PLUTONIUM FRACTION BY VOLUME
C RETURN RCP HEAT CAPACITY (BTU/FT**3-DEG F)
C COND CONDUCTIVITY (BTU/SEC-FT-DEG F)
C THIS SUBROUTINE IS BASED ON EXPRESSIONS USED IN MATPRO; SEE
C TREE-NUREG-1005, APPENDIX A. THOSE EXPRESSIONS HAVE BEEN APPROXIMATED BY POLYNOMIAL FITS WHOSE MAXIMUM ERRORS ARE ABOUT ONE STANDARD DEVIATION IN EXPERIMENTAL DATA.
C RCP ERROR = 2 PER CENT 300 < TEMP < 3000 DEG K
C COND ERROR = 10 PER CENT 400 < TEMP < 2500 DEG K
C
DIMENSION RC(4), RCM(4), CN(3), CNM(3)
DATA RC/1.7869, 3.62E3, -2.61, 6.59E-4/
DATA RCM/1.8169, 3.72E3, -2.57, 6.13E-4/
DATA CN/10.8, -8.84E-3, 2.25E-6/
DATA CNM/9.68, -8.44E-3, 2.25E-6/
DATA CVTC,CVTRC/1.61E-4, 1.49E-5/

C-------------------------------
C TEM=(.5556*(TFUEL+.459.7)
IF (FP02.GT.1.E-7) GO TO 20
C U02 FUEL
C 10 RCP = FTD*( RC(1)+ TEM*(RC(2) + TEM*(RC(3) + TEM*RC(4)) )
BT = 2.74 - TEM * 5.8E-4
POR = 1. - BT*(1. - FTD)
C--THE FACTOR /(1. - BT*(1. -.95)) IS INCORPORATED IN THE FIT CN(3)
COND = POR* ( CN(1) + TEM*(CN(2) + TEM*CN(3) )
GO TO 100
C MIXED OXIDE FUEL
C 20 RCP = FTD *( (1.+0.455*FP02) *
*( RCM(1) + TEM*(RCM(2) + TEM*(RCM(3) + TEM*RCM(4)) )
BT = 2.74 - TEM * 5.8E-4
POR = FTD / (1. - BT*(1. - FTD))
C THE FACTOR (1.+BT*(1. -.96))/ .96 IS INCORPORATED IN CNM(3)
COND = POR*( CNM(1) + TEM*(CNM(2) + TEM*CNM(3) )
C 100 CONTINUE
C COND CONVERTED FROM (W/M-DEG K) TO (BTU/SEC-FT-DEG F)
COND=COND*CVTC
C RCP CONVERTED FROM (J/M**3-DEG K) TO (BTU/FT**3-DEG F)
RCP=RCP*CVTC
RETURN
END SUBROUTINE MPG (INIT, BURN, EFFB, FRAC, PRESS, CPR, EXPR, GRGM,
THG, RADFU, PG, TQ, GMIX, TF, TC, HGAP)
C 1. OPEN GAP COMPONENT, BASED ON CONDUCTIVITY OF A MIXTURE OF FOUR
**CONVERSATIONAL MONITOR SYSTEM**

Noble gases: a small gap correction is applied if PGAS > 0.

2. Contribution from partial fuel-clad contact

3. Radiation component

IF RADFU > (RADFU+THG) - ROUGH, THEN IN ADDITION TO THE ABOVE:

4. Closed gap law = CPR * (PRESS**EXPR)

Parts 1 & 2 are based on Tree-NureG-1005, Appendix C, with cracked pellet model; part 4 is user-supplied.

MPG is called with INIT = .TRUE. to perform initialization

Normal calls have INIT = .FALSE.

Arguments: INIT = .TRUE.

