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SCDAP/RELAP5/MOD 3.1 Code Manual

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User's Guide and Input Manual

Edited by
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Prepared for
U.S. Nuclear Regulatory Commission

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SCDAP/RELAP5/MOD 3.1 Code Manual

User's Guide and Input Manual

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ABSTRACT

The SCDAP/RELAP5 code has been developed for best estimate transient simulation of light water reactor coolant systems during a severe accident. The code models the coupled behavior of the reactor coolant system, core, fission product released during a severe accident transient as well as large and small break loss of coolant accidents, operational transients such as anticipated transient without SCRAM, loss of offsite power, loss of feedwater, and loss of flow. A generic modeling approach is used that permits as much of a particular system to be modeled as necessary. Control system and secondary system components are included to permit modeling of plant controls, turbines, condensers, and secondary feedwater conditioning systems.

This volume provides guidelines to code users based upon lessons learned during the developmental assessment process. A description of problem control and the installation process is included. Appendix A contains the description of the input requirements.

FIN W6095-SCDAP/RELAP5 CODE IMPROVEMENT AND ASSESSMENT

EXECUTIVE SUMMARY

The specific features of SCDAP/RELAP5/MOD3.1 are described in this five volume set of manuals covering the theory, use, and assessment of the code for severe applications. This set replaces the SCDAP/RELAP5/MOD3 Code Manual, NUREG/CR-5273.

The SCDAP/RELAP5 computer code is designed to describe the overall reactor coolant system (RCS) thermal-hydraulic response, core damage progression, and in combination with VICTORIA^a, fission product release and transport during severe accidents. The code is being developed at the Idaho National Engineering Laboratory (INEL) under the primary sponsorship of the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission (NRC).

The code is the result of merging the RELAP5/MOD3^b and SCDAP models. The RELAP5 models calculate the overall RCS thermal hydraulics, control system interactions, reactor kinetics, and the transport of noncondensable gases. Although previous versions of the code have included the analysis of fission product transport and deposition behavior using models derived from TRAP-MELT, this capability is being replaced through a data link to the detailed fission product code, VICTORIA, as a result of an effort to reduce duplicative model development and assessment.

The SCDAP code models the core behavior during a severe accident. Treatment of the core includes fuel rod heatup, ballooning and rupture, fission product release, rapid oxidation, zircaloy melting, UO₂ dissolution, ZrO₂ breach, flow and freezing of molten fuel and cladding, and debris formation and behavior. The code also models control rod and flow shroud behavior.

The development of the current version of the code was started in the spring of 1992. This version contains a number of significant improvements to the SCDAP models since the last versions of the code, SCDAP/RELAP5/MOD2.5 and SCDAP/RELAP5/MOD3[7af], were released. These improvements include the addition of several new models to describe the earlier phases of a severe accident, changes in the late phase models to provide more "physically intuitive" behavior for full plant calculations, and changes to improve the overall reliability and usability of the code. The improvements in the early phase models include the addition of models to treat (a) the effects of grid spacers including the effects of Inconel spacer grid-zircaloy cladding material interactions, (b) BWR B₄C control blade-zircaloy channel box material interactions, and (c) accelerated heating, melting, and hydrogen generation during the reflood of damaged fuel rods. An extension to the molten pool models to treat the sporadic growth of the boundaries of the molten pool into adjacent regions of relatively intact assemblies or rubble debris beds is the most significant change to the late phase models. Improvements in overall reliability and usability of the code for plant calculations include changes in the overall code numerics to reduce the likelihood of numerical instabilities or code failures and changes in the codes input/output processors. The most noticeable of these for the code users is the conversion of the SCDAP input to a form more compatible with the RELAP5 style. In addition to these modeling and coding changes, SCDAP/RELAP5/MOD3.1 has also been subjected to (a) an intensive effort of verification testing to identify and resolve outstanding code errors and

a. T. Heames et al., *VICTORIA: A Mechanistic Model of Radionuclide Behavior in the Reactor Coolant System Under Severe Accident Conditions*, NUREG/CR-5545, SAND90-0756, Rev. 1, December 1992.

b. C. M. Allison, C. S. Miller, N. L. Wade (Eds.) *RELAP5/MOD3 Code Manual*, Volumes I through IV, NUREG/CR-5535, EGG-2596, June 1990.

(b) a systematic assessment of the code to quantify the uncertainties in the predicted results.

The RELAP5 code is based on a nonhomogeneous and nonequilibrium model for the two-phase system that is solved by a fast, partially implicit numerical scheme to permit economical calculation of system transients. The objective the RELAP5 development effort from the outset was to produce a code that includes important first order effects necessary for accurate prediction of system transients but is sufficiently simple and cost effective such that parametric or sensitivity studies are possible. The development of SCDAP/RELAP5 has this same focus.

The code includes many generic component models from which general systems can be simulated. The component models include fuel rods, control rods, pumps, valves, pipes, heat structures, reactor point kinetics, electric heaters, jet pumps, turbines, separators, accumulators, and control system components. In addition, special process models are included for effects such as form loss, flow at an abrupt area change, branching, choked flow, boron tracking, and noncondensable gas transport.

This volume, Volume III, gives detailed descriptions of the input preparation and execution procedures. It also provides code installation procedures, as well as general guidelines on code applications.

ACKNOWLEDGMENTS

Development of a complex computer code such as SCDAP/RELAP5 is the result of a team effort. Acknowledgments are made to those who made significant contributions to the earlier versions of SCDAP/RELAP5 in particular for the contributions of G. H. Beers, E. R. Carlson, and T. M. Howe. Acknowledgment is also made of E. C. Johnsen for her work in code configuration control, to B. D. Reagan for her support in preparing figures and correcting equations, and to L. G. Price and N. Wade for technical editing support. The authors also acknowledge the RELAP5 development team, specifically R. J. Wagner, R. A. Riemke, and C. S. Miller for their contributions to SCDAP/RELAP5.

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CONTENTS

	ABSTRACT	iii
	EXECUTIVE SUMMARY	v
	ACKNOWLEDGMENTS	vii
1.	INTRODUCTION	1-1
1.1	General Code Capabilities	1-1
1.2	Relationship to Other NRC-Sponsored Software	1-2
1.3	Quality Assurance	1-3
1.4	Organization of the SCDAP/RELAP5 Manuals	1-3
1.5	Organization of Volume III	1-3
2.	CORE STRUCTURES	2-1
2.1	Fuel Rod	2-1
2.2	Ag-In-Cd Control Rod	2-1
2.3	Flow Shroud	2-1
2.4	Simulator Rod	2-2
2.5	BWR Control Blade/Channel Box Model	2-2
2.6	B4C Control Rod Model	2-2
3.	SCDAP/RELAP5 USER GUIDELINES	3-1
3.1	SCDAP/RELAP5 Card Number Input	3-1
3.2	Input Preparation	3-2
3.2.1	Input Deck Arrangement	3-2
3.2.2	Model Input Debugging	3-2
3.3	Problem Execution	3-3
3.3.1	Time Step and Edit Selections	3-4
3.4	Plot Variables	3-4
3.5	Guidelines for Late Phase Damage Progression	3-5
3.6	Code Diagnostics	3-6
3.7	Steam Starvation Limits	3-7
3.8	Nested Radiation Enclosures	3-8
3.9	Cold Wall Effects on Core Damage Progression	3-8
3.9.1	Noncondensable Model	3-9
3.10	BWR CHANNEL BOX USER GUIDE	3-10
3.10.1	BWR Blade/Box Cards	3-10
3.10.2	Radiation Enclosure Cards	3-13
3.10.3	Minor Edit Requests	3-15
4.	NODALIZATION GUIDELINES	4-1
4.2	Ex-vessel Example Nodalizations	4-1
4.2.1	Ex-Vessel Hydrodynamic Cell Size	4-2
4.2.2	Steam Generator Primary Nodalization	4-3
4.2.2.1	U-Tube Steam Generator Nodalization	4-3
4.2.2.2	Once-Through Steam Generators	4-3
4.2.3	Steam Generator Secondaries	4-6
4.2.4	Primary Coolant Pump	4-8
4.2.5	Pressurizer	4-9
4.3	Break Nodalization	4-9

	4.3.1	LOCA Modeling	4-9
	4.3.2	Surge Line Modelling	4-13
5.		PROBLEM CONTROL	5-1
	5.1	Problem Types and Options	5-1
	5.2	Time Step Control	5-1
	5.3	Printed Output	5-3
	5.3.1	Input Editing	5-3
	5.3.2	Major Edits	5-4
	5.3.3	Cladding Oxidation and Rupture Information	5-4
	5.3.4	Minor Edits	5-4
	5.4	Edits of SCDAP Heat Structures	5-5
	5.4.1	Temperature Distribution	5-5
	5.4.2	Cladding Radius	5-5
	5.4.3	Cladding Oxidation	5-5
	5.4.4	Meltdown	5-5
	5.4.5	Fission Product and Aerosol Release	5-6
	5.4.6	Cladding Ballooning and Rupture	5-7
	5.4.7	Fuel Rod Power	5-7
	5.5	Edits of Fission Product Transport Results	5-7
	5.6	SCDAP/RELAP5 Control Card Requirements	5-8
	5.6.1	Transient Termination	5-8
	5.6.2	Problem Changes at Restart	5-8
6.		INSTALLATION	6-1
	6.1	Transmittal Contents	6-1
	6.2	Machine and Operating System Considerations	6-1
	6.3	Transmittal Tape Files	6-2
	6.4	Upper and Lower Case Considerations	6-3
	6.5	Installation Procedures	6-4
	6.5.1	Make Based Installation	6-4
	6.5.2	Installation Problems	6-6
	6.5.2.1	C Language Difficulties	6-6
	6.6	Utility Routines	6-7
	6.6.1	Update Program	6-7
	6.7	Select Program	6-8
	6.8	Usplit Utility	6-8
	6.9	CNV32 Program	6-8
	6.10	Compilation of Usplit.f, Select.f, and CNV32.f	6-9
	6.11	Recompilation of Specific Routines	6-9
	6.12	Make Utility	6-10
	6.13	Define Options Used in SCDAP/RELAP5	6-11
	6.14	Installation Scripts	6-13
7.		REFERENCES	7-1

Figure 3-1.	BWR control blade and channel box dimensions specified by the user.	3-12
Figure 3-2.	Example arrangement of fuel rod components.	3-13
Figure 3-3.	Radial node numbers used to print BWR blad/box temperatures at minor edits.	3-17
Figure 3-4.	Locations of intact blade/box and frozen crust thickness variables.....	3-19
Figure 4-1.	Nodalization of primary coolant loops (Loop C shown).	4-4
Figure 4-2.	Example of Once-Through Steam Generator (OTSG) nodalization.	4-5
Figure 4-3.	Nodalization of secondary side of steam generators.	4-7
Figure 4-4.	Nodalization of pressurizer.....	4-10
Figure 4-5.	Coolant system break modeling.....	4-11

SCDAP/RELAP5/MOD3.1^a Code Manual

Volume III: SCDAP/RELAP5 User's Guide and Input Manual

1. INTRODUCTION

The SCDAP/RELAP5 computer code is designed to describe the overall reactor coolant system (RCS) thermal-hydraulic response, core damage progression, and, in combination with VICTORIA,¹ fission product release and transport during severe accidents. The code is being developed at the Idaho National Engineering Laboratory (INEL) under the primary sponsorship of the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission (NRC).

1.1 General Code Capabilities

The code is the result of merging the RELAP5/MOD3² and SCDAP³ models. The RELAP5 models calculate the overall RCS thermal hydraulics, control system interactions, reactor kinetics, and transport of noncondensable gases. Although previous versions of the code have included the analysis of fission product transport and deposition behavior using models derived from TRAP-MELT, this capability is being replaced through a data link to the detailed fission product code, VICTORIA, as a result of an effort to reduce duplicative model development and assessment. The SCDAP models calculate the damage progression in the core structures and the formation, heatup, and melting of debris.

SCDAP/RELAP5 is capable of modeling a wide range of system configurations from single pipes to different experimental facilities to full-scale reactor systems. The configurations can be modeled using an arbitrary number of fluid control volumes and connecting junctions, heat structures, core components, and system components. Flow areas, volumes, and flow resistances can vary with time through either user control or models that describe the changes in geometry associated with damage in the core. System structures can be modeled with RELAP5 heat structures, SCDAP core components, or SCDAP debris models. The RELAP5 heat structures are one-dimensional models with slab, cylindrical, or spherical geometries. The SCDAP core components include representative light water reactor (LWR) fuel rods, silver-indium-cadmium (Ag-In-Cd) and B₄C control rods and/or blades, electrically heated fuel rod simulators, and general structures. A two-dimensional, finite element model based upon the COUPLE4 code may be used to calculate the heatup of debris and/or surrounding structures. This model takes into account the decay heat and internal energy of newly fallen or formed debris and then calculates the transport by conduction of this heat in the radial and axial directions to the wall structures and water

a. The MOD3.1 designates a generic version of the code. Where needed, specific developmental version identification will be included with the code name. For example, SCDAP/RELAP5/MOD3[8x] would specify developmental version 8x.

surrounding the debris. Perhaps the most important use of this model is to calculate the heatup of the vessel wall so that the time at which the vessel may rupture can be determined. Other system components available to the user include pumps, valves, electric heaters, jet pumps, turbines, separators, and accumulators. Models to describe selected processes, such as reactor kinetics, control system response, and tracking noncondensable gases, can be invoked through user control.

The development of the current version of the code was started in the spring of 1992. This version contains a number of significant improvements since the last versions of the code, SCDAP/RELAP5/MOD2.5 and SCDAP/RELAP5/MOD3[7af], were released. These improvements include the addition of several new models to describe the earlier phases of a severe accident, changes in the late phase models to provide more "physically intuitive" behavior for full plant calculations, and changes to improve the overall reliability and usability of the code. The improvements in the early phase models include the addition of models to treat (a) the effects of grid spacers including the effects of Inconel spacer grid-zircaloy cladding material interactions, (b) BWR B₄C control blade-zircaloy channel box material interactions, and (c) accelerated heating, melting, and hydrogen generation during the reflood of damaged fuel rods. An extension to the molten pool models to treat the sporadic growth of the boundaries of the molten pool into adjacent regions of relatively intact assemblies or rubble debris beds is the most significant change to the late phase models. Improvements in overall reliability and usability of the code for plant calculations include changes in the overall code numerics to reduce the likelihood of numerical instabilities or code failures and changes in the codes input/output processors. The most noticeable of these for the code users is the conversion of the SCDAP input to a form more compatible with the RELAP5 style. In addition to these modeling and coding changes, SCDAP/RELAP5/MOD3.1 has also been subjected to (a) an intensive effort of verification testing to identify and resolve outstanding code errors and (b) a systematic assessment of the code to quantify uncertainties in the predicted results.

1.2 Relationship to Other NRC-Sponsored Software

SCDAP/RELAP5 and RELAP5 are developed in parallel and share a common configuration. Both codes share a common source deck. Separate codes are formed only prior to compilation, so changes made to the source deck are automatically reflected in both codes.

The development and application of the code is also related to several other NRC-sponsored software packages. Theoretical work associated with the development of PARAGRASS-VFP,⁵ has resulted in model improvements for fission product release. A data link to the VICTORIA code will allow for the detailed treatment of phenomena such as fission product and aerosol transport, deposition, and resuspension. A link with PATRAN⁶ and ABAQUS⁷ provides the user with the means to calculate the details of lower head failure. Animated plant response displays are possible through links to the Nuclear Plant Analyzer (NPA)⁸ display software, which gives the user an efficient way of analyzing the large amount of data generated. Detailed plant simulations from accident initiation through release of fission products to the atmosphere are made available through links to the CONTAIN⁹ containment response and CRAC2¹⁰ or MACCS¹¹ atmospheric dispersion consequence codes.

1.3 Quality Assurance

SCDAP/RELAP5 is maintained under a strict code configuration system that provides a historical record of the changes made to the code. Changes are made using an update processor that allows separate identification of improvements made to each successive version of the code. Modifications and improvements to the coding are reviewed and checked as part of a formal quality program for software. In addition, the theory and implementation of code improvements are validated through assessment calculations that compare the code-predicted results to idealized test cases or experimental results.

1.4 Organization of the SCDAP/RELAP5 Manuals

The specific features of SCDAP/RELAP5/MOD3.1 are described in a five-volume set of manuals covering the theory, use, and assessment of the code for severe applications. Although Volume I describes (a) the overall code architecture, (b) interfaces between the RELAP5 system models, and (c) any system models unique to SCDAP/RELAP5, the code user is referred to the companion set of six volumes which describe the RELAP5² system thermal hydraulics and associated models.

Volume I presents a description of SCDAP/RELAP5/MOD3.1-specific thermal-hydraulic models (relative to RELAP5/MOD3), and interfaces between the thermal-hydraulic models and damage progression models.

Volume II contains detailed descriptions of the severe accident models and correlations. It provides the user with the underlying assumptions and simplifications used to generate and implement the basic equations into the code, so an intelligent assessment of the applicability and accuracy of the resulting calculation can be made.

Volume III provides the user's guide and code input for the severe accident modeling. SCDAP input was recently changed to be consistent with the free-form input used by RELAP5. User guidelines are produced specifically for the severe accident code. The user should also refer to the RELAP5/MOD3 Code Manual Volume V: User Guidelines for a complete set of guidelines.

Volume IV describes the material property library, MATPRO. It contains descriptions of the material property subroutines available for severe accident analysis.

Volume V documents the assessments of SCDAP/RELAP5/MOD3.1 created in early 1993. It includes nodalization sensitivity studies and time-step sensitivity studies, assessments using standard PWR and BWR plant models, and assessments using code-to-data comparisons.

1.5 Organization of Volume III

The purpose of this volume is to help educate the code user by documenting the modeling experience that has been accumulated from developmental assessment and application of the RELAP5 and SCDAP codes. This information will include a blend of the model developer recommendations with respect to how

the model was intended to be applied and the application experience that indicates what has been found to work or not to work. Where possible, definite recommendations of approaches known to work are made and approaches known not to work are pointed out as pitfalls to avoid.

The objective of the user's guide is to reduce the uncertainty associated with severe accident modeling of light water reactor (LWR) coolant systems. However, we do not imply that uncertainty can be eliminated or even quantified in all cases, since the range of possible system configurations and transients that could occur is large and constantly evolving. Hence, the effects of nodalization, time step selection, and modeling approach are not completely quantified. As the assessment proceeds, there will be a continual need to update the user guidelines document to reflect the current state of modeling knowledge.

Section 2 describes the type of core structures that can be modeled with SCDAP/RELAP5. Section 3 provides user guidelines, and section 4 describes problem control and output editing. Section 5 discusses the installation process. Appendix A documents the input requirements for SCDAP/RELAP5.

2. CORE STRUCTURES

The core structures represent those portions of the reactor core which are solid at the beginning of the analysis. This may include fuel rods, control rods, flow shrouds, simulator rods, or channel boxes.

2.1 Fuel Rod

The fuel rod behavior model calculates the thermal, mechanical, and chemical response of fuel rods during severe accidents. The fuel rod behavior models consider nuclear heat generation, temperature distribution, zircaloy cladding oxidation, fuel deformation, liquefaction, and fission product release. Nuclear heat generation, in combination with the heat generation of cladding oxidation, determines the fuel rod temperature. The rod temperature is computed by a two-dimensional finite difference scheme. The oxidation heat of zircaloy is the dominant heat source after temperatures reach 1,500 K. Cladding deformation is based on mechanical models developed for FRAP-T6¹² and FRAPCON-2.¹³ The model considers both axisymmetric cladding collapse or ballooning and asymmetric localized ballooning. The melt, flow, and refreezing of liquefied U-O-Zr is also considered. The liquid material is assumed to flow as an axisymmetric slug depositing both heat and a frozen crust upon the underlying ZrO₂ layer. The release of inert gases (krypton, xenon, helium) and volatile fission product (cesium, iodine) is modeled using the PARAGRASS⁵ model.

2.2 Ag-In-Cd Control Rod

Control rod temperatures are computed using the same heat conduction model as the fuel rods. User specified nuclear heating, chemical heating caused by oxidation of the zircaloy guide tube and stainless steel cladding, and convective and radiative heat transfer from the coolant and adjacent fuel rods are considered. The melting and relocation of control rod materials are described in the following manner. If the stainless steel is below its melting temperature, no relocation of molten Ag-In-Cd occurs. If the guide tube melts, or is breached, molten absorber moves through the breach in the zircaloy guide tube and moves as a film on the outside of the guide tube. Unlike the flow of molten Zr-U-O for fuel rods, the momentum and energy equations are not solved to describe the freezing of the molten Ag-In-Cd; rather, the material freezes when it reaches a lower elevation where the guide tube temperature is 200 K less than the solid temperatures of Ag-In-Cd. For subsequent heatup and melting of stainless steel and zircaloy, the molten material relocates internally downward within the oxidized ZrO₂ on the guide tube, filling up the voids formed by the relocation of molten Ag-In-Cd. The molten mixture of stainless steel and zircaloy will remain contained within the ZrO₂ shell until the ZrO₂ is either melted, allowing the molten mixture to flow downward in the flow channel until it freezes, or is shattered upon reflood.

2.3 Flow Shroud

The structures internal to the core other than fuel and control rods can be modeled using the basic heat conduction equation. Heat generation can be user specified and oxidation related. The structures can be defined by multiple layers of materials, with the oxidation and relocation of exterior layers caused by melting considered. Zircaloy layers are oxidized using the same kinetics as described for fuel rods. The molten zircaloy relocates downward to a region where the structural surface temperature can also be

modeled; however, oxidation rate equations must be user specified and no material relocation or loss of geometry can be considered. Both melting and non-melting models can be used for the structures outside the core as well, since the same material limitations apply.

2.4 Simulator Rod

The simulator rod is used in out of pile experiments to simulate the behavior of fuel rods during a severe accident scenario. The simulator rod is heated electrically by tungsten wire at the center. The simulator rod behavior model calculates the thermal, mechanical, and chemical response of simulator rods during severe accidents. The model considers electric heat generation, temperature distribution, zircaloy cladding oxidation, and fuel deformation and liquefaction. Electric heat generation, in combination with the heat generation of cladding oxidation, determines the fuel rod temperature. The rod temperature is computed by a two-dimensional finite difference scheme. Cladding deformation is based on mechanical models developed for FRAP-T6 and FRAPCON-2. The melt, flow, and refreezing of liquefied U-O-Zr are also considered.

2.5 BWR Control Blade/Channel Box Model

Analyses of the DF-4 and CORA experiments have shown that the effects of B_4C /stainless steel interactions, as well as stainless steel/Zircaloy interactions, must be included to predict control blade relocation accurately. Melting of a control blade begins at the inner surfaces of the absorber rodlets where stainless steel reacts with B_4C . The absorber rodlets fail at a temperature that is lower than the melting temperature of pure stainless steel. Stainless steel from the control blade then relocates downward and forms a blockage between the control blade and channel box, where it reacts with the Zircaloy. The Zircaloy channel box adjacent to the stainless steel blockage fails (enters into the formation of a eutectic mixture) at a temperature that is much lower than the melting of pure Zircaloy.

2.6 B_4C Control Rod Model

The B_4C control rod model remains in the code for several reasons. First the new control blade / channel box model does not yet model relocation of molten control rod material through the channel box wall and into the fuel rod bundle. Therefore, although this model is not as sophisticated as the combined control blade / channel box model described in Section 2.5, this model must still be used to extend analyses past the time of control rod relocation. Secondly, some reactors do make use of cylindrical B_4C control rods.

Control rod temperatures are computed using the same heat conduction model as the fuel rods. User specified nuclear heating, chemical heating caused by oxidation of the zircaloy guide tube and stainless steel cladding, and convective and radiative heat transfer from the coolant and adjacent fuel rods are considered. The melting and relocation of control rod materials are described in the following manner. If the stainless steel is below its melting temperature, no relocation of molten Ag-In-Cd occurs. If the guide tube melts, or is breached, molten absorber moves through the breach in the zircaloy guide tube and moves as a film on the outside of the guide tube. Unlike the flow of molten Zr-U-O for fuel rods, the momentum and energy equations are not solved to describe the freezing of the molten Ag-In-Cd; rather, the material freezes when it reaches a lower elevation where the guide tube temperature is 200 K less than the solid

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3. SCDAP/RELAP5 USER GUIDELINES

The objective of the user guidelines is to reduce the uncertainty associated with severe accident modeling of light water reactor (LWR) coolant systems. However, we do not imply that uncertainty can be eliminated or even quantified in all cases, since the range of possible system configurations and transients that could occur is large and constantly evolving. As experience with the code is gained, there will be a continual need to update the user guidelines document to reflect the current state of modeling knowledge.

3.1 SCDAP/RELAP5 Card Number Input

The SCDAP/RELAP5 input structure has traditionally comprised three different styles--RELAP5 card number, SCDAP unformatted, and COUPLE fixed format. While the SCDAP unformatted input was free-form, it provided no capability for input checking or error recovery during the input process. The COUPLE input scheme required that the input be right-justified within a specified range of columns. This input structure made creation of severe core accident analysis input decks time-consuming, frustrating, and unreliable due to extremely primitive levels of input checking. The input had virtually no error detection, and bad input often ended in floating point exceptions and I/O errors. Resolving input errors often required knowledge of the code structure, use of debugging tools, and use of code debug printout. Since RELAP5-style card-number input provided significantly greater flexibility in input checking, and since users are already familiar with this style of input, all SCDAP/RELAP5 input has been converted to use RELAP5-style card-number input.

Input for SCDAP/RELAP5 is processed on three levels, (a) input echo; (b) individual card, or R level processing; and (c) initialization, or I level processing. This input philosophy provides the maximum diagnostic information for each input submittal. During input echoing, the input deck is echoed to the output file; and cards with the same card numbers (replacement cards) are detected. At the R level processing, the cards are read in and, wherever possible, basic range checking is performed to be sure that the input variables fall within physical limits. At this input level the code is able to provide only primitive input checking, since information is available only about the current card. During the initialization, or I level processing, more global range checking is performed; and the code is able to verify self-consistency between cards.

As a minimum, all input will be subjected to four comparative checks: (1) physical/code limits, such as a fuel pellet radius greater than the inner cladding radius, (2) consistency of input, such as a radial node omitted at a material interface, (3) number of words on a card, and (4) variable type. A fifth check, for range of normal use, will also occur during input processing wherever applicable. Input violations of physical and/or code limits, consistency of input, number of words on a card, and variable type will result in an input error but will not abort input processing. Wherever possible, input data that has previously been shown to cause a code abort are now tested, and diagnostic messages issued. Rejected input will be identified and reset to a benign value to allow complete input processing. The selected ranges of allowable input are listed with the card input descriptions in Appendix A. This appendix also contains additional information on the type of checks that will be performed.

Sequential expansion, as found in RELAP5, is used wherever possible. In sequential expansion, sets of data used to specify parameters are followed by an integer, which specifies the range over which the

parameters should be applied. As an example, if a data set can be applied to each axial node of a component, then the integer would be the final axial node over which the data were to be applied. Utilization of sequential expansion significantly decreases the size of an input deck and is a technique which RELAP5 users have applied for many years. Additional examples are available in Reference 2.

3.2 Input Preparation

Attention to detail in preparing, documenting, and checking the input limits errors and provides a valuable model reference for tracking error corrections and subsequent model improvements. By using standardized input format and conventions, input errors are easier to detect. The following sections discuss standard procedures for model documentation and quality assurance, input deck arrangement, and conventions.

3.2.1 Input Deck Arrangement

The code accepts data based on the "card number" specified in the first field on each line of input. For a given card number, the code accepts the input parameters specified in the code manual as sequences of floating point, integer, and alphanumeric entries. On any given card, the data entries must appear in the proper sequence and be separated by one or more blanks. The cards may appear in any order, as long as all required cards and data entries are present. If a card number is duplicated in the input listing, the code identifies it as a "replacement card" and uses the information on the last card entered with that number.

As stated above, the input deck cards may appear in any order. In practice, however, arranging the cards in a logical manner is preferred. At the INEL input decks typically start with the title, job control, and time step control cards. These are followed in sequence by the minor edit requests, trip specifications, hydrodynamic components, heat structures user-input data tables, control variables, and reactor kinetic specifications. An input deck is generally arranged by increasing card numbers when this arrangement is used. Within each of the above groups, data are similarly arranged in order of the card numbers (e.g., the trips are listed in numerical order).

A well-organized input deck includes comment cards that aid interpreting the input from a printed listing. Comments may be inserted through the use of the asterisk (*). On any line, all entries following an asterisk are assumed to be comments. With this format, an analyst will spend a minimum amount of time counting fields and searching through the manual to understand the input.

3.2.2 Model Input Debugging

The input processing routines provide excellent error-checking and error-interpretation capabilities. Input processing error checking is invoked when executing both new- and restart-type problems. All model input errors result in the generation of an informative error message. The presence of one or more input errors results in job termination and a message that the termination was due to input error. As a word of caution, the SCDAP/RELAP5 error-checking functions are primarily intended to check for compliance with the input data requirements. Secondly, checking is performed for model consistency (e.g., that fuel rod diameter does not exceed pitch). However, the input error-checking function may not uncover basic input errors such as incorrectly specifying a radius of 0.050 m as 0.50 m. Therefore, successful completion of SCDAP/RELAP5 input processing should not be considered a replacement for a quality assurance activity.

such as a 'workbook', as described in the RELAP5 user guidelines².

An efficient method for debugging a new SCDAP/RELAP5 input deck is described as follows. The complete model is first assembled into a single file and the model is executed in either the transient or steady-state modes as specified on card 100. Either the INP-CHK or the RUN option may be selected on card 101. A typical new input deck will likely contain many input errors so the execution will result in generation of a series of error messages. It is common for one actual error to propagate into the generation of multiple error messages. Therefore, the list of error messages generated will in general be much longer than the actual number of errors in the model. The user should read and consider each of the error messages in the order they were generated. This process results in one of the following determinations for each of the error messages: (a) the message clearly indicates an error in the deck and the resolution is clear, (b) the message is found to be caused by the existence of a previous error and is expected to be resolved when the primary error is corrected, and (c) the reason the message was generated is not clear. In practice, the error messages are very informative and the actual input errors are obvious to the analyst. A significant effort can be expended tracing the source of each error message. Instead, it is more efficient to survey the error messages, correct the obvious errors, and again execute the model. As a rule of thumb, only about one third of the error messages generated are caused by actual errors; the remainder are second-generation messages resulting from the primary errors. This iterative process proceeds rapidly to the removal of all input errors. Experience shows that a large input deck that has been entered with moderate care can be debugged with this process in about five iterations.

The iterative debugging process described in the previous paragraph can be much easier if the output of the debugging runs are reviewed on a terminal by an editor capable of searching for data strings. All input error messages are preceded by a string of eight asterisks (*****) and the removal of all errors results in the generation of the message "Input processing completed successfully". The user should be cautioned that even when there are no input error messages (marked by eight asterisks), there may still be input warning messages (marked by eight dollar signs). Although not fatal, these messages may assist in identifying additional errors.

The user should be aware that the input processing is subdivided into several sections of data checking that are performed in sequence. Depending on the nature of the errors found, the job may be terminated at the end of one of the sections before all of the error-checking sections have been executed. In this instance, only error messages for the sections that have been checked will appear. When these errors have been corrected and the checking proceeds to the next section, the number of error messages may increase. In other words, the analyst should realize that in this iterative process the number of error messages may not monotonically decrease.

3.3 Problem Execution

When the input deck has successfully passed input processing, an initial time edit will be generated by the code. If the RUN option is selected, problem execution proceeds from the conditions specified in the initial edit. The initial edit will be identified as zero time for NEW problems and as the time of the restart

edit for RESTART problems.

3.3.1 Time Step and Edit Selections

The problem execution is controlled by the options specified on the 201-299 time step control cards. These cards specify the time step sizes and output features desired as the problem progresses from one time interval to the next. Card 201 specifies these options and the end time for the first time interval, Card 202 for the second time interval, and so on. Subdividing the problem into time intervals facilitates modifying the execution to suit the expected nature of the problem. For example, consider the case of a modeling action (such as closing a valve or tripping a pump) that is of particular interest and may slow the calculation at a given time (say 10 seconds). For this case, a first execution interval might be selected to end at 9 seconds. The second interval might include a reduced time step, and perhaps increased edit and plot frequencies, from 9 to 15 seconds. After 15 seconds, a third interval would then be used to return the time step and edit options to their original values. Note that execution is terminated if the problem time reaches the end of the last interval specified on the 201-299 cards.

For each time interval, minimum and maximum time steps are specified. The code will attempt to execute the problem at the maximum time step. The first time step taken will be at the maximum value. The user is cautioned to use a small maximum time step size when first executing a model for which gross approximations of initial conditions have been specified. Time step size is automatically reduced based on a number of tests. The material Courant limit may not be violated. Mass, fluid property, quality, and extrapolation errors are monitored in each calculational cell and the time step is reduced if errors exceed internally preset limits. The major edit output indicates the criteria and model region causing time step reduction. This indication can be useful for improving model performance.

The code accomplishes time step reductions by repeated division by two until the errors are within acceptable limits, the minimum time step size is reached, or a failure is encountered. The severe accident subcode, SCDAP, now has the ability to impact the time step selection as well. Phenomena which have more impact during severe accident analysis, such as radiation heat transfer, can apply significant stress to the code. These phenomena can now be used to force SCDAP/RELAP5 to repeat the time advancement with a reduced time increment.

3.4 Plot Variables

One of the primary resources for an analyst using the SCDAP/RELAP5 code is the plot file. Severe accident transients, by the very nature, have parameters which are changing rather dramatically with time, and system 'snapshots', such as are provided by the major edits, reveal only part of the story. The severe accident analyst is encouraged to make extensive use of the ability to plot parameters from the restart/plot file. Due to the large number of parameters which could appear on the plot file, the philosophy of SCDAP/RELAP5 is to allow the code user to specify the parameters of interest at input. Specification of the parameters of interest are done by use of '208' cards, and the code user is referred to Appendix A of this report

for details on the use of these cards.

3.5 Guidelines for Late Phase Damage Progression

The uncertainties involved in modeling the late phase damage progression make it useful to perform bounding studies on the calculated times of molten pool slumping and failure of the lower head. The areas of modeling with large uncertainty include: 1. strength and configuration of solidified material that supports a pool of molten core material; 2. fragmentation temperature of embrittled fuel rods that are quenched; 3. flow area of break in piping system, 4. configuration of slumping molten material, and 5. heat transfer coefficient between debris and the lower head of the reactor vessel. A parameter for each of these areas of modeling can be defined by the code user so that a series of analyses can be performed to bound the possible behavior of the reactor. This section provides guidelines for the range of values of these parameters in order to calculate the range of possible reactor behavior.

An integer parameter is provided on SCDAP input card 40001100 to provide an estimate of the range of time in which a molten pool slumps to the lower head. If this parameter is set to a value of one, then the molten pool is considered to slump to the lower head whenever material at the periphery of the core has become molten. In this modeling option, solidified material at the periphery of the core is considered to have no strength for supporting a molten pool. This value of the input parameter provides an estimate of the earliest possible time of molten pool slumping. If the parameter on Card 40001100 is set to a value of zero, then the crust supporting the molten pool is considered to always have the strength necessary for supporting a molten pool. The molten pool does not slump to the lower head until its supporting crust at some point is calculated to melt. This value of the input parameter provides an estimate of the latest possible time for slumping of the molten pool. For both values of the input parameter, if the molten pool is calculated to slump, all of the molten material is calculated to slump. The assumption is applied that the initial point of failure of the crust is eroded to a depth sufficient to allow drainage of the entire molten pool. This assumption and the two types of slumping behavior defined by Card 40001100 are an interim solution until a model is implemented for calculating the structural integrity of the crust.

The fragmentation temperature of embrittled fuel rods is defined on Card 107 of the RELAP5 input. Embrittled fuel rods are considered to fragment when their temperature decreases to a value less than the fragmentation temperature. The fragmentation temperature is user defined because the code does not have a mechanistic model for fragmentation. The most likely time for embrittled fuel rods to fragment is during the period of rapid temperature change that occurs when the mode of heat transfer at the cladding surface changes from film boiling to nucleate boiling. The thermal stresses in the cladding are maximum during this period of time. An upper bound value on fragmentation temperature is estimated to be the temperature at which the mode of heat transfer at the surface of fuel rods being quenched changes from film boiling to transition boiling. The lower bound of the fragmentation temperature is estimated to be the temperature at which the nucleate boiling mode of heat transfer occurs, which is near the saturation temperature of water. Other mechanisms for fuel rod fragmentation may be possible. If the user identifies one of these other mechanisms being in operation, then a fragmentation temperature appropriate for this mechanism should be defined. The user defined value for fragmentation temperature has no influence on calculated results for the case of severe accidents in which no embrittled fuel rods are cooled below the upper bound value of the fragmentation temperature or in which all of the fuel rods are cooled to temperatures less than the lower bound value of fragmentation temperature. If fuel rods with cladding that is calculated to be embrittled are

cooled to a temperature less than the fragmentation temperature, then the fuel rods are considered to disintegrate into porous debris. The upper bound on the calculated extent of core fragmentation is obtained by defining the fragmentation temperature to have its upper bound value. The lower bound on the calculated extent of core fragmentation is obtained by defining the fragmentation temperature to have its lower bound value.

The flow area of a break is defined by the RELAP5 input card for the valve component that represents the break. The break size is estimated to range from 25% to 200% of the flow area of the pipe that broke. Creep rupture calculations must first be requested for each possible location in the reactor piping system at which creep rupture may occur. The locations for which creep rupture is to be performed are defined on RELAP5 Cards 21000110 and 21000000. Then after the calculations have identified the time and location of the first creep rupture, the calculations are repeated with a break being defined for the location with a creep rupture.

Molten material that slumps from a molten pool may be represented as either an intact stream as it slumps or breaking up into small droplets. The representation of the slumping molten material is defined on RELAP5 Card 103N. If the stream of molten material is represented as an intact stream, then heat is not transferred from the molten material as it slumps. The molten material is at the same temperature when it impacts the lower head as it was when it was in the molten pool in the core region. In addition, the material that slumps to the lower head is defined to have no porosity. As a result, the lower head of the reactor vessel may heatup rapidly. If the molten material breaks into small droplets as it passes through liquid water, then the molten material is cool when it impacts the lower head. In addition, the material is considered to have open porosity that can be filled with water. The heat transferred from the small droplets of molten material to water may cause a significant increase in pressure in the primary coolant system. If the user defines breakup of the slumping material but the lower plenum of the vessel is not filled with water, then the slumping stream of material is considered to remain intact and not breakup.

The gap heat transfer coefficient between debris in the lower plenum and the lower head that supports this debris is defined on the COUPLE Card 5ccc1101. The gap heat transfer coefficient may range from 500 W/m²K to 10,000 W/m²K (Reference 14). The upper bound value of the gap heat transfer coefficient results in a more rapid heatup of the lower head than the lower bound value.

3.6 Code Diagnostics

In the past, SCDAP/RELAP5 has been considered a research tool by both development staff and user community. As such, it was considered more significant to implement state of the art core damage progression models, than to develop the user interface. However, the developing maturity of the code now requires that the code-user interface be easier to understand. A significant effort has been expended to eliminate (a) code failures without error messages, (b) confusing diagnostics sent only to the screen, and (c) confusing error or warning messages. A survey of international code users was used to identify confusing diagnostics and code errors that lead to abnormal aborts. While this will undoubtedly be an on-going effort, with additional areas of improvement identified by the user community, this effort has increased the quality of diagnostic information.

In order to eliminate code stops without error messages, stop statements or calls to abort routines were removed and, where necessary, replaced with statements setting a logical variable, 'fail', to true. This action allows the completion of the current time step, and then forces a major edit and a graceful exit. Where possible, logic to repeat a time advancement with a smaller time step has been implemented. Also, error diagnostics were added to identify where the failure occurred. Representative changes were successfully tested to ensure that time-step completion would occur and that the expected messages would result. Many users complained about the nonconvergence messages from the equation solver DSGEDR, which is used to solve the molten material relocation equations. This problem has been resolved with the implementation of the automatic time advancement repetition capability, which now merely repeats the time advancement with a reduced time step.

Major edit output has been improved. The information needed to define the molten pool and debris regions has been reduced in length, and the number of tables showing core configuration has been reduced from six to one. A new output format replaces references to variable names with clear descriptions for output parameters.

SCDAP/RELAP5 generates one- or two-line messages whenever significant changes in core conditions occur. These messages, denoted real time messages, are printed as soon as the condition is changed, and therefore will appear between major edits. Since the information in these messages are sometimes difficult to interpret, an effort is being made to clarify and/or eliminate them. However, changing this output is difficult, because these write statements number in the hundreds and are spread throughout the code. Changes have been implemented to add subroutine identifier statements to all lines of this output for identification. Statements that are printed following a single major event are grouped under the header 'core degradation event'. Also, times for these events are now printed with greater number of significant digits, to ensure that timing is known; and the times are listed as 'event time' to help the user when searching output with a text editor. In the future a table will also be generated during the major edit, which will summarize core degradation event timing since the last edit.

The user community is encouraged to identify confusing, unneeded, or missing output and to pass their suggestions to the development staff. An on-going effort will be made to improve the user interface to SCDAP/RELAP5.

3.7 Steam Starvation Limits

During the developmental assessment calculations documented in Volume V, an anomaly was observed in some experimental analyses. Although the calculated cladding surface temperatures closely matched the measured temperatures, in some experiments the bundle hydrogen production was over-predicted. Since, obviously, the physics of oxidation are well understood, either a systematic error was being introduced into the experimental data, or a phenomena not currently being modeled is affecting the oxidation process in some experiments.

One of the most basic assumptions used in the hydrodynamic portion of SCDAP/RELAP5 is that the fluid/gas mixture within a hydrodynamic volume is homogeneously mixed within each hydrodynamic volume. While this assumption is valid in most cases, it is conceivable that during rapid oxidation a large quantity of noncondensable gas could be generated sufficiently quickly that it will inhibit the transport of steam to the oxidizing surface. The model for this limitation is described in detail in Volume II, but

essentially applies a factor of the ratio of the partial pressure of steam to the local bulk pressure as a multiplier on the steam availability. The limit then only becomes effective as the noncondensable quality becomes high. Any component may then be oxidation limited either by the availability of steam or the diffusion of steam through a noncondensable.

It has become a standard practice for analysis of experimental facilities, and therefore is recommended as a user guideline, to take a group of fuel rods that would normally be represented as a single SCDAP/RELAP5 component, and to characterize that group with two components, identical except for oxidation limit. As an example if the user has a group of n fuel rods which respond identically, and can therefore be represented with a single component, then it is recommended that the user characterize their response with two components, one component representing $n-1$ fuel rods with the diffusion limit active, and one component representing a single fuel rod with the steam starvation limit active. The diffusion limited component can then simulate the behavior of the bulk of the core, and can be used to predict core average parameters, hydrogen production for example. The single fuel rod, with oxidation limited only by steam starvation, can then represent the behavior of the instrumented rods, and can be used to predict maximum cladding temperature. This procedure should bound the effects of noncondensables.

It should be noted that the model to limit oxidation by the diffusion of steam through noncondensables is the default, with steam starvation limit obtained only on request through the 4ccc4001 - 999 cards, as described in Appendix A.

3.8 Nested Radiation Enclosures

The ability of SCDAP/RELAP5 to model radiation transfer across nested radiation enclosures has been considerably enhanced. In the past each core component could exist in one and only one radiation enclosure. Additionally two sided components, such as the shroud component, could only radiate heat from the inner surface. However, analyses such as that of the CORA experiments, where an insulated flow shroud was surrounded by a high-temperature shield, required the ability to model nested radiation enclosures. In these experiments, heat from electrical heater rods is transferred to the inner surface of the insulated flow shroud, then conducts through the shroud to its outer surface, and then is transferred by convection and radiation to the inner surface of the high-temperature shield. The model of radiation heat transfer requires the representation of two radiation enclosures; one representing the space inside the insulated flow shroud and another representing the space between the outer surface of the flow shroud and the inner surface of the high-temperature shield. Both of these enclosures are connected with the insulated flow shroud.

3.9 Cold Wall Effects on Core Damage Progression

Thermal and hydraulic analyses of nuclear reactor core response under accident conditions have been successfully carried out in the past with models that assume that large fractions of the core behave in a similar manner. Such analyses typically use a hot channel approach, which assumes that a significant group of fuel rods (typically on the order of one-third of the core) represent a group of the highest power fuel rods, while the remainder of the core is modeled as a second group of average fuel rods. Each group is then sectioned into its own hydraulic channel. Such a modeling approach forces two assumptions on the analysis. The first assumption is, obviously, that the fuel rods in a large fraction of the core behave in an identical manner. The second assumption, both more subtle and more significant to this discussion, is that

each of the fuel rods within the group acts independently of every other fuel rod within that group. This 'hot channel' analytical technique has been successful in the past because this second assumption has been reasonably valid for thermal-hydraulic phenomena. Such is not the case, however, for the phenomena associated with early phase severe accident conditions.

Phenomena associated with the core response to early phase severe accident conditions, particularly relating to the mechanical response of the fuel rods, are strongly dependent on conditions experienced by an adjoining fuel rod. For instance, if a fuel rod experiences an azimuthal temperature variation around its cladding, due to a neighboring cold wall, while an adjacent fuel rod encounters cladding ballooning conditions, then coolant flow in the unit cell with the ballooned rod is diverted into the unit cell without ballooning, causing additional cooling of the adjacent fuel rod, thereby making it less likely to experience ballooning conditions. Similar conditions are generated by any phenomena which causes flow diversion, such as during melt relocation. The inability of the typical hot-channel analytical technique to track this type of dependent behavior forces the analysis to predict co-planar blockages and over-estimates the reduction in flow area. The flaw in this analytical technique has become particularly obvious for experimental facilities which examine both early and late phase severe accident behavior. These facilities, by their very nature, are forced to expose the experimental apparatus to relatively large radial temperature gradients, with cold wall effects generated by facility boundaries, thermal flow shrouds, and by instrumentation.

The SCDAP/RELAP5 code, developed for best-estimate transient simulation of light water reactor coolant systems during a severe accident, has been extended to allow the code user to specify multiple parallel hydraulic flow channels within a single radiation enclosure. This extension will allow the code user to avoid the 'hot channel' analysis technique, and will permit the use of parametric studies to evaluate the cold wall effect on core damage progression. This extension will allow the user to perform sensitivity studies of cold wall effects, and parametric nodalization studies. The effects of cold walls on core damage progression has been shown to be potentially significant, particularly in experimental facilities, where significant radial temperature gradients have been observed.

Additionally, it appears that under some conditions, plant analysis models that have been successfully used to examine the thermal hydraulic behavior of a system under accident conditions can be inappropriate for severe accident analysis, particularly when system aspects, such as the presence of one or more cold walls, are not appropriately modeled. The typical hot-channel thermal-hydraulic analysis that has been used in the past, inherently assumes that each fuel rod in each channel behaves independently. This assumption can impose phenomena such as co-planar blockage and over-prediction of flow area reduction when phenomena such as cold-wall effects, cladding deformation, or melt relocation are being experienced.

3.9.1 Noncondensable Model

The noncondensable model is implemented by specifying a noncondensable gas type on control card 110 and indicating a noncondensable quality on one or more volume initial condition cards. A mixture of noncondensable gases may be specified by indicating more than one gas type on card 110 and specifying their mass fractions on card 115. It should be noted that only one noncondensable gas mixture may be used in a problem, although the fractions of each gas type may change in each hydrodynamic volume, and the noncondensable gas must be hydrogen (or include hydrogen in the case of a mixture). This means that if

nitrogen is present in one part of the system and hydrogen is present in another, then the system has a mixture of hydrogen and nitrogen, with the mixture consisting of 100% nitrogen and 0% hydrogen in one location and a mixture of 0% nitrogen and 100% hydrogen in another.

The noncondensable model assumes the gas is tracked with the vapor phase. Furthermore, the resulting gas-steam mixture is assumed to be isothermal (i.e., the gas and steam are in thermal equilibrium). A total pressure is calculated for the gas-steam mixture; the partial pressure of steam is available as a standard output variable.

3.10 BWR CHANNEL BOX USER GUIDE

This Chapter describes the input data that the user must specify on SCDAP input cards for the BWR control blade and channel box component. Also, information is provided to help the user interpret the printed output.

3.10.1 BWR Blade/Box Cards

The specific SCDAP input cards for the BWR control blade and channel box component are documented in Appendix A. This Section provides additional information to help the user prepare data for the input deck. All descriptions in this Section refer to the new SCDAP input format with RELAPS-style card numbers (see Section A.1 of Appendix A).

Cards 40003000, 40003100, and 40003200 contain parameters that are common to all BWR blade/box components. These cards should appear not more than once in an input deck. Default values (see Appendix A) are provided for each of the parameters on Cards 40003000, 40003100, and 40003200. If no other information is available, the user should invoke these default values by omitting Cards 40003000, 40003100, and 40003200.

The failure (liquefaction) temperatures on Card 40003000 are used to account for the effects of eutectic interactions between B_4C /stainless steel and stainless steel/Zircaloy. Eutectic interactions are modeled by using failure (liquefaction) temperatures that are less than the melting temperatures of the pure materials.

The metal/water reaction parameters on Card 40003100 affect the B_4C and Zircaloy oxidation calculations. The user must specify a maximum fraction of B_4C in each node that can react. This maximum fraction is used by the advanced $B_4C/H_2/H_2O$ chemistry package to control the mass of B_4C available for the chemical equilibrium calculations. The user can also select different Zircaloy oxidation correlations for the low and medium temperature regions. These Zircaloy oxidation correlations are described in Section 2.5 of this report.

On Card 40003200 (relocation parameters), the user must specify two mass fractions of oxides (stainless steel and ZrO_2) that are carried along with the underlying pure materials when they melt. The user must also specify two heat transfer coefficients between molten material (stainless steel and Zircaloy) flowing downward and the underlying solid structures. (The model does not currently include correlations for these heat transfer coefficients.) The recommended default values (see Appendix A) for these heat

transfer coefficients were determined empirically from ORNL analyses of the DF-4 and CORA experiments.

The control blade and channel box dimensions specified by the user on Cards 4ccc0200 and 4ccc0300 are sketched in Figure 3-1. The actual control blade radial dimensions shown in the top of Figure 3-1 are converted by the model into the equivalent slab geometry shown in the bottom of the figure. The equivalent slab thicknesses are calculated so that the cross-sectional area of each layer in the equivalent slab geometry is identical to the cross-sectional area in the actual geometry. The distance between the channel box and the first row of fuel rods (dimension 7 in Figure 3-1) is used in the relocation calculations to determine when the region on the fuel-bundle side of the channel box is blocked..

As is the case for all other SCDAP components, the internal modeling for the BWR blade/box component is performed using a local set of dimensions that describes the single blade/box structure shown in Figure 3-1. However, the BWR blade/box component can be used to represent many copies of this individual blade/box structure by specifying the value on Card 4ccc0100. If a value of 1 is specified on Card 4ccc0100, then the component will perform calculations for half of a control blade and two channel box segments with lengths as indicated in Figure 3-1 (dimensions 8 and 9).

The geometric view factors specified on Card 4ccc0300 are for radiation between the channel box and the control blade, which is modeled internally by the BWR blade/box component. These geometric view factors must be calculated by the user using the geometry sketched at the bottom of Figure 3-1. The sense of direction is from the channel box to the control blade, i.e., the view factors are based on the areas of the channel box segments.

Initial conditions for the BWR blade/box component are specified on Cards 4ccc0500 and 4ccc0601-99. The three oxide thicknesses on Card 4ccc0500 apply to all axial nodes. The initial stainless steel oxide layer must be specified nonzero because this value is used as a denominator in the stainless steel oxidation calculations. This restriction does not apply to the initial ZrO₂ layers; they may be specified zero. The initial control blade temperatures specified for each axial node on Cards 4ccc0601-99 (Word 1) apply to all three radial nodes. The initial channel box temperatures specified for each axial node on Cards 4ccc0601-99 (Word 2) apply to both channel box segments.

If fuel rod or electrically-heated simulator rod components can receive molten material from a B~YR blade/box component, then this information is specified on Cards 4ccc0701-99 and 4ccc0801-99. Cards 4ccc0701-99 apply to radial spreading from channel box segment No. 1 while Cards 4ccc0801-99 apply to segment No. 2. The mass fractions of molten material from channel box segment Nos. 1 and 2 are used to determine how molten material is proportioned between multiple fuel or simulator rod components that are located adjacent to the same channel box segment.

The mass fractions on Cards 4ccc0701-99 and 4ccc0801-99 can be used to represent radial spreading that occurs initially into the first row of fuel rods and later into the remainder of the fuel bundle. For example, assume the BWR fuel assembly shown in Figure 3-1 is modeled with SCDAP using one BWR blade/box component (No. 1) and three fuel rod components (Nos. 2, 3, and 4). If the following cards are specified for BWR blade/box radial spreading:

```
*crd.no comp.no frac.seg1
```

Figure 3-1. BWR control blade and channel box dimensions specified by the user.

```

40010701 2 0.999
40010702 4 0.001
*crd.no comp.no frac.seg2
40010801 3 0.999
40010802 4 0.001

```

then almost all molten material from channel box segment No. 1 (99.9%) will initially be received by fuel rod component No. 2 and almost all molten material from channel box segment No. 2 (99.9%) will initially be received by fuel rod component No. 3. However, the BWR blade/box relocation logic adjusts the mass fractions on Cards 4ccc0701-99 and 4ccc0801-99 when one of the fuel rods becomes blocked at an axial level by cohesive, rubble, or molten debris. Referring to the above example, after fuel rod component No. 2 becomes blocked at an axial level by debris, the mass fraction on Card 40010701 (0.999) is changed to 0.0 and the mass fraction on Card 40010702 (0.001) is increased to 1.0. Subsequently, all molten material from channel box segment No. 1 will be received by fuel rod component No. 4..

Figure 3-2. Example arrangement of fuel rod components.

3.10.2 Radiation Enclosure Cards

Each BWR blade/box component must be associated with two SCDAP radiation enclosures. One enclosure is for the fuel-bundle side of the channel box and the other is a "dummy" enclosure for the interstitial side of the channel box. Radiation calculations on the fuel-bundle side of the channel box are

performed within the SCDAP radiation model using independent surfaces to represent the two channel box segments. The dummy enclosure on the interstitial side of the channel box is not actually used to perform radiation calculations between the channel box and the control blade (these calculations are performed internally by the BWR blade/box model), but this enclosure is needed to initialize properly the hydrodynamic calculations for the interstitial volume. If the user does not define both SCDAP radiation enclosures for each BWR blade/box component, an error message is printed and execution is terminated after the completion of input processing.

When a BWR blade/box component is included within a radiation enclosure, the view factors and path lengths for that enclosure must be specified by the user on Cards 4ccc1001-99 and 4ccc1101-99. Because the two segments on the fuel-bundle side of the channel box are treated independently, view factors between channel box segment Nos. 1 and 2 can be calculated and specified, if necessary.

In the radiation enclosure section of an input deck (see the following example), the component number of a BWR blade/box component must be listed three times on Cards 4ccc1000. The first two BWR blade/box entries must be consecutive and are part of a radiation enclosure that represents the fuel-bundle region. These first two entries refer to segment Nos. 1 and 2, respectively, on the fuel-bundle side of the channel box. The third BWR blade/box entry must be on a separate Card 4ccc1000 that represents the dummy enclosure for the interstitial side of the channel box. The input cards that define this dummy enclosure must follow the cards that define the fuel-bundle radiation enclosure.

For example, suppose there are two components in a SCDAP input deck and component No. 1 is a fuel rod and component No. 2 is a BWR blade/box. To model radiation between the fuel rods and the two channel box segments, the user must define enclosure No. 3 for the fuel bundle side of the channel box, followed by dummy enclosure No. 4 for the interstitial side of the channel box, using the following format:

```
*crd.no
40030000
*card. no
40031000
*crd.no
40031001
40031002
40031003
*crd.no
40031101
40031102
40031103
*crd.no
40040000
*crd.no
40041000
*crd.no
40041001
*crd.no
40041101
```

```
name type fuel    bundle comp.nos 1 2 2 view . factor 0.2818 0.9400 0.2094 path . length 0.001 0.005
```


0.015 name dummy comp.nos

2

view.factor 1.0 path.length 0.0

0.6782

0.0

0.2267

0.005 0.0 0.015 type bundle 0.0400

0.0600

0.5639

0.015

0.015

0.010

Component No. 2 (BWR blade/box) is listed twice on Card 40031000 and once on Card 40041000 of the above example. The view factor and path length arrays for enclosure No. 3 have two sets of entries for component No. 2. The second value on Card 40031001 (0.6782) is the view factor from the fuel rods to channel box segment No. 1. The third value on Card 40031001 (0.0400) is the view factor from the fuel rods to channel box segment No. 2. The third value on Card 40031002 (0.0600) is the view factor from channel box segment No. 1 to channel box segment No. 2. For enclosure No. 4, the view factor on Card 40041001 and the path length on Card 40041101 are dummy values.

3.10.3 Minor Edit Requests

The BWR blade/box variables that can be printed at "Minor Edits" or written to the restart-plot file are listed below. Although the variable names are identical to those used for other SCDAP components, the definitions listed below apply only to BWR blade/box components. These variables are "Expanded Edit/Plot Variables" and, therefore, are not written to the restart-plot file by default. To write these variables to the restart-plot file, a RELAP5 Card 2080xxxx with the appropriate name and index listed below must be added to the input deck. For all variable names listed below, "Index" is defined as: ii = radial node number, kk = axial node number, and jj = SCDAP component number.

Table 3-1. BWR blade / box variables.

Name	<u>Index</u>	BWR blade/box definition
CADCT	iikkjj	Temperature (K) at radial node ii and axial node kk of component jj. For a BWR blade/box component, valid values of radial node ii are 114 (see Figure 3-1 for locations).

Table 3-1. BWR blade / box variables. (Continued)

Name	Index	BWR blade/box definition
DAMLEV	kkjj	<p>Level of damage (unitless) at axial node kk of component jj. For a BWR blade/box component, this indicates when the channel box wall has failed and a flow path has opened between the interstitial and fuel bundle coolant volumes</p> <p>.0.0 = Both channel box segments intact .0.1 = Channel box segment No. 1 gone .0.2 = Channel box segment No. 2 gone .0.3 = Both channel box segments gone</p>
H20XD2	kkjj	Total hydrogen production rate (kg/s) at axial node kk of component jj. For a BWR blade/box component, this is the total hydrogen from the control blade and both sides of the channel box.
OXDEO	kkjj	Frozen crust thickness (m) on the interstitial side of channel box segment No. 2 at axial node kk of component jj.
RCI	kkjj	Equivalent thickness (m) of the intact control blade sheath at axial node kk of component jj.
RCO	kkjj	Frozen crust thickness (m) on the control blade at axial node kk of component jj.
ROCRST	kkjj	Thickness (m) of the intact channel box segment No. 1 at axial node kk of component jj.
RPEL	kkjj	Thickness (m) of the intact channel box segment No. 2 at axial node kk of component jj.
RULIQ	kkjj	Equivalent thickness (m) of the intact absorber rodlet (B ₄ C and stainless steel) at axial node kk of component jj.
WREMUO	kkjj	Frozen crust thickness (m) on the fuel-bundle side of channel box segment No. 2 at axial node kk of component jj.
WREMZR	kkjj	Frozen crust thickness (m) on the fuel-bundle side of channel box segment No. 1 at axial node kk of component jj.

The locations of the BWR blade/box radial nodes for temperature variable CADCT are shown in Figure 3-1. The intact structures of the control blade and the channel box are at radial locations 2-4, 6, and 12. The temperatures defined for radial locations 1 and 14 are average surface temperatures that are used as boundary conditions for the RELAP5 hydrodynamic calculations. The temperatures at the other radial locations (5, 7, 8-11, and 13) have unique values only when those nodes are blocked and filled with relocated material; otherwise they are set equal to the temperature of the adjacent intact structure..

The variable DAMLEV is defined so that it can be used to control gas flow between the interstitial and fuel bundle coolant volumes after the channel box wall has failed. This is accomplished by using RELAP5 servo valve components with valve areas calculated by control system components based upon the values of DAMLEV.

Figure 3-3. Radial node numbers used to print BWR blad/box temperatures at minor edits.

The locations of the intact blade/box and frozen crust thickness variables are shown in Figure 3-1. These eight variables can be used with the Nuclear Plant Analyzer (NPA) program to generate animated drawings depicting the melting and downward relocation of the control blade and channel box structures. This is accomplished by using NPA "Deform Boxes" to represent each variable at each axial node. Note that variables RULIQ and RCI are the equivalent (not the actual) thicknesses of the intact absorber rodlet (B_4C and stainless steel) and the control blade sheath. The user can determine the initial values of RULIQ and RCI using information printed during the processing of input data (see Appendix B) so that the NPA Deform Boxes can be initialized properly..

3.10.4 Restart Calculations

A BWR blade/box calculation can be continued from a previous calculation by specifying the problem type on RELAP5 Card 100 as "restart" and the appropriate restart number on RELAP5 Card 103. Information from the restart-plot file is used to initialize the variables for BWR blade/box components.

Figure 3-4. Locations of intact blade/box and frozen crust thickness variables.

4. NODALIZATION GUIDELINES

A significant amount of work has been done to characterize the number of volumes/nodes which are appropriate for modelling components in severe accident analyses. The user is referred to Reference 2 for additional details on modelling ex-vessel components, and to Volume V of this report for the details of a core nodalization study which has been performed for both PWR's and BWR's.

4.1 Core Nodalization Guidelines

Requirements for the nodalization of the reactor core for a severe accident analysis is significantly different from that needed for a comparatively simple hydraulic analysis. Section 3.9 discussed the reasons why a one- or two-channel analysis technique, which has been successful for analysis of thermal-hydraulic phenomena, is not appropriate for the phenomena associated with early phase severe accident conditions.

The nodalization of the core with five radial segments and ten to twenty axial nodes is considered to result in an adequate calculation of the behavior of the core during late phase damage progression. The nodalization sensitivity study presented in Volume V of this report showed that the calculated time of slumping of the molten pool may be 7% later using twenty axial nodes instead of ten axial nodes. The nodalization sensitivity study also showed that for the case of surge line rupture being ignored (high pressure case) the use of three radial segments instead of five radial segments results in an incorrect calculation of the location in the core at which late phase damage progression begins and results in a significantly earlier calculated time of beginning of late phase damage. Each radial segment should contain one SCDAP component to represent the fuel rods in that segment and one SCDAP component to represent the control rods/control blades in that segment. For PWRs, each radial segment should contain one RELAP5 control volume that represents the fluid in that segment only. For BWRs, each radial segment should contain two RELAP5 control volumes, one that represents the fluid flowing through the fuel assemblies and one that represents the fluid flowing between the fuel assemblies. Each RELAP5 control volume should be divided into as many subvolumes as axial nodes in the SCDAP components, and the subvolumes should overlay the axial segments of the SCDAP components. The reader is referred to the nodalization study documented in Volume V of this report for additional details.

4.2 Ex-vessel Example Nodalizations

This section provides example SCDAP/RELAP5 nodalizations for PWRs. The purpose of this section is to provide guidance for ex-vessel nodalization that may be used for analyzing a wide variety of small break LOCAs and operational transients. The user is cautioned that no model is generally applicable for simulating all transient scenarios. Care should be taken so that modeling and nodalization are appropriate for the particular application.

For economic reasons, the numbers of hydrodynamic cells and heat structure mesh points in general should be minimized. The computer run time needed to execute a problem simulation is determined almost completely by the number of hydrodynamic cells in the model. The number of heat structures generally increases in tandem with the number of cells. Therefore, a major economic benefit is gained by limiting the number of hydrodynamic cells in a model. Some additional economic benefit may be obtained by minimizing the number of mesh points within the heat structures. Limiting the number of other model features (such

as trips and control variables) provides only minimal economic benefits. An additional motivation for employing the largest calculational cells possible, is that when small cells are used, the time step size is reduced as a result of the material Courant limit. The Courant limit, discussed in Reference 2, limits the calculational time step based on the ratio of cell length to fluid velocity.

The process of minimizing model size must, however, always consider the phenomena to be modeled; minimizing must not proceed past the point where important phenomena are excluded from the simulation. This consideration is complicated, however, because the importance of phenomena varies from one region of the model to another and is strongly affected by the transient to be simulated. For example, the important model regions and simulation phenomena for small and large break loss-of-coolant accidents are dramatically different; therefore, appropriate modeling for these two sequences varies dramatically.

In summary, the modeler should select the minimum number of hydrodynamic cells and heat structure mesh points needed to calculate the important phenomena for the simulated transient. This guidance suggests that a general model (i.e., one that is to be used to simulate many different types of transients) should contain sufficient noding detail for all phenomena anticipated. If the important phenomena are uncertain, a detailed noding scheme should be employed. Conversely, if the important phenomena are well known, nodalization of the non-critical model regions may be simplified. If sufficient time and funds are available, it is recommended that a general model of a reactor system be assembled first. Analysis using the general model will then provide the information needed to determine what model simplifications are appropriate. The following sections provide additional guidance concerning hydrodynamic cell and heat structure sizing. General suggestions for appropriate noding may be inferred from Section 4.

4.2.1 Ex-Vessel Hydrodynamic Cell Size

As discussed above, large hydrodynamic cell sizes should be used for economic reasons. However, in each region of the model, the detail of the calculational cells must be sufficient to allow the simulation of important regional thermal-hydraulic phenomena. As a starting point, cell lengths for ex-vessel hydrodynamic volumes of 1 to 3 m (3 to 10 ft) are recommended in phenomena-dominating regions (e.g., pressurizer, and steam generator) of a light water reactor model. Cells of much longer lengths are appropriate in less important regions of the model (e.g., the feedwater train and steam lines). The cell sizes presented in these applications may be taken as guideline recommendations for modeling light water reactors. For totally new applications or where the calculation results may be particularly sensitive to the model discretization, a convergence study is recommended to ensure that a proposed nodal layout is adequate.

Good modeling practice includes blending the transition from regions of small cells to regions of large cells. For this blending, it is recommended that the volumes of adjacent cells not differ by more than an order of magnitude.

Other considerations affecting cell size selection are the locations of natural boundaries, flow connections, and instruments within the prototype fluid system. Good modeling practice includes placing junctions at natural fluid system boundaries and at flow loss features (such as support plates, grid spacers, bends, and orifices). Using this practice, the flow loss is placed at the proper location with respect to the fluid volumes. For similar reasons, the placement of junctions at flow connection points is a good practice. Cell size selection should also consider placing model features at prototypical instrument locations (e.g., placing a cell

center at the location of a pressure tap or a junction at the location of a flow meter). This practice facilitates the use of the code output because the calculated and measured data are directly comparable without further effort.

4.2.2 Steam Generator Primary Nodalization

The nodalization for the primary side of two types of steam generators are presented, U-tube steam generators (UTSG's) and once-through steam generators (OTSG's).

4.2.2.1 U-Tube Steam Generator Nodalization. Standard INEL nodalization for one of the primary coolant loops is shown in Figure 4-1. Pipe 408 represents the many thousands of steam generator tubes of a U-tube steam generator. Representing the steam generator tube primaries with an 8-cell pipe component is a nodalization scheme that compromises between calculational fidelity and expense. This scheme has proven is generally useful, however the modeler should individually consider the nodalization requirements for the problem to be modeled. The tube nodalization scheme shown may not be sufficiently detailed to model phenomena associated with reflux cooling and greatly reduced secondary-side levels. Branch 410 represents the steam generator outlet plenum. Modeling of the steam generator secondary region is described in the section 4.2.3.

Heat structures are employed to model the hot and cold leg piping walls, the steam generator plena heads, the plena separation plate, the tubesheet, and the steam generator tubes.

4.2.2.2 Once-Through Steam Generators. The OTSG is a counterflow heat exchanger that employs straight tubes. The standard INEL OTSG nodalization is shown in Figure 4-2. Components 116 and 125, represent the OTSG inlet and outlet plena, respectively. Single-sided heat structures represent the significant metal structures (such as the steam generator heads and the tubesheets). Reactor coolant flows downward through the insides of the tubes; 8-cell pipes 120 and 121 represent the tube primaries. Pipe 120 represents 90% of the OTSG tubes, pipe 121 represents the other 10% (the reason for separating the tubes in this manner is discussed below). Two-sided heat structures model the tube walls.

On the secondary side, the downcomer region is modeled with 4-cell pipe 305. Main feedwater enters the downcomer at the upper end of this component. Single-sided heat structures represent the steam generator shell and the vertical baffle that separates the boiler and downcomer regions. Branch 306 represents the region at the lower tubesheet, where the flow changes direction from downward to upward.

The boiler region is separated into two parallel flow paths, representing 90% and 10% of the flow area. The paths are connected by crossflow junctions. Components 310 through 323 represent the 90% region while components 360 through 372 represent the 10% region. The split boiler region model is recommended to simulate phenomena during periods of emergency feedwater injection. This injection enters the boiler around the circumference of the boiler, near the upper tubesheet (junction 854 in the model) and is directed radially inward, into the tube bundle. Because the OTSG employs over 15,000 tubes, the emergency feedwater wets only a small portion of the tubes around the periphery of the tube bundle. As the emergency feedwater falls downward, it encounters the tube support plates (there are 17 in the OTSG) that tend to spread the injection flow further into the tube bundle. The split boiler nodalization represents a compromise modeling scheme for simulating this behavior. An initial 10% bundle penetration is expected, and the crossflow connections to the 90% region allow simulation of the inward spreading.

M355-WHT-791-03

Figure 4-1. Nodalization of primary coolant loops (Loop C shown).

At the top of the boiler region, flows from the parallel boiler channels are combined in branch 325 before exiting the steam generator through a steam annulus, modeled with components 330 and 340.

Modeling the behavior of an OTSG is perhaps the most difficult of nuclear thermal-hydraulic system code problems encountered. The difficulty arises for two reasons. First, a complete spectrum of heat transfer phenomena is experienced between the tube wall and the secondary fluid. At the bottom of the tubes, heat transfer is to subcooled liquid. As the flow progresses up the tubes, the liquid is then saturated and boiled away. To preheat the feedwater, a portion of the steam flow is bled into the downcomer through an aspirator near mid-boiler (modeled with the junction between components 365 and 305 in Figure 4-2). Further up the tubes, any remaining droplets are vaporized and the steam is significantly superheated. Second, the OTSG heat removal rate is very sensitive to the secondary-side liquid level. As the level increases, more of the tube surface area experiences effective heat transfer (e.g., boiling) rather than ineffective heat transfer (e.g., convection to steam). Moreover, the sensitivity of OTSG heat removal to level is present during normal operation, while for UTSGs this is a concern only during accidents that involve an extreme depletion of secondary liquid.

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Figure 4-2. Example of Once-Through Steam Generator (OTSG) nodalization.

The OTSG steam generator nodalization shown in Figure 4-2 has proven adequate for simulating normal operation. The difficulty in obtaining a satisfactory OTSG simulation described above is partly nodalization dependent. Nodalization is by nature discrete, and this causes the steam generator heat removal in the model to be even more sensitive to the secondary level than in the prototype. In the model, as the level moves across cell boundaries, discrete jumps in overall heat transfer are encountered. These changes often cause the model to become unstable, oscillating between two solutions at two different secondary levels. Moving to finer axial noding may remedy the oscillation, however the proximity of the liquid level to cell boundaries often is more important than cell size.

4.2.3 Steam Generator Secondaries

Standard INEL nodalization for a U-tube steam generator secondary is shown in Figure 4-3. In the secondary region, main feedwater enters the steam generator downcomer annulus at branch 258 where it is combined with the recirculation liquid flow returning from the separator (component 278) through downcomer annulus branch 254. The combined flow descends through the downcomer (annulus 262) and enters the boiler (pipe 266). Note that the axial nodalization was made consistent between the tube primary, boiler, and downcomer regions. The use of four axial hydrodynamic cells in the boiler region has proven generally useful. However, finer nodalization of the boiler region may be needed for simulating phenomena associated with reflux cooling mode and significantly depleted steam generator secondary inventory. The user is advised to carefully consider the nodalization needs for a particular application. Overall steam generator performance is dependent on correctly simulating the recirculation ratio (the boiler flow rate divided by the feedwater/steam flow rate) because it controls the heat transfer process on the outside of the tubes. The flow losses associated with the horizontal baffles in the tube bundle region often are not well-characterized. Therefore, if a satisfactory initial agreement with the desired recirculation ratio is not attained, adjustment of input form losses in the boiler may be justified.

The two-phase mixture exiting the boiler region flows through the mid-steam generator regions (branches 270 and 274) before entering the separator (branch 278). The separator model is idealized and includes three modes of operation that are determined by the separator void fraction. The void fractions defining these modes are input by the user. At low void fractions, the separator model reverts to a normal branch component, allowing carryover of liquid into the steam dome (branch 282). At high void fractions, the separator also reverts to a normal branch component, allowing carryunder of steam through the liquid return path into the downcomer. At intermediate void fractions, an idealized separation process is calculated: all liquid is returned to the downcomer and all vapor is passed to the steam dome.

The modeler should carefully consider the elevation chosen to locate the separator. In the steam generator model, separation will take place based on the void fraction in the separator volume, whose lower and upper elevations are user-specified. In the actual plant, separation is accomplished in two stages (swirl-vane separators and steam dryers) that reside at two different elevations. Therefore, the model is at best a compromise of the actual separation processes. The selections of separator elevation span and void limits determine when recirculation is interrupted as the secondary mixture levels decline. Note that these levels decline significantly when a steam generator's heat load is reduced, such as following a reactor trip. The levels also decline significantly during transients where the secondary inventory is depleted, such as during a secondary side LOCA.

M355-WHT-791-04

Figure 4-3. Nodalization of secondary side of steam generators.

Heat structures are employed in the model to represent the steam generator tubes, the cylindrical shell and spherical head, the cylindrical baffle separating the boiler and downcomer regions, and the internals of

the separator and steam dome regions.

It often is difficult to obtain a satisfactory agreement with steam generator full-power conditions. The difficulty arises because the heat transfer coefficient calculated on the outside surface of the steam generator tubes is based on general vertical-pipe correlations rather than correlations that account for the swirling flows present within the tube bundle region. The swirling flow pattern results because horizontal baffles in the boiler direct the flow back and forth across the tube bundle instead of allowing the flow to proceed axially (vertically upward) through the boiler. The effect of this discrepancy is that tube heat transfer is understated by the code, resulting in excessively high calculated primary coolant temperatures (the temperatures increase until the core heat is driven across the tubes). Since the source of the calculated error is understood (i.e., a general heat transfer correlation is not appropriate for this application), it is recommended that the modeler "adjust" the heat transfer on the outside of the tubes to remedy the discrepancy.

The recommended adjustment is to reduce the input heated equivalent diameter on the heat structure cards for the outer tube surface. It is recommended that instead of using the boiler region hydraulic diameter as the heated diameter that the minimum tube-to-tube spacing (the distance from the outside of a tube to the outside of its neighbor) be used. If the modeler decides not to follow this recommendation, it will be necessary to compromise an important parameter (such as using a lower secondary pressure, higher primary temperature, or lower feedwater temperature) to simulate full-power steam generator operation.