Input:
- Burn burnup (MWD/MTU)
- Grgh root mean square of fuel pellet and cladding
- Thg gap thickness (ft)

Return:
- Grgh if GRGH = 0 on input, a default value of 1.34E-6 feet is returned
- Effb fractional effect of burnup, used in partial fuel-clad contact model
- Frac fraction of fuel perimeter in light contact with clad

Arguments: INIT = .FALSE. (Normal entry)

Input:
- Frac fraction of fuel perimeter touching clad
- Press pressure of fuel against clad for closed gap
- Cpr coefficient of press
- Expr exponent of press
- Grgh RMS of fuel and clad GRGH nesses (ft)
- Thg gap thickness (ft)
- Pg pressure of gas mixture in gap, for small gap correction factor (PSIA)
- Tg temperature of gas mixture in gap (DEG F)
- Gmix four mole fractions of noble gases

1. Helium
2. Argon
3. Krypton
4. Zenon

The four elements of GMIX must sum to 1

TF temperature of fuel pellet surface (DEG F)

TC temperature of inner clad surface (DEG F)

Return:
- Hgap gap heat transfer coefficient (BTU/FT**3-DEG F)

Logical INIT

Dimension GMIX(4)

Dimension AM(4,4), BM(4,4)

Combining factors which are functions only of the molecular weights of the four noble gases

<table>
<thead>
<tr>
<th>DATA AM</th>
<th>0.</th>
<th>.295, .232, .194,</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>.362, 0., .309, .332,</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.413, .235, 0., .286,</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>.435, .260, .232, 0.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DATA BM</th>
<th>0., 1.78, 2.14, 2.39,</th>
</tr>
</thead>
</table>

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DIMENSION CC(4), EE(4), CON(4), CSR(4)
DATA EE / .668, .701, .872, .923 /

CC CONVERT TO DGAP(M)
DGAP = THG*.3048

CC TEMPERATURES CONVERTED FROM (DEG F) TO (DEG K)
TCLAD=.5556*(TC+459.67)
TGAS=.5556*(TG+459.67)
TFUEL=.5556*(TF+459.67)

CC CONVERT TO PGAS(N/M**2)
PGAS=PGr*.693E3

CC CONVERT TO ROUGH(M)
ROUGH=GRGi*.3048

IF (INIT) GO TO 200

C NOBLE GAS CONDUCTIVITIES
CON(1) = 0.
DO 10 I = 1, 4
IF (GMIX(I).LT.1.E-6) GO TO 10
CON(I) = CC(I)*TGAS**EE(I)
CSR(I) = SQRT(CON(I))
10 CONTINUE

C SMALL GAP CORRECTION FOR HELIUM:
GAP = AMAX1(ROUGH, DGAP)
FAC = PGAS / GAP
IF (FAC.LT.1.E-9) GO TO 15
CON(1) = CON(1) / (1.+ CON(1)*.2103*SQRT(TGAS)/FAC)
CSR(1) = SQRT(CON(1))
15 CONTINUE

C MIXTURE CONDUCTIVITY
GCOND = 0.
DO 30 I = 1, 4
IF (GMIX(I).LT.1.E-6) GO TO 30
XSUM = GMIX(I)
DO 20 J = 1, 4
IF (J.EQ.I) GO TO 20
IF (GMIX(J).LT.1.E-6) GO TO 20
TS = CSR(J) + CSR(I)*BM(I,J)
XSUM = XSUM + GMIX(j)*AM(I,J)*TS*TS/CON(J)
20 CONTINUE
GCOND = GCOND + CON(I)*GMIX(I)/XSUM
30 CONTINUE

HGAP = GCOND / (DGAP + ROUGH)
FILE: COBRA3C FORTRAN A

C CONVERSATIONAL MONITOR SYSTEM

C PARTIAL FUEL-CLAD CONTACT MODEL
C
HGAP = (1.-FRAC)*HGAP + FRAC*GCOND/ROUGH
C
C RADIATION HEAT TRANSFER CONTRIBUTION
C
REMISF = AMAX1(1.1485, AMIN1(2.451, -.154+TFUEL*1.3025E-3 ))
REMISC = 1.33
RFVIEW = REMISF + (REMISC-1.)*RADFU/(RADFU+THG)
C
HGAP = HGAP + 5.279E-8*(TFUEL+TCLAD)*(TFUEL*TFUEL+TCLAD*TCLAD)/RFVIEW