4.2.4 Primary Coolant Pump

A typical nodalization for the primary coolant pumps is again shown in Figure 4-1. Pipe 412 represents the pump suction cold leg. To ensure proper simulation of behavior in the loop seal region, cell 4 of this pipe is input as horizontal. This orientation allows the formation of horizontally stratified flows at the bottom of the loop seal. It is recommended that at least one horizontal cell be used for simulating loop seal phenomena. Cells 1, 2, 3, and 5 of pipe 412 provide sufficient vertically-oriented calculational cells for simulating the formation of liquid levels in the loop seal region and for simulating countercurrent flow limiting phenomena.

The pump discharge cold leg is modeled with branches 416 and 418 and pipe 420. This nodalization scheme has proven suitable for simulating horizontal stratification of fluid within the cold legs during loss-of-coolant accidents. The nodalization also provides for proper simulation of the fluid temperature distribution in the region; the junction between the branches is located such that the ECC injection site is correctly modeled. The user should remember that SCDAP/RELAP5 provides a one-dimensional representation of the flow and therefore is not capable of resolving thermal stratification of warm and cold liquids within the same pipe. Therefore, although the model may observe the bulk movement of cold ECC liquid toward the core, it is not capable of observing a stream of cold liquid residing in the bottom of the horizontal pipe. The high and low pressure ECC functions are modeled with pairs of time-dependent volumes and junctions. The ECC fluid injection temperature is specified by the time-dependent volume while the injection flow rate is specified as a function of the cold leg pressure by the time-dependent junction. This method allows simulating the head/flow characteristics of the centrifugal ECC pumps. A SCDAP/RELAP5 accumulator component is used to simulate the injection behavior of the nitrogen-charged

accumulators. This lumped-parameter component model mechanistically represents the tank and surge pipe hydrodynamics, heat transfer from tank wall and water surface, water surface vaporization to the gas dome, and gas dome condensation.

4.2.5 Pressurizer

Standard INEL nodalization for the pressurizer and its associated systems is shown in Figure 4-4. The pressurizer upper head is modeled with branch 340 and the pressurizer cylindrical body and lower head are modeled with 7-cell pipe 341. Generally, good agreement with experimental and plant data has been attained for slow and fast pressurizer insurges and outsurges with this nodalization. The surge line is modeled with 3-cell pipe 343.

The functions of the two power-operated relief valves (PORVs) are lumped into valve 344 and those of the three code safety valves are lumped into valve 346. The valves open in response to a significant primary coolant system overpressure. Operation of these valves, including their hysteresis effects, is simulated using the methods described in example 2 in Section 5.4.2 of Reference 2. The pressurizer spray system is modeled with single volumes 335, 337, and 339, and valves 336 and 338. The spray valves open in response to a mild primary coolant system overpressurization. Operation of these valves is simulated using logic similar to the PORV and code safety valves. The flow area of all valves is that necessary for delivering the rated flow capacity at the rated upstream pressure.

Heat structures are used to represent the cylindrical pressurizer shell and its spherical lower and upper heads, and the pressurizer surge line pipe wall. Heat structures are also used to simulate operation of the pressurizer heaters. Heater power is increased in response to an underpressurization of the primary coolant system pressure and is terminated if a low pressurizer level is sensed.

4.3 Break Nodalization

4.3.1 LOCA Modeling

A common code application is simulating a loss-of-coolant accident (LOCA) involving the full or partial rupture of a coolant pipe within an air-filled containment. These applications may involve experimental facility or full-scale plant LOCA simulations.

The need to adequately measure the break flow in an experimental facility usually dictates a complex experimental break geometry to provide clearance for instrumentation. The experimental facility break design often involves a side pipe leading from the broken pipe to a break orifice and valve. This complex design is best modeled in detail (i.e., the geometry upstream and downstream of the break should be modeled directly). Courant limiting considerations will be important in this application because the fluid velocities in the pipe leading to the break will be large. In most analyses of experimental facility LOCAs, benchmarking the break flow path has been necessary to compensate for uncertainties in the break path resistance and the code break flow models. The benchmarking process consists of using experimental data that characterize the break resistance to adjust the model flow losses for an adequate comparison between measured and calculated break flow. The adjustment is typically accomplished by adjusting the discharge coefficients on the

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Figure 4-4. Nodalization of pressurizer

break junction.

For full-scale plant applications, the break modeling process typically is more straightforward because the break geometry is simpler. Common LOCA applications for full-scale plants include the opening of circular breaks on the top, side, or bottom of a coolant pipe and the double-ended break of a coolant pipe. For

full-scale plants, breaks typically are assumed to open instantly. Figure 4-5 shows a recommended nodalization for modeling small and double-ended breaks in a coolant pipe. In both applications, the broken pipe is simulated with volumes 110 and 120.

Communicative break

Double-ended break

1-6977

Figure 4-5. Coolant system break modeling.

The small communicative break is simulated by adding single junction 950 and TMDPVOL 960 to the existing hot leg pipe model. The term "communicative" implies a portion of the normal flow through the pipe continues after the break is opened. Note that the break components may be installed on restart, at

the time of break opening, by including components 950 and 960 in the input stream. Break junction 950 should employ the abrupt area change option, simulating the combined flow losses associated with the sharp-edged area reduction from the pipe to the break plane and the sharp-edged expansion from the break plane to the containment. Junction 950 should employ the choking option and be initialized at a zero flow condition. The junction control flags provide the capability to locate the break on the top, side, or bottom of the pipe.

TMDPVOL 960 simulates the containment into which the break discharges; this implies the containment state is a boundary condition in the calculation. Frequently, a constant-pressure containment assumption is used. If the containment pressure response is known (e.g., as a function of the integrated break flow), then that response may be included in the simulation. For the double-ended break the nodalization includes two break junctions and two TMDPVOLs, as shown in Figure 4-5. Note that two TMDPVOLs are needed because no more than one junction may be attached to a TMDPVOL. As for the small break, the break junctions should employ the abrupt area change and choking options. Care should be used when specifying the initial break conditions. In the example shown, the initial mass flow rate for junction 950 should be positive at the same rate as at the inlet to volume 110; the initial mass flow for junction 970 should be negative and of the same magnitude.

In the above examples, the breaks also could have been implemented by including trip valve components at the break junctions in the original model rather than by adding them on restart. The valves would then be tripped open at the time of the break. Using this technique, the breaks may be opened at any time, not just at a restart point.

The containment condition specification is more important in some applications than in others. For small break applications, the primary coolant system depressurization typically is small, the pressure drop across the break remains large, and the break flow remains both choked and positive (into the containment). The containment conditions specified in this situation are not particularly significant to the simulation. The problem is only moderately sensitive to the containment pressure and is insensitive to its gas species. However, for large breaks, transitions between choked- and friction-dominated flow, and intermittent reverse flow from the containment are likely. In this case, it is important to adequately specify the containment conditions.

For some problems where the response of the containment is particularly important, it may be possible for an approximation of the containment behavior to be included as a part of the model. This could be accomplished by modeling the containment and the actual containment mass and heat balances. The code has not been extensively applied in this manner, however.

As a final note, the analyst should appreciate that critical break flow simulation represents an area of significant uncertainty. For some problems, this uncertainty may be a controlling factor for the outcome of the simulation. It is therefore recommended that care be taken to independently check code-calculated break flow results either against experimental data in similar geometries or against standard critical flow correlations.

A recommended procedure for correctly specifying the break area and discharge coefficient is linked to the break scenario, the break plane geometry, and whether any data exists for that geometry. Assuming a

discharge coefficient of 1.0 is valid, the following generalities are known concerning the SCDAP/RELAP5 critical flow model:

- For subcooled conditions, the SCDAP/RELAP5-calculated flow is too large. Often, it is found that a discharge coefficient of about 0.8 is needed to predict break flow in representative geometries containing break nozzles with length-to-diameter ratios less than 1.0.
- For low-quality saturated conditions, SCDAP/RELAP5-calculated mass flow rates are too low, often by as much as 20%, even when a discharge coefficient of 1.0 is used.
- Higher-quality saturated conditions at the break plane, such as are approximated by the homogeneous equilibrium model, are well-simulated with SCDAP/RELAP5.

4.3.2 Surge Line Modelling

One of the transient phenomena which is unique to severe accident analysis is failure of the pressurizer surge line. Surge line break modelling differs from most breaks because of the fact that the timing of the failure is not a boundary condition, but is calculated by the SCDAP/RELAP5 code. Modelling of the failure of a surge line can be performed in one of the following two methods.

METHOD 1:

- 1 Model the surge line walls with RELAP5 heat structures.
- 2 Identify surge line heat structures for the creep rupture calculation, on cards 21000110 and 21000000.
- 3 Specify the 'DCREPH' variable on 208 cards to allow it's use with a logical trip.
- 4 Specify a logical trip to be driven 'true' when any 'DCREPH' variables indicates rupture.
- 5 Model the surge line failure with a valve from the surge line to containment. This valve could be modelled as the communicative break shown in Figure 4-5, with the valve numbered 950. The valve should be initially closed, and open when the trip specified in step 4 is driven 'true'.

METHOD 2:

- 1 Model the surge line walls with RELAP5 heat structures.
- 2 Identify surge line heat structures for the creep rupture calculation on cards 21000110 and 21000000.
- 3 Perform a calculation to identify the time of the first creep rupture.
- 4 Restart the calculation with a break being defined for the time of creep rupture.

The flow area of the valve which models the surge line rupture, is probably plant and transient specific. Analysts at the INEL have surveyed a number of creep rupture failure experiments and have concluded that generally the failures showed longitudinal cracks that had opened to various degrees, from about 1/4 of the axial flow area to an area at least as large as the axial flow area. It should be noted that there is a wide scatter of experimental data in this area. In the model for surge line rupture for the Surry plant¹⁵, a rupture flow area equal to 1/3 of the pipe axial flow area was judged appropriate. This amounts to a valve diameter of approximately 1/2 of the surge line pipe.

5. PROBLEM CONTROL

5.1 Problem Types and Options

SCDAP/RELAP5 provides for four problem types: NEW, RESTART, PLOT, and STRIP. The first two are concerned with simulating hydrodynamic systems; NEW starts a simulation from input data describing the entire system; RESTART restarts a previously executed NEW or RESTART problem. PLOT and STRIP are output type runs using the restart plot file written by NEW or RESTART problems. NEW and RESTART problems require an additional option to be selected, STDY-ST, or TRANSNT.

A RESTART problem may restart from any restart record. A note indicating the restart number and record number is printed at the end of the major edit whenever a restart record is written. The restart number is equal to the number of attempted advancements and is the number to be used on Card 103 to identify the desired restart record. The record number is simply a count of the number of restart records written, with the restart record at time equal zero having record number zero. Quantities written in the restart plot records by default are noted in the input data description in Appendix A. User specified input can add additional quantities to the restart plot records in Appendix A.

PLOT and STRIP are output type runs. PLOT generates plots from data stored on the restart plot file. STRIP writes selected information from a restart plot file onto a new file. The new file consists of records containing time and the user selected variables in the order selected by the user. Data to be plotted or stripped are limited to that written in the plot records on the restart plot file.

5.2 Time Step Control

Input data for time step control consist of one or more cards containing a time limit, minimum time step, requested (maximum) time step, control option, minor edit plot/frequency, major edit frequency, and restart frequency. The time limit must increase with increasing card numbers. The information on the first card is used until the problem time exceeds the card limit, then the next card is used, and so on. In restart problems, these cards may remain or may be totally replaced. Cards are skipped if necessary until the problem time at restart is properly positioned with regard to the time limit values.

Several time step control options are available. Transfer of information between the hydrodynamic and heat conduction advancements is explicit, and the advancement routines are coded so that each advancement can use a different time step. Although not now used, each heat structure can also use its own time step. The time step control option is represented by a number between 0 and 15 that can be thought of as a four bit number. Entering zero (no bits set) attempts to advance both the hydrodynamic and heat conduction advancements at the requested time step. However, the hydrodynamic time step will be reduced such that the Courant limit is satisfied. If out of range water property conditions are encountered, the advancement will be retried with reduced time steps. The problem will be terminated if the time step must be reduced beyond the minimum time step. Each time step reduction halves the previously attempted time step. At the beginning of an advancement for a requested time step, a step counter is set to one. Whenever a reduction occurs, the step counter is doubled. When a successful advancement occurs, the step counter is reduced by one. When the step counter is decremented to 0, the problem has been advanced over one requested time step. Doubling of the time step is allowed only when the step counter is even, and the

step counter is halved when the time step is doubled. With no bits set, the time step is doubled whenever possible. At the completion of advancements over a requested time step, the next requested advancement is obtained and may be different from the previous requested time step if data from the next time step control card are used. If necessary, the new requested time step is reduced by halving until the new actual time step is < 1.5 times the last successful time step.

Setting bit one (entering 1, 3, 5, 7, 9, 11, 13, or 15) includes the features described for entering zero and in addition uses the halving and doubling procedures to maintain an estimate (mass error) of hydrodynamic truncation error within program defined limits. If an acceptable error is not reached and the next reduction would lead to a time step below the minimum time step, the advancement is accepted. The first 100 such occurrences are noted in the output.

If the second bit is set (entering 2, 3, 6, 7, 10, 11, 14, or 15), the heat structure time step will be the same as the hydrodynamic time step. The time step control for the hydrodynamics is determined by the status of the first bit as described above, and both the heat conduction and hydrodynamic advancements are repeated when a time step reduction occurs.

If the third bit is set (entering 4, 5, 6, 7, 12, 13, 14, or 15), the heat transfer will use the maximum time step and the hydrodynamics will use the partially implicit hydrodynamic and heat slab coupling. The time step control for hydrodynamics is determined by the status of the first bit, as described above.

If the fourth bit is set (entering 8, 9, 10, 11, 12, 13, 14, or 15), the hydrodynamics will use the nearly implicit hydrodynamic numerical scheme. The time step can be as large as five times the Courant limit for the TRANSNT option and ten times the Courant limit for the STDY-ST option. The time step control for hydrodynamics is determined by the status of the first bit, as described above.

Note that combinations of the effects of setting of the individual bits are achieved by setting bits in combination. For example, entering five (setting bits three and one) results in the combined effects described above for bits three and one. Older versions of SCDAP/RELAP5 would convert 2 to 3 to maintain compatibility. This is no longer done.

Entering zero is not recommended except for special program testing situations. If bit one is set, care must be taken in selection of the requested time step. Individually, the hydrodynamic and heat conduction advancements are stable; the hydrodynamic time step is controlled to ensure stability, the heat conduction solution with constant thermal properties is stable for all time steps, and the change of thermal properties with temperature has not been a problem. The explicit coupling of the hydrodynamic volumes and heat structures through heat structure boundary conditions can be unstable, and excessive truncation error with large time steps can occur. This has been observed in test problems. Entering three usually eliminates the problem, but often with unnecessary calculations. Judicious use of this option during dryout and initial rewetting may be cost-effective. Most LOFT and Semiscale simulations have entered three for the entire problem.

The minor edit, major edit, and restart frequencies are based on the requested time step size. A frequency n means that the action is taken when a period of time equal to n requested time steps has elapsed. The edits and the restart record are written at time zero and at the specified frequencies up to the

time limit on the time step control card. The maximum time step is reduced if needed, and the edits and restart record are forced at the time limit value. Actions at the possibly new specified frequencies begin with the first advancement with a new time step control card. A restart forces a major and minor edit to be written, and a major edit forces a minor edit to be written. Plot information is written to the internal plot and restart plot files whenever a minor edit is written. Note that minor edits are produced only if minor edit requests are entered; a plot file is written only if plot requests are entered; and plot and restart data are written on the restart plot file only if the file is requested.

An option used for program testing can force a plot print, minor edit, major edit, or combinations of these to be written at each advancement. Care should be used, since considerable output can be generated.

Major edits forced by the program testing option or the last major edit of the problem terminated by approach to the job CPU limit may not coincide with the requested time step. When this occurs, a warning message is printed that states that not all quantities are advanced to the same time points.

The control option is a packed word containing a major edit select option, a debug output option, and the time step control. The major edit select option allows sections of major edits for the hydrodynamic volumes and junctions, heat structures, and statistics to be skipped. The debug output option forces any combination of plot, minor edits, or major edit output to be written at each successful advancement rather than at just the completion of advancement over a requested time step. All options can be changed with each time step control card.

5.3 Printed Output

A program version identification is printed at the beginning of printed output and the first page following the listing of input data.

5.3.1 Input Editing

Printed output for a problem begins with a list of card images, one per line, preceded by a sequence number. The sequence number is not the same as the card number on data cards. Notification messages are listed when data card replacement or deletion occurs. Punctuation errors, such as an alphabetic character in numeric fields, multiple signs, periods, etc., are noted by an error message; and a \$ is printed under the card image indicating the column position of the error.

Input processing consists of three phases. The first phase simply reads and stores all the input data for a problem such that the data can later be retrieved by card number. Error checking is limited to punctuation checking, and erroneous data flagged during this phase nearly always causes additional diagnostics in later phases. The second phase does the initial processing of data. Input data are moved and expanded into dynamic arrays sized for the problem being solved, and default options are applied. Processing and error checking is local to the data being processed. That is, when processing a single junction component, no checking is performed regarding the existence of connected volumes. Similarly, hydrodynamic volumes connected to heat structure surfaces are not checked during processing of heat structure boundary data. At the end of this phase, all data cards should have been used. Unused cards are considered errors and are listed. Asterisks following the card number indicate that the card number was

bad, an error was noted in the card image listing, and that the number is the sequence number rather than the card number. The third phase completes input processing and performs requested initialization. Once the second phase has been completed, data specifying linkages between various blocks of data can now be processed and checked. Examples of error checking are junction connections made to nonexistent volumes, heat structure surfaces connected to nonexistent hydrodynamic volumes, specified thermal properties, and power data not entered. Solution of steady state heat conduction for initial temperature distribution in heat structures is an example of initialization.

Depending on the type of data, input is edited in only one of the last two edits or in both of them. Error diagnostics can be issued during either phase, even if no editing for the erroneous data is done in a phase. When an error is detected, possible corrective actions are disregarding the data, which usually leads to other diagnostics; inserting benign data; or marking data as being entered but useless for further processing. These actions are taken so that (other than errors on problem type and options) input processing continues despite severe errors. Regardless of errors, all data are given preliminary checking. Severe errors can limit cross-checking. Correcting input errors diagnosed in a submittal may lead to other diagnostics in a subsequent submittal, as elimination of errors allow more detailed checking. Except for exceeding requested computer time and printed output limits, any abnormal termination is considered a programming error and even exceeding computer time limits is prevented during transient execution. The final message of input processing indicates successful input processing or that the problem is being terminated because of input errors.

5.3.2 Major Edits

Major edits are an editing of most of the key quantities being advanced in time. The amount of output depends on the input deck and output options chosen by the code user. Output includes a time step summary, trip information, reactor kinetics information, one to four sections of hydrodynamic volume information, hydrodynamic volume time step control information, one or two sections of hydrodynamic junction information, metal-water reaction information, heat structure/heat transfer information, heat structure temperatures, reflood information, reflood surface temperatures, cladding rupture information, control variable information, and generator pump, turbine, and accumulator information. Major edits are quite lengthy, and care should be used in selecting print frequencies. Some sections of major edits can be bypassed through input data on time step control cards.

5.3.3 Cladding Oxidation and Rupture Information

If the user has activated the metal-water reaction model by using an icccg003 card, the cladding inside and outside oxide penetration depth is printed before the heat structure output. An example is where there are two stacks of eight heat structures. The second stack at Elevation 5 shows some inside cladding oxidation. This is because this elevation has ruptured. The pressure is the pressure inside the gap.

5.3.4 Minor Edits

Minor edits are condensed edits of user specified quantities. The frequency of minor edits is user specified and may be different from the major edit frequency. The selected quantities are held until 50 time values are stored. The minor edit information is then printed, 50 time values on a page, nine of the selected

quantities per page, with time printed in the leftmost column on each page. Minor edits can print selected quantities at frequent intervals using much less paper than major edits. Section 4 of Appendix A indicates how to request minor edits and what the user specified quantities represent.

5.4 Edits of SCDAP Heat Structures

The values of variables that describe the state of SCDAP heat structures are printed at the same times that major edits are performed for the RELAP5 calculations. The printout describes the temperature, deformation, and oxidation of fuel rods and control rods and the fission product release from fuel rods. The state of each SCDAP heat structure is printed in the order of its number identifier. In other words, Component 1 is printed first, then Component 2, and so forth.

5.4.1 Temperature Distribution

The first section of printout shows the temperature distribution of the SCDAP heat structure with a component identification number of 1. The fuel centerline and cladding surface temperatures are printed for each axial node. The temperatures have the units of degrees Kelvin. The elevation of each axial node in units of meters is also printed. The radial temperature distribution is shown at the elevation of the midplane of the SCDAP heat structure, and the temperature at each radial node is printed for the midplane elevation.

5.4.2 Cladding Radius

The next section of printout shows the inner and outer radii of the fuel rod cladding. This printout indicates the extent of cladding ballooning. The inner and outer radii are printed for each axial node. The leftmost radius that is printed applies to the lowest axial node and the rightmost radius applies to the highest axial node.

5.4.3 Cladding Oxidation

The next ten lines of numbers that are printed show the results of calculations of cladding oxidation. The oxidation variables are printed for each axial node, with the lowest axial node printed leftmost and the top axial node printed rightmost. The extent of the cladding oxidation is displayed by the line printing the fraction of cladding oxidation at each node. If the value of the fraction of cladding oxidation is equal to one, then the cladding is entirely a shell of ZrO_2 .

5.4.4 Meltdown

The next eleven lines of numbers show the extent of fuel rod liquefaction and meltdown. The extent to which liquefied cladding has dissolved the outer part of fuel pellets is shown by the line printing the inner radius of annulus of dissolved UO_2 . If no fuel dissolution has occurred, then the printed value of the inner radius is equal to the outer radius of the fuel pellets. The next line of numbers indicates whether a cohesive debris is located at each axial node. If the value of the indicator is 1 at an axial node, then liquefied material from a higher axial node has slumped down and solidified at the axial node. The solidified material has completely filled in the space between fuel rods and has the configuration of a hardpan. The thickness of the hardpan is shown in the next line of numbers. If the fractional height of

cohesive debris is 1.0, then the hardpan thickness is equal to the height of the axial node. The next several lines of printout show the relocation of fuel and cladding. Unless fuel has slumped below the fuel rod, the sum of the mass of UO_2 solidified at each axial node per rod equals the sum of the mass of UO_2 removed from each axial node per rod. The same rule holds for cladding. If the mass of zirconium removed from an axial node is greater than zero, then all the metallic zirconium has slumped from that node and oxidation no longer occurs at then node.

5.4.5 Fission Product and Aerosol Release

The next several lines of printout show the results of calculations of fission product and aerosol releases. The fission product inventory within the fuel is shown by the printout of matrix of numbers. The leftmost column of numbers applies to the lowest axial node (axial Node 1), and the rightmost applies to the highest axial node. Each row of the matrix shows the mass in units of kilograms per axial node per fuel rod of a certain species of fission product. The first row shows the inventory of xenon, the second row krypton, the third row cesium, the fourth row iodine, and the fifth row is the inventory of tellurium as calculated by the PARAGRASS⁴⁻¹ fission gas release model.

The balance of the rows show the inventory of aerosols for which the initial masses are input by the code user and for which the release is calculated by the CORSOR model.⁴⁻² The sixth row shows the retained mass of zirconium. If no aerosol release of zirconium has been calculated by the CORSOR model, then the mass of zirconium will equal the user input mass of zirconium per axial node. Similarly, the seventh row shows the inventory per axial node per rod for iron, the ninth row ruthenium, the tenth row a special isotope of zirconium, the eleventh row barium, the twelfth row strontium, the thirteenth row tellurium, the fourteenth row silver, the fifteenth row a special isotope of cesium, and the sixteenth row a special isotope of iodine.

The next line of numbers shows the inventory of fission products in the fuel cladding gap. The species are printed in the same order as for the printout of the fuel inventory. The leftmost species is xenon, the second leftmost species is krypton, and so forth. In addition, the mass of helium in the gap is printed as the seventeenth number.

The next line of numbers shows the cumulative release of fission products to the coolant. The mass is units of kilograms per rod is shown for each species. The species are printed in the same order as for the printout of the fuel inventory. In addition, the cumulative release of helium and hydrogen are shown as the seventeenth and eighteenth numbers respectively.

The code user can also obtain cumulative release of fission products to the coolant by subtracting the current inventory from the initial inventory. The difference in initial and current inventories is the amount released to the coolant in the case that the cladding has failed. If the cladding has not failed, then the difference is the amount released to the fuel cladding gap.

5.4.6 Cladding Ballooning and Rupture

The next three lines of numbers show the results of the cladding ballooning model. The first line shows the axial node at which the maximum amount of cladding ballooning is occurring. If the cladding has ruptured, it shows the axial node at which rupture occurred. The next line shows the cladding hoop strain at each axial node. The next line shows the pressure of gases in the fuel cladding gap. If the cladding has ruptured, the gas pressure is equal to the coolant pressure at that location.

5.4.7 Fuel Rod Power

The next three lines of numbers show the fuel rod heat generation rate. The first line shows the total heat generation rate (sum of prompt fission power, fission product decay heat, and actinide product decay heat) in units of W/m at each axial node. The next line of numbers is redundant data that are to be ignored by the code user. The third line shows the axially averaged linear heat generation rate.

The remaining lines of printout for the component are redundant and should be ignored by the code user.

5.5 Edits of Fission Product Transport Results

An edit of fission product transport results is included with major edits. This edit is not produced until fission products are released from SCDAP components unless the user initializes the fission product transport model with nonzero masses. The edit is ordered in numerically increasing order by the hydrodynamic system, then by the volumes within the system. Only hydrodynamic systems having fission product transport are listed.

For each volume, the following information is presented for each quality being tracked. The labels in the left column are the identifiers for the quantities:

- Src Fission product source to volume (kg/s).
- liq Fission product mass in volume carried by the liquid phase (kg).
- vap Fission product mass in the volume in vapor form (kg).
- tot Total fission product mass in both vapor and aerosol form in the volume (kg).
- nn Fission product in aerosol bin number nn (kg).

For volumes connected to heat structures, the bordering surface is identified and the following quantities are edited for each quantity being tracked.

- mc Vapor phase fission product mass condensed on heat transfer surface (kg).
- ma Vapor phase fission product mass absorbed in heat transfer surface (kg).
- mp Aerosol fission product mass deposited on heat transfer surface (kg).

5.6 SCDAP/RELAP5 Control Card Requirements

Very general procedures using the control language statements have been developed to simplify SCDAP/RELAP5 execution. Control card sequences used to execute SCDAP/RELAP5 on a CRAY using the UNICOS operating system are documented in Section 23, Appendix A.

5.6.1 Transient Termination

The transient advancement should not abort except for exceeding print line limits.

The user may optionally specify one or two trips to terminate a problem. Normal termination is from one of these trips or the advancement reaching the final time on the last time step control card. Minor and major edits are printed and a restart record is written at termination. Since trips can be redefined and new time step cards can be entered at restart, the problem can be restarted and continued.

Transient termination can also occur based on two tests on the CPU time remaining for the job. One test terminates if the remaining CPU time at the completion of a requested time step is less than an input quantity. The second test is similar, but the comparison is to a second input quantity and is made after every time advancement. The input quantity for the first test is larger than for the second test because the preferred termination is at the completion of a requested time step. In either case, the termination can be restarted.

Failure terminations can occur from several sources, including hydrodynamic solution outside the range of water property subroutines, heat structure temperatures outside of thermal property tables or functions, and attempting to access an omitted pump curve. Attempting to restart at the point of failure or at an earlier time without some change in the problem input will only cause another failure. Problem changes at restart may allow the problem to be successfully restarted. Requested plots are generated after a failure termination.

5.6.2 Problem Changes at Restart

The most common use of the restart option is simply to continue a problem after a normal termination. If the problem terminated because of approaching the CPU time limit, the problem can be restarted with no changes to information obtained from the restart file. If the problem stopped because the advancement time reaching the time end on the last time step card, new time cards must be entered. If the problem was terminated by a trip, the trip causing the termination must be redefined to allow the problem to continue. Thus, the code must provide for some input changes for even a basic restart capability.

The ability to modify the simulated system at restart is a desirable feature. The primary need for this feature is to provide for a transition from a steady state condition to a transient condition. In many cases, simple trips can activate valves that initiate the transient. Where trips are not suitable, the capability to redefine the problem at restart can save effort in manually transcribing quantities from the output of one simulation to the input of another. One example of a problem change between steady state and transient is the use of a liquid filled, time dependent volume in place of the vapor region of a pressurizer during steady state. The time dependent volume provides the pressurizer pressure and supplies or absorbs water from the

primary system as needed. The time dependent volume is replaced by the vapor volumes at initiation of the transient. This technique avoids modeling the control system that maintains liquid level and temperature during steady state calculations when they are not needed in the transient.

Another reason for a problem change capability is to reduce the cost of simulating different courses of action at some point in the transient. An example is a need to determine the different system responses when a safety system continues to operate or fails late in the simulation. One solution is to run two complete problems. An alternative is to run one problem normally and restart that problem at the appropriate time with a problem change for the second case.

The problem change capability could also be used to renodalize a problem for a certain phase of a transient. This has not been necessary or desirable for problems run at the INEL. For this reason, techniques to automate the redistribution of mass, energy, and momentum when the number of volumes changes have not been provided.

The current status of allowed problem changes at restart in SCDAP/RELAP5 are summarized below. In all instances, the problem definition is that obtained from the restart tape unless input data are entered for deletions, modifications, or additions. The problem defined after input changes must meet the same requirements as a new problem.

Time step control can be changed at restart. If time step cards are entered at restart, all previous time step cards are deleted. New cards need only define time step options from the point of restart to the end of the transient.

Minor edit and plot input data cards can be changed at restart. If any of the minor edit cards are entered, all previous cards are deleted. New cards must define all desired minor edit quantities. The plot request data cards are handled in the same manner.

Trip cards can be entered at restart. The user can specify that all previous trips be deleted and can then define new trips. The user can also specify that the previously defined trips remain but that specific trips be deleted, be reset to false, be redefined, or that new trips be added.

Existing hydrodynamic components can be deleted or changed, and new components can be added. An especially useful feature is that the tables in time dependent volumes and junctions can be changed. If a component is changed, all of the cards for the component must be entered.

Control system components can be deleted, changed, or added.

Heat structures, general tables, and material properties can also be deleted, changed, or added. If these are changed, all of the cards for heat structures, general tables, and material properties must be entered.

Reactor kinetics can be added or deleted on restart. A complete set of reactor kinetics data must be input, i.e., individual sections of kinetics data may not be specified as replacement data.

Problem Control

In summary, all modeling features in SCDAP/RELAP5 can be added, deleted, or changed at restart.

6. INSTALLATION

At the INEL, the RELAP5, SCDAP/RELAP5, and Athena programs are maintained in common source files with procedures available to separate the codes. Often, multiple versions of the codes are supported. These installation notes are intended to describe the installation of the SCDAP/RELAP5.

6.1 Transmittal Contents

A typical transmittal consists of a transmittal letter, code manuals, a media containing the code, and a record showing the writing of the media. The usual media is a magnetic tape containing a 'tar' file consisting of several compressed files. (The tar program is a Unix utility that gathers multiple files or directories of files into one file and can later extract all or selected files from the one file.) These installation notes assume such a transmittal. Information concerning other media are contained in the transmittal letter. The type of media and the recording details should have been arranged before code transmittal based on the recording capabilities at the INEL and the reading capabilities at the requesting facility.

6.2 Machine and Operating System Considerations

The SCDAP/RELAP5 computer program should execute on a wide variety of scientific computers with minimal modifications. In particular, the code should execute on all 64-bit computers, that is computers using 64 bits for both floating point and integer arithmetic. Sixty four bit computers include CRAY-1, CRAY/XMP, CRAY/YMP, CRAY-2, and CDC-NOS-VE machines. It should also execute on the multitude of 32-bit computers that range from workstations to supercomputers and that have 32-bit integer arithmetic but provide 64-bit floating point arithmetic through double precision operations. Applicable 32-bit computers include Decstation, HP, IBM mainframe, Ibmisc, Sun, Apollo, and Vax.

The term code portability should be defined. Here it means that a common source file is maintained for all computers, and through one or two stages of precompiling, the code is made suitable for a particular computer. Some would dispute this definition, maintaining that a code is portable only if the source file is directly applicable to different computers. Some would further maintain that such portability can be achieved if standard Fortran-77 is used.

The first version of SCDAP/RELAP5 was written before Fortran-77 was available. Features of Fortran-77 have eliminated several hardware dependencies. These include use of generic functions, character variables and statements, and open statements. The prior packing and unpacking of small integer and logical quantities was highly machine dependent. Most of the packing and unpacking has been removed, and the remaining packing and unpacking of mostly one bit quantities uses word length independent techniques. The bit handling functions used are from a Mil-spec standard and many computers have implemented that standard. For systems that have not implemented the standard, simple one line statement functions and in some cases an ishft function in the environmental library provides the functions. Many of the machine dependencies are needed to overcome deficiencies in the Fortran standard. For example, the standard does not allow specification of variable range and precision requirements. Unless modified, the Fortran for a 64-bit machine in single precision would use 64 bits while the 32-bit machine would use only 32 bits. Additional statements are needed to indicate double precision

on the 32-bit machine. Some compilers have compiler options for automatically converting to double precision, but that is nonstandard and not available on all systems. Other sources of nonstandard coding is the need of some subroutines to know the smallest and largest floating point numbers, the smallest floating point increment, and the ability to access the radix, fraction, and power part of a floating point number. The next standard should remedy these, but until then, precompilers are used to handle hardware and software differences.

The SCDAP/RELAP5 code is no longer supported for the CDC 60-bit machines such as the Cyber-6600 and Cyber-176. The small memory of those machines and the larger memory requirements of the current versions lead to implementation difficulties. Also these machines are rapidly being phased out of service.

At the INEL, SCDAP/RELAP5 executes on a CRAY/XMP-24 using the Unicos operating system. The program is maintained on that machine using the Update program for source maintenance. Scripts for the installation of SCDAP/RELAP5 on the INEL CRAY machine using the Update program are on the transmittal tape. SCDAP/RELAP5 has also been installed on CDC-NOS-VE machines, IBM mainframe machines, several types of Unix based workstations including Decstations, Vaxstations, Apollo workstations, Sun workstations, IBM-Risc workstations, and even a personal computer. Scripts for a Unix based installation using the make utility are on the transmittal tape. These scripts do not use the Update program and should serve as a base for installation on any Unix machine including the CRAY. Even with the use of the Unix system on many computers, it still is not possible to easily write installation scripts for all Unix machines since there are differences in the Fortran compiler's name and options and the library maintenance program's name and options. The scripts shown here are an attempt at a common script and use "C-shell" if ...endif logic to select machine specific options. Much of the machine dependent commands merely set shell variables, which are passed to the part of the script common to all machines. Options are provided for several machines, and the scripts have been tested on several computers.

The current versions of SCDAP/RELAP5 have been installed on CDC-NOS-VE and IBM mainframe computers but the scripts or control language for installation on these machines are not available from the INEL. Since the SCDAP/RELAP5 staff does not use these computers, it is difficult to obtain the skill to develop efficient installation scripts. We request that recipients of the code that have developed such procedures to document them for others' use. Hopefully, from the descriptions of the scripts in these notes, a user knowledgeable of his operating system will be able to install the code.

6.3 Transmittal Tape Files

Listed below are the files needed for installation of SCDAP/RELAP5. Additional files may be present on the transmittal tape and additional files would usually be additional sample problems and printed output. The first name is the file name used in the scripts. The scripts assume that the files are transferred to disk using the first file names and that the files are stored in one directory. The second name is the local file name used when writing the transmittal tape on a Cyber machine. The dayfile from the job creating the tape is usually included in the transmittal. In a change from previous transmittals, the file names are now generic, that is they are not coded to indicate the code version, so that generic scripts can be used.

1. selap.s SELAPS SCDAP/RELAP5 source in Update source format.

2. envrl.s	ENVRLS	Environmental library source in Update source format.
3. matpro.s	MATPROS	Material property library source in Update source format.
4. usplit.f	USPLITF	Utility program for separating the individual files packed into a common file.
5. select.f	SELECTF	Precompiler program to select the appropriate code for a particular computer and operating system.
6. cnv32.f	CNV32F	Precompiler program to convert code for 32-bit machines.
7. instls	INSTLS	Master script for installation of RELAP5 using the Update program.
8. dinstls	DINSTLS	Master script for installation of RELAP5 on Unix systems and using the make utility.
9. dutilty	DUTILTY	Script to compile and load usplit, select, and cnv32 programs.
10. goodies	GOODIES	Packed file containing other scripts, makefiles, and text files for installing RELAP5.
11. indecks	INDECKS	Packed file containing input decks.

The usual transmittal tape format consists of the files above, written in a format agreed upon by the recipient and the INEL. This normally requires some individual processing for each file. An alternate tar format is available for Unix machines. All the files are gathered into one file by the command

```
tar cv *
```

where it is assumed that the transmittal files were the only files in the directory. When this file is transferred to the machine for the new installation, the command below retrieves the individual files.

```
tar xv
```

Most of the files written in a tar file will usually be compressed and have a .Z suffix. To uncompress the files enter

```
uncompress *
```

The compressed files with the .Z suffix will now be uncompressed and will no longer have the .Z suffix.

6.4 Upper and Lower Case Considerations

The magnetic tape is in ASCII with both upper and lower case characters. At the INEL, the Fortran source files are maintained and compiled in lower case. Accordingly, the required alphabetic input (e. g., snglvol specifying a hydrodynamic component type) must be in lower case. User supplied names may be in any combination of lower or upper case. Lower case is used for convenience in maintaining source and input decks since editor commands use lower case extensively. Many format statements, especially those writing sentences, use upper case for standard capitalization.

Most installations have utilities and editors that can switch files between upper and lower case. The Fortran and input decks can be converted to upper case if desired or needed. One C coded subroutine (readnonb) in the environmental library used for CRAY Unicos installations and the scripts should be used as transmitted. If the deck names are capitalized, the list of .F files in the Makefiles should be changed to upper case letters.

6.5 Installation Procedures

Two installation scrips are maintained, one based on the Unix make utility, the other based on the update utility.

6.5.1 Make Based Installation

The next subsection describes loading the transmittal files assuming that the transmittal media is a magnetic tape containing a 'tar' file written by the Unix tar utility. The following subsection states the requirements to be met when unloading the code from a different media or format. The third section describes the installation after the code information is extracted from the media.

6.6.1.1 Tar File Installation. The transmittal tape was written on a workstation using a command similar to:

```
tar cv selp8_Version
```

On some workstations, the tar command is used but, in addition, a dd command may actually write the tar file. The command above contains a version indicator. That number will be used in this description but the actual version number indicated in the transmittal letter or on the tape label should be substituted.

To read the tape, execute a command similar to:

```
tar xv
```

or

```
tar cvf tape_name selp8_Version
```

The second form is used if the desired tape unit is not the defined unit. If a dd command was used to write the tape, a dd command will also be needed to read the tape. The actual command to read the tape will be written on the tape label inside the tape container. The tar command reading the tape will create a selp8_Version directory within the same directory from which the tar command is issued. The selp8_Version directory will contain this README file and three subdirectories, selp8rt, print, and Verrun. The selp8rt subdirectory contains ten or eleven files in compressed format containing the program source, installation scripts, and sample input. There will be only ten files if the SCDAP option is not included in the transmittal.

Assuming no directory change since the tar command to read to tape, transfer to the selp8rt directory by executing the command:

cd selp8rt

The following command uncompresses the code

uncompress

6.6.1.2 Non Tar Format Transmittal. The ten or eleven files containing the code must be unloaded from tape into a directory containing only the code files. The procedures for unloading the file depend on the media and software used to record the files. Often there will be separate processing for each file. The transmittal letter should include enough information to effectively transfer from the media to the directory on disk.

6.6.1.3 Installation From Disk Files. This description assumes that the current working directory is the one containing the ten or eleven files containing the code. The following commands are then executed:

```
chmod 755 !$
ln * !$
cd !$
dinstls lcray | relap lnonpal >&dinstls.out &
      ldecrisc lnpa |
      lhp |
      libmrisc |
      lsun |
      lsunnew |
      lsgi
```

The mkdir command creates an additional subdirectory, the chmod command sets permissions for the subdirectory, and the ln command links all the files in selp8rt into selp8r. The cd command transfers to the selp8r directory, and the dinstls command installs the code in that directory. This process of using an additional directory simplifies recovery in case of troubles, since a rm -r * command executed in the selp8r directory removes all files created by the ln and dinstls commands without destroying the original files in selp8rt. After correcting the problem, the ln and dinstls commands can be retried.

The second column shows some of the machines on which this transmittal should execute. This version is capable of executing on other machines as well.

If the NPA subroutines are available, specifying NPA will load the NPA subroutines. To specify the source of the NPA libraries, execute the following command before executing the dinstls command.

```
setenv NPA directory_containing_NPA_libraries
```

The dinstls script through the use of lower lever scripts builds utilities, environmental library, thermodynamic property files, material property library, SCDAP/RELAP5 libraries, an executable, and run several sample problems that are routinely run as a new version is created.

The scripts do not destroy any transmitted files, but they do move some files to subdirectories. If something goes wrong, the script cannot simply be restarted. If the problem can be fixed, you can remove all files and subdirectories in the directory used for the installation, relink from the other directory, and reissue the `dinstls` command.

Transmittals have been tested on a Decstation-5000 (`decrisc`), an HP workstation (`hp`), an Ibmisc-6000 (`ibmrisc`), and a Sun workstation (`sunnew`). The `print` subdirectory contains four additional subdirectories: `decrisc`, `hp`, `ibmrisc`, and `sunnew`. Each subdirectory contains output files in compressed format from the installation on a machine with the same name as the subdirectory. These files can be viewed or printed after uncompressing. The files with suffix `.out` contain output from the `dinstls` script. Print files from execution of sample problems have a `.p` suffix and the strip files have a `.st` suffix.

The results are slightly different in some of the sample problems. All machines use IEEE floating point arithmetic, but the handling of underflow may be different on the machines (probably because of software differences). The cause of the differences has not been identified. A diagnostic message has been noticed during execution with the IBMisc version. A comparable message was not obtained on the Decstation and the results appear satisfactory. The warning messages concerning floating point arithmetic on the Sun workstation results from using an option that causes aborts on illegal floating point operations.

6.5.2 Installation Problems

Methods to resolve installation problems will be described in this section. It is generally expected that the resolution of specific problems would be inappropriate here, unless those problems are generic to all users. Those that encounter problems during installation of SCDAP/RELAP5 should first read the `README` file, which was included with the transmittal. If that fails, the users is encouraged to contact the code developer's at the INEL.

The most frequent difficulty when installing SCDAP/RELAP5 is the failure of the fortran optimizer. The first step most code developer's will take is to repeat the installation with the optimization reduced for the offending routine. Refer to "Recompilation of Specific Routines" on page 9 for additional details.

6.5.2.1 C Language Difficulties

The most prevalent source of problems during the installation of those portions of the code which are written in the C language, is the lack of an ANSI standard compiler. This has been a particular problem for Hewlett Packard workstations, which default to a non-ANSI standard compiler which is insufficient for installation of SCDAP/RELAP5. The resolution for this difficulty is the installation of the freeware GNU C compiler, called 'gcc'. The source for this compiler, along with the prerequisite bison parser generator, is available at a number of sites, and contains installation instructions. After installation of 'gcc', it is necessary to modify the transmittal files to make use of the new compiler, rather than the default. This is done in the following manner.

- Make a working copy of the installation files.
- Within the working copy of the installation directory, make a temporary directory, called 'tmp'.
- Change to the 'tmp' directory (`cd tmp`).

- Unpack the installation support files (tar xf ../install.tar).
- Edit the installation script 'denvrl'
- locate that portion of the script which is activated for the machine to code is to be installed on.
- replace the 'cc' commands with 'gcc', and replace the option '-aA' with '-ansi' if necessary.
- remove the installation support files install.tar (rm ../install.tar).
- Create a new installation support file (tar cf ../install.tar).
- Proceed with the installation.

6.6 Utility Routines

This section describes several utility routines and scripts used in installation and maintenance.

6.6.1 Update Program

Complete documentation for the Update program can be found in CDC and CRAY publications. The following is a brief overview of the Update utility.

The Update program is a source code maintenance program that maintains source files as decks and comdecks. Decks are usually main programs, subroutines, and functions, and comdecks are common sections of code that can be included into a deck being prepared for compilation through '*call comdeck' statements. The decks and comdecks are maintained in a file called an oldpl. An oldpl is created during a creation run by reading an input file where the beginning of comdecks and decks are marked by *comdeck name and *deck name cards. The source files in this transmittal are in the proper format for input to Update. Once the oldpl has been created, modifications to decks and comdecks can be made, new oldpl's can be created containing the modifications, and decks can be extracted for compiling. A useful feature is that if a comdeck (usually containing a common block) is changed, each deck referencing that comdeck can be automatically extracted for compilation.

Another useful feature is that compile time options can be handled by Update. Define variables can be set defined or undefined. These define variables have no relation to the variables in the source code maintained by Update. When a statement *if def,name,n is encountered in a deck or comdeck, the following n lines of code are included in the compile file if name is defined or excluded if name is undefined. If a statement *if -def,name,n is encountered, the minus sign indicates a reversal of the include/exclude logic. If the number of lines is missing, lines up to an *endif card are included or excluded. Nesting of *if def statements is allowed. The CRAY version of Update does not permit the number of lines option, and only *if def and matching *endif statements are used. Define variables are defined by entering *define name statements. The CRAY version also allows define variables to be defined in the control statement.

6.7 Select Program

The action of the Update program in excluding undefined options leads to maintenance difficulties. When looking at a compilation listing of a particular version derived with Update, there is no indication on the listing of the alternate versions. The select program implements logic similar to the Update program using \$if [-]def,name[,n] and \$endif logic except that excluded cards are not omitted but instead are marked as comment cards by placing an asterisk in column one. Statement numbers are limited to four digits to ensure room for the asterisk. Most compilers recognize an asterisk in column one as a comment card and the select program can be easily modified to use c for the compilers that do not. The \$ in the \$if def and \$endif statements are also changed to * to mark them as comment cards. The result is that options marked with the \$ logic are always listed. The define variables for select are defined by \$define name statements placed at the first lines presented to select.

Most options are selected using the \$ logic. The * logic is usually limited to cases where an entire deck is to be included or omitted.

If the Update program is used, the *if def logic would have been performed by Update and the information passed to the select program would not have *if statements. The Update program also processes *call name statements by replacing in the output file the *call name statement with the text lines headed by *comdeck name. Thus when Update is used, the select program does not encounter *if def or *call name statements. If Update is not used, select handles these statements. The *if def statements are processed in the same manner as \$if logic. The *call name statements that Update uses to include comdecks are converted to include 'name.h' statements. Many compilers provide for the include statement to incorporate common coding. The significance of the .h suffix is explained later. Note that when Update is used, the Update program copies the common information stored in the comdecks into the decks. When update is not used, the inclusion of comment text is delayed until the compilation step.

The select program is transmitted in the select.f file.

6.8 Usplit Utility

The usplit utility program is transmitted in the usplit.f file. This program reads a source file suitable for input to the Update program and writes each comdeck beginning with *comdeck name as a separate file name .H. Similarly, each deck beginning with *deck name is written as a separate file name .F. The *comdeck and *deck lines are the first records in the separated files. Text beginning with *hlpdeck name is written as file name and the *hlpdeck is not included in the separate file.

6.9 CNV32 Program

The source for this program is cnv32.f. This program converts the source file, which is oriented to a 64-bit machine to a 32-bit machine version. Changes include: real statements without a length designation are changed to real*8; selected integer and logical variable references with subscripts have 1 or 2 added as the first subscript so that they occupy the same space as real*8 floating point variables; and single precision floating point literals are changed to double precision literals.

The cnv32 program reads a file, mlist, which contains a list of integer and logical global variables that must be converted to occupy the same space as real*8 variables. Local variables needing the conversion are indicated by a list of `"*in32 name"` statements and terminated `"*in32end"` in the source. The mlist file needed for processing of the selap file is packed in the file goodies. No mlist file is needed for processing the envrl and matpro files.

6.10 Compilation of Usplit.f, Select.f, and CNV32.f

The usplit, select, and cnv32 programs are written in standard Fortran and have compiled, loaded, and executed successfully on most computers. On the Masscomp computer, the system removed the first column of the output file and to overcome this, an extra blank was introduced at the beginning of each line of output. This change is indicated in comment cards in the source files.

6.11 Recompilation of Specific Routines

There are several scripts which are not used directly in an installation but are used for program modification and debugging and serve to illustrate some features of the installation.

Suffixes are frequently used as part of Unix file names. For example, the usplit program separated comdecks and decks into files with .H appended to comdeck names and .F appended to deck names. Thus comdeck contrl would be in file contrl.H and deck relap5 would be in file relap5.F. The .H and .F are examples of suffixes. Fortran compilers require that the deck to be compiled have a suffix .f and will generate an object deck with .o as the suffix. In this installation, executable files obtained through compilation and loading have a .x suffix.

The doith, doithf, and doithfp scripts are called by

doith comdeckname

doithf deckname

The \$1 field of the doith script is a substitutable parameter and is equal to the comdeckname field in the doith command. In the first appearance in the script, the suffix .H is appended and in the second appearance .h is appended. The cat (standard Unix) utility creates a "standard output file" consisting of the define file concatenated to the comdeckname.H file. The define file contain lines of \$define name statements and the names appearing in the define statements are set as defined. This means that in \$if def,name or *if def,name statements, if the name appears in a \$define name statement, name is defined; if the name does not appear in a \$define name statement, the name is undefined. In the scripts, the define file is automatically generated based on the machine specified and the options selected. The define file generated for a Decstation for SCDAP/RELAP5 and no NPA linkage is

```
$define decrisc
$define doe
$define erf
$define fourbyt
$define impnon
$define in32
```

```
$define unix  
$define selap  
$define nonpa
```

The pipe operator, |, indicates that the standard output of the cat command is to be entered directly (piped) as the standard input of select. Thus the input to select is the define file defining the compile time options followed by the comdeck to be processed. Similarly, the standard output of select is piped to cnv32. The standard output of cnv32 is written as comdeckname.h. The resultant file is the comdeck converted for 32-bit machines. These .h files are read by the compiler when processing includes 'comdeckname.h' files generated by the select program from *call statements. The doith script can be viewed as a means of converting .H files to .h files.

The first line of the doith script is similar to the doith script except that subscripts .F and .f are used. The second line calls the f77 compiler to generate the object file as deckname.o. The doith script can be viewed as a means of converting .F files to .f and .o files.

The compiler options include generating symbol tables for debugging. Loading the symbol tables for the entire program when debugging can be very time consuming and the initial installation is done without symbol tables. The doith script is used to compile selected decks with symbol tables as needed for debugging.

6.12 Make Utility

The make program is a Unix utility used to maintain programs. It generates "targets" using an input file describing dependencies between files and rules for generating files from other files. The input files are generally called makefiles and seven makefiles are packed in the goodies file for the Unix type of installation. Except for the list of files to be processed, the makefiles are very similar.

The default target is a library. The dependency statement states that the library file is dependent on the .o files and the rule for creating the library file from the .o files is to use the ar program. The make program checks the creation dates of the target file and the .o files. If one or more .o files do not exist or are newer than the library file, the rule for generating the library must be executed. But the .o files are themselves targets and are dependent on .F and .h files. Similarly, .h files are dependent on .H files. The make program builds a graph of dependencies, and from the creation dates of the files, executes rules as needed to obtain the target file. The .H files are converted to .h files and the .F files are converted to .f and .o files using commands similar to those in the doith and doith scripts. In an installation, all target files are missing and must be generated. In maintenance applications, an editor is typically used to modify one or more .H and .F files. From the creation dates of the corresponding .H and .h files, only modified .H files will be processed. The modified .F files will be processed but all .F files referring to the modified .H files will also be processed since the dependency rules include information about the *call comdeck statements (or the equivalent include statements after select processing). The .F decks not modified or not having references to modified common decks are not processed.

Included on the transmittal tape is the makefile for the environmental library. This and the other makefiles are ready for installation. If during modification, decks or comdecks are added or deleted, the makefile will need modification. This can be done manually, but most of the changes can be done

automatically. Following the `SRCS = \` line is a list of .F files. The user should update that list by adding or deleting decks (with .F appended). No characters, not even blanks may follow the \ which indicates continuation to the next line. No other changes are necessary. Execution of `make -f makefilee Deps` will update the dependency lists. The list of .o files is directly obtained from the .F list. By searching the .F files for *call statements, the list of .H and .h files and the dependencies between .o and .h files are determined.

To repeat, this step defining the dependencies is not needed for installation. This step has been done at the INEL, and the makefiles as transmitted are ready for installation. This step is needed only if decks or comdecks are added or if decks have *call name statements added or deleted.

6.13 Define Options Used in SCDAP/RELAP5

The following define options are used in the SCDAP/RELAP5 source, the environmental source, or the material property source. The define options selected can be used in processing all three source files. Following the table, each option is described.

apollo	athena	blkdtabufr	cb205	cdc	cdc60
cdccra	cos	cray	ctime	ctss	decrisc
doe	erf	fourbyte	hp	ibm	ibmrisc
ieee	imprnon	in32	lcm	mass	mmfld
nopen	npa	plots	selap	sun	timed
unicos	unix	vax	blkdta		

Data statements that load data into common blocks have been gathered into routines that are either block data routines or subroutines containing only a return statement as an active statement. If the blkdta option is undefined, the routines are subroutines and one call to each subroutine is made. The subroutine when called simply returns. The advantage of this over block data is that the subroutine reference will force loading of the subroutine from a library while block data routines are more difficult to load from a library. Loading data into common blocks from a subroutine is not standard but most compilers allow it. Leaving the blkdta option undefined is recommended but defining blkdta can be done if the compiler requires use of block data routines. Some special considerations to load the block data object decks may be needed.

bufr- If the bufr option is defined, buffer in and buffer out statements are used to read and write the rstplt file and the unformatted form of the strip file. The software must also support a record concept and the length function that returns the size of a record read. The bufr defined option is recommended for CRAY-1, CRAY-XMP, and CDC-NOS-VE machines. It is not recommended for the CRAY-2 machine. When the bufr option is undefined, unformatted read and write statements are used. These are standard Fortran statements that can be used with any machine, but may be slower than the buffer in and buffer out statements. In the typical read or write statement, `write (rstplt) len, a(i),i=1,len)`, the implied do loop was not treated as a block write.

cdc - This option is defined for CDC-NOS-VE machines. It no longer signifies CDC-6600 or

7600 machines since those are no longer supported.

cdccra - This option is defined for CDC-NOS-VE machines or CRAY machines.

cos - This option is defined for the COS operating system on CRAY machines.

cray - This option is defined for CRAY machines.

ctss - This option is defined when using the CTSS operating system on CRAY computers.

fourbyt - When the bufr option is undefined, this option selects whether the reads and writes of restart information uses eight or four byte words. This option should be undefined when bufr is defined or when bufr is undefined but the machine uses 64 bits for both integer and floating point data. Thus CRAY and CDC-NOS-VE should have fourbyt undefined. The RELAP5 portion of the code writes restart records that are multiples of eight byte words and the fourbyt option may be undefined on many 32-bit machines. The RELAP5 code executed on IBM Decstation, and Vax machines with fourbyt undefined. The SCDAP portion does require the fourbyt option on 32-bit machines. The safest option for 32-bit machines is to define fourbyt. Compilers should treat the reads and writes as block operations and there should be no difference in execution time.

hp - This option is defined for HP machines.

ibm - This option is defined for IBM mainframe machines.

ibmrisc - This option is defined for Ibmrisc machines.

imponon - Many compilers allow an implicit none statement. This statement when entered in a routine removes all implicit typing of variables and requires each variable and function to be typed. Multiple explicit typing is also considered an error. Additionally, the Cray compiler requires subroutine names called in a routine to appear in external statements. This provides an automatic level of checking by the compiler to avoid inadvertent multiple use of variable names during code development. All comdecks defining common blocks or dynamic blocks have explicit typing. Some subroutines have been modified such that all local variables are explicitly typed. When imponon is defined, an implicit none statement is activated in those subroutines. Eventually, all routines will be explicitly typed. Although most important for code developers, imponon is recommended to be defined for all systems allowing implicit none statements. The IBM mainframe compiler does not allow implicit none and imponon should be undefined for that machine.

in32 - This option is defined for 32-bit machines, that is, machines that can perform 64-bit floating point computations but only 32-bit integer operations. This option is needed for Decstation, HP, IBM, Ibmrisc, Masscomp, Macintosh, and Vax computers.

lcm - This option once referred to the use of LCM storage on Cyber-176 computers. Those computers are no longer supported, and this option should be undefined. It has been left in the environmental library in case support of multiple levels of memory is needed in the future.

mass - This option should be defined for the Masscomp computer.

npa - This option should be defined when linkage to the Nuclear Plant Analyzer (NPA) is

desired. This option should be undefined unless the NPA system has been installed.

plots - This option when defined enables the plot capability contained within SCDAP/RELAP5. The internal plot capability has not been made compatible, is not currently operational on any computer, and should be disabled by having this option undefined.

selap - This option selects between the RELAP5 code and the SCDAP/RELAP5 code. This option when undefined selects the RELAP5 code and when defined selects the SCDAP/RELAP5 code. Some RELAP5 only transmittals will have all SCDAP subroutines removed and some will also have all interface coding removed. For SCDAP/RELAP5 transmittals, this option when undefined selects only the RELAP5 capability, and when defined selects the integrated SCDAP/RELAP5 capability. The SCDAP/RELAP5 code when given RELAP5 only input data generates the same results as if the RELAP5 only code was installed.

unicos - This option is defined for the CRAY computers operating under Unicos.

vax - This option is defined for Vax computers.

6.14 Installation Scripts

The scripts are highly repetitive and consist mostly of if, elseif, and endif statements, which are based on the input arguments define symbols. The symbols primarily define compiler names and options which are not standard on various Unix machines. The common part of the scripts execute commands making use of the symbols to handle system differences.

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Appendix A

Input Requirements

CONTENTS

A.1	INTRODUCTION	A1-1
A.1.1	Control Format	A1-1
A.1.2	Data Deck Organization	A1-1
A.1.3	Title Card	A1-2
A.1.4	Comment Cards	A1-2
A.1.5	Data Cards	A1-2
A.1.6	Continuation Cards	A1-3
A.1.7	Terminator Cards	A1-4
A.1.8	Sequential Expansion Format	A1-4
A.1.9	Upper/Lower Case Sensitivity	A1-5
A.1.10	Data Card Requirements	A1-5
A.2	MISCELLANEOUS CONTROL CARDS	A2-1
A.2.1	Card 1, Developmental Model Control	A2-1
A.2.2	Card 100, Problem Type and Option	A2-5
A.2.3	Card 101, Input Check or Run Option	A2-6
A.2.4	Card 102, Units Selection	A2-6
A.2.5	Card 103, Restart Input File Control Card	A2-6
A.2.6	Card 104, Restart-Plot File Control Card	A2-7
A.2.7	Card 105, CPU Time Remaining and Diagnostic Edit Card	A2-8
A.2.8	Card 110, Noncondensable Gas Species	A2-9
A.2.9	Card 111, Metal Species	A2-9
A.2.10	Cards 115 and 116, Noncondensable and Metal Species Mass Fractions	A2-9
	A.2.10.1 Card 115, Initial Mass Fraction for Each Noncondensable Gas Type	A2-9
	A.2.10.2 Card 116, Metal Mass Fractions.....	A2-9
A.2.11	Card 119, Gravity Constant and Fixed/Moving Option	A2-10
A.2.12	Cards 120 Through 129, Hydrodynamic System Control Cards	A2-10
	A.2.12.1 Hydrodynamic System Card for Fixed Problem	A2-11
	A.2.12.2 Hydrodynamic System Card for Moving Problem.....	A2-11
A.2.13	Cards 140 Through 147, Self-Initialization Option Control Cards	A2-11
	A.2.13.1 Card 140, Self-Initialization Control Card	A2-12
	A.2.13.2 Cards 141 Through 142, Self-Initialization Pump Controller and Identification Cards	A2-12
	A.2.13.3 Cards 143 Through 144, Self-Initialization Steam Flow Controller Identification Cards.....	A2-12
	A.2.13.4 Cards 145 and 146, Self-Initialization Feedwater Controller Identification Cards	A2-13
	A.2.13.5 Card 147, Pressure and Volume Control Component Identification Card.....	A2-13
A.2.14	Card 190, Type of Transient Rotation Angles	A2-14
A.2.15	Cards 191 Through 193, Transient Rotation Angles	A2-14
A.2.16	Cards 194 Through 196, Transient Displacement Cards	A2-14

A.3	CARDS 200 THROUGH 299, TIME STEP CONTROL CARDS	A3-1
A.3.1	Card 200, Initial Time Value	A3-1
A.3.2	Cards 201 Through 299, Time Step Control	A3-1
A.4	CARDS 301 THROUGH 399, MINOR EDIT REQUESTS	A4-1
A.4.1	General Quantities	A4-1
A.4.2	Component Quantities	A4-1
A.4.3	Volume Quantities	A4-2
A.4.4	Junction Quantities	A4-4
A.4.5	Heat Structure Quantities	A4-4
A.4.6	Reactor Kinetic Quantities	A4-5
A.4.7	Control System Quantities	A4-5
A.4.8	Cards 2080xxxx, Expanded Edit/Plot Variables	A4-5
A.4.8.1	General Quantities.....	A4-6
A.4.8.2	Component-Related Quantities	A4-7
A.4.8.3	Volume-Related Quantities	A4-8
A.4.8.4	Junction-Related Quantities	A4-10
A.4.8.5	Heat Structure-Related Quantities.....	A4-10
A.4.8.6	Reflood-Related Quantities	A4-11
A.4.8.7	Reactor Kinetic-Related Quantities.....	A4-11
A.4.8.8	Fission Product Quantities.....	A4-13
A.4.8.9	SCDAP Quantities.....	A4-14
A.4.8.10	SCDAP Quantities for BWR Blade/Box Component	A4-17
A.4.8.11	COUPLE Quantities	A4-18
A.5	CARDS 400 THROUGH 799 OR 20600000 THROUGH 20620000, TRIP INPUT DATA	A5-1
A.5.1	Card 400, Trips Cancellation Card	A5-1
A.5.2	Card 20600000, Trip Card Series Type	A5-1
A.5.3	Cards 401 Through 599 or 20600010 Through 20610000, Variable Trip Cards	A5-1
A.5.4	Cards 601 Through 799 or 20610010 Through 20620000, Logical Trip Cards	A5-2
A.5.5	Card 600, Trip Stop Advancement Card	A5-3
A.6	CARDS 801 THROUGH 999, INTERACTIVE INPUT DATA	A6-1
A.7	CARDS CCCXXNN, HYDRODYNAMIC COMPONENTS	A7-1
A.7.1	Card ccc0000, Component Name and Type	A7-1
A.7.2	Single Volume Component	A7-1
A.7.2.1	Cards ccc0101 Through ccc0109, Single Volume Geometry Cards...	A7-1
A.7.2.2	Card ccc0111, ORNL ANS Interphase Model Pitch and Span Values	A7-3
A.7.2.3	Card ccc0141, Additional Wall Friction Card.....	A7-3
A.7.2.4	Cards ccc0142, Alternate Wall Friction Card	A7-3
A.7.2.5	Card ccc0200, Single Volume Initial Conditions.....	A7-4
A.7.3	Time-Dependent Volume Component	A7-5
A.7.3.1	Cards ccc0101 Through ccc0109, Time-Dependent Volume Geometry Cards.....	A7-6
A.7.3.2	Card ccc0200, Time-Dependent Volume Data Control Word.....	A7-7

A.7.3.3	Cards ccc0201 Through ccc0299, Time-Dependent Volume Data Cards.....	A7-9
A.7.3.4	Card ccc0301, Noncondensable Mass Fraction Card.....	A7-10
A.7.3.5	Card ccc0302, Metal Mass Fractions Card	A7-10
A.7.4	Single Junction Component	A7-10
A.7.4.1	Cards ccc0101 Through ccc0109, Single Junction Geometry Cards.....	A7-10
A.7.4.2	Card ccc0110, Single Junction Diameter and CCFL Data Card	A7-12
A.7.4.3	Card ccc0201, Single Junction Initial Conditions	A7-12
A.7.5	Time-Dependent Junction Component	A7-13
A.7.5.1	Card ccc0101, Time-Dependent Junction Geometry Card	A7-13
A.7.5.2	Card ccc0200, Time-Dependent Junction Data Control Card.....	A7-13
A.7.5.3	Cards ccc0201 Through ccc0299, Time-Dependent Junction Data Cards	A7-14
A.7.6	Pipe, Annulus, Or Pressurizer Component	A7-14
A.7.6.1	Card ccc0001, Pipe, Annulus, or Pressurizer Information Card	A7-15
A.7.6.2	Card ccc0002, Pipe Angles and Elevation Options.....	A7-15
A.7.6.3	Cards ccc0101 Through ccc0199, Pipe, Annulus, or Pressurizer X-Coordinate Volume Flow Areas	A7-16
A.7.6.4	Cards ccc1601 Through ccc1699, Pipe, Annulus, or Pressurizer Y-Coordinate Volume Flow Areas	A7-16
A.7.6.5	Cards ccc1701 Through ccc1799, Pipe, Annulus, or Pressurizer Z-Coordinate Volume Flow Areas.....	A7-17
A.7.6.6	Cards ccc0201 Through ccc0299, Pipe, Annulus, or Pressurizer Junction Flow Areas.....	A7-17
A.7.6.7	Cards ccc0301 Through ccc0399, Pipe, Annulus, or Pressurizer X-Coordinate Volume Lengths	A7-17
A.7.6.8	Cards ccc1801 Through ccc1899, Pipe, Annulus, or Pressurizer Y-Coordinate Volume Lengths	A7-17
A.7.6.9	Cards ccc1901 Through ccc1999, Pipe, Annulus, or Pressurizer Z-Coordinate Volume Lengths.....	A7-18
A.7.6.10	Cards ccc2901 Through ccc2999, Pipe, Annulus, or Pressurizer Elbow/Spiral Angle/Radius Of Curvature.....	A7-18
A.7.6.11	Cards ccc0401 Through ccc0499, Pipe, Annulus, or Pressurizer Volume Volumes.....	A7-19
A.7.6.12	Cards ccc0501 Through ccc0599, Pipe, Annulus, or Pressurizer Volume First or Azimuthal Angles	A7-19
A.7.6.13	Cards ccc0601 Through ccc0699, Pipe, Annulus, or Pressurizer Volume Second or Vertical Angles.....	A7-19
A.7.6.14	Cards ccc1501 Through ccc1599, Pipe Third Angle.....	A7-20
A.7.6.15	Cards ccc0701 Through ccc0799, Pipe, Annulus, or Pressurizer X-Coordinate (Elevation) Changes	A7-20
A.7.6.16	Cards ccc2101 Through ccc2199, Pipe, Annulus, or Pressurizer Y-Coordinate (Elevation) Changes	A7-21
A.7.6.17	Cards ccc2201 Through ccc2299, Pipe, Annulus, or Pressurizer Z-Coordinate (Elevation) Changes.....	A7-21

A.7.6.18	Cards ccc0801 Through ccc0899, Pipe, Annulus, or Pressurizer Volume X-Coordinate Friction Data.....	A7-22
A.7.6.19	Cards ccc2301 Through ccc2399, Pipe, Annulus, or Pressurizer Volume Y-Coordinate Friction Data.....	A7-22
A.7.6.20	Cards ccc2401 Through ccc2499, Pipe, Annulus, or Pressurizer Volume Z-Coordinate Friction Data	A7-22
A.7.6.21	Cards ccc2501 Through CCC2599, Pipe, Annulus, or Pressurizer Additional Wall Friction Data.....	A7-22
A.7.6.22	Cards ccc2601 Through ccc2699, Pipe, Annulus, or Pressurizer Alternate Wall Friction Data	A7-23
A.7.6.23	Cards ccc0901 Through ccc0999, Pipe, Annulus, or Pressurizer Junction Loss Coefficients	A7-23
A.7.6.24	Cards ccc1001 Through ccc1099, Pipe, Annulus, or Pressurizer Volume X-Coordinate Control Flags	A7-24
A.7.6.25	Cards ccc2701 Through ccc2799, Pipe, Annulus, or Pressurizer Volume Y-Coordinate Control Flags	A7-24
A.7.6.26	Cards ccc2801 Through ccc2899, Pipe, Annulus, or Pressurizer Volume Z-Coordinate Control Flags.....	A7-25
A.7.6.27	Cards ccc1101 Through ccc1199, Pipe, Annulus, or Pressurizer Junction Control Flags.....	A7-25
A.7.6.28	Cards ccc1201 Through ccc1299, Pipe, Annulus, or Pressurizer Volume Initial Conditions	A7-25
A.7.6.29	Cards ccc2001 Through ccc2099, Pipe, Annulus, or Pressurizer Initial Boron Concentrations	A7-27
A.7.6.30	Card ccc1300, Pipe, Annulus, or Pressurizer Junction Conditions Control Words	A7-27
A.7.6.31	Cards cc1301 Through ccc1399, Pipe, Annulus, or Pressurizer Junction Initial Conditions	A7-28
A.7.6.32	Cards ccc1401 Through ccc1499, Pipe, Annulus, or Pressurizer Junction Diameter and CCFL Data Cards.....	A7-28
A.7.6.33	Cards ccc3101 Through ccc3199, ORNL ANS Interphase Model Pitch and Span Values.....	A7-28
A.7.7	Branch, Separator, Jetmixer, Turbine, Or ECC Mixer Component	A7-29
A.7.7.1	Card ccc0001, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Information Card	A7-31
A.7.7.2	Cards ccc0101 Through ccc0109, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Volume Geometry Cards	A7-31
A.7.7.3	Card ccc0111, ORNL ANS Interphase Model Pitch and Span Values.....	A7-33
A.7.7.4	Card ccc0141, Additional Wall Friction Card.....	A7-33
A.7.7.5	Card ccc0142, Alternate Wall Friction Card.....	A7-33
A.7.7.6	Card ccc0200, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Volume Initial Conditions	A7-34
A.7.7.7	Cards ccn101, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Geometry Card	A7-36
A.7.7.8	Cards ccn110 Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Diameter And CCFL Data Cards.....	A7-38

A.7.7.9	Cards cccn201, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Initial Conditions	A7-38
A.7.7.10	Card ccc0300, Turbine/Shaft Geometry Card.....	A7-38
A.7.7.11	Card ccc0400, Turbine Performance Data Card.....	A7-39
A.7.8	Valve Junction Component	A7-39
A.7.8.1	Cards ccc0101 Through ccc0109, Valve Junction Geometry Cards.....	A7-39
A.7.8.2	Card ccc0110, Valve Junction Diameter and CCFL Data Card.....	A7-41
A.7.8.3	Card ccc0201, Valve Junction Initial Conditions.....	A7-42
A.7.8.4	Card ccc0300, Valve Type Card	A7-42
A.7.8.5	Cards ccc0301 Through ccc0399, Valve Data and Initial Conditions	A7-42
A.7.8.6	Cards ccc0400 Through ccc0499, Valve CSUBV Table	A7-46
A.7.9	Pump Component	A7-47
A.7.9.1	Cards ccc0101 Through ccc0107, Pump Volume Geometry Cards..	A7-47
A.7.9.2	Card ccc0108, Pump Inlet (Suction) Junction Card.....	A7-48
A.7.9.3	Card ccc0109, Pump Outlet (Discharge) Junction Card	A7-49
A.7.9.4	Card ccc0110, Pump Inlet (Suction) Junction Diameter and CCFL Data Card.....	A7-49
A.7.9.5	Card ccc0111, Pump Outlet (Discharge) Junction Diameter and CCFL Data Card.....	A7-50
A.7.9.6	Card ccc0200, Pump Volume Initial Conditions	A7-50
A.7.9.7	Card ccc0201, Pump Inlet (Suction) Junction Initial Conditions.....	A7-52
A.7.9.8	Card ccc0202, Pump Outlet (Discharge) Junction Initial Conditions	A7-52
A.7.9.9	Card ccc0301, Pump Index and Option Card.....	A7-52
A.7.9.10	Cards ccc0302 Through ccc0304, Pump Description Card.....	A7-53
A.7.9.11	Card ccc0308, Pump Variable Inertia Card.....	A7-54
A.7.9.12	Card ccc0309, Pump-Shaft Connection Card.....	A7-54
A.7.9.13	Card ccc0310, Pump Stop Data Card	A7-55
A.7.9.14	Cards cccxx00 Through cccxx99, Single-Phase Homologous Curves.....	A7-55
A.7.9.15	Cards cccxx00 Through cccxx99, Two-Phase Multiplier Tables ...	A7-56
A.7.9.16	Cards cccxxX00 Through cccxx99, Two-Phase Difference Tables	A7-56
A.7.9.17	Cards ccc6001 Through ccc6099, Relative Pump Motor Torque Data	A7-56
A.7.9.18	Card ccc6100, Time-Dependent Pump Velocity Control Card.....	A7-56
A.7.9.19	Cards ccc6101 Through ccc6199, Time-Dependent Pump Velocity	A7-57
A.7.10	Multiple Junction Component	A7-57
A.7.10.1	Card ccc0001, Multiple Junction Information Card.....	A7-57
A.7.10.2	Cards ccc0nnm, Multiple Junction Geometry Card	A7-57
A.7.10.3	Cards ccc1nnm, Multiple Junction Initial Condition Cards.....	A7-59
A.7.10.4	Cards ccc2nnm, Multiple Junction Diameter and CCFL Data Cards.....	A7-60