C CONVERT HGAP FROM (W/M**2-DEG K)) TO (BTU/SEC-FT**2-DEG F)
HGAP=HGAP*4.89E-5

C CLOSED GAP CONTACT HEAT TRANSFER
C
IF (DGAP .GE. ROUGH) RETURN
HGAP = HGAP + CPR * (PRESS **EXPR)
RETURN

C INITIALIZATION OF MPG, CALLED ONLY ONCE
C
200 IF (GRGH.LE.O.) GRGH = 1.34E-6
C
C FRACTION OF FUEL IN LIGHT CONTACT WITH CLAD, A FUNCTION OF BURNUP
C
C--FRACTIONAL EFFECT OF BURNUP, INDEPENDENT OF FUEL RADIUS
IF (BURN=600.) 210,210,220
210   EFFB = 0.
   GO TO 230
220   CONTINUE
   TS = .001*BURN - .6
   TS = TS+TS
   EFFB = 1. - 1./(TS+TS + 1.)
230   CONTINUE
C
C--FRACTION OF CIRCUMFERENCE OF FUEL IN LIGHT CONTACT WITH CLAD
A1 = 100. - 98.*EFFB
A2 = 4. - .5*EFFB
FRAC = 1./ (A1*(100.*DGAP/RADFU)**A2 + 1.42857) + .3
RETURN
END
SUBROUTINE MPC (TCL, RCP, COND)
C
C CALCULATES HEAT CAPACITY AND CONDUCTIVITY OF ZIRCALOY AS A FUNCTION
C OF TEMPERATURE
C
C ARGUMENTS
C
INPUT TCL TEMPERATURE (DEG F)
C RETURN RCP HEAT CAPACITY (BTU/FT**3-DEG F)
CONDUCTIVITY (BTU/SEC-FT-DEG F)

DIMENSION CN(4)
DATA CN /7.51, 2.09E-2, -1.45E-5, 7.67E-9 /

HEAT CAPACITY

TEMP=.5556*(TCL+459.67)
IF (TEMP.GT.1090.) GO TO 20
RCP = 1673456. + TEM * 721.6
GO TO 50

20 IF (TEMP.GE.1254.) GO TO 30
RCP = 5346400. - 36080.*ABS(TEM-1170.)
GO TO 50

30 RCP = 2315680.

50 CONTINUE

COND = CN(1)+ TEM*(CN(2)+ TEM*(CN(3)+ TEM*CN(4)))

CONVERT FROM (J/M**3-DEG K) TO (BTU/FT**3-DEG F)
RCP = RCP*CVTRC
RETURN

SUBROUTINE HTCOR(IHTR,QV,QL,HVFC,HLNB,HLFC,TW,TL,TV,P,ALP,X,ROV,ROL,VV,VL,HD,IHTM,CHFR,TSAT,FLUX,NCHF,NN,IIJ,1)

THIS ROUTINE COMPUTES HEAT TRANSFER COEFFICIENTS AND/OR HEAT FLUXES

THE TOTAL HEAT FLUX IS ASSUMED TO BE OF THE FORM:
Q=QV+QL+HVFC(TW-TV)+HLNB(TW-TSAT)+HLFC(TW-TL)

NORMALLY QV AND QL WILL BE ZERO AND ONE OR MORE OF THE HEAT TRANSFER COEFFICIENTS HVFC, HLB, AND HLFC WILL BE NON-ZERO.

IN TRANSITION BOILING, HOWEVER, THE HEAT TRANSFER COEFFICIENTS ARE ZERO AND Q=QV+QL.