A.7.11	Accumulator Component	A7-60
A.7.11.1	Cards ccc0101 Through ccc0199, Accumulator Volume Geometry Cards.....	A7-61
A.7.11.2	Card ccc0141, Additional Wall Friction Card.....	A7-62
A.7.11.3	Card ccc0142, Alternate Wall Friction Card	A7-62
A.7.11.4	Card ccc0200, Accumulator Tank Initial Thermodynamics Conditions	A7-62
A.7.11.5	Card ccc1101, Accumulator Junction Geometry Card.....	A7-62
A.7.11.6	Card ccc2200, Accumulator Tank Initial Fill Conditions, Standpipe/Surge Line Length/Elevation, and Tank Wall Heat Transfer Terms.....	A7-64
A.7.12	Multidimensional Input	A7-65
A.7.12.1	Card ccc0001, MULTID Information Card	A7-66
A.7.12.2	Card ccc0002, Rotation Angle Data Card	A7-66
A.7.12.3	Cards ccc0xn, Mesh Interval Cards.....	A7-67
A.7.12.4	Cards ccc1nn, Volume Option Cards	A7-68
A.7.12.5	Cards ccc2nn, Volume Friction Data Cards	A7-69
A.7.12.6	Cards ccc3001 Through ccc5999, Junction Data Cards.....	A7-71
A.7.12.7	Cards ccc6nn, Volume Initial Condition Cards.....	A7-72
A.7.12.8	Cards ccc7001 Through ccc9999, Junction Initial Condition Data	A7-74
A.8	CARDS 1CCCGXNN, HEAT STRUCTURE INPUT	A8-1
A.8.1	Card 1cccg000, General Heat Structure Data	A8-1
A.8.1.1	General Heat Structure Data Card.....	A8-1
A.8.1.2	Heat Structure Delete Card.....	A8-2
A.8.2	Card 1cccg001, Gap Conductance Model Initial Gap Pressure Data	A8-2
A.8.3	Card 1cccg003, Metal-Water Reaction Control Card	A8-3
A.8.4	Card 1cccg004, Fuel Cladding Deformation Model Control Card	A8-3
A.8.5	Cards 1cccg011 Through 1cccg099, Gap Deformation Data	A8-3
A.8.6	Card 1ccg100, Heat Structure Mesh Flags	A8-3
A.8.7	Cards 1cccg101 Through 1cccg199, Heat Structure Mesh Interval Data (Radial)	A8-4
A.8.7.1	Format 1	A8-4
A.8.7.2	Format 2	A8-4
A.8.8	Cards 1cccg201 Through 1cccg299, Heat Structure Composition Data (Radial)	A8-4
A.8.9	Card 1cccg300, Fission Product Decay Heat Flag	A8-5
A.8.10	Cards 1cccg301 Through 1cccg399, Heat Structure Source Distribution Data (Radial)	A8-5
A.8.11	Card 1cccg400, Initial Temperature Flag	A8-5
A.8.12	Cards 1cccg401 Through 1cccg499, Initial Temperature Data	A8-6
A.8.12.1	Format 1 (Word 1 on Card 1cccg400 = 0)	A8-6
A.8.12.2	Format 2 (Word 1 on Card 1cccg400 = -1).....	A8-6
A.8.13	Cards 1cccg501 Through 1cccg599, Left Boundary Condition Cards	A8-6
A.8.14	Cards 1cccg601 Through 1cccg699, Right Boundary Condition Cards	A8-8
A.8.15	Cards 1cccg701 Through 1cccg799, Source Data Cards	A8-8
A.8.16	Cards 1cccg801 Through 1cccg899, Additional Left Boundary Cards	A8-9

	A.8.17 Cards 1cccg901 Through 1cccg999, Additional Right Boundary Cards	A8-10
A.9	CARD 50000000, RADIATION MODEL CONTROL CARD	A9-1
	A.9.1 Card 5ss00000, Radiation Set Card	A9-1
	A.9.2 Cards 5ssnn001 Through 5ssnn099, Radiation Heat Structure Data	A9-1
	A.9.3 Cards 5ssnn101 Through 5ssnn199, Radiation View Factors	A9-2
A.10	CARDS 201MMMNN, HEAT STRUCTURE THERMAL PROPERTY DATA	A10-1
	A.10.1 Card 201mmm00, Composition Type and Data Format	A10-1
	A.10.2 Cards 201mmm01 Through 201mmm49, Thermal Conductivity Data or Gap Mole Fraction Data	A10-1
	A.10.2.1 Table Format	A10-2
	A.10.2.2 Functional Format	A10-2
	A.10.3 Cards 201mmm51 Through 201mmm99, Volumetric Heat Capacity Data ..	A10-3
	A.10.3.1 Table Format	A10-3
	A.10.3.2 Functional Format	A10-3
A.11	CARDS 202TTTNN, GENERAL TABLE DATA	A11-1
	A.11.1 Card 202ttt00, Table Type and Multiplier Data	A11-1
	A.11.2 Cards 202ttt01 Through 202ttt99, General Table Data	A11-2
A.12	CARDS 30000000 THROUGH 30399999, REACTOR KINETICS INPUT	A12-1
	A.12.1 Card 30000000, Reactor Kinetics Type Card	A12-1
	A.12.2 Card 30000001, Reactor Kinetics Information Card	A12-1
	A.12.2.1 Point Kinetics Format.....	A12-1
	A.12.2.2 One-Dimensional Kinetics Format.....	A12-2
	A.12.3 Card 30000002, Fission Product Decay Information	A12-2
	A.12.4 Card 30000003, One-Dimensional Kinetics Control Information	A12-3
	A.12.5 Card 30000004, One-Dimensional Kinetics Control Parameters	A12-4
	A.12.6 Card 30000005, One-Dimensional Kinetics Bottom Albedo Matrix	A12-5
	A.12.7 Card 30000006, One-Dimensional Kinetics Top Albedo Matrix	A12-5
	A.12.8 Card 30000007, Neutron Velocity Data	A12-5
	A.12.9 Cards 30000101 Through 30000199, Delayed Neutron Constants	A12-5
	A.12.10 Cards 30000201 Through 30000299, Fission Product Decay Constants	A12-5
	A.12.11 Cards 30000301 Through 30000399, Actinide Decay Constants	A12-6
	A.12.12 Cards 30000401 Through 30000499, Power History Data	A12-6
	A.12.13 Point Kinetics Feedback Input	A12-7
	A.12.13.1 Cards 30000011 Through 30000020, Reactivity Curve or Control Variable Numbers	A12-7
	A.12.13.2 Cards 30000501 Through 30000599, Density Reactivity Table...	A12-7
	A.12.13.3 Cards 30000601 Through 30000699, Doppler Reactivity Table..	A12-7
	A.12.13.4 Cards 30000701 Through 30000799, Volume Weighting Factors.....	A12-7
	A.12.13.5 Cards 30000801 Through 30000899, Heat Structure or SCDAP Component Weighting Factors.....	A12-8
	A.12.13.6 Cards 30001701 Through 30001799, Volume Weighting Factors	A12-8
	A.12.13.7 Cards 30001801 Through 30001899, Heat Structure or SCDAP Component Weighting Factors.....	A12-9
	A.12.13.8 Cards 300019c1 Through 300019c9, Feedback Table Coordinate Data	A12-9

A.12.13.9	Cards 30002001 Through 30002999, Feedback Table Data	A12-9
A.12.14	One-Dimensional Kinetics Feedback Input	A12-10
A.12.14.1	Cards 30010101 Through 30010199, One-Dimensional Mesh Intervals	A12-10
A.12.14.2	Cards 30010401 Through 30010499, Assignment of Zones to One-Dimensional Mesh Intervals	A12-10
A.12.14.3	Cards 30010501 Through 30010599, Assignment of Compositions to One-Dimensional Mesh Intervals	A12-11
A.12.14.4	Cards 30010601 Through 30010699, Target Power Distribution Data	A12-11
A.12.14.5	Neutron Cross-Section Data for RAMONA Option	A12-11
A.12.14.6	Neutron Cross-Section Data for HWR Option	A12-13
A.12.15	Control Rod Model Data	A12-16
A.12.15.1	Card 30400000, Control Rod Information	A12-16
A.12.15.2	Cards 304000nn, Control Rod Data	A12-16
A.12.15.3	Cards 304nn0xx, Control Rod Group Weight Factors	A12-16
A.13	CARDS 20300000 THROUGH 20499999, PLOT REQUEST INPUT DATA	A13-1
A.13.1	Card 203000kk, Plot General Heading and Specifications	A13-1
A.13.2	Cards 20300000 Through 20300009, General Plot Heading Cards	A13-1
A.13.3	Cards 20300010 Through 20300019, General Plot Options Keywords	A13-2
A.13.4	Card 20300020, General Plot Size Dimensions	A13-4
A.13.5	Card 20300030, Input Check Plot Request Card	A13-5
A.13.6	Cards 203nnnkk, Plot Requests and Specifications	A13-5
A.13.6.1	Cards 203nnn00 Through 203nnn09, Plot Requests	A13-5
A.13.6.2	Cards 203nnn10 Through 203nnn19, Independent Variable Requests	A13-6
A.13.6.3	Cards 203nnn20 Through 203nnn29, Plot Comparison Data Table Reference	A13-7
A.13.6.4	Cards 203nnn30 Through 203nnn32, Plot Title and Axes Titles	A13-7
A.13.6.5	Cards 203nnn40 Through 203nnn41, Plot Axes Specifications	A13-7
A.13.6.6	Cards 203nnn50 Through 203nnn59, Curve Drawing Specifications	A13-10
A.13.6.7	Cards 203nnn60 Through 203nnn69, Plot Option Changes	A13-11
A.13.6.8	Card 203nnn70, Plot Size Dimension Changes	A13-11
A.13.7	Cards 204mmmlI, Plot Comparison Data Tables	A13-11
A.13.7.1	Card 204mmmm00, Plot Comparison Data Table Request	A13-11
A.13.7.2	Cards 204mmmm01 Through 204mmmm08, Dependent Variable Units Conversion	A13-12
A.13.7.3	Card 204mmmm10, Table Independent Variable	A13-13
A.13.7.4	Cards 204mmmm11 Through 204mmmm18, Independent Variable Units Conversion	A13-13
A.13.7.5	Card 204mmmm19, Data Curve Specification	A13-14
A.13.7.6	Cards 204mmmm20 Through 204mmmm99, Plot Comparison Data Table Input Data	A13-15
A.14	CARDS 205CCCNN OR 205CCCCN, CONTROL SYSTEM INPUT DATA	A14-1
A.14.1	Card 20500000, Control Variable Card Type	A14-1
A.14.2	Card 205ccc00 or 205cccc0, Control Component Type Card	A14-1

A.14.3	Cards 205ccc01 Through 205ccc98 or 205cccc1 Through 205cccc8, Control Component Data Cards	A14-2
A.14.3.1	Sum-Difference Component.....	A14-2
A.14.3.2	Multiplier Component	A14-3
A.14.3.3	Divide Component.....	A14-3
A.14.3.4	Differentiating Components	A14-3
A.14.3.5	Integrating Component.....	A14-4
A.14.3.6	Functional Component	A14-4
A.14.3.7	Standard Function Component	A14-5
A.14.3.8	Delay Component.....	A14-5
A.14.3.9	Unit Trip Component	A14-6
A.14.3.10	Trip Delay Component.....	A14-6
A.14.3.11	Integer Power Component.....	A14-6
A.14.3.12	Real Power Component.....	A14-6
A.14.3.13	Variable Power Component	A14-7
A.14.3.14	Proportional-Integral Component.....	A14-7
A.14.3.15	Lag Component	A14-8
A.14.3.16	Lead-Lag Component.....	A14-8
A.14.3.17	Constant Component	A14-9
A.14.3.18	Shaft Component.....	A14-9
A.14.3.19	PUMPCTL Component.....	A14-10
A.14.3.20	STEAMCTL Component	A14-11
A.14.3.21	FEEDCTL Component.....	A14-11
A.15	CARDS 20700000 THROUGH 20799999, FISSION PRODUCT AND AEROSOL TRANSPORT	A15-1
A.15.1	Card 20700000, Aerosol Size Bins	A15-1
A.15.2	Cards 20700001 Through 20700005, Hydrodynamic System Specification	A15-1
A.15.3	Card 20700010, Convergence Criteria	A15-2
A.15.4	Cards 20700011 Through 20700018, Species Selection Cards	A15-2
A.15.5	Cards 2070nnnm, Initial Conditions	A15-2
A.15.5.1	Card 2070nnn0, Initial Volume Number.....	A15-2
A.15.5.2	Cards 2070nnn1 Through 2070nnn9, Species.....	A15-3
A.16	ADDITIONAL PLOT VARIABLES	A16-1
A.16.1	Cards 20800nnn, Additional Plot Variables	A16-1
A.17	CREEP RUPTURE	A17-1
A.17.1	CARD 21000000, Creep Rupture Control Card for COUPLE Wall	A17-1
A.17.2	Cards 21000021 Through 21000029, Creep Rupture Location Elements in COUPLE Wall	A17-1
A.17.3	Cards 21000101 Through 21000110, Creep Rupture Locations for SCDAP/RELAP5 Heat Structures	A17-2
A.18	SEVERE ACCIDENT CORE BEHAVIOR INPUT	A18-1
A.18.1	Global Input	A18-1
A.18.1.1	Card 40000100, SCDAP Control	A18-1
A.18.1.2	Cards 40000201 Through 40000299, Axial Node Heights.....	A18-2
A.18.1.3	Card 40000400, Gamma Heating.....	A18-3
A.18.1.4	Card 107 / Card 40000500, Core Debris Control Card.....	A18-3

A.18.1.5 Card 108 / Card 40000600, Core Slumping Control Card	A18-3
A.18.1.6 Card 109, Undocumented card	A18-4
A.18.1.7 Card 118, Heat Transfer Weight and Switches	A18-4
A.18.1.8 Card 40001000, Grid Spacer Elevation	A18-5
A.18.1.9 Cards 40001001 Through 40001099, Grid Spacer Description	A18-5
A.18.1.10 Card 40001100, Definition of Core Slumping Model	A18-5
A.18.1.11 Cards 40001101 Through 40001199, Core Bypass Volume Identification	A18-6
A.18.1.12 Cards 40001201 Through 40001299, Core Bypass Volume Elevations	A18-6
A.18.2 Debris Bed Characteristics	A18-6
A.18.2.1 Cards 40002001 Through 40002020, Debris Time	A18-7
A.18.2.2 Cards 40002021 Through 40002040, Debris Porosity	A18-7
A.18.2.3 Cards 40002041 Through 40002060, Debris Particle Diameter	A18-7
A.18.2.4 Cards 40002061 Through 40002080, Debris Stainless Steel Mass	A18-7
A.18.2.5 Cards 40002081 Through 40002099, Debris Zircaloy Mass	A18-7
A.18.3 User-Specified Material Property Definition	A18-8
A.18.3.1 Card 40009nn1, Material Specific Heat	A18-9
A.18.3.2 Card 40009nn2, Densities of User-Specified Material	A18-9
A.18.3.3 Card 40009nn3, Thermal Conductivity of User-Specified Material	A18-9
A.18.4 Fuel Rod Component	A18-9
A.18.4.1 Card 4ccc0000, Fuel Rod Component	A18-9
A.18.4.2 Card 4ccc0100, Number of Rods	A18-9
A.18.4.3 Card 4ccc0200, Fuel Rod Plenum Geometry	A18-10
A.18.4.4 Cards 4ccc0301 Through 4ccc0399, Fuel Rod Dimensions	A18-10
A.18.4.5 Card 4ccc0400, Upper and Lower Hydraulic Volumes	A18-10
A.18.4.6 Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes	A18-11
A.18.4.7 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing	A18-11
A.18.4.8 Cards 4ccc0601 Through 4ccc0699, Initial Temperatures	A18-12
A.18.4.9 Card 4ccc1000, Power Data	A18-12
A.18.4.10 Card 4ccc1100, Power Multiplier	A18-12
A.18.4.11 Card 4ccc1200, Power Fractions for Reactor Kinetics Option	A18-12
A.18.4.12 Card 4ccc13p0, Axial Power Profile Time	A18-13
A.18.4.13 Cards 4ccc13p1 Through 4ccc13p9, Axial Power Profile Data	A18-13
A.18.4.14 Cards 4ccc1401 Through 4ccc1499, Radial Power Profile	A18-13
A.18.4.15 Card 4ccc1500, Shutdown Time and Fuel Density	A18-13
A.18.4.16 Cards 4ccc1501 Through 4ccc1599, Decay Power	A18-13

A.18.4.17	Cards 4ccc1601 Through 4ccc1699, Previous Power History	A18-14
A.18.4.18	Card 4ccc2000, PARAGRASS Species	A18-14
A.18.4.19	Cards 4ccc2001 Through 4ccc2099, PARAGRASS Species Mass	A18-14
A.18.4.20	Card 4ccc2100, Initial Fuel Fission Product Inventory.....	A18-14
A.18.4.21	Cards 4ccc2101 Through 4ccc2199, Initial Fuel Fission Product Mass.....	A18-14
A.18.4.22	Card 4ccc2200, Initial Gap Fission Product Inventory	A18-15
A.18.4.23	Cards 4ccc2201 Through 4ccc2299, Initial Gap Fission Product Mass	A18-15
A.18.4.24	Card 4ccc3000, Gas Internal Pressure.....	A18-15
A.18.4.25	Cards 4ccc3201 Through 4ccc3299, Time Temperature Pressure Profile	A18-15
A.18.4.26	Card 4ccc4000, Option Definition	A18-15
A.18.4.27	Card 4ccc9000, Volume of External Volumes.....	A18-16
A.18.4.28	Cards 4ccc9001 Through 4ccc9099, Time Temperature History of External Volumes.....	A18-16
A.18.5	Simulator Component	A18-16
A.18.5.1	Card 4ccc0000, Fuel Rod Component.....	A18-16
A.18.5.2	Card 4ccc0100, Number of Rods	A18-16
A.18.5.3	Card 4ccc0200, Simulator Rod Geometry.....	A18-16
A.18.5.4	Card 4ccc0250, Upper Plenum Boundary Conditions	A18-16
A.18.5.5	Card 4ccc0251, Lower Plenum Boundary Conditions.....	A18-17
A.18.5.6	Cards 4ccc0301 Through 4ccc0399, Fuel Rod Dimensions	A18-17
A.18.5.7	Card 4ccc0400, Upper and Lower Hydraulic Volumes	A18-17
A.18.5.8	Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes.....	A18-18
A.18.5.9	Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing	A18-18
A.18.5.10	Cards 4ccc0601 Through 4ccc0699, Initial Temperatures.....	A18-18
A.18.5.11	Card 4ccc1000, Power Data	A18-18
A.18.5.12	Card 4ccc1100, Power Multiplier.....	A18-18
A.18.5.13	Card 4ccc1200, Power Fractions for Reactor Kinetics Option ...	A18-19
A.18.5.14	Card 4ccc13p0, Axial Power Profile Time.....	A18-19
A.18.5.15	Cards 4ccc13p1 Through 4ccc13p9, Axial Power Profile Data..	A18-19
A.18.5.16	Cards 4ccc1401 Through 4ccc1499, Radial Power Profile.....	A18-19
A.18.5.17	Card 4ccc1500, Shutdown Time and Fuel Density	A18-19
A.18.5.18	Cards 4ccc1501 Through 4ccc1599, Decay Power.....	A18-20
A.18.5.19	Cards 4ccc1601 Through 4ccc1699, Previous Power History	A18-20
A.18.5.20	Card 4ccc2000, PARAGRASS Species	A18-20
A.18.5.21	Cards 4ccc2001 Through 4ccc2099, PARAGRASS Species.....	A18-20
A.18.5.22	Card 4ccc2100, Fuel Fission Product Species.....	A18-20
A.18.5.23	Cards 4ccc2101 Through 4ccc2199, Fuel Fission Product Inventory	A18-20
A.18.5.24	Card 4ccc2200, Gap Fission Product Species	A18-21
A.18.5.25	Cards 4ccc2201 Through 4ccc2299, Gap Fission Product Inventory	A18-21
A.18.5.26	Card 4ccc3000, Gas Internal Pressure.....	A18-21
A.18.5.27	Cards 4ccc3201 Through 4ccc3299, Time Temperature Pressure Profile	A18-21

A.18.5.28 Card 4ccc9000, Volume of External Volumes.....	A18-21
A.18.5.29 Cards 4ccc9001 Through 4ccc9099, Time Temperature History of External Volumes.....	A18-22
A.18.6 ATR Fuel Element Component	A18-22
A.18.6.1 Card 4ccc0000, Fuel Element Component.....	A18-22
A.18.6.2 Card 4ccc0100, Number and Perimeter of Fuel Element.....	A18-22
A.18.6.3 Card 4ccc0400, Upper and Lower Hydraulic Volumes	A18-22
A.18.6.4 Cards 4ccc0401 Through 4ccc0450, Inner Hydraulic Volumes.....	A18-22
A.18.6.5 Cards 4ccc0451 Through 4ccc0499, Outer Hydraulic Volumes.....	A18-22
A.18.6.6 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing	A18-22
A.18.6.7 Cards 4ccc0601 Through 4ccc0699, Initial Temperature Distribution.....	A18-22
A.18.6.8 Cards 4ccc0801 Through 4ccc0899, Material Types	A18-23
A.18.6.9 Cards 4ccc0901 Through 4ccc0999, Material Layer Spacing.....	A18-23
A.18.6.10 Card 4ccc1000, Power Data	A18-23
A.18.6.11 Card 4ccc1100, Power Multiplier.....	A18-23
A.18.6.12 Card 4ccc1200, Power Fractions for Reactor Kinetics Option ...	A18-23
A.18.6.13 Card 4ccc13p0, Axial Power Profile Time.....	A18-23
A.18.6.14 Cards ccc13p1 Through 4ccc13p9, Axial Power Profile Data....	A18-24
A.18.6.15 Cards 4ccc1401 Through 4ccc1499, Radial Power Profile.....	A18-24
A.18.6.16 Card 4ccc1500, Shutdown Time and Fuel Density	A18-24
A.18.6.17 Cards 4ccc1501 Through 4ccc1599, Decay Power.....	A18-24
A.18.6.18 Cards 4ccc1601 Through 4ccc1699, Previous Power History	A18-25
A.18.6.19 Cards 4ccc2101 Through 4ccc2199, ATR Component Fission Product Masses.....	A18-25
A.18.7 Card 4ccc0000, Shroud Component	A18-25
A.18.7.1 Card 4ccc0000, Component Name.....	A18-25
A.18.7.2 Card 4ccc0100, Number of Shroud Configurations	A18-25
A.18.7.3 Card 4ccc0200, Shroud Geometry.....	A18-25
A.18.7.4 Card 4ccc0400, Upper and Lower Hydrodynamic Volumes	A18-26
A.18.7.5 Cards 4ccc0401 Through 4ccc0499, Volume Number of Hydrodynamic Volumes.....	A18-26
A.18.7.6 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing	A18-26
A.18.7.7 Cards 4ccc0601 Through 4ccc0699, Initial Radial Temperature Distribution.....	A18-26
A.18.7.8 Card 4ccc0800, Embedded Flow Channel Description.....	A18-27
A.18.7.9 Card 4ccc0801 Through 4ccc0899 Hydrodynamic Connections to Embedded Flow Channels.....	A18-27
A.18.7.10 Card 4ccc0900, Indices of Materials	A18-27
A.18.7.11 Cards 4ccc0901 Through 4ccc0999, Material Layer Radii.....	A18-27
A.18.7.12 Card 4ccc1000, Power Data	A18-28
A.18.7.13 Cards 4ccc1100, Power Multiplier	A18-28
A.18.7.14 Cards 4ccc1200, Power Fractions for Reactor Kinetics Option..	A18-28
A.18.7.15 Cards 4ccc13p0, Axial Power Profile Time	A18-28
A.18.7.16 Cards 4ccc13p1 Through 4ccc13p9, Axial Power Profile Data..	A18-28

A.18.7.17	Cards 4ccc1401 Through 4ccc1499, Radial Power Profile.....	A18-29
A.18.7.18	Cards 4ccc1500, Shutdown Time and Fuel Density	A18-29
A.18.7.19	Cards 4ccc1501 Through 4ccc1599, Decay Power.....	A18-29
A.18.7.20	Cards 4ccc1601 Through 4ccc1699, Previous Power History	A18-29
A.18.7.21	Card 4ccc5000, Shroud Insulation and Failure	A18-30
A.18.7.22	Cards 4ccc8n01 Through 4ccc8n99, Heat Flux Boundary Condition Specification.....	A18-30
A.18.8	Control Rod Component	A18-30
A.18.8.1	Card 4ccc0000, Control Rod Component	A18-30
A.18.8.2	Card 4ccc0100, Number of Rods	A18-30
A.18.8.3	Card 4ccc0300, Control Rod Materials	A18-31
A.18.8.4	Card 4ccc0301 Through 4ccc0399, Control Rod Geometry.....	A18-31
A.18.8.5	Card 4ccc0400, Upper and Lower Hydraulic Volumes	A18-31
A.18.8.6	Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes.....	A18-31
A.18.8.7	Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing.....	A18-32
A.18.8.8	Cards 4ccc0601 Through 4ccc0699, Initial Temperatures.....	A18-32
A.18.8.9	Card 4ccc0700, Internal Gas Pressure.....	A18-33
A.18.8.10	Card 4ccc0800, Mass of Silver.....	A18-33
A.18.8.11	Card 4ccc1000, Power Data	A18-33
A.18.8.12	Card 4ccc1100, Power Multiplier.....	A18-33
A.18.8.13	Card 4ccc1200, Power Fractions For Reactor Kinetics Option ..	A18-33
A.18.8.14	Card 4ccc13p0, Axial Power Profile Time.....	A18-33
A.18.8.15	Cards 4ccc13p1 Through 4ccc13p9, Axial Power Profile Data..	A18-34
A.18.8.16	Cards 4ccc1401 Through 4ccc1499, Radial Power Profile.....	A18-34
A.18.8.17	Cards 4ccc1501 Through 4ccc1599, Decay Power.....	A18-34
A.18.8.18	Cards 4ccc1601 Through 4ccc1699, Previous Power History	A18-34
A.18.9	BWR Control Rods	A18-34
A.18.9.1	Card 4ccc0000, BWR Control Rod Component	A18-34
A.18.9.2	Card 4ccc0100, Number of Rods	A18-35
A.18.9.3	Cards 4ccc0301 Through 4ccc0399, BWR Control Rod Geometry	A18-35
A.18.9.4	Card 4ccc0400, Upper and Lower Hydraulic Volumes	A18-35
A.18.9.5	Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes.....	A18-35
A.18.9.6	Cards 4ccc0601 Through 4ccc0699, Initial Temperatures.....	A18-35
A.18.10	BWR Blade/Box Component Input	A18-35
A.18.10.1	Card 4ccc0000, SCDAP Component Name and Type.....	A18-35
A.18.10.2	Card 4ccc0100, Number of Individual BWR Blade/Box Structures.....	A18-36
A.18.10.3	Card 4ccc0200, Control Blade and Channel Box Radial Dimensions.....	A18-36
A.18.10.4	Card 4ccc0300, Control Blade and Channel Box Lengths and View Factors	A18-36
A.18.10.5	Card 4ccc0400, Upper and Lower Volume Numbers	A18-37
A.18.10.6	Cards 4ccc0401 Through 4ccc0499, Fuel Bundle and Interstitial Volume Numbers	A18-37
A.18.10.7	Card 4ccc0500, Initial Oxide Thicknesses	A18-38
A.18.10.8	Cards 4ccc0601 Through 4ccc0699, Initial Temperatures of Control Blade and Channel Box.....	A18-38

A.18.11 SCDAP Radiation Enclosure Grouping	A18-38
A.18.11.1 Card 4ccc0000, Bundle Components	A18-38
A.18.11.2 Card 4ccc1000, Number of Components in Bundle.....	A18-39
A.18.11.3 Cards 4ccc1001 Through 4ccc1099, View Factors.....	A18-39
A.18.11.4 Cards 4ccc1101 Through 4ccc1199, Radiation Path Length	A18-39
A.18.11.5 Card 4ccc2000, Pitch of Rods	A18-39
A.18.11.6 Cards 4ccc2001 Through 4ccc2099, Matrix of Components of the Bundle	A18-39
A.18.12 Core Slumping Cards	A18-39
A.18.12.1 Card 4ccc0000, Core Slumping.....	A18-39
A.18.12.2 Card 4ccc0100, COUPLE Mesh.....	A18-39
A.18.12.3 Cards 4ccc0301 Through 4ccc0399, User-Defined Core Slumping	A18-40
A.18.12.4 Cards 4ccc0401 Through 4ccc0499, Mass of Each Material That Slumped	A18-40
A.18.12.5 Cards 4ccc0501 Through 4ccc0599, Characteristics of Slumped Material	A18-40
A.18.12.6 Card 4ccc0600, Mass Fractions.....	A18-40
A.18.12.7 Card 4ccc0700, Characteristics of Material 1	A18-41
A.18.12.8 Cards 4ccc1001 Through 4ccc1099, Data for Species.....	A18-41
A.19 COUPLE INPUT	A19-1
A.19.1 COUPLE Control Cards	A19-1
A.19.1.1 Card 50000000 COUPLE Control.....	A19-1
A.19.1.2 Card 50004000 Ex-Vessel Heat Transfer Control.....	A19-1
A.19.1.3 Card 5m001000, COUPLE Debris Bed Model Control Card	A19-1
A.19.1.4 Card 5m002000, COUPLE Debris Bed Model Control Card	A19-2
A.19.1.5 Card 5m003000, COUPLE Power Card.....	A19-3
A.19.1.6 Card 5m003001 Through 5m003009, COUPLE Fission Product Decay Power Fractions.....	A19-3
A.19.2 FORMATTED COUPLE INPUT	A19-4
A.19.3 Title Block	A19-4
A.19.3.1 Header for Title Block.....	A19-4
A.19.3.2 Title Card.....	A19-4
A.19.3.3 Title Card.....	A19-5
A.19.3.4 Block Terminator.....	A19-5
A.19.4 Mesh Generation Block	A19-5
A.19.4.1 Header for Mesh Generation Block.....	A19-5
A.19.4.2 Mesh Generator Control Card	A19-5
A.19.4.3 Line Segment Cards.....	A19-5
A.19.4.4 Mesh Generation Block Terminator	A19-7
A.19.5 Material Block	A19-7
A.19.5.1 Material Block Assignment.....	A19-7
A.19.5.2 Material Block Terminator.....	A19-8
A.19.6 Material Block	A19-8
A.19.6.1 Material Block Header.....	A19-8
A.19.6.2 Material Data Information.....	A19-8
A.19.6.3 Emissivity	A19-9

A.19.6.4	Material Properties	A19-9
A.19.6.5	Material Data	A19-9
A.19.6.6	MHTGR Material Data.....	A19-10
A.19.6.7	Material Block Terminator.....	A19-10
A.19.7	Time Step Data	A19-10
A.19.7.1	Time Step Data Block Header.....	A19-10
A.19.7.2	Temperature Control Card.....	A19-10
A.19.7.3	Description of Lower Head of Vessel	A19-11
A.19.7.4	User-Defined Layer of the COUPLE Mesh	A19-12
A.19.7.5	Block Terminator.....	A19-12
A.19.8	Internal Heat Generation Block	A19-12
A.19.8.1	Internal Heat Generation Block Header	A19-12
A.19.8.2	Number of Materials Without Internal Generation	A19-12
A.19.8.3	Power Densities	A19-12
A.19.8.4	Block Terminator.....	A19-13
A.19.8.5	Material Numbers Without Internal Generation.....	A19-13
A.19.8.6	Mass Fractions.....	A19-13
A.19.8.7	Fission Products.....	A19-14
A.19.8.8	Block Terminator.....	A19-14
A.19.9	Convection Data Block	A19-14
A.19.9.1	Convection Data Block Header	A19-14
A.19.9.2	Number of Nodes with Convection.....	A19-14
A.19.9.3	Boundary Conditions at Start of Analysis for Finite Elements That Can Fill With Slumping Debris	A19-15
A.19.9.4	Identification of Surfaces With Convective and Radiative Heat Transfer.....	A19-15
A.19.9.5	Number of Interfacing SCDAP/RELAP5 Volumes.....	A19-15
A.19.9.6	Block Terminator.....	A19-15
A.19.10	Initial Temperature	A19-16
A.19.10.1	Initial Temperature Block Header.....	A19-16
A.19.10.2	Number of Temperature Nodes.....	A19-16
A.19.10.3	Block Terminator.....	A19-16
A.19.11	Plot Control	A19-16
A.19.11.1	Plot Control Header.....	A19-16
A.19.11.2	Plot Control Card.....	A19-16
A.19.11.3	Plot Control Block Terminator.....	A19-16
A.19.12	Solution Control	A19-16
A.19.12.1	Solution Control Header.....	A19-16
A.19.12.2	Solution Control Block Terminator.....	A19-16
A.19.12.3	Problem Termination Card.....	A19-16
A.20	NEW STYLE COUPLE INPUT	A20-1
A.20.1	COUPLE Control	A20-1
A.20.1.1	Card 50000020, Second Title Card	A20-1
A.20.2	Mesh Generator	A20-1
A.20.2.1	Card 5ccc0100, Mesh Generator Control Card	A20-1
A.20.2.2	Cards 5ccc0201 Through 5ccc0299, Line Segment Cards.....	A20-1
A.20.3	Material Input	A20-2

A.20.3.1	Cards 5ccc0401 Through 5ccc0499, Material Block Assignment ..	A20-2
A.20.3.2	Card 5ccc0500, Emissivity	A20-2
A.20.3.3	Cards 5ccc0501 Through 5ccc0599, Material Properties.....	A20-2
A.20.3.4	Card 5ccc0600, Temperature Control Card.....	A20-3
A.20.3.5	Cards 5ccc0601 Through 5ccc0699, Initial Mesh Temperature.....	A20-3
A.20.4	Geometry	A20-3
A.20.4.1	Card 5ccc0700, Description of Lower Head of Vessel	A20-3
A.20.4.2	Cards 5ccc0701 Through 5ccc0799, User-Defined Layer of the COUPLE Mesh.....	A20-4
A.20.5	Power	A20-4
A.20.5.1	Card 5ccc0800, Number of Materials Without Internal Heat Generation	A20-4
A.20.5.2	Cards 5ccc0801 Through 5ccc0899, Power Densities	A20-4
A.20.5.3	Cards 5ccc0901 Through 5ccc0999, Mass Fractions	A20-4
A.20.5.4	Cards 5ccc1001 Through 5ccc1099, Fission Products.....	A20-5
A.20.5.5	Cards 5ccc1101 Through 5ccc1199, Surfaces with Convective and Radiative Heat Transfer Identification	A20-5
A.21	CARDS 1001 THROUGH 1999, STRIP REQUEST DATA	A21-1
A.22	CARDS 1001 THROUGH 1999, COMPARE DUMP FILES CONTROL DATA....	A22-1
A.23	SCDAP/RELAP5 OPERATING PROCEDURES	A23-1

List of Tables

A-1.	User Specified Materials.....	A18-8
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APPENDIX A - INPUT REQUIREMENTS

A.1 INTRODUCTION

Complete descriptions of data deck organization and data card requirements for all problem types allowed in SCDAP/RELAP5 are presented in this appendix.

A.1.1 Control Format

Input is described in terms of input records or cards, where an input record or card is an 80-character record. Punched cards are nearly obsolete, and one would be hard pressed to find a key punch at most installations. Now data are entered from interactive terminals, personal computers, or workstations, and the input usually exists only as disk files or is archived on tape. Data are usually viewed as lines on a CRT screen or lines of printed output. Nonetheless, the word *card* is used extensively in this input description to mean an input record.

SCDAP/RELAP5 attempts to read a 96-character record. If the actual input record is smaller, blank characters are added to the end of the input record to extend it to 96 characters. Each 96-character input record, preceded by a sequential card number starting at one and incrementing by one, is printed as the first part of a problem output. Only the first 80 characters are used for SCDAP/RELAP5 input; the additional 16 columns are for use with editors or utility programs such as UPDATE.

Most interactive editors allow the input of at least 80 character records. With many terminals allowing only 80 characters per line, it is convenient to limit the data record to 72 characters so that the data and editor supplied line numbers fit on one line (eight columns for line number and separator, 72 columns of data). Some editors provide for the optional storing of editor line numbers following the data portion of the record. If the data field is 72 columns, the line numbers might be stored in columns 73 to 80. These line numbers will be processed by SCDAP/RELAP5 as input, since SCDAP/RELAP5 uses the first 80 characters. To avoid this, either request the editor to store line numbers starting at character position 81, put a terminating character before the line number, or don't store the line numbers. The line numbers, if saved, are listed in the output echo of the input data.

If the UPDATE program is used to maintain the input deck, the update command must be used to specify that the card data are 80 columns instead of the default of 72.

A.1.2 Data Deck Organization

A SCDAP/RELAP5 problem input deck consists of at least one title card, optional comment cards, data cards, and a terminator card. A listing of these input cards is printed at the beginning of each SCDAP/RELAP5 problem. The order of the title, data, and comment cards is not critical, except that only the last title card, and, in the case of data cards having duplicate data card numbers, only the last data card is used. It is recommended that for a base deck, the title card be first, followed by data cards in card number order. Comment cards should be used freely to document

the input. For parameter studies and for temporary changes, a new title card with the inserted, modified, and deleted data cards and identifying comment cards should be placed just ahead of the terminating card. In this manner, a base deck is maintained; yet changes are easily made.

When a card format error is detected, a line containing a caret (^) located under the character causing the error and a message giving the card column of the error are printed. An error flag is set such that input processing continues, but the SCDAP/RELAP5 problem is terminated at the end of input processing. A standard SCDAP/RELAP5 error message (error message preceded by *****) is printed if a card error is found. Usually a card error will cause additional error comments to be printed during further input processing when the program attempts to process the erroneous data.

A.1.3 Title Card

A title card must be entered for each SCDAP/RELAP5 problem. A title card is identified by an equal sign (=) as the first nonblank character. The title (remainder of the title card) is printed as the second line of the first page following the list of input data. If more than one title card is entered, the last one entered is used.

A.1.4 Comment Cards

An asterisk (*) or a dollar sign (\$) appearing as the first nonblank character identifies the card as a comment card. Blank cards are treated as comment cards. The only processing of comment cards is the printing of their contents. Comment cards may be placed anywhere in the input deck except before continuation cards.

A.1.5 Data Cards

Data cards may contain varying numbers of fields that may be integer, real (floating point), or alphanumeric. Blanks preceding and following fields are ignored.

The first field on a data card is a card identification number that must be an unsigned integer. The value for this number depends upon the data being entered and will be defined for each type. If the first field has an error or is not an integer, an error flag is set. Consequently, data on the card are not used, and the card will be identified by the card sequence number in the list of unused data cards. After each card number and the accompanying data are read, the card number is compared to previously entered card numbers. If a matching card number is found, the data entered on the previous card are replaced by data from the current card. If the card being processed contains only a card number, the card number and data from the last previous card with that card number are deleted. Deleting a nonexistent card is not considered an error. If a card causes replacement or deletion of data, a statement is printed indicating that the card is a replacement card.

Comment information may follow the data fields on any data card by beginning the comment with an asterisk or dollar sign.

A numeric field must begin with either a digit (0 through 9), a sign (+ or -), or a decimal

point (.). A comma or blank (with one exception subsequently noted) terminates the numeric field. The numeric field has a number part and optionally an exponent part. A numeric field without a decimal point or an exponent is an integer field; a number with either a decimal point, an exponent, or both is a real field. A real number without a decimal point (i.e., with an exponent) is assumed to have a decimal point immediately in front of the first digit. The exponent part denotes the power of 10 to be applied to the number part of the field. The exponent part has an E or D, a sign (+ or -), or both followed by a number giving the power of 10. These rules for real numbers are identical to those for entering data in FORTRAN E or F fields, except that no blanks (with one exception) are allowed between characters to allow real data written by FORTRAN programs to be read. The exception is that a blank following an E or D denoting an exponent is treated as a plus sign. Acceptable ways of entering real numbers, all corresponding to the quantity 12.45, are illustrated by the following six fields:

12.45, +12.45, 0.1245+2, 1.245+1, 1.245E 1, 1.245D+1

Alphanumeric fields have three forms. The most common alphanumeric form is a field that begins with a letter and terminates with a blank, a comma, or the end of the card. After the first alphabetic character, any characters except commas and blanks are allowed. The second form is a series of characters delimited by quotes (") or apostrophes ('). Either a quote or an apostrophe initiates the field, and the same character terminates the field. The delimiters are not part of the alphanumeric word. If the delimiter character is also a desired character within the field, two adjacent delimiting characters are treated as a character in the field. The third alphanumeric form is entered as nHz, where n is the number of characters in the field, and the field starts at the first column to the right of H and extends for n columns. With the exception of the delimiters (even these can be entered if entered in pairs), the last two alphanumeric forms can include any desired characters. In all cases, the maximum number of alphanumeric characters that can be stored in a word is eight. If the number of characters is less than eight, the word is left justified and padded to the right with blanks. If more than eight characters are entered, the field generates as many words as needed to store the field, eight characters per word, and the last word is padded with blanks as needed. Regardless of the alphanumeric type, at least one blank or comma must separate fields.

It should be noted that the CDC-7600-6600 class of computers stores 10 characters per word, while most other computers (e.g., CRAY, Cyber 205, and IBM) hold only eight characters per word. All alphanumeric words required by SCDAP/RELAP5, such as component types, system names, or processing options, have thus been limited to eight characters. It is highly recommended that the user limit all other one-word alphanumeric quantities to eight characters so that input decks can be easily used on all computer versions. Examples of such input are alphanumeric names entered to aid identification of components in output edits.

A.1.6 Continuation Cards

A continuation card, indicated by a plus sign as the first nonblank character on a card, may follow a data card or another continuation card. Fields on each card must be complete, that is, a field may not start on one card and be continued on the next card. The data card and each

continuation card may have a comment field starting with an asterisk or dollar sign. No card number field is entered on the continuation card, since continuation cards merely extend the amount of information that can be entered under one card number. Deleting a card deletes the data card and any associated continuation cards.

A.1.7 Terminator Cards

The input data are terminated by a slash or a period card. The slash and period cards have a slash (/) and a period (.) respectively as the first nonblank character. Comments may follow the slash and period on these cards.

When a slash card is used as the problem terminator, the list of card numbers and associated data used in a problem is passed to the next problem. Cards entered for the next problem are added to the passed list or act as replacement cards, depending on the card number. The resulting input is the same as if all previous slash cards were removed from the input data up to the last period card or the beginning of the input data.

When a period card is used as the problem terminator, all previous input is erased before the input to the next problem is processed.

A.1.8 Sequential Expansion Format

Several different types of input are specified in sequential expansion format. This format consists of sets of data, each set containing one or more data items followed by an integer. The data items are the parameters to be expanded, and the integer is the termination point for the expansion. The expansion begins at one more than the termination point of the previous set and continues to the termination point of the current set. For the first set, the expansion begins at one. The termination points are generally volume, junction, or mesh point numbers, and always form a strictly increasing sequence. The input description will indicate the number of words per set (always at least two) and the last terminating point. The terminating point of the last expansion set must equal the last terminating point. Two examples are given. For the volume flow areas in a pipe component, the format is two words per set in sequential expansion format for *nv* sets. Using the number of volumes in the pipe (*nv*) as 10, the volume flow areas could be entered as:

```
0010101 0.01,10
```

In this case, the volume flow areas for Volumes 1 through 10 have the value 0.01. The pipe volume friction data format is three words per set for *nv* sets. Possible data might be:

```
0010801 1.0-6,0,8 1.0-3,0,9
```

```
0010802 1.0-6,0,10
```

Here, Volumes 1 through 8 and 10 have the same values and Volume 9 has a different value.

A.1.9 Upper/Lower Case Sensitivity

Historically, computer systems allowed only upper case alphabetic characters. Accordingly, the following input descriptions use upper case for required input, e.g., SNGLVOL, 1.25E5. Now, many systems have upper and lower case alphabetic characters. Some applications are case sensitive, others are not. At the INEL, required input must be in lower case, and the user should check the requirements at other installations. At installations with both upper and lower case capability, there are utilities and editors that can easily switch alphabetic characters to the desired case.

A.1.10 Data Card Requirements

In the following description of the data cards, the card number is given with a descriptive title of the data contained on the card. Next, an explanation is given of any variable data included in the card number. Then, the order of the data, the type, and the description of the data item are given. The type is indicated by A for alphanumeric, I for integer, and R for real.

A.2 MISCELLANEOUS CONTROL CARDS

A.2.1 Card 1, Developmental Model Control

This card has been added to the code for the convenience of developers in testing model improvements or new models. This card is not a standard input feature of the code. The description of this card has been added to the input requirements because several laboratories are receiving test versions to assist in developing and testing the code. Anyone using this card must realize that they are selecting options still under development and that they are using an experimental as opposed to a production version of the code.

The purpose of this card is to allow developers and analysts to quickly test new models by activating or deactivating a model through simple input instead of program modification, compilation, and loading. Ninety logical variables having only false or true values are provided and defined at the start of program execution as false. This input sets the logical variables to true or resets them to false at the beginning of a new problem or at any restart. Fortran IF statements added as part of the experimental coding activate or deactivate models based on the values of the logical variables.

As described above, up to 90 options can be defined and the options are identified with a number from 1 through 90. Which options are defined and what they control are very much version dependent. The usual practice is to enter the option capability using a currently unused option number as the new model or improvement is first coded. During further development and testing, the model may change and the effect of the option can change in a manner ranging from large to subtle. When the model has been completed or even abandoned, the production version of the model is coded and the option capability is removed. The option number is then available for reuse with a completely different model. Thus, the options are version dependent as to what option numbers are in use, what models they control, and the particular features of the models. Accordingly, these options should be used only by those in direct contact with the developers.

Each current option is described below. In light of the discussion above, the user should verify that the code version in use corresponds to this description. Programmers using this option feature are asked to include coding that issues error messages when unused options are selected and to issue a brief statement of the purpose of selected options. Remember, however, that all coding associated with these options is experimental and these output conventions may not be thoroughly checked.

Up to 91 numbers consisting of 0 or any of the currently available option numbers may be entered on this card. A positive nonzero number, *n*, activates Option *n* by setting the logical variable *n* to true; a negative nonzero number, *-n*, deactivates Option *n* by setting the logical variable *n* to false. Attempting to activate an unused option is an error, and attempting to deactivate an already inactive option or an unused option is also an error. The status of the options is printed in any NEW or RESTART problem containing this card or a RESTART problem in which the restart point had an option selected. The printout includes a listing of the 90 option numbers and a false (option not selected) or a true (option selected) value plus the brief description of each selected option.

MISCELLANEOUS CONTROL CARDS

The number 0 is not an option number but may be entered to force the brief descriptions of all available options to be printed regardless of whether they are active. The 0 input should be used only once to observe the available options and then removed so that the list better emphasizes the selected options.

W1-20(I) ZERO OR AN AVAILABLE OPTION NUMBER AS DESCRIBED ABOVE.

Option 1. This option adds an explicit viscous-like term to the momentum equations in the nearly-implicit scheme. This term is documented in the discussion of the semi-implicit scheme.

Option 2. This option uses a $\tau = 0.5$ and a lower limit 0.5 in the SCDAP/RELAP5/MOD3 time smoothing. The 0.5 limit was used in SCDAP/RELAP5/MOD2.5 time smoothing and gives more old time value weighting.

Option 3. This option allows specification of an modified form of the pv term in the energy equation. The specification of which volumes should use the alternate form is through a volume flag. This option is being tested as a means of overcoming an energy error when a large pressure difference exists between adjacent volumes.

Option 5. This option uses a hyperbolic function ($y = 1/x$) that ramps between two constants to determine the time constant used in a simplified SCDAP/RELAP5/MOD2.5 time smoothing scheme. Here x equals the min-max ratio of the magnitude of the two-phasic velocities. The computed time constant y is then scaled by 0.6dtn where dtn is the Courant dt. The physical interpretation of this is as follows. Courant dt is proportional to the ratio of cell length to the maximum of the magnitude of the two-phasic velocities. Hence, $(0.6y)(\text{dtn})$ is proportional to the time for the fluids to move past one cell. Safeguards against temporal nonconvergence and oversmoothing when the time step is not very small are also added to ensure robust running.

Option 6. This option advances COUPLE components before the hydrodynamics components are advanced. The standard code advances COUPLE components after the hydrodynamics.

Option 7. This option uses the SCDAP/RELAP5/MOD2.5 logic for the appearance of noncondensables in a volume that previously held only liquid.

Option 8. This option provides time step control based on the change in void fraction and is designed to limit the time step when the void fraction in any cell is decreasing rapidly such as during periods of condensation. The time step will be repeated if the decrease in void fraction in any hydrodynamic volume is considered too large. The time step will be repeated if the new void fraction is less than 0.001 and the old void fraction was greater than 0.01. The time step will also be repeated if the new void fraction is between 0.01 and 0.10 and the change in void fraction during the time step exceeds 20% of the new void fraction. If the new void fraction

exceeds 0.10, the time step will be repeated if the change exceeds 50% of the new void fraction. The time steps are repeated only when the void fraction is decreasing. This option is being tested in conjunction with Options 10 and 12 for improved performance at low pressures.

- Option 9. This option provides a user-controlled (on/off) transition to plug flow when the vapor velocity exceeds the criterion for transition from stratified flow in horizontal geometries. The need for this change occurs during the reflood phase in the horizontal core of the Hanford N-Reactor. The process tubes in the core region are long and have a small diameter. As subcooled coolant enters the process tubes, high condensation occurs that results in local depressurization and high steam velocities toward the condensation site. Instabilities occur that eventually cause the code to fail. This change introduces a plug flow model that limits condensation to a value just large enough to condense all the vapor that can flow at the critical velocity, using the full channel cross-section area. The critical velocity is the velocity large enough to cause transition from a stratified flow condition. The concept behind this model is that condensation lowers the local pressure and draws in steam, which pushes the water into a plug. The area of the plug limits condensation and reduces steam flow, which causes a return to stratified flow.
- Option 10. This option provides time step control based on change in pressure within a hydrodynamic volume. This change causes the code to repeat a time step if the change in pressure during a time step exceeds the old time value, the new time value, or 50,000 Pa. This time step control allows the pressure to change by no more than a factor of two during a time step. This change generally causes the code to run slower but more reliably. With this change activated, the code will more accurately track pressure waves and oscillations but may cause certain problems to run unacceptably slowly. This option has no effect if Option 8 is not selected.
- Option 11. This option scales the γ_s term in SCDAP/RELAP5/MOD2.5 time smoothing by $dt/(0.6(dtn))$ where dtn is the Courant dt. The γ_s term is similar to the variable x considered in Option 5. Physically, this has a similar meaning to what is done in Option 5. The safeguard against oversmoothing in SCDAP/RELAP5/MOD2.5 time smoothing is changed in two ways. First, it is bumped up to 0.96 to allow this scheme to be time step insensitive when dt is between Courant dt and 0.25 times Courant dt. Second, the safeguard is now set up in a manner that allows temporal convergence as dt tends toward zero. For small dt, the time smoothing for interfacial drag coefficient now uses the time constant τ_F in SCDAP/RELAP5/MOD2.5 time smoothing. This option is inactive unless Option 17 is also activated.
- Option 12. This option provides a user-controlled (on/off) water packer developed for horizontal reactors such as the Hanford N-Reactor. The interfacial drag coefficient

term for the momentum equation, F_{ij} , is adjusted as a function of vapor void fraction. For void fractions of 0.001 or less, F_{ij} is forced to an arbitrarily large value of 10^{10} . For void fractions greater than 0.01, the regularly calculated F_{ij} is used. For void fractions between 0.001 and 0.01, a cubic interpolation scheme is used to adjust F_{ij} between the calculated value and 10^{10} . As a cell is calculated to fill with liquid and the calculated cell pressure rises, the lower inertia vapor is the phase first to respond, either moving on to the next cell or moving back to an upstream cell. The effect of this model is that, as the void fraction decreases, the interfacial drag is increased, thus allowing the moving vapor to either drag liquid onto the next cell or impede the incoming liquid from an upstream cell. In either case, the model eases overfilling and overpressurization of the cell.

- Option 16. This option uses a 1.0 second time smoothing constant. Time smoothing is discussed in the code manuals, and the current SCDAP/RELAP5/MOD3 time smoothing constants are 0.1 second for pre-CHF flow regimes and 0.5 seconds for post-CHF flow regimes.
- Option 17. This option modifies the time step for mass error control.
- Option 18. This option adds the sharp interface and reverse void profile logic from SCDAP/RELAP5/MOD2.5.
- Option 19. This option uses the Bestion correlation (in SCDAP/RELAP5/MOD2.5) rather than the EPRI correlation (in SCDAP/RELAP5/MOD3) for bundles (when volume flag $b = 1$).
- Option 20. This option uses a time step algorithm that allows a time step up to twice the Courant time step. Starting with Version 7j, the SCDAP/RELAP5/MOD2.5 time step algorithm is the default, and the earlier SCDAP/RELAP5/MOD3 time step algorithm is activated by using this option.
- Option 21. Do not use. Presently this option only acquires additional storage arrays for testing numerical techniques.
- Option 22. This option selects an improved algorithm for computing the friction factor and also allows input to be entered to define a user-supplied friction factor.
- Option 23. This options selects a boron transport algorithm that greatly reduces the numerical diffusion of boron compared to the standard algorithm.
- Option 24. This option selects a SRL subcooled boiling model.
- Option 25. Do not use. This option adds y and z coordinate direction information to one-dimensional volumes. Coding is not complete for this change.
- Option 26. This option selects the coding for more implicit numerics in heat conduction and hydrodynamic advancement. Do not use as this option is not yet operational.

Card 100, Problem Type and Option

- Option 27. This option sets the time constant for radiation time smoothing to be 10.0. This option can be overridden by Option 29.
- Option 28. This option is designed to be used for cases of intense oxidation that results in one or more control volumes having fluid composed almost exclusively of hydrogen, and with the further result that the code is reducing the time step to a small value (<1 msec). This option reduces the rate of diffusion of hydrogen and oxygen at the oxidation surface and thus reduces the rate of oxidation. It should only be used when the code is taking small time steps and the rate of oxidation does not have an important impact on the damage progression, such as after more than 50% of the core is calculated to be molten.
- Option 29. This option sets the time constant for radiation time smoothing to be $1.0E-6$. This option takes precedence over Option 27, if both are on.
- Option 30. This option turns on the implicit coupling between SCDAP radiation heat transfer and fluid. Allow the time step to equal Δt Courant taking into account radiation heat transfer and fluid.
- Option 36. This option reduces the time step when the liquid phase is more than 50 K superheated.

A.2.2 Card 100, Problem Type and Option

This card is always required.

- W1(A) PROBLEM TYPE. Enter one of the following: NEW, RESTART, PLOT, REEDIT, STRIP, or CMPCOMS.
- NEW specifies a new simulation problem. RESTART specifies continuation from some point in a previous problem using information from the RSTPLT file. PLOT specifies plotting results from a previous simulation run using the RSTPLT file. REEDIT has not been implemented. STRIP specifies that data are to be extracted (stripped) from the RSTPLT file, and only the data specified are written to the STRIP file. CMPCOMS specifies that a comparison is to be made between dump records on two files written in one or two previous runs.
- W2(A) PROBLEM OPTION. This word is needed if W1 is NEW or RESTART and is optional if W1 is STRIP. If NEW is entered, enter either STDY-ST or TRANSNT to specify the type of simulation. When STRIP is entered in W1, W2 may be optionally entered with BINARY or FMTOUT. BINARY is assumed if W2 is not entered. BINARY indicates the unformatted (BUFFER OUT) file. FMTOUT indicates that the same information is to be written as 80-column formatted records. One use of this option is to allow simulation results to be transmitted to a different type of computer. Formats are:

STRIP Record 1.	(5A8,10X,A8)
STRIP Record 2.	(A10,3I10)
STRIP Record 3.	(8A10)
STRIP Record 4.	(A10,7I10/(8I10))
STRIP Record 5 ..., N.	(A10, 5X,1P,4E15.6/(5E15.6))

STRIP record above refers to the data in one record of the unformatted file. Multiple 80-column formatted records may be written for STRIP Records 3 through n.

A.2.3 Card 101, Input Check or Run Option

This card is optional for all types.

W1(A) OPTION. Enter either INP-CHK or RUN; if this card is omitted, RUN is assumed. If INP-CHK is entered, the problem execution stops at the end of input processing; if RUN is entered, the problem is executed if no input errors are detected. This card has no effect on a CMPCOMS problem.

A.2.4 Card 102, Units Selection

This card is optional for all problem types. If the card is omitted, SI units are assumed for both input and output. If the card is used, enter either SI or BRITISH for each word. SI units used are the basic units, kg, m, s, and the basic combined units such as $\text{Pa} = \text{kg}\cdot\text{m}/\text{s}^2\cdot\text{m}^2$. British units are a mixture of lb (mass), ft, and s primarily, but pressure is in lb_f/in^2 (lb_f is pounds force), heat energy is in Btu, and power is in MW. Thermal conductivity and heat transfer units use s, not h.

W1(A) INPUT UNITS.

W2(A) OUTPUT UNITS. If this word is missing, SI units are assumed for output.

A.2.5 Card 103, Restart Input File Control Card

This card is required for all problem types (W1 of Card 100) except NEW and is not allowed for type NEW.

When the problem option (W2 on Card 100) is the same as the problem being restarted, the steady-state or transient is continued and data on the RSTPLT file up to the point of restart are saved. If the restart continues from the point the previous problem terminated, restart and plot information is added to the end of the previous RSTPLT file. If the restart is before the termination point of the previous simulation, restart and plot data after the point of restart are overwritten by new results. A copy should be saved if RSTPLT files from each simulation are needed. If the problem options are different, data up to the point of restart are not saved, problem advancement time is reset to zero, and the RSTPLT file will contain information as if this problem type were

NEW.

- W1(I) RESTART NUMBER. This must be a number printed in one of the restart print messages and whose associated restart information is stored in the RSTPLT file. If the problem type (W1 on Card 100) is STRIP, this number must be 0.
- W2(A) COMPRESS FLAG. This optional flag indicates whether the restart-plot file is written in an uncompressed or compressed format. If the word is not entered or if NCMPRESS is entered, the restart plot file is assumed to be in uncompressed format. If CMPRESS is entered, the restart plot file is assumed to be in compressed format.
- W3-7(A) RESTART PLOT FILE NAME. This optional alphanumeric entry can be used to enter the file name of the restart plot file. Up to 40 characters may be entered as one alphanumeric field. (The code internally treats the field as up to five eight-character words.) The default file name for the restart plot file is rstplt. This may be overridden on Unix machines by using the -r option on the command line. Either the default name, the name from the command field, or the name from this field on a previous case may be overridden by this field.

A.2.6 Card 104, Restart-Plot File Control Card

This card can be entered for NEW, RESTART, and STRIP options. For the strip option, this card controls the strip file and the NONE option is not allowed. If this card is omitted, the restart-plot file is rewound at the end of the problem but no further action is taken. The user may need to provide system control cards to dispose of the file. To prevent the restart-plot file from being written, a card with NONE must be entered.

- W1(A) ACTION. This word may not be blank. If NONE, no restart-plot file is written. If this word is NCMPRESS, the restart-plot file is written in uncompressed format. If this word is CMPRESS, the file is written in compressed mode. The NCMPRESS and CMPRESS options may be entered only in NEW problems. In RESTART problems, this information is entered on the 103 Card.
- W2-6(A) RESTART PLOT FILE NAME. This optional alphanumeric entry can be used to enter the file name of the restart plot file. Up to 40 characters may be entered as one alphanumeric field. (The code internally treats the field as up to five eight-character words.) The default file name for the restart plot file is rstplt. This may be overridden on Unix machines by using the -r option on the command line. Either the default name, the name from the command field, or the name from this field on a previous case may be overridden by this field. This information can be entered only on NEW problems; in RESTART problems, this information may be entered on the 103 Card.

A.2.7 Card 105, CPU Time Remaining and Diagnostic Edit Card

Card 105 controls termination of transient advancement based on the CPU time remaining for the job. Some operating systems allow specification of the CPU time allocated for a job as part of the job control language and also provide a means to determine the CPU time remaining during job execution. As an alternative, Word 3 of this card may be entered as the CPU time allocated. An alternative CPU remaining time is computed by decrementing this quantity by the CPU used as measured by the program. If Word 3 is omitted or zero, the alternative CPU remaining time is assumed infinite. At the end of each time step, the CPU time remaining for the job is determined from the minimum of the system (if available) and alternative CPU remaining times. If the remaining CPU time is less than Word 1, the transient is immediately terminated. The advancement may not be at the end of a requested time step because of time step reduction; the hydrodynamic, heat conduction, and reactor kinetics may not be advanced to the same point; or the advancement may not be successful and the advancement is scheduled to be repeated with reduced time step. Major edits, minor edits, plot edits, and a restart record are forced. The transient can be restarted from this point as if the problem had not been interrupted. The transient is also terminated after successful advancement over a requested time step and the CPU time is less than Word 2. Word 2 should be larger than Word 1. The default values for Words 1 and 2 are 1.0 and 2.0 seconds. The default values are used if the card is not supplied or the entered numbers are less than default values. Word 2 is also forced to be 1.0 second larger than Word 1. The time values must include time for the final minor and major edits (very little time required), plotting, and any other processing to follow termination of SCDAP execution. This card is optional, but its use with Word 3 nonzero is strongly recommended on systems that do not provide a system CPU limit.

Card 105 also controls the diagnostic edit printout through the use of Words 4 and 5. If these words are missing or zero, no debug options are in effect. If Word 4 is greater than zero, then Word 4 is the attempted advancement count number to start a diagnostic edit, and Word 5 is the attempted advancement count number to stop the diagnostic edit as well as the calculation. If Word 4 is -1, a dump file is written on the file specified by the -A option on the command line at the completion of the advancement given in Word 5. Entering 0 in Word 5 writes the dump file just before start of transient advancement. The problem is terminated after writing the dump file. If Word 4 is -2, a dump file is written on the file given by the -A option after the advancement given in Word 5; the time advancement is then repeated and a dump file following the repeated advancement is written on the file given by the -B option. The problem is terminated after writing the second dump file. Word 5 must be greater than 0 when Word 4 is -2. The default file names are -A dumpfil1 and -B dumpfil2.

W1(R)	CPU REMAINING LIMIT 1 (s).
W2(R)	CPU REMAINING LIMIT 2 (s).
W3(R)	CPU TIME ALLOCATED (s). This quantity is optional.
W4(I)	DEBUG CONTROL WORD AS DESCRIBED ABOVE.

W5(I) DEBUG CONTROL WORD AS DESCRIBED ABOVE.

If the program is compiled with compile time option CTSS defined, entering Word 1 as 0.0 will cause no testing for CPU termination; and normal CTSS termination at the end of CPU time can occur. In this case, the problem can be restarted from the drop file.

A.2.8 Card 110, Noncondensable Gas Species

This card is required for all SCDAP/RELAP5 calculations and for RELAP5 calculations that use noncondensable gas. Hydrogen must be included for SCDAP/RELAP5 problems. Nitrogen must be included for any problem having accumulators or specifying noncondensables in initial conditions or time-dependent volumes.

W1-WN(A) NONCONDENSABLE GAS TYPE. Enter any number of words (maximum 5) of the following noncondensable gas types: argon, helium, hydrogen, nitrogen, xenon, krypton, or air.

A.2.9 Card 111, Metal Species

W1-W2(A) METAL SPECIES. Enter up to five words defining the metal species to be tracked. Species may be u, zr, steel, al, or o₂.

A.2.10 Cards 115 and 116, Noncondensable and Metal Species Mass Fractions

Card 115 is related to Card 110 and similarly Card 116 is related to Card 111. Card 115 is required if Card 110 is entered unless only one species is entered on Card 110 and then the mass fraction is set to 1.0. The number of words on Card 115 must equal the number of words on Card 110. A similar requirement holds for Card 116. The sum of the mass fractions on each card must sum to one. The mass fractions on these cards are default values and are used for initial conditions of active volumes and for values of time-dependent volumes unless mass fractions are entered in the hydrodynamic component data.

A.2.10.1 Card 115, Initial Mass Fraction for Each Noncondensable Gas Type

This card is required if Card 110 is entered, unless only one species is entered on Card 110 and then the mass fraction is set to 1.0. The number of words on Card 115 must equal the number of words on Card 110. This word cannot be entered on a RESTART problem.

W1-W2(R) MASS FRACTION FOR EACH NONCONDENSABLE GAS TYPE.

A.2.10.2 Card 116, Metal Mass Fractions

W1-WN(R) MASS FRACTION FOR EACH METAL SPECIES.

A.2.11 Card 119, Gravity Constant and Fixed/Moving Option

This card is optional and specifies the gravitational constant and whether the problem is fixed in space or can move. If not entered, the earth gravitational constant of 9.80665 m/s is used and all systems are fixed in space.

- W1(2) GRAVITATIONAL CONSTANT (m/s^2 , ft/s^2). A positive number including zero is used as the gravitational constant. If -1.0 is entered, the earth gravitational constant is used.
- W2(A) ENTER FIXED OR MOVING. FIXED for a problem fixed in space or MOVING for a problem that has translational and/or rotational movement. If this word is not entered, a fixed problem is assumed. Additional storage is assigned for moving problems and will be unused if MOVING is specified but no data specifying movement are entered. See the description for Cards 190 through 196 for specifying translational and rotational movement. Additional hydrodynamic input is required for moving problems and will be described using the term 'moving problem'.

A.2.12 Cards 120 Through 129, Hydrodynamic System Control Cards

Independent hydrodynamic systems can be described by the hydrodynamic component input. The term independent hydrodynamic systems means that there is no possibility of flow between the independent systems. A typical example would be the primary and secondary systems in a reactor where heat flows from the primary system to the secondary system in the steam generator but there is no fluid connection. If a tube rupture was modeled, the two systems would no longer be independent. Input processing lists an elevation for each volume in each independent hydrodynamic system and includes a check on elevation closure for each loop within a system. A reference volume is established for each system through input or default.

The processing for elevation changes and checks on proper loop closure is extended for moving problems. An elevation change in a volume is the component on the fixed z axis of a movement from one face of the volume to the opposite face. In a fixed problem, the only body force is gravity along the negative z axis. With translational and rotational movement, additional body forces with components in all three directions are possible. Analogous to elevations changes, the components along each fixed axis because of the face to face movements along each coordinate direction in a volume are required. In moving problems, the loop closure test and associated edited output is done for all three fixed axes.

These cards are optional for each system. If not entered for a system, that system contains H_2O as the fluid unless a different fluid is specified in hydrodynamic component data and the lowest numbered volume in each system is the reference volume. Additionally, the reference volume has a default elevation of zero for fixed problems and position coordinates of zero for a moving problem. These cards should not be entered in a RESTART problem.

The card format is different between fixed and moving problems. Each card describes one system.

A.2.12.1 Hydrodynamic System Card for Fixed Problem

- W1(I) REFERENCE VOLUME NUMBER. This must be a volume in the hydrodynamic system.
- W2(R) REFERENCE ELEVATION OF THE VOLUME CENTER RELATIVE TO A FIXED Z-AXIS (m, ft).
- W3(A) FLUID TYPE. Enter H₂O or D₂O.
- W4(A) OPTIONAL ALPHANUMERIC NAME OF SYSTEM USED IN OUTPUT EDITING. *NONE* is used if this is word not entered.

A.2.12.2 Hydrodynamic System Card for Moving Problem

- W1(I) REFERENCE VOLUME NUMBER IN FORM CCCXXXXXF. This quantity with the f field set to 0 must be a volume in the hydrodynamic system. This input quantity may be a positive or negative number. The sign of this number and the value of the f field indicate the position within the volume given by the coordinates in the next three words. If W1 is positive and f equals 0, the coordinates are to the center of the volume. If W1 is positive and f equals 1 through 6, the coordinates are to the center of the face given by f. If W1 is negative, f ranging from 0 through 7 indicates one of the eight corners of the solid. Using f as a binary number xyz where x, y, and z are 0 or 1, a 0 indicates the coordinate position closest to the origin and a 1 indicates the position away from the origin.
- W2(R) THE X-COORDINATE OF THE VOLUME RELATIVE TO A FIXED X-Y-Z AXES (m, ft).
- W3(R) THE Y-COORDINATE OF THE VOLUME RELATIVE TO A FIXED X-Y-Z AXES (m, ft).
- W4(R) THE Z-COORDINATE OF THE VOLUME RELATIVE TO A FIXED X-Y-Z AXES (m, ft).
- W5(A) FLUID TYPE. Enter H₂O or D₂O.
- W6(A) OPTIONAL ALPHANUMERIC NAME OF SYSTEM USED IN OUTPUT EDITING. *NONE* is used if this word is not entered.

A.2.13 Cards 140 Through 147, Self-Initialization Option Control Cards

These cards are optional. Data supplied on these cards are used to invoke the self-initialization

MISCELLANEOUS CONTROL CARDS

option. These data describe which and how many of each controller will be used. To retain generality and flexibility, the self-initialization option does not require that the steady-state and nearly implicit solution scheme options be concurrently turned on. However, this is the recommended procedure. These latter options are invoked through input data Cards 100 and 201 through 299. In addition to the data cards described below, the user must furnish data on the controllers to be used, as described in Section A.14.

A.2.13.1 Card 140, Self-Initialization Control Card

This card specifies the number and type of controllers desired.

- W1(I) NUMBER OF PUMP CONTROLLERS.
- W2(I) NUMBER OF STEAM FLOW CONTROLLERS.
- W3(I) NUMBER OF FEEDWATER CONTROLLERS.

A.2.13.2 Cards 141 Through 142, Self-Initialization Pump Controller and Identification Cards

These cards establish the relationship between the pump number and the number of the pump controller. For each pump so referenced, the user must use the time-dependent pump velocity option. For pump component Card ccc6100, Words 2 and 3 must be the alphanumeric and numeric parts for the pump controller. The time-dependent pump velocity data (pump component Cards ccc6100 through ccc6199) should be input so that the search variable and pump velocity are related by a straight line through the origin with a slope of 1.

- W1(I) COMPONENT NUMBER OF PUMP NUMBER 1.
- W2(I) CONTROLLER IDENTIFICATION NUMBER FOR PUMP NUMBER 1.
- W3(I) COMPONENT NUMBER OF PUMP NUMBER 2.
- W4(I) CONTROLLER IDENTIFICATION NUMBER FOR PUMP NUMBER 2.

A maximum of six pump/controller pairs may be entered.

A.2.13.3 Cards 143 Through 144, Self-Initialization Steam Flow Controller Identification Cards

These cards establish the relationship between the steam flow control valve number and the steam flow controller number.

- W1(I) COMPONENT NUMBER OF STEAM FLOW CONTROL VALVE NUMBER 1.
- W2(I) CONTROLLER NUMBER OF STEAM FLOW CONTROLLER FOR STEAM FLOW CONTROL VALVE NUMBER 1.

- W3(I) COMPONENT NUMBER OF STEAM FLOW CONTROL VALVE NUMBER 2.
- W4(I) CONTROLLER NUMBER OF STEAM FLOW CONTROLLER FOR STEAM FLOW CONTROL VALVE NUMBER 2.

A maximum of six control valve/controller pairs may be entered. Note that in the above it is assumed that the valve is the control component. However, the user is not constrained to use a valve and may use a pump or a time-dependent junction. CAUTION: Only a servo valve, a time-dependent junction, or a pump may be used, or a diagnostic error will result.

A.2.13.4 Cards 145 and 146, Self-Initialization Feedwater Controller Identification Cards

These cards establish the relationship between the feedwater valve number and the feedwater controller number.

- W1(I) COMPONENT NUMBER OF FEEDWATER VALVE NUMBER 1.
- W2(I) CONTROLLER ID NUMBER OF THE FEEDWATER CONTROLLER FOR FEEDWATER VALVE NUMBER 1.
- W3(I) COMPONENT NUMBER OF FEEDWATER VALVE NUMBER 2.
- W4(I) CONTROLLER ID NUMBER OF THE FEEDWATER CONTROLLER FOR FEEDWATER VALVE NUMBER 2.

A maximum of six control valve/controller pairs may be entered. Note that in the above it is assumed that a valve component is the control component. However, the user is not constrained to use a valve and may use a pump or time-dependent junction. CAUTION: Only a servo valve, time-dependent junction, or a pump is allowed, or a diagnostic will result, such as a time-dependent junction with the controller output used as the independent variable in place of time.

A.2.13.5 Card 147, Pressure and Volume Control Component Identification Card

This card identifies the component number, connection data, and pressure level for the time-dependent volume that is to provide pressure and volume control during the self-initialization null transient.

- W1(I) COMPONENT NUMBER OF TIME-DEPENDENT VOLUME THAT REPLACES THE PRESSURIZER.
- W2(I) COMPONENT NUMBER TO WHICH THE ABOVE TIME-DEPENDENT VOLUME IS CONNECTED. CAUTION: Only a single junction is allowed or an error will result.
- W3(R) DESIRED STEADY-STATE PRESSURE.

A.2.14 Card 190, Type of Transient Rotation Angles

The following card is entered only for a moving problem and specifies whether Euler or pitch-yaw-roll angles are used. If the card is not entered, Euler angles are assumed. Three angles are used to specify the rotational position in both systems. With Euler angles, Angle 1 rotates about the inertial z axis, Angle 2 rotates about the new local x axis, and Angle 3 rotates about the new local z axis. With pitch-yaw-roll angles, the pitch angle is a rotation about the inertial y axis, yaw is a rotation about the new local z axis, and roll is a rotation about the new local x axis. A positive angle indicates a rotation in the counterclockwise direction. In a rotation, the rotation axis is fixed, and the other two axes move. A positive 90-degree rotation about the x axis would move the new y axis to the old z axis position; a positive 90-degree rotation about the y axis would move the new z axis to the old x axis, and a positive 90-degree rotation about the z axis would move the new x axis to the old y axis.

W1(A) EULER OR PYR. Enter EULER to specify Euler angles or PYR for pitch-yaw-roll angles.

A.2.15 Cards 191 Through 193, Transient Rotation Angles

These cards are entered only in a moving problem and specify the transient rotation angles as a function of time. Card 191 describes the Euler Angle 1 or the pitch angle, Card 192 describes the Euler Angle 2 or the yaw angle, and Card 194 describes the Euler Angle 3 or the roll angle. The angle α is given by

$$\alpha = A \sin \left[2\pi \left(\frac{t}{T} + \frac{\phi}{360} \right) \right] + \alpha_0 + \omega_0 t .$$

where t is time and the other quantities are input.

- W1(R) AMPLITUDE A (deg). This must be a positive nonzero number ≤ 360.0 .
- W2(R) PERIOD T (s). This must be a positive nonzero number. A value of zero implies infinite period, that is $1/T = 0$.
- W3(R) PHASE ANGLE (ϕ) (deg). The absolute value of this quantity must be ≤ 360.0 .
- W4(R) OFFSET ANGLE (α_0) (deg). The absolute value of this quantity must be ≤ 360 .
- W5(R) CONSTANT PART OF ROTATIONAL SPEED (ω_0) (deg/s).

A.2.16 Cards 194 Through 196, Transient Displacement Cards

These cards are entered only in a moving problem and specify the transient displacement as a function of time. Card 194 describes the displacement in the fixed x direction, Card 195 the displacement in the fixed y direction, and Card 196 the displacement in the fixed z direction. The displacement d is given by

$$d = A \sin \left[2\pi \left(\frac{t}{T} + \frac{\phi}{360} \right) \right]$$

- W1(R) AMPLITUDE A (m, ft). This must be a positive nonzero number.
- W2(R) PERIOD T (s). This must be a positive nonzero number. A value of zero implies infinite period, that is $1/T = 0$.
- W3(R) PHASE ANGLE (ϕ) (deg). The absolute value of this quantity must be ≤ 360.0 .

A.3 CARDS 200 THROUGH 299, TIME STEP CONTROL CARDS

A.3.1 Card 200, Initial Time Value

This card is optional. If not entered, the simulation time at the start of the advancements is zero. If this card is entered, the simulation time is set to the entered value. This should only be used for NEW problems.

W1(R) Initial time. This value must be greater than or equal to zero.

A.3.2 Cards 201 Through 299, Time Step Control

At least one card of this series is required for NEW problems. If this series is entered for RESTART problems, it replaces the series from the problem being restarted. This series is not used for other problem types. Card numbers need not be consecutive.

W1(R) TIME END FOR THIS SET (s). This quantity must increase with increasing card number.