NOMENCLATURE:
FILE: COBRA3C FORTRAN A

CONVERSATIONAL MONITOR SYSTEM

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 ALO VAPOR DENSITY (KG/M**3)
C ADL 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 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 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,DTSDF,DELP,DEVDP,DELT,DEVDT,
2 DRLDP,DRLDP,DRDLP,DRVT
C COMMON/CHFSV/CHSAVE(20,20,31)
C DATA GCON/9.8066/
C HVFC=0.0
C HLFC=0.0
C HLN=0.0
C CHFR=1.0
C QV=0.0
C QL=0.0
C IHR=0
C VVA=ABS(VV)
C VLA=ABS(VL)
C RHD=1./HD
C 
C PROPERTIES CALCULATED ONCE EACH TIME STEP AND SAVED
C 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 PROPERTIES OBTAINED FROM STATE AT SATURATION TEMP. CORRESP.
C TO PRESSURE P.
C
TSAT1 = 9.0395*POW(P, .223E0) + 255.2
CALL STATE(P, TSAT1, TSAT1, ROVS, ROLS, EV, EL, TSAT, DTSAT, DELDP,
1 DEVDP, DELDT, DEVDT, DRDLP, DRVDP, DRDPT, DRVDT, 2, IERR)
SPVV = 1./ROVS
SPVL = 1./ROLS
HFG = EV+P*SPVV -EL-P*SPVL
BETAV = -DRDVT*SPVV
BETAL = -DRDPT*SPVL
CPV = DEVDT -P*DRDVT*SPVV*SPVV
CPL = DELDT -P*DRDPT*SPVL*SPVL
4 CONTINUE
VISV = VISVP(TV)
VISL = VISLP(TL)
CNDV = CONDV(P, TV)
CNDL = CONDL(P, TL)
SIG = SURTT(TL)
GV = ALP*ROV*VVA
GL = (1.-ALP)*ROL*VLA
G = GV + GL
10 CONTINUE
C
... DETERMINE HEAT TRANSFER REGIME ...
C
TEST QUALITY
C
IF(X.GE.0.99)GO TO 300
C
TEST FOR COLD WALL
C
IF(TW.LE.TSAT)GO TO 200
C
IF(IHTM.LT.2)GO TO 30
C
COMPUTE MINIMUM STABLE FILM BOILING TEMPERATURE
C
IF (P.GT.68.96E5) GO TO 20
THN = 581.5 + .01876*SQRT( AMAX1(P-1.0345E5,(0.)) )
GO TO 25
20 THN = 630.37 + .00432*SQRT(P-68.96E5)
25 CONTINUE
PSI=0.0
IF (P.LT.4.827E5) PSI = 127.3 - 26.37E-5*P
CALL MPC(TW, RCP, COND)
C
RRKCPW = 1./(RCP*COND)
C
INVERSE OF RCP OF ZIRCALOY TIMES CONDUCTIVITY OF OXIDE
RRKCPW = 3.1E-7 - 1.3E-10*TW
RKCPL=ROL*CNDL*CPL
C
TMSFB = THN + (THN-TL)*POW(RKCPL*RRKCPW,.5E0) - PSI
C
TEST WHETHER TWALL EXCEEDS TMSFB
C
IF(TW.LT.TMSFB)GO TO 30

C COMPUTE FILM BOILING HEAT TRANSFER COEFFICIENT

CALL FILM(HVFC,ALP,ROV,ROL,VVA,VLA,HD,RHD,TL,TW,TSAT,HFG,1 CPV,CPL,P,VISV,VISL,BETAV,SIG,IMTR,X)
GO TO 1000

C 30 CONTINUE

C DETERMINE HEAT TRANSFER COEFFICIENTS USING CHEN CORRELATION

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,.8EO) *POW(PRL,.4EO)
RETP = REL*POW(F,1.25EO)*1.E-4
S=.1
IF(RETP.LT.70.O.AND.RETP.GE.32.5) S=1./(1.+.42*POW(RETP,.78EO))
IF(RETP.LT.32.5) S=1./(1.+.12*POW(RETP,1.14EO))
HS = .00126*SQRT(CNDL*CPL/(SIG*GCON)) *POW(PRL,-.29EO) *POW(ROL,.25EO) *POW(CPL*ROL/(HFG*ROV),.24EO)
RETP = REL*POW(F,1.25EO)*1.E-4
S=.1
IF(RETP.LT.70.O.AND.RETP.GE.32.5) S=1./(1.+.42*POW(RETP,.78EO))
IF(RETP.LT.32.5) S=1./(1.+.12*POW(RETP,1.14EO))

32 PRL = VISL*CPL/CNDL
REL = GX*HD*RVISL
HLF = .023*F*CNDL*RHD*POW(REL,.8EO) *POW(PRL,.4EO)
RETP = REL*POW(F,1.25EO)*1.E-4
S=.1
IF(RETP.LT.70.O.AND.RETP.GE.32.5) S=1./(1.+.42*POW(RETP,.78EO))
IF(RETP.LT.32.5) S=1./(1.+.12*POW(RETP,1.14EO))

QCHEN = HLF*(TW-TL) + HLN*(TW-TSAT)
IF(IHTM.LT.2) GO TO 400

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
CHSAVE(NN,II,JJ)=QCHF/CVTHF

IF(QCHEN.LE.QCHF) GO TO 400
FILE: COBRA3C FORTRAN A

CONVERSATIONAL MONITOR SYSTEM

PAGE 140

C SOLVE THE EQUATION
C HLFC*(TCHF-TL) + HLNBT*(TCHF-TSAT)**1.24*(PWALL-P)**.75 = QCHF
C FOR TCHF USING NEWTON'S ITERATION
C
   TCHF=AMAX1(TL,TSAT+.1)
   DO 35 K=1,10
   TCS=AMAX1(TCHF-TSAT,(0.))
   PWALL=(.1162558+(TCHF-255.2))**4,4843049
   DQ=QCHF-HLFC*(TCHF-TL)-HS*POW(TCS,1.24E0)*POW(PWALL-P,.75E0)
   DQDT=HLF + HS*POW(TCS,.24E0)*POW(PWALL-P,.75E0) *
   (1.24 + 3.3632287*TCS*POW((TCHF-255.2),(PWALL-P)))
   DTCHF = DQ/DQDT
   TCHF = TCHF + DTCHF
   IF(ABS(DTCHF).LE.0.1) GO TO 40
35 CONTINUE
   GO TO 500
C 35 CONTINUE
C
   ... INDIVIDUAL CORRELATIONS FOLLOW ...
C
C CONVECTION TO SINGLE PHASE LIQUID
C MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS
C
C NOTE: MCADAMS SHOULD EVALUATE PROPERTIES AT A LIQUID FILM TEMP
C
   200 CONTINUE
   T1=ROL*ROL*GCON*BETA+CPV*ABS(TW-TL)/(VISL*CNVL)
   HMA=.13*CNVL*POW(T1,.333333E0)
   REL=ROL*VLA*HD/VISL
   PRL=VISL*CPV/CNVL
   VISW=VISLQ(TW)
   HST=.023*CNVL*RHD*POW(REL,.8E0)*POW(PRL,.33E0)*
   1*POW(VISL/VISW,.14E0)
   HLFC=AMAX1(HMA,HST)
   CHFR=.000.0
   IHTR=1
   IF(HMA.GT.HST) IHTR=2
   GO TO 1000
C
C CONVECTION TO SINGLE PHASE VAPOR
C MAX OF SIEDER-TATE AND MCADAMS CORRELATIONS
C
C NOTE: MCADAMS SHOULD EVALUATE PROPERTIES AT A VAPOR FILM TEMP
C
   300 CONTINUE
   T1=ROV*ROV*GCON*BETA+CPV*ABS(TW-TV)/(VISV*CNVD)
   HMA=.13*CNVD*POW(T1,.333333E0)
   REV=ROV*VVA*HD/VISV
   PRV=VISV*CPV/CNVD
   VISW=VISVP(TW)
   HST=.023*CNVD*RHD*POW(REV,.8E0)*POW(PRV,.33E0)*
   1*POW(VISV/VISW,.14E0)
   HVFC=AMAX1(HMA,HST)
   IHTR=9
IF(HMA.GT.HST) IHTR = 10
GO TO 1000
C
C SUBCOOLED OR SATURATED NUCLEATE BOILING
C
400 CONTINUE
IHTR = 4
C
IF(TL.LT.TSAT) IHTR = 3
GO TO 1000
C
C TRANSITION BOILING
C
500 CONTINUE
CALL FILM(HVTB,ALP,ROV,ROL,VVA,VLA,HL,HD,RH,TL,TV,TMSF,TSAT,HFG,
1 CPV,CPL,P,VIS,VI,SBETAV,SIG,IHTR,X)
RDTMC = 1./(TMSF-TCHF)
EPS = (TMSF-TW)*RDTMC
EPS2 = EPS*EPS
QMSF = HVTB*(TMSF-TV)
QV = (1.-EPS2)*QMSF
QL = EPS2*QCHF
DQDLTW = -2.*EPS*QCHF*RDTMC
DQVDW = 2.*EPS*QMSF*RDTMC
HLFC = DQDLTW
HLVC = DQVDW
QL = QL + DQDLTW*(TL-TW)
HVFC = DQVDW
QV = QV + DQVDW*(TV-TW)
IHTR = 5
C
1000 CONTINUE
RETURN
2000 WRITE(I3,2020)
2020 FORMAT(1H
ERROR DETECTED IN SUBROUTINE HTCOR. ATTEMPT TO USE',
1 'NCHF=5 OPTION FOR TOO LARGE A PROBLEM. ')
END