W2(R) MINIMUM TIME STEP (s). This quantity should be a positive number $< 1.0E-6$. If a larger number is entered, it is reset to $1.0E-6$.

W3(R) MAXIMUM TIME STEP (s). This quantity is also called the requested time step. In transient problems (Word 2 = TRANSNT for Card 100), the user should be careful not to make this too large for the first time step.

W4(I) TIME STEP CONTROL OPTION. This word has the packed format ssdt.

The digits ss, that represent a number from 0 through 15, are used to control the printed content of the major edits. The number is treated as a four-bit binary number. If no bits are set (i.e., the number is 0), all the standard major printed output is given. If the first bit from the right is set (i.e., ss = 1 if the other bits are not set), the heat structure temperature block is omitted. If the second bit from the right is set (i.e., ss = 2 if the other bits are not set), the second portion of the junction block is omitted. If the third bit from the right is set (i.e., ss = 4 if the other bits are not set), the second portion of the volume block is omitted. If the fourth bit from the right is set (i.e., ss = 8 if the other bits are not set), the statistics block is omitted.

The digit d, that represents a number from 0 through 7, can be used to obtain extra output at every hydrodynamic time step. The number is treated as a three-bit binary number. If no bits are set (i.e., the number is 0), the standard output at the requested frequency using the maximum time step is obtained (see Words 5 and 6 of this card). If the number is nonzero, output is obtained at each time step; and the bits indicate which output is obtained. If the first bit from the right is set (i.e., d = 1 if the other bits are not set), major edits are obtained every time step. If the

second bit from the right is set (i.e., $\underline{d} = 2$ if the other bits are not set), minor edits are obtained every time step. If the third bit from the right is set (i.e., $\underline{d} = 4$ if the other bits are not set), internal plot records are written every time step. These options should be used carefully, since considerable output can be generated. This extra output is generated only for the current run and is not written to the RSTPLT file.

The digits $\underline{tt}$, that represent a number from 0 through 31, are used to control the time step. The recommended way to run most calculations with the semi-implicit hydrodynamic scheme is to use $\underline{tt} = 3$; with the nearly-implicit scheme use $\underline{tt} = 11$. The number is treated as a four-bit binary number. If no bits are set (i.e., the number is 0), no error estimate time step control is used, and the maximum time step is attempted for both hydrodynamic and heat structure advancement. The hydrodynamic time step, however, is reduced to the material Courant limit and further to the minimum time step for causes such as water property failures. If the first bit from the right is set (i.e., $\underline{tt} = 1$ if the other bits are not set), heat transfer uses the maximum time step; and the hydrodynamics, in addition to the time step control when no bits are set, uses a mass error analysis to control the time step between the minimum and maximum time step. If the second bit from the right is set (i.e., $\underline{tt} = 2$ if the other bits are not set), the heat structure time step is the same as the hydrodynamic time step. If the third bit from the right is set (i.e., $\underline{tt} = 4$ if the other bits are not set), heat transfer uses the hydrodynamic time step and the hydrodynamics, in addition to the time step control described for no bits set, uses a partially implicit hydrodynamic and heat slab coupling. If the fourth bit from the right is set (i.e., $\underline{tt} = 8$ if the other bits are not set), heat transfer uses the hydrodynamic time step and the hydrodynamics, in addition to the time step control described for no bits set, uses the nearly-implicit hydrodynamic numerical scheme. If the fifth bit from the right is set (i.e., $\underline{tt} = 16$ if the other bits are not set), the test for convergence of a steady-state calculation is not made.

Using $\underline{tt} = 0$ is not recommended except for special testing situations. The use of $\underline{tt} = 1$ is possible if the maximum time step is kept sufficiently small to ensure that the explicit connection between the hydrodynamics and heat conduction/heat transfer calculations remains stable. If there is any doubt, use $\underline{tt} = 3$ (sets first bit and second bit), which is the recommended way to run most calculations with the semi-implicit hydrodynamic scheme. At the present time, the third bit is not fully operational. The fourth bit, which activates the nearly-implicit scheme, is recommended during a steady-state and/or self-initialization case problem, where the time step is limited by the material Courant limit. The nearly-implicit scheme can also be used during slower phases of a transient problem, although the user is advised that the answers may change somewhat from the semi-implicit scheme answers (depending on the time step size) and also the calculation may not run any faster than the semi-implicit scheme. The use of $\underline{tt} = 11$ (sets first, second, and fourth bits) is the recommended way at this time to run most calculations with the

nearly-implicit hydrodynamic scheme. In steady-state calculations, setting the fifth bit for the early part of the run can ensure the calculation runs to a user-specified time; then setting the fifth bit off can allow the steady-state convergence test control the termination of the problem.

- W5(I) MINOR EDIT AND PLOT FREQUENCY. This is the number of maximum or requested time advances per minor edit and write of plot information.
- W6(I) MAJOR EDIT FREQUENCY. This is the number of requested time advances per major edit.
- W7(I) RESTART FREQUENCY. This is the number of requested time advances per write of restart information.

A.4 CARDS 301 THROUGH 399, MINOR EDIT REQUESTS

These cards are optional for NEW and RESTART problems, are required for a REEDIT problem, and are not allowed for PLOT and STRIP problems. If these cards are not present, no minor edits are printed. If these cards are present, minor edits are generated and the order of the printed quantities is given by the card number of the request card. One request is entered per card, and the card numbers need not be consecutive. For RESTART problems, if these cards are entered, all the cards from the previous problem are deleted. The quantities in Section A.4.1 through Section A.4.7 are always written to the restart-plot file. The quantities in Section A.4.8 are written to the restart-plot file only if a 2080xxxx card is used.

W1(A) VARIABLE CODE.

W2(I) PARAMETER.

The quantities that can be edited and the required input are listed below. For convenience, quantities that can be used in plotting requests, in trip specifications, as search variables in tables, and as operands in control statements are listed. Units for the quantities are also given. Interactive input variables described in Section A.6 can be used in batch or interactive jobs in the same manner as the variables listed below. The parameter for interactive input variables is 1000000000. Quantities compared in variable trips must have the same units, and input to tables specified by variable request codes must have the specified units.

A.4.1 General Quantities

<u>Code</u>	<u>Quantity</u>
CPUTIME	The current CPU time for this problem (s). The parameter is zero.
EMASS	Estimate of mass error (kg, lb). The parameter is zero.
NULL	Specifies null field. Allowed only on trip cards. The parameter is zero.
TIME	Time (s). The parameter is zero. This specification cannot be used for minor edit requests.
TIMEOF	Time of trip occurring (s). The parameter is the trip number. This specification is allowed only on trip cards.
TMASS	Total mass of water, steam, and noncondensables in the entire system (kg, lb). The parameter is zero.

A.4.2 Component Quantities

The quantities listed below are unique to certain components; for example, a pump velocity can only be requested for a pump component. The parameter is the component number, i.e., the three-digit number ccc used in the input cards.

<u>Code</u>	<u>Quantity</u>
ACQTANK	Total energy transport to the gas by heat and mass transfer in the accumulator (W, Btu/s).
ACRHON	Accumulator noncondensable density (kg/m^3 , lb/ft^3).
ACTTANK	Mean accumulator tank wall metal temperature (K, $^{\circ}\text{F}$).
ACVDM	Gas volume in the accumulator tank, standpipe, and surge line (m^3 , ft^3).
ACVLIQ	Liquid volume in the accumulator tank, standpipe, and surge line (m^3 , ft^3).
PMPVEL	Pump velocity in the pump component (rad/s, rev/min).
PMPHEAD	Pump head in the pump component (Pa, lb_f/in^2).
PMPTRQ	Pump torque in the pump component ($\text{N}\cdot\text{m}$, $\text{lb}_f\cdot\text{ft}$).
TUREFF	The efficiency of the turbine component.
TURPOW	The power developed in the turbine component (W, Btu/s).
TURTRQ	The torque developed in the turbine component ($\text{N}\cdot\text{m}$, $\text{lb}_f\cdot\text{ft}$).
TURVEL	The rotational velocity of the turbine component (rad/s, rev/min).
VLVAREA	Valve area ratio in the valve component. This is the ratio of the partially open valve physical area to the junction area.
VLVSTEM	Relative valve stem position in the valve component. This is the ratio of the partially open valve physical area to the fully open valve physical area.

A.4.3 Volume Quantities

For most of the following variable codes, the parameter is the volume number. Some of the quantities are associated with the coordinate directions in the volume and these quantities are computed for each coordinate direction in use. The parameter for the coordinate direction related quantities is the volume number plus F, where F is described below. The quantities requiring the volume number plus F are so identified.

Every volume has at least one coordinate direction, and some volumes may have up to three orthogonal coordinate directions. Each coordinate has an inlet face and an outlet face. Faces are numbered 1 through 6, where Faces 1 and 2 are the inlet and outlet faces associated with Coordinate 1, respectively. Faces 3 and 4 are inlet and outlet faces associated with Coordinate 2, and Faces 5 and 6 are inlet and outlet faces associated with Coordinate 3. All volumes use Coordinate 1. The quantity F to be added to the volume number to form the parameter used with coordinate direction related quantities is 0 or the face number. When F is 0 (i.e., just the volume number), 1, or 2, the

Volume Quantities

volume velocity is for Coordinate 1. When F is 3 or 4, the volume velocity is for Coordinate 2; and when F is 5 or 6, the volume velocity is for Coordinate 3. The coordinate dependent quantities for Coordinate 1 using the parameter with F equal to 0 are automatically written to the plot records. The other coordinate dependent quantities can be written to the plot records using the 208 card series. Input checks are made that the parameter specifies a volume coordinate direction that is in use.

<u>Code</u>	<u>Quantity</u>
BORON	Boron density (kg/m^3 , lb/ft^3).
FLOREG	Flow regime number. The parameter is the volume number plus F.
P	Volume pressure (Pa , lb_f/in^2).
Q	Total volume heat source to liquid and vapor (W , Btu/s).
QUALA	Volume noncondensable mass fraction.
QUALE	Volume equilibrium quality.
QUALS	Volume static quality.
QWG	Volume heat source to vapor (W , Btu/s).
RHO	Total density (kg/m^3 , lb/ft^3).
RHOF	Liquid density (kg/m^3 , lb/ft^3).
RHOG	Vapor density (kg/m^3 , lb/ft^3).
SATTEMP	Volume saturation temperature based on the partial pressure of steam (K , $^{\circ}\text{F}$).
SOUNDE	Volume sonic velocity (m/s , ft/s).
TEMPF	Volume liquid temperature (K , $^{\circ}\text{F}$).
TEMPG	Volume vapor temperature (K , $^{\circ}\text{F}$).
UF	Liquid specific internal energy (J/kg , Btu/lb).
UG	Vapor specific internal energy (J/kg , Btu/lb).
VAPGEN	Volume vapor generation rate per unit volume ($\text{kg/m}^3\cdot\text{s}$, $\text{lb/ft}^3\cdot\text{s}$).
VELF	Volume-oriented liquid velocity (m/s , ft/s). The parameter is the volume number plus F.
VELG	Volume-oriented vapor velocity (m/s , ft/s). The parameter is the volume

number plus F.

VOIDF Liquid void fraction.

VOIDG Vapor void fraction.

A.4.4 Junction Quantities

For the following variable request codes, the parameter is the junction number, i.e., the nine-digit number cccnn0000 printed in the major edit.

<u>Code</u>	<u>Quantity</u>
MFLOWJ	Combined liquid and vapor flow rate (kg/s, lb/s).
QUALAJ	Junction noncondensable mass fraction.
RHOFJ	Junction liquid density (kg/m ³ , lb/ft ³).
RHOGJ	Junction vapor density (kg/m ³ , lb/ft ³).
UFJ	Junction liquid specific internal energy (J/kg, Btu/lb).
UGJ	Junction vapor specific internal energy (J/kg, Btu/lb).
VELFJ	Junction liquid velocity (m/s, ft/s).
VELGJ	Junction vapor velocity (m/s, ft/s).
VOIDFJ	Junction fraction.
VOIDGJ	Junction vapor void fraction (void fraction).

A.4.5 Heat Structure Quantities

For the request code, HTVAT, the parameter is the seven-digit heat structure number cccg0nn. For the remaining codes, the parameter is the seven-digit heat structure number ccc0gnn with a two-digit number appended. For codes other than HTTEMP, the appended number is 00 for the left boundary and 01 for the right boundary. For HTTEMP, the appended number is the mesh point number. Only the surface temperatures are written by default in plot records on the RSTPLT file, and thus plot requests in plot-type problems and strip requests are limited to those temperatures unless the interior temperatures are forced to the RSTPLT file through 2080xxxx cards.

<u>Code</u>	<u>Quantity</u>
HTCHF	Critical heat flux (W/m ² , Btu/s·ft ²).
HTHTC	Heat transfer coefficient (W/m ² ·K, Btu/s·ft ² ·°F).

Reactor Kinetic Quantities

HTRNR	Heat flux (W/m^2 , $\text{Btu/s}\cdot\text{ft}^2$).
HTTEMP	Mesh point temperature (K, $^{\circ}\text{F}$).
HTVAT	Volume-averaged temperature in the heat structure (K, $^{\circ}\text{F}$).

A.4.6 Reactor Kinetic Quantities

The parameter is zero for the following reactor kinetic quantities.

<u>Code</u>	<u>Quantity</u>
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The following list is for point kinetics variables.

RKFIPOW	Reactor power from fission (W).
RKGAPOW	Reactor power from fission product decay (W).
RKREAC	Reactivity (dollars).
RKRECPER	Reciprocal period (s^{-1}).
RKTPOW	Total reactor power, i.e., sum of fission and fission product decay power (W).

The following list is for one-dimensional space dependent kinetic variables.

<u>Code</u>	<u>Quantity</u>
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RKOFIPOW	Total reactor fission power (W).
RKOGAPOW	Total reactor decay power (W).
RKORECPR	Reciprocal reactor period (W).
RKOTPOW	Total reactor power (W).

A.4.7 Control System Quantities

The parameter is the control component number; i.e., the three-digit number ccc or the four-digit number cccc used in the input cards.

CNTRLVAR	Control component number. These quantities are assumed dimensionless except for a SHAFT component.
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A.4.8 Cards 2080xxxx, Expanded Edit/Plot Variables

Several additional quantities have been added to the list of variables, which may be used in minor edits, plot requests, control systems, and trip logic. The additional variables and their associated parameters are listed in Section A.4.8.1 through Section A.4.8.11.

CARDS 301 THROUGH 399, MINOR EDIT REQUESTS

These additional request variables are not written to the restart-plot file (necessary for plotting) unless the user enters Cards 2080xxxx. The format of these cards is given below. They are only required for the additional variables that the user wants to have written on the restart-plot file. The user can specify that between 1 and 9999 of these variables be written to the restart-plot file.

The additional variables can be used in the usual manner on minor edit cards, trip cards, control system input cards, and on plot request cards.

The following cards are used to cause the requested variables to be written onto the RSTPLT file. These cards are not to be used for the previously available variable request codes (see Section A.4.1 through Section A.4.7), since they are always written to the RSTPLT file. The field xxxx need not be consecutive.

- W1(A) VARIABLE REQUEST CODE. See Section A.4.8.1 through Section A.4.8.11 for the valid request code.
- W2(I) PARAMETER. Enter the parameter associated with the variable request code.

A.4.8.1 General Quantities

<u>Code</u>	<u>Quantity</u>
COUNT	The current attempted advancement count number. The parameter is 0.
DT	The current time step (s). The parameter is 0.
DTCRNT	The current Courant time step (s). The parameter is 0.
ERRMAX	The current estimate of the truncation mass error. The parameter is 0.
STDTRN	Steady-state/transient flag. The parameter is 0. For steady-state, the value is 0.0. For transient, the value is 1.0.
TESTDA	An array testda of twenty quantities, [(real testda(20))] has been defined for the convenience of program developers. This entry with a parameter ranging from 1 through 20 selects testda(parameter). The testda array is initially set to zero and programming must be inserted to set testda values. The usual purpose of this capability is to allow a simple method for debug information to be printed in minor edits or to be plotted.
RRANGL	Rotation angle of moving problem. The parameter is from 1 through 3. The parameter specifies the Euler Angle Number, or for pitch-yaw-roll angles. 1 specifies the pitch angle, 2 specifies the yaw angle, and 3 specifies the roll angle.
RRANGW	Rotational velocity of moving problem. The parameter is from 1 through 3 and is the same as for RRANGL.

RRDISA	Translation acceleration coordinate for moving problem. The parameter is the same as for RRDISP.
RRDISP	Translation position coordinate for moving problem. The parameter is from 1 through 3 indicating the x, y, and z coordinate, respectively.
RRDISV	Translation velocity coordinate for moving problem. The parameter is the same as for RRDISP.
RRDMEG	Coordinate of rotational acceleration vector in inertial frame. The parameter is the same as for RROMEG.
RROMEG	Coordinate of rotational velocity vector in inertial frame. The parameter is from 1 through 3 indicating the x, y, and z coordinate, respectively.

A.4.8.2 Component-Related Quantities

The quantities listed below are unique to certain components; for example, a pump motor torque can only be requested for a pump component ccc used in the input cards.

<u>Code</u>	<u>Component Type</u>	<u>Quantity</u>
ACPGTG	Accumulator	Vapor specific heat, C_p , at vapor temperature (J/kg·K, Btu/lb·°F).
ACPNIT	Accumulator	Noncondensable specific heat, C_p , at vapor temperature (J/kg·K, Btu/lb·°F).
ACVGTG	Accumulator	Vapor specific heat, C_v , at vapor temperature (J/kg·K, Btu/lb·°F).
AHFTG	Accumulator	Liquid enthalpy at vapor temperature (J/kg, Btu/lb).
AHFGTF	Accumulator	Heat of vaporization at liquid temperature (J/kg, Btu/lb).
AHFGTG	Accumulator	Heat of vaporization at vapor temperature (m ³ /kg, ft ³ /lb).
AHGTF	Accumulator	Vapor enthalpy at liquid temperature (J/kg, Btu/lb).
AVISCN	Accumulator	Noncondensable viscosity (kg/m·s, lb/ft·s).
BETAV	Accumulator	Steam saturation coefficient of expansion (K ⁻¹ , °F ⁻¹).

CARDS 301 THROUGH 399, MINOR EDIT REQUESTS

DMGDT	Accumulator	Time rate of change in dome vapor mass (kg/s, lb/s).
OMEGA	Inertial Valve	Valve disk angular velocity (rad/s, rev/min).
PMPMT	Pump	Pump motor torque (N•m, lb•ft).
PMPNRT	Pump	Calculated pump inertia (kg•m ² , lb•ft ²).
THETA	Inertial Valve	Valve disk angular position (deg).

A.4.8.3 Volume-Related Quantities

For the following variable codes, the parameter is the volume number or the volume number plus F. See Section A.4.3 for discussion of F. Quantities requiring the volume number plus F are so noted.

Code	Quantity
AHTCOFG	Heat transfer coefficient between slab and vapor (W/m ² •K, Btu/s•ft ² •°F).
AVOL	Area of the volume (m ² , ft ²). The parameter is the volume number plus F.
BETAFF	Liquid isobaric coefficient of the thermal expansion (K ⁻¹ , °F ⁻¹).
BETAGG	Vapor isobaric coefficient of the thermal expansion (K ⁻¹ , °F ⁻¹).
CSUBPF	Liquid specific heat, C _p , bulk conditions (J/kg•K, Btu/lb•°F).
CSUBPG	Vapor specific heat, C _p , bulk conditions (J/kg•K, Btu/lb•°F).
DRFDP	Partial derivative of RHOF with respect to pressure (s ² /m ² , s ² /ft ²).
DRFDUF	Partial derivative of RHOF with respect to U _f (kg•s ² /m ⁵ , lb•s ² /ft ⁵).
DRGDP	Partial derivative of RHOG with respect to pressure (s ² /m ² , s ² /ft ²).
DRGDUG	Partial derivative of RHOG with respect to U _g (kg•s ² /m ⁵ , lb•s ² /ft ⁵).
DSNDDP	Partial derivative of SOUNDE with respect to pressure (m ² •s/kg, ft ² •s/lb).
DTDP	Partial derivative of T _{sat} with respect to pressure (K/Pa, in ² •°F/lb _f).
DTDUG	Partial derivative of T _{sat} with respect to U _g (s ² •K/m ² , s ² •°F/ft ²).
DTDXA	Partial derivative of T _{sat} with respect to X _n (K, °F).
DTFDP	Partial derivative of T _f with respect to pressure (K/Pa, in ² •°F/lb _f).
DTFDUF	Partial derivative of T _f with respect to U _f (s ² •K/m ² , s ² •°F/ft ²).

DTGDP	Partial derivative of T_g with respect to pressure (K/Pa , $in^2 \cdot ^\circ F/lb_f$).
DTGDUG	Partial derivative of T_g with respect to U_g ($s^2 \cdot K/m^2$, $s^2 \cdot ^\circ F/ft^2$).
DTGDXA	Partial derivative of T_g with respect to X_n (K , $^\circ F$).
FLOREG	Flow regime number. The parameter is the volume number plus F.
FWALF	Liquid wall frictional drag coefficient ($kg/m^3 \cdot s$, $lb/ft^3 \cdot s$). The parameter is the volume number plus F.
FWALG	Vapor wall frictional drag coefficient ($kg/m^3 \cdot s$, $lb/ft^3 \cdot s$). The parameter is the volume number plus F.
GAMMAW	Vapor generation rate at the wall per unit volume ($kg/m^3 \cdot s$, $lb/ft^3 \cdot s$).
GRAVV	Coordinate of equivalent gravity caused by the summation of gravity, translation accelerations, and rotation effects (m/s^2 , ft/s). The parameter is as described for HYPOSV.
HIF	Liquid side interfacial heat transfer coefficient per unit volume ($W/m^3 \cdot K$, $Btu/s \cdot ft^3 \cdot ^\circ F$).
HIG	Vapor side interfacial heat transfer coefficient per unit volume ($W/m^3 \cdot K$, $Btu/s \cdot ft^3 \cdot ^\circ F$).
HTCOFF	Heat transfer coefficient between slab and liquid ($W/m^2 \cdot K$, $Btu/s \cdot ft^2 \cdot ^\circ F$).
HVMIX	Enthalpy of the liquid and vapor (J/kg , Btu/lb).
HYPOSV	Coordinate in inertial frame of center of volume with respect to center of rotation in moving problem (m , ft). The parameter is the volume number plus F. The x coordinate is selected when F is 1 or 2, the y coordinate is selected when F is 3 or 4, and the z coordinate is selected when F is 5 or 6.
PECLTV	Peclet number.
PPS	Vapor partial pressure (Pa , lb_f/in^2).
RGDXA	Partial derivative of RHOG with respect to X_n (kg/m^3 , lb/ft^3).
RHOM	Total density for the mass error check (kg/m^3 , lb/ft^3).
SATHF	Liquid specific enthalpy at saturation conditions (J/kg , Btu/lb).
SATHG	Vapor specific enthalpy at saturation conditions (J/kg , Btu/lb).
VISCF	Liquid viscosity ($kg/m \cdot s$, $lb/ft \cdot s$).

VISCG	Vapor viscosity (kg/m·s, lb/ft·s).
SIGMA	Surface tension (J/m ² , Btu/ft ²).
THCONF	Liquid thermal conductivity (W/m·K, Btu/s·ft·°F).
THCONG	Vapor thermal conductivity (W/m·K, Btu/s·ft·°F).
TSATT	Saturation temperature corresponding to total pressure (K, °F).
VELF	Volume-oriented liquid velocity (m/s, ft/s). The parameter is the volume number plus F.
VELG	Volume-oriented vapor velocity (m/s, ft/s). The parameter is the volume number plus F.
VVOL	Volume of the volume (m ³ , ft ³).

A.4.8.4 Junction-Related Quantities

For the following variable codes, the parameter is the junction number, i.e. the nine-digit number cccnn0000 printed in the major edit.

<u>Code</u>	<u>Quantity</u>
COJ	Junction distribution coefficient.
FIJ	Interphase friction (N·s ² /m ⁵ , lb _F ·s ² /ft ⁵).
FLORGJ	Junction flow regime number.
FORMFJ	Liquid form loss factor (dimensionless).
FORMGJ	Vapor form loss factor (dimensionless).
IREGJ	Vertical bubbly/slug flow junction flow regime number.
SONICJ	Junction sound speed (m/s, ft/s).
VGJJ	Vapor drift velocity (m/s, ft/s).
VOIDJ	Junction vapor fraction (void fraction) used in the interphase drag.
XEJ	Junction equilibrium quality.

A.4.8.5 Heat Structure-Related Quantities

<u>Code</u>	<u>Quantity</u>
HTGAMW	Wall vapor generation rate per unit volume (kg/m ³ ·s, lb/ft ³ ·s). The parameter

is the heat structure geometry number $cccg0nn$ with a two-digit number appended (00 for the left boundary, and 01 for the right boundary).

HTMODE Boundary heat transfer mode number (unitless). The mode number indicates which heat transfer regime is currently in effect. The parameter is the seven-digit heat structure geometry number $cccg0nn$ with a two-digit number appended. The two-digit appended Number 00 specifies the left boundary, and 01 specifies the right boundary. This same quantity is valid for the reflood heat structures.

HTRG Heat flux to vapor phase (W/m^2 , $Btu/s \cdot ft^2$). The parameter is the heat structure geometry number $cccg0nn$ with a two-digit number appended (00 for left boundary, and 01 for right boundary).

I A.4.8.6 Reflood-Related Quantities

For the following variable codes, the parameter is the heat structure geometry number, i.e., the seven-digit number $cccg0nn$.

<u>Code</u>	<u>Quantity</u>
QFCHFN	Critical heat flux (W/m^2 , $Btu/s \cdot ft^2$).
QFHTCN	Critical heat transfer coefficient ($W/m^2 \cdot K$, $Btu/s \cdot ft^2 \cdot ^\circ F$).
TCHFQF	Temperature corresponding to QFCHFN (K, $^\circ F$).
TREWET	Rewet temperature (K, $^\circ F$).
ZTRWT	Position of CHF point (m, ft).

I A.4.8.7 Reactor Kinetic-Related Quantities

These variables are from the one-dimensional space-dependent kinetic model. The parameter is defined in the definition of the quantity.

<u>Code</u>	<u>Parameter</u>	<u>Quantity</u>
RKOBK1	II	Buckling in fast neutron group in Axial Level II (cm^{-2}).
RKOBK2	II	Total buckling in thermal neutron group in Axial Level II (cm^{-2}).
RKOBTB	II	Bias thermal buckling in Axial Level II (cm^{-2}).
RKOCRPSN	cc	Insertion depth of control rod cc (m, ft)
RKOD1	II	Diffusion coefficient in fast neutron group in

CARDS 301 THROUGH 399, MINOR EDIT REQUESTS

		Axial Level II (cm).
RKOD2	II	Diffusion coefficient in thermal neutron group in Axial Level II (cm).
RKOLVCFR	II	Control fraction in Axial Level II.
RKOLVFIP	II	Fission power in Axial Level II (W).
RKOLVGAP	II	Total decay power in Axial Level II (W).
RKOLVPWA	II	Actinide decay power in Axial Level II (W).
RKOLVPWK	II	Fission product decay power in Axial Level II (W).
RKOPHI1	II	Neutron flux in fast neutron group in Axial Level II ($\text{n/cm}^2\text{-s}$).
RKOPHI2	II	Neutron flux in thermal neutron group in Axial Level II ($\text{n/cm}^2\text{-s}$).
RKOPOWA	0	Total reactor actinide decay power (W).
RKOPOWK	0	Total fission product decay power (W).
RKOSIGA1	11	Macroscopic absorption cross section in fast neutron group in Axial Level 11 (cm^{-1}).
RKOSIGA2	11	Macroscopic absorption cross section in thermal neutron group in Axial Level 11 (cm^{-1}).
RKOSIGR	11	Macroscopic removal cross section in fast neutron group in Axial Level 11 (cm^{-1}).
RKOSIGF1	11	Macroscopic fission cross section in fast neutron group in Axial Level 11 (cm^{-1}).
RKOSIGF2	11	Macroscopic fission cross section in thermal neutron group in Axial Level 11 (cm^{-1}).
RKOZNALP	zz	Average void fraction in zone zz. Only valid if RAMONA feedback selected.
RKOZNBOR	zzvv	Average poison density in volume region vv of zone zz. If RAMONA feedback is selected, vv is omitted (kg/m^3 , lb/ft^3).
RKOZNDEN	zzvv	Average fluid density in volume region vv of

		zone zz. Only valid if HWR feedback selected (kg/m ³ , lbm/ft ³).
RKOZNFIP	zz	Total fission power in zone zz (W).
RKOZNGAP	zz	Total decay power in zone zz (W).
RKOZNPWA	zz	Total actinide decay power in zone zz (W).
RKOZNPWK	zz	Total fission product decay power in zone zz (W).
RKOZNTF	zzss	Average structure temperature in structure region ss of zone zz. If RAMONA feedback is selected, ss is omitted (K, °F).
RKOZNTM	zzvv	Average fluid temperature in volume region vv of zone zz. If RAMONA feedback is used, vv is omitted (K, °F).
RKOZNTPW	zz	Total reactor power in zone zz (W).

A.4.8.8 Fission Product Quantities

The alphanumeric part of the variable code for fission product transport has the form FP*tt**i*, where *tt* and *i* are substituted as follows. The notation V and H indicate hydrodynamic Volume and Heat structure surface quantities, respectively.

<u>tt</u>	<u>Volume or Surface</u>	<u>Quantity</u>
LI	V	Fission product mass in volume or carried by liquid phase (kg).
MA	H	Vapor phase fission product mass absorbed in heat transfer surface (kg).
MC	H	Vapor phase fission product mass condensed on heat transfer surface (kg).
MP	H	Aerosol fission product mass deposited on heat transfer surface (kg).
NN	V	Fission product mass in aerosol bin number nn in volume (kg). Aerosol bin number ranges from 01 up to the number of bins.
SR	V	Fission product source to volume (kg/s).
TO	V	Total fission product mass in both vapor and

aerosol form in volume (kg).

VA

V

Fission product mass in volume in vapor form (kg).

Part *j* is one of the species listed in Section A.15.4, Cards 20700011, Species Selection Cards. For hydrodynamic volume quantities, the parameter is the volume number. For heat structure surface quantities, the parameter is the heat structure number appended with 00 for the left surface and 01 for the right surface.

A.4.8.9 SCDAP Quantities

The subfields of the index are *jj* for the radial node number, *kk* for the axial node number, and *jj* for the component number. For example, if the temperature is to be plotted at the sixth radial node of the fourth axial node of the third component, then the code CADCT with Index 060403 would be specified.

<u>Code</u>	<u>Index</u>	<u>Quantity</u>
ACHDPN	jj	Temperature of the bottom surface of the cohesive debris layer for component jj (K).
BGNHG	0	Core nuclear heat generation (W).
BGMCT	0	Core maximum surface temperature (K).
BGTFPRN	0	Core cumulative noncondensable fission product release (kg).
BGTFPRS	0	Core cumulative soluble fission product release (kg).
BGTH	0	Core total hydrogen generation rate (kg/s).
BGTHQ	0	Core total oxidation heat generation (W).
BGTHQU	0	Global oxidation heat generation due to uranium oxidation (W).
BGTHU	0	Global hydrogen generation rate due to uranium oxidation (kg/s).
BRCHV	kkjj	Indicator of whether double-sided oxidation is taking place at axial node kk of component jj: 0.0 = no, 1.0 = yes.
CADCT	iikkjj	Component temperatures (K).

CAOXDEO	kkjj	Component axial oxide thickness (m).
CRUCB	kkjj	Indicator of whether crust supporting molten pool has failed: 0.0 = no, 1.0 = yes.
DAMLEV	kkjj	Level of damage at axial node kk of component jj (unitless). 0.0 = Intact geometry. 0.1 = Ruptured due to ballooning. 0.2 = Rubble (fragmented). 0.4 = Cohesive debris. 1.0 = Molten pool.
DCREPC	ii	Fraction of life expended for ii-th COUPLE heat structure identified for creep rupture calculation.
DCREPH	ii	Fraction of life expended for ii-th RELAP5 heat structure identified for creep rupture calculation.
DZFRCQ	kkjj	Height of cohesive debris at axial node kk of component jj (m).
EFFOXD	kkjj	Effective oxide thickness at axial node kk of component jj. SCDAP/RELAP5 now uses two oxide thicknesses: the first is the physical oxide thickness, OXDEO, and the second is an effective thickness, used to calculate the oxidation rate.
H2OXD2	kkjj	Hydrogen production rate at axial node kk of component jj (kg/s).
HOOP	kkjj	Cladding hoop strain of component jj at axial node kk.
OXDEO	kkjj	Oxide thickness of the cladding at axial node kk of component jj (m).
PGAS	jj	Gas pressure inside component jj (MPa).
RCI	kkjj	Inside radius of the cladding at axial node kk of component jj (m).
RCO	kkjj	Outside radius of the cladding (not including the

CARDS 301 THROUGH 399, MINOR EDIT REQUESTS

		crust of solidified material) at axial node kk of component jj (m).
REPOOL	0	Equivalent radius of the molten pool of core material (m).
RNALF	kkjj	Inner radius of the alpha oxide layer at axial node kk of component jj (m).
RNOXD	kkjj	Inner radius of the oxide layer at axial node kk of component jj (m).
ROCRST	kkjj	Outside radius of cladding (including the crust of the solidified material) of component jj at axial node kk (m).
RPEL	kkjj	Radius of fuel pellet of component jj at axial node kk (m).
RULIQ	kkjj	Outside radius of the solid part of the fuel pellet at axial node kk of component jj (m).
SHQIN	0	Total heat flowing through the inside surface of the flow shroud (W). (Available only if the shroud component is input.)
SHQOUT	0	Shroud total heat out (W). (Available only if the shroud component is input.)
THKHPN	jj	Thickness of cohesive debris layer in component jj (m).
WDTQLP	jj	Thermal energy in the material from component jj that slumped below the bottom of component jj (J).
WFROSR	kkjj	Mass of stainless steel resolidified at axial node kk of component jj (kg).
WFROUO	kkjj	Mass of UO ₂ resolidified at axial node kk of component jj (kg).
WFROZR	kkjj	Mass of zircaloy resolidified at axial node kk of component jj (kg).
WREMSR	kkjj	Mass of stainless steel remaining at axial node kk of component jj (kg).

WREMUO	kkjj	Mass of removed fuel of component jj at axial node kk (kg).
WREMZR	kkjj	Mass of removed cladding of component jj at axial node kk (kg).
ZBTCOH	jj	Elevation of the bottom surface of the cohesive debris bed for component jj (m).
ZBTRUB	jj	Elevation of the bottom of the rubble debris bed for component jj (m).
ZTPCOH	jj	Elevation of the top surface of the cohesive debris bed for component jj (m).
ZTPRUB	jj	Elevation of the top of the rubble debris bed for component jj (m).

I A.4.8.10 SCDAP Quantities for BWR Blade/Box Component

The expanded edit/plot variable defined for the BWR blade/box component are listed below. Although the variable names are identical to those used for other SCDAP components, the definitions listed below apply only to BWR blade/box components. The subfields of the index are ii for the radial node number, kk for the axial node number, and jj for the component number.

<u>Code</u>	<u>Index</u>	<u>Quantity</u>
CADCT	iikkjj	Temperatures (K) at radial node ii and axial node kk of component jj. For a BWR blade/box component, valid values of radial node ii are 1-14.
DAMLEV	kkjj	Level of damage (unitless) at axial node kk of component jj. For a BWR blade/box component, this indicates when the channel box wall has failed and a flow path has opened between the interstitial and fuel bundle coolant volumes. 0.0 = Both channel box segments intact. 0.1 = Channel box segment 1 gone. 0.2 = Channel box segment 2 gone. 0.3 = Both channel box segments gone.
H2OXD2	kkjj	Total hydrogen production rate (kg/s) at axial node kk of component jj. For a BWR blade/box

CARDS 301 THROUGH 399, MINOR EDIT REQUESTS

		component, this is the total hydrogen from the control blade and both sides of the channel box.
OXDEO	kkjj	Frozen crust thickness (m) on the interstitial side of channel box segment 2 at axial node kk of component jj.
RCI	kkjj	Equivalent thickness (m) of the intact control blade sheath at axial node kk of component jj.
RCO	kkjj	Frozen crust thickness (m) on the control blade at axial node kk of component jj.
ROCRST	kkjj	Thickness (m) of the intact channel box segment 1 at axial node kk of component jj.
RPEL	kkjj	Thickness (m) of the intact channel box segment 2 at axial node kk of component jj.
RULIQ	kkjj	Equivalent thickness (m) of the intact absorber rodlet (B ₄ C and stainless steel) at axial node kk of component jj.
WREMUE	kkjj	Frozen crust thickness (m) on the fuel bundle side of channel box segment 2 at axial node kk of component jj.
WREMZR	kkjj	Frozen crust thickness (m) on the fuel bundle side of channel box segment 1 at axial node kk of component jj.

A.4.8.11 COUPLE Quantities

<u>Code</u>	<u>Index</u>	<u>Quantity</u>
FPDEB	ii jj kk	Fission product ii in element jj in COUPLE mesh number kk.
HGTDEB	kk	Debris bed height in COUPLE mesh kk.
OXTHK	jjj kk	Aluminum oxide thickness (m) in element jjj for COUPLE mesh kk.
TMPCOU	jj kk	Debris bed temperature at node jj in COUPLE mesh number kk.
TMPDMX	kk	Maximum debris bed temperature in COUPLE mesh number kk.

1 = I
2 = CsI
3 = CsOH
4 = Te
5 = HI
6 = HTe
7 = Cd
8 = Ag
9 = UO₂
10 = Sn
11 = Fe
12 = Ru
13 = Ba
14 = Sb
17 = Zn
18 = Xe
19 = Kr

A.5 CARDS 400 THROUGH 799 OR 20600000 THROUGH 20620000, TRIP INPUT DATA

These cards are optional for NEW and RESTART type problems and are not used for other problem types. Two different card series are available for entering trip data, but only one series type may be used in a problem. Card Numbers 401 through 799 allow 199 variable trips and 199 logical trips. Card Numbers 20600010 through 20620000 allow 1,000 variable trips and 1,000 logical trips.

A.5.1 Card 400, Trips Cancellation Card

This card is allowed only for RESTART problems. This card causes all trips in the problem being restarted to be deleted. Any desired trips must be reentered.

W1(A) DISCARD. Any other entry is an error.

A.5.2 Card 20600000, Trip Card Series Type

This card, if omitted, selects Card Numbers 401 through 599 for variable trips and 601 through 799 for logical trips. The trip numbers are equal to the card numbers. If this card is entered, Card Numbers 206nnnn0 are used for entering trip data and nnnn is the trip number. Trip Numbers 1 to 1,000 are variable trips, and 1,001 to 2,000 are logical trips. Trip numbers do not have to be consecutive.

W1(A) EXPANDED. Any other entry is an error.

A.5.3 Cards 401 Through 599 or 20600010 Through 20610000, Variable Trip Cards

Each card defines a logical statement or trip condition concerned with the quantities being advanced in time. A trip is false or not set if the trip condition is not met, and true if it is met. On restart, new trips can be introduced, old trips can be deleted, and a new trip with the same number as an old trip replaces the old trip.

The variable codes and parameters are the same as described for minor edits, Section A.4. NULL is allowed for the right side when only a comparison to the constant is desired. The variable code TIMEOF, with the parameter set to the trip number, indicates the time at which the trip was last set.

W1(A) VARIABLE CODE. On RESTART problems, this word can also contain DISCARD or RESET. DISCARD deletes the trip; RESET sets the trip to false. If DISCARD or RESET are entered, no further words are entered on the card.

W2(I) PARAMETER.

W3(A) RELATIONSHIP. This may be either EQ, NE, GT, GE, LT, or LE, where the

symbols have the standard FORTRAN meaning. Do not enter periods as part of the designator. For example, use GE rather than .GE. to specify greater than or equal to.

- W4(A) VARIABLE CODE.
- W5(I) PARAMETER.
- W6(R) ADDITIVE CONSTANT.
- W7(A) LATCH INDICATOR. If L, the trip once set true remains true even if the condition later is not met. If N, the trip is tested at each time advancement.
- W8(R) TIMEOF QUANTITY (s). This word is optional. If it is not entered, the trip is initialized as false and the associated TIMEOF quantity is set to -1.0. If -1.0 is entered, the trip is initialized as false. If zero or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than zero for NEW problems and must not be greater than the time of restart for RESTART problems.

The logical statement is: Does the quantity given by Words 1 and 2 have the relationship given by Word 3 with the quantity given by Words 4 and 5 plus Word 6? If the relationship is false, the trip is false or not set. If the relationship is true, the trip is true or set. The TIMEOF variable is -1.0 if the trip is false. If the trip is true, this variable is the time the trip was last set true. A latched trip is never reset, so the trip time never changes once it changes from -1.0. For the nonlatched trips, the trip time when set remains constant until the trip condition becomes false and then the trip time is -1.0 again. If the trip condition becomes true again, the process is repeated. For trips such as a time test, L should be used to eliminate repeated testing, although no error or difference in results will occur if N is used.

A.5.4 Cards 601 Through 799 or 20610010 Through 20620000, Logical Trip Cards

If these cards are entered, at least one of the variable trip cards must have been entered. Each card defines a logical relationship with the trips defined on these cards or on the variable trip cards.

- W1(I) TRIP NUMBER. The absolute value of this number must be one of the trip numbers defined by the variable or logical trip cards. A negative trip number indicates that the complement of the trip is to be used in the test.
- W2(A) OPERATOR. The operator may be AND, OR, or XOR. For RESTART problems, this quantity may also contain DISCARD or RESET. DISCARD deletes the trip and RESET sets the trip to false. If DISCARD or RESET are entered, no further words are entered on the card and Word 1 (W1) may be zero.
- W3(I) TRIP NUMBER. This is similar to Word 1 (W1).

Card 600, Trip Stop Advancement Card

- W4(A) LATCH INDICATOR. If L, the trip when set remains set. If N, the trip is tested each time advancement.
- W5(R) TIMEOF QUANTITY (s). This word is optional. If not entered, the trip is initialized as false and the associated TIMEOF quantity is set to -1.0. If -1.0 is entered, the trip is initialized as false. If zero or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than zero for NEW problems and must not be greater than the time of restart for RESTART problems.

The trip condition is given by the result of the logical expression:

CONDITION OF TRIP IN W1 OPERATOR CONDITION OF TRIP IN W3.

A.5.5 Card 600, Trip Stop Advancement Card

This card can be entered in NEW and RESTART problems. One or two trip numbers may be entered. If either of the indicated trips are true, the problem advancement is terminated. These trips are tested only at the end of a requested advancement. If the trips can cycle true and false, they should be latched-type trips to ensure being true at the test time.

- W1(I) TRIP NUMBER.
- W2(I) TRIP NUMBER. A second trip number need not be entered.

A.6 CARDS 801 THROUGH 999, INTERACTIVE INPUT DATA

An interactive and color display capability exists when the code is interfaced with Nuclear Plant Analyzer (NPA) software. This capability allows a user to view selected results on a color graphics terminal and to modify user-defined input quantities. A user can view SCDAP/RELAP5 output in a format that enhances understanding of the transient phenomena and enter commands during the simulation. This input, coupled with trip and control system capability, allows a user to initiate operator-like actions, such as opening/closing valves, starting/stopping/changing speed on pumps, and changing operating power settings.

These data may be entered for either batch or interactive jobs. These cards may be used in a NEW or RESTART job; in a restart job, they add to or replace data in the restarted problem.

These cards define variables that may be changed during execution by data input from a computer terminal if the job is being run interactively. The card input defines input variable names and initial values. These variables are completely independent from the Fortran variable names used in the SCDAP/RELAP5 coding even if they are spelled the same. These user-defined variables can appear wherever variables listed in Section A.6 can be used. Thus, the user-defined variables can be used in trips, control variable statements, search arguments for some tables, edited in minor edits, and plotted. With appropriate input, an interactive user can effect changes similar to those made by a reactor operator, such as opening/closing/repositioning valves or setting new operating points in controllers. When entering these user-defined variables, the variable name is the alphanumeric part of the request code and 1000000000 is the numeric part.

W1(A) VARIABLE NAME. Enter the variable name or DELETE in a RESTART job to delete the variable.

W2(R) INITIAL VALUE. This is not needed if DELETE is entered in Word 1.

In interactive execution, the initial value is used until changed by a terminal entry. The value can be changed at any time and as often as needed. One or more variables can be changed by entering the variable name and value pairs on the computer terminal. An example is VLV1 = 0 VLV2,1 VLV3,0, POWER = 3050.+6, where VLV1, VLV2, VLV3, and POWER are user-defined variable names. The format is identical to data input on cards. An equal sign is treated as a terminating comma. The values should be floating-point quantities, but integers are converted to floating point values. The NPA interface also allows other more convenient methods for entering new values during the simulation.

W3(R) CONVERSION FACTOR. Word 2 or any terminal-entered replacement value is entered in user-defined units. These quantities should be converted to SI units if they are to be involved in comparisons or computations with quantities advanced in time. User units can be used only if these input interactive variables are used with control variables defined in compatible units. This word, if nonzero, is the conversion factor. If this word is positive, the conversion is:

$V(\text{converted}) = V(\text{input}) * W3.$

If negative,

$V(\text{converted}) = V(\text{input}) / 1.8 - W3.$

For temperature conversion from °F to K, Word 3 should be -255.3722222. If this word is missing, the conversion factor defaults to 1.0. If this word is zero, the next two words must contain a variable request code; and the conversion factor appropriate for this quantity is supplied by the code. If SI units are in use, the supplied conversion factor is 1.0. If British units are in use, the appropriate conversion factor is supplied.

A.7 CARDS CCCXXNN, HYDRODYNAMIC COMPONENTS

These cards are required for NEW type problems and may be entered for RESTART problems. Hydrodynamic systems are described in a NEW problem. In a RESTART problem, the hydrodynamic systems may be modified by deleting, adding, or replacing components. The resultant problem must describe at least two volumes and one junction. The hydrodynamic card numbers are divided into fields, where ccc is the component number (the component numbers need not be consecutive), xx is the card type, and nn is the card number within type. When a range is indicated, the numbers need not be consecutive.

A.7.1 Card ccc0000, Component Name and Type

This card is required for each component.

- W1(A) COMPONENT NAME. Use a name descriptive of the component's use in system. A limit of 10 characters is allowed for CDC-7600 computers, and a limit of 8 characters is allowed for most other computers, e.g., CRAY, Cyber-205, and IBM computers.
- W2(A) COMPONENT TYPE. Enter one of the following component types, SNGLVOL, TMDPVOL, SNGLJUN, TMDPJUN, PIPE, ANNULUS, BRANCH, SEPARATR, JETMIXER, TURBINE, ECCMIX, VALVE, PUMP, MTPLJUN, ACCUM, MULTID, PRIZER, or the command DELETE. The command DELETE is allowed only in RESTART problems, and the component number must be an existing component at the time of restart. The DELETE command deletes the component.

The remaining cards for each component depend on the type of component.

A.7.2 Single Volume Component

A single volume component is indicated by SNGLVOL on Card ccc0000. The junction connection code determines the placement of the volume within the system. More than one junction may be connected to an inlet or outlet. If an end has no junctions, that end is considered a closed end. Normally, only a branch has more than one junction connected to a volume end.

A.7.2.1 Cards ccc0101 Through ccc0109, Single Volume Geometry Cards

This card (or cards) is required for a single volume component. The nine words can be entered on one or more cards, and the card numbers need not be consecutive.

- W1(R) VOLUME FLOW AREA (m^2 , ft^2).
- W2(R) LENGTH OF VOLUME (m, ft).
- W3(R) VOLUME OF VOLUME (m^3 , ft^3). The program requires that the volume equals the volume flow area times the length ($W3 = W1 * W2$). At least two of the three

quantities, W1, W2, and W3 must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.

- W4(R) AZIMUTHAL ANGLE (degrees). The absolute value of this angle must be ≤ 360 degrees and is defined as a positional quantity. This quantity is not used in the calculation but is specified for possible automated drawing of nodalization diagrams.
- W5(R) INCLINATION ANGLE (degrees). The absolute value of this angle must be ≤ 90 degrees. The angle 0 degrees is horizontal; and positive angles have an upward inclination, i.e., the inlet is at the lowest elevation. This angle is used in the interphase drag calculation.
- W6(R) ELEVATION CHANGE (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the vertical angle orientation is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign.
- W7(R) WALL ROUGHNESS (m, ft).
- W8(R) HYDRAULIC DIAMETER (m, ft). If zero, the hydraulic diameter is computed from $2.0 * (\text{volume area} / \pi) ** 0.5$. A check is made that the pipe roughness is less than half the hydraulic diameter.
- W9(I) VOLUME CONTROL FLAGS. This word has the packed format pvbfe.

The digit p specifies whether the water packing scheme is to be used. p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer.

The digit v specifies whether the vertical stratification model is to be used. v = 0 specifies that the vertical stratification model is to be used for the volume, and v = 1 specifies that the vertical stratification model is not to be used for the volume. The vertical stratification model is recommended when modeling a pressurizer.

The digit b specifies the interphase friction used. b = 0 means that the pipe interphase friction model will be applied, b = 1 means that the rod bundle interphase friction model will be applied, and b = 2 means that the ORNL ANS narrow channel model will be applied.

The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed for the volume, and f = 1 specifies that wall friction effects are not to be computed for the volume.

The digit e specifies if nonequilibrium or equilibrium is to be used. e = 0 specifies

that a nonequilibrium (unequal temperature) calculation is to be used, and $\epsilon = 1$ specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

A.7.2.2 Card ccc0111, ORNL ANS Interphase Model Pitch and Span Values

This card is required if the interphase friction flag b in Word 9 of Card ccc0101 through ccc0109 is set to 2.

W1(R) PITCH (channel width) (m, ft).

W2(R) SPAN (channel or plate length perpendicular to flow) (m, ft).

A.7.2.3 Card ccc0141, Additional Wall Friction Card

This card is optional and is currently allowed only if Change Option 22 is enabled. If this card is not entered, the default values are 1.0 for the shape factor and 0.14 for the viscosity ratio exponent. Two, four, or six quantities may be entered on the card, and the data not entered are set to default values.

W1(R) SHAPE FACTOR FOR X-COORDINATE.

W2(R) VISCOSITY RATIO EXPONENT FOR X-COORDINATE.

W3(R) SHAPE FACTOR FOR Y-COORDINATE.

W4(R) VISCOSITY RATIO EXPONENT FOR Y-COORDINATE.

W5(R) SHAPE FACTOR FOR Z-COORDINATE.

W6(R) VISCOSITY RATIO EXPONENT FOR Z-COORDINATE.

A.7.2.4 Cards ccc0142, Alternate Wall Friction Card

This card is optional and is currently allowed only if Change Option 22 is enabled and the code is compiled with the 'frifac' option. This card allows the specification of user-defined turbulent friction factor for each coordinate direction. The turbulent friction factor has the form $f = A + B(Re)^C$ where A, B, and C are entered for each coordinate of each volume. If this card is not entered, the standard turbulent friction factor is used for all coordinates. If the card is entered, the standard turbulent friction factor can be selected for a particular coordinate direction by entering zeros for the three quantities. Three, six, or nine quantities may be entered on the card, and the data not entered are set to zeros.

W1(R) A FOR X-COORDINATE.

W2(R) B FOR X-COORDINATE.

W3(R)	C FOR X-COORDINATE.
W4(R)	A FOR Y-COORDINATE.
W5(R)	B FOR Y-COORDINATE.
W6(R)	C FOR Y-COORDINATE.
W7(R)	A FOR Z-COORDINATE.
W8(R)	B FOR Z-COORDINATE.
W9(R)	C FOR Z-COORDINATE.

A.7.2.5 Card ccc0200, Single Volume Initial Conditions

This card is required for a single volume.

W1(I) CONTROL WORD. This word has the packed format εbt.

The digit ε specifies the fluid. ε = 0 is the default fluid, ε = 1 specifies water, ε = 2 specifies D₂O, and ε = 3 specifies H₂. The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default ε = 0, then H₂O is assumed as the fluid.

The digit b specifies whether boron is present or not. The digit b = 0 specifies that the volume fluid does not contain boron; b = 1 specifies that a boron concentration in parts of boron per parts of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. Entering t = 0 through 3 specifies only one component (steam/water). Entering t = 4 through 6 allows the specification of two components (steam/water and noncondensable gas).

If t = 0, the next four words are interpreted as pressure (Pa, lb_f/in²), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), and vapor void fraction; these quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the volume control flag. If equilibrium, the static quality is checked; but only the pressure and internal energies are used to define the thermodynamic state.

If t = 1, the next two words are interpreted as temperature (K, °F) and quality in equilibrium condition.

Time-Dependent Volume Component

If $t = 2$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and quality in equilibrium condition.

If $t = 3$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, $^{\circ}\text{F}$) in equilibrium condition.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for quality are:

$1.0\text{E-}9 \leq \text{quality} \leq 0.99999999$, two-phase conditions, and $\text{quality} < 1.0\text{E-}9$ or $\text{quality} > 0.99999999$, single-phase.

Noncondensable options are:

If $t = 4$, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, $^{\circ}\text{F}$), and equilibrium quality. Using this input option with $\text{quality} > 0.0$ and ≤ 1.0 , saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Quality is reset to 1.0 using this dry noncondensable option.

If $t = 5$, the next three words are interpreted as temperature (K, $^{\circ}\text{F}$), equilibrium quality, and noncondensable quality. Both the equilibrium and noncondensable qualities are restricted to be between $1.0\text{E-}9$ and 0.99999999 .

If $t = 6$, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, and noncondensable quality. The combinations of vapor void fraction and noncondensable quality must be thermodynamically consistent. If noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present and noncondensable quality is greater than 0.0, then the vapor void fraction must not be 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable), then vapor void fraction must also be 1.0. When both the vapor void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor specific internal energy.

W2-W6(R) QUANTITIES AS DESCRIBED UNDER WORD 1 (W1). Depending on the control word, two through five quantities may be required. Enter only the minimum number required. If entered, boron concentration follows the last required word for thermodynamic conditions.

A.7.3 Time-Dependent Volume Component

This component is indicated by TMDPVOL on card ccc0000.

A.7.3.1 Cards ccc0101 Through ccc0109, Time-Dependent Volume Geometry Cards

This card (or cards) is required for a time-dependent volume component. The nine words can be entered on one or more cards, and the card numbers need not be consecutive.

- W1(R) VOLUME FLOW AREA (m^2 , ft^2).
- W2(R) LENGTH OF VOLUME (m, ft).
- W3(R) VOLUME OF VOLUME (m^3 , ft^3). The program requires that the volume equals the volume flow area times the length ($W3 = W1 * W2$). At least two of the three quantities, W1, W2, and W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.
- W4(R) AZIMUTHAL ANGLE (degrees). The absolute value of this angle must be ≤ 360 degrees. This quantity is not used in the calculation but is specified for possible automated drawing of nodalization diagrams.
- W5(R) INCLINATION ANGLE (degrees). The absolute value of this angle must be ≤ 90 degrees. The angle 0 degrees is horizontal, and positive angles have an upward inclination, i.e., the inlet is at the lowest elevation. This angle is used in the interphase drag calculation.
- W6(R) ELEVATION CHANGE (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the vertical angle orientation is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign.
- W7(R) WALL ROUGHNESS (m, ft).
- W8(R) HYDRAULIC DIAMETER (m, ft). If zero, the hydraulic diameter is computed from $2.0 * (\text{volume area} / \pi) ** 0.5$. A check is made that the pipe roughness is less than half the hydraulic diameter.
- W9(I) VOLUME CONTROL FLAGS. This word has the packed format pvbfe.

The digit p is not used and should be input as zero (p = 0). The major edit will show p = 1.

The digit v is not used and should be input as zero (v = 0). The major edit will show v = 1.

The digit b specifies the interphase friction used. b = 0 means that the pipe interphase friction model will be applied, and b = 1 means that the rod bundle interphase friction model will be applied.

The digit $\underline{f}$ specifies whether wall friction is to be computed. $\underline{f} = 0$ specifies that wall friction effects are to be computed for the volume, and $\underline{f} = 1$ specifies that wall friction effects are not to be computed for the volume.

The digit $\underline{e}$ specifies if nonequilibrium or equilibrium is to be used. $\underline{e} = 0$ specifies that a nonequilibrium (unequal temperature calculation) is to be used, and $\underline{e} = 1$ specifies that an equilibrium (equal temperature) calculation is to be used.

Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

A.7.3.2 Card ccc0200, Time-Dependent Volume Data Control Word

This card is required for a time-dependent volume.

W1(I) Control word for time-dependent data on ccc02nn cards. This word has the packed format $\underline{e}\underline{b}\underline{t}$.

The digit $\underline{e}$ specifies the fluid. $\underline{e} = 0$ is the default fluid, $\underline{e} = 1$ specifies H_2O , $\underline{e} = 2$ specifies D_2O , and $\underline{e} = 3$ specifies H_2 . The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words within the hydrodynamic system must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default $\underline{e} = 0$, then H_2O is assumed as the fluid.

The digit $\underline{b}$ specifies whether boron is present or not. The digit $\underline{b} = 0$ specifies that the volume fluid does not contain boron; $\underline{b} = 1$ specifies that a boron concentration in parts of boron per parts of liquid water (which may be zero) is being entered after the other required thermodynamic information.

The digit $\underline{t}$ specifies how the words of the time-dependent volume data in Cards ccc0201 through ccc0209 are to be used to determine the initial thermodynamic state. Entering $\underline{t}$ equal to 0 through 3 specifies one component (steam/water). Entering $\underline{t}$ equal to 4 through 6 allows the specification of two components (steam/water and noncondensable gas).

With Options 4 through 6, Card 110 defining components of the noncondensable gas must be entered and mass fractions of the components are entered on Card ccc0301, if entered, or are taken from the default data on Card 115. Entering $\underline{t} = 7$ specifies three components, liquid/steam, noncondensable gas, and a molten metal. Option 7 requires Card 110 and Card ccc0301 or Card 115 similarly to Options 4 through 6. In addition, Option 7 requires Card 111 defining components of the metal. The mass fractions are defined by Card ccc0302 if entered or from Card 116.

If $\underline{t} = 0$, the second, third, fourth, and fifth words of the time-dependent volume

data on Cards ccc0201 through ccc0299 are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), and vapor void fraction; these quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the volume control flag. If equilibrium, the static quality is checked, but only the pressure and internal energies are used to define the thermodynamic state.

If $t = 1$, the second and third words of the time-dependent volume data on Cards ccc0201 through ccc0299 are interpreted as temperature (K, $^{\circ}\text{F}$) and quality in equilibrium condition.

If $t = 2$, the second and third words of the time-dependent volume data on Cards ccc0201 through ccc0299 are interpreted as pressure (Pa, lb_f/in^2) and quality in equilibrium condition.

If $t = 3$, the second and third words of the time-dependent volume data on Cards ccc0201 through ccc0299 are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, $^{\circ}\text{F}$) in equilibrium conditions.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for quality are:

$1.0\text{E-}9 \leq \text{quality} \leq 0.99999999$, two-phase conditions, and $\text{quality} < 1.0\text{E-}9$ or $\text{quality} > 0.99999999$, single-phase.

Noncondensable options are:

If $t = 4$, the second, third, and fourth words of the time-dependent data on Cards ccc0201 through ccc0299 are interpreted as pressure (Pa, lb_f/in^2), temperature (K, $^{\circ}\text{F}$), and equilibrium quality. Using this input option with $\text{quality} > 0.0$ and ≤ 1.0 , saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Quality is reset to 1.0 using this dry noncondensable option.

If $t = 5$, the second, third, and fourth words of the time-dependent data on Cards ccc0201 through ccc0299 are interpreted as temperature (K, $^{\circ}\text{F}$), equilibrium quality, and noncondensable quality. Both the equilibrium and noncondensable qualities are restricted to be between $1.0\text{E-}9$ and 0.99999999 .

If $t = 6$, the second, third, fourth, fifth, and sixth words of the time-dependent data on Cards ccc0201 through ccc0299 are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, and noncondensable quality. The combinations of vapor void fraction and noncondensable quality must be thermodynamically

consistent. If noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must not be 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable), then vapor void fraction must also be 1.0. When both the vapor void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor specific internal energy.

If $t = 7$, the next seven words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, noncondensable quality, metal internal energy (J/kg, Btu/lb), and metal void fraction. The sum of the vapor void fraction and the metal void fraction must be greater than or equal to zero and less than or equal to one. The noncondensable quality must be greater than or equal to zero and less than or equal to one.

- W2(I) TABLE TRIP NUMBER. This word is optional. If missing or zero and Word 3 is missing, no trip is used and the time argument is the advancement time. If nonzero and Word 3 is missing, this number is the trip number and the time argument is -1.0 if the trip is false and the advancement time minus the trip time if the trip is true.
- W3(A) ALPHANUMERIC PART OF VARIABLE REQUEST CODE. This quantity is optional. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. If the trip number is zero, the specified argument is used. If the trip number is nonzero, -1.0E + 75 is used if the trip is false and the specified argument is used if the trip is true. TIME can be selected, but note that the trip logic is different than if this word were omitted.
- W4(I) NUMERIC PART OF VARIABLE REQUEST CODE. This is assumed zero if missing.

A.7.3.3 Cards ccc0201 Through ccc0299, Time-Dependent Volume Data Cards

These cards are required for time-dependent volume components. The card numbers need not be consecutive, but the value of the search variable in a succeeding set must be equal to or greater than the value in the previous set. One or more sets of data, up to 5,000 sets are allowed. A set of data is made up of the search variable followed by the required data indicated by the control word in Card ccc0200. Linear interpolation is used if the search argument lies between the search variable entries. End-point values are used if the argument lies outside the table values. Only one set is needed if constant values are desired, and computer time is reduced when only one set is entered. Step changes can be accommodated by entering the two adjacent sets with the same search variable values or an extremely small difference between them. Given two identical argument

values, the set selected will be the closest to the previous argument value. Sets may be entered one or more per card and may be split across cards. The total number of words must be a multiple of the set size.

Inputting time-dependent volume tables where the search variable is a thermodynamic variable from some other component can run into difficulties if the component numbering is such that the time-dependent volume is initialized before the component providing the needed search variable. A reliable fix for this is to make the search variable a control system output in the desired units, while the thermodynamic variable is the control system input in code internal (SI) units. The control system initial value can be set to the desired initial value of the search variable, and this will be used by the time-dependent table.

A.7.3.4 Card ccc0301, Noncondensable Mass Fraction Card

This card has not yet been implemented. This card is optional. If omitted, the mass fractions are obtained from the mass fractions entered on Card 115.

W1-WN(R) MASS FRACTIONS FOR THE NONCONDENSABLE SPECIES ENTERED
ON CARD 110. The number of words on this card should be the same as on
Card 110.

A.7.3.5 Card ccc0302, Metal Mass Fractions Card

This card has not yet been implemented. This card is optional. If omitted, the mass fractions are obtained from the mass fractions entered on Card 116.

W1-WN(R) MASS FRACTIONS FOR THE METAL SPECIES ENTERED ON CARD 111.
The number of words on this card should be the same as on Card 111.

A.7.4 Single Junction Component

A single junction component is indicated by SNGLJUN on card ccc0000.

A.7.4.1 Cards ccc0101 Through ccc0109, Single Junction Geometry Cards

This card (or cards) is required for single junction components.

W1(I) FROM CONNECTION CODE TO A COMPONENT. This refers to the component from which the junction coordinate direction originates. For connecting to a time-dependent volume, the connection code is ccc000000, where ccc is the component number of the time-dependent volume. An old or an expanded format can be used to connect all other volumes. In the old format, use ccc000000 if the connection is to the inlet side of the component and use ccc010000 if the connection is to the outlet side of the volume. In the old format, W6 is used to specify a crossflow connection. In the expanded format, the connection code is ccvvn000n, where cc is the component number, vv is the volume number, and n indicates the face number. A nonzero n specifies the

expanded format. N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. N equal to 3 through 6 specifies crossflow. Current crossflow models do not require inlet-outlet orientation; but, in future versions, n equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction, n equal to 5 and 6 would do the same for the third coordinate direction. Since crossflows are specified directly in the expanded format, the crossflow flag in W6 is ignored on input but set appropriately for output edits.

- W2(I) TO CONNECTION CODE TO A COMPONENT. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.
- W3(R) JUNCTION AREA (m^2 , ft^2). If zero, the area is set to the minimum volume flow area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.
- W4(R) FORWARD FLOW ENERGY LOSS COEFFICIENT.
- W5(R) REVERSE FLOW ENERGY LOSS COEFFICIENT.
- W6(I) JUNCTION CONTROL FLAGS. This word has the packed format fvcchs.

The digit f specifies CCFL options. f = 0 means that the CCFL model will not be applied, and f = 1 means that it will be applied.

The digit y specifies horizontal stratification entrainment/ pullthrough options. y = 0 means the model is not applied; y = 1 means an upward-oriented junction; y = 2 means a downward-oriented junction; and y = 3 means a centrally (side) located junction.

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means that the choking model will not be applied.

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means an abrupt area change.

The digit h specifies nonhomogeneous or homogeneous. h = 0 specifies the nonhomogeneous (two velocity momentum equations) option, and h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit printout will show a 1.

The digit s specifies normal or crossflow junctions. s = 0 specifies a normal junction. s = 1 specifies a crossflow junction and that the to volume is a crossflow volume. s = 2 specifies a crossflow junction and that the from volume is a crossflow volume; s = 3 specifies a crossflow junction and that both the from and to volumes are crossflow volumes.

- W7(R) SUBCOOLED DISCHARGE COEFFICIENT. This quantity is applied only to subcooled liquid choked flow calculations. The quantity must be > 0 and ≤ 2.0 . If missing, it is set to 1.0.
- W8(R) TWO-PHASE DISCHARGE COEFFICIENT. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 and ≤ 2.0 . If missing, it is set to 1.0.
- W9(R) SUPERHEATED DISCHARGE COEFFICIENT. This quantity is applied only to superheated vapor choked flow calculations. The quantity must be > 0 and ≤ 2.0 . If missing, it is set to 1.0.

A.7.4.2 Card ccc0110, Single Junction Diameter and CCFL Data Card

This card is optional. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model, then enter all four words for the appropriate CCFL model.

- W1(R) JUNCTION HYDRAULIC DIAMETER, D_j (m, ft). This quantity is the junction hydraulic diameter used in the CCFL correlation equation and interphase drag and must be ≥ 0 . If zero is entered or if the default is used, the junction diameter is computed from $2.0 * (\text{junction area} / \pi) ** 0.5$.
- W2(R) FLOODING CORRELATION FORM, β . If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1 . The default value is 0 (Wallis form).
- W3(R) GAS INTERCEPT, C . This quantity is the gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0 . The default value is 1.
- W4(R) SLOPE, m . This quantity is the slope used in the CCFL correlation and must be > 0 . The default value is 1.

A.7.4.3 Card ccc0201, Single Junction Initial Conditions

This card is required for single junction components.

- W1(I) CONTROL WORD. If zero, the next two words are velocities; if one, the next two words are mass flows.
- W2(R) INITIAL LIQUID VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s), depending on the control word.
- W3(R) INITIAL VAPOR VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s), depending on the control word.

W4(R) INTERFACE VELOCITY (m/s, ft/s). Enter zero.

A.7.5 Time-Dependent Junction Component

This component is indicated by TMDPJUN on Card ccc0000.

A.7.5.1 Card ccc0101, Time-Dependent Junction Geometry Card

This card is required for time-dependent junction components.

- W1(I) FROM CONNECTION CODE TO A COMPONENT. This refers to the component from which the junction coordinate direction originates. For connecting to a time-dependent volume, the connection code is ccc000000, where ccc is the component number of the time-dependent volume. An old or an expanded format can be used to connect all other volumes. In the old format, use ccc000000 if the connection is to the inlet side of the component and use ccc010000 if the connection is to the outlet side of the volume. In the old format, it is not possible to specify a crossflow connection. In the expanded format, the connection code is cccvv000n, where ccc is the component number, vv is the volume number, and n indicates the face number. A nonzero n specifies the expanded format. N equal to 1 and 2 specifies the inlet and outlet faces respectively or the volume's coordinate direction. N equal to 3 through 6 specifies crossflow. Current crossflow models do not require inlet-outlet orientation; but, in future versions, n equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction, n equal to 5 and 6 would do the same for the third coordinate direction. Since crossflows are specified directly in the expanded format, the crossflow flag in W6 is ignored on input but set appropriately for output edits.
- W2(I) TO CONNECTION CODE TO A COMPONENT. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.
- W3(R) JUNCTION AREA (m^2 , ft^2). If zero, the area is set to the minimum flow area of the adjoining volumes. There are no junction area restrictions for time-dependent junctions.

A.7.5.2 Card ccc0200, Time-Dependent Junction Data Control Card

This card is optional. If this card is missing, the second and third words of the time-dependent data are assumed to be velocities.

- W1(I) CONTROL WORD. If zero, the second and third words of the time-dependent junction data in Cards ccc0201 through ccc0299 are velocities. If one, the second and third words of the time-dependent junction data in Cards ccc0201 through ccc0299 are mass flows.

- W2(I) TABLE TRIP NUMBER. This word is optional. If missing or zero and Word 3 is missing, no trip is used and the time argument is the advancement time. If nonzero and Word 3 is missing, this number is the trip number and the time argument is -1.0 if the trip is false and the advancement time minus the trip time if the trip is true.
- W3(A) ALPHANUMERIC PART OF VARIABLE REQUEST CODE. This quantity is optional. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. If the trip number is zero, the specified argument is always used. If the trip number is nonzero, -1.0E75 is used if the trip is false and the specified argument is used if the trip is true. TIME can be selected, but note that the trip logic is different than if this word is omitted.
- W4(I) NUMERIC PART OF VARIABLE REQUEST CODE. This is assumed zero if missing.

A.7.5.3 Cards ccc0201 Through ccc0299, Time-Dependent Junction Data Cards

These cards are required for time-dependent junction components. The card numbers need not be consecutive, but the value of the search variable in a succeeding set must be equal to or greater than the value in the previous set. One or more sets of data up to 5,000 sets may be entered. Each set consists of the search variable, liquid velocity (m/s, ft/s) or mass flow (kg/s, lb/s), vapor velocity (m/s, ft/s) or mass flow (kg/s, lb/s), and metal velocity (m/s, ft/s) or metal flow (kg/s, lb/s). Enter zero for interface velocity. The choice of velocity or mass flow depends on the value of control word W1 in Section A.7.5.2. Zero may be entered for a velocity of flow if the phase or material is not present. The interpolation and card formats for the time-dependent data are identical to that in Section A.7.3.3.

A.7.6 Pipe, Annulus, Or Pressurizer Component

A pipe component is indicated by PIPE, an annulus component is indicated by ANNULUS, and a pressurizer component is indicated by PRIZER on Card ccc0000. The PIPE and ANNULUS components are similar, except that the ANNULUS component must be vertical and all the water is in the film (i.e., no drops) when in the annular-mist flow regime. The remaining input for both components is identical. The PRIZER component can be used to model a noncondensable driven pressurizer and requires additional input on Card ccc0001. More than one junction may be connected to the inlet or outlet. If an end has no junctions, that end is considered a closed end.

The input for a pipe or annulus component assumes that the pipe has at least two volumes with one junction separating the two volumes. It is possible to input a one-volume pipe or annulus. To implement this special case, the user must set the number of volumes and the volume number on the volume cards to one. In addition, the user should not input any of the junction cards.

The volumes in a pipe are usually considered one-dimensional components and flow in the volumes is along the x-coordinate. Crossflow junctions can connect the pipe volumes in the y and z-coordinate directions using a form of the momentum equation that does not include momentum flux terms. Optional input may be added that allow the full one-dimensional momentum equations

to be used in the y- and z-coordinate directions.

A.7.6.1 Card ccc0001, Pipe, Annulus, or Pressurizer Information Card

This card is required for pipe components.

- W1(I) NUMBER OF VOLUMES, nv. nv must be greater than zero and less than 100. The number of associated junctions internal to the pipe is nv-1. The outer junctions are described by other components.
- W2(I) SURGE LINE CONNECTION JUNCTION NUMBER. This word must have the same format as printed in the output. This input is required for a PRIZER component and must not be entered for PIPE or ANNULUS components.
- W3(R) USER SPECIFIED INTERFACIAL HEAT TRANSFER COEFFICIENT FROM LIQUID TO THE SATURATION STATE ($\text{W/m}^2\text{-K}$, $\text{Btu/hr}\cdot\text{ft}^2\text{-}^\circ\text{F}$). This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components.
- W4(R) USER SPECIFIED INTERFACIAL HEAT TRANSFER COEFFICIENT FROM VAPOR TO THE SATURATION STATE ($\text{W/m}^2\text{-K}$, $\text{Btu/hr}\cdot\text{ft}^2\text{-}^\circ\text{F}$). This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components.

A.7.6.2 Card ccc0002, Pipe Angles and Elevation Options

This card is optional for pipe components.

- W1(A) ANGLES OPTION. Enter EULER for Euler angles, PYR for pitch, yaw, and roll angles, and SPH for spherical angles. Each volume of a pipe is initially assumed to have its local x-axis (the one-dimensional flow coordinate) aligned with the fixed x-axis. The volume is then rotated using the two or three input angles before being placed within the hydrodynamic system. This quantity states how the angles are interpreted. If this card is missing, spherical angles are used.
- W2(I) ELEVATION CHANGE OPTION 1. This word is optional. Nine quantities, Δ_{xx} , Δ_{yx} , Δ_{zx} , Δ_{xy} , Δ_{yy} , Δ_{zy} , Δ_{xz} , Δ_{yz} , and Δ_{zz} need to be defined. The Δ s are changes along the fixed space coordinate given by the first subscript caused by traversing the local coordinate given by the second subscript from its inlet to its outlet. For regular volumes such as sections of a circular pipe, these quantities can be computed by the code from the volume's volume, flow area, and flow length input. For irregularly shaped volumes, input is provided to enter all nine Δ quantities. If x-coordinate data only (the standard one-dimensional input) is entered, the flow lengths and flow areas in the y- and z-directions are computed from the x-coordinate data and the volume of the volume assuming a right circular pipe. Flow areas and flow lengths for the y- and z-coordinates may be entered

using optional input similar to that used for the x-coordinate. Initially, Δ_{xx} , Δ_{yy} , and Δ_{zz} are set to the flow lengths for the x-, y-, and z-coordinates, respectively, and the Δ 's with unequal subscripts are set to zero. The Δ 's are then reevaluated because of the effects of any rotations. The Δ 's can be overwritten using optional input. No rotation effects are applied to the data entered on these cards and thus the data on these cards must reflect the desired orientation of the volume. Enter 1 to indicate that the elevation changes on the x-coordinate change data are entered in the original format of one elevation change (Δ_{zx}) per volume. Enter 3 to indicate that three coordinate changes (Δ_{xx} , Δ_{yx} , and Δ_{zx}) are entered for each volume. The coordinate changes for the y- and z-coordinates are always three coordinate changes per volume. This quantity is assumed 1 if this word or card is not entered.

The minimum required pipe component input provides information necessary to describe flow along the x-coordinate. Additional input or default calculations can describe geometry information along the y- and z-coordinate. One use of this additional input is to provide more information for a possible graphical output presentation of each hydrodynamic system. The additional input is not used in the simulation unless junctions attach to the y- and z-faces of the pipe volumes. Before this additional input was available, junctions attaching to the y- and z-faces of pipe volume were called 'crossflow junctions', and an incomplete form of the momentum equation was used. One of the omitted terms was the momentum flux or spatial acceleration term. If a particular coordinate is active, junctions connecting to the faces of that coordinate now use the complete momentum equation unless the crossflow flags are on. The x-coordinate is always active and the y- and z-coordinate are set active as noted in the following input.

The coordinate changes, Δ 's, are used to compute the position of the center of a volume and are used in the momentum equations for body forces such as gravity. One or more flow loops may exist in hydrodynamic systems. For all problems, the code checks that the coordinate changes affecting the fixed z-direction (Δ 's with the first subscript equal to z) are consistent. For moving problems, this check is done for all three coordinate directions.

A.7.6.3 Cards ccc0101 Through ccc0199, Pipe, Annulus, or Pressurizer X-Coordinate Volume Flow Areas

The format is two words per set in sequential expansion format for nv sets. These cards are required, and the card numbers need not be consecutive. The words for one set are:

W1(R) VOLUME FLOW AREA (m^2 , ft^2).

W2(I) VOLUME NUMBER.

A.7.6.4 Cards ccc1601 Through ccc1699, Pipe, Annulus, or Pressurizer Y-Coordinate Volume Flow Areas

The format is two words per set in sequential expansion format for nv sets. These cards are optional and if entered activate the y-coordinate for each volume and allow the full one-dimensional momentum equations to be used in connections to the y faces. The card numbers need not be

consecutive. The words for one set are:

W1(R) VOLUME FLOW AREA (m^2 , ft^2).

W2(I) VOLUME NUMBER.

A.7.6.5 Cards ccc1701 Through ccc1799, Pipe, Annulus, or Pressurizer Z-Coordinate Volume Flow Areas

The format is two words per set in sequential expansion format for nv sets. These cards are optional and if entered activate the z-coordinate for each volume and allow the full one-dimensional momentum equations to be used in connections to the z faces. The card numbers need not be consecutive. The words for one set are:

W1(R) VOLUME FLOW AREA (m^2 , ft^2).

W2(I) VOLUME NUMBER.

A.7.6.6 Cards ccc0201 Through ccc0299, Pipe, Annulus, or Pressurizer Junction Flow Areas

These cards are optional, and, if entered, the card numbers need not be consecutive. The format is two words per set in sequential expansion format for nv-1 sets.

W1(R) INTERNAL JUNCTION FLOW AREA (m^2 , ft^2). If cards are missing or a word is zero, the junction flow area is set to the minimum area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or less than the minimum of the adjacent volume areas. There is no restriction for smooth area changes.

W2(I) JUNCTION NUMBER.

A.7.6.7 Cards ccc0301 Through ccc0399, Pipe, Annulus, or Pressurizer X-Coordinate Volume Lengths

These cards are required for pipe components. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) PIPE VOLUME LENGTH (m, ft).

W2(I) VOLUME NUMBER.

A.7.6.8 Cards ccc1801 Through ccc1899, Pipe, Annulus, or Pressurizer Y-Coordinate Volume Lengths

These cards are optional and if entered activate the y-coordinate for each volume and allow the full one-dimensional momentum equation for connections to the y faces. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) PIPE VOLUME LENGTH (m, ft).

W2(I) VOLUME NUMBER.

A.7.6.9 Cards ccc1901 Through ccc1999, Pipe, Annulus, or Pressurizer Z-Coordinate Volume Lengths

These cards are optional and if entered activate the z-coordinate for each volume and allow the full one-dimensional momentum equation for connections to the z faces. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) PIPE VOLUME LENGTH (m, ft).

W2(I) VOLUME NUMBER.

A.7.6.10 Cards ccc2901 Through ccc2999, Pipe, Annulus, or Pressurizer Elbow/Spiral Angle/Radius Of Curvature

These cards are optional and allow the description of a curved pipe or spiral. The card format is three words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) ANGLE OF A CURVED PIPE. It is a positive number (degrees) or radius of curvature (m, ft) if entered as a negative number. A zero indicates a straight section of pipe. The angle of the curved pipe is the angle formed by the radius of curvature drawn from the center of the inlet face to the radius of curvature drawn from the center of the outlet face. The radius of curvature is a positive number; the minus sign is only to distinguish it from the angle input. Using ζ for the angle of curved pipe, r for the radius of curvature, and l for the volume length, these quantities are related by

$$l = r\zeta \frac{\pi}{180}$$

For a straight pipe, the x-coordinate or normal flow direction of the volume is initially aligned along the space x-coordinate. A curved pipe is initially positioned in the horizontal r - θ plane, that coincides with the fixed x - y plane. The positive flow direction is in the counterclockwise azimuthal direction and the radius of curvature extends from the r - θ origin to the center of the flow area. The inlet face is in the x - z plane. This initially aligned figure can then be rotated to the desired orientation for placement in the hydrodynamic system.

W2(R) INCLINATION ANGLE (degrees). This angle is the inclination of a spiral. Entering zero specifies a curved pipe. Entering a nonzero specifies a spiral and this quantity is the angle of change in the fixed z -coordinate.

W3(I) VOLUME NUMBER.

A.7.6.11 Cards ccc0401 Through ccc0499, Pipe, Annulus, or Pressurizer Volume Volumes

The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive.

W1(R) VOLUME (m^3 , ft^3). If these cards are missing, volumes equal to zero are assumed. The code requires that each volume equal the flow area times length. For any volume, at least two of the three quantities, area, length, or volume, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the quantities are zero, the volume must equal the area times the length within a relative error of 0.000001.

W2(I) VOLUME NUMBER.

A.7.6.12 Cards ccc0501 Through ccc0599, Pipe, Annulus, or Pressurizer Volume First or Azimuthal Angles

These cards are optional, and, if not entered, the angles are set to zero. Earlier versions of the input description stated, "The azimuthal angles are not used in the calculation, but are entered for possible automated nodding graphics." That remains true as long as the spherical angle (default) option is used and the problem is a fixed problem. The reason is that the azimuthal angle information led to coordinate changes in the horizontal direction only. The coordinate changes are used only in body force calculations for fixed problems and the only body force is gravity, which is limited to the vertical directions. The horizontal information is required for moving problems since components of the body forces can be in the horizontal directions. This angle can affect the vertical coordinate changes when using the Euler or pitch-yaw-roll option. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(R) FIRST OR AZIMUTHAL ANGLE (degrees). The absolute value of the angle must be ≤ 360 degrees.

W2(I) VOLUME NUMBER.

A.7.6.13 Cards ccc0601 Through ccc0699, Pipe, Annulus, or Pressurizer Volume Second or Vertical Angles

These cards are required for pipe components. This angle directly controls the vertical orientation if the spherical angle (default) option is used. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(R) VERTICAL ANGLE (degrees). The absolute value of the angle must be ≤ 90 degrees if spherical angles are used and must be ≤ 360 degrees if Euler or pitch-yaw-roll angles are used. For spherical angles, the angle 0 degrees is horizontal, and a positive angle has an upward direction, i.e., the outlet is at a higher elevation than the inlet. This angle is used in the interphase drag calculation.

W2(I) VOLUME NUMBER.

A.7.6.14 Cards ccc1501 Through ccc1599, Pipe Third Angle

These cards define the third rotation angle for each volume and may be entered only if Card ccc0002, Section A.7.6.2 is entered with Word 1 indicating Euler or pitch-yaw-roll angles.

W1(R) THIRD ANGLE (degrees). The absolute value of the angle must be ≤ 360 degrees.

W2(I) VOLUME NUMBER.

A.7.6.15 Cards ccc0701 Through ccc0799, Pipe, Annulus, or Pressurizer X-Coordinate (Elevation) Changes

These cards are optional. If these cards are missing, the coordinate changes or elevation changes are computed from the x-coordinate volume length and a rotation matrix computed from the angle information. If these cards are entered, the entered data becomes the x-coordinate change or elevation change data. Two formats entering one or three coordinate changes per volume are provided. The format is selected in W2 of Card ccc0002 (Section A.7.6.2). The card format is two or four words per set in sequential expansion format up to nv sets, and card numbers need not be consecutive.

One coordinate change per volume format:

W1(R) ELEVATION CHANGE. That is the coordinate change along fixed z-axis because of the traverse from inlet to outlet along the local x-coordinate, Δ_{zx} (m, ft). A positive value is an increase in elevation. The magnitude must be equal to or less than the volume length.

W2(I) VOLUME NUMBER.

Three coordinate changes per volume format:

W1(R) COORDINATE CHANGE ALONG FIXED X-AXIS BECAUSE OF THE TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL X-COORDINATE, Δ_{xx} , (m, ft).

W2(R) COORDINATE CHANGE ALONG FIXED Y-AXIS BECAUSE OF THE TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL X-COORDINATE, Δ_{yx} , (m, ft).

W3(R) COORDINATE CHANGE ALONG FIXED Z-AXIS BECAUSE OF THE TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL X-COORDINATE, Δ_{zx} , (m, ft).

W4(I) VOLUME NUMBER.

A.7.6.16 Cards ccc2101 Through ccc2199, Pipe, Annulus, or Pressurizer Y-Coordinate (Elevation) Changes

These cards are optional. If these cards are missing, the coordinate changes are computed from the y-coordinate volume length and a rotation matrix computed from the angle information. If these cards are entered, the entered data overwrites the previously computed coordinate change data. The card format is four words per set in sequential expansion format up to nv sets, and card numbers need not be consecutive.

- W1(R) COORDINATE CHANGE ALONG FIXED X-AXIS BECAUSE OF THE
TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL
Y-COORDINATE, Δ_{xy} , (m, ft).
- W2(R) COORDINATE CHANGE ALONG FIXED Y-AXIS BECAUSE OF THE
TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL
Y-COORDINATE, Δ_{yy} , (m, ft).
- W3(R) COORDINATE CHANGE ALONG FIXED Z-AXIS BECAUSE OF THE
TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL
Y-COORDINATE, Δ_{zy} , (m, ft).
- W4(I) VOLUME NUMBER.

A.7.6.17 Cards ccc2201 Through ccc2299, Pipe, Annulus, or Pressurizer Z-Coordinate (Elevation) Changes

These cards are optional. If these cards are missing, the coordinate changes are computed from the z-coordinate volume length and a rotation matrix computed from the angle information. If these cards are entered, the entered data overwrites the previously computed coordinate change data. The card format is four words per set in sequential expansion format up to nv sets, and card numbers need not be consecutive.

- W1(R) COORDINATE CHANGE ALONG FIXED X-AXIS BECAUSE OF THE
TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL
Z-COORDINATE, Δ_{xz} , (m,ft).
- W2(R) COORDINATE CHANGE ALONG FIXED Y-AXIS BECAUSE OF THE
TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL
Z-COORDINATE, Δ_{yz} , (m,ft).
- W3(R) COORDINATE CHANGE ALONG FIXED Z-AXIS BECAUSE OF THE
TRAVERSE FROM INLET TO OUTLET ALONG THE LOCAL
Z-COORDINATE, Δ_{zz} , (m,ft).
- W4(I) VOLUME NUMBER.

A.7.6.18 Cards ccc0801 Through ccc0899, Pipe, Annulus, or Pressurizer Volume X-Coordinate Friction Data

These cards are required for pipe components. The card format is three words per set for nv sets, and card numbers need not be consecutive.

- W1(R) WALL ROUGHNESS (m, ft).
- W2(R) HYDRAULIC DIAMETER (m, ft). If zero, the hydraulic diameter is computed from $2.0 * (\text{volume area} / \pi) ** 0.5$. A check is made that the roughness is less than half the hydraulic diameter.
- W3(I) VOLUME NUMBER.

A.7.6.19 Cards ccc2301 Through ccc2399, Pipe, Annulus, or Pressurizer Volume Y-Coordinate Friction Data

These cards are optional and may be entered if volume flow area or volume length data were entered for the y-coordinate. If the cards are not entered, the wall roughness defaults to zero and the default hydraulic diameter is computed as if zero was entered in Word 2. The format for these cards is the same as for the friction data for the x-coordinate (Section A.7.6.18).

A.7.6.20 Cards ccc2401 Through ccc2499, Pipe, Annulus, or Pressurizer Volume Z-Coordinate Friction Data

These cards are optional and may be entered if volume flow area or volume length data were entered for the y-coordinate. If the cards are not entered, the wall roughness defaults to zero and the default hydraulic diameter is computed as if zero was entered in Word 2. The format for these cards is the same as for the friction data for the x-coordinate (Section A.7.6.18).

A.7.6.21 Cards ccc2501 Through CCC2599, Pipe, Annulus, or Pressurizer Additional Wall Friction Data

These cards are optional and are currently allowed only if Change Option 22 is enabled. If these cards are not entered, the default values are 1.0 for the shape factor and 0.14 for the viscosity ratio exponent. The card format is seven words per set in sequential expansion format for nv sets and card numbers need not be consecutive.

- W1(R) SHAPE FACTOR FOR X-COORDINATE.
- W2(R) VISCOSITY RATIO EXPONENT FOR X-COORDINATE.
- W3(R) SHAPE FACTOR FOR Y-COORDINATE.
- W4(R) VISCOSITY RATIO EXPONENT FOR Y-COORDINATE.
- W5(R) SHAPE FACTOR FOR Z-COORDINATE.

W6(R) VISCOSITY RATIO EXPONENT FOR Z-COORDINATE.

W7(I) VOLUME NUMBER.

A.7.6.22 Cards ccc2601 Through ccc2699, Pipe, Annulus, or Pressurizer Alternate Wall Friction Data

These cards are optional and are currently allowed only if Change Option 22 is enabled and the code is compiled with the 'frifac' option. These cards allow the specification of user-defined turbulent friction factors for selected volumes and coordinate directions. The turbulent friction factor has the form $f = A + B(Re)^{-C}$ where A, B, and C are entered for each coordinate of each volume. If these cards are not entered, the standard turbulent friction factor is used for all coordinates of all volumes. If the cards are entered, the standard turbulent friction factor can be selected for a particular volume and coordinate direction by entering zeros for the three quantities. The card format is 10 words per set in sequential expansion format for nv sets and card numbers need not be consecutive.

W1(R) A FOR X-COORDINATE.

W2(R) B FOR X-COORDINATE.

W3(R) C FOR X-COORDINATE.

W4(R) A FOR Y-COORDINATE.

W5(R) B FOR Y-COORDINATE.

W6(R) C FOR Y-COORDINATE.

W7(R) A FOR Z-COORDINATE.

W8(R) B FOR Z-COORDINATE.

W9(R) C FOR Z-COORDINATE.

W10(I) VOLUME NUMBER.

A.7.6.23 Cards ccc0901 Through ccc0999, Pipe, Annulus, or Pressurizer Junction Loss Coefficients

These cards are optional and if missing, the energy loss coefficients are set to zero. The card format is three words per set in sequential expansion format for nv-1 sets, and card numbers need not be consecutive.

W1(R) FORWARD FLOW ENERGY LOSS COEFFICIENT.

W2(R) REVERSE FLOW ENERGY LOSS COEFFICIENT.

W3(I) JUNCTION NUMER.

A.7.6.24 Cards ccc1001 Through ccc1099, Pipe, Annulus, or Pressurizer Volume X-Coordinate Control Flags

These cards are required for pipe volumes. The card format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(I) VOLUME CONTROL FLAGS. This word has the packed format pybfe and includes flags for the volume and the x-coordinate.

The digit p specifies whether the water packing scheme is to be used. p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer.

The digit y specifies whether the vertical stratification model is to be used. y = 0 specifies that the vertical stratification model is to be used for the volume, and y = 1 specifies that the vertical stratification model is not to be used for the volume. The vertical stratification model is recommended when modeling a pressurizer.

The digit b specifies the interphase friction that is used. b = 0 means that the pipe interphase friction model will be applied, b = 1 means that the rod bundle interphase friction model will be applied, and b = 2 means that the ORNL ANS narrow channel model will be applied.

The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed for the volume, and f = 1 specifies that wall friction effects are not to be computed for the volume.

The digit e specifies if nonequilibrium or equilibrium is to be used. e = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

W2(I) VOLUME NUMBER.

A.7.6.25 Cards ccc2701 Through ccc2799, Pipe, Annulus, or Pressurizer Volume Y-Coordinate Control Flags

W1(I) VOLUME CONTROL FLAGS. This word has the packed format pybfe and enters flags only for the y-coordinate.

W2(I) VOLUME NUMBER.

A.7.6.26 Cards ccc2801 Through ccc2899, Pipe, Annulus, or Pressurizer Volume Z-Coordinate Control Flags

W1(I) VOLUME CONTROL FLAGS. This word has the packed format p**v**b**f**e and enters flags only for the z-coordinate.

W2(I) VOLUME NUMBER.

A.7.6.27 Cards ccc1101 Through ccc1199, Pipe, Annulus, or Pressurizer Junction Control Flags

These cards are required for pipe components. The card format is two words per set in sequential expansion format for nv-1 sets, and card numbers need not be consecutive.

W1(I) JUNCTION CONTROL FLAGS. This word has the packed format f**v**c**a****h**s.

The digit f specifies CCFL options. f = 0 means that the CCFL model will not be applied, and f = 1 means that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0).

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means that the choking model will not be applied.

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means an abrupt area change.

The digit h specifies nonhomogeneous or homogeneous. h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit printout will show a one.

The digit s is not used and should be input as zero (s = 0).

W2(I) JUNCTION NUMBER.

A.7.6.28 Cards ccc1201 Through ccc1299, Pipe, Annulus, or Pressurizer Volume Initial Conditions

These cards are required for pipe components. The card format is seven words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(I) CONTROL WORD. This word has the packed format ε**b**t. ε specifies the fluid. ε = 0 is the default fluid, ε = 1 specifies H₂O, ε = 2 specifies D₂O, and ε = 3 specifies H₂. The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not

entered and all control words use the default $g = 0$, then H_2O is assumed as the fluid.

The digit b specifies whether boron is present or not. $b = 0$ specifies that the volume fluid does not contain boron; $b = 1$ specifies that a boron concentration in parts of boron per parts of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. Entering t equal to 0 through 3 specifies one component (steam/water). Entering t equal to 4 through 6 allows the specification of two components (steam/water and noncondensable gas).

If $t = 0$, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), and vapor void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the volume control flag. If equilibrium, the static quality is checked, but only the pressure and internal energies are used to define the thermodynamic state. W6 should be 0.0.

If $t = 1$, the next two words are interpreted as temperature (K, $^{\circ}F$) and quality in equilibrium condition. W4, W5, and W6 should be 0.0.

If $t = 2$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and quality in equilibrium condition. W4, W5, and W6 should be 0.0.

If $t = 3$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, $^{\circ}F$) in equilibrium condition. W4, W5, and W6 should be 0.0.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for quality are:

$1.0E-9 \leq \text{quality} \leq 0.99999999$, two-phase conditions, and

$\text{quality} < 1.0E-9$ or $\text{quality} > 0.99999999$, single-phase.

Noncondensable options are:

If $t = 4$, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, $^{\circ}F$), and equilibrium quality. Using this input option with $\text{quality} > 0.0$ and ≤ 1.0 , saturated noncondensables will result. W5 and W6 should be 0.0. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Quality is reset to 1.0 using this dry noncondensable option.

If $t = 5$, the next three words are interpreted as temperature (K, $^{\circ}F$), equilibrium

quality, and noncondensable quality. Both the equilibrium and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. W5 and W6 should be 0.0.

If $t = 6$, the next five words are interpreted as pressure (Pa, lb_f/in²), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, and noncondensable quality. The combinations of vapor void fraction and noncondensable quality must be thermodynamically consistent. If noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality > 0.0), then the vapor void fraction must not be 0.0. If the noncondensable quality is set to 0.0 (pure noncondensable), then vapor void fraction must also be 1.0. When both the vapor void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor-specific internal energy.

W2-W6(R) QUANTITIES AS DESCRIBED UNDER WORD 1. Five quantities must be entered, and zeros should be entered for unused quantities. If any control word (Word1) indicates that boron is present, Cards ccc2001 through ccc2099 must be entered to define the initial boron concentrations. Boron concentrations are not entered in Words 2 through 6.

W7(I) VOLUME NUMBER.

A.7.6.29 Cards ccc2001 Through ccc2099, Pipe, Annulus, or Pressurizer Initial Boron Concentrations

These cards are required only if boron is specified in one of the control words (Word 1) in Cards ccc1201 through ccc1299. The card format is two words per set in sequential expansion format for nv sets. Boron concentrations must be entered for each volume, and zero should be entered for those volumes whose associated control word did not specify boron.

W1(R) BORON CONCENTRATION. Parts of boron per parts of liquid.

W2(I) VOLUME NUMBER.

A.7.6.30 Card ccc1300, Pipe, Annulus, or Pressurizer Junction Conditions Control Words

This card is optional, and, if missing, velocities are assumed on Cards ccc1301 through ccc1399.

W1(I) CONTROL WORD. If zero, the first and second words of each set on Cards ccc1301 through ccc1399 are velocities. If one, the first and second words of each set on Cards ccc1301 through ccc1399 are mass flows.

A.7.6.31 Cards cc1301 Through ccc1399, Pipe, Annulus, or Pressurizer Junction Initial Conditions

- W1(R) INITIAL LIQUID VELOCITY OR MASS FLOW. Velocity is in m/s, ft/s or mass flow in kg/s, lb/s.
- W2(R) INITIAL VAPOR VELOCITY OR MASS FLOW. Velocity is in m/s, ft/s or mass flow in kg/s, lb/s.
- W3(R) INTERFACE VELOCITY (m/s, ft/s). Enter zero.
- W4(I) JUNCTION NUMBER.

A.7.6.32 Cards ccc1401 Through ccc1499, Pipe, Annulus, or Pressurizer Junction Diameter and CCFL Data Cards

These cards are optional. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model, then enter all four words for the appropriate CCFL models.

- W1(R) JUNCTION HYDRAULIC DIAMETER, D_j (m, ft). This quantity is the junction hydraulic diameter used in the CCFL correlation equation and interphase drag and must be ≥ 0 . If a zero is entered or if the default is used, the junction diameter is computed from $2.0 * (\text{junction area} / \pi) ** 0.5$.
- W2(R) FLOODING CORRELATION FORM, β . If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1 . The default value is 0 (Wallis form).
- W3(R) GAS INTERCEPT, C . This quantity is the gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0 . The default value is 1.
- W4(R) SLOPE, M . This quantity is the slope used in the CCFL correlation and must be > 0 . The default value is 1.
- W5(I) JUNCTION NUMBER.

A.7.6.33 Cards ccc3101 Through ccc3199, ORNL ANS Interphase Model Pitch and Span Values

These cards are required if any of the interphase friction flags b in the volume control flags entered on Cards ccc1001 through ccc1099 are set to 2.

- W1(R) PITCH (CHANNEL WIDTH) (m, ft).

W2(R) SPAN (CHANNEL OR PLATE LENGTH PERPENDICULAR TO FLOW)
(m, ft).

W3(I) VOLUME NUMBER.

A.7.7 Branch, Separator, Jetmixer, Turbine, Or ECC Mixer Component

A branch component is indicated by BRANCH, a steam separator is indicated by SEPARATR, a jetmixer is indicated by JETMIXER, a turbine is indicated by TURBINE, and an ECC mixer is indicated by ECCMIX on Card ccc00000. In junction references, the code for the component inlet is ccc000000 and the code for the component outlet is ccc010000. More than one junction may be connected to the inlet or outlet. If an end has no junctions, that end is considered a closed end. Normally, only a branch has more than one junction connected to a volume end. Multiple junctions may connect to the ends of pipes and single volumes except that a warning message is issued even though the connections are handled correctly. Limiting multiple connections to branch components allows the warning message to indicate probable input error. If multiple junctions are connected on one end of a branch, each junction should be modeled as an abrupt area change.

A separator component is a specialized branch component having three junctions. NJ defined below must be three, and no junctions in other components may connect to this component. N defined below must have values of 1, 2, and 3. For the junctions, $n = 1$ is the vapor outlet, $n = 2$ is the liquid fall back, and $n = 3$ is the separator inlet. The to part of the vapor outlet junction must refer to outlet of the separator (cc010000), and the from part of the liquid fall back must refer to the inlet of the separator (ccc000000). To include the direct path from a steam generator downcomer to the steam dome, a bypass volume is recommended. The smooth or abrupt junction option can be used for the three junctions. Appropriate user input energy loss coefficients may be needed to match a known pressure drop across the separator. It is recommended that choking be turned off for all three junctions. The vapor outlet and liquid fall back junctions should use the nonhomogeneous option. The CCFL flag must be turned off ($f = 0$) for all three junctions. The horizontal stratification flag is not used for separator junctions and should be set to zero ($v = 0$). The rod bundle interphase friction flag must be turned off ($b = 0$) in the separator volume. The vertical stratification model flag is not used in the separator volume and should be set to zero ($v = 0$). The water packing scheme flag is not used in the separator volume and should be set to zero ($p = 0$).

A jetmixer component is a specialized branch using three junctions numbered in the same manner as the separator. For the junctions, $n = 1$ represents the drive, $n = 2$ represents the suction, and $n = 3$ represents the discharge. The to part of the drive and suction junctions must refer to the inlet end of the jetmixer (ccc000000), and the from part of the discharge junction must refer to the outlet end of the jetmixer (ccc010000). To model a jet pump properly, the junction flow areas of the drive and suction should equal the volume flow area. The CCFL flag must be turned off ($f = 0$) for all three junctions. The horizontal stratification flag is not used for jetmixer junctions and should be set to zero ($v = 0$). The rod bundle interphase friction flag must be turned off ($b = 0$) in the jetmixer volume. The vertical stratification model flag is not used in the jetmixer volume and

should be set to zero ($\underline{v} = 0$). The water packing scheme flag is not used in the jetmixer volume and should be set to zero ($\underline{p} = 0$).

A turbine component is a specialized branch with additional input to describe the turbine characteristics. A simple turbine might use only one turbine component. A multistage turbine with steam extraction points might require several turbine components. NJ must be equal to 1 or 2. For the junctions, $n = 1$ is the turbine junction that models the stages, and $n = 2$ is the steam extraction (bleed) junction that must be crossflow. The primary steam inlet junction ($n = 1$) is a normal junction, and the steam extraction line ($n = 2$) is modeled as a crossflow junction. The turbine junction ($n = 1$) must be the only entrance junction, and there must be only one exit junction (part of another component). The to part of the steam inlet junction ($n = 1$) must refer to the inlet end of the turbine volume (ccc000000). A restriction currently exists such that the volume and junction upstream (usual flow) must be the numerically preceding volume and junction. For the first turbine, there must be an artificial turbine component preceding it (i.e., constant-efficiency turbine with $\underline{h} = 0$). The volume and junction upstream of the artificial turbine need not be the numerically preceding volume and junction. The inertia and the friction of this artificial turbine should be entered somewhat less than that of the normal turbines. The horizontal stratification flag must be turned off ($\underline{v} = 0$). If several turbine components are in series, the choking flag should be left on ($\underline{c} = 0$) for the first component but turned off for the other components ($\underline{c} = 1$). The smooth junction option ($\underline{a} = 0$) should be used at both inlet and outlet junctions. The inlet and outlet junctions must be input as homogeneous junctions ($\underline{h} = 2$). If a steam extraction (bleed) junction is present, it must be a crossflow junction ($\underline{s} = 1, 2$, or 3). The CCFL flag must be turned off ($\underline{f} = 0$) for both junctions. The rod bundle interphase friction flag must be turned off ($\underline{b} = 0$) in the turbine volume. The vertical stratification model flag is not used in the turbine volume and should be set to zero ($\underline{v} = 0$). The water packing scheme flag is not used in the turbine volume and should be set to zero ($\underline{p} = 0$).

An ECC mixer (ECCMIX) component is a specialized branch that requires three junctions with a certain numbering order. The physical extent of the ECC mixer is a length of the cold leg, or any other horizontal pipe, centered around the position of the ECC injection location. The length of this pipe segment should be equal to three times the inside diameter of the pipe (if the physical arrangement of the system permits). Junction number one (the lowest numbered junction) must be the ECC connection. This is, in some respects, similar to the drive junction of a jetmixer component. Junction number two (the junction with higher number than the first one) should be the one that is the flow inlet to this component in normal operation. The geometrical angle between the axis of junctions one and two is one of the necessary inputs, as will be specified later. The third, or discharge, junction is the normal outlet of flow through this pipe segment. The to part of junctions one and two must refer to the inlet end of the ECC mixer (ccc000000), and the from part of the discharge junction must refer to the outlet end of the ECC mixer (ccc010000).

Two or more ECCMIX components may be considered along a pipe. These may be connected in tandem or through pipe components between them.

The component identification word on Card cc0000 should be ECCMIX for the ECC mixer. This word directs the code to use a specific flow regime map and a specific interfacial heat transfer

package for steam condensation.

A.7.7.1 Card ccc0001, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Information Card

This card is required for branch components.

- W1(I) NUMBER OF JUNCTIONS, NJ. NJ is the number of junctions described in the input data for this component and must be equal to or greater than zero and less than 10. This number must be 3 for SEPARATR, JETMIXER, and ECCMIX components and must be 1 or 2 for TURBINE components. For BRANCH components, not all junctions connecting to the branch need to be described with this component input, and NJ is not necessarily the total number of junctions connecting to the branch. Junctions described in single junctions, time-dependent junctions, pumps, separators, jetmixers, and other branches can be connected to this branch.
- W2(I) INITIAL CONDITION CONTROL. This word is optional and, if missing, the junction initial velocities in the first and second words on Cards cccn201 are assumed to be velocities. If zero, velocities are assumed; if nonzero, mass flows are assumed.
- W3(A) ANGLES OPTION. Enter EULER for Euler angles, PYR for pitch-yaw-roll angles, and SPH for spherical angles. The volume is initially assumed to have its local x-axis (the one-dimensional flow coordinate) aligned with the fixed x-axis. The volume is then rotated using the two or three angles before being placed within the hydrodynamic system. This quantity states how the angles are interpreted. This word is optional and if missing, spherical angles are assumed.
- W4(R) THIRD ANGLE. This word is optional and is used only if W3 specifies Euler or pitch-yaw-roll angles.
- W5(I) ELEVATION CHANGE OPTION. This word is optional.

A.7.7.2 Cards ccc0101 Through ccc0109, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Volume Geometry Cards

This card (or cards) is required for branch, separator, jetmixer, turbine, and ECC mixer components. The nine words can be entered on one or more cards, and the card numbers need not be consecutive.

- W1(R) VOLUME FLOW AREA (m^2 , ft^2).
- W2(R) LENGTH OF VOLUME (m, ft).
- W3(R) VOLUME OF VOLUME (m^3 , ft^3). The code requires that the volume equals the volume flow area times the length ($W3 = W1 * W2$). At least two of the three

quantities, W1, W2, and W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.

- W4(R) AZIMUTHAL ANGLE (degrees). The absolute value of this angle must be ≤ 360 degrees. This quantity is not used in the calculation but is specified for possible automated drawing of nodalization diagrams.
- W5(R) INCLINATION ANGLE (degrees). The absolute value of this angle must be ≤ 90 degrees. The angle 0 degrees is horizontal, and positive angles have an upward inclination, i.e., the inlet is at the lowest elevation. This angle is used in the interphase drag calculation. For ECCMIX, the allowable inclination angle is less than ± 15 degrees. Any other value will be considered an input error.
- W6(R) ELEVATION CHANGE (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the vertical angle orientation is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign.
- W7(R) WALL ROUGHNESS (m, ft).
- W8(R) HYDRAULIC DIAMETER (m, ft). If zero, the hydraulic diameter is computed from $2.0 * (\text{volume area} / \pi) ** 0.5$. A check is made that the pipe roughness is less than half the hydraulic diameter.
- W9(I) VOLUME CONTROL FLAGS. This word has the packed format pvbfe.

The digit p specifies whether the water packing scheme is to be used. p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer. This digit is used for the BRANCH and ECCMIX components. For the SEPARATR, JETMIXER, and TURBINE components, the digit is not used and should be input as 0. The major edit will show p = 1.

The digit v specifies whether the vertical stratification model is to be used. v = 0 specifies that the vertical stratification model is to be used for the volume, and v = 1 specifies that the vertical stratification model is not to be used for the volume. The vertical stratification model is recommended when modeling a pressurizer. This digit is used for the BRANCH component. For the SEPARATR, JETMIXER, ECCMIX, and TURBINE components, the digit is not used and should be input as 0. The major edit will show v = 1.

The digit b specifies the interphase friction that is used. b = 0 means that the pipe interphase friction model will be applied, b = 1 means that the rod bundle interphase friction model will be applied, and b = 2 means that the ORNL ANS

narrow channel model will be applied. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, ECCMIX, and TURBINE components, the digit is not used and should be input as 0. The major edit will show $\underline{b} = 0$.

The digit $\underline{f}$ specifies whether wall friction is to be computed. $\underline{f} = 0$ specifies that wall friction effects are to be computed for the volume, and $\underline{f} = 1$ specifies that wall friction effects are not to be computed for the volume. For a separator, the code will set $\underline{f} = 1$ and no wall friction will be calculated.

The digit $\underline{e}$ specifies if nonequilibrium or equilibrium is to be used. $\underline{e} = 0$ specifies that a nonequilibrium (unequal temperature) calculation is to be used, and $\underline{e} = 1$ specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

A.7.7.3 Card ccc0111, ORNL ANS Interphase Model Pitch and Span Values

This card is required if the interphase friction flag $\underline{b}$ in Word 9 of Card ccc0101 through ccc0109 is set to 2.

W1(R) PITCH (CHANNEL WIDTH) (m, ft).
W2(R) SPAN (CHANNEL OR PLATE LENGTH PERPENDICULAR TO FLOW)
 (m, ft).

A.7.7.4 Card ccc0141, Additional Wall Friction Card

This card is optional except for a turbine component and is currently allowed only if Change Option 22 is enabled. If this card is not entered, the default values are 1.0 for the shape factor and 0.14 for the viscosity ratio exponent. Two, four, or six quantities may be entered on the card, and the data not entered are set to default values.

W1(R) SHAPE FACTOR FOR X-COORDINATE.
W2(R) VISCOSITY RATIO EXPONENT FOR X-COORDINATE.
W3(R) SHAPE FACTOR FOR Y-COORDINATE.
W4(R) VISCOSITY RATIO EXPONENT FOR Y-COORDINATE.
W5(R) SHAPE FACTOR FOR Z-COORDINATE.
W6(R) VISCOSITY RATIO EXPONENT FOR Z-COORDINATE.

A.7.7.5 Card ccc0142, Alternate Wall Friction Card

This card is optional except for a turbine component and is currently allowed only if Change

Option 22 is enabled and the code is compiled with the 'frifac' option. This card allows the specification of user defined turbulent friction factor for each coordinate direction. The turbulent friction factor has the form $f = A + B(Re)^{-C}$ where A, B, and C are entered for each coordinate of each volume. If this card is not entered, the standard turbulent friction factor is used for all coordinates. If the card is entered, the standard turbulent friction factor can be selected for a particular coordinate direction by entering zeros for the three quantities. Three, six, or nine quantities may be entered on the card, and the data not entered are set to zeros.

W1(R) A FOR X-COORDINATE.
W2(R) B FOR X-COORDINATE.
W3(R) C FOR X-COORDINATE.
W4(R) A FOR Y-COORDINATE.
W5(R) B FOR Y-COORDINATE.
W6(R) C FOR Y-COORDINATE.
W7(R) A FOR Z-COORDINATE.
W8(R) B FOR Z-COORDINATE.
W9(R) C FOR Z-COORDINATE.

A.7.7.6 Card ccc0200, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Volume Initial Conditions

This card is required for branch, separator, jetmixer, turbine, and ECC mixer components.

W1(I) CONTROL WORD. This word has the packed format gbt; g specifies the fluid; g = 0 is the default fluid, g = 1 specifies H₂O, g = 2 specifies D₂O, and g = 3 specifies H₂. The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default g = 0, then water is assumed to be the fluid.

The digit b specifies whether boron is present. b = 0 specifies that the volume fluid does not contain boron, and b = 1 specifies that a boron concentration in parts of boron per parts of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. t = 0 through 3 specifies one component (steam/water); t = 4 through 6 allows the specification of two components (steam/water and

noncondensable gas).

If $t = 0$, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), and vapor void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on volume control flag. If equilibrium, the static quality is checked; but only the pressure and internal energies are used to define the thermodynamic state.

If $t = 1$, the next two words are interpreted as temperature (K, $^{\circ}\text{F}$) and quality in equilibrium condition.

If $t = 2$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and quality in equilibrium condition.

If $t = 3$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, $^{\circ}\text{F}$) in equilibrium condition.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for quality are:

$1.0\text{E-}9 \leq \text{quality} \leq 0.99999999$, two-phase conditions, and

$\text{quality} < 1.0\text{E-}9$ or $\text{quality} > 0.99999999$, single-phase.

Noncondensable options are:

If $t = 4$, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, $^{\circ}\text{F}$), and equilibrium quality. Using this input option with $\text{quality} > 0.0$ and ≤ 1.0 , saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Quality is reset to 1.0 using this dry noncondensable option.

If $t = 5$, the next three words are interpreted as temperature (K, $^{\circ}\text{F}$), equilibrium quality, and noncondensable quality. Both the equilibrium and noncondensable qualities are restricted to be between $1.0\text{E-}9$ and 0.99999999 .

If $t = 6$, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, and noncondensable quality. The combinations of vapor void fraction and noncondensable quality must be thermodynamically consistent. If noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must not be 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable), then

vapor void fraction must also be 1.0. When both the vapor void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor-specific internal energy.

W2-W6(R) QUANTITIES AS DESCRIBED UNDER WORD 1. Depending on the control word, two through five quantities may be required. Enter only the minimum number required. If entered, boron concentration follows the last required word for thermodynamic conditions.

A.7.7.7 Cards cccn101, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Geometry Card

These cards are required if NJ is greater than zero. Cards with n equal to 1 through 9 are entered, one for each junction. N equal to 1, 2, and 3 must be used for SEPARATR, JETMIXER, and ECCMIX components. For a BRANCH component, n need not be consecutive, but NJ cards must be entered. The card format for Words 1 through 6 is listed below and is identical to Words 1 through 6 on Card ccc0101 of the Single Junction Geometry Card, except that n instead of 0 is used in the fourth digit. Word 7 is not used for BRANCH, JETMIXER, and TURBINE components. Word 7 is defined for SEPARATR and ECCMIX components.

W1(I) FROM CONNECTION CODE TO A COMPONENT. This refers to the component from which the junction coordinate direction originates. For connecting to a time-dependent volume, the connection code is ccc000000, where ccc is the component number of the time-dependent volume. An old or an expanded format can be used to connect all other volumes. In the old format, use ccc000000 if the connections to the inlet side of the component and use ccc010000 if the connection is to the outlet side of the volume. In the old format, W6 is used to specify a crossflow connection. In the expanded format, the connection code is cccvv000n, where ccc is the component number, vv is the volume number, and n indicates the face number. A nonzero n specifies the expanded format. N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. N equal to 3 through 6 specifies crossflow. Current crossflow models do not require inlet-outlet orientation; but, in future versions, n equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction, n equal to 5 and 6 would do the same for the third coordinate direction. Since crossflows are specified directly in the expanded format, the crossflow flag in W6 is ignored on input but set appropriately for output edits.

W2(I) TO CONNECTION CODE TO A COMPONENT. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) JUNCTION AREA (m^2 , ft^2). If zero, the area is set to the minimum volume area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) FORWARD FLOW ENERGY LOSS COEFFICIENT.

W5(R) REVERSE FLOW ENERGY LOSS COEFFICIENT.

W6(I) JUNCTION CONTROL FLAGS. This word has the packed format fvcahs.

The digit f specifies CCFL options. f = 0 means that the CCFL model will not be applied, and f = 1 means that the CCFL model will be applied. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, ECCMIX, and TURBINE components, this digit is not used and should be set to 0. The major edit output will show f = 0.

The digit v specifies horizontal stratification entrainment/pullthrough options. v = 0 means the model is not applied; v = 1 means an upward oriented junction; v = 2 means a downward oriented junction; and v = 3 means a centrally (side) located junction. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, ECCMIX, and TURBINE components, this digit is not used and should be set to 0.

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means that the choking model will not be applied.

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means an abrupt area change.

The digit h specifies nonhomogeneous or homogeneous. h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option and h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit printout will show h = 1.

The digit s specifies a normal or crossflow junction. This digit is used for the BRANCH, SEPARATR, and TURBINE components. s = 0 specifies a normal junction; s = 1 specifies a crossflow junction and that the to volume is a crossflow volume; s = 2 specifies a crossflow junction and that the from volume is a crossflow volume; and s = 3 specifies a crossflow junction and that the from and to volumes are crossflow volumes. For the JETMIXER component, this digit is not used and should be input as 0.

W7(R) VOID FRACTION LIMIT. For SEPARATR or ANGLE (for ECCMIX). This word is needed only for a SEPARATR or an ECCMIX component. For SEPARATR, this word is VOID FRACTION LIMIT. For the vapor exit junction (n = 1), this quantity (VOVER) is the vapor void fraction above which flow out of the vapor outlet is pure vapor. If the word is missing, a default value of 0.5 is used. For the liquid fall back junction (n = 2), this quantity (VUNDER) is the liquid void fraction above which flow out of the liquid fall back is pure liquid. If the word is missing, a default value of 0.15 is used. For the separator inlet, this word is not

used.

For ECCMIX, this word is ANGLE and is the angle between the axis of the ECC injection line and the main pipe (or the angle between Junctions 1 and 2). This angle must be between 0 and 180 degrees. If missing, a 90-degree connection for the ECC pipe is assumed.

A.7.7.8 Cards cccn110 Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Diameter And CCFL Data Cards

These cards are optional. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculations, then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model, then enter all four words for the appropriate CCFL model.

- W1(R) JUNCTION HYDRAULIC DIAMETER, D_j (m, ft). This quantity is the junction hydraulic diameter used in the CCFL correlation equation and interphase drag. This number must be ≥ 0 . If a zero is entered or if the default is used, the junction diameter is computed from $2.0 * (\text{junction area} / \pi) ** 0.5$.
- W2(R) FLOODING CORRELATION FORM, β . If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1 . The default value is 0 (Wallis form).
- W3(R) GAS INTERCEPT, c . This quantity is the gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0 . The default value is 1.
- W4(R) SLOPE, m . This quantity is the slope used in the CCFL correlation and must be > 0 . The default value is 1.

A.7.7.9 Cards cccn201, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Initial Conditions

These cards are required depending on the value of NJ as described for Cards cccn101.

- W1(R) INITIAL LIQUID OR MASS FLOW. Velocity is in m/s, ft/s or mass flow in kg/s, lb/s.
- W2(R) INITIAL VAPOR VELOCITY OR MASS FLOW. Velocity is in m/s, ft/s or mass flow in kg/s, lb/s.
- W3(R) INTERFACE VELOCITY (m/s, ft/s). Enter zero.

A.7.7.10 Card ccc0300, Turbine/Shaft Geometry Card

This card is used only for TURBINE components.

Valve Junction Component

- W1(R) TURBINE STAGE SHAFT SPEED, ω (rad/s, rev/min). This speed should equal the shaft speed used in the SHAFT component.
- W2(R) INERTIA OF ROTATING STAGES IN STAGE GROUP, I_i . ($\text{kg}\cdot\text{m}^2$, $\text{lb}\cdot\text{ft}^2$).
- W3(R) SHAFT FRICTION COEFFICIENT, f_i ($\text{N}\cdot\text{m}\cdot\text{s}$, $\text{lb}\cdot\text{ft}\cdot\text{s}$). The frictional torque equals $f_i\omega$. This frictional torque is used by the SHAFT component.
- W4(I) SHAFT COMPONENT NUMBER TO WHICH THE TURBINE STAGE IS CONNECTED.
- W5(I) DISCONNECT TRIP NUMBER. If zero, the turbine is always connected to the shaft. If nonzero, the turbine is connected to the shaft when the trip is false and disconnected when the trip is true.
- W6(I) DRAIN FLAG. At the present time, this is not used and can be neglected or set to zero.

A.7.7.11 Card ccc0400, Turbine Performance Data Card

This card is used only for TURBINE components.

- W1(I) TURBINE TYPE.
- 0 = Two-row impulse stage group.
- 1 = General impulse-reaction stage group.
- 2 = Constant efficiency stage group.
- W2(R) ACTUAL EFFICIENCY η_0 AT THE MAXIMUM EFFICIENCY DESIGN POINT.
- W3(R) DESIGN REACTION FRACTION, r . This is the fraction of the enthalpy decrease that takes place in the rotating blade system.
- W4(R) MEAN STAGE RADIUS, R (m, ft).

A.7.8 Valve Junction Component

A valve junction component is indicated by VALVE on Card ccc0000.

A.7.8.1 Cards ccc0101 Through ccc0109, Valve Junction Geometry Cards

This card (or cards) is required for valve junction components.

- W1(I) FROM CONNECTION CODE TO A COMPONENT. This refers to the component from which the junction coordinate direction originates. For connecting to a time-dependent volume, the connection code is ccc000000, where

ccc is the component number of the time-dependent volume. An old or an expanded format can be used to connect all other volumes. In the old format, use ccc000000 if the connection is to the inlet side of the component and use ccc010000 if the connection is to the outlet side of the volume. In the old format, it is not possible to specify a crossflow connection. In the expanded format, the connection code is ccvvn000n, where ccc is the component number, vv is the volume number, and n indicates the face number. A nonzero n specifies the expanded format. N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. N equal to 3 through 6 specifies crossflow. Current crossflow models do not require inlet-outlet orientation; but, in future versions, n equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction, n equal to 5 and 6 would do the same for the third coordinate direction. Since crossflows are specified directly in the expanded format, the crossflow flag in W6 is ignored on input but set appropriately for output edits.

W2(I) TO CONNECTION CODE TO A COMPONENT. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) JUNCTION AREA (m², ft²). This quantity is the full open area of the valve except in the case of a relief valve. For valves other than relief valves, if this area is input as zero, the area is set to the minimum area of adjoining volumes. If nonzero, this area is used. For relief valves, this term is the valve inlet throat area. If this term is input as zero, it will default to the area calculated from the inlet diameter term input on Cards ccc0301 through ccc0309, in which case the inlet diameter term cannot be input as zero. If both this area and the inlet diameter are input as nonzero, this area will be used but must agree with the area calculated from the inlet diameter within $1.0 \times 10^{-5} \text{ m}^2$. However, if this area is input as nonzero and the inlet diameter is input as zero, the inlet diameter will default to the diameter calculated from this area. When an abrupt area change model is specified, the area must be less than or equal to the minimum of the adjoining volume areas.

W4(R) FORWARD FLOW ENERGY LOSS COEFFICIENT.

W5(R) REVERSE FLOW ENERGY LOSS COEFFICIENT.

W6(I) JUNCTION CONTROL FLAGS. This word has the packed format fvcahs.

The digit f specifies CCFL options. f = 0 means that the CCFL model will not be applied, and f = 1 means that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0).

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means that the choking model will not be applied.

The digit $\underline{a}$ specifies area change options. $\underline{a} = 0$ means either a smooth area change or no area change, and $\underline{a} = 1$ means an abrupt area change. Either option may be input for a motor or servo valve. If the smooth area change option is input, then a C_v table must be input; or, if no C_v table is input, then the abrupt area change option must be input. For all other valves, the abrupt area change option must be input.

The digit $\underline{h}$ specifies nonhomogeneous or homogeneous. $\underline{h} = 0$ specifies the nonhomogeneous (two-velocity momentum equations) option; $\underline{h} = 2$ specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option ($\underline{h} = 2$), the major edit printout will show $\underline{h} = 1$.

The digit $\underline{s}$ is not used and should be input as zero ($\underline{s} = 0$). The major edit printout will show $\underline{s} = 0$.

- W7(R) SUBCOOLED DISCHARGE COEFFICIENT. This quantity is applied only to subcooled choked flow calculations. The quantity must be > 0 and ≤ 2.0 . If missing, it is set to 1.0.
- W8(R) TWO-PHASE DISCHARGE COEFFICIENT. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 or ≤ 2.0 . If missing, it is set to 1.0.
- W9(R) SUPERHEATED DISCHARGE COEFFICIENT. This quantity is applied only to superheated choked flow calculations. The quantity must be > 0 and ≤ 2.0 . If missing, it is set to 1.0.

A.7.8.2 Card ccc0110, Valve Junction Diameter and CCFL Data Card

This card is optional. If this card is being used to specify the junction hydraulic diameter for the interphase drag calculation, then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model, then enter all four words for the appropriate CCFL model.

- W1(R) JUNCTION HYDRAULIC DIAMETER, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation and interphase drag and must be ≥ 0 . If a zero is entered or if the default is used, the junction diameter is computed from $2.0 * (\text{junction area}/\pi)^{0.5}$.
- W2(R) FLOODING CORRELATION FORM, β . If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1 . The default value is 0 (Wallis form).
- W3(R) GAS INTERCEPT, c . This is the gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0 . The default value f is 1.

W4(R) SLOPE, m. This is the slope used in the CCFL correlation and must be > 0 . The default value is 1.

A.7.8.3 Card ccc0201, Valve Junction Initial Conditions

This card is required for valve junction components.

W1(I) CONTROL WORD. If zero, the next two words are velocities; if one, the next two words are mass flows.

W2(R) INITIAL LIQUID VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s), depending on the control word.

W3(R) INITIAL VAPOR VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s), depending on the control word.

W4(R) INTERFACE VELOCITY (m/s, ft/s). Enter zero.

A.7.8.4 Card ccc0300, Valve Type Card

This card is required to specify the valve type.

W1(A) VALVE TYPE. This word must contain one of the following: CHKVLV for a check valve, TRPVLV for a trip valve, INRVLV for an inertial swing check valve, MTRVLV for a motor valve, SRVVLV for a servo valve, or RLFVLV for a relief valve.

A.7.8.5 Cards ccc0301 Through ccc0399, Valve Data and Initial Conditions

These cards are required for valve junction components. Six different types of valves are allowed. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The card format of these cards depends on the valve type.

A.7.8.5.1 Check Valve. This behaves as an on, off switch. If the valve is on, then it is fully open; and if the valve is off, it is fully closed.

W1(I) CHECK VALVE TYPE. Enter +1 for a static pressure-controlled check valve (no hysteresis), 0 for a static pressure/flow-controlled check valve (has hysteresis effect), or -1 for a static/dynamic pressure-controlled check valve (has hysteresis effect).

W2(I) CHECK VALVE INITIAL POSITION. The valve is initially open if zero, closed if one.

W3(R) CLOSING BACK PRESSURE (Pa, lb_f/in^2).

W4(R) LEAK RATIO. This is the fraction of the junction area for the leakage when the valve is nominally closed. If omitted or input as zero, then either the smooth or

the abrupt area change model may be specified. If input as nonzero, then the abrupt area change model must be specified.

A.7.8.5.2 Trip Valve. This behaves as an on, off switch as described for the check valve.

W1(I) TRIP NUMBER. This must be a valid trip number. If the trip is false, the valve is closed; if the trip is true, the valve is open.

A.7.8.5.3 Inertial Valve. This behaves realistically in that the valve area varies considering the hydrodynamic forces and the flapper inertia, momentum, and angular acceleration. The abrupt area change model must be specified.

W1(I) LATCH OPTION. The valve can open and close repeatedly if the latch option is zero. The valve either opens or closes only once if the latch option is one.

W2(I) VALVE INITIAL CONDITION. The valve is initially open if zero, initially closed if one.

W3(R) CLOSING BACK PRESSURE (Pa, lb_f/in²).

W4(R) LEAKAGE FRACTION. Fraction of the junction area for leakage when the valve is nominally closed.

W5(R) INITIAL FLAPPER ANGLE (degrees). The flapper angle must be within the minimum and maximum angles specified in Words W6 and W7.

W6(R) MINIMUM ANGLE (degrees).

W7(R) MAXIMUM ANGLE (degrees).

W8(R) MOMENT OF INERTIA OF VALVE FLAPPER (kg·m², lb·ft²).

W9(R) INITIAL ANGULAR VELOCITY (rad/s).

W10(R) MOMENT LENGTH OF FLAPPER (m, ft).

W11(R) RADIUS OF FLAPPER (m, ft).

W12(R) MASS OF FLAPPER (kg, lb).

A.7.8.5.4 Motor Valve. This behaves realistically in that the valve area varies as a function of time by either of two models specified by the user. The user must also select the model for valve hydrodynamic losses by specifying either the smooth or the abrupt area change model. If the smooth area change model is selected, a table of flow coefficients must also be input as described in Cards ccc0400 through ccc0499, CSUBV Table Section A.7.8.6. If the abrupt area change model is selected, a flow coefficient table cannot be input.

W1(I) OPEN TRIP NUMBER.

- W2(I) CLOSE TRIP NUMBER. Both the open and close trip numbers must be valid trips. When both trips are false, the valve remains at its current position. When one of the trips is true, the valve opens or closes depending on which trip is true. The transient will be terminated if both trips are true at the same time.
- W3(R) VALVE CHANGE RATE (s^{-1}). If Word 5 is not entered, this quantity is the rate of change of the normalized valve area as the valve opens or closes. If Word 5 is entered, this quantity is the rate of change of the normalized valve stem position. This word must be greater than zero.
- W4(R) INITIAL POSITION. This number is the initial normalized valve area or the initial normalized stem position depending on Word 5. This quantity must be between 0.0 and 1.0.
- W5(I) VALVE TABLE NUMBER. If this word is omitted or input as zero, the valve area is determined by the valve change rate and the trips. If this word is input as nonzero, the valve stem position is determined by the valve change rate and the trips; and the valve area is determined from a general table containing normalized valve area versus normalized stem position.

Input for general tables is discussed in Cards 202ttnn, General Table Data, Section A.11. For this case, the normalized stem position is input as the argument value and the normalized valve area is input as the function value.

A.7.8.5.5 Servo Valve. This behaves as described for a motor valve except that the valve flow area or stem position is calculated by a control system. Input for control systems is discussed in Section A.1. Input specifying the hydrodynamic losses for servo valves is also identical to that for motor valves.

- W1(I) CONTROL VARIABLE NUMBER. The value of the indicated control variable is either the normalized valve area or the normalized stem position, depending on whether Word 2 is entered. The control variable is also the search argument for the CSUBV table if it is entered.
- W2(I) VALVE TABLE NUMBER. If this word is not entered, the control variable value is the normalized flow area. If it is entered, the control variable value is the normalized stem position; and the general table indicated by this word contains a table of normalized area versus normalized stem position. Input for the general table is identical to that for a motor valve.

A.7.8.5.6 Relief Valve. The valve area varies considering the hydrodynamic forces and the valve mass, momentum, and acceleration. The abrupt area change model must be specified. The junction area input by Card ccc0101 through ccc0199 is the valve inlet area.

- W1(I) VALVE INITIAL CONDITION. The valve is initially closed if zero, open if one.

- W2(R) INLET DIAMETER (m, ft). This is the inside diameter of the valve inlet. If this term is input as zero, it will default to the diameter calculated from the junction area input on Card ccc0101 through ccc0109. If both this diameter and the junction area are input as nonzero, care must be taken that these terms are input with enough significant digits so that the areas agree within $1.0 \times 10^{-5} \text{ m}^2$. If the junction area is input as zero, then this diameter must be input as nonzero.
- W3(R) VALVE SEAT DIAMETER (m, ft). Nonzero input is required. This term is the outside diameter of the valve seat, including the minimum diameter of the inner adjustment ring. This term must also be greater than or equal to the inlet diameter.
- W4(R) VALVE PISTON DIAMETER (m, ft). If input as zero, the default is to the valve seat diameter.
- W5(R) VALVE LIFT (m, ft). Nonzero input is required. This is the distance the valve piston rises above the valve seat at the fully open position.
- W6(R) MAXIMUM OUTSIDE DIAMETER OF THE INNER ADJUSTMENT RING (m, ft). If this input is zero, it will default to the valve seat diameter; in which case W7(R), following, must be input as zero. If this input is nonzero, the value must be greater than or equal to the valve seat diameter. If input is greater than the valve seat diameter, a nonzero input of W7(R), is allowed. Also refer to the warning stated for W9(R).
- W7(R) HEIGHT OF OUTSIDE SHOULDER RELATIVE TO THE VALVE SEAT FOR INNER ADJUSTMENT RING (m, ft). Input of a positive, nonzero value is not allowed. Input of a zero value is required if W6(R) preceding is defaulted or input equal to the valve seat diameter. If the shoulder is below the seat, this distance is negative. Also refer to the warning stated for W9(R).
- W8(R) MINIMUM INSIDE DIAMETER OF THE OUTER ADJUSTMENT RING (m, ft). If this input is zero, it will default to the valve piston diameter, in which case W9(R) must be input as positive and nonzero. If this input is nonzero, the value must be greater than or equal to the valve piston diameter. Input of a negative W9(R) is allowed only if this diameter is greater than the valve piston diameter. Also refer to the warning stated for W9(R).
- W9(R) HEIGHT OF INSIDE BOTTOM EDGE RELATIVE TO THE VALVE SEAT FOR OUTER ADJUSTMENT RING (m, ft). This may be input as positive, zero, or negative. If this input is negative, then W8(R) preceding must be greater than the valve piston diameter. If the bottom edge is below the valve seat, this distance is negative. WARNING: Input of this term and terms W6(R), W7(R), and W8(R) preceding must be done with care to ensure that the resultant gap between the adjustment rings is positive and nonzero; otherwise, an input error will result.

W10(R)	BELLOWS AVERAGE DIAMETER (m, ft). If this term is input as zero, it will default to the valve piston diameter, resulting in a model not containing a bellows for which the valve bonnet region is vented to the atmosphere.
W11(R)	VALVE SPRING CONSTANT (N/m, lb _f /ft). Positive, nonzero input is required.
W12(R)	VALVE SETPOINT PRESSURE (Pa, lb _f /in ²). Positive input is required.
W13(R)	VALVE PISTON, ROD, SPRING, BELLOWS MASS (kg, lb). Nonzero input is required.
W14(R)	VALVE DAMPING COEFFICIENT (N·s/m, lb _f ·s/ft).
W15(R)	BELLOWS INSIDE PRESSURE (Pa, lb _f /in ²). Defaults to standard atmospheric pressure if omitted or input as zero.
W16(R)	INITIAL STEM POSITION. This is the fraction of total lift and is required if W1(I) is input as one. Total lift is input as W5(R).
W17(R)	INITIAL VALVE PISTON VELOCITY (m/s, ft/s). This must be zero or omitted if W1(I) is input as zero.

A.7.8.6 Cards ccc0400 Through ccc0499, Valve CSUBV Table

The CSUBV table may be input only for motor and servo valves. If the CSUBV table is input, the smooth area change model must be specified on the valve junction geometry card (Card ccc0101 through ccc0109). If the smooth area change model is specified, a CSUBV table must be input.

The CSUBV table contains forward and reverse flow coefficients as a function of normalized flow area or normalized stem position.

A.7.8.6.1 Cards ccc0400, Factors. This card is optional. The factors apply to the flow area or the stem position and the flow coefficient entries in the CSUBV table.

W1(R) NORMALIZED FLOW AREA OR NORMALIZED STEM POSITION.

W2(R) FLOW COEFFICIENT FACTOR.

A.7.8.6.2 Cards ccc0401 through ccc0499, Table Entries. The table is entered by using three-word sets. W1 is the flow area or stem position and must be normalized. The factor W1 on Card ccc0400 can be used to normalize the flow area or stem position. In either case, the implication is that if the valve is fully closed, the normalized term is zero. If the valve is fully open, the normalized term is one. Any value may be input that is between zero and one. The forward and reverse flow coefficients are W2 and W3, respectively. The code internally converts flow coefficients to energy loss coefficients by the formula $K = 2 \cdot A_j^2 / (\text{RHO} \cdot \text{CSUBV}^2)$, where RHO is density of water at 60 °F (288.71 K), A_j is the full open valve area, and CSUBV is the flow

coefficient. On Card ccc0400, W2 may be used to modify the definition of CSUBV. A smooth area change must be specified in W6 on Card ccc0101 to use the CSUBV table. CSUBV is entered in British units only.

- W1(R) NORMALIZED FLOW AREA OR NORMALIZED STEM POSITION.
- W2(R) FORWARD CSUBV {gal/[min•(lb/in²)**0.5]}. The CSUBV is input in British units only and is converted to SI units using 7.598055E-7 as the conversion factor.
- W3(R) REVERSE CSUBV {gal/[min•(lb/in²)**0.5]}.

A.7.9 Pump Component

A pump component is indicated by PUMP on Card ccc0000. A pump consists of one volume and two junctions, one attached to each end of the volume.

A.7.9.1 Cards ccc0101 Through ccc0107, Pump Volume Geometry Cards

This card (or cards) is required for a pump component. The seven words can be entered on one or more cards, and the card numbers need not be consecutive.

- W1(R) VOLUME FLOW AREA (m², ft²).
- W2(R) LENGTH OF VOLUME (m, ft).
- W3(R) VOLUME OF VOLUME (m³, ft³). The program requires that the volume equals the volume flow area times the length (W3 = W1*W2). At least two of the three quantities, W1, W2, W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.
- W4(R) AZI8MUTHAL ANGLE (degrees). The absolute value of this angle must be ≤ 360 degrees. This quantity is not used in the calculation but is specified for possible automated drawing of nodalization diagrams.
- W5(R) INCLINATION ANGLE (degrees). The absolute value of this angle must be ≤ 90 degrees. The angle 0 degrees is horizontal, and positive angles have an upward direction, i.e., the outlet is at a higher elevation than the inlet. This angle is used in the interphase drag calculation.
- W6(R) ELEVATION CHANGE (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be equal to or less than the volume length. If the vertical angle orientation is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign.
- W7(I) VOLUME CONTROL FLAGS. This word has the packed format pvbfe.

The digit p is not used and should be input as 0 (p = 0). The major edit output will

show $\underline{p} = 1$.

The digit $\underline{v}$ is not used and should be input as 0 ($\underline{v} = 0$). The major edit output will show $\underline{v} = 1$.

The digit $\underline{b}$ is not used and should be input as 0 ($\underline{b} = 0$). The major edit will show $\underline{b} = 0$.

The digit $\underline{f}$ that normally specifies whether wall friction is to be computed is not used. No wall friction is computed for a pump, since it is included in the homologous pump data. The major edit output will show $\underline{f} = 1$, which indicates that no friction flag is set.

The digit $\underline{e}$ specifies if nonequilibrium or equilibrium is to be used; $\underline{e} = 0$ specifies that a nonequilibrium (unequal temperature) calculation is to be used, and $\underline{e} = 1$ specifies that an equilibrium (equal temperature) calculation is to be used.

Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

A.7.9.2 Card ccc0108, Pump Inlet (Suction) Junction Card

This card is required for a pump component.

W1(I) VOLUME CODE OF CONNECTING VOLUME ON INLET SIDE. This refers to the component from which the junction coordinate direction originates. For connecting to a time-dependent volume, the connection code is ccc000000, where ccc is the component number of the time-dependent volume. An old or an expanded format can be used to connect all other volumes. In the old format, use ccc000000 if the connection is to the inlet side of the component and use ccc010000 if the connection is to the outlet side of the volume. In the old format, it is not possible to specify a crossflow connection. In the expanded format, the connection code is ccvvn000n, where ccc is the component number, vv is the volume number, and n indicates the face number. A nonzero n specifies the expanded format. N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. N equal to 3 through 6 specifies crossflow. Current crossflow models do not require inlet-outlet orientation; but, in future versions, n equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction, n equal to 5 and 6 would do the same for the third coordinate direction. Since crossflows are specified directly in the expanded format, the crossflow flag in W6 is ignored on input but set appropriately for output edits. For yet another possible change, entering the crossflow flags is recommended.

With the old format, connections are possible only to the inlet or crossflow faces of the first pipe volume or to the outlet or crossflow faces of the last pipe volume. With the expanded format, connections can be made to any face of any pipe

volume. Output edits use the expanded format regardless of the input format.

W2(R) JUNCTION AREA (m^2 , ft^2). If zero, the area is set to the minimum of the volume areas of adjacent volumes. If an abrupt area change, the area must be equal to or less than the minimum of the adjacent volume areas. If a smooth area change, no restrictions exist.

W3(R) FORWARD FLOW ENERGY LOSS COEFFICIENT.

W4(R) REVERSE FLOW ENERGY LOSS COEFFICIENT.

W5(I) JUNCTION CONTROL FLAGS. This word has the packed format fvcahs.

The digit f specifies CCFL options. f = 0 means that the CCFL model will not be applied, and f = 1 means that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0).

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means that the choking model will not be applied.

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means an abrupt area change.

The digit h specifies nonhomogeneous or homogeneous. h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option; h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit printout will show a one.

The digit s is not used and should be input as zero (s = 0).

A.7.9.3 Card ccc0109, Pump Outlet (Discharge) Junction Card

This card is required for a pump component. The format for this card is identical to Card ccc0108 except data are for the outlet junction.

A.7.9.4 Card ccc0110, Pump Inlet (Suction) Junction Diameter and CCFL Data Card

This card is optional. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, then the diameter should be entered in Word 2 and any allowable values should be entered in Words 2 through 4 (will not be used). If the card is being used for the CCFL model, then enter all four words for the appropriate CCFL model.

W1(R) JUNCTION HYDRAULIC DIAMETER, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation and interphase drag and must be ≥ 0 . If a zero is entered or the default is used, the junction diameter is computed from $2.0 * (\text{junction area} / \pi) ** 0.5$.

- W2(R) FLOODING CORRELATION FORM, β . If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1 . The default value is 0 (Wallis form).
- W3(R) GAS INTERCEPT, c . This is the gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0 . The default value is 1.
- W4(R) SLOPE, m . This is the slope used in the CCFL correlation and must be > 0 . The default value is 1.

A.7.9.5 Card ccc0111, Pump Outlet (Discharge) Junction Diameter and CCFL Data Card

This card is optional. If this card is being used to just specify the junction hydraulic diameter for the interphase drag calculation, then the diameter should be entered in Word 2 and any allowable values should be entered in Words 2 through 4 (will not be used). If the card is being used for the CCFL model, then enter all four words for the appropriate CCFL model. The format for this card is identical to Card ccc0110 except that data are for the outlet junction.

A.7.9.6 Card ccc0200, Pump Volume Initial Conditions

This card is required for a pump component.

- W1(I) CONTROL WORD. This word has the packed format $\underline{e} \underline{b} \underline{t}$. $\underline{e}$ specifies the fluid; $\underline{e} = 0$ is the default fluid, $\underline{e} = 1$ specifies H_2O , $\underline{e} = 2$ specifies D_2O , and $\underline{e} = 3$ specifies H_2 . The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If cards 120 through 129 are not entered and all control words use the default $\underline{e} = 0$, then H_2O is assumed to be the fluid.

The digit $\underline{b}$ specifies whether boron is present. $\underline{b} = 0$ specifies that the volume fluid does not contain boron; $\underline{b} = 1$ specifies that a boron concentration in parts of boron per parts of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit $\underline{t}$ specifies how the following words are to be used to determine the initial thermodynamic state. $\underline{t} = 0$ through 3 specifies one component (steam/water). Entering $\underline{t} = 4$ through 6 allows the specification of two components (steam/water and noncondensable gas).

If $\underline{t} = 0$, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), and vapor void fraction. These quantities will be interpreted as nonequilibrium or

equilibrium conditions depending on volume control flag. If equilibrium, the static quality is checked, but only the pressure and internal energies are used to define the thermodynamic state.

If $t = 1$, the next two words are interpreted as temperature (K, °F) and quality in equilibrium condition.

If $t = 2$, the next two words are interpreted as pressure (Pa, lb_f/in²) and quality in equilibrium condition.

If $t = 3$, the next two words are interpreted as pressure (Pa, lb_f/in²) and temperature (K, °F) in equilibrium condition.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for quality are:

$1.0\text{E-}9 \leq \text{quality} \leq 0.99999999$, two-phase conditions, and

$\text{quality} < 1.0\text{E-}9$ or $\text{quality} > 0.99999999$, single-phase.

Noncondensable options are:

If $t = 4$, the next three words are interpreted as pressure (Pa, lb_f/in²), temperature (K, °F), and equilibrium quality.

Using this input option with $\text{quality} > 0.0$ and ≤ 1.0 , saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure.

Setting quality to 0.0 is used as a flag that will initialize the volume to all noncondensables (dry noncondensable) with no temperature restrictions. Quality is reset to 1.0 using this dry noncondensable option.

If $t = 5$, the next three words are interpreted as temperature (K, °F), equilibrium quality, and noncondensable quality. Both the equilibrium and noncondensable qualities are restricted to be between $1.0\text{E-}9$ and 0.99999999 .

If $t = 6$, the next five words are interpreted as pressure (Pa, lb_f/in²), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, and noncondensable quality. The combinations of vapor void fraction and noncondensable quality must be thermodynamically consistent. If noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must not be 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable), then vapor void fraction must also be 1.0. When both the vapor void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor-specific internal energy.

W2-W6(R) QUANTITIES AS DESCRIBED UNDER WORD 1. Depending on the control word, two through five quantities may be required. Enter only the minimum number required. If entered, boron concentration follows the last required word for thermodynamic conditions.

A.7.9.7 Card ccc0201, Pump Inlet (Suction) Junction Initial Conditions

This card is required for a pump component.

W1(I) CONTROL WORD. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) INITIAL LIQUID VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s).

W3(R) INITIAL VAPOR VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s).

W4(R) INITIAL INTERFACE VELOCITY (m/s, ft/s). Enter zero.

A.7.9.8 Card ccc0202, Pump Outlet (Discharge) Junction Initial Conditions

This card is similar to Card ccc0201 except that data are for the outlet junction.

A.7.9.9 Card ccc0301, Pump Index and Option Card

This card is required for a pump component.

W1(I) PUMP TABLE DATA INDICATOR. If zero, single-phase homologous tables are entered with this component. A positive nonzero number indicates that the single-phase tables are to be obtained from the pump component with this number. If -1, use built-in data for the Bingham pump. If -2, use built-in data for the Westinghouse pump.

W2(I) TWO-PHASE INDEX. Enter -1 if the two-phase option is not to be used. Enter zero if the two-phase option is desired and two-phase multiplier tables are entered with this component. Enter nonzero if the two-phase option is desired and the two-phase multiplier table data are to be obtained from the pump component with the number entered. There are no built-in data for the two-phase multiplier table.

W3(I) TWO-PHASE DIFFERENCE TABLE INDEX. Enter -3 if the two-phase difference table is not needed (i.e., if W2 is -1). Enter zero if a table is entered with this component. Enter a positive nonzero number if the table is to be obtained from pump component with this number. Enter -1 for built-in data for the Bingham pump. Enter -2 for built-in data for the Westinghouse pump.

W4(I) PUMP MOTOR TORQUE TABLE INDEX. If -1, no table is used. If zero, a

table is entered for this component. If nonzero, use the table from the component with this number.

- W5(I) TIME-DEPENDENT PUMP VELOCITY INDEX. If -1, no time-dependent pump rotational velocity table is used and the pump velocity is always determined by the torque-inertia equation. If zero, a table is entered with this component. If nonzero, the table from the pump component with this number is used. A pump velocity table cannot be used when the pump is connected to a shaft control component.
- W6(I) PUMP TRIP NUMBER. When the trip is off, electrical power is supplied to the pump motor; when the trip is on, electrical power is disconnected from the pump motor. The pump velocity depends on the pump velocity table and associated trip, the pump motor torque data, and this trip. If the pump velocity table is being used, the pump velocity is always computed from that table. If the pump velocity table is not being used, the pump velocity depends on the pump motor torque data and this trip. If the trip is off and no pump motor torque data are present, the pump velocity is the same as for the previous time step. This will be the initial pump velocity if the pump trip has never been set. Usually the pump trip is a latched trip, but that is not necessary. If the trip is off and a pump motor torque table is present, the pump velocity is given by the torque-inertia equation where the net torque is given by the pump motor torque data and the homologous torque data. If the trip is on, the torque-inertia equation is used and the pump motor torque is set to zero. If the pump trip number is zero, no trip is tested and the pump trip is assumed to always be off.
- W7(I) REVERSE INDICATOR. If zero, no reverse is allowed; if one, reverse is allowed.

A.7.9.10 Cards ccc0302 Through ccc0304, Pump Description Card

This card (or cards) is required for a pump component.

- W1(R) RATED PUMP VELOCITY (rad/s, rev/min).
- W2(R) RATIO OF INITIAL PUMP VELOCITY TO RATED PUMP VELOCITY. Used for calculating initial pump velocity.
- W3(R) RATED FLOW (m^3/s , gal/min).
- W4(R) RATED HEAD (m, ft).
- W5(R) RATED TORQUE ($\text{N}\cdot\text{m}$, $\text{lb}_\text{f}\cdot\text{ft}$).
- W6(R) MOMENT OF INERTIA ($\text{kg}\cdot\text{m}^2$, $\text{lb}\cdot\text{ft}^2$). This includes all direct coupled rotating components, including the master for a motor driven pump.

- W7(R) RATED DENSITY (kg/m^3 , lb/ft^3). If zero, initial density is used. This is the density used to generate homologous data.
- W8(R) RATED PUMP MOTOR TORQUE ($\text{N}\cdot\text{m}$, $\text{lb}\cdot\text{ft}$). If this word is zero, the rated pump motor torque is computed from the initial pump velocity and the pump torque that is computed from the initial pump velocity, initial volume conditions, and the homologous curves. This quantity must be nonzero if the relative pump motor torque table is entered.
- W9(R) TF2 FRICTION TORQUE COEFFICIENT ($\text{N}\cdot\text{m}$, $\text{lb}\cdot\text{ft}$). This parameter multiplies the speed ratio (absolute pump speed/rated speed) to the second power. The friction torque factors are summed together.
- W10(R) TF0, FRICTION TORQUE COEFFICIENT ($\text{N}\cdot\text{m}$, $\text{lb}\cdot\text{ft}$). This is constant frictional torque.
- W11(R) TF1, FRICTION TORQUE COEFFICIENT ($\text{N}\cdot\text{m}$, $\text{lb}\cdot\text{ft}$). This multiplies the speed ratio to the first power.
- W12(R) TF3, FRICTION TORQUE COEFFICIENT ($\text{N}\cdot\text{m}$, $\text{lb}\cdot\text{ft}$). This multiplies the speed ratio to the third power.

A.7.9.11 Card ccc0308, Pump Variable Inertia Card

Pump inertia is given by Word 6 of Card ccc0302 if this card is not entered. If this card is entered, pump inertia is computed from

$$I = I_3 S^3 + I_2 S^2 + I_1 S + I_0 \quad \text{if } S > W1$$

where S is the relative pump speed defined as the absolute value of the pump rotational velocity divided by the rated rotational velocity.

- W1(R) RELATIVE SPEED AT WHICH TO USE THE CUBIC EXPRESSION FOR INERTIA. When the relative speed is less than this quantity, the inertia from Word 6 of Card ccc0302 is used.