NOTE: IN BROMLEY'S AND MCDAMS' CORRELATIONS VAPOR PROPERTIES
ARE EVALUATED AT BULK VAPOR TEMPERATURE AND NOT
AT VAPOR FILM TEMPERATURE.
IN GROENEVELD'S CORRELATION THE VAPOR PRANDTL NUMBER
IS EVALUATED AT BULK VAPOR TEMPERATURE AND NOT
AT WALL TEMPERATURE.

HIGH FLOW FILM BOILING
GROENEVELD 5.7 OR MODIFIED DITTUS-BOELTER (FOR LOW PRESSURE)
CNDV = COND(P,T)
REV = HD+ROV+(VLA+ALP+(VVA-VLA))/VISV
PRV = VISV*CPV/CNDV
IF(PLT.1.33E0) GO TO 10
Y = 1.-1*POW((1.-X)*1.3E0)
HGDB = .052*CONV*REV*POW(REV,.68800)*POW(PRIV,1.26E0)*
1 POW(Y,-1.06E0)
IHTR = 6
GO TO 20
HGDB = .023*CONV*REV*POW(REV,.80000)*POW(PRIV,0.40000)
IHTR = 7
20 CONTINUE
H = HGDB
C
TEST FOR LOW OR HIGH FLOW
C
AJG = ALP*ROV+VVA/SQRT(GCON+HD+ROV+(ROL-ROV))
AJF = (1.-ALP)*ROL+VLA/SQRT(GCON+HD+ROL+(ROL-ROV))
AJ = SQRT(AJG)+SQRT(AJF)
IF(AJ,GE.2.0) RETURN
C
LOW FLOW FILM BOILING
C
BROMLEY PLUS MAX OF MCADAMS AND FORCED CONVECTION (AS FOR HIGH FLOW)
C
CLAM = PI2*SQRT(SIG/(ROL-ROV))
HFGP = HFGP+.5*CPV*(TW-TSAT)
T1 = GCON+(ROL-ROV)*ROV+(CNDV*3)+HFGP/(CLAM*VISV*(TW-TSAT))
HMB = .62*POW(T1,25E0)
C
T1 = ROV*ROV+GCON+BEAT*CPV*ABS(TW-TV)/(VISV*CNDV)
HMA = .13*CNDV*POW(T1,33333E0)
C
H = .1.-ALP)*HMB + ALP*AMAX1(HGDB,HMA)
IHTR = 8
C
RETURN
C
END
SUBROUTINE CHF5(QCHF,ALP,ROV,ROL,G,P,X,HD,HFG,SIG)
C
DETERMINES CRITICAL HEAT FLUX
C
DATA GCON/9.8066/
DATA EE /2.7182818/
DATA PBAR=1.0E-5*P
GHI=1350.0
GLO=27.0
IF(PBAR,GE.83.0,AND,X,GE.0.5)GHI=270.0
IF(X,LT,GLO)GO TO 20
C
BIAS CORRELATION FOR HIGH FLOW
C
EN=-0.4
IF(HD,LT.0.01)EN=-0.6
C
PAGE 142
GT=A MAX1 (G, GHI)
Q10=0.0
IF (GT.LT.300.0) GO TO 10
F=.7249 + .099*PBAR*POW(EE,-(.032)*PBAR)
G6=POW(GT,(-166667))
Q10=2.76Q10
10 CONTINUE
H=1.159 + .149*PBAR*POW(EE,-.01960*PBAR) + 0.99*PBAR/
1 (10.0+PBAR*PBAR)