W2-W5(R) I_3, I_2, I_1, I_0 ($\text{kg}\cdot\text{m}^2$, $\text{lb}\cdot\text{ft}^2$).

A.7.9.12 Card ccc0309, Pump-Shaft Connection Card

If this card is entered, the pump is connected to a SHAFT component. The pump may still be driven by a pump motor that can be described in this component, by a turbine also connected to the SHAFT component, or from torque computed by the control system and applied to the SHAFT component. The pump speed table may not be entered if this card is entered.

- W1(I) CONTROL COMPONENT NUMBER OF THE SHAFT COMPONENT.
- W2(I) PUMP DISCONNECT TRIP. If this quantity is omitted or zero, the pump is

always connected to the SHAFT. If nonzero, the pump is connected to the shaft when the trip is false and disconnected when the trip is true.

A.7.9.13 Card ccc0310, Pump Stop Data Card

If this card is omitted, the pump will not be stopped by the program.

- W1(R) ELAPSED PROBLEM TIME FOR PUMP STOP (s).
- W2(R) MAXIMUM FORWARD VELOCITY FOR PUMP STOP (rad/s, rev/min).
- W3(R) MAXIMUM REVERSE VELOCITY FOR PUMP STOP (rad/s, rev/min).
Reverse velocity is a negative number.

A.7.9.14 Cards cccxx00 Through cccxx99, Single-Phase Homologous Curves

These cards are needed only if W1 of Card ccc0301 is zero. There are 16 possible sets of homologous curve data to completely describe the single-phase pump operation, that is, a curve for each head and torque for each of the eight possible curve types or regimes of operation. Entering all 16 curves is not necessary, but an error will occur from an attempt to reference one that has not been entered.

Card numbering is ccc1100 through ccc1199 for the first curve, ccc1200 through ccc1299 for the second curve, through ccc2600 to ccc2699 for the sixteenth curve. Data for each individual curve are input on up to 99 cards, which need not be numbered consecutively.

- W1(I) CURVE TYPE. Enter one for a head curve; enter two for a torque curve.
- W2(I) CURVE REGIME. See Volume 1 of this manual for definitions. The possible integer numbers and the corresponding homologous curve octants are: 1 (HAN or BAN), 2 (HVN or BVN), 3 (HAD or BAD), 4 (HVD or BVD), 5 (HAT or BAT), 6 (HVT or BVT), 7 (HAR or BAR), and 8 (HVR or BVR).
- W3(R) INDEPENDENT VARIABLE. Values for each curve range from -1.0 to 0.0 or from 0.0 to 1.0 inclusive. The variable is v/α for W2(I) = 1, 3, 5, or 7 and α/v for W2(I) = 2, 4, 6, or 8. If the tabular data do not span the entire range of the independent variable, end point values are used for data outside the table. This usually leads to incorrect pump performance data. Thus entering data to cover the complete range is recommended.
- W4(R) DEPENDENT VARIABLE. The variable is h/α^2 or β/α^2 for W2(I) = 1, 3, 5, or 7 and h/v^2 or β/v^2 for W2(I) = 2, 4, 6, or 8.

Additional pairs as needed are entered on this or following cards, up to a limit of 100 pairs.

A.7.9.15 Cards cccxx00 Through cccxx99, Two-Phase Multiplier Tables

These cards are needed only if W2 of Card ccc0301 is zero; xx is 30 and 31 for the pump head multiplier table and the pump torque multiplier table, respectively.

- W1(I) EXTRAPOLATION INDICATOR. This is not used, enter zero.
- W2(R) VOID FRACTION.
- W3(R) HEAD OR TORQUE DIFFERENCE MULTIPLIER DEPENDING ON TABLE TYPE.

Additional pairs of data as needed are entered on this or additional cards as needed, up to a limit of 100 pairs. Void fractions must be in increasing order.

A.7.9.16 Cards cccxxX00 Through cccxx99, Two-Phase Difference Tables

These cards are required only if W3 of Card ccc0301 is zero. The two-phase difference tables are homologous curves entered in a similar manner to the single-phase homologous data. Card numbering is ccc4100 through ccc4199 for the first curve, ccc4200 through ccc4299 for the second curve, through ccc5600 to ccc5699 for the 16th curve. Data are the same as the data for the single-phase data except that the dependent variable is the difference between single-phase and fully degraded two-phase data.

A.7.9.17 Cards ccc6001 Through ccc6099, Relative Pump Motor Torque Data

These cards are required only if W4 of Card ccc0301 is zero. If the pump velocity table is not being used and these cards are present, the torque-inertia equation is used. When the electrical power is supplied to the pump motor (the pump trip is off), the net torque is computed from the rated pump motor torque times the relative pump motor torque from this table and the torque from the homologous data. If the electrical power is disconnected from the pump (the pump trip is on), the pump motor torque is zero.

- W1(R) PUMP VELOCITY (rad/s, rev/min).
- W2(R) RELATIVE PUMP MOTOR TORQUE.

Additional pairs as needed are added on this or additional cards, up to a maximum of 100 pairs.

A.7.9.18 Card ccc6100, Time-Dependent Pump Velocity Control Card

This card is required only if W5 of Card ccc0301 is zero. The velocity table, if present, has priority in setting the pump velocity over the pump trip, the pump motor torque data, and the torque-inertia equation.

- W1(I) TRIP NUMBER. If the trip number is zero, the pump velocity is always computed from this table using time as the search argument. If the trip number is nonzero, the trip determines which table is to be used. If the trip is off, the pump velocity

Multiple Junction Component

is set from the trip, the pump motor torque data, and the torque-inertia equation. If the trip is on, the pump velocity is computed from this table. If Word 3 is missing, the search variable in the table is time and the search argument is time minus the trip time. If this word is used, it takes precedence over the trip number used in Word 6 of the ccc0301 Card.

- W2(A) ALPHANUMERIC PART OF VARIABLE REQUEST CODE. This quantity is optional. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. TIME can be selected, but the trip time is not subtracted from the advancement time.
- W3(I) NUMERIC PART OF VARIABLE REQUEST CODE. This is assumed to be zero if missing.

A.7.9.19 Cards ccc6101 Through ccc6199, Time-Dependent Pump Velocity

These cards are required only if W5 of Card ccc0301 is zero.

- W1(R) SEARCH VARIABLE. Units depend on the quantity selected for the search variable.
- W2(R) PUMP VELOCITY (rad/s, rev/min).

Additional pairs as needed are added on this or additional cards, up to a maximum of 100 pairs. Time values must be in increasing order.

A.7.10 Multiple Junction Component

A multiple junction component is indicated by MTPLJUN on Card ccc0000.

The one or more junctions specified by this component can connect volumes in the same manner as several single junction components except that all the volumes connected by the junctions in the component must be in the same hydrodynamic system. If this restriction is violated, corrective action is to merge the hydrodynamic systems.

A.7.10.1 Card ccc0001, Multiple Junction Information Card

- W1(I) NUMBER OF JUNCTIONS, NJ. This number must be > 0 and < 100 .
- W2(I) INITIAL CONDITION CONTROL. This word is optional and, if missing, is assumed to be zero. If zero is entered, the initial conditions on Cards ccc1nnm are velocities; if one is entered, the initial conditions are mass flows.

A.7.10.2 Cards ccc0nnm, Multiple Junction Geometry Card

Junctions are described by one or more sets of data; nn being the set number and m being the card number within a set. The junctions are numbered as ccciinn00, where ii is 01 for the first junction described in a set and increments by one for each additional junction. The quantity nn

CARDS CCCXXNN, HYDRODYNAMIC COMPONENTS

may be 01 through 99, and m may be 1 through 9. Cards are processed by increasing set number nn, and cards within a set by increasing m. Neither nn or m need be strictly consecutive.

W1(I) FROM CONNECTION CODE TO A COMPONENT. This refers to the component from which the junction coordinate direction originates. For connecting to a time-dependent volume, the connection code is ccc000000, where ccc is the component number of the time-dependent volume. An old or an expanded format can be used to connect all other volumes. In the old format, use ccc000000 if the connection is to the inlet side of the component and use ccc010000 if the connection is to the outlet side of the volume. In the old format, 6 is used to specify a crossflow connection. In the expanded format, the connection code is ccvvn000n, where ccc is the component number, vv is the volume number, and n indicates the face number. A nonzero n specifies the expanded format. N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. N equal to 3 through 6 specifies crossflow. Current crossflow models do not require inlet-outlet orientation; but, in future versions, n equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction, n equal to 5 and 6 would do the same for the third coordinate direction. Since crossflows are specified directly in the expanded format, the crossflow flag in W6 is ignored on input but set appropriately for output edits.

W2(I) TO CONNECTION CODE TO A COMPONENT. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) JUNCTION AREA (m^2 , ft^2). If zero, the area is set to the minimum volume area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) FORWARD FLOW ENERGY LOSS COEFFICIENT.

W5(R) REVERSE FLOW ENERGY LOSS COEFFICIENT.

W6(I) JUNCTION CONTROL FLAGS. This word has the packed format fvcahs.

The digit f specifies CCFL options. f = 0 means that the CCFL model will not be applied, and f = 1 means that the CCFL model will be applied.

The digit y is not used and should be input as zero (y = 0).

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means that the choking model will not be applied.

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means an abrupt area change.

Multiple Junction Component

The digit h specifies nonhomogeneous or homogeneous. h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option; h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit printout will show h = 1.

The digit s specifies normal or crossflow junction. s = 0 specifies normal junction, s = 1 specifies a crossflow junction and that the to volume is a crossflow volume, s = 2 specifies a crossflow junction and that the from volume is a crossflow volume, and s = 3 specifies a crossflow junction and that the from and to volumes are crossflow volumes.

- W7(R) SUBCOOLED DISCHARGE COEFFICIENT. This quantity is applied only to subcooled liquid choked flow calculations. The quantity must be > 0 and ≤ 2.0 .
- W8(R) TWO-PHASE DISCHARGE COEFFICIENT. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 and ≤ 2.0 .
- W9(R) SUPERHEATED DISCHARGE COEFFICIENT. This quantity is applied only to superheated vapor choked flow calculations. The geometry must be > 0 and ≤ 2.0 .
- W10(I) FROM VOLUME INCREMENT.
- W11(I) TO VOLUME INCREMENT. Words 1 and 2 contain the from and to connection codes respectively for the first junction defined by the set. If the set defines more than one junction, connection codes for the following junctions are given by the connection code of the previous junction plus the increments in Words 9 and 10. The increments may be positive, negative, or zero. Junctions are defined up to the limit in Word 12. Words 3 through 8 apply to all junctions defined by the set. If additional sets are entered, Words 1 and 2 apply to the next junction, and increments are applied as with the first set. Word 12 for the second and following sets must be greater than Word 12 of the preceding set, and Word 12 of the last set must equal NJ. new set is used whenever a new increment is needed, Words 3 through 8 need changed, or a change in junction numbering is desired.
- W12(I) ENTER ZERO. This is reserved for future capability.
- W13(I) JUNCTION LIMIT. Described above.

A.7.10.3 Cards ccc1nm, Multiple Junction Initial Condition Cards

Initial velocities are entered using one or more sets of data. The processing of sets of data is identical to that described in Section A.7.10.2 except that there need be no relationship in the division of junctions within sets between these cards (ccc1nm) and the multiple junction geometry cards (ccc0nm). Likewise, these cards do not affect the numbering of the junctions.

- W1(R) INITIAL LIQUID VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s), depending on control Word 2 of

Card ccc0001.

W2(R) INITIAL VAPOR VELOCITY OR MASS FLOW. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s), depending on control Word 2 of Card ccc0001.

W3(I) JUNCTION LIMIT NUMBER.

A.7.10.4 Cards ccc2nnm, Multiple Junction Diameter and CCFL Data Cards

These cards are optional. If the card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model, then enter all four words for the appropriate CCFL model. The processing of sets of data is identical to that described in Section A.7.10.2 except that there need be no relationship in the division of junctions within sets between these cards (Ccc1nnm) and the multiple junction geometry cards (ccc0nnm). Likewise, these cards do not affect the numbering of the junctions.

W1(R) JUNCTION HYDRAULIC DIAMETER, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation and interphase drag and must be ≥ 0 . If a zero is entered or if the default is used, the junction diameter is computed from $2.0 * (\text{JUNCTION AREA} / \pi) ** 0.5$.

W2(R) FLOODING CORRELATION FORM, β . If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1 . The default value is 0 (Wallis form).

W3(R) GAS INTERCEPT, c . This is the gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0 . The default value f is 1.

W4(R) SLOPE, m . This is the slope used in the CCFL correlation and must be > 0 . The default value is 1.

W5(I) JUNCTION LIMIT NUMBER.

A.7.11 Accumulator Component

An accumulator component is indicated by ACCUM on Card ccc0000.

An accumulator is a lumped parameter component treated by special numerical techniques that model both the tank and surge line until the accumulator is emptied of liquid. When the last of the liquid leaves the accumulator, the code automatically resets the accumulator to an equivalent single volume with an outlet junction and proceeds with calculations using the normal hydrodynamic solution algorithm.

In the following input requirements, it is assumed that the component is an accumulator in which liquid completely fills the surge line but may or may not occupy the tank. It is further assumed that the accumulator is not initially in the injection mode. Hence, the initial pressure must be input lower than the injection point pressure, including elevation head effects; and junction initial conditions may not be input (i.e., initial hydrodynamic velocities are set to zero in the code). It is further assumed that the noncondensable gas in the accumulator is nitrogen and that the gas and liquid are initially in equilibrium. No other junctions (except the accumulator junction) should be connected to the accumulator volume.

A.7.11.1 Cards ccc0101 Through ccc0199, Accumulator Volume Geometry Cards

- W1(R) VOLUME FLOW AREA (m^2 , ft^2). This is the flow area of the tank.
- W2(R) LENGTH OF VOLUME (m, ft). This is the length of the tank above the standpipe/surge line inlet.
- W3(R) VOLUME OF VOLUME (m^3 , ft^3). This is the volume of the tank above the standpipe/surge line inlet. The code requires that the volume equals the volume flow area times length ($W3 = W1 * W2$). At least two of the three quantities, W1, W2, or W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, they must satisfy the condition that volume equals area times length within a relative error ± 0.000001 .
- W4(R) AZIMUTHAL ANGLE (degrees). The absolute value of this angle must be ≤ 360 degrees. This quantity is not used in the calculation but is specified for possible automated drawing of nodalization diagrams.
- W5(R) INCLINATION ANGLE (degrees). Only +90 or -90 degrees is allowed. The accumulator is assumed to be a vertical tank with the standpipe/surge line inlet at the bottom. This angle is used in the interphase drag calculation.
- W6(R) ELEVATION CHANGE (m, ft). This is the elevation change from the standpipe/surge line inlet to the top of the tank. A positive value is an increase in elevation. The absolute value of this quantity must be nonzero, less than or equal to the volume length, and have the same sign as the angle for vertical orientation.
- W7(R) WALL ROUGHNESS (m, ft).
- W8(R) HYDRAULIC DIAMETER (m, ft). If zero, the hydraulic diameter of the tank is computed from $2.0 * (\text{volume area} / \pi) * 0.5$. A check is made that the pipe roughness is less than half the hydraulic diameter of the tank.
- W9(I) VOLUME CONTROL FLAGS. Enter pvbfe.
- The flag p is not used and should be input as zero ($p = 0$). The major edit will show $p = 1$.

The flag y is not used and should be input as zero (y = 0). The major edit will show y = 1.

The flag b is not used and should be input as zero (b = 0). The major edit will show b = 0.

Enter f = 0 if wall friction is to be computed, and f = 1 if wall friction is not to be computed.

The flag e must be specified zero, since only a nonequilibrium (unequal temperature) calculation is allowed.

A.7.11.2 Card ccc0141, Additional Wall Friction Card

This card is optional and is currently allowed only if Change Option 22 is enabled. If this card is not entered, the default values are 1.0 for the shape factor and 0.14 for the viscosity ratio exponent.

W1(R) SHAPE FACTOR FOR X-COORDINATE.

W2(R) VISCOSITY RATIO EXPONENT FOR X-COORDINATE.

A.7.11.3 Card ccc0142, Alternate Wall Friction Card

This card is optional and is currently allowed only if Change Option 22 is enabled and the code is compiled with the 'frifac' option. This card allows the specification of a user defined turbulent friction factor. The turbulent friction factor has the form $f = A + B(\text{Re})^{-C}$ where A, B, and C are entered on this card. If this card is not entered, the standard turbulent friction factor is used.

W1(R) A FOR X-COORDINATE.

W2(R) B FOR X-COORDINATE.

W3(R) C FOR X-COORDINATE.

A.7.11.4 Card ccc0200, Accumulator Tank Initial Thermodynamics Conditions

W1(R) PRESSURE (Pa, lb_f/in^2).

W2(R) TEMPERATURE (K, °F).

W3(R) BORON CONCENTRATION. Parts of boron per parts of liquid water.

A.7.11.5 Card ccc1101, Accumulator Junction Geometry Card

W1(I) TO CONNECTION CODE TO A COMPONENT. The from connection is not entered, since it is always from the accumulator. The to connection code refers to the component from which the junction coordinate direction originates. For connecting to a time-dependent volume, the connection code is ccc000000, where

ccc is the component number of the time-dependent volume. An old or an expanded format can be used to connect all other volumes. In the old format, use ccc000000 if the connection is to the inlet side of the component and use ccc010000 if the connection is to the outlet side of the volume. In the old format, W5 is used to specify a crossflow connection. In the expanded format, the connection code is ccvvn000n, where ccc is the component number, vv is the volume number, and n indicates the face number. A nonzero n specifies the expanded format. N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. N equal to 3 through 6 specifies crossflow. Current crossflow models do not require inlet-outlet orientation; but, in future versions, n equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction, n equal to 5 and 6 would do the same for the third coordinate direction. Since crossflows are specified directly in the expanded format, the crossflow flag in W6 is ignored on input but set appropriately for output edits.

- W2(R) JUNCTION AREA (m^2 , ft). This is the average area of the surge line and standpipe.
- W3(R) FORWARD FLOW ENERGY LOSS COEFFICIENT.
- W4(R) REVERSE FLOW ENERGY LOSS COEFFICIENT.
- W5(I) JUNCTION CONTROL FLAGS. This word has the packed format fvcahs.

The accumulator model automatically disables the following terms as long as liquid remains in the accumulator. However, when the accumulator empties of liquid, the model is automatically converted to an active normal volume. The following terms are then enabled and used as defined.

The digit f is not used and should be input as zero (f = 0). The major edit output will show f = 0.

The digit y is not used and should be input as zero (y = 0).

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means the choking model will not be applied.

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 is not allowed for an accumulator.

The digit h specifies nonhomogeneous or homogeneous. h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option; h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit will show h = 1.

The digit s specifies normal or crossflow junction. s = 0 specifies a normal

junction, $s = 1$ specifies a crossflow junction and that the to volume is a crossflow volume, and $s = 2$ or 3 is not allowed for an accumulator.

A.7.11.6 Card ccc2200, Accumulator Tank Initial Fill Conditions, Standpipe/Surge Line Length/Elevation, and Tank Wall Heat Transfer Terms

- W1(R) LIQUID VOLUME IN TANK (m^3 , ft^3). This is the volume of water contained in the tank above the standpipe/surge line inlet.
- W2(R) LIQUID LEVEL IN TANK (m, ft). This is the liquid level of water contained in the tank above the standpipe/surge line inlet entrance. Either W1 or W2 must be specified as nonzero.
- W3(R) LENGTH OF SURGE LINE AND STANDPIPE (m, ft). If input as zero, then the surge line and standpipe are not modeled.
- W4(R) ELEVATION DROP OF SURGE LINE AND STANDPIPE (m, ft). This is the elevation drop from the standpipe/surge line inlet entrance to the injection point. A positive number denotes a decrease in elevation.
- W5(R) TANK WALL THICKNESS (m, ft). This is not allowed to be zero.
- W6(I) HEAT TRANSFER FLAG. If zero, heat transfer will be calculated. If one, no heat transfer will be calculated.
- W7(R) TANK DENSITY (kg/m^3 , lb/ft^3). If zero, the density will default to that for carbon steel.
- W8(R) TANK VOLUMETRIC HEAT CAPACITY ($J/kg \cdot K$, $Btu/lb \cdot ^\circ F$). If zero, the heat capacity will default to that for carbon steel.
- W9(I) TRIP NUMBER. If zero or if no number is input, then no trip test is performed. If nonzero then this must be a valid trip number, the operations performed are similar to those performed for a trip valve. If the trip is false, then the accumulator is isolated and no flow through the junction can occur. If the trip is true, then the accumulator is not isolated and flow through the junction will occur in the normal manner for an accumulator.

A.7.12 Multidimensional Input

A multidimensional component is indicated by MULTID on Card ccc0000. This component defines a one-, two-, or three-dimensional array of volumes and the internal junctions connecting the volumes. The multidimensional component is described as a three-dimensional component but can be reduced to two or one dimensions by defining only one interval in the appropriate coordinate directions. The geometry can be either Cartesian (x,y,z) or cylindrical (r,θ,z). In cylindrical geometry, the r-direction can start at zero or nonzero, and θ can cover 360 degrees (i.e., a full circle) or can cover less than 360 degrees (wedge shape, semicircle, etc).

An orthogonal, three-dimensional grid is defined by mesh interval input data in each of the three coordinate directions. The edges of the hydrodynamic volumes are defined by the grid lines. Given nx intervals in the x- or r-coordinate direction, ny intervals in the y- or θ-coordinate direction, and nz intervals in the z-coordinate direction, nx*ny*nz volumes are defined. The number of volumes in a three-dimensional component is limited to 999 volumes. Volumes are numbered cccxyzz0, where x, yy, and zz are the position numbers in the three coordinate directions. Position numbers in each coordinate direction start with one at the origin and increase consecutively in the positive coordinate direction. x represents the position number for the first coordinate direction, which is x in cartesian geometry and r in cylindrical geometry. The use of one digit for the first coordinate limits the number of volumes in that coordinate to nine volumes. yy represents the position number of the second coordinate direction, which is y in Cartesian geometry and θ in cylindrical geometry. zz represents the position number of the third coordinate, which is the z-coordinate direction in both geometries. The use of two digits for the second and third directions allows up to 99 volumes in those coordinate directions. The maximum values of x, yy, and zz are nx, ny, and nz, respectively.

The volume face number is given by cccxyzzf, where the face number, f, is added to the volume number. The face numbers are 1 and 2 for the inlet and outlet faces, respectively, of the x- or r-coordinate, 3 and 4 for the inlet and outlet faces for the y- or θ-coordinate, and 5 and 6 for the inlet and outlet faces for the z-coordinate. The volume-face number is the volume connection code used in the from and to portion of junction input.

Junctions for this component are generated between all internal faces, that is, all faces common to the volumes in the component. The number of junctions is $(nx-1)*ny*nz + nx*(ny-1)*nz + nx*ny*(nz-1)$ for Cartesian geometry and for cylindrical geometry where the θ-coordinate does not cover a full circle. When the θ coordinate covers 360 degrees, the number of junctions increases by nx*nz. The coordinate directions of the junctions are aligned in the positive directions of the coordinates. For numbering purposes, the junctions are associated with the from face of the two volumes being joined. Thus, the junctions are numbered cccxyzzf, where f is limited to 2, 4, or 6.

External junctions may connect to any exterior faces of the volumes and also any interior faces. External junctions connecting to internal faces imply branching or merging flow, since internal junctions connect all internal faces. Some adjustments to the volumes and flow areas of the volumes and flow areas of the junctions should be made to account for the piping necessary to reach

the internal face.

A.7.12.1 Card ccc0001, MULTID Information Card

This card is required.

- W1(I) NUMBER OF X OR R COORDINATE INTERVALS (nx). This word must be greater than zero and less than 10.
- W2(I) NUMBER OF Y OR θ COORDINATE INTERVALS (ny). This word must be greater than zero and less than 100.
- W3(I) NUMBER OF Z COORDINATE INTERVALS (nz). This word must be greater than zero and less than 100.
- W4(I) VELOCITY/MASS FLOW FLAG. This word is optional and if missing, is assumed to be zero. The initial junction conditions are velocities if zero is entered and are mass flows if one is entered.
- W5(I) GEOMETRY AND θ FLAG. This word is optional and if missing, is assumed to be zero. This word if zero indicates Cartesian geometry and if the magnitude of this word is one, cylindrical geometry is indicated. If the sign of this word is positive, θ is assumed to extend to 360 degrees; if the sign is negative, θ is assumed to extend to < 360 degrees. The extra plane of junctions perpendicular to the θ direction exists when this quantity is one and does not exist when this quantity is zero or minus one. The sign is appropriate only to cylindrical geometry.
- W6(R) VALUE OF INNERMOST RADIAL COORDINATE (m, ft). This word is optional and if missing is assumed 0.0. This word must be zero in Cartesian geometry, and must be greater than or equal to zero in cylindrical geometry. A nonzero value allows the specification of a cylinder with a hollow center.
- W7(I) THREE-DIMENSIONAL FLAG. This word is optional and if missing is assumed to be zero. If this word is zero, the three-dimensional momentum equations are used. If this word is one, the normal one-dimensional equations are used on each of the coordinate directions. Crossflow indicators may not be used if this word is zero but may be used if this word is one.

A.7.12.2 Card ccc0002, Rotation Angle Data Card

This card is optional and if missing, the following angles are assumed to be zero.

- W1(R) HORIZONTAL ROTATION ANGLE (degrees).
- W2(R) VERTICAL ROTATION ANGLE (degrees).
- W3(R) AZIMUTHAL ROTATION ANGLE (degrees).

The names of the angles above are not very accurate but are used here to relate to the angles used in other components such as a pipe. In a pipe or single volume, the horizontal angle specified the rotation of a volume in the horizontal plane, the vertical angle specified the rotation of a volume in the vertical plane, and the azimuthal angle was not used. The horizontal angle had to be entered, but other than being checked for its absolute value being ≤ 360 degrees, was not used. The vertical angle, whose absolute angle had to be ≤ 90 degrees, was checked and was used to specify the direction of gravity.

The angles used in MULTID are more accurately known as Euler angles, which are commonly used to describe the position of a rigid body in space. The reference coordinates are the standard right hand x-, y-, z-coordinate system in Cartesian geometry. The z-axes of both Cartesian and cylindrical geometries coincide and are oriented in the vertical direction with the positive direction being upward. The x-, y-, and r- θ coordinates are in the horizontal plane with the $\theta = 0$ line coinciding with the x-axis. The coordinate system of the multidimensional component is initially aligned with the reference coordinates. The first angle specifies the rotation of the component's coordinate system about its original z-axis, the second angle is the rotation of the component's coordinate system about its new x-axis, and the third angle is the rotation of the component's coordinate system about its new z-axis. A positive angle specifies counterclockwise rotation as viewed by an observer on the positive part of the rotation axis looking towards the origin. In a 90-degree counterclockwise rotation about the z-axis, the position of the x-axis would be moved to the previous position of the y-axis. Similarly, a 90-degree counterclockwise rotation about the x-axis would move the y-axis to the previous position of the z-axis. The input range of each Euler angle is from 0.0 through plus or minus 360 degrees.

The effects of the horizontal and vertical angles of the pipe volumes and the Euler angles are similar within the limitations of not having an azimuthal angle and the vertical angle being limited to 90 degrees.

The most common usage of the Euler angle data is to move the axial coordinate in cylindrical geometry from the vertical direction to the horizontal plane. The following input accomplishes that: 0.0, 90.0, 0.0. If the azimuthal nodding consisted of six 60-degree mesh intervals, two of the azimuthal grid lines would coincide with the vertical direction. If the third angle was specified as plus or minus 30 degrees, the center of two of the azimuthal intervals would lie on a vertical line.

A.7.12.3 Cards ccc0xnn, Mesh Interval Cards

These required cards enter the mesh interval data for the three coordinate directions. The digit x is 1 for x- or r-coordinate, 2 for y or θ coordinate, and 3 for z-coordinate. The nn digits, which may range from 01 through 99, sequences the cards within a series and need not be consecutive. One or more sets of data in sequential expansion format may be entered on each card.

W1(R) MESH INTERVAL (m, ft, or degrees).

W2(I) VOLUME COORDINATE NUMBER. The number of the first volume coordinate number next to the origin is 1 and the last volume number is nx for

x-coordinate, ny for y-coordinate, or nz for z-coordinate. The last volume coordinate number must equal nx, ny, or nz depending on the value of n.

In cylindrical geometry, the θ coordinates are entered in degrees. The sum of the intervals cannot exceed 360 degrees. The sum must equal 360 degrees if W5 on Card ccc0001 is 1 and must not equal 360 degrees if W5 is -1.

Presently, a further restriction exists on the θ intervals when the innermost radius is zero. Then, the number of θ intervals must be even and the size of the interval must have 180-degree symmetry.

A.7.12.4 Cards ccc1nnn, Volume Option Cards

These cards are optional. nnn ranges from 001 through 999 and need not be consecutive.

These cards use an overlay format. The first six words define a rectangular solid in Cartesian geometry and an annular segment in cylindrical geometry. The solid figure consists of volumes where the x- or r-coordinate number ranges from x1 through x2, the y or θ coordinate number ranges from y1 through y2, and the z-coordinate number ranges from z1 through z2.

The quantities following the six overlay numbers apply to the volumes within the solid defined by the overlay. Overlays may reference any volume more than once; the data used in a volume is the information in the last overlay referencing that volume. Default data are stored in volumes not referenced by an overlay.

W1(I) X1 (m, ft)

W2(I) X2 (m, ft)

W3(I) Y1 (m, ft)

W4(I) Y2 (m, ft)

W5(I) Z1 (m, ft)

W6(I) Z2 (m, ft)

W7(R) VOLUME FACTOR. Default is 1.0. This quantity must be greater than zero and $\leq$ one. The original volume of each volume is computed from the mesh interval data. The actual volume's volume may be reduced by the factor in this word to account for solid material such as fuel pins within the volume. It could also account for piping that accesses interior volumes. The volume flow areas for the three coordinate directions are computed from the actual volume divided by the volume's length along the coordinate direction. The length is the appropriate mesh interval except for the θ direction where it is the mesh interval times the radius to the midpoint of the volume.

- W8(I) SCALAR VOLUME FLAG. This word applies to the scalar-oriented options for a volume.
- W9(I) X- OR R-COORDINATE VOLUME FLAG (m, ft).
- W10(I) Y- OR θ -COORDINATE VOLUME FLAG (m, ft, degree).
- W11(I) Z-COORDINATE VOLUME FLAG (m, ft).

W8 through W11 use a packed format pvbfe. Only the e option may be used for the scalar-volume flag (W8), and the e option may not be used for the coordinate flags. The default values for the flags are 00000.

The digit p specifies whether the water packing scheme is to be used. p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used.

The digit y specifies whether the vertical stratification model is to be used. y = 0 specifies that the vertical stratification model is to be used, and y = 1 specifies that the vertical stratification model is not to be used.

The digit b specifies the interphase friction to be used. b = 1 means that the Bestion/Analytis rod bundle interphase friction model is to be applied; b = 0 means that the normal interphase friction model is to be applied.

The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed for the volume, and f = 1 specifies that wall friction effects are not to be computed.

The digit e specifies if nonequilibrium or equilibrium is to be used. e = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and e = 1 specifies that an equilibrium (equal temperature) calculation is to be used. Equilibrium volumes should not be connected to nonequilibrium volumes. The equilibrium option is provided only for comparison to other codes.

A.7.12.5 Cards ccc2nnn, Volume Friction Data Cards

These cards are optional. nnn ranges from 001 through 999 and need not be consecutive. These cards use an overlay format similar to the ccc1nnn cards described above. Not all volumes need to be referenced by the overlay. At least 12 words must be entered on this card. If Change Option 22 is enabled, 12 or 18 words may be entered. If the 'frifac' compile option is enabled, 12, 18, or 27 words may be entered. Words 7 through 18 enter additional wall friction data, which specify shape factors and viscosity ratios. Words 19 through 27 specify data for an alternate friction factor model. The alternate data allow the specification of user-defined friction factors for selected volumes and coordinate directions. The turbulent friction factor has the form $f = A + B(Re)^{-C}$, where A, B, and C are entered for each coordinate. The standard turbulent model can be specified for a particular volume and coordinate by entering zeros for the three values.

CARDS CCCXXNN, HYDRODYNAMIC COMPONENTS

Continuation cards can be used to enter the large number of words for this card number.

W1(I)	X1
W2(I)	X2
W3(I)	Y1
W4(I)	Y2
W5(I)	Z1
W6(I)	Z2
W7(R)	WALL ROUGHNESS FOR THE X- OR R-COORDINATE (m, ft). The default value is zero.
W8(R)	HYDRAULIC DIAMETER FOR THE X- OR R-COORDINATE (m, ft). Default value is zero. If zero, hydraulic diameter is computed from four times the flow area divided by the wetted perimeter. The flow area and wetted perimeter are appropriate for the geometry and the coordinate direction.
W9(R)	WALL ROUGHNESS FOR THE Y- OR θ -COORDINATE (m, ft). The default value is zero.
W10(R)	HYDRAULIC DIAMETER FOR THE Y- OR θ -COORDINATE (m, ft). Default value is zero. If zero, hydraulic diameter is computed from four times the flow area divided by the wetted perimeter. The flow area and wetted perimeter are appropriate for the geometry and the coordinate direction.
W11(R)	WALL ROUGHNESS FOR THE Z-COORDINATE (m, ft). The default value is zero.
W12(R)	HYDRAULIC DIAMETER FOR THE Z-COORDINATE (m, ft). Default value is zero. If zero, hydraulic diameter is computed from four times the flow area divided by the wetted perimeter. The flow area and wetted perimeter are appropriate for the geometry and the coordinate direction.
W13(R)	SHAPE FACTOR FOR X-COORDINATE. The default value is 1.0.
W14(R)	VISCOSITY RATIO EXPONENT FOR X-COORDINATE. The default value is 0.14.
W15(R)	SHAPE FACTOR FOR Y-COORDINATE. The default value is 1.0.
W16(R)	VISCOSITY RATIO EXPONENT FOR Y-COORDINATE. The default value is 0.14.

W17(R)	SHAPE FACTOR FOR Z-COORDINATE. The default value is 1.0.
W18(R)	VISCOSITY RATIO EXPONENT FOR Z-COORDINATE. The default value is 0.14.
W19(R)	A FOR X-COORDINATE. The default value is zero.
W20(R)	B FOR X-COORDINATE. The default value is zero.
W21(R)	C FOR X-COORDINATE. The default value is zero.
W22(R)	A FOR Y-COORDINATE. The default value is zero.
W23(R)	B FOR Y-COORDINATE. The default value is zero.
W24(R)	C FOR Y-COORDINATE. The default value is zero.
W25(R)	A FOR Z-COORDINATE. The default value is zero.
W26(R)	B FOR Z-COORDINATE. The default value is zero.
W27(R)	C FOR Z-COORDINATE. The default value is zero.

A.7.12.6 Cards ccc3001 Through ccc5999, Junction Data Cards

These cards are optional. The range of card numbers need not be consecutive.

These cards use the first six words as overlay information to specify a range of volumes and use a seventh number to specify the volume face. The information following the face number is applied to the junction originating from the specified face of each volume included in the overlay. Not all junctions need to be referenced by these cards.

W1(I)	X1.
W2(I)	X2.
W3(I)	Y1.
W4(I)	Y2.
W5(I)	Z1.
W6(I)	Z2.
W7(I)	FACE NUMBER. The face number is limited to 2, 4, or 6.
W8(R)	JUNCTION AREA FACTOR. Default value is one. This quantity must be greater than zero and $\leq$ one. The original junction area is computed from the mesh interval data. The actual area is the original area times this factor. This quantity

can be used to account for solid structures within the volume.

W9(R) FORWARD FLOW ENERGY LOSS COEFFICIENT. The default value is zero.

W10(R) REVERSE FLOW ENERGY LOSS COEFFICIENT. The default value is zero.

W11(I) JUNCTION CONTROL FLAGS. This word has the packed format fvcahs. The default value is 000000.

The digit f specifies CCFL options. f = 0 means that the CCFL model is not applied, and f = 1 means that it is applied.

The digit v specifies horizontal stratification entrainment/pullthrough options. v = 0 means the model is not applied; v = 1 means an upward-oriented junction; v = 2 means a downward-oriented junction; and v = 3 means a centrally (side) located junctions.

The digit c specifies choking options. c = 0 means that the choking model is applied, and c = 1 means that the choking model is not applied.

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means an abrupt area change.

The digit h specifies nonhomogeneous or homogeneous. h = 0 specifies the nonhomogeneous (two-velocity momentum equations) option, and h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous (h = 2), the major edit printout will show a 1.

The digit s specifies normal or crossflow junction. s = 0 specifies a normal junction. s = 1 specifies a crossflow junction and that the to volume is a crossflow volume. s = 2 specifies a crossflow junction and that the from volume is a crossflow volume. s = 3 specifies a crossflow junction and that both the from and to volumes are crossflow volumes.

W12(R) JUNCTION HYDRAULIC DIAMETER (m, ft). This word is optional and was not used in SCDAP/RELAP5/MOD2.5 but is used in SCDAP/RELAP5/MOD3.1. The default value is zero. If zero is entered, hydraulic diameter is set to four times the junction area divided by the wetted perimeter.

A.7.12.7 Cards ccc6nnn, Volume Initial Condition Cards

These cards are required. nnn ranges from 001 through 999 and need not be consecutive.

These cards use the first six words as overlay information to specify the range of volumes for which the following initial condition information applies. Each volume must be referenced at least once by these cards.

W1(I)	X1.
W2(I)	X2.
W3(I)	Y1.
W4(I)	Y2.
W5(I)	Z1.
W6(I)	Z2.
W7(I)	CONTROL WORD. This word has the packed format <u>gbt</u> .

The digit g specifies the fluid. $g = 0$ is the default fluid; $g = 1$ specifies H_2O ; $g = 2$ specifies D_2O , and $g = 3$ specifies H_2 . The default fluid is that set for the hydrodynamic system by Cards 120 through 129 or this control word in another volume in this hydrodynamic system. The fluid type set on Cards 120 through 129 or these control words must be consistent (i.e., not specify different fluids). If Cards 120 through 129 are not entered and all control words use the default $g = 0$, then H_2O is assumed as the fluid.

The digit b specifies whether boron is present or not. The digit $b = 0$ specifies that the volume fluid does not contain boron; $b = 1$ specifies that a boron concentration in parts of boron per parts of liquid (which may be zero) is being entered after the other required thermodynamic information.

The digit t specifies how the following words are to be used to determine the initial thermodynamic state. Entering $t = 0$ through 3 specifies only one component (steam/water). Entering $t = 4$ through 6 allows the specification of two components (steam/water and noncondensable gas).

If $t = 0$, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), and vapor void fraction; these quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the volume control flag. If equilibrium, the static quality is checked; but only the pressure and internal energies are used to define the thermodynamic state.

If $t = 1$, the next two words are interpreted as temperature (K, $^{\circ}F$) and quality in equilibrium condition.

If $t = 2$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and quality in equilibrium condition.

If $t = 3$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, $^{\circ}F$) in equilibrium condition.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for quality are:

$1.0E-9 \leq \text{quality} \leq 0.99999999$ implies two-phase conditions.

$\text{quality} < 1.0E-9$ or $\text{quality} > 0.99999999$ implies single-phase.

Noncondensable options are:

If $t = 4$, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, $^{\circ}\text{F}$), and equilibrium quality. Using this input option with $\text{quality} > 0.0$ and ≤ 1.0 , saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Quality is reset to 1.0 using this dry noncondensable option.

If $t = 5$, the next three words are interpreted as temperature (K, $^{\circ}\text{F}$), equilibrium quality, and noncondensable quality. Both the equilibrium and noncondensable qualities are restricted to be between $1.0E-9$ and 0.99999999 .

If $t = 6$, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, and noncondensable quality. The combinations of vapor void fraction and noncondensable quality must be thermodynamically consistent. If noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must not be 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable), then vapor void fraction must also be 1.0. When both the vapor void fraction and the noncondensable quality are set to 1.0, the volume temperature is calculated from the noncondensable energy equation using the input vapor specific internal energy.

W8-W14(R) INITIAL CONDITION DATA.

A.7.12.8 Cards ccc7001 Through ccc9999, Junction Initial Condition Data

These cards are required. The range of card numbers need not be consecutive. These cards use the first six words as overlay information to specify a range of volumes and in addition use a seventh number to specify the volume face. The information following the face number is applied to the junction originating from the specified face of each volume included in the overlay. All junctions must be referenced at least once by these cards.

W1(I) X1.

W2(I) X2.

Multidimensional Input

W3(I)	Y1.
W4(I)	Y2.
W5(I)	Z1.
W6(I)	Z2.
W7(I)	FACE NUMBER. The face number is limited to 2, 4, or 6.
W8(R)	INITIAL LIQUID VELOCITY OR MASS FLOW (m/sec, ft/sec or kg/sec, lb/sec).
W9(R)	INITIAL VAPOR VELOCITY OR MASS FLOW (m/sec, ft/sec or kg/sec, lb/sec).

A.8 CARDS 1CCCGXNN, HEAT STRUCTURE INPUT

These cards are used in NEW and RESTART type problems and are required only if heat structures are described. The heat structure card numbers are divided into fields where:

ccc is a heat structure number. The heat structure numbers need not be consecutive. It is suggested, but not required, that if heat structures and hydrodynamic volumes are related, they be given the same number.

g is a geometry number. The combination cccg is a heat structure geometry combination referenced in the heat structure input data. The g digit is provided to differentiate between different types of heat structures (such as fuel pins and core barrel) that might be associated with the same hydrodynamic volume.

x is the card type.

nn is the card number within a card type.

A.8.1 Card 1cccg000, General Heat Structure Data

This card is required for heat structures. Use eight words for new data input or one word for deleting a heat structure.

A.8.1.1 General Heat Structure Data Card

W1(I)	NUMBER OF AXIAL HEAT STRUCTURES WITH THIS GEOMETRY, nh.
This number must be > 0 and < 100.
W2(I)	NUMBER OF RADIAL MESH POINTS FOR THIS GEOMETRY, np. This number must be < 100. Enter > 1 if no reflood is specified, and > 2 if reflood is specified.
W3(I)	GEOMETRY TYPE. Enter 1 for rectangular, 2 for cylindrical, and 3 for spherical. Spherical geometry is not allowed if reflood is specified. Cylindrical geometry must be specified when the gap conductance model is used.
W4(I)	STEADY-STATE INITIALIZATION FLAG. Use zero if the initial conditions are entered on input cards; use one if a steady-state condition is to be calculated for the initial temperature distribution.
W5(R)	LEFT BOUNDARY COORDINATE (m, ft).
W6(I)	REFLOOD CONDITION FLAG. This quantity is optional if no reflood calculation is to be performed. This quantity may be 0, 1, 2, or a trip number. If zero, no reflood calculation is to be performed. If nonzero, all the heat structures in this heat structure/geometry are assumed to form a two-dimensional representation of a fuel pin. The radial mesh is defined on Card 1cccg1nn. Each heat structure represents an axial level of the fuel pin, with the first heat structure

being the bottom level. Each heat structure should be connected to a hydrodynamic volume representing the same axial section of the coolant channel. The length of the axial mesh in the fuel pin is given by the height of the connected hydrodynamic volume. The heat structures represent the temperatures at the midpoint of the axial mesh. Once the reflood calculation is initiated, additional mesh lines are introduced at each end of the fuel pin and between the heat structures. Once the reflood calculation is initiated, it remains activated; and the two-dimensional heat conduction calculation uses a minimum of $2 \cdot n_h + 1$ axial mesh nodes. Additional mesh lines are introduced and later eliminated as needed to follow the quench front. If 1 is entered, the reflood calculation is initiated when the connected hydrodynamic volumes are nearly empty. If 2 is entered, the reflood calculation begins when dryout begins. If a trip number is entered, the reflood calculation is initiated when the trip is set true. When using the expanded trip number format, 1 and 2 are possible trip numbers. A 1 or 2 entered in this word is not treated as a trip number.

- W7(I) BOUNDARY VOLUME INDICATOR. Enter zero or one to indicate that reflood heat transfer applies to the left or right boundary, respectively.
- W8(I) MAXIMUM NUMBER OF AXIAL INTERVALS. Enter 2, 4, 8, 16, 32, 64, or 128 to indicate the maximum number of axial subdivisions a heat structure can have. Storage is allocated for the number indicated, even though a transient may not require that level of subdivision.

A.8.1.2 Heat Structure Delete Card

This card is entered only for RESTART problems. If entered, all heat structures associated with the heat structure geometry number cccg are deleted.

- W1(A) ENTER DELETE.

A.8.2 Card 1cccg001, Gap Conductance Model Initial Gap Pressure Data

This card is needed only if the gap conductance model is to be used. If the card is entered, W1 of Card 1cccg100 must be zero, Cards 1cccg011 through 1cccg099, and Cards 1cccg201 through 1cccg299 are required. W2 of Card 201mmm00 must be 3, and a table of the gas component name and mole fraction must be specified in the gap material data (Cards 201mmm01 through 201mmm49).

- W1(R) INITIAL GAP INTERNAL PRESSURE (Pa, lb_f/in²).
- W2(I) GAP CONDUCTANCE REFERENCE VOLUME. This word is required. The pressure of the gas in a fuel pin for the gap conductance model is given by $P(t) = P(O)/T(O) \cdot T(t)$, where $P(t)$ is the pressure in the fuel pin and $T(t)$ is the temperature in the reference volume. $P(O)$ is W1 above, and $T(O)$ is the initial

value if the volume is also being defined with these input data or the value from the restart block. The reference volume is usually the volume most closely associated with the nonfuel region in a fuel pin at the top of a stack of fuel pellets.

A.8.3 Card 1cccg003, Metal-Water Reaction Control Card

cccg is a heat structure geometry number. If this card is not present, no metal-water reaction will be calculated.

W1(R) INITIAL OXIDE THICKNESS ON CLADDING'S OUTER SURFACE.

A.8.4 Card 1cccg004, Fuel Cladding Deformation Model Control Card

cccg is a heat structure geometry number. If this card is not present, no deformation calculations will be done. If this card is present, then Card 1cccg001 must also be present.

W1(I) FORM LOSS FACTOR FLAG. Enter 0 if no additional form loss factors are to be calculated after a rod ruptures. Enter 1 if additional form loss factors are to be calculated. Either a 0 or a 1 must be entered.

A.8.5 Cards 1cccg011 Through 1cccg099, Gap Deformation Data

These cards are required for the gap conductance model only. The card format is sequential format, five words per set, describing nh heat structures.

W1(R) FUEL SURFACE ROUGHNESS (m, ft). This number must be ≥ 0 . An appropriate value is 10^{-6} m. A negative entry is reset to 10^{-6} m with no errors.

W2(R) CLADDING SURFACE ROUGHNESS (m, ft). This number must be either positive or zero. An appropriate value is 2×10^{-6} m. A negative entry is reset to 2×10^{-6} m with no errors.

W3(R) RADIAL DISPLACEMENT CAUSED BY FISSION GAS INDUCED FUEL SWELLING AND DENSIFICATION (m, ft). This number must be ≥ 0 . A negative entry is reset to zero. An appropriate value can be obtained from calculations using FRAPCON-2 or FRAP-T6.

W4(R) RADIAL DISPLACEMENT CAUSED BY CLADDING CREEPDOWN (m, ft). The value is normally negative. A positive entry is reset to zero. An appropriate value can be obtained from calculations using FRAPCON-2 or FRAP-T6.

W5(I) HEAT STRUCTURE NUMBER.

A.8.6 Card 1ccg100, Heat Structure Mesh Flags

This card is required for heat structure input.

- W1(I)** MESH LOCATION FLAG. If zero, geometry data including mesh interval data, composition data, and source distribution data, are entered with this heat structure input. If nonzero, that information is taken from the geometry data from the heat structure geometry (cccg) number in this word. If this word is nonzero, the remaining geometry information described in Section A.8.6 through Section A.8.10 is not entered.
- W2(I)** MESH FORMAT FLAG. This word is needed only if W1 is zero, although no error occurs if it is present when W1 is nonzero. The mesh interval data are given as a sequence of pairs of numbers in one of two formats to be used in Cards 1cccg101 through 1cccg199. If this word is one, the pairs of numbers contain the number of mesh intervals in this region and the right boundary coordinate. For the first pair, the left coordinate of the region is the left boundary coordinate previously entered in W5 of Card 1cccg000; for succeeding pairs, the left coordinate is the right coordinate of the previous pair. If this word is 2, the format is a sequential expansion of mesh intervals; i.e., the distance in W1 on Cards 1cccg101 through 1cccg199 is used for each interval starting from the leftmost, as yet unspecified, interval to and including the interval number specified in W2.

A.8.7 Cards 1cccg101 Through 1cccg199, Heat Structure Mesh Interval Data (Radial)

These cards are required if W1 of Card 1cccg100 is zero. In Format 1, the sum of the numbers of intervals must be np-1. In Format 2, the sequential expansion must be for NP-1 intervals. The card numbers need not be sequential.

A.8.7.1 Format 1

- W1(I)** NUMBER OF INTERVALS.
- W2(R)** RIGHT COORDINATE (m, ft).

A.8.7.2 Format 2

- W1(R)** MESH INTERVAL (m, ft.).
- W2(I)** INTERVAL NUMBER.

A.8.8 Cards 1cccg201 Through 1cccg299, Heat Structure Composition Data (Radial)

These cards are required if W1 of Card 1cccg100 is zero and must not be entered otherwise. The card format is two numbers per set in sequential expansion format for np-1 intervals. The card numbers need not be in sequential order.

- W1(I)** COMPOSITION NUMBER. The absolute value of this quantity is the

composition number, and it must be identical to the subfield mmm used in Heat Structure Thermal Property Data, Section A-10. The sign indicates whether the region over which this composition is applied is to be included or excluded from the volume averaged temperature computation. If positive, the region is included; if negative, the region is not included. The option to exclude regions from the volume averaged temperature integration is to limit the integration to fuel regions only for use in reactivity feedback calculations. Gap and cladding regions should not be included in this case. If the gap conductance model is used, only one interval can be used for the gap model.

W2(I) INTERVAL NUMBER.

A.8.9 Card 1ccccg300, Fission Product Decay Heat Flag

This card sets the fission product decay heat flag. The code will then treat Card 1CCCCG301 as a gamma attenuation coefficient card. This card is not needed if fission product decay heat is not used on this heat structure.

W1(A) DKHEAT.

A.8.10 Cards 1ccccg301 Through 1ccccg399, Heat Structure Source Distribution Data (Radial)

These cards are required if W1 of Card 1ccccg100 is zero and must not be entered otherwise. The card format is two numbers per set in sequential expansion format for np-1 intervals. The card numbers need not be in sequential order. Radial power peaking factors are entered here.

W1(R) SOURCE VALUE. These are relative values only and can be scaled by any factor without changing the results. By entering different values for the various mesh intervals, a characteristic shape of a power curve can be described.

W2(I) MESH INTERVAL NUMBER.

If Card 1ccccg300 is entered, then the Card 1ccccg301 is treated as a gamma attenuation coefficient card.

W1(R) GAMMA ATTENUATION COEFFICIENT. These are values dependent on the heat structure material. A value of 50 is recommended for stainless steel.

W2(I) MESH INTERVAL NUMBER.

A.8.11 Card 1ccccg400, Initial Temperature Flag

This card is optional; if missing, W1 is assumed to be zero.

W1(I) INITIAL TEMPERATURE FLAG. If this word is zero or -1, initial temperatures are entered with the input data for this heat structure geometry. If greater than zero,

initial temperatures for this heat structure geometry are taken from the heat structure geometry number in this word.

A.8.12 Cards 1cccg401 Through 1cccg499, Initial Temperature Data

These cards are required if W1 on Card 1cccg400 is zero or -1.

A.8.12.1 Format 1 (Word 1 on Card 1cccg400 = 0)

If W1 is zero, one temperature distribution is entered, and the same distribution is applied to all of the nh heat structures. The card format is two numbers per set in sequential expansion format for np mesh points.

W1(R) TEMPERATURE (K, °F).

W2(I) MESH POINT NUMBER.

A.8.12.2 Format 2 (Word 1 on Card 1cccg400 = -1)

If W1 of Card 1cccg400 is -1, a separate temperature distribution must be entered for each of the nh heat structures. The distribution for the first heat structure is entered on Card 1cccg401, the distribution for the second heat structure is entered on Card 1cccg402, and the remaining distributions are entered on consecutive card numbers. Continuation cards can be used if the data do not fit on one card.

W1-WNP(R) TEMPERATURE (K, °F). Enter the np mesh point temperatures in order from left to right.

A.8.13 Cards 1cccg501 Through 1cccg599, Left Boundary Condition Cards

The boundary condition data for the heat structures with this geometry are entered in a slightly modified form of sequential expansion using six quantities per set for the number of heat structures with this geometry (nh sets). The modification deals with Words 1 and 2.

W1(I) BOUNDARY VOLUME NUMBER OR GENERAL TABLE. This word specifies the hydrodynamic volume number (of the form cccnn0000) or general table associated with the left surface of this heat structure. These are used to specify the sink temperature. If zero, no volume or general table is associated with the left surface of this heat structure, and a symmetry or insulated boundary condition is used (i.e., a zero temperature gradient at the boundary), or a temperature of zero is used for a surface temperature or a sink temperature in boundary conditions. A boundary volume number is entered as a positive number. A general table is entered as a negative number (-1 through -999). If Word 1 is zero, this word should be zero.

W2(I) INCREMENT. This word and W1 of this card are treated differently from the standard sequential expansion. W1 of the first set applies to the first heat structure of the heat structure geometry set. The increment is applied to W1, and that applies to the second heat structure. The increment is applied up to the limit in W6 of a set. W1 of the next set applies to the next heat structure, and increments are applied as for the first set. The increment may be zero or nonzero, positive or negative.

W3(I) BOUNDARY CONDITION TYPE.

If 0, a symmetry or insulated boundary condition is used. The boundary volume must be 0.

If 1 or 1nn, a convective boundary condition where the heat transfer coefficient obtained from Heat Transfer Package 1 is used. Entering 1 or 100 specifies the standard heat transfer and CHF correlations. Entering 101 specifies standard heat transfer correlations but with a special Savannah River CHF correlation. Entering 102 specifies standard heat transfer but with Petukv forced convection replacing Dittus-Boelter and a special ORNL ANS CHF addition. The 102 option is appropriate for fuel plates with narrow flow channels. The sink temperature is the temperature of the boundary volume. W1 must specify a boundary volume with this boundary condition type. Generally, the boundary volume would not be a time-dependent volume. Caution should be used in specifying a time-dependent volume, since the elevation and length are set to zero and the velocities in an isolated time-dependent volume will be zero.

If 1.000, the temperature of the boundary volume or the temperature from the general table (as specified in W1) is used as the left surface temperature. If W1 is zero, the surface temperature is set to zero.

If 1xxx, the temperature in general Table xxx is used as the left surface temperature.

If 2xxx, the heat flux from Table xxx is used as the left boundary condition.

If 3xxx, a convective boundary condition is used where the heat transfer coefficient as a function of time is obtained from general Table xxx. The sink temperature is the temperature of the boundary volume or from the table specified in W1. If W1 is zero, the sink temperature is set to zero.

If 4xxx, a convective boundary condition is used where the heat transfer coefficient as a function of surface temperature is obtained from general Table xxx. The sink temperature is the temperature of the boundary volume or from the table specified in W1. If W1 is zero, the sink temperature is set to zero.

If reflood is specified, the left boundary condition type must be the same for all nh

heat structures and similarly for the right boundary condition type. The left and right boundary types need not be the same, but neither can be 1,000 or 1xxx.

- W4(I) SURFACE AREA CODE. If zero, W5 is the left surface area. If one, W5 is: (a) the surface area in rectangular geometry; (b) the cylinder height or equivalent in cylindrical geometry; or (c) the fraction of a sphere (0.5 is a hemisphere) in spherical geometry.
- W5(R) SURFACE AREA OR FACTOR. As indicated in W4, this word contains the surface area (m^2 , ft^2) or a geometry dependent multiplier (m^2 , ft^2) for rectangular; (m, ft) for cylindrical; or dimensionless for spherical geometries. If the symmetry boundary condition is specified (W3=0), this word must still be entered nonzero.
- W6(I) HEAT STRUCTURE NUMBER.

A.8.14 Cards 1cccg601 Through 1cccg699, Right Boundary Condition Cards

These cards are the same as Cards 1cccg501 through 1cccg599, except for the right boundary. The left and right surface areas must be compatible with the geometry.

A.8.15 Cards 1cccg701 Through 1cccg799, Source Data Cards

These cards are required for heat structure data. The card format is sequential expansion format, five words per set, describing nh heat structures.

- W1(I) SOURCE TYPE. If zero, no source is used. If a positive number < 1,000, power from the general table with this number is used as the source. If 1,000 through 1,999, the number has the form 1zzt and the source is taken from a reactor kinetics calculation. The field zz must be 00 for point reactor kinetics and is the zone number for one-dimensional reactor kinetics. The zone number specified must be in use in the one-dimensional kinetics problem. The field t = 0 specifies total reactor power, t = 1 specifies total decay power, t = 2 specifies fission power, t = 3 specifies fission product decay power, and t = 4 specifies actinide decay power. If 10,001 through 19,999, the source is the control variable whose number is this quantity minus 10,000.
- W2(R) INTERNAL SOURCE MULTIPLIER. Axial peaking factors may be entered here. These values are multiplied by the power in the general table number in W1 to obtain the total power generated in this heat structure.
- W3(R) DIRECT HEATING MULTIPLIER FOR LEFT BOUNDARY VOLUME.
- W4(R) DIRECT HEATING MULTIPLIER FOR RIGHT BOUNDARY VOLUME.

W5(I) HEAT STRUCTURE NUMBER.

A.8.16 Cards 1cccg801 Through 1cccg899, Additional Left Boundary Cards

These cards are required whenever the left boundary communicates energy with the left hand fluid volume. The cards are in sequential expansion format, nine cards per set, describing NH heat structures. Sequential expansion would only be used where the critical heat flux value was not important, since the length to all heat structures in the expansion would be the same.

- W1(R) HEATED EQUIVALENT DIAMETER (m, ft). This is $4 \cdot A(\text{flow})/P(\text{heated})$ and is recommended to be greater than or equal to the local hydraulic diameter since $P(\text{heated}) \leq P(\text{wetted})$. It is possible to input this diameter to be less than the local hydraulic diameter. If W1 equals 0.0, the volume hydraulic diameter is used.
- W2(R) HEATED LENGTH FORWARD (m, ft). Distance from the heated inlet to the center of this slab. The forward flow direction is defined by the hydraulic input. This is to get the hydraulic entrance length effect. It must be > 0 . To ignore the length effect, put in a large number (i.e., > 10.0).
- W3(R) HEATED LENGTH REVERSE (m, ft). Distance from the heated outlet to the center of this slab. This is used for length when the flow reverses.
- W4(R) GRID SPACER LENGTH FORWARD (m, ft). Distance from the center of this slab to the nearest grid or obstruction upstream. This is to get the boundary layer disturbance and atomization effect of grid spacer in rod bundles. If grid K losses (W6 and W7) are zero, W4 and W5 are not used.
- W5(R) GRID SPACER LENGTH REVERSE (m, ft). Distance from the downstream grid to this slab.
- W6(R) GRID LOSS COEFFICIENT FORWARD. Used for forward flow in rod bundles. Used only for CHF calculation.
- W7(R) GRID LOSS COEFFICIENT REVERSE.
- W8(R) LOCAL BOILING FACTOR. Enter 1 if there is no power source in the heat structure or if the local equilibrium quality is negative (i.e., liquid is subcooled and void is zero). This is the local heat flux/average heat flux from start of boiling. If the power profile is not flat, a steady-state run may help determine this number.
- W9(R) HEAT STRUCTURE NUMBER.

A.8.17 Cards 1cccg901 Through 1cccg999, Additional Right Boundary Cards

These cards are the same as Cards 1cccg801 through 1cccg899 but apply to the right boundary.

A.9 CARD 50000000, RADIATION MODEL CONTROL CARD

Any heat structure may radiate to any other heat structure or set of heat structures in a user-defined enclosure. An enclosure is a set of heat structures that communicate via thermal radiation. The calculation ignores fluid in the enclosure.

W1(I) NUMBER OF SETS OF RADIATION ENCLOSURES, NSET. This word must be less than 100 and greater than 0 for radiation to be on.

A.9.1 Card 5ss00000, Radiation Set Card

SS is the set number. One of these cards must be input for each radiating set. The first word is required, the other three are optional.

W1(I) NUMBER OF RADIATING HEAT SLABS, NRH. This word is the number of radiating heat slabs (surfaces) that participate in radiation heat transfer in set SS. The maximum is 99.

W2(R) MINIMUM TEMPERATURE, TRMIN (K, °F). This word is the minimum temperature of all surfaces in a radiation enclosure below which radiation will no longer be calculated. The default value is 900 K.

W3(R) MINIMUM VOID FRACTION, VOIDMN. This word is the minimum void fraction below which radiation will no longer be calculated. The default value is 0.75. Each volume connected to any of the radiating surfaces in the set is checked and if any have a void fraction greater than Word 3, radiation stays on in the enclosure set.

W4(I) VIEW FACTOR SET, REFSET. If input, this is the number of the set (SS) from which view factors are to be obtained. If no number is found here, the view factors must be input for this set.

A.9.2 Cards 5ssnn001 Through 5ssnn099, Radiation Heat Structure Data

For these cards, ss must take on every value from 1 to NSET (Word 1 in Card 50000000) and nn must take on every value from 1 to NRH (Word 1 on Card 5ss00000) for each ss. Data are entered for each conductor surface that participates in radiation heat transfer.

W1(I) HEAT STRUCTURE GEOMETRY LEVEL, JRH. This word is CCCGOZZ, where CCCG is the heat structure geometry combination of NH and ZZ is the axial level number participating in radiation.

W2(I) SURFACE FLAG, JLR. For this word, 0 = left surface and 1 = right surface of nn.

W3(R) EMISSIVITY OF SURFACE NN.

A.9.3 Cards 5ssnn101 Through 5ssnn199, Radiation View Factors

There are NRH•NRH values in each set. ss is the set number (from 1 to NSET). nn is the surface number (from 1 to NRH). For a given nn, the sum of the view factors must be 1.0 and the view factor times the surface area must equal the view factor times the area of the receiving surface.

W1(R) VIEW FACTOR, VFIJ. View factor from surface nn to surface W2(I).

W2(I) RADIATION SURFACE NUMBER TO WHICH NN RADIATES. Repeat the above two words until view factors to all NHR surfaces from all surfaces are entered. Sequential expansion is used.

A.10 CARDS 201MMMNN, HEAT STRUCTURE THERMAL PROPERTY DATA

These cards are used in NEW or RESTART problems. These cards are required if Cards 1ccccgtxnm, Heat Structure Input Cards, are entered. These data, if present, are processed and stored even if no Cards 1ccccgxnm are entered.

The subfield mmm is the composition number, and the cards with this subfield describe the thermal properties of composition mmm. The composition numbers entered on Cards 1ccccg201 through 1ccccg299 correspond to this subfield. A set of Cards 201mmmmnn must be entered for each composition number used, but mmm need not be consecutive. During RESTART, thermal property may be deleted, new compositions may be added, or data may be modified by entering new data for an existing composition.

A.10.1 Card 201mmm00, Composition Type and Data Format

This card is required.

W1(A) MATERIAL TYPE. Thermal properties for four materials are stored within the program: carbon steel (C-STEEL), stainless steel (S-STEEL), uranium dioxide (UO₂), and zirconium (ZR). These properties are selected by entering the name in parentheses for this word. If a user-supplied table or function is to be used, enter TBL/FCTN for this word. At present, the data are primarily to demonstrate capability. The user should check whether the data are satisfactory. The word DELETE may be entered in RESTART problems to delete a composition.

The next two words are required only if TBL/FCTN is entered for W1.

W2(I) THERMAL CONDUCTIVITY FORMAT FLAG OR GAP MOLE FRACTION FLAG. Enter 1 if a table containing temperature and thermal conductivity is to be entered; enter 2 if functions are to be entered. Enter 3 if the gap conductance model is used, and thus a table containing gas component names and mole fractions is to be entered.

W3(I) VOLUMETRIC HEAT CAPACITY FLAG. Enter 1 if a table containing temperature and volumetric heat capacity is to be entered; enter -1 if a table containing only volumetric heat capacities is to be entered and the temperature values are identical to the thermal conductivity table; enter 2 if functions are to be entered.

A.10.2 Cards 201mmm01 Through 201mmm49, Thermal Conductivity Data or Gap Mole Fraction Data

These cards are required if W1 of Card 201mmm00 contains TBL/FCTN. For a table, enter pairs of temperatures and thermal conductivities or pairs of gas component names and mole fractions according to the specification of W2 of Card 201mmm00. One to 7 pairs of gas names

and their mole fractions can be entered. The gas component names that may be entered are: HELIUM, ARGON, KRYPTON, XENON, NITROGEN, HYDROGEN, and OXYGEN. No particular order of the pairs is required. Do not enter any gas component with a zero mole fraction. Normalization of the total mole fraction to one is performed if the sum of the mole fractions entered is not one. The table of gas composition data is applicable to any gap and is required if Card 1cccg001 is present.

| A.10.2.1 Table Format

If only one word is entered, that word contains the thermal conductivity that is assumed constant. Otherwise, pairs of numbers are entered. The number of pairs is limited to 100. The temperatures must be in increasing order. The end-point temperatures must bracket the expected temperatures during a transient. That is, if the temperature is outside the bracketed range, a failure will occur and a diagnostic edit will be printed.

W1(R) TEMPERATURE (K, °F). Or gas name.

W2(R) THERMAL CONDUCTIVITY (W/m.K, Btu/s.ft.°F). Or mole fraction.

| A.10.2.2 Functional Format

In the functional format, sets of nine quantities are entered, each set containing one function and its range of application. The function is

$$C = A0 + A1*TX + A2*TX**2 + A3*TX**3 + A4*TX**4 + A5*TX**(-1)$$

where TX = T-C and T is the temperature argument. Each function has a lower and upper limit of application. The first function entered must be for the lowest temperature range. The lower limit of each following function must equal the upper bound of the previous function.

W1(R) LOWER LIMIT TEMPERATURE (K, °F).

W2(R) UPPER LIMIT TEMPERATURE (K, °F).

W3(R) A0 (W/m.K, Btu/s.ft.°F).

W4(R) A1 (W/m.K², Btu/s.ft.°F²).

W5(R) A2 (W/m.K³, Btu/s.ft.°F³).

W6(R) A3 (W/m.K⁴, Btu/s.ft.°F⁴).

W7(R) A4 (W/m.K⁵, Btu/s.ft.°F⁵).

W8(R) A5 (W/m, Btu/s.ft.).

W9(R) C (K, °F).

A.10.3 Cards 201mmm51 Through 201mmm99, Volumetric Heat Capacity Data

These cards are required if W1 of Card 201mmm00 contains TBL/FCTN. The card numbers need not be consecutive.

A.10.3.1 Table Format

If only one word is entered, that word contains the volumetric heat capacity that is assumed constant. Pairs of temperatures and volumetric heat capacities are entered if the temperatures are different than the thermal conductivity table or if functions are used for thermal conductivity. If the temperature values are identical, only the volumetric heat capacities need be entered. The number of pairs or single entries is limited to 100. The temperatures must be in increasing order. The end-point temperatures must bracket the expected temperatures during the transient. That is, if the temperature is outside the bracketed range, a failure will occur and a diagnostic edit will be printed.

W1(R) TEMPERATURE (K, °F). If only volumetric heat capacities are being entered, this word is not entered.

W2(R) VOLUMETRIC HEAT CAPACITY ($\text{J/m}^3 \cdot ^\circ\text{K}$, $\text{Btu/ft}^3 \cdot ^\circ\text{F}$).

A.10.3.2 Functional Format

In the functional format, sets of nine quantities are entered, each set containing one function and its range of application. The function is

$$C = A0 + A1 \cdot TX + A2 \cdot TX^{**2} + A3 \cdot TX^{**3} + A4 \cdot TX^{**4} + A5 \cdot TX^{**(-1)}$$

where $TX = T - C$ and T is the temperature argument. Each function has a lower and upper limit of application. The first function entered must be for the lowest temperature range. The lower limit of each following function must equal the upper bound of the previous function.

W1(R) LOWER LIMIT TEMPERATURE (K, °F).

W2(R) UPPER LIMIT TEMPERATURE (K, °F).

W3(R) $A0$ ($\text{J/m}^3 \text{ K}$, $\text{Btu/ft}^3 \cdot ^\circ\text{F}$).

W4(R) $A1$ ($\text{J/m}^3 \text{ K}^2$, $\text{Btu/ft}^3 \cdot ^\circ\text{F}^2$).

W5(R) $A2$ ($\text{J/m}^3 \text{ K}^3$, $\text{Btu/ft}^3 \cdot ^\circ\text{F}^3$).

W6(R) $A3$ ($\text{J/m}^3 \text{ K}^4$, $\text{Btu/ft}^3 \cdot ^\circ\text{F}^4$).

W7(R) $A4$ ($\text{J/m}^3 \text{ K}^5$, $\text{Btu/ft}^3 \cdot ^\circ\text{F}^5$).

W8(R) $A5$ (J/m^3 , Btu/ft^3).

W9(R) C (K, °F).

A.11 CARDS 202TTTNN, GENERAL TABLE DATA

These cards are used only in NEW or RESTART type problems and are required only if any input references general tables. ttt is the table number, and table references such as for power, heat transfer coefficients, and temperatures refer to this number. Data must be entered for each table referenced, but ttt need not be consecutive. Tables entered but not referenced are stored, and this is not considered an error. During RESTART, general tables may be added, existing tables may be deleted, or existing tables may be modified by entering new data.

A.11.1 Card 202ttt00, Table Type and Multiplier Data

W1(A) TABLE TYPE. Enter POWER for power versus time; enter HTRNRATE for heat flux versus time; enter HTC-T for heat transfer coefficient versus time; enter HTC-TEMP for heat transfer coefficient versus temperature; enter TEMP for temperature versus time; enter REAC-T for reactivity versus time; enter NORMAREA for normalized area versus normalized length. In RESTART problems, DELETE can be entered to delete general table ttt. When a general table is used to define a FUNCTION type control system variable, table type REAC-T can be used to prevent undesirable units conversion, since no British to SI units conversion is done for REAC-T entries.

The following two, three, or four words are optional and allow trips and factors or units changes to be applied to the table entries. If the factors are omitted, the data are used as entered. One multiplier is used for time, power, heat transfer flux, heat transfer coefficient, normalized length, and normalized area; a multiplier and additive constant are used for temperature as $T = M \cdot TX + C$, where M is the multiplier, C is the additive constant, and TX is the temperature entered. The first one or two factors apply to the argument variable, time or temperature; one factor is applied if the argument is time, and two factors are used if the argument is temperature. The remaining one or two factors are used for the function; two factors being used if temperature is the function.

W2(I) TABLE TRIP NUMBER. This number is optional unless factors are entered. If missing or zero, no trip is used; and the time argument is the time supplied to the table for interpolation. If nonzero, the number is the trip number; and the time argument is -1.0 if the trip is false and the time supplied to the table minus the trip time if the trip is true. This field may be omitted if no factors are entered. This number must be zero or blank for tables that are not a function of time.

W3-W5(R) FACTORS. As described above, enter factors such that when applied to the table values entered, the resultant values have the appropriate units. For the NORMAREA table, the resultant values for both the normalized length and area must be ≥ 0 and ≤ 1.0 .

A.11.2 Cards 202ttt01 Through 202ttt99, General Table Data

The card numbers need not be consecutive. The units given are the units required after the factors on Card 202ttt00 have been applied. Pairs of numbers are entered; the limit on the number of pairs is 99.

- W1(R) ARGUMENT VALUE (s, if time; K, °F, if temperature; dimensionless, if normalized length).
- W2(R) FUNCTION VALUE (W, MW, if power; K, °F, if temperature; W/m^2 , Btu/s·ft², if heat flux; $W/m^2 \cdot K$, Btu/sft²·°F, if heat transfer coefficient; dollars, if reactivity; dimensionless, if normalized area).

The tables use linear interpolation for segments between table search argument values. For search arguments beyond the range of entered data, the end-point values are used.

A.12 CARDS 30000000 THROUGH 30399999, REACTOR KINETICS INPUT

These cards are required if a space-independent (point) reactor kinetics or a one-dimensional reactor kinetics calculation is desired. These cards may be entered in a NEW problem or on a RESTART. If no reactor kinetics data are present in a RESTART problem, the data will be added; if reactor kinetics data are already present, the data are deleted and replaced by the new data. A complete set of reactor kinetics data must always be entered. Initial conditions are computed the same for NEW or RESTART problems; the initial conditions can be obtained from assuming infinite operating time at the input power or from an input power history.

A.12.1 Card 30000000, Reactor Kinetics Type Card

This card is required for either point or one-dimensional kinetics problems.

- W1(A) KINETICS TYPE. Enter POINT, ONED, or DELETE. Enter POINT for the point reactor kinetics option. Enter ONED for the one-dimensional kinetics option. Enter DELETE in a restart problem if reactor kinetics is to be deleted. No other data are needed if reactor kinetics is being deleted.
- W2(A) FEEDBACK TYPE. Enter SEPARABL, TABLE3, TABLE4, RAMONA, or HWR. The first three options are allowed only in POINT kinetics problems, and the fourth and fifth options are allowed only in ONED type problems. If Word 2 is not entered, a default value is assumed. If the kinetics type is POINT, the default is SEPARABL. If the kinetics type is ONED, the default is RAMONA. If SEPARABL is entered, reactor kinetics feedback caused by moderator density, moderator temperature, and fuel temperature is assumed to be separable, and feedback data are entered on Cards 30000501 through 30000899. If TABLE3 or TABLE4 is entered, reactivity is obtained from a table defining reactivity as a function of three or four variables (moderator density, moderator temperature, fuel temperature, and boron density) using Cards 30001001 through 30002999. If RAMONA is entered, cross sections including feedback and control rod effects are computed using a method from the RAMONA code and generalized in the TRAC-BD code. If HWR is entered, the cross sections including feedback and control rod effects are computed using a formulation specified by the heavy water New Production Reactor project at Savannah River.

A.12.2 Card 30000001, Reactor Kinetics Information Card

This card is required in both point and one-dimensional kinetics problems but the format is slightly different between the two problem types.

I A.12.2.1 Point Kinetics Format

- W1(A) FISSION PRODUCT DECAY TYPE. Enter NO-GAMMA for no fission product decay calculations, GAMMA for standard fission product decay calculations, or

CARDS 30000000 THROUGH 30399999, REACTOR KINETICS INPUT

GAMMA-AC for fission product decay plus actinide decay calculations.