Q11=15.0487*H*POW(100.0+HD,EN)*POW(GT,(-.6))*(1.0-X)
QB=A MAX1 (Q10, Q11)
QCHF=QB
C
IF (G.GT.GHI) GO TO 100
20 CONTINUE
C
CHF=VOID CORRELATION FOR LOW FLOW
C
T1=SIG*GCON*GCON*(ROL-ROV)*ROV*ROV
QVC=.0178*(1.-ALP)*HFG*POW(T1,(.25))
QCHF=QVC
C
IF (G.LE.GLO) GO TO 100
C
LINEAR INTERPOLATION BETWEEN BIASI AND CHF=VOID
C
WT=(G-GLO)/(GHI-GLO)
QCHF=WT*QB+(1.-WT)*QVC
C
100 CONTINUE
RETURN
END
FUNCTION POW(A,B)
POW=A**B
RETURN
END
FUNCTION CONDL (P, TL)
C
THERMAL CONDUCTIVITY OF LIQUID WATER
W/M DEG K FUNCTION OF PASCAL, DEG K
C
ERROR OF APPROXIMATION < 5 PERCENT FOR 273 < TL < 573 DEG K
VALUE AT 150 BAR, 300 DEG C = .55
C
TS = TL - 415.
CONDL = .686 - 5.87E-6*TS*TS + 7.3E-10*P
RETURN
END
FUNCTION CONDV (P, TV)
C THERMAL CONDUCTIVITY OF DRY STEAM W/M DEG K FUNCTION OF PASCAL, DEG K
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 VISCOSITY OF SATURATED LIQUID WATER KG/M SEC FUNCTION OF DEG K
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 / (-8.5BE4 + TL*(91.+ TL))
RETURN
END
FUNCTION VISNP (TV)
C VISCOSITY OF SATURATED STEAM KG/M SEC FUNCTION OF DEG K
C ERROR OF APPROXIMATION = 3 PERCENT FOR 373 < TV < 623 DEG 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
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)
SURFACE TENSION OF LIQUID WATER

\[ \text{SurTT} = \frac{80.72 - \text{TL} \times 0.126}{5140 + \text{TL}} \]

IF(SurTT < 0.0) SurTT = 0.0

RETURN

END
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
.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
62. .48315.82118.394.08
1 1 1.
33. 1. 10.
1 1 1.
62. .48315.82118.394.08
33. 1. 9.0
33. 1. 9.0
2
.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
0526.6 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 \[\text{first card}\]

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 1.601 .640 .67 .61 .660 .701 .680 .751 .590 .801 .500 .851 .275 .901 .650 .96 .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.
1.105.46051.015 1 1 1 1.
1.105.46051.015 1 1 1 1.
1.105.46051.015 1 1 1 1.
1.105.46051.015 1 1 1 1.
8 8 8 8 8 8
1 1 1 1.
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 .2564 8 .7692
1 2 .441.475 1 .2564 2 .2564 8 .5128
1 3 .441.475 2 .3089 8 .7166
1 4 .441.475 1 .2564 3 .2867 7 .2564 8 .2564
1 5 .441.611 1 .2442 2 .2942 3 .2730
1 6 .441.475 3 .2867 5 .2564 7 .2564 8 .2564
1 7 .441.475 3 .2867 4 .2039 5 .2564 6 .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 .449.495 9 4716.
1 15 .441.711 4 .1934
1.5 0.08 650.3675 8.8 0.078 410. .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  546.2292200.
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
INPUT FOR CASE 1 BWR TURBINE TRIP W/O BYPASS NEW FUEL ROD MODEL

SIMILAR CHANNELS ALL SEPARATED EG. BWR

DATE 9/24/80 TIME 14:46:31
COBRA INPUT DATA

NB. DATA READ FROM CARD20 WOULD BE READ OR SET WITH THE NEUTRONICS DATA IN MEKIN

CARD IMAGES

---

IMAP ND1X ND2X
NAX AFLUX
AXIAL HEAT FLUX
RADIAL POWERS
Z NDX NDT TTME
INDICATORS
EPSF
CHANNEL DATA, TYPE 1
GRID DATA, TYPE 1
CHANNEL DATA, TYPE 2
GRID DATA, TYPE 2
CHANNELS OF TYPE 2
GRID POSITIONS
FUEL THERMAL DATA
NCF, NCC, THG
FTD, FPU02
HYDRAULIC MODEL INDICATORS
TWO-PHASE FRICTION (J4)
VOID FRACTION (J2, J3)
INLET FLOW DIVISION (IG)
CONSTANTS
IN MT OR T IN GIN PEXIT
TRANS INDIC FOR P W G Q
PRESSURE TRANSIENT
INLET FLOW TRANSIENT
INLET POWER TRANSIENT
KDEBUG
PRINTING

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
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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

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CHANNEL, ROD AND GRID DATA

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CHANNEL DATA

*CHANNEL NUMBERING MAP
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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

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

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 PU02 = 0.0
(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

\[ F = A*(R**B) + C \]

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

\[ J_4 = 2 \]

(J4=0 HOMOGENEOUS, =1 ARMAND, =2 BAROCZY, =5 POLYNOMIAL IN QUALITY)

(4) VOID FRACTION

\[ J_2 = 1 \]

(J2=0 NO SUBCOOLED VOID, =1 LEVY MODEL)
\[ J_3 = 2 \]

(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 = 1.0000E-03

(8) COUPLING PARAMETER FOR THE MIXING TERM
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- **Mass Flow Out**: 0.67137E+02 LB/SEC
- **Mass Flow Error**: 0.0 LB/SEC

### Energy Balance
- **Flow Energy In**: 0.35489E+05 BTU/SEC
- **Energy Added**: 0.82320E+04 BTU/SEC
- **Flow Energy Out**: 0.45523E+05 BTU/SEC
- **Energy Error**: 0.18027E+04 BTU/SEC

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**NEW FUEL ROD MODEL**  
**DATE 9/24/80**  
**TIME 14:46:34**

**TIME = 0.0 SECONDS**  
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ITERATIONS = 3
## CHANNEL RESULTS

**CASE 1**  BWR TURBINE TRIP W/O BYPASS  NEW FUEL ROD MODEL

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**TIME** = 2.50000 SECONDS  **DATA FOR CHANNEL 1**

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### Case 1: BWR Turbine Trip W/O BYPASS New Fuel Rod Model

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**Iterations:** 2
References


14. Weisman, J., "Revision of COBRA-IIIC/MIT for Proper Handling of Problems with Channels of Widely Varying Size," Informal memo provided by members of steering committee for MIT COBRA-IIIC/MIT project at July 1979 project meeting.


30. Shoreham Nuclear Power Station, Unit 1 FSAR, 1976.