- W2(R) TOTAL REACTOR POWER (W). This is the sum of fission power, fission product decay power, and actinide decay power. Watts are used for both SI and British units.
- W3(R) INITIAL REACTIVITY (dollars). This quantity must be ≤ 0 .
- W4(R) DELAYED NEUTRON FRACTION OVER PROMPT NEUTRON GENERATION TIME (s^{-1}).
- W5(R) FISSION PRODUCT YIELD FACTOR. This is usually 1.0 for best-estimate problems, and 1.2 has been used with ANS73 data for conservative mode problems. The factor 1.0 is assumed if this word is not entered.
- W6(R) ^{239}U YIELD FACTOR. This is the number of ^{239}U atoms produced per fission times any conservative factor desired. The factor 1.0 is assumed if this word is not entered.

A.12.2.2 One-Dimensional Kinetics Format

- W1(A) FISSION PRODUCT DECAY TYPE. Enter NO-GAMMA for no fission product decay calculations, GAMMA for standard fission product decay calculations, or GAMMA-AC for fission product decay plus actinide decay calculations.
- W2(R) TOTAL REACTOR POWER (W). This is the sum of fission power, fission product decay power, and actinide decay power. Watts are used for both SI and British units.
- W3(R) REACTOR CORE CROSS-SECTION AREA (m^2 , ft^2). The default value is 1.0 m^2 .
- W4(R) DELAYED NEUTRON FRACTION. This number must be > 0.0 and < 0.1 . The default is 0.0065.
- W5(R) FISSION PRODUCT YIELD FACTOR. This is usually 1.0 for best-estimate problems, and 1.2 has been used with ANS73 data for conservative mode problems. The factor 1.0 is assumed if this word is not entered.
- W6(R) ^{239}U YIELD FACTOR. This is the number of ^{239}U atoms produced per fission times any conservative factor desired. The factor 1.0 is assumed if this word is not entered.

A.12.3 Card 30000002, Fission Product Decay Information

This card is optionally entered for either POINT or ONED problems if W1 of Card 30000001 contains GAMMA or GAMMA-AC. If this card is not entered, the proposed 1973 ANS

standard fission product data are used if default data are used.

- W1(A) FISSION PRODUCT TYPE. Enter ANS73, ANS79-1, or ANS79-3. If default fission product data are used, ANS73 specifies the Proposed 1973 ANS standard data, ANS79-1 specifies the 1979 standard data for ^{235}U , and ANS79-3 specifies the 1979 ANS standard data for the three isotopes, ^{235}U , ^{238}U , and ^{239}Pu . ANS79-3 also requires that power fractions for each isotope must be entered. If fission product data are entered, ANS73 and ANS79-1 specify only one isotope and ANS79-3 specifies three isotopes and also requires that the number of decay heat groups for each isotope be entered.
- W2(R) ENERGY RELEASE PER FISSION (MeV/fission). If not entered or zero, the default value of 200 MeV/fission is used.
- W3-W5(R) IF ANS79-3 IS SPECIFIED IN W1. The fraction of power generated in ^{235}U , ^{238}U , and ^{239}Pu must be entered in these three words. The sum of the fractions must add to one.
- W6-W8(I) NUMBER OF GROUPS PER ISOTOPE. If ANS79-3 is entered in W1 and default data are not being used, the number of decay groups for ^{235}U , ^{238}U , and ^{239}Pu must be entered in these words. The number of groups for each isotope must be ≤ 50 .

A.12.4 Card 30000003, One-Dimensional Kinetics Control Information

This card is required for ONED type problems. The first word must be entered and the remaining words are optional.

- W1(I) NUMBER OF REACTOR KINETICS MESH INTERVALS. This quantity must be > 1 and < 100 . The default value is 1.
- W2(I) BOTTOM BOUNDARY CONDITION FLAG. This quantity controls the bottom boundary condition and is 0 if a zero flux boundary condition is desired, or is 1 if the bottom albedo matrix is to be used. The default value is 0.
- W3(I) TOP BOUNDARY CONDITION FLAG. This quantity controls the top boundary condition and is 0 if a zero flux boundary condition is desired, or is 1 if the top albedo matrix is to be used. The default value is 0.
- W4(I) TIME STEP CONTROL. This quantity is 0 to specify no time step control and the advancement is to be made over the hydrodynamic time step in one advancement. This quantity is 1 to specify an automatic time step control using k-infinity data to control the subinterval. This quantity is 2 to specify an automatic time step control using the kinetics equation to control the subinterval. The default value is 2.

- W5(I) INTEGRATION OPTION. Enter 0 to specify the theta method or enter 1 to specify the exponential method. The default value is 1.
- W6(I) STEADY-STATE SELECTION FLAG. Enter 0 to specify an eigenvalue calculation. Enter 1 to adjust thermal buckling such that the target relative power distribution and the target global eigenvalue will be produced. The default value is 0.
- W7(I) STEADY-STATE SOURCE ACCELERATION FLAG. Enter 1 for no acceleration (debugging only). Enter 2 for a two point linear extrapolation using the factor entered in W2 of Card 3000000. Enter 3 for three point Chebyshev semi-iterative polynomial extrapolation. Enter 4 for Wielandt eigenvalue shift acceleration. The recommended option is 4 except as noted in the description of W6 in Card 30000004. The default value is 4.

A.12.5 Card 30000004, One-Dimensional Kinetics Control Parameters

This card is optional for ONED type problems.

- W1(R) TIME DIFFERENCING PARAMETER. This quantity must be ≥ 0.5 and ≤ 1.0 . This quantity when equal to 0.5 implies Crank-Nicholson advancement and when equal to 1.0 implies fully implicit advancement. If W4 of Card 30000003 is > 0 , 1.0 is used. The default value is 1.0.
- W2(R) MAXIMUM FRACTIONAL FLUX CHANGE. This is the maximum fractional flux change allowed per subinterval when running under automatic time step control. Automatic time step control is selected in W4 of Card 30000003. This quantity must be ≥ 0.0 and ≤ 1.0 . The default value is 0.1.
- W3(R) CONVERGENCE CRITERION. This criterion is used for both the steady-state source iterations and the buckling adjustment. This quantity must be > 0.0 and ≤ 0.001 . The default value is $1.0E-8$.
- W4(R) TARGET EIGENVALUE. This quantity must be > 0.0 and ≤ 2.0 . The default value is 1.0. This quantity is always tested for proper range but is used only if W6 on Card 30000003 is 1.
- W5(R) EXTRAPOLATION FACTOR. This quantity must be ≥ 0.0 and ≤ 1.0 . This quantity is used only if W7 of Card 30000003 is 2. The default value is 0.5.
- W6(R) EIGENVALUE SHIFT FACTOR. This quantity is used if W7 of Card 30000003 is 4. Recommended value is 0.01, but this may have to be increased for some problems if the solution appears to be converging to one of the higher harmonics rather than the fundamental eigenvalue. The user can also switch to Chebyshev

extrapolation (W7 on Card 30000003 set to 3) in such cases. The default value is 0.01.

A.12.6 Card 30000005, One-Dimensional Kinetics Bottom Albedo Matrix

This card is optional and used only for ONED type problems. If the bottom boundary condition type (W2 on Card 30010003) is 1, this matrix is used. The bottom albedo matrix contains zeros if this card is not entered.

W1-W4(R) BOTTOM ALBEDO MATRIX.

A.12.7 Card 30000006, One-Dimensional Kinetics Top Albedo Matrix

This card is optional and used only for ONED type problems. If the top boundary condition type (W3 on Card 30010003) is 1, this matrix is used. The top albedo matrix contains zeros if this card is not entered.

W1-W4(R) TOP ALBEDO MATRIX.

A.12.8 Card 30000007, Neutron Velocity Data

This card is required for ONED type problems. Note that the units are cm/s rather than m/s.

W1(R) GROUP 1 NEUTRON VELOCITY (cm/s). The default value is 10^7 cm/s.

W2(R) GROUP 2 NEUTRON VELOCITY (cm/s). The default value is 10^7 cm/s.

A.12.9 Cards 30000101 Through 30000199, Delayed Neutron Constants

If these cards are missing, constants for the six generally accepted delayed neutron groups are supplied. Otherwise, two numbers for each delay group are entered, one or more pairs per card. Card numbers need not be consecutive. The number of pairs on these cards defines the number of delay groups. Up to 50 delay groups may be entered.

W1(R) DELAYED NEUTRON PRECURSOR YIELD RATIO.

W2(R) DELAYED NEUTRON DECAY CONSTANT (s^{-1}).

A.12.10 Cards 30000201 Through 30000299, Fission Product Decay Constants

These cards are not needed if W1 of Card 30000001 is NO-GAMMA. If this word is GAMMA or GAMMA-AC, data from these cards or default data are used to define fission product decay. If the cards are missing, data as defined in W1 of Card 30000002 are supplied. Up to 50 fission

product groups may be entered. Data are entered on cards similarly to Cards 30000101 through 30000199. The factor in W5 of Card 30000001 is applied to the yield fractions.

W1(R) FISSION PRODUCT YIELD FRACTION (MeV).

W2(R) FISSION PRODUCT DECAY CONSTANT (s^{-1}).

A.12.11 Cards 30000301 Through 30000399, Actinide Decay Constants

These cards are not needed unless W1 of Card 30000001 is GAMMA-AC. If GAMMA-AC is entered, data from these cards or default data are used to define actinide decay. If the cards are missing, default data are supplied.

W1(R) ENERGY YIELD FROM ^{239}U DECAY (MeV).

W2(R) DECAY CONSTANT OF ^{239}U (s^{-1}).

W3(R) ENERGY YIELD FROM ^{239}Np (MeV).

W4(R) DECAY CONSTANT OF ^{239}Np (s^{-1}).

A.12.12 Cards 30000401 Through 30000499, Power History Data

If these cards are not present, initial conditions for fission product and actinide groups are for steady-state operation at the power given in W2 of Card 30000001. This is equivalent to operation at that power for an infinite time. If these cards are present, the power history consisting of power and time duration is used to determine the fission product and actinide initial conditions. The power from gamma and actinide decay is assumed to be zero at the beginning of the first time duration. Data are entered in three- or six-word sets, one or more sets per card. Card numbers need not be consecutive.

W1(R) REACTOR POWER (W). This quantity is the total reactor power, that is, the sum of fission power and decay power, and must be ≥ 0 . If a decay power obtained from the power history exceeds this quantity, the fission power is assumed to be zero.

W2(R) TIME DURATION. Units are as given in next word. This quantity must be greater than or equal to 0.

W3(A) TIME DURATION UNITS. Must be sec, min, hr, day, or wk.

W4-W6(R) POWER FRACTIONS. If ANS79-3 is entered in W1 of Card 30000002, the power fractions for ^{235}U , ^{238}U , and ^{239}Pu must be entered in these words.

A.12.13 Point Kinetics Feedback Input

Feedback information for point kinetics information are entered on the following cards. For steady-state computations in which constant power is desired, these cards can be omitted and the feedback reactivity will be zero.

A.12.13.1 Cards 30000011 Through 30000020, Reactivity Curve or Control Variable Numbers

Reactivity (or scram) curves from the general tables (Cards 202tttnn) or control variables that contribute to reactivity feedback are specified on these cards. These cards are not used if there are no references to reactivity contributions from general tables or control variables. Tables and control variables referenced must be defined. No error is indicated if reactivity curves are defined but not referenced on this card, but memory space is wasted. Curve numbers, which are the ttt of the general table card number or control variable number code, are entered one or more per card. Card numbers need not be consecutive.

W1(I) TABLE OR CONTROL VARIABLE NUMBER. Up to 20 numbers may be entered. Numbers from 1 through 999 indicate general table numbers. Numbers > 10,000 indicate the control variable whose number is the entered number minus 10,000.

A.12.13.2 Cards 30000501 Through 30000599, Density Reactivity Table

This table is required if the SEPARABL option is being used and if Cards 30000701 through 30000799 are entered. One or more pairs of numbers are entered to define reactivity as a function of moderator density. Data are entered one or more pairs per card, and card numbers need not be consecutive. Up to 100 pairs may be entered.

W1(R) MODERATOR DENSITY (kg/m^3 , lb/ft^3).

W2(R) REACTIVITY (dollars).

A.12.13.3 Cards 30000601 Through 30000699, Doppler Reactivity Table

This table is required if the SEPARABL option is being used and if Cards 30000801 through 30000899 are entered. One or more pairs of numbers are entered to define Doppler reactivity as a function of volume-averaged fuel temperature. Data are entered one or more pairs per card, and card numbers need not be consecutive. Up to 100 pairs may be entered.

W1(R) TEMPERATURE (K, °F).

W2(R) REACTIVITY (dollars).

A.12.13.4 Cards 30000701 Through 30000799, Volume Weighting Factors

These cards are used only if the SEPARABL option is being used and are omitted if no reactor

kinetics feedback from hydrodynamics is present. Each card contains the input for reactivity feedback caused by conditions in one or more hydrodynamic volumes. Words 1 and 2 are a volume number and an increment. Words 3 and 4 are the reactivity data for the volume defined by Word 1; Words 5 and 6 are the reactivity data for the volume defined by Word 1 plus Word 2; Words 7 and 8 contain data for the volume defined by Word 1 plus two times Word 2; etc. Each card must contain at least four words. Volumes must be defined by hydrodynamic component data cards, and any volume reactivity data must be defined only once on these cards. Card numbers need not be consecutive.

- W1(I) HYDRODYNAMIC VOLUME NUMBER.
- W2(I) INCREMENT.
- W3(R) WEIGHTING FACTOR FOR DENSITY FEEDBACK, $W_{\rho i}$.
- W4(R) WATER TEMPERATURE COEFFICIENT, $a_{w i}$ (dollars/K, dollars/°F). The weighting factor in Word 3 is not applied to this quantity.

A.12.13.5 Cards 30000801 Through 30000899, Heat Structure or SCDAP Component Weighting Factors

These cards are used only if the SEPARABL option is being used and are omitted if no reactor kinetics feedback from heat structures or SCDAP components are present. Each card contains the input for reactivity feedback caused by conditions in one or more heat structures or SCDAP components representing fueled portions of the reactor. Data are entered in a manner similar to Cards 30000701 through 30000799.

For each heat structure specified on these cards, input on the heat structure data Cards 1cccc2nn must define the fueled region as the region over which the volume-average temperature is computed. Usually, either Word 3 or 4 is zero.

- W1(I) HEAT STRUCTURE NUMBER OR SCDAP COMPONENT IIJJ. ii equals the axial node, and jj equals the component number.
- W2(I) INCREMENT.
- W3(R) WEIGHTING FACTOR FOR DOPPLER FEEDBACK, $W_{F i}$.
- W4(R) FUEL TEMPERATURE COEFFICIENT, $a_{F i}$ (dollars/K, dollars/°F). The weighting factor in Word 3 is not applied to this quantity.

A.12.13.6 Cards 30001701 Through 30001799, Volume Weighting Factors

These cards are used only if the SEPARABL option is not being used. Each card contains the weighting factor for reactivity feedback caused by moderator density, moderator temperature, and boron density in one or more hydrodynamic volumes. The same factor is assumed to apply to all three effects, so only one factor is entered for each value. At least three quantities must be entered

on each card. The use of the increment field is similar to that in Section A.12.13.5.

W1(I) HYDRODYNAMIC VOLUME NUMBER.

W2(I) INCREMENT.

W3(R) WEIGHT FACTOR.

A.12.13.7 Cards 30001801 Through 30001899, Heat Structure or SCDAP Component Weighting Factors

These cards are used only if the SEPARABL option is not being used. Each card contains the weighting factor for reactivity feedback caused by temperature in one or more heat structures or SCDAP components. At least three quantities must be entered on each card. The use of the increment field is similar to that in Section A.12.13.5.

W1(I) HEAT STRUCTURE NUMBER OR SCDAP COMPONENT IIJJ. ii is the axial node, and jj is the component number.

W2(I) INCREMENT.

W3(R) WEIGHT FACTOR.

A.12.13.8 Cards 300019c1 Through 300019c9, Feedback Table Coordinate Data

If the TABLE3 option is being used, the feedback table is a function of three variables: moderator density ($c = 1$), moderator temperature ($c = 2$), and fuel temperature ($c = 3$). If the TABLE4 option is being used, the feedback table is a function of four variables: the three above and boron density ($c = 4$). These cards define the coordinates of the table, and table values are entered (on another card set) for each point defined by all combinations of the coordinate values. The table size is the product of the number of coordinate values entered for each variable. At least two coordinate points must be entered, and up to 20 points may be entered for each variable. Coordinate values are entered in increasing magnitude, one or more per card on one or more cards as desired. Card numbers need not be consecutive. The c in the parentheses above defines the c to be used in the card number.

W1(R) COORDINATE VALUE. kg/m^3 , lb/ft^3 for moderator and boron densities; K, $^{\circ}\text{F}$ for moderator and heat structure temperatures.

A.12.13.9 Cards 30002001 Through 30002999, Feedback Table Data

Values defining the table are entered in pairs. The first is a coded number defining the position of the table entry. The second number is the table entry. One or more pairs may be entered on one or more cards as needed. Card numbers need not be consecutive. There is no required ordering for the coded number, but a coded number may be entered only once.

W1(I) CODED NUMBER. The coded number has the form ddmmffbb, where the letter pairs represent coordinate numbers of the independent variables of the table. The

dd pair refers to moderator density, mm refers to moderator temperature, ff refers to heat structure temperature, and bb refers to boron density. The paired numbers range from 00 to one less than the number of coordinate values for that variable. The 00 pair refers to the first coordinate value. If boron dependence is not included, bb is always 00. All table values must be entered.

W2(R) TABLE VALUE.

A.12.14 One-Dimensional Kinetics Feedback Input

The description of the one-dimensional kinetics mesh assumes a reactor core in the axial direction with the mesh starting at the bottom of the core and extending upward. This assumption is for descriptive purposes only and no orientation is built into input processing. The direction can be assumed to be reversed and the mesh can represent a horizontal direction.

A.12.14.1 Cards 30010101 Through 30010199, One-Dimensional Mesh Intervals

Mesh intervals starting from the bottom and extending to the top of the core are entered in sequential expansion format on these cards. The number of intervals after expansion must equal W1 of Card 30000003. The sequential expansion input consists of pairs of numbers with the last mesh interval number equaling W1 of Card 30000003. Pairs of words are entered as needed.

W1(R) MESH INTERVAL (m, ft).

W2(I) KINETICS MESH INTERVAL NUMBER.

A.12.14.2 Cards 30010401 Through 30010499, Assignment of Zones to One-Dimensional Mesh Intervals

Mesh intervals for the one-dimensional kinetics calculation are usually smaller than the hydrodynamic mesh in the axial direction. Zone numbers are used to relate the kinetics mesh to the hydrodynamic mesh. This input assigns kinetics mesh intervals to zones using sequential expansion format. The next set of input assigns compositions to zones and assigns hydrodynamic volumes and heat structures to zones. Unique zone numbers, ranging from 1 through 99, are assigned to contiguous kinetics mesh intervals starting from the bottom and extending to the top of the core. Each zone must contain only contiguous kinetics mesh intervals. Each zone must have a unique zone number, but the zone numbers need not be sequential or even be in increasing order. Pairs of words are entered as needed, with the last mesh interval number equaling Word 1 of Card 30000003.

W1(I) ZONE NUMBER. A zone number must be > 0 and < 100 .

W2(I) KINETICS MESH INTERVAL NUMBER.

A.12.14.3 Cards 30010501 Through 30010599, Assignment of Compositions to One-Dimensional Mesh Intervals

Compositions are assigned to kinetics mesh intervals starting from the bottom and extending to the top of the core using sequential expansion format. There are no restrictions on the assignment of composition to mesh intervals and intervals in the same zone may have different compositions.

W1(I) COMPOSITION NUMBER. A composition number must be > 0 and < 100 .

W2(I) KINETICS MESH INTERVAL NUMBER.

A.12.14.4 Cards 30010601 Through 30010699, Target Power Distribution Data

Data are entered only if W6 on Card 30000003 is 1. Target power distribution data for each kinetics mesh interval starting at the bottom of the core and extending to the top of the core are entered on these cards. The number of words entered must equal the number of mesh intervals entered in W1 of Card 30000003. The relative values only are important, the absolute values are not since the data are normalized before use.

W1, W2..(R) POWER DISTRIBUTION VALUES.

A.12.14.5 Neutron Cross-Section Data for RAMONA Option

The following cards are input if the RAMONA neutron cross-section option is specified as Word 2 on Card 30000000.

A.12.14.5.1 Cards 301zz101 Through 301zz199, Volume Feedback Factors.

These cards assign hydrodynamic volumes to zone zz for computing averaged properties needed to compute cross-section information for the one-dimensional steady-state and kinetics advancement using the RAMONA option. The hydrodynamic volumes in this zone should be at the same axial levels as the kinetic mesh intervals in this zone. Each volume is usually in just one axial level, but volumes in contiguous axial levels can be entered. If the hydrodynamic mesh uses more than the axial dimension to represent the core, volumes in the horizontal plane but in the same axial levels may be entered. The above are recommendations. The input allows any hydrodynamic volume to be entered in any zone but volumes may not appear in more than one zone. Quadruples of words are entered as needed. The void fraction, moderator temperature, and poison density weight factors for each zone are normalized so that they sum to one.

W1(I) VOLUME NUMBER.

W2(R) VOLUME WEIGHTING FACTOR FOR AVERAGE VOID FRACTION.

W3(R) VOLUME WEIGHTING FACTOR FOR AVERAGE FLUID TEMPERATURE.

W4(R) VOLUME WEIGHTING FACTOR FOR AVERAGE POISON DENSITY.

A.12.14.5.2 Cards 301zz201 Through 301zz299, Heat Structure Feedback

Factors. These cards assign heat structures to zone zz for computing averaged properties needed to compute cross-section information using the RAMONA option. The assigned heat structures are usually connected to the hydrodynamic volumes assigned to the same zone on Cards 301zz0xx. However, the input allows any heat structure to be entered. Pairs of words are entered as needed. The heat structure weight factors for each zone are normalized so that they sum to one.

W1(I) HEAT STRUCTURE NUMBER.

W2(R) HEAT STRUCTURE WEIGHTING FACTOR.

A.12.14.5.3 Card 30200000, Temperature Units Card. This card contains the temperature units code. The units code indicates the units of the reference temperatures. If this quantity is 1, the units are K; if 2, the units are °C; if 3, the units are °R; and if 4, the units are °F.

W1(I) REFERENCE TEMPERATURE UNITS CODE. The default is 1.

A.12.14.5.4 Cards 302cc000, Composition Reference Data Cards. These cards contain the neutron yields and the reference temperatures.

W1(R) GROUP 1 NEUTRON YIELD. The default is 2.5.

W2(R) GROUP 2 NEUTRON YIELD. The default is 2.5.

W3(R) MODERATOR REFERENCE TEMPERATURE. The default is 273.16 K.

W4(R) FUEL REFERENCE TEMPERATURE. The default is 273.16 K.

A.12.14.5.5 Cards 302cc0nx, Composition Coefficient Data Cards. The nine factors defining cross-section type n for composition cc are entered on these cards. If data for a composition number are entered but not referenced on Cards 301zz0xx, the data are read and checked but discarded. The units for each cross-section are denoted by the symbol U. Group 1 is the fast group and Group 2 is the thermal group.

<u>n</u>	<u>Cross-section type</u>
1	Group 1 diffusion coefficient ($U_1 = \text{cm}$).
2	Group 2 diffusion coefficient ($U_2 = \text{cm}$).
3	Group 1 macroscopic absorption cross-section ($U_3 = \text{cm}^{-1}$).
4	Group 2 macroscopic absorption cross-section ($U_4 = \text{cm}^{-1}$).
5	Group 1 macroscopic downscatter cross-section ($U_5 = \text{cm}^{-1}$).
6	Group 1 macroscopic fission cross-section ($U_6 = \text{cm}^{-1}$).
7	Group 2 macroscopic fission cross-section ($U_7 = \text{cm}^{-1}$).

8	Group 1 transverse buckling ($U_8 = \text{cm}^{-2}$).
9	Group 2 transverse buckling ($U_9 = \text{cm}^{-2}$).
W1(R)	A_1 .
W2(R)	A_2 .
W3(R)	A_3 .
W4(R)	A_4 .
W5(R)	A_5 .
W6(R)	A_6 .
W7(R)	A_7 .
W8(R)	A_8 .
W9(R)	A_9 .

A.12.14.6 Neutron Cross-Section Data for HWR Option

The following cards are entered if the HWR option is specified as Word 2 on Card 30000000.

A.12.14.6.1 Card 30100000, Volume and Heat Structure Feedback Region Data.

The number of volume regions and the number of heat structure regions in the neutron cross-section function for the HWR option are entered on this card.

W1(I)	NUMBER OF VOLUME FEEDBACK REGIONS.
W2(I)	NUMBER OF HEAT STRUCTURE FEEDBACK REGIONS.

A.12.14.6.2 Cards 301zz1nx, Volume Feedback Weighting Factors. These cards assign volumes to volume feedback region n of zone zz . Volume feedback region variables are volume average fluid density, volume average fluid temperature, and volume average poison density. Pairs of numbers are entered as needed. The value of n varies from 1 up to and including the value of Word 1 on Card 30100000. The fluid density, fluid temperature, and poison density weighting factors for each volume region of each zone are normalized so that they sum to one.

W1(I)	VOLUME NUMBER.
W2(R)	VOLUME WEIGHTING FACTOR FOR AVERAGE FLUID DENSITY.
W3(R)	VOLUME WEIGHTING FACTOR FOR AVERAGE FLUID TEMPERATURE.
W4(R)	VOLUME WEIGHTING FACTOR FOR AVERAGE POISON DENSITY.

A.12.14.6.3 Cards 301zz2nx, Heat Structure Feedback Weighting Factors. These cards assign heat structures to heat structure feedback region n of zone zz. The value of n varies from 1 up to and including the value of Word 2 on Card 30100000. The assigned heat structure are usually connected to the hydrodynamic volumes assigned to the same region in the same zone in Cards 301zz0nx. However, the input allows any heat structure to be entered. The heat structure weighting factors for each heat structure region of each zone are normalized so that they sum to one.

W1(I) HEAT STRUCTURE NUMBER.

W2(R) HEAT STRUCTURE WEIGHTING FACTOR.

A.12.14.6.4 Cards 302cc000, Composition Neutron Yield Data. This card contains the neutron yields for composition cc.

W1(R) GROUP 1 NEUTRON YIELD. The default is 2.5.

W2(R) GROUP 2 NEUTRON YIELD. The default is 2.5.

A.12.14.6.5 Cards 302cc0nx, Neutron Base Cross-Section Data. These cards contain the base controlled and uncontrolled neutron cross-sections for composition cc. The units for each of the cross-sections is denoted by the symbol U. Group 1 is the fast group and Group 2 is the thermal group.

n	<u>Cross-section type</u>
1	Group 1 diffusion coefficient ($U_1 = \text{cm}$).
2	Group 2 diffusion coefficient ($U_2 = \text{cm}$).
3	Group 1 macroscopic absorption cross-section ($U_3 = \text{cm}^{-1}$).
4	Group 2 macroscopic absorption cross-section ($U_4 = \text{cm}^{-1}$).
5	Group 1 macroscopic total removal cross-section ($U_5 = \text{cm}^{-1}$).
6	Group 1 macroscopic fission cross-section ($U_6 = \text{cm}^{-1}$).
7	Group 2 macroscopic fission cross-section ($U_7 = \text{cm}^{-1}$).
8	Group 1 buckling ($U_8 = \text{cm}^{-2}$).
9	Group 2 buckling ($U_9 = \text{cm}^{-2}$).
W1(R)	BASE UNCONTROLLED CROSS-SECTION VALUE (U_n).
W2(R)	BASE CONTROLLED CROSS-SECTION VALUE (U_n).

A.12.14.6.6 Cards 302cc1nx, Volume Region Temperature Data. These cards contain the coefficients and reference temperatures for the volume region temperature terms in the

neutron cross-section function for neutron cross-section n of composition cc . Pairs of data are entered and the number of pairs must be equal to Word 1 on Card 30100000.

- W1(R) FIRST VOLUME REGION TEMPERATURE COEFFICIENT (1/K).
- W2(R) FIRST VOLUME REGION TEMPERATURE REFERENCE VALUE (K).
- W3(R) SECOND VOLUME REGION TEMPERATURE COEFFICIENT (1/K).
- W4(R) SECOND VOLUME REGION TEMPERATURE REFERENCE VALUE (K).

A.12.14.6.7 Cards 302cc2nx, Volume Region Poison Density Data. These cards contain the coefficient and reference poison density for the volume region poison density terms in the neutron cross-section function for cross-section n of composition cc . Pairs of data are entered and the number of pairs must be equal to Word 1 on Card 30100000.

- W1(R) FIRST VOLUME REGION POISON DENSITY COEFFICIENT $[1 / (\text{kg}/\text{m}^3)]$.
- W2(R) FIRST VOLUME REGION POISON DENSITY REFERENCE VALUE (kg/m^3) .
- W3(R) SECOND VOLUME REGION POISON DENSITY COEFFICIENT $[1 / (\text{kg}/\text{m}^3)]$.
- W4(R) SECOND VOLUME REGION POISON DENSITY REFERENCE VALUE (kg/m^3) .

A.12.14.6.8 Cards 302cc3nx, Volume Region Fluid Density Data. These cards contain the linear and quadratic coefficients and the reference fluid density for the volume region fluid density terms in the neutron cross-section function for cross-section n of composition cc . Triplets of data are entered and the number of triplets must be equal to Word 1 on Card 30100000.

- W1(R) FIRST VOLUME REGION FLUID DENSITY LINEAR COEFFICIENT $[1 / (\text{kg}/\text{m}^3)]$.
- W2(R) FIRST VOLUME REGION FLUID DENSITY QUADRATIC COEFFICIENT $[1 / (\text{kg}/\text{m}^3)^2]$.
- W3(R) FIRST VOLUME REGION FLUID DENSITY REFERENCE VALUE (kg/m^3) .
- W4(R) SECOND VOLUME REGION FLUID DENSITY LINEAR COEFFICIENT $[1 / (\text{kg}/\text{m}^3)]$.
- W5(R) SECOND VOLUME REGION FLUID DENSITY QUADRATIC COEFFICIENT $[1 / (\text{kg}/\text{m}^3)^2]$.
- W6(R) SECOND VOLUME REGION FLUID DENSITY REFERENCE VALUE (kg/m^3) .

A.12.14.6.9 Cards 302cc4nx, Heat Structure Region Temperature Data. These cards contain the coefficients and reference temperatures for the heat structure region temperature terms in the neutron cross-section function for cross-section n of composition cc. Pairs on values are entered and the number of pairs must equal Word 2 on Card 30100000.

- W1(R) FIRST HEAT STRUCTURE REGION COEFFICIENT (1/K).
- W2(R) FIRST HEAT STRUCTURE REGION REFERENCE VALUE (K).
- W3(R) SECOND HEAT STRUCTURE REGION COEFFICIENT (1/K).
- W4(R) SECOND HEAT STRUCTURE REGION REFERENCE VALUE (K).

A.12.15 Control Rod Model Data

These cards contain the data for the control rod model and are only input if the one-dimensional kinetics model has been selected.

| A.12.15.1 Card 30400000, Control Rod Information

This card contains general information about the control rod model.

- W1(I) INSERTION DIRECTION FLAG. A value of zero means up from the bottom of the reactor core and a value of one means down from the top on the reactor core. The default is 0.

| A.12.15.2 Cards 304000nn, Control Rod Data

These cards contain data for control rod group nn.

- W1(R) INITIAL INSERTION DEPTH OF CONTROL ROD GROUP (m).
- W2(R) ACTIVE LENGTH OF CONTROL ROD (m). A value of 0.0 denotes a full-length control rod. The default is 0.
- W3(I) CONTROL VARIABLE OR GENERAL TABLE FROM WHICH INSERTION DEPTH IS TO BE DETERMINED. A value of zero specifies that the control rod remains inserted at its initial insertion depth. The default is 0.

| A.12.15.3 Cards 304nn0xx, Control Rod Group Weight Factors

These cards contain the control rod group weights for axial level nn. The values are the relative weights between the groups and will be normalized when used. Pairs of numbers are entered as needed. If a weight factor is not specified for a particular control rod group, its weight factor is assumed to be zero.

- W1(I) CONTROL ROD GROUP IDENTIFIER.

Control Rod Model Data

W2(R)	WEIGHT FACTOR FOR CONTROL ROD GROUP.
W3(I)	CONTROL ROD GROUP IDENTIFIER.
W4(R)	WEIGHT FACTOR FOR CONTROL ROD GROUP.

A.13 CARDS 20300000 THROUGH 20499999, PLOT REQUEST INPUT DATA

The plotting capability described in this section is not currently active. Besides not being converted to machine dependent form from the original CDC-7600 version, a proprietary plotting package was required. Most users use the strip option to write an ASCII coded file containing data to be plotted and interface this file to plotting routines available within their organizations.

These cards are used in NEW, RESTART, or PLOT problems. The input data for plotting permits extensive user control over the plots, and graphs suitable for report use can be generated. However, if plots of selected quantities versus time are desired using default options, then only the cards described in Section A.13.6.1 are needed.

For convenience to the user, a check plot option is provided that will produce plots of input data, such as time-dependent volumes and junctions, general tables, plot comparison data tables, valve area and flow coefficients, etc. This option can be used by the input of the "check plot" general plot request input card. The plots are constructed upon completion of the third phase of input data processing so that all information processed by the code will be included. Once the option is activated, it will remain in effect for all subsequent restarts and plot only jobs including restarts with renodalization until cancelled by the user with appropriate input.

A.13.1 Card 203000kk, Plot General Heading and Specifications

These cards are optional and may be input to define the general plot heading, plot options, and plot size specifications if the user desires to specify these parameters. Input of these cards is equivalent to redefining the general plot default conditions. The number group kk designates either data group or card sequence numbers, as noted in the following.

A.13.2 Cards 20300000 Through 20300009, General Plot Heading Cards

Each card defines a line of the general heading for the plots. This general heading will be written at the top of each plot. Up to three lines of heading may be input, in which case each line of the heading will be written at the top of the plots in the ascending order of the card sequence number kk, where kk ranges from 00 through 09. If more than three lines are input, an error will result. The cards need not be consecutively numbered. Each line of the heading must be composed of alphanumeric characters enclosed by apostrophe symbols. The length of each line is limited to ten computer words. The \$ symbol may not be embedded in the character string. If more than one blank is input between any words, the extraneous blanks are automatically deleted. All blanks preceding the first nonblank character are automatically deleted, and the entire heading line is automatically left-justified. However, each line of the heading is centered as it is written on the plot. If a heading line is composed of blanks, the card will be ignored. If the cards are omitted, the first heading line will default to the SCDAP/RELAP5 computer code heading printed in the output and the second heading line will default to the problem title as input on the title card described in Section A.1.3. The heading may be suppressed by inputting =NONE on the 20300000 card.

For RESTART or PLOT runs, it may be desired to modify previously defined headings. For these cases, if either of the keywords DELETE or DISCARD is input as the first word on Cards 20300000 through 20300009, the existing plot heading will be deleted and replaced by the default heading. If the user wishes to specify a new heading, then input is done in the normal manner, which will replace the existing heading. The heading may also be suppressed as discussed above. Input of both a keyword and a new plot heading is not allowed and will result in an error.

A.13.3 Cards 20300010 Through 20300019, General Plot Options Keywords

These cards are input to define the general plot options to be in effect for all of the plots. However, many of the options may be modified for an individual plot, as described for the 203nnn50 through 203nnn59 cards. Options that may not be modified for individual plots are appropriately noted. Input of the general plot options allows the user to redefine the default conditions for the units of the plot, the drawing of the grid, the character style of the lettering, the page border, the axes frame, the mode of printing plot information in the printout, and the plot orientation on the page. The plot option keywords may be input in any order or omitted. If any keyword is misspelled or an undefined keyword is input, an error will result. Keywords are also provided to enable a "debug dump" of plot-related files at the three levels of data processing. These options are not recommended for the typical user and are provided for the convenience of code designers who wish to modify the plot capability or trace the effects of errors discovered in the plot package. The keywords are described as follows:

PRINTUNITS	Plots are made in the same units as the printout. This is the default.
SI	Plots are made in SI units.
BRITISH	Plots are made in British units.
NOGRID	No plot axes grid is drawn. This is the default.
DOTGRID	A plot axes dotted line grid is drawn.
LINEGRID	A plot axes solid line grid is drawn.
STDCHAR	All lettering on the plot is in the simplest, fastest style. This is the default. Also refer to the INTENSITYN option.
DUPLEX	Lettering of the plot is drawn in the engineering/drafting style with two passes per character to ensure high resolution. Also refer to the INTENSITYN option.
COMPLEX	Lettering on the plot is drawn in a high resolution textbook style. Also refer to the INTENSITYN option.
BORDER	A page border is drawn around the plot that includes a binder margin allowance. This is the default.

NOBORDER	No page border is drawn.
FRAME	A frame is drawn around the axes extremities.
NOFRAME	No frame is drawn around the axes extremities. This is the default.
NOPLPRINT	User input plot-related data will not be printed, and DISSPLA messages during plotting will not be printed in the printout. An ID message will be drawn on the plot page margin. If the PLPRINT option has been input as a general plot option, the NOPLPRINT option may be input for an individual plot, only to suppress the printout of DISSPLA messages during plotting. This is the default.
PLPRINT	If input as a general plot option, PLPRINT causes the printout of all plot-related user input, including plot comparison data table input. If the check plot request card is also input, then the check plot data used for plotting will be printed. DISSPLA messages during plotting will also be printed in the printout. If input as an individual plot option, PLPRINT only causes DISSPLA messages to be printed during plotting.
HORIZONTAL	The plot is with the independent variable axis parallel with the long page axis. This is the default.
VERTICAL	The plot is oriented with the dependent variable axis parallel with the long page axis.
INTENSITYN	The plot curves are drawn by performing m passes over the curve. The value of m is set according to the following values of n. If n is 0 or 1 then m = 1. This intensity is the default if the intensity option is omitted and the STDCHAR lettering option is activated. If n is 2 or 3, then m=2. This intensity is the default if the intensity option is omitted and the DUPLEX lettering option is activated. $n \geq 4$, then m=4. This intensity is the default if the intensity option is omitted and the COMPLEX lettering option is activated.
DELETE	This may be input only for RESTART and PLOT jobs. If input, the general plot options are reset to their default values. Any of the keywords previously described may also be input with their noted effect.
DISCARD	This is identical to DELETE.

The plot debug options are general plot options only and may not be input for individual plots. These options are not recommended for use by a typical user. They are provided for the convenience of code designers who desire debug dumps of plot-related files for the purpose of modifying the plot package capability or for tracing the effects of errors discovered during plot processing. The debug option keywords may be input in any order and any combination except the keyword NODEBUG. Use of the NODEBUG keyword will cancel all plot debug options in the

current input and, for either RESTART or PLOT jobs, will cancel all plot debug options previously defined. Use of the plot debug option will automatically activate the PLPRINT option for which all plot-related user input and check plot data will be printed. The debug option keywords are listed as follows:

DEBUGR	This will activate a debug dump and user input printout of plot-related files at the second level of input processing (i.e., the "R" level subroutines).
DEBUGI	This will activate a debug dump and check plot printout at the third level of input processing (i.e., the "I" level subroutines).
DEBUGP	This activates a debug dump of plot-related files at the plot level (i.e., the PLOTMD level subroutines).
DEBUGRI	This is a single keyword combining the effects of DEBUGR and DEBUGI.
DEBUGALL	This is a single keyword combining the effects of DEBUGR, DEBUGI, and DEBUGP.
DEBUGPR	This activates the debug option for plot requests.
DEBUGCR	This activates the debug option for plot comparison data table requests.
DEBUGPRCR	This is a single keyword combining the effects of DEBUGPR and DEBUGCR.
NODEBUG	This cancels all plot debug options currently input. For RESTART or PLOT jobs, this cancels all plot debug options previously defined.

A.13.4 Card 20300020, General Plot Size Dimensions

This card is optional and is input to define the general plot size dimensions. If the card is omitted, the plot size dimensions default to fit a standard page size of 8-1/2 by 11 inches. The general plot size dimensions are applied to all of the plots. However, any or all of the dimensions may be modified for an individual plot, as described for the 203nnn60 cards.

Up to three real numbers may be input that are described as follows:

W1(R)	PWIDTH. This is the length of the plot axis extremities parallel to the short page axis. The default of PWIDTH is 6 inches.
W2(R)	PHIGHT. This is the length of the plot axis extremities parallel to the long page axis. The default of PHIGHT is 8 inches.
W3(R)	PMAGNF. This is a magnification factor to be applied to the overall plot. The default of PMAGNF is 1.

Words 1 and 2 may be input in any order, as PWIDTH is defined as the minimum of Words 1

or 2 and PHIGHT is defined as the maximum of Word 1 or Word 2.

For RESTART or PLOT jobs, input of the card will redefine the general plot size dimensions. If it is desired to reset these terms to their default values, then each term must be input as zero.

A.13.5 Card 20300030, Input Check Plot Request Card

This card is optional and is input to direct the code to construct plot files and plot data files for plotting of component tabular data. This option is provided for user convenience to provide plots as a visual aid in checking input data or for graphical presentation of component input data in reports. Only one of the following keywords need be input:

CHK-PLT	This activates the check plot option.
DELETE	DELETE should be used only for RESTART or PLOT jobs. Input causes deactivation of the check plot option for the current and all following restarts.
DISCARD	An equivalent of DELETE.

A.13.6 Cards 203nnnkk, Plot Requests and Specifications

These cards are input to define a plot request and to define the specifications for drawing the plot. The cards specifying the basic plot requests are required. All of the remaining cards are optional. If the optional cards are input and the corresponding plot request card is omitted, an error will result.

I A.13.6.1 Cards 203nnn00 Through 203nnn09, Plot Requests

These cards are required for each plot. Any input card of the form 203nnnkk, where kk ranges from 00 through 09, is a plot request card. The first word input on the card with the lowest sequence number kk must be a valid alphanumeric variable code followed by up to nine parameters as described for the minor edit requests (see Section A.4). However, the keywords DELETE or DISCARD may be input as a variable code for RESTART or PLOT runs as described below. The data format for the input of a plot request is described as follows:

W1(A)	DEPENDENT VARIABLE CODE (required). This is defined as for the minor edit request variable code described in Section A.4.
W2(I)	PARAMETER(1) (required). This is defined as for the minor edit request parameter described in Section A.4.
W3-10(I)	PARAMETER(2) - (9) (optional). This is defined as for Word 2.

Each variable code parameter combination defines a dependent variable to be plotted. The curve (or curves) to be plotted is determined by the independent variable request Card 203nnn10. If a variable code is omitted or input more than once in the request string, an error will result. If

more than nine parameters are input, an error will result. Invalid variable codes and parameters will also cause an error.

For RESTART or PLOT runs, the existing plot records are loaded from the restart records and these may be modified. If DELETE or DISCARD is input as the dependent variable code for a plot request (Card 203nnn00 through 203nnn09), the entire plot request record will be deleted. If the user wishes to replace, insert, or add a plot request, the input is the same as for a normal execution. If the keywords DELETE or DISCARD are input, no other words or cards may be input for the deleted record or an error will result.

A.13.6.2 Cards 203nnn10 Through 203nnn19, Independent Variable Requests

These cards are optional; and if omitted, the independent variable defaults to TIME.

If these cards are input, then any card of the form 203nnnll, where ll ranges from 10 through 19, is an independent variable request card. The first word input on the card with the lowest sequence number kk must be a valid alphanumeric variable code followed by up to nine parameters, as described for the plot requests (Cards 203nnn00 through 203nnn09). If a variable code is input more than once, an error will result. Independent variable requests may be input in any one of the following formats.

First, the independent variable code word may be input with no parameter following, as follows:

W1(A) INDEPENDENT VARIABLE CODE. This is defined as for the minor edit request variable code described in Section A.4. For this format, the parameters will default to those input on the plot request Cards 203nnn00 through 203nnn09.

Second, the independent variable code word may be input followed by only one parameter, as follows:

W1(A) INDEPENDENT VARIABLE CODE. This is defined as for the minor edit request variable code described in Section A.4.

W2(I) PARAMETER(1). This is defined as for the minor edit request parameter described in Section A.4. For this format, the independent variable code word and parameter will be assigned as the independent variable for each of the dependent variables input on the plot request Cards 203nnn000 through 203nnn09.

Third, the independent variable code word may be input followed by several parameters, as follows:

W1(A) INDEPENDENT VARIABLE CODE. This is defined as for the minor edit request variable code described in Section A.4.

W2(I) PARAMETER(1). This is defined as for the minor edit request parameter described in Section A.4.

W3-W...(I) PARAMETER(2) - (n). This is defined as for Word 2, where n is the (n+1)(I) the number of parameters input on the plot request Cards 203nnn00 through 203nnn09.

For this format, each independent variable and parameter in the sequence is successfully paired with its corresponding dependent variable and parameter in the sequence input on the plot request cards (Cards 203nnn00 through 203nnn09). If the number of independent variable parameters input does not correspond to the number of dependent variable parameters input on the plot request cards then an error will result.

A.13.6.3 Cards 203nnn20 Through 203nnn29, Plot Comparison Data Table Reference

These cards define the table number for plot comparison input data to be plotted on the same graph as SCDAP/RELAP5 results for visual comparison. Up to 10 table numbers can be input. Each table number entered is defined by the 204mmm00 card described in Section A.13.7, where the number mmm00 is the plot comparison data table number. Each number entered must refer to a plot comparison data table that has been input, or an error will result.

For RESTART or PLOT jobs, if a plot request is deleted that references a plot comparison data table and if the plot comparison data table is not referenced by a remaining plot request, then an error will result unless the table is also deleted.

A.13.6.4 Cards 203nnn30 Through 203nnn32, Plot Title and Axes Titles

These three cards are optional and input the plot title and the x and y axes titles, respectively. The format for each of the title cards is identical to that for the header cards (Cards 20300000 through 20300009). Any or all of the cards may be omitted. However, when input, the card sequence number kk designates the type of title entered. The plot title is input on the 203nnn30 card and is written on the plot as the last line of the header. If the plot title card is omitted, it defaults to a blank character string and is ignored. The x-axis title is input on the 203nnn31 card and written on the plot parallel to the independent variable axis (x-axis). If the x-axis title card is omitted, it defaults to the independent variable code, parameter, and units encoded together. If the x-axis title card begins with the character string (=units), the SCDAP/RELAP5 units label for the variable being plotted will be appended to the user input title. The x-axis title is input on the 203nnn32 card and is written on the plot parallel to the dependent variable axis (y-axis). If the y-axis title card is omitted, it defaults to the dependent variable code, parameter and units encoded together. If the y-axis title card begins with the character string (=units), the SCDAP/RELAP5 units label for the variable being plotted will be appended to the user input title.

A.13.6.5 Cards 203nnn40 Through 203nnn41, Plot Axes Specifications

These cards input the specifications for drawing the plot independent and dependent variable axes, respectively. The cards are optional and may be omitted, in which case defaults are set that will produce optimal and attractive axes.

None of the input terms will completely define an axes specification except the keyword LINEAR, unless the following plot design criteria are satisfied. The plot axes are designed with respect to SCDAP/RELAP5 computational results. To achieve maximum visual effect the plotted curve of SCDAP/RELAP5 results must span as much of the independent variable axis as possible and the dependent variable axis must span all of the data plotted. The axes must also be subdivided into intervals rounded to the first significant figure for simple labeling. The terms input by each card are described as follows.

A.13.6.5.1 Card 203nnn40, Independent Variable Axis Specification. This card inputs the independent variable axis (x-axis) specification. The card is optional and may be omitted, in which case the default values will be set. If the card is input, the first two words are required, but up to five words of data may be input in the following format.

- W1(R) SPECIFIED X-AXIS MINIMUM OR MAXIMUM. Refer to W2(R).
- W2(R) SPECIFIED X-AXIS MAXIMUM OR MINIMUM. Input of W1(R) and W2(R) allows the user to define the independent variable (x) interval over which data are to be plotted. Hence, any comparison data point or SCDAP/RELAP5 result point will not be plotted if its corresponding independent variable point lies outside the interval $x_{min} \leq x \leq x_{max}$, where x_{min} is the minimum of W1(R) or W2(R) and x_{max} is the maximum of W1(R) or W2(R). However, in the code, when the plot files are loaded, if it is found that the actual minimum x is $> x_{min}$ or the actual maximum x is $< x_{max}$, then the corresponding user specification is reset to the actual minimum or maximum x , respectively. This is done to ensure maximum use of the plot space available. If the x-axis specification card is omitted, then x_{min} and x_{max} default to $-1.0E+99$ and $+1.0E+99$, respectively.
- W3(I) SPECIFIED NUMBER OF LABELED X-AXIS INTERVALS (NDIVX). Defaults to 5.
- W4(I) SPECIFIED NUMBER OF GRID SUBINTERVALS (IXGRID). IXGRID is the number of grid subintervals per labeled interval. IXGRID is ignored if NOGRID is specified in the plot options. If IXGRID is omitted or input as zero, it defaults to one if a grid is specified in the plot options.
- W5(A) X-AXIS TYPE KEYWORDS, LINEAR OR LOG. Defaults to LINEAR. The LOG option has temporarily been disabled.

x_{min} specifies the independent variable minimum only if it is greater than or equal to the actual minimum of the data. Similarly, x_{max} specifies the independent variable maximum only if it is less than or equal to the actual maximum of the data. If x_{min} and x_{max} satisfy these conditions, then the curve will be plotted beginning at x_{min} and ending at x_{max} . However, the axis extremities must still be adjusted to the NDIVX and IXGRID specification.

The terms NDIVX and IXGRID specify the number of subintervals into which the axis is divided. The design criteria specify that these subintervals must be rounded to the first significant

digit and that the axis must be spanned by as much of the data as possible. Therefore the axis extremities not only may be expanded but the number of labeled intervals specified by NDIVX may be reduced or increased to give an optimum axis.

The axis type keywords LINEAR or LOG specify that the axis is to be drawn as a linearly scaled or as a logarithmically (base 10) scaled axis, respectively. If the keyword is omitted, the default is to LINEAR. If the keyword LOG has been specified and during the course of processing a plot data point is found to be zero or negative, an error message will be printed, the axis type will be reset to LINEAR, and the plot will be completed.

A.13.6.5.2 Card 203nnn41, Dependent Variable Axis Specification. This card inputs the dependent variable axis (y-axis) specification. The card is optional and may be omitted, in which case the default values will be set. If the card is input, the first two words are required, but up to five words of data may be input in the following format.

- W1(R) SPECIFIED Y-AXIS MINIMUM OR MAXIMUM. Refer to W2(R).
- W2(R) SPECIFIED Y-AXIS MAXIMUM OR MINIMUM. Input of W1(R) and W2(R) allows the user to define the dependent variable (y) interval within which data are to be plotted. By input of these two terms, the user is specifying the approximate y-axis extremities for the plot. Any data point loaded for plotting must lie within the interval $y_{\min} \leq y < y_{\max}$, where $y_{\min}$ is the minimum of W1(R) or W2(R) and $y_{\max}$ is the maximum of W1(R) or W2(R). However, in the code, when the plot files are loaded, if it is found that the actual minimum y is $< y_{\min}$ or the actual maximum y is $> y_{\max}$, then the corresponding user specification is reset to the actual minimum or maximum y , respectively. This is done to ensure that the plot contains all of the data points within the plot interval specifications. If the y-axis specification card is omitted, then $y_{\min}$ and $y_{\max}$ default to $-1.0E+99$ and $+1.0E+99$, respectively.
- W3(I) SPECIFIED NUMBER OF Y-AXIS INTERVALS (NDIVY). Defaults to 5.
- W4(I) SPECIFIED NUMBER OF GRID SUBINTERVALS (IYGRID). IYGRID is the number of grid subintervals per labeled interval. IYGRID is ignored if NOGRID is specified in the plot options. If IYGRID is omitted or input as zero and a grid is specified in the plot options, then IYGRID defaults to one.
- W5(A) Y-AXIS TYPE KEYWORDS, LINEAR OR LOG. Defaults to LINEAR. (The LOG option has temporarily been disabled.)

Rules that apply to the use of the dependent variable axis specifications are the same as those for the independent variable axis, except for the terms $y_{\min}$ and $y_{\max}$. To achieve an optimum plot design, all of the dependent variable data plotted must be included within the y-axis extremities. Therefore, $y_{\min}$ specifies the dependent variable minimum only if it is less than or equal to the actual minimum of the data. Similarly, $y_{\max}$ specifies the dependent variable maximum only if it is greater than or equal to the actual maximum of the data.

A.13.6.6 Cards 203nnn50 Through 203nnn59, Curve Drawing Specifications

These cards input the specifications for drawing each curve requested in a plot request (Cards 203nnn00 through 203nnn09). The sequence number of the card refers to the sequence number of the plot request for which the curve drawing specification is input. For example, 203nnn50 refers to the first plot request, 203nnn53 refers to the fourth plot request, etc. If a curve drawing specification refers to an undefined plot request, an error will result. Any or all of the cards may be omitted, in which case appropriate defaults will be selected. The data entered on the cards specify a curve legend label, the type of line drawn for the curve, the type of symbol drawn for the curve, and the number of data points skipped between symbols. No provision is allowed for spline fitting or smoothing of calculational results. If only one curve is to be drawn, the legend label is ignored and no legend is written on the plot. The data are input in the following format.

- W1-W2(A) LEGEND LABEL. This defines the legend label and is composed of two alphanumeric words enclosed by quotation symbols (defaults to the variable code, parameter words described for the plot request Cards 203nnn00 through 203nnn09). If the legend label is entered, it must be composed of sufficient characters for two words. The \$ symbol may not be embedded in the character string.
- W3(A) CURVE LINE TYPE KEYWORD. This must be entered as one of the following:
- LINE A continuous line will be drawn connecting the data points.
- DOTS A dotted line will be drawn connecting the data points.
- DASHES A dashed line will be drawn connecting the data points.
- CDOTS A chain dotted line will be drawn connecting the data points. The chain pattern is composed of a long dash followed by a space, a dot, and a space.
- CDASHES A chain dashed line will be drawn connecting the data points. The pattern is composed of a long dash followed by a space, a short dash, and a space.
- W4(I) SYMBOL INDEX. This defines the plot symbol to be drawn at intervals of a specified number of data points. If W4 is omitted or input as zero, a symbol will not be drawn. Similarly, if several curves are drawn with the same line specification, a default symbol will be selected. The symbol index is checked for each curve to be drawn. If a redundant symbol has been input, an error message will be printed and the input symbol will be reset to the next available symbol.
- W5(I) NUMBER OF DATA POINT INTERVALS. This defines the number of data point intervals between plot symbols. The plot symbol defined by W4 will be drawn at intervals of W5 data points. If W5 is omitted, it will default to five.

A.13.6.7 Cards 203nnn60 Through 203nnn69, Plot Option Changes

These cards define changes to any or all of the general plot options input by Cards 20300010 through 20300019. These changes will be in effect for only the nnn00 plot, and the general plot options will remain in effect for all other plots. The input format for these cards is identical to that for the 20300010 through 20300019 cards.

A.13.6.8 Card 203nnn70, Plot Size Dimension Changes

This card defines changes to the general plot size dimensions input by Card 20300020. The changes will be in effect only for the nnn00 plot, and the general plot size dimensions will remain in effect for all other plots. The input format for this card is identical to that for the 20300020 card.

A.13.7 Cards 204mmml, Plot Comparison Data Tables

These cards input tables of data that are to be plotted on the same graphs as SCDAP/RELAP5 results for visual comparison. Each set of cards defines the table dependent and independent variables and the format by which the data are input. The plot curve specifications for each table are also defined.

A.13.7.1 Card 204mmm00, Plot Comparison Data Table Request

This card inputs the variable code naming the plot comparison data table dependent variable, its corresponding units keyword, and the two keywords defining the table data input format. The card is required to define a plot comparison data table. If the card is omitted and table specifications or data are entered, an error will result. The data input by the card are entered in the following format.

- W1(A) TABLE DEPENDENT VARIABLE CODE (YNAME). YNAME is required and may not be omitted. The variable code is defined similarly to that for Cards 301 through 399 and 203nnn00 through 203nnn09, except that the keywords DELETE or DISCARD may also be entered. The variable code YNAME for a plot comparison data table must be identical to the variable code PARNAM for a plot request referencing the table, or an error will result. For RESTART or PLOT jobs, if the keyword DELETE or DISCARD is input as YNAME, the entire data table record will be deleted. If the user wishes to replace, insert, or add a plot comparison data table, the input is the same as for a NEW job. If keywords DELETE or DISCARD are input, no other cards may be input for the deleted record or an error will result. If a plot request is deleted that references a plot comparison data table and if the plot comparison data table is not referenced by a remaining plot request, then an error will result.
- W2(A) DEPENDENT VARIABLE UNITS KEYWORD. SCDAP/RELAP5 calculations are performed in SI units throughout the code. Therefore, plot comparison data must be converted upon input to SI units for use by the code, even though the units in which a plot is to be made may not be SI units. The units keywords allowed are

described as follows. If omitted, the default is SI.

- SI THE DEPENDENT VARIABLE DATA IS INPUT IN SI UNITS. This is the default.
- BRITISH THE DEPENDENT VARIABLE DATA IS INPUT IN BRITISH UNITS. The code will automatically correct the input to SI units.
- SPECIAL THE DEPENDENT VARIABLE DATA IS INPUT IN SPECIAL UNITS. For this card, the coefficients for a units equation must be input on Cards 204mmm01 through 204mmm08 or an error will result.
- W3(A) TABLE FORMAT SPECIFICATION KEYWORD. Enter one of the two table format specification keywords PAIRS or SETS. If PAIRS is entered, the table data must be input as pairs of independent, dependent variables (or vice versa). If SETS is entered, the table data must be input in complete sets of independent and dependent variables (or vice versa). Refer to the 204mmm20 through 204mmm99 cards for additional explanation. If W3 is omitted or input as " ", it defaults to PAIRS.
- W4(A) TABLE FORMAT SPECIFICATION KEYWORD. Enter one of the two table format specification keywords INDEPFIRST or DEPFIRST. If INDEPFIRST is entered, the table data must be input with the independent variable occurring first. If DEPFIRST is entered, the table data must be input with the dependent variable occurring first. Refer to the 204mmm20 through 204mmm99 cards for additional explanation. If W4 is omitted or input as " ", it defaults to INDEPFIRST.

A.13.7.2 Cards 204mmm01 Through 204mmm08, Dependent Variable Units Conversion

These cards are required if SPECIAL is entered as W2 on Card 204mmm00. Each card inputs a unit conversion coefficient $a(k)$, where the coefficient index k is implied by the Card Number 204mmm0k and where k ranges from 1 through 8. The units conversion equation is

$$y(\text{SI}) = a(8) * (a(1) + y * \{a(2) + y * [a(3) + y * a(4)]\} + a(5) * y ** a(6) + a(7) * \text{ALOG}(y)).$$

Any of the cards may be omitted, in which case the omitted coefficient will default. However, at least one card must be input or an error will result. The coefficients default to the following values:

$$a(1) = 0.0$$

$$a(2) = 1.0$$

$$a(3) = 0.0$$

$$a(4) = 0.0$$

$$a(5) = 0.0$$

$$a(6) = 1.0$$

$$a(7) = 0.0$$

$$a(8) = 1.0$$

Any value may be entered for a coefficient providing the following conditions are satisfied. At least one of the coefficients a(1) through a(5) or a(7) must be nonzero. The coefficient a(6) may not be entered as zero. Y may not be entered as zero if a(7) is nonzero. The coefficient a(8) may not be entered as zero. If any of these conditions is not satisfied, an error will result.

A.13.7.3 Card 204mmm10, Table Independent Variable

This card inputs the variable code naming the plot comparison data table independent variable and its corresponding table units keyword. The card may be omitted, in which case the variable code will default to TIME and the units keyword will default to SI. The format for the data must be entered as follows.

W1(A) VARIABLE CODE FOR THE TABLE INDEPENDENT VARIABLE (XNAME). XNAME is the variable code for the table independent variable. The variable code is defined similarly to that for Cards 300 through 399 and 203nnn10 through 203nnn99. The variable code XNAME must be identical to the variable code XARNAM for a plot request referencing the table or an error will result. XNAME defaults to the variable code TIME.

W2(A) TABLE INDEPENDENT VARIABLE UNITS KEYWORD. Enter a units keyword defining the units of the table independent variable input data. The keywords and the rules for entering them are identical to those for W2 of Card 204mmm00. If the keyword entered is SPECIAL, then the appropriate units coefficient Cards 204mmm11 through 204mmm18 must be entered, as described for Cards 204mmm01 through 204mmm08

A.13.7.4 Cards 204mmm11 Through 204mmm18, Independent Variable Units Conversion

These cards are required if SPECIAL is entered as W2 on Card 204mmm10. Each card inputs a unit conversion coefficient b(k), where the coefficient index k is implied by the card number 204mmm1k and where k ranges from 1 through 8. The units conversion equation is

$$x(SI) = b(8)*(b(1) + x*\{b(2) + x*[b(3) + x*b(4)]\} + b(5)*x**b(6) + b(7)*ALOG(x)).$$

The rules applying to the b and X terms are the same as those explained for the a and y terms for Cards 204mmm01 through 204mmm08.

A.13.7.5 Card 204mmm19, Data Curve Specification

This card is optional, and the data entered are similar to that explained for the 203nnn40 card, except that a SPLINE option is included for smoothing of the curve drawn for the table data. The data are input in the following format.

W1-W2(A)	LEGEND LABEL. This defines the legend label and is composed of two alphanumeric words enclosed by quotation symbols. It defaults to YNAME as entered on the 204mmm00 card and the Table Number mmm00 encoded together. If the legend label is entered, it must be composed of sufficient characters for two words.
W3(A)	CURVE LINE TYPE KEYWORD. Must be entered as one of the following:
NOLINE	No line will be drawn connecting the data points. This automatically requires that a plot symbol is drawn at each data point. To define the plot symbol, refer to W4.
LINE	A continuous line will be drawn connecting the data points.
DOTS	A dotted line will be drawn connecting the points.
DASHES	A dashed line will be drawn connecting the points.
CDOTS	A chain dotted line will be drawn connecting the points. The chain pattern is composed of a long dash followed by a space, a dot, and a space.
CDASHES	A chain dashed line will be drawn connecting the points. The pattern is composed of a long dash followed by a space, a short dash, and a space.
W4(I)	SYMBOL INDEX. This defines the plot symbol to be drawn at intervals of a specified number of data points. If W4 is omitted or input as zero, a symbol will not be drawn. If the line type keyword input for W3 is NOLINE, a default symbol will be selected. Similarly, if several curves are drawn with the same line specification, a default symbol will be selected. The symbol index is checked for each curve to be drawn. If a redundant symbol has been input, an error message will be printed and the input symbol will be reset to the next available symbol.
W5(I)	NUMBER OF DATA POINT INTERVALS. This defines the number of data point intervals between plot symbols. The plot symbol defined by W4 will be drawn at intervals of W5 data points. If W5 is omitted, it will default to five. However, if the line type keyword input for W3 is NOLINE, then W5 is set to one unconditionally.
W6(A)	SPLINE INTERPOLATION KEYWORD. The keywords that may be entered are SPLINE and NOSPLINE. If W6 is omitted or input as "", it will default to NOSPLINE and the curve will be drawn with straight-line segments connecting each data point. If W6 is entered as the keyword SPLINE, the curve will be drawn

as a smooth continuous curve by means of spline interpolation between data points. If W6 is entered as any word other than SPLINE or NOSPLINE, an error will result.

A.13.7.6 Cards 204mmm20 Through 204mmm99, Plot Comparison Data Table Input Data

These cards contain the plot comparison data and are required if a 204mmm00 Card is input. Storage has been allocated for up to 4,000 data points. The same number of independent and dependent variable data points must be entered or an error will result. The order of the card numbering sequence determines the order in which the independent variables are plotted. The cards need not be numbered successively and need not be input in the order in which the code will sort them. If more than one independent variable is entered per card, the independent variables must be entered in the order in which they are to be plotted. The dependent variable data points must be entered in a one-to-one correspondence order with the independent variable data. If more than 80 cards are required to input the data, continuation cards may be used.

The format for entering the data is defined by W3 and W4 on the 204mmm00 Card. For example, if W3 is PAIRS and W4 is INDEPFIRST, then the data must be entered as an independent-dependent variable pair followed by the next independent-dependent variable pair, etc. If W3 is SETS and W4 is DEPFIRST, then the data must be entered as the entire set of dependent variable data followed by the entire set of independent variables. If the number of dependent variables entered is not equal to the number of independent variables, an error will result.

A.14 CARDS 205CCCNN OR 205CCCCN, CONTROL SYSTEM INPUT DATA

These cards are used in NEW and RESTART problems if a control system is desired. They are also used to define the generic control components employed with the self-initialization option. Input can also be used to compute additional quantities from the normally computed quantities. These additional quantities can then be output in major and minor edits and plots.

Two different card types are available for entering control system data, but only one type can be used in a problem. The digits ccc or cccc form the control variable number (i.e., control component number). The card format 205cccn allows 999 control variables, where ccc ranges from 001 through 999. The card format 205cccn allows 9,999 control variables, where cccc ranges from 1 through 9,999.

If the self-initialization option is selected, the data cards described in Section A.14.2, A.14.3.19, and A.14.3.20 must be included. If loop flow control is to be included, the data cards described in Section A.14.3.18 must also be included.

A.14.1 Card 20500000, Control Variable Card Type

If this card is omitted, Card Type 205cccn is used. If this card is entered, either card format can be selected. This card cannot be entered on RESTART problems if control components exist from the restart problem, in which case the card format from the restart problem must be used.

W1(I) CONTROL VARIABLE FORMAT. Enter 999 to select the 205cccn format or 9,999 (4,095 also allowed) to select the 205cccn format.

A.14.2 Card 205ccc00 or 205cccc0, Control Component Type Card

One card must be entered for each of the generic control components when using the self-initialization option.

W1(A) ALPHANUMERIC NAME. Enter a name descriptive of the component. This name will appear in the printed output along with the component number. A limit of 10 characters is allowed for CDC 7600 computers, and a limit of 8 characters is allowed for most other computers.

W2(A) CONTROL COMPONENT TYPE. Enter one of the component names, SUM, MULT, DIV, DIFFRENI, DIFFREND, INTEGRAL, FUNCTION, STDFNCTN, DELAY, TRIPUNIT, TRIPDLAY, POWERI, POWERR, POWERX, PROP-INT, LAG, LEAD-LAG, CONSTANT, SHAFT, PUMPCTL, STEAMCTL, or FEEDCTL, or the command, DELETE. If DELETE is entered, enter any alphanumeric word in Word 1 and zeros in the remaining words. No other cards are needed when deleting a component.

- W3(R) SCALING FACTOR. For a CONSTANT component, this quantity is the constant value. No additional words are entered on this card, and Cards 205ccc01 through 205ccc09 or 205cccc1 through 205cccc9 are not entered. For the PUMPCTL, STEAMCTL, or FEEDCTL components, this is the gain multiplier (G) for the output signal.
- W4(R) INITIAL VALUE.
- W5(I) INITIAL VALUE FLAG. Zero means no initial condition calculation and W4 is used as the initial condition; one means compute initial condition.
- W6(I) LIMITER CONTROL. Enter zero or omit this and the following words if no limits on the control variable are to be imposed. Enter 1 if only a minimum limit is to be imposed, 2 if only a maximum limit is to be imposed, and enter 3 if both minimum and maximum limits are to be imposed.
- W7(R) MINIMUM OR MAXIMUM VALUE. This word is the minimum or maximum value if only one limit is to be imposed or is the minimum value if both limits are to be imposed.
- W8(R) MAXIMUM VALUE. This word is used if both limits are to be imposed.

A.14.3 Cards 205ccc01 Through 205ccc98 or 205cccc1 Through 205cccc8, Control Component Data Cards

The format of these cards depends on the control component type. An equation is used to describe the processing by each component. The symbol Y represents the control variable defined by the component. The symbols A_j , $j=1,2,\dots,J$, represent constants defined by the control component input data. The variables V_j , $j=1,2,\dots,J$, represent any of the variables listed in the minor edit input description. Besides hydrodynamic component data, heat structure data, reactor kinetic data, etc., any of the control variables including the variable being defined may be specified. The symbol S is the scale factor (or G, the gain multiplier, for self-initialization control components) on Card 205ccc00 or 205cccc0. The variables V_j use the code's internal units (SI). To use British units, the user must convert from SI to British using the scale factor S (or the gain multiplier G) and the constants A_j .

A.14.3.1 Sum-Difference Component

This component is indicated by SUM in Word 2 of Card 205ccc00 or 205cccc0. The sum-difference component is defined by

$$Y = S(A_0 + A_1*V_1 + A_2*V_2 + \dots + A_J*V_J)$$

W1(R) CONSTANT A_0 .

W2(R) CONSTANT A_1 .

- W3(A) ALPHANUMERIC NAME OF VARIABLE REQUEST CODE FOR V_1 .
- W4(I) NUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 . At least four words that define a constant and one product term must be entered. Additional sets of three words corresponding to Words 2 through 4 can be entered for additional product terms up to 20 product terms. One or more cards may be used as desired. Card numbers need not be strictly consecutive. The sign of A_j determines addition or subtraction of the product terms.

| A.14.3.2 Multiplier Component

This component is indicated by MULT in Word 2 of Card 205ccc00 or 205cccc0. The multiplier component is defined by

$$Y = S V_1 V_2 \dots V_j$$

- W1(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .
- W2(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 . At least two words must be entered. Additional pairs of words can be entered on this or additional cards to define additional factors. Card numbers need not be strictly consecutive.

| A.14.3.3 Divide Component

This component is indicated by DIV in Word 2 of Card 205ccc00 or 205cccc0. The divide component is defined by

$$Y = S/V_1 \text{ or } Y = S V_2/V_1.$$

Specifying two words on the card indicates the first form, and specifying four words on the card indicates the second form. Execution will terminate if a divide by zero is attempted.

- W1(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .
- W2(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .
- W3(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_2 .
- W4(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_2 .

| A.14.3.4 Differentiating Components

These components are indicated by DIFFRENI or DIFFREND in Word 2 of Card 205ccc00 or 205cccc0. The differentiating component is defined by

$$Y = S \frac{dV_1}{dt}$$

This is evaluated by

$$Y = S*[2(V1 - V1o)/\Delta t] - Y_o \quad (\text{DIFFRENI})$$

$$Y = S*(V1 - V1o)/\Delta t \quad (\text{DIFFREND}),$$

where Δt is the time step, and $V1o$ and Y_o are values at the beginning of the time step. The numerical approximations for the DIFFRENI and INTEGRAL components are exact inverses of each other. However, an exact initial value is required to use the DIFFRENI component, and erroneous results are obtained if an exact initial value is not furnished. The DIFFREND component uses a simple difference approximation that is less accurate, is not consistent with the integration approximation, but does not require an initial value. Use of DIFFRENI is not recommended.

Since differentiation, especially numerical differentiation, can introduce noise into the calculation, it should be avoided if possible. When using control components to solve differential equations, the equations can be arranged such that INTEGRAL components can handle all indicated derivatives except possibly those involving noncontrol variables.

W1(A) ALPHANUMERIC NAME OF VARIABLE REQUEST CODE FOR V_1 .

W2(I) INTEGER NAME OF VARIABLE REQUEST CODE FOR V_1 .

| A.14.3.5 Integrating Component

This component is indicated by INTEGRAL in Word 2 of Card 205ccc00 or 205cccc0. The integrating component is defined by

$$Y = S \int_0^t V_1 dt$$

or, in Laplace notation,

$$y(s) = \frac{SV_1(s)}{s}$$

This is evaluated by

$$Y = Y_o + S*(V1 + V1o)*\Delta t/2,$$

where Δt is the time step and Y_o and $V1o$ are the values at the beginning of the time step.

W1(A) Alphanumeric name of the variable request code for V_1 .

W2(I) Integer name of the variable request code for V_1 .

| A.14.3.6 Functional Component

This component is indicated by FUNCTION in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = S[\text{FUNCTION}(V_1)]$$

where FUNCTION is defined by a general table. This allows the use of any function conveniently defined by a table lookup and linear interpolation procedure. The function component can also be used to set limiting values.

W1(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W2(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W3(I) GENERAL TABLE NUMBER OF THE FUNCTION.

| A.14.3.7 Standard Function Component

This component is indicated by STDFNCTN in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = S[\text{FNCTN}(V_1, V_2, \dots)]$$

where FNCTN is ABS (absolute value), SQRT (square root), EXP (e raised to power), LOG (natural logarithm), SIN (sine), COS (cosine), TAN (tangent), ATAN (arc tangent), MIN (minimum value), or MAX (maximum value). All function types except MIN and MAX must have only one argument; MIN and MAX function types must have at least two arguments and may have up to 20 arguments. If the control variable being defined also appears in the argument list of MIN or MAX, the old time value is used in the comparison.

W1(A) FNCTN.

W2(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W3(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

| A.14.3.8 Delay Component

This component is indicated by DELAY in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = SV_1(t - t_d)$$

where t is time and t_d is the delay time.

W1(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W2(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W3(R) DELAY TIME, t_d (s).

W4(I) NUMBER OF HOLD POSITIONS. This quantity, h , must be > 0 and ≤ 100 . This quantity determines the length of the table used to store past values of the quantity V_1 . The maximum number of time-function pairs that can be stored is $h+2$. The delay table time increment, d_{TM} , is $d_{TM} = t_d/h$. The delayed function is obtained

by linear interpolation for $V_1(t-t_d)$ using the stored past history. As the problem is advanced in time, new time values are added to the table. Once the table is filled, new values replace values that are older than the delay time. There are no restrictions on $t_d T$ or d_{TM} relative to the time steps on Cards 2nn.

| A.14.3.9 Unit Trip Component

This component is indicated by TRIPUNIT in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = S * U (\pm T_1),$$

where U is 0.0 if the trip, T_1 , is false and is 1.0 if the trip is true. If the complement of T_1 is specified, U is 1.0 if the trip is false and 0.0 if the trip is true.

W1(I) TRIP NUMBER, T_1 . A minus sign may prefix the trip number to indicate that the complement of the trip is to be used.

| A.14.3.10 Trip Delay Component

This component is indicated by TRIPDLAY in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = S T_{rptim}(T_1),$$

where T_{rptim} is the time the trip last turned true. If the trip is false, the value is -1.0; if the trip is true, the value is zero or a positive number.

W1(I) TRIP NUMBER, T_1 .

| A.14.3.11 Integer Power Component

This component is indicated by POWERI in Word2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = (SV_1)^{I_1}.$$

W1(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W2(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W3(I) I_1 .

| A.14.3.12 Real Power Component

This component is indicated by POWERR in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = (SV_1)R^1.$$

W1(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W2(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W3(R) R_1 .

A.14.3.13 Variable Power Component

This component is indicated by POWERX in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = (SV_1)V^2$$

W1(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W2(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W3(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_2 .

W4(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_2 .

A.14.3.14 Proportional-Integral Component

This component is indicated by PROP-INT in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = S \left[A_1 V_1 + A_2 \int_0^t V_1 dt \right]$$

or in Laplace transform notation,

$$Y(s) = S \left[A_1 + \frac{A_2}{s} \right] V_1(s)$$

If the control variable is initialized,

$$Y(t_0) = SA_1 V_1(t_0)$$

If it is desired that the output quantity Y remain constant as long as the input quantity remains constant, V_1 must initially be zero regardless of the initialization flag.

W1(R) A_1 .

W2(R) A_2 .

W3(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W4(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

A.14.3.15 Lag Component

This component is indicated by LAG in Word 2 of Card 205ccc00 or 205cccc0. This component is defined by

$$Y = \int_0^t \left(\frac{SV_1 - Y}{A_1} \right) dt$$

or, in Laplace transform notation,

$$Y(s) = \frac{S}{1 + A_1 s} V_1(s)$$

If the control variable is initialized,

$$Y(t_0) = SV_1(t_0)$$

If the initialization flag is set on and if the initial values of Y and V_1 satisfy a specified relationship (see control component description in Volume 1), Y remains constant as long as V_1 retains its initial value.

W1(R) LAG TIME, A_1 (s).

W2(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W3(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

A.14.3.16 Lead-Lag Component

This component is indicated by LEAD-LAG in Word 2 of Card 205ccc00 or 205cccc0. The component is defined by

$$Y = \frac{A_1 SV_1}{A_2} + \int_0^t \left(\frac{SV_1 - Y}{A_2} \right) dt$$

or, in Laplace transform notation,

$$Y(s) = S \frac{1 + A_1 s}{1 + A_2 s} V_1(s)$$

If the control variable is initialized,

$$Y(t_0) = SV_1(t_0)$$

If the initialization flag is set on and if the initial values of Y and V_1 satisfy a specified relationship (see control component description in Volume 1), Y remains constant as long as V_1 retains its initial value.

W1(R) LEAD TIME, A_1 (s).

W2(R) LAG TIME, A_2 (s).

W3(A) ALPHANUMERIC NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

W4(I) INTEGER NAME OF THE VARIABLE REQUEST CODE FOR V_1 .

A.14.3.17 Constant Component

Cards 205ccc01 through 205ccc09 or 205cccc1 through 205cccc9 are not entered. The quantity in Word 3 of Card 205ccc00 or 205cccc0 is the constant value used for this component.

A.14.3.18 Shaft Component

This component is indicated by SHAFT in Word 2 of Card 205ccc00 or 205cccc0. A GENERATR component may optionally be associated with a SHAFT component. The SHAFT component advances the rotational velocity equation

$$\sum_i I_i \frac{d\omega}{dt} = \sum_i \tau_i - \sum_i f_i \omega + \tau_c$$

where I_i is the moment of inertia of component i , ω is rotational velocity, τ_i is torque of component i , f_i is the friction factor of component i , and τ_c is an optional torque from a control component. The summations include the shaft as well as the pump, turbine, and generator components connected to the shaft.

The SHAFT control component differs somewhat from other control components. The scale factor on Card 205ccc00 or 205cccc0 must be 1.0. The initial value and optional minimum and maximum values have units (rad/s, rev/min), and British-SI units conversion are applied to these quantities. The output of the SHAFT in minor and major edits is in the requested units. Card number ranges are restricted so that both data to complete the SHAFT component description and optional data to describe a generator can be entered. Units conversion is applied to the following cards.

A.14.3.18.1 Card 205ccc01 Through 205ccc05 or 205cccc1 Through 205cccc5, Shaft Description Card.

- W1(I) TORQUE CONTROL VARIABLE NUMBER. If zero, there is no contribution to torque from the control system. If nonzero, the control variable with this number is assumed to be a torque and is added to the torques from the other components attached to the shaft. The torque must be in SI units.
- W2(R) SHAFT MOMENT OF INERTIA, I_1 ($\text{kg}\cdot\text{m}^2$, $\text{lb}\cdot\text{ft}^2$).
- W3(R) FRICTION FACTOR FOR THE SHAFT, f_1 ($\text{N}\cdot\text{m}\cdot\text{s}$, $\text{lb}\cdot\text{ft}\cdot\text{s}$).
- W4(A) TYPE OF ATTACHED COMPONENT. Enter either TURBINE, PUMP, or GENERATR.
- W5(I) COMPONENT NUMBER. This is the hydrodynamic component number for a TURBINE or PUMP, or the control variable number for this SHAFT component if

GENERATR.

Additional two-word pairs may be entered to attach additional components to the shaft, up to a total of 10 components. Only one generator, the one defined as part of this SHAFT component, may be attached.

A.14.3.18.2 Card 205ccc06 or 205cccc6, Generator Description Card. Each SHAFT component may optionally define an associated GENERATR component.

- W1(R) INITIAL ROTATIONAL VELOCITY (rad/s, rev/min).
- W2(R) SYNCHRONOUS ROTATIONAL VELOCITY (rad/s, rev/min).
- W3(R) MOMENT OF INERTIA, I_i ($\text{kg}\cdot\text{m}^2$, $\text{lb}\cdot\text{ft}^2$).
- W4(R) FRICTION FACTOR, f_i ($\text{N}\cdot\text{m}\cdot\text{s}$, $\text{lb}\cdot\text{ft}\cdot\text{s}$).
- W5(I) GENERATOR TRIP NUMBER. When the trip is false, the generator is connected to an electrical distribution system and rotational velocity is forced to the synchronous speed. When the trip is true, the generator is not connected to an electrical system and the generator and shaft rotational velocity is computed from the rotational velocity equation.
- W6(I) GENERATOR DISCONNECT TRIP NUMBER. If zero, the generator is always connected to the shaft. If nonzero, the generator is connected to the shaft when the trip is false and disconnected when the trip is true.

A.14.3.19 PUMPCTL Component

This component is specified when using the self-initialization option and loop flow control is desired but is not limited to that use. For each PUMPCTL component enter:

- W1(A) ALPHANUMERIC NAME OF SET POINT VARIABLE.
- W2(I) PARAMETER PART OF SET POINT VARIABLE.
- W3(A) ALPHANUMERIC NAME OF SENSED VARIABLE.
- W4(I) PARAMETER PART OF SENSED VARIABLE.
- W5(R) SCALE FACTOR. Scale factor(s) applied to sensed and setpoint values, S_i . Must be nonzero.
- W6(R) INTEGRAL NAME TIME CONSTANT, T_2 (s).
- W7(R) PROPORTIONAL PART-TIME CONSTANT, T_1 (s).

Standard use of PUMPCTL controller require the following interpretation of the input data. W1 and W2 contain CNTRLVAR and ccc (or cccc), respectively, where ccc (or cccc) is a

CONSTANT type control element containing the desired (set point) flow rate. W3 is MFLOWJ, and W4 is the junction number at which the flow is to be sensed and compared to the set point. W5 is the S_j value used to divide the difference between the desired (set point) and sensed flow rate to produce the error signal E_1 . E_1 must be initially zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. W6 and W7 are the T_2 and T_1 values, respectively. All variables having units must be in SI units.

A.14.3.20 STEAMCTL Component

This component is specified when using the self-initialization option to control steam flow from one or more steam generators but is not limited to that use. For each STEAMCTL component enter:

- W1(A) ALPHANUMERIC NAME OF SET POINT VARIABLE.
- W2(I) PARAMETER PART OF SET POINT VARIABLE.
- W3(A) ALPHANUMERIC NAME OF SENSED VARIABLE.
- W4(I) PARAMETER PART OF SENSED VARIABLE.
- W5(R) SCALE FACTORS. Scale factor(s) applied to sensed and set point values, S_j . Must be nonzero.
- W6(R) INTEGRAL NAME TIME CONSTANT, T_4 (s).
- W7(R) PROPORTIONAL PART-TIME CONSTANT, T_3 (s).

Standard use of the STEAMCTL controller requires the following interpretation of the input data. W1 and W2 would contain CNTRLVAR and ccc (or cccc), respectively, where ccc (or cccc) is a CONSTANT type control element. This constant would be the desired (set point) cold leg temperature (for Suboptions A and B) or secondary pressure (Suboptions C and D). W3 would be TEMPF (for Suboptions A and B) or P (for Suboptions C and D), and W4 would be the volume number where the temperature (Suboptions A and B) or pressure (Suboptions C and D) is sensed. W5 is the S_j value used to divide the difference between the desired (set point) and sensed temperature (Suboptions A and B) or pressure (Suboptions C and D) to produce the error signal E_2 . E_2 must be initially zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. W6 and W7 are the T_4 and T_3 values, respectively. All variables having units must be in SI units.

A.14.3.21 FEEDCTL Component

This component is specified when using the self-initialization option to control feedwater flow to a steam generator but is not limited to that use. For each FEEDCTL component enter:

- W1(A) ALPHANUMERIC NAME OF FIRST SET POINT VARIABLE.

CARDS 205CCCNN OR 205CCCCN, CONTROL SYSTEM INPUT DATA

W2(I)	PARAMETER PART OF FIRST SET POINT VARIABLE.
W3(A)	ALPHANUMERIC NAME OF SENSED VARIABLE TO BE COMPARED WITH FIRST SET POINT.
W4(I)	PARAMETER PART OF SENSED VARIABLE TO BE COMPARED WITH FIRST SET POINT.
W5(R)	SCALE FACTOR. Scale factor applied to sensed and setpoint values (first setpoint), S_k . Must be nonzero.
W6(A)	ALPHANUMERIC NAME OF SECOND SET POINT VARIABLE.
W7(I)	PARAMETER PART OF SECOND SET POINT VARIABLE.
W8(A)	ALPHANUMERIC NAME OF SENSED VARIABLE TO BE COMPARED WITH SECOND SET POINT.
W9(I)	PARAMETER PART OF SENSED VARIABLE TO BE COMPARED WITH SECOND SET POINT.
W10(R)	SCALE FACTOR. Scale factor applied to sensed and setpoint values (second setpoint), S_m . Must be nonzero.
W11(R)	INTEGRAL NAME TIME CONSTANT, T_6 (s).
W12(R)	PROPORTIONAL PART-TIME CONSTANT, T_5 (s).

Standard use of the FEEDCTL controller requires the following interpretation of the input data. W1 and W2 contain CNTRLVAR and ccc (or cccc), respectively, where ccc (or cccc) is a CONSTANT type control element. This constant would be the desired (set point) steam generator secondary side water level. The latter may be expressed alternatively as a desired secondary coolant mass or as a differential pressure measured between two locations in the steam generator downcomer. W3 and W4 would contain CNTRLVAR and ccc (or cccc), respectively, where ccc (or cccc) is the number of the control component that describes the summing algorithm to compute the sensed variable (e.g., collapsed water level may be computed by summing the product of VOIDF and volume length over the control volumes in the riser section). W5 is the S_k value used to divide the difference between the desired (set point) and sensed water level to produce the first portion of the error signal E_3 . W6 is MFLOWJ, and W7 is the junction number of the steam exit junction from the steam generator. W8 is MFLOWJ, and W9 is the junction number of the feedwater inlet junction. W10 is the S_m value used to divide the difference between the sensed steam flow and sensed feedwater flow to produce the second portion of the error signal E_3 . E_3 must be initially zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. W11 and W12 are the T_6 and T_5 values, respectively. All variables having units must be in SI units.

A.15 CARDS 20700000 THROUGH 20799999, FISSION PRODUCT AND AEROSOL TRANSPORT

These cards are required only when the fission product aerosol behavior models are desired when performing a severe accident analysis. These cards are optional and may be entered in NEW or RESTART problems.

A.15.1 Card 20700000, Aerosol Size Bins

W1(I) **NUMBER OF BINS OR DELETE FLAG.** Zero may be entered in a RESTART problem having a fission product transport model and indicates that the model is to be terminated and all fission product data are to be deleted. No other cards in the range 20700001 through 20799999 may be entered. A positive nonzero quantity may be entered in a RESTART problem with a fission product model to indicate that the current fission product data are to be discarded and a new model entered. A positive nonzero number in a NEW problem or a RESTART without a fission product transport model indicates that the fission product transport model is to be started. The nonzero number is the number of aerosol bins. The number of bins must be > 1 and < 50 .

A.15.2 Cards 20700001 Through 20700005, Hydrodynamic System Specification

These cards specify the hydrodynamic systems for which the fission product transport calculation is to be made. These cards may be entered in NEW or RESTART problems. A hydrodynamic system is selected by entering one of the volumes in the hydrodynamic system. Only one volume per system may be entered on these cards. A positive volume number indicates that a fission product transport calculation is to be added to the hydrodynamic system. A negative volume number means that the fission product transport model is to be terminated for the hydrodynamic system and the associated data discarded. An input error results if an attempt is made to specify the fission product transport model for a hydrodynamic system already having the model. If in a RESTART, no hydrodynamic systems with fission transport remain, all fission product data are discarded. If Card 20700000 with W1 nonzero is entered, an input error results if no hydrodynamic systems with fission product transport are present.

If volumes are added or deleted in hydrodynamic systems with fission product transport, fission product data corresponding to those volumes are similarly added or deleted. If an entire hydrodynamic system is deleted, the corresponding fission product system is deleted. All fission product systems may be deleted in this manner, but an input error results if this occurs and Card 20700000 with W1 nonzero is entered. If hydrodynamic systems are merged (by junctions connecting them), the fission product systems are similarly merged.

Data may be entered one or more words per card, one or more cards as needed.

W1(I) **VOLUME NUMBER OF SELECTED HYDRODYNAMIC SYSTEM.** This

number is plus or minus, as described above.

A.15.3 Card 20700010, Convergence Criteria

This card may be entered whenever Card 20700000 with W1 nonzero is entered or in any RESTART problem with an existing fission product model. Default values or previously entered values are used if this card is omitted.

W1(R) FIRST CONVERGENCE VALUE (E_1).

W2(R) SECOND CONVERGENCE VALUE (E_2).

A.15.4 Cards 20700011 Through 20700018, Species Selection Cards

These cards must be entered whenever Card 20700000 with W1 nonzero is entered and are not entered otherwise. Each word specifies a species to be tracked, and a species may be entered only once. At least one species must be entered, and all species may be entered if desired.

The allowed symbols and species are: I (iodine), CsI (cesium iodide), CsOH (cesium hydroxide), Te (tellurium), HI (hydrogen iodide), HTe (hydrogen telluride), Cd (cadmium), Ag (silver), UO₂ (uranium dioxide), Sn (tin), Fe (iron), Ru (ruthenium), B (barium), Sr (strontium), Cs* (user-defined), and I* (user-defined). The symbols are entered, one or more symbols per card, on one or more cards as desired for the desired species.

W1(A) SPECIES SYMBOL.

A.15.5 Cards 2070nnnm, Initial Conditions

Whenever a hydrodynamic volume is associated with the fission product transport model, whether by the specification of a system or by addition of volumes through renodalization, the initial aerosol masses are assumed zero. These cards can be entered in NEW or RESTART problems to set different initial values or to reset values in existing volumes. Since the fission product aerosol masses are zero for undamaged fuel, these cards are generally not needed. Entering data for a volume not involved in a fission product transport calculation is an error.

In the card numbering, nnn ranges from 002 to 999; and each nnn contains the initial conditions for one volume or a range of volumes. The cards are processed in order of increasing nnn. The initial conditions for a volume may be set in one specification and overridden in a subsequent specification. Not all species need to be entered in each specification; and, when not entered, the initial spatial densities remain at the previously set value or the default zero value.

A.15.5.1 Card 2070nnn0, Initial Volume Number

W1(I) INITIAL VOLUME NUMBER.

W2(I) FINAL VOLUME NUMBER. Both W1 and W2 must specify hydrodynamic

volumes in the problem. These volumes and all volumes with volume numbers between these words are initialized to the aerosol masses on Cards 2070nnn1 through 2070nnn9. All the volumes specified must be part of systems having fission product transport. If this word is omitted or equal to W1, the initial conditions are for the volume specified in W1.

| A.15.5.2 Cards 2070nnn1 Through 2070nnn9, Species

- W1(A) SPECIES SYMBOL. The allowed species are limited to those entered on Cards 20700011 through 20700018.
- W2(R) AEROSOL MASS OF SPECIES IN LIQUID FORM (kg, lb).
- W3(R) AEROSOL MASS OF SPECIES IN VAPOR FORM (kg, lb).
- W4...(R) AEROSOL MASS OF SPECIES IN SPATIAL DENSITIES FOR THE AEROSOLS IN EACH BIN (kg, lb).

A.16 ADDITIONAL PLOT VARIABLES

These cards put variables on a restart tape so their history from start of analysis is plotted. These variables do not need to be listed as variables printed in minor edits. All TRAPMELT and SCDAP variables to be plotted must be listed on a 20800nnn card.

A.16.1 Cards 20800nnn, Additional Plot Variables

These cards consist of the card number, followed by the variable name as specified in section A4, Minor Edit Requests.

Example input:

20800001 CADCT 000060201.

20800278 GAMMAW 231010000.

A.17 CREEP RUPTURE

The following cards are for the creep rupture model, which is used in conjunction with the COUPLE debris bed model. None of these cards are read on a RESTART problem.

A.17.1 CARD 21000000, Creep Rupture Control Card for COUPLE Wall

This card is optional if the COUPLE model is used but cannot be present if the COUPLE model is not used. All three values may be changed on RESTART.

W1(I) IMAT. Material index for COUPLE wall:

1	=	A-508 Class 2 carbon steel.
2	=	316 stainless steel.
3	=	Inconel 600.

If absent on a NEW problem, IMAT is set to 1.

W2(I) NCVOL. Volume number of containment. If there is not containment volume in the problem or if the user wishes not to use the containment pressure in the creep rupture calculations for the COUPLE wall, then the user should use zero for NCVOL. If absent on a new problem, NCVOL is set to zero.

W3(R) PEXT. Pressure outside the COUPLE wall. If NCVOL is > 0 , then this input value of PEXT is ignored and PEXT comes from the containment volume.

If NCVOL = 0, the PEXT is used for constant outside pressure. If NCVOL = 0 and PEXT is absent on a new problem, then PEXT is set to atmospheric pressure.

A.17.2 Cards 21000021 Through 21000029, Creep Rupture Location Elements in COUPLE Wall

One Card 2100002i is read for each COUPLE wall creep rupture calculation location i.

On a restart run, the pressure of any Card 2100002i will replace existing NELEM(i,j)'s for that i; and the creep rupture damage term for location i will be reset to 0.0. Thus, one should not repeat all initial 2100002i Cards in a restart run; only those for values of i which the user wishes to replace. On a restart run, one may also add new locations by specifying previously unused values of i. To remove location i on restart without replacement, specify W1(I) = 0 on Card 2100002i.

Each Card 2100002i lists n (1 to 11) elements of the COUPLE grid, which describe location i on the COUPLE wall.

W1(I) NELEM(1). Element 1 in location i.

WN(I) NELEM(N,1). Element n in location i.

A.17.3 Cards 21000101 Through 21000110, Creep Rupture Locations for SCDAP/RELAP5 Heat Structures

One Card 210001ii is read for each creep rupture calculation location ii, where the location is at the given heat structure.

On a restart run, the presence of any Card 210001ii will replace the data for location ii, and the creep rupture damage term for location ii will be reset to 0.0. Thus, one should not repeat all initial 210001ii Cards in a restart run, only those for values of ii that the user wishes to replace. On a restart run, one may add new locations by specifying previously unused values of ii. To remove location ii on restart without replacement, specify NHS(i) = 0 on Card 210001ii.

W1(I) NHS. Heat structure for which creep rupture failure calculation is to be done. The format for NHS is cccg00x, where ccc is the heat structure number and g is its geometry number.

W2(I) IMATHS. Material index for COUPLE wall:

1 = A-508 Class 1 carbon steel.

2 = 316 stainless steel.

3 = Inconel 600.

W3(R) PRIHS. Inner (left) pressure. If > 0.0 , this constant pressure is used. If absent or ≤ 0.0 , pressure is from adjacent volume.

W4(R) PROHS. Outer (right) pressure. If > 0.0 , this constant pressure is used. If absent or ≤ 0.0 , pressure is from adjacent volume.

A.18 SEVERE ACCIDENT CORE BEHAVIOR INPUT

The presence of these cards activates the SCDAP (Severe Core Damage Analysis) portion of the code and are required only when performing analysis of a severe accident scenario. Each card number begins with the digit '4,' followed by a unique three-digit component number, followed by a four-digit card number, as in '4ccctnn', where ccc represents the component number, tt represents the card type, and nn represents the card count.

Input Error Trapping

Comparative checks will occur during input processing for variable type, number of words on a card, range of normal use, and physical/code limits. Further checks will also be performed for consistency of input. For example, one consistency check will examine radial node placement and verify that radial nodes have been placed at material interfaces.

Input violations of variable type, number of words, physical limit, and consistency of input will result in an input error, but will not abort input processing. Error messages will be printed in the output file flagged with the character string "*****". If the input is outside the range of normal use, a warning message will be printed in the output file and marked with the character string "\$\$\$\$\$\$".

To assist the user during deck building and input processing, selected ranges of allowable input will be identified with the card input descriptions. The range for a given input variable will be identified in the following manner:

A.18.1 Global Input

These cards are required for NEW type problems. These cards describe general core geometry, and are also used to input core-wide parameters. These cards are identified with a component number of zero (000).

A.18.1.1 Card 40000100, SCDAP Control

This card is used to define general control parameters and to set a number of flags that control the types of facility dependent phenomena to be modeled.

This card is required for NEW problems, and cannot currently be changed for RESTART problems.

SEVERE ACCIDENT CORE BEHAVIOR INPUT

W1(I) NUMBER OF AXIAL NODES. The range^a is $2 \leq x \leq 10$.

W2(I) HEAT CONDUCTION FLAG. Always input the integer 1.

W3(I) REACTOR ENVIRONMENT.

This flag identifies phenomena for modeling fuel component meltdown and fission product release.

1 = PWR.

2 = BWR.

4 = ATR.

5 = Electrically heated core.

6 = SRS.

W4(I) POWER HISTORY TYPE.

This flag is used to specify the decay power reduction caused by the release of volatile fission products after fuel disruption. Six different built-in correction relations are provided, as follows:

1 = Generic PWR (33800 MWD/tU).

2 = TMI (3250 MWD/tU).

3 = PBF Severe Fuel Damage Test Series.

4 = PBF (Other test series).

5 = Full decay power.

6 = No decay power.

W5(I) Oxide shattering trip. If present, this trip number causes all the oxide in-core to be shattered when the trip becomes true. If specified as nonzero, the default logic to determine oxide shattering on reflood is not used.

A.18.1.2 Cards 40000201 Through 40000299, Axial Node Heights

This card is required for a NEW problem and cannot currently be changed for RESTART problems. The card format is two words per set in sequential expansion format.

W1(R) AXIAL NODE HEIGHT (m, ft). There must be a one-to-one correspondence between axial node heights and connected RELAP5 volume heights. The default is 0.1 m and the

a. The upper limit for the number of axial nodes in a SCDAP component is set in the code at compile time by the parameter ndax.

range is $0.0 \text{ m} < x \leq 2.0 \text{ m}$.

W2(I) AXIAL NODE. Node number used for sequential expansion.

A.18.1.3 Card 40000400, Gamma Heating

This card is optional for a NEW problem, and cannot currently be changed for RESTART problems.

W1(R) GAMMA HEAT FRACTION. The fraction of power used to directly heat the coolant by gamma heating. The default is 0.026, and the range^a is $0.0 \leq x \leq 0.057$.

A.18.1.4 Card 107 / Card 40000500, Core Debris Control Card

This card is required in a NEW SCDAP-type problem. Word 1 is not read in a RESTART problem, so NVOLTP cannot be changed.

W1(I) NVOLTP. This is the RELAP5 volume at top center of core. The bottom of this volume is contiguous with the top of the core.

W2(R) TFRAG. Fragmentation temperature of core (K). The default value is 100.0.

W3(I) NTFRAG. Indicator for TFRAG. The default value is 1.

0 Use TFRAG directly.

1 Add TSAT to TFRAG.

W4(R) TENDSS. Problem time for end of steady-state conditions (s). The default is 0.0.

This input variable controls the time, out to which the code uses an empirical function to calculate fuel rod internal pressure. This empirical function is applicable only for steady-state conditions. After the time exceeds TENDSS, the internal pressure is calculated by the ideal gas law taking into account the changes in the gas temperature and cladding deformation.

A.18.1.5 Card 108 / Card 40000600, Core Slumping Control Card

Values on this card must always be in SI units.

For a NEW SCDAP/RELAP5 problem, this card is required with at least the first constant present. Default values are provided for all remaining constants and are set to its default value.

For a RESTART run, this card is optional. For Words 2 through 8, if input values are absent or are $< 10.E-10$, respective constants will be obtained from the restart file.

W1(I) Number of the volume to receive any slumped core material. On a RESTART run, NCVOL may not be changed; it may be input as 0 or original value.

a. Upper limit base on fission of ²³⁵U.

SEVERE ACCIDENT CORE BEHAVIOR INPUT

- | W2(R) Thickness at which breach occurs in the hardpan in the core region that supports the liquefied core. Maximum value allowed is 0.5 m. The default is 0.03 m.
- | W3(R) Period during which the molten pool in the core region is drained because of failure of the supporting crust. The default is 10.0 seconds.
- | W4(R) Period during which material from an individual rod meltdown slumps into the lower head of the vessel. The default is 10.0 seconds.
- | W5(R) Period during which area changes because of core meltdown are spread. The default is 10.0 seconds.
- | W6(R) Period during which volume changes because of core meltdown are spread. The default is 10.0 seconds.
- | W7(R) Minimum flow area per fuel rod in cohesive debris in core region. The default is $1.4E-6 \text{ m}^2$. Let $A_o = (\text{Pitch}^2 - \pi d_r^2)/4$; d_r = diameter of rods, then if $AFLWR1/A_o > 0.1$, cohesive debris formation does not result in complete flow blockage; otherwise it does.
- | For analysis of experiments in which the total number of flow channels are two or less, word 7 $\geq 0.5 A_o$.

A.18.1.6 Card 109, Undocumented card.

| A.18.1.7 Card 118, Heat Transfer Weight and Switches

This card is optional for both NEW and RESTART runs.

- | W1(R) Weight for new time step values of heat transfer coefficients and fluxes.
Old time step weight = $1.0 - W1$. The default = 0.1.
- | W2(I) Turn off convection heat transfer calculations.

1 = Yes.
0 = No (default).
- | W3(I) Turn off radiation heat transfer calculations.

1 = Yes.
0 = No (default).
- | W4(I) Turn off ballooning calculations.

1 = Yes.
0 = No (default).
- | W5(I) Turn off oxidation calculations

1 = Yes.

0 = No (default).

A.18.1.8 Card 40001000, Grid Spacer Elevation

This card is optional and is used to define the elevation of each grid spacer. If this card is not used, then no grid spacers will be modeled. It may not be changed on RESTART.

W1(R) ELEVATION (m, ft). Elevation of the first grid spacer. The bottom of the core is at elevation zero.

WN(R) ELEVATION (m, ft). Elevation of the grid spacer n. The bottom of the core is at elevation zero. The range is $0.0 \text{ m} < x \leq 10.0 \text{ m}$.

A.18.1.9 Cards 40001001 Through 40001099, Grid Spacer Description

This card is required for a NEW problem only if a grid spacer elevation has been specified. This card cannot be changed for RESTART problems. Sequential expansion format is used.

W1 (I) GRID SPACER MATERIAL. Input one word per spacer.

0 = Zircaloy.

1 = Inconel.

W2(R) MASS OF GRID SPACER (kg, lb_m). Mass per rod. Total mass of spacer divided by number of rods in array. The range is $0.0 \text{ kg} < x \leq 0.004 \text{ kg}$.

W3(R) HEIGHT OF GRID SPACER (m, ft). The range is $0.0 \text{ m} < x < 0.125 \text{ m}$.

W4(R) PLATE THICKNESS OF GRID SPACER (m, ft). The range is $0.0 \text{ m} < x \leq 0.01 \text{ m}$.

W5(R) RADIUS OF CONTACT (m, ft). The radius of a circle which will have the same area as the contact area between the grid spacer and the fuel rod cladding. The range is $0.0 \text{ m} < x \leq 0.002 \text{ m}$.

W6(I) GRID SPACER NUMBER. Sequential expansion applies.

A.18.1.10 Card 40001100, Definition of Core Slumping Model

This card is used to define the model for determining when a pool of molten material in the core region slumps to the lower head. This card is not required for a NEW problem, and may not currently be changed on a RESTART problem.

W1(I) INDICATOR OF MODEL FOR DETERMINING WHEN A POOL OF MOLTEN MATERIAL IN THE CORE REGION SLUMPS.

0 = Model that results in latest possible slumping (Default).

1 = Model that results in earliest possible slumping.

If this parameter is set to a value of one, then the molten pool is considered to slump to the lower head whenever material at the periphery of the core has become molten. In this modeling option, solidified material at the periphery of the core is considered to have no strength for supporting a molten pool. This value of the input parameter provides an estimate of the earliest possible time of molten pool slumping. If the parameter on Card 40001100 is set to a value of zero, then the crust supporting the molten pool is considered to always have the strength necessary for supporting a molten pool. The molten pool does not slump to the lower head until its supporting crust at some point is calculated to melt. This value of the input parameter provides an estimate of the latest possible time for slumping of the molten pool. For both values of the input parameter, if the molten pool is calculated to slump, all of the molten material is calculated to slump. The assumption is applied that the initial point of failure of the crust is eroded to a depth sufficient to allow drainage of the entire molten pool. This assumption and the two types of slumping behavior defined by Card 40001100 are an interim solution until a model is implemented for calculating the structural integrity of the crust.

A.18.1.11 Cards 40001101 Through 40001199, Core Bypass Volume Identification

These cards are used to specify the core bypass hydrodynamic volumes and are used for radial spreading of core melt. These cards are required for a NEW problem and may not be changed during RESTART problems.

W1(I) RELAP5 HYDRODYNAMIC VOLUME.

WN(I) RELAP5 HYDRODYNAMIC VOLUME.

A.18.1.12 Cards 40001201 Through 40001299, Core Bypass Volume Elevations

These cards are used to specify the elevations of the core bypass volumes identified on cards 40001101 through 40001199. The elevations are referenced from the bottom of the core to the top of each RELAP5 control volume.

W1(R) ELEVATION OF BYPASS VOLUME 1 (m, ft). Distance from bottom of core to top of bypass volume 1.

WN(R) ELEVATION OF BYPASS VOLUME N (m, ft). Distance from bottom of core to top of bypass volume n.

A.18.2 Debris Bed Characteristics

The debris cards are optional and may be entered for NEW problems only. The debris bed cards allow the formation of a user-specified debris bed at a user-specified problem time. These cards are intended to be used for debris bed model assessment and are not intended for use in most transient analysis. Enter one card for each fuel rod component. All debris cards will self-expand (i.e., if there are not a sufficient number of words on a card, the last word entered will be repeated to fill the required words needed for that card during input processing.)

It is recommended that component numbers be ordered in the sequence that they are located in the

reactor core, with the sequence beginning at the center of the core and advancing to the periphery of the core. This ordering makes the printed core degradation map easy to understand. The group of fuel rods at the center of the core should be identified as component number 1 (ccc = 001), and the group of fuel rods at the periphery of the core should have the largest component number for fuel rods. Control rods should be assigned a component number that is one digit greater than the component number of the fuel rods that surround them. Water rods (represented by SCDAP as fuel rods with no fuel pellets), should be assigned a component number that is two digits greater than the component number of the fuel rods that surround them.

A.18.2.1 Cards 40002001 Through 40002020, Debris Time

W1(R) TIME OF DEBRIS BED FORMATION (s). Enter the time of debris bed formation for each axial node 1.

WN(R) TIME OF DEBRIS BED FORMATION (s). Enter the time of debris bed formation for each axial node n. The default value is 1e+30.

A.18.2.2 Cards 40002021 Through 40002040, Debris Porosity

W1(R) POROSITY. Enter the debris bed porosity at each axial node 1.

WN(R) POROSITY. Enter the debris bed porosity at each axial node n. The range is $0.0 < X < 1.0$. The default value is 0.54.

A.18.2.3 Cards 40002041 Through 40002060, Debris Particle Diameter

W1(R) PARTICLE DIAMETER (m). Enter the particle diameter at each axial node.

WN(R) PARTICLE DIAMETER (m). Enter the particle diameter at each axial node. The default value is 0.00087 m.

A.18.2.4 Cards 40002061 Through 40002080, Debris Stainless Steel Mass

This card is optional. If entered the mass of UO_2 will be reset to zero.

W1(R) MASS OF STAINLESS STEEL (kg). The mass of stainless steel at each axial node 1 per fuel rod.

WN(R) MASS OF STAINLESS STEEL (kg). The mass of stainless steel at axial node n per fuel rod.

A.18.2.5 Cards 40002081 Through 40002099, Debris Zircaloy Mass

W1(R) MASS OF ZIRCALOY (kg). Enter the mass of zircaloy at each axial node, 1 per fuel rod.

WN(R) MASS OF ZIRCALOY (kg). Enter the mass of zircaloy at axial node n per fuel rod.

A.18.3 User-Specified Material Property Definition

The user is permitted the ability to specify material properties for Material Indices 9, 10, 11, and 12. A series of cards 40009nn1, 40009nn2, and 40009nn3 must be entered for each material to be specified, where nn is the material number whose properties are being specified.

Materials 50 through 59 are entered as pairs, even index being the material and odd the oxide..

Table A-1: User Specified Materials

Index	<u>Material</u>
1	Zircaloy
2	Zr-U-O Mixture (liquid)
3	ZrU-O Mixture (frozen)
4	Tungsten
5	ZrO ₂
6	Unirradiated fuel, UO ₂
7	Cracked fuel, UO ₂
8	Relocated fuel, UO ₂
9	Steam-gas atmosphere. User may specify properties
10	User-specified properties
11	User-specified properties
12	User-specified properties
13	Metallic uranium
14	Disabled
15	Aluminum
16	Al ₂ O ₃
17	Lithium
18	Stainless Steel 304
19	Stainless Steel Oxide
20	Control Rod Absorber Material (Ag/In/Cd or B ₄ C)
50-59	User Specified Material Properties

Material properties are defined by a table of ten pairs of values, with the material temperature as the independent variable and the material property as the dependent variable. Temperatures are defined as being:

300, 550, 700, 873, 1083, 1173, 1248, 1700, 2100, 2500

A.18.3.1 Card 40009nn1, Material Specific Heat

This card is optional for NEW problems and cannot currently be input for RESTART problems. Note that the user may specify properties only for Materials 9, 10, 11, and 12.

W1..(R) MATERIAL SPECIFIC HEAT AT SPECIFIED TEMPERATURES.

A.18.3.2 Card 40009nn2, Densities of User-Specified Material

This card is optional for NEW problems and cannot currently be input for RESTART problems. Note that the user may specify properties only for Materials 9, 10, 11, and 12

W1..(R) MATERIAL DENSITIES AT SPECIFIED TEMPERATURES.

A.18.3.3 Card 40009nn3, Thermal Conductivity of User-Specified Material

This card is optional for NEW problems and cannot currently be input for RESTART problems. Note that the user may specify properties only for Materials 9, 10, 11, and 12

W1..(R) MATERIAL THERMAL CONDUCTIVITY AT SPECIFIED TEMPERATURES. nn
material number whose properties are being specified.

A.18.4 Fuel Rod Component

This component describes a group of UO_2 fuel rods. All of the fuel rods that are described by this component are assumed to behave identically. Multiple groups of oxide fuel rods may be described within a single core.

A.18.4.1 Card 4ccc0000, Fuel Rod Component

This card is required for fuel rod components and may not be input for RESTART calculations.

W1(A) COMPONENT NAME. An eight-character name that should be descriptive of this component.

W2(A) COMPONENT KEYWORD. Enter the four-character word "fuel."

A.18.4.2 Card 4ccc0100, Number of Rods

This card is required for fuel rod components, and may not be input for RESTART calculations.

W1(I) NUMBER OF RODS. Number of rods simulated by this component. All rods simulated by a single component are assumed to behave identically.

- W2(R) FUEL ROD PITCH (m, ft.). The distance from fuel rod center to fuel rod center of adjacent fuel rods. The range^a is $0.0126 \text{ m} \leq X \leq 0.0187 \text{ m}$.
- W3(R) AVERAGE BURNUP OF FUEL (MW-s/kg). This word is optional. The default is 0.0 and the range is $0.0 \leq x \leq 4752000.0 \text{ MW} \frac{\text{s}}{\text{kg}}$.

A.18.4.3 Card 4ccc0200, Fuel Rod Plenum Geometry

This card is required for fuel rod components and may not be input for RESTART calculations. The volume input is used in the calculation of internal gas pressure.

- W1(R) PLENUM LENGTH (m, ft.). The range is between 3% and 11% of the rod length .
- W2(R) PLENUM VOID VOLUME (m^3 , ft^3). Enter the plenum volume less the volume occupied by the spring. The range is $0.0 < x \leq 0.000049 \text{ m}^3$.
- W3(R) LOWER PLENUM VOID VOLUME (m^3 , ft^3). Enter the gas volume of the lower fuel rod plenum.

A.18.4.4 Cards 4ccc0301 Through 4ccc0399, Fuel Rod Dimensions

This card is required for fuel rod components, and may not be input for RESTART calculations. Radial dimensions of the fuel rod materials are specified for each axial node.

- W1(R) FUEL PELLETT RADIUS (m, ft.). The range is $0.00385 \text{ m} \leq x \leq 0.00685 \text{ m}$. If this component represents a water rod, then define a fuel pellet radius of $1 \times 10^{-4} \text{ m}$ or less.
- W2(R) INNER CLADDING RADIUS (m, ft.). The range is $W1 < x < W3$ and $0.003935 \text{ m} \leq x \leq 0.00634 \text{ m}$.
- W3(R) OUTER CLADDING RADIUS (m, ft.). The range is $W2 \leq x < \frac{W2 \text{card} 4\text{ccc} 0100}{2}$ and $0.00457 \text{ m} \leq x \leq 0.00715 \text{ m}$.
- W4(I) AXIAL NODE.

A.18.4.5 Card 4ccc0400, Upper and Lower Hydraulic Volumes

This card is required for fuel rod components and may not be input for RESTART calculations. Specified on this card are the RELAP5 hydraulic volumes, which will act as a heat sinks for a molten pool crust that may form.

- W1(I) RELAP5 HYDRAULIC VOLUME LOCATED ABOVE FUEL ROD.
- W2(I) RELAP5 HYDRAULIC VOLUME LOCATED BELOW FUEL ROD.

a. All fuel performance and rod geometry range values are based on NUREG/CR-3950, PNL-5210, Vol. 6.

A.18.4.6 Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes

This card is required for fuel rod components and may not be input for RESTART calculations. It specifies the RELAP5 hydraulic volumes that provide the boundary conditions for the core component. A hydraulic volume must be specified for each axial node of the component, but the same hydraulic volume may be specified for a number of axial nodes. The style of this card, specifying a volume number and an increment, has been designed to match the style RELAP5 uses to specify left and right boundary conditions for the heat structures. The user is referred to Cards 1ccc501, in the RELAP5 heat structure specification, for further information.

- W1(I) RELAP5 VOLUME NUMBER. This word specifies the hydrodynamic volume number (of the form cccnn0000) associated with the surface of this component. One volume number must be specified for each axial node of the component, starting with the bottom node (Node 1).
- W2(I) INCREMENT. This word (of the form nn0000) and W1 of this card are treated differently from the standard sequential expansion. W1 applies to the first axial node within a set. The increment is applied to W1 to obtain the volume connected to the next axial node. The increment is repeated up to the axial node identified by W3. W1 of the next set applies to the next axial node, and increments are applied as for the first set. The increment may be zero or nonzero, positive or negative.
- W3(I) AXIAL NODE.

A.18.4.7 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing

This card is required for fuel rod components and may not be input for RESTART calculations. This card specifies the radial nodalization. To correctly interpret the nodalization, all numbers for a specific axial node must be specified with a single card number. Use continuation cards if necessary. The radial nodalization may be specified by either of two formats, but not both.

Format 1

Specify the number of intervals to be used across each material. The code will divide the radial distance across each material into the number of equally spaced mesh intervals specified. The number of radial nodes will be $n+1$, which is the total number of intervals plus one.

- W1(I) NUMBER OF INTERVALS ACROSS FUEL.
- W2(I) NUMBER OF INTERVALS ACROSS GAP. One interval is recommended.
- W3(I) NUMBER OF INTERVALS ACROSS CLADDING.

Format 2

Specify the radial position of each radial node for each axial node. In this format, the user must be careful to input the same number of radial nodes for each axial node, although the position of the radial

nodes may be changed for each axial node.

W1(R) RADIUS TO RADIAL NODE 1 (m, ft). Enter pellet center radius of 0.0.

WN(R) RADIUS TO RADIAL NODE N (m, ft.). Enter radial node n. Radial nodes must be placed at least at the material interfaces (i.e., fuel pellet radius, and cladding inner radius). Radial nodes must be entered in ascending order and end with the last node placed on the cladding outer surface.

WN+1(I) AXIAL NODE.

A.18.4.8 Cards 4ccc0601 Through 4ccc0699, Initial Temperatures

This card is required for fuel rod components, and may not be changed on RESTART calculations.

W1 (R) TEMPERATURE (K, °F). Initial temperature at Radial Node 1. The range is $300.0 \text{ K} \leq x \leq 3123.0 \text{ K}$.

WN (R) TEMPERATURE N (K, °F). Enter an initial temperature for each radial node to radial node n, which is the last radial node. The range is $300.0 \text{ K} \leq x \leq 3123.0 \text{ K}$.

WN+1(I) AXIAL NODE. Input temperature at each radial node.

A.18.4.9 Card 4ccc1000, Power Data

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) SOURCE OF DATA ('table', 'cntrlvar', 'decay' or 'kinetics'). If the 'kinetics' option is specified, then the transient decay heat is calculated in the molten pool and porous debris. Otherwise, the decay heat in the molten pool or porous debris is constant and equal to the value at the time of formation of the molten pool or porous debris.

W2(I) TABLE OR CONTROL VARIABLE NUMBER (if necessary).

A.18.4.10 Card 4ccc1100, Power Multiplier

This card is required for NEW problems only if the source of the power data is table, or cntrlvar. This card cannot currently be input for RESTART problems.

W1(R) POWER MULTIPLIER. The default is 1.0.

A.18.4.11 Card 4ccc1200, Power Fractions for Reactor Kinetics Option

This card is required for NEW problems only if the kinetics option is specified. This card cannot currently be input for RESTART problems.

W1(R) FRACTION OF REACTOR FISSION POWER IN THIS COMPONENT. The range is $0.0 \leq x \leq 1.0$.

W2(R) FRACTION OF REACTOR FISSION PRODUCT DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

W3(R) FRACTION OF REACTOR ACTINIDE DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

A.18.4.12 Card 4ccc13p0, Axial Power Profile Time

P axial power profile number (start with Number 1).

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) END TIME (s).

A.18.4.13 Cards 4ccc13p1 Through 4ccc13p9, Axial Power Profile Data

This information is required for each profile.

W1.. (R) AXIAL POWER FACTOR AT AXIAL NODES. p axial power profile number. The range is $0.1 \leq x \leq 1.4$.

A.18.4.14 Cards 4ccc1401 Through 4ccc1499, Radial Power Profile

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) RADIAL POWER FACTOR.

W2(I) RADIAL NODE AT PELLET SURFACE. The last radial node that is input must align with the outer radius of the fuel pellet. The range is $x \leq 20$.

A.18.4.15 Card 4ccc1500, Shutdown Time and Fuel Density

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) TIME OF SHUTDOWN (s). This word is required.

W2(R) FRACTION OF FUEL THEORETICAL DENSITY. This word is required. The range is $0.94 \leq x \leq 0.96$.

W3(R) U^{239} PRODUCTION PER FISSION. This word is required only if the power for this component is computed using the decay option. The range is $0.0 \leq x \leq 1.43$.

W4(R) U^{235} ENRICHMENT. This word is required only if the power for this component is computed using the decay option. The range is $0.018 \leq x \leq 0.04$.

A.18.4.16 Cards 4ccc1501 Through 4ccc1599, Decay Power

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) PROMPT AND DELAYED NEUTRON POWER (W/m^3).

W2(R) FISSION PRODUCT DECAY POWER (W/m^3).

W3(R) ACTINIDE PRODUCT DECAY POWER (W/m^3).

W4(R) TRANSIENT POWER TIME (s).

A.18.4.17 Cards 4ccc1601 Through 4ccc1699, Previous Power History

This card is optional for NEW problems and may not currently be changed on RESTART problems. A prior power history can be defined for the decay heat calculation and is required to initialize the fission product inventory (PARAGRASS). The power is assumed to be a series of plateaus, with no interpolation. The last power density in this table is the transient power density until the problem time exceeds the shutdown time. Time in this table is referenced to the start of the operation of the reactor and not to the start of the time in the transient analysis.

W1(R) POWER HISTORY (W/m^3). The range is $40.57 \times 10^6 \frac{\text{W}}{\text{m}^3} \leq x \leq 279.3 \times 10^6 \frac{\text{W}}{\text{m}^3}$.

W2(R) TIME (s).

A.18.4.18 Card 4ccc2000, PARAGRASS Species

This card is optional for fuel rod components and may not be input for RESTART calculations.

W1.. (A) SPECIES NAME. Enter the species (xe, kr, cs, i) to be tracked.

A.18.4.19 Cards 4ccc2001 Through 4ccc2099, PARAGRASS Species Mass

This card is required only if Card 4ccc2000 above is entered.

W1(R) MASS OF SPECIE (kg, lb_m). Enter the initial mass of the first specie specified on Card 4ccc0700.

WN(R) MASS OF SPECIE N (kg, lb_m). Enter the initial mass of the next specie specified on Card 4ccc2000 and repeat until all specie masses specified on Card 4ccc2000 have been entered.

A.18.4.20 Card 4ccc2100, Initial Fuel Fission Product Inventory

This card is optional and may not be changed on RESTART calculations.

W1.. (A) SPECIES NAME. Enter the species ('te', 'zr', 'sr', 'fe', 'ru', 'zr*', 'ba') to be tracked.

A.18.4.21 Cards 4ccc2101 Through 4ccc2199, Initial Fuel Fission Product Mass

This card is required only if Card 4ccc2100 above is present.

W1(R) MASS OF SPECIE (kg, lb_m). Enter the initial mass of the first specie specified on Card 4ccc0710.

WN(R) MASS OF SPECIE N (kg, lb_m). Enter the initial mass of the next specie specified on Card 4ccc0710 and repeat until all specie masses specified on Card 4ccc0710 have been entered.

A.18.4.22 Card 4ccc2200, Initial Gap Fission Product Inventory

This card is optional and may not be changed on RESTART calculations.

W1.. (A) SPECIES NAME. Enter the species (xe, kr, cs, i, te) to be tracked.

A.18.4.23 Cards 4ccc2201 Through 4ccc2299, Initial Gap Fission Product Mass

This card is required only if Card 4ccc2200 is present.

W1(R) MASS OF SPECIE (kg, lb_m). Enter the initial mass of the first specie specified on Card 4ccc0720.

WN(R) MASS OF SPECIE N (kg, lb_m). Enter the initial mass of the next specie specified on Card 4ccc0720 and repeat until all specie masses specified on Card 4ccc0720 have been entered.

A.18.4.24 Card 4ccc3000, Gas Internal Pressure

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) HELIUM GAS AS-FABRICATED INVENTORY IN THE ROD (kg).

W2(R) INTERNAL GAS PRESSURE PER ROD (Pa).

A.18.4.25 Cards 4ccc3201 Through 4ccc3299, Time Temperature Pressure Profile

This card is optional for NEW problems. If omitted, no time is dependency assumed. This card cannot currently be input for RESTART problems.

W1(R) TIME (s). The time to which the axial surface temperature profile and fuel average hydrostatic pressure are used

W2(R) CLADDING SURFACE TEMPERATURE (K).

W3(R) FUEL HYDROSTATIC PRESSURE (Pa).

A.18.4.26 Card 4ccc4000, Option Definition

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1(A) KEYWORD TO IDENTIFY OPTION TO BE DEFINED. For the oxidation limit due to steam diffusion through hydrogen the keyword is 'limit'.

W2(A) FLAG SPECIFYING WHETHER TO APPLY OPTION. ('on' or 'off')

The only option currently applied to the fuel rod component is whether or not to limit oxidation to account for the diffusion limit of steam through hydrogen. This option defaults to 'on'.

A.18.4.27 Card 4ccc9000, Volume of External Volumes

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1.. (R) VOLUME OF EXTERNAL VOLUMES (m^3).

A.18.4.28 Cards 4ccc9001 Through 4ccc9099, Time Temperature History of External Volumes

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1(R) TIME (s).

W2..(R) TEMPERATURE OF EXTERNAL VOLUMES (K). Repeat for all times up to a maximum of 10.

A.18.5 Simulator Component

This input describes a group of electrically heated fuel rod simulators.

A.18.5.1 Card 4ccc0000, Fuel Rod Component

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) COMPONENT NAME.

W2(A) COMPONENT TYPE-- *cora*.

A.18.5.2 Card 4ccc0100, Number of Rods

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) NUMBER OF RODS.

W2(R) ROD PITCH (m). The range is $0.0126 \text{ m} \leq x \leq 0.0187 \text{ m}$.

W3(R) RADIUS OF TUNGSTEN FILAMENT (m).

A.18.5.3 Card 4ccc0200, Simulator Rod Geometry

This card is required for NEW problems and cannot currently be input for RESTART problems.

W2(R) PLENUM VOLUME (m^3). The range is $0.0 < x \leq 0.000049 \text{ m}^3$.

A.18.5.4 Card 4ccc0250, Upper Plenum Boundary Conditions

This card describes the source of sink temperature data to be used to model axial heat conduction

calculations from the top of the simulator rod.

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1(A) KEYWORD. The default is no axial heat conduction is modeled.

'control' = sink temperature defined by control variable

'table' = sink temperature define by general table

W2(I) UPPER BOUNDARY CONTROL VARIABLE OR RELAP5 TABLE NUMBER.

A.18.5.5 Card 4ccc0251, Lower Plenum Boundary Conditions

This card describes the source of sink temperature data to be used to model axial heat conduction calculations from the bottom of the simulator rod. This card is optional for NEW problems, and cannot currently be input for RESTART problems.

W1(A) KEYWORD. The default is no axial heat conduction is modeled.

control = sink temperature defined by control variable.

table = sink temperature define by general table.

W2(I) LOWER BOUNDARY CONTROL VARIABLE OR RELAP5 TABLE NUMBER.

A.18.5.6 Cards 4ccc0301 Through 4ccc0399, Simulator Dimensions

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) FUEL PELLET RADIUS (m). The range is $0.00385 \text{ m} \leq x \leq 0.00685 \text{ m}$.

W2(R) INNER CLADDING RADIUS (m). The range is $W1 < x < W3$ and $0.003935 \text{ m} \leq x \leq 0.00634 \text{ m}$.

W3(R) OUTER CLADDING RADIUS (m). The range is $W2 < x < \frac{W2_{card4ccc0100}}{2}$ and $0.00457 \text{ m} \leq x \leq 0.00715 \text{ m}$.

W4(I) AXIAL NODE NUMBER.

A.18.5.7 Card 4ccc0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 VOLUME LOCATED ABOVE SIMULATOR ROD.

W2(I) RELAP5 VOLUME LOCATED BELOW SIMULATOR ROD.

A.18.5.8 Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 VOLUME NUMBER. One volume number for each axial node, starting with Node 1.

A.18.5.9 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing

This card is required for NEW problems and cannot currently be input for RESTART problems. The information may be entered in either Format 1 or 2, but not both.

Format 1:

W1(I) NUMBER OF EQUALLY SPACED INTERVALS ACROSS THE FUEL.
W2(I) NUMBER OF EQUALLY SPACED INTERVALS ACROSS THE GAP.
W3(I) NUMBER OF EQUALLY SPACED NODES ACROSS THE CLADDING.
W4(I) AXIAL NODE NUMBER.

Format 2:

W1..(R) RADIAL MESH SPACING (m). One number per radial node. Format 2 uses axial self-expansion.

A.18.5.10 Cards 4ccc0601 Through 4ccc0699, Initial Temperatures

These cards use both axial and radial self-expansion. They are required for NEW problems and cannot currently be input for RESTART problems.

W1..(R) TEMPERATURE (K). The range is $300.0\text{ K} \leq x \leq 3,123.0\text{ K}$.

A.18.5.11 Card 4ccc1000, Power Data

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) SOURCE OF DATA ('table', 'cntrlvar', 'decay' or 'kinetics').
W2(I) TABLE OR CONTROL VARIABLE NUMBER (if necessary).

A.18.5.12 Card 4ccc1100, Power Multiplier

This card is required for NEW problems only if the source of the power data is table, or cntrlvar. This card cannot currently be input for RESTART problems.

W1(R) POWER MULTIPLIER. The default is 1.0.

A.18.5.13 Card 4ccc1200, Power Fractions for Reactor Kinetics Option

This card is required for NEW problems only if the kinetics option is specified. This card cannot currently be input for RESTART problems.

- W1(R) FRACTION OF REACTOR FISSION POWER IN THIS COMPONENT. The range is $0.0 \leq x \leq 1.0$.
- W2(R) FRACTION OF REACTOR FISSION PRODUCT DECAY POWER. The range is $0.0 \leq x \leq 1.0$.
- W3(R) FRACTION OF REACTOR ACTINIDE DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

A.18.5.14 Card 4ccc13p0, Axial Power Profile Time

P axial power profile number (start with Number 1). This card is required for NEW problems and cannot currently be input for RESTART problems.

- W1(R) END TIME (s).

A.18.5.15 Cards 4ccc13p1 Through 4ccc13p9, Axial Power Profile Data

This information is required for each profile

- W1.. (R) AXIAL POWER FACTOR AT AXIAL NODES. p axial power profile number. The range is $0.1 \leq x \leq 1.4$.

A.18.5.16 Cards 4ccc1401 Through 4ccc1499, Radial Power Profile

This card is required for NEW problems and cannot currently be input for RESTART problems.

- W1(R) RADIAL POWER FACTOR.
- W2(I) RADIAL NODE AT PELLET SURFACE. The last radial node input must align with the outer radius of the fuel pellet. The range is $x \leq 20$.

A.18.5.17 Card 4ccc1500, Shutdown Time and Fuel Density

This card is optional for NEW problems and cannot currently be input for RESTART problems.

- W1(R) TIME OF SHUTDOWN (s). This word is required.
- W2(R) FRACTION OF FUEL THEORETICAL DENSITY. This word is required. The range is $0.94 \leq x \leq 0.96$.
- W3(R) U^{239} PRODUCTION PER FISSION. This word is required only if the power for this component is computed using the decay option. The range is $0.0 \leq x \leq 1.43$.
- W4(R) U^{235} ENRICHMENT. This word is required only if the power for this component is

computed using the decay option. The range is $0.018 \leq x \leq 0.04$.

A.18.5.18 Cards 4ccc1501 Through 4ccc1599, Decay Power

This card is required for NEW problems and cannot currently be input for RESTART problems.

- W1(R) PROMPT AND DELAYED NEUTRON POWER (W/m^3).
 W2(R) FISSION PRODUCT DECAY POWER (W/m^3).
 W3(R) ACTINIDE PRODUCT DECAY POWER (W/m^3).
 W4(R) TRANSIENT POWER TIME (s).

A.18.5.19 Cards 4ccc1601 Through 4ccc1699, Previous Power History

This card is optional for NEW problems and may not currently be changed on RESTART problems. A prior power history can be defined for the decay heat calculation and is required to initialize the fission product inventory (PARAGRASS). The power is assumed to be a series of plateaus, with no interpolation. The last power density in this table is the transient power density until the problem time exceeds the shutdown time. Time in this table is referenced to the start of the operation of the reactor and not to the start of the time in the transient analysis.

- W1(R) POWER HISTORY (W/m^3). The range is $40.57 \times 10^6 \frac{\text{W}}{\text{m}^3} \leq x \leq 279.3 \times 10^6 \frac{\text{W}}{\text{m}^3}$.
 W2(R) TIME (s).

A.18.5.20 Card 4ccc2000, PARAGRASS Species

This card is optional for NEW problems and cannot currently be input for RESTART problems.

- W1.. (A) SPECIES NAME. xe, kr, cs, i.

A.18.5.21 Cards 4ccc2001 Through 4ccc2099, PARAGRASS Species

This card is required for NEW problems only if Card 700 above is included. This card cannot currently be input for RESTART problems.

- W1(R) MASS OF SPECIE SPECIFIED ABOVE (kg).

A.18.5.22 Card 4ccc2100, Fuel Fission Product Species

This card is optional for NEW problems and cannot currently be input for RESTART problems.

- W1.. (A) SPECIES NAME. Enter the species to be tracked: te, zr, sr, fe, ru, zr*, ba.

A.18.5.23 Cards 4ccc2101 Through 4ccc2199, Fuel Fission Product Inventory

This card is required for NEW problems only if Card 710 above is included. This card cannot currently

be input for RESTART problems.

W1(R) MASS OF SPECIE SPECIFIED ABOVE (kg).

A.18.5.24 Card 4ccc2200, Gap Fission Product Species

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1.. (A) SPECIES NAME. xe, kr, cs, i, te.

A.18.5.25 Cards 4ccc2201 Through 4ccc2299, Gap Fission Product Inventory

This card is required for NEW problems, only if Card 720 above is present. This card cannot currently be input for RESTART problems.

W1(R) MASS OF SPECIE SPECIFIED ABOVE (kg).

A.18.5.26 Card 4ccc3000, Gas Internal Pressure

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) HELIUM GAS AS-FABRICATED INVENTORY IN THE ROD (kg).

W2(R) INTERNAL GAS PRESSURE PER ROD (Pa).

A.18.5.27 Cards 4ccc3201 Through 4ccc3299, Time Temperature Pressure Profile

This card is required for NEW problems and cannot currently be input for RESTART problems. If omitted no time dependency assumed.

W1(R) TIME (s).

W2.. (R) CLADDING SURFACE TEMPERATURE (K).

W3(R) FUEL HYDROSTATIC PRESSURE (Pa).

A.18.5.28 Card 4ccc9000, Volume of External Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1.. (R) VOLUME (m^3).

A.18.5.29 Cards 4ccc9001 Through 4ccc9099, Time Temperature History of External Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) TIME (s).

W2..(R) TEMPERATURE OF EXTERNAL VOLUMES (K). Repeat for all times up to a

maximum of 10.

A.18.6 ATR Fuel Element Component

A.18.6.1 Card 4ccc0000, Fuel Element Component

This card is required for NEW problems and may not currently be changed on restart.

W1(A) COMPONENT NAME.

W2(A) KEYWORD - *atr*.

A.18.6.2 Card 4ccc0100, Number and Perimeter of Fuel Element

This card is required for NEW problems and may not currently be changed on RESTART.

W1(A) NUMBER OF FUEL ELEMENTS.

W2(R) AVERAGE FUEL ELEMENT PERIMETER (m).

A.18.6.3 Card 4ccc0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) RELAP5 VOLUME ABOVE THE FUEL ELEMENT.

W2(I) RELAP5 VOLUME BELOW THE FUEL ELEMENT.

A.18.6.4 Cards 4ccc0401 Through 4ccc0450, Inner Hydraulic Volumes

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) RELAP5 VOLUME NUMBERS CONNECTED TO THE INNER SURFACE.

A.18.6.5 Cards 4ccc0451 Through 4ccc0499, Outer Hydraulic Volumes

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) RELAP5 VOLUME NUMBERS CONNECTED TO THE OUTER SURFACE.

A.18.6.6 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing

This card is required for NEW problems and may not currently be changed on RESTART.

W1(R) RADIAL NODE SPACING (m). Starting from the outer surface. Uses axial self-expansion.

A.18.6.7 Cards 4ccc0601 Through 4ccc0699, Initial Temperature Distribution

This card is required for NEW problems and may not currently be changed on RESTART.

W1(R) INITIAL TEMPERATURE (K). For each radial node at present axial node. Uses axial and radial self-expansion. The range is $300.0 \text{ K} \leq x \leq 913.0 \text{ K}$.^a

A.18.6.8 Cards 4ccc0801 Through 4ccc0899, Material Types

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) MATERIAL INDEX. The first and last index numbers must be 15 or 16. Also, the number of material indexes specified must equal the number of material layers specified on the next card. Must be constant with axial nodes, the numbers are used for consistency.

A.18.6.9 Cards 4ccc0901 Through 4ccc0999, Material Layer Spacing

W1(R) MATERIAL LAYER SPACING (m). Starting from outer layer. Must be constant with axial nodes, the numbers are used for consistency.

A.18.6.10 Card 4ccc1000, Power Data

This card is required for NEW problems and may not currently be input for RESTART problems.

W1(A) SOURCE OF DATA ('table', 'cntrlvar', 'decay' or 'kinetics').

W2(I) TABLE OR CONTROL VARIABLE NUMBER (if necessary).

A.18.6.11 Card 4ccc1100, Power Multiplier

This card is required for NEW problems only if the source of the power data is table, or cntrlvar. This card may not currently be input for RESTART problems.

W1(R) POWER MULTIPLIER. The default is 1.0.

A.18.6.12 Card 4ccc1200, Power Fractions for Reactor Kinetics Option

This card is required for NEW problems only if the kinetics option is specified. This card may not currently be input for RESTART problems.

W1(R) FRACTION OF REACTOR FISSION POWER IN THIS COMPONENT. The range is $0.0 \leq x \leq 1.0$.

W2(R) FRACTION OF REACTOR FISSION PRODUCT DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

W3(R) FRACTION OF REACTOR ACTINIDE DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

A.18.6.13 Card 4ccc13p0, Axial Power Profile Time

P axial power profile number. Start with Number 1. This card is required for NEW problems and may

a. Based on the melting point of aluminum.

not currently be input for RESTART problems.

W1(R) END TIME (s).

A.18.6.14 Cards ccc13p1 Through 4ccc13p9, Axial Power Profile Data

This card is required for NEW problems and may not currently be changed on RESTART. This information is required for each profile.

W1.. (R) AXIAL POWER FACTOR AT AXIAL NODES. p axial power profile number. The range is $0.1 \leq x \leq 1.4$.

A.18.6.15 Cards 4ccc1401 Through 4ccc1499, Radial Power Profile

This card is required for NEW problem and may not currently be input for RESTART problems.

W1(R) RADIAL POWER FACTOR.

W2(I) RADIAL NODE AT PELLET SURFACE. The last radial node that is input must align with the outer radius of the fuel pellet. The range is $x \leq 20$.

A.18.6.16 Card 4ccc1500, Shutdown Time and Fuel Density

This card is optional for NEW problems and may not currently be input for RESTART problems.

W1(R) TIME OF SHUTDOWN (s). This card is required. Default is 1.0e8.

W2(R) FRACTION OF FUEL THEORETICAL DENSITY. This card is required. The range is $0.94 \leq x \leq 0.96$. Default is 0.95.

W3(R) U^{239} PRODUCTION PER FISSION. This word is required only if the power for this component is computed using the decay option.

W4(R) U^{235} ENRICHMENT. This word is required only if the power for this component is computed using the decay option.

If the power data option on Card 1000 is 'decay,' then you must input either the 15xx Cards, or the 1600, 17xx, and 18xx Card series.

A.18.6.17 Cards 4ccc1501 Through 4ccc1599, Decay Power

This card is required for NEW problems and may not currently be input for RESTART problems.

W1(R) PROMPT AND DELAYED NEUTRON POWER (W/m^3).

W2(R) FISSION PRODUCT DECAY POWER (W/m^3).

W3(R) ACTINIDE PRODUCT DECAY POWER (W/m^3).

W4(R) TRANSIENT POWER TIME (s).

A.18.6.18 Cards 4ccc1601 Through 4ccc1699, Previous Power History

This card is optional for NEW problems and may not currently be input for RESTART problems. A prior power history can be defined for the decay heat calculation and is required to initialize the fission product inventory (PARAGRASS). The power is assumed to be a series of plateaus, with no interpolation. The last power density in this table is the transient power density until the problem time exceeds the shutdown time. Time in this table is referenced to the start of the operation of the reactor and not to the start of the transient analysis.

W1(R) POWER HISTORY (W/m^3). The range is $40.57 \times 10^6 \frac{\text{W}}{\text{m}^3} \leq x \leq 279.3 \times 10^6 \frac{\text{W}}{\text{m}^3}$.

W2(R) TIME (s).

A.18.6.19 Cards 4ccc2101 Through 4ccc2199, ATR Component Fission Product Masses

This card is required if the component type is atr.

W1(R) INITIAL MASS OF FISSION PRODUCT NN (kg).

W2(I) AXIAL NODE FOR SEQUENTIAL EXPANSION.

A.18.7 Card 4ccc0000, Shroud Component

A.18.7.1 Card 4ccc0000, Component Name

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) COMPONENT NAME.

W2(A) KEYWORD - *shroud*.

A.18.7.2 Card 4ccc0100, Number of Shroud Configurations

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) NUMBER OF SHROUDS.

A.18.7.3 Card 4ccc0200, Shroud Geometry

This card is required for NEW problems and cannot currently be input for RESTART problems. Words 1 and 2 are required, words 3 and 4 are optional.

W1(R) PERIMETER OF INNER SHROUD SURFACE. (m, ft) Required input.

W2(R) SHROUD FLOW AREA THICKNESS (m, ft). Required input.

W3(I) MOLTEN POOL INTERACTION FLAG. Optional flag to determine whether or not

shroud interfaces with molten pool. If 0 is entered no interaction is modeled, if 1 interaction is modeled. Default is to model shroud interaction with molten pool.

W3(R) THRESHOLD THICKNESS (m, ft). Threshold thickness of liquefied structural material for breakup of crust of solidified molten pool material at periphery of core. If maximum possible rate of melting of structure at periphery of core due to interaction with molten pool is to be modeled, this word should be 0.0, if minimum, this word should be 1.0 m.

A.18.7.4 Card 4ccc0300, Indices of Materials

This card is required for NEW problems and cannot currently be input for RESTART problems. A shroud component must have at least three materials (even if all three have the same index), and a maximum number defined by the parameter 'ndmatr' in common block 'scddat'. As transmitted by the INEL this parameter is ten.

W1.. (I) MATERIAL INDEX. Material layers beginning with outer layer. Indices from SCDAP Material Indices.

A.18.7.5 Cards 4ccc0301 Through 4ccc0399, Material Layer Radii

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1.. (R) RADIUS OF EACH MATERIAL LAYER (m). Assuming the outer shroud radius equals 0.0, enter the remaining radii in consecutive order. Each material interface must fall on a mesh point.

A.18.7.6 Card 4ccc0400, Upper and Lower Hydrodynamic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 VOLUME ABOVE THE SHROUD.

W2(I) RELAP5 VOLUME BELOW THE SHROUD.

A.18.7.7 Cards 4ccc0401 Through 4ccc0499, Volume Number of Hydrodynamic Volumes

This card defines the RELAP5 control volume, which provides the boundary conditions for the component. There are usually two control volumes defined for each axial node. However, for the shroud component only, there is the capability to specify a heat flux boundary condition on the outside of the shroud. This is done by specifying zero (0) for the outer hydrodynamic volume and then including Card 4ccc8000. Refer to Cards 4ccc8n01 through 4ccc8n99, Heat Flux Boundary Condition Specifications for further information. This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 VOLUME NUMBER FOR THE BOUNDING VOLUME ON THE INNER SURFACE OF THE SHROUD. This is the maximum radial node number for the shroud on the inner surface.

W2(I) RELAP5 VOLUME NUMBER FOR THE BOUNDING VOLUME ON THE OUTER SURFACE OF THE SHROUD. This is radial node number 1 on the outer surface.

W3(I) INCREMENT.

W4(I) AXIAL NODE NUMBER.

A.18.7.8 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing

This card specifies the location of radial mesh points across the component. A heat conduction solution is performed at each radial mesh point.

Error trapping includes checks to ensure that the first radial mesh point is located at 0.0, that the mesh points are in consecutive order, and that there is a mesh point at each material interface. For the first axial node only, all radial nodes must be on one card number, even if it is necessary to use continuation cards.

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1.. (R) DISTANCE FROM OUTER SURFACE OF SHROUD TO RADIAL NODE 1 (m).

Wn (R) DISTANCE FROM OUTER SURFACE OF SHROUD TO RADIAL NODE N (m).

Wn+1(I) AXIAL NODE NUMBER.

A.18.7.9 Cards 4ccc0601 Through 4ccc0699, Initial Radial Temperature Distribution

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) INITIAL TEMPERATURE AT EACH RADIAL NODE (K).

Wn(R) INITIAL TEMPERATURE AT RADIAL NODE N (K).

Wn+1(I) AXIAL NODE NUMBER. The range is $300. K \leq x \leq 2,033.0 K^a$

A.18.7.10 Card 4ccc0800, Embedded Flow Channel Description

This card allows the user to model embedded hydrodynamic flow channels within the SHROUD component. This card is optional for NEW problems, and cannot currently be input for RESTART problems.

W1(I) Interval linked to embedded hydrodynamic flow channels.

A.18.7.11 Card 4ccc0801 Through 4ccc0899 Hydrodynamic Connections to Embedded Flow Channels.

If Card 4ccc0800 is entered then this card is required. If not, then this card is not used.

a. Upper limit based on the melting point of zircaloy.

W1(I) HYDRODYNAMIC VOLUME. Linked to embedded flow channel at the lowest axial node.

W2(I) INCREMENT. Number to be added to W1 to form hydrodynamic volumes for each volume above W1.

A.18.7.12 Card 4ccc1000, Power Data

This card is required for NEW problems and may not currently be input for RESTART problems.

W1(A) SOURCE OF DATA ('table', 'cntrlvar', 'decay' or 'kinetics').

W2(I) TABLE OR CONTROL VARIABLE NUMBER (if necessary).

A.18.7.13 Card 4ccc1100, Power Multiplier

This card is required for NEW problems only if the source of the power data is table, or cntrlvar. This card may not currently be input for RESTART problems.

W1(R) POWER MULTIPLIER. The default is 1.0.

A.18.7.14 Card 4ccc1200, Power Fractions for Reactor Kinetics Option

This card is required for NEW problems only if the kinetics option is specified. This card may not currently be input for RESTART problems.

W1(R) FRACTION OF REACTOR FISSION POWER IN THIS COMPONENT. The range is $0.0 \leq x \leq 1.0$.

W2(R) FRACTION OF REACTOR FISSION PRODUCT DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

W3(R) FRACTION OF REACTOR ACTINIDE DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

A.18.7.15 Card 4ccc13p0, Axial Power Profile Time

P axial power profile number. Start with Number 1. This card is required for NEW problems and may not currently be input for RESTART problems.

W1(R) END TIME (s).

A.18.7.16 Cards ccc13p1 Through 4ccc13p9, Axial Power Profile Data

This card is required for NEW problems and may not currently be changed on RESTART. This information is required for each profile.

W1.. (R) AXIAL POWER FACTOR AT AXIAL NODES. p axial power profile number. The range is $0.1 \leq x \leq 1.4$.

A.18.7.17 Cards 4ccc1401 Through 4ccc1499, Radial Power Profile

This card is required for NEW problem and may not currently be input for RESTART problems.

- W1(R) RADIAL POWER FACTOR.
- W2(I) RADIAL NODE AT PELLET SURFACE. The last radial node that is input must align with the outer radius of the fuel pellet. The range is $x \leq 20$.

A.18.7.18 Card 4ccc1500, Shutdown Time and Fuel Density

This card is optional for NEW problems and may not currently be input for RESTART problems.

- W1(R) TIME OF SHUTDOWN (s). This card is required. Default is 1.0e8.
- W2(R) FRACTION OF FUEL THEORETICAL DENSITY. This card is required. The range is $0.94 \leq x \leq 0.96$. Default is 0.95.
- W3(R) U^{239} PRODUCTION PER FISSION. This word is required only if the power for this component is computed using the decay option.
- W4(R) U^{235} ENRICHMENT. This word is required only if the power for this component is computed using the decay option.

If the power data option on Card 1000 is 'decay,' then you must input either the 15xx Cards, or the 1600, 17xx, and 18xx Card series.

A.18.7.19 Cards 4ccc1501 Through 4ccc1599, Decay Power

This card is required for NEW problems and may not currently be input for RESTART problems.

- W1(R) PROMPT AND DELAYED NEUTRON POWER (W/m^3).
- W2(R) FISSION PRODUCT DECAY POWER (W/m^3).
- W3(R) ACTINIDE PRODUCT DECAY POWER (W/m^3).
- W4(R) TRANSIENT POWER TIME (s).

A.18.7.20 Cards 4ccc1601 Through 4ccc1699, Previous Power History

This card is optional for NEW problems and may not currently be input for RESTART problems. A prior power history can be defined for the decay heat calculation and is required to initialize the fission product inventory (PARAGRASS). The power is assumed to be a series of plateaus, with no interpolation. The last power density in this table is the transient power density until the problem time exceeds the shutdown time. Time in this table is referenced to the start of the operation of the reactor and not to the start of the transient analysis.

- W1(R) POWER HISTORY (W/m^3). The range is $40.57 \times 10^6 \frac{W}{m^3} \leq x \leq 279.3 \times 10^6 \frac{W}{m^3}$.

W2(R) TIME (s).

A.18.7.21 Card 4ccc5000, Shroud Insulation and Failure

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) MATERIAL OF SHROUD.

W2(R) TIME AT WHICH SHROUD FAILS. After the time of shroud failure, both sides of the metallic Zr liner on the inside surface of the shroud are calculated to oxidize. In addition, a multiplier is applied to thermal conductivity of the shroud insulation.

W3(R) MULTIPLIER ON THERMAL CONDUCTIVITY FOR FAILED SHROUD.

A.18.7.22 Cards 4ccc8n01 Through 4ccc8n99, Heat Flux Boundary Condition Specification

These cards are used to specify a table of heat flux as a function of time, to be applied on the outer surface of the shroud, and are read if, and only if, the hydrodynamic volume used for the outer surface boundary condition is specified as zero (0). The '100s' digit, shown as 'n' in the card number is used to determine the heat flux profile number, in that the first profile should be entered on Cards 4ccc8101 through 4ccc8199, and the second on 4ccc8201 through 4ccc8299, and so forth.

There are two possible formats for this card. In the first, a time is entered as Word 1, and a heat flux is entered as Word 2, with no additional input. In this format the specified heat flux will be applied to all axial nodes of the component. In the second format, a time is entered as Word 1, and a series of heat fluxes are entered as Words 2 through n, where n is the number of axial nodes plus 1. In this format, Word 2 specifies the heat flux to be applied at Node 1, Word 3 specifies that at Node 2, and so forth.

This card is required for NEW problems, and cannot currently be input for RESTART problems.

W1(R) TIME (s).

W2(R) HEAT FLUX (W/m^2 , Btu/s-ft^2).

A.18.8 Control Rod Component

A.18.8.1 Card 4ccc0000, Control Rod Component

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) COMPONENT NAME.

W2(A) COMPONENT TYPE-- control.

A.18.8.2 Card 4ccc0100, Number of Rods

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) NUMBER OF RODS. The range is $1 \leq x$.

W2(R) CONTROL ROD PITCH (m). If a fuel rod component is entered, the control rod pitch should be equal to the pitch of the fuel rod, if it is in the same bundle.

A.18.8.3 Card 4ccc0300, Control Rod Materials

This card is optional for NEW problems and cannot currently be input for RESTART problems. The materials identified by default are control rod absorber material (Ag/In/Cd for PWR's, B₄C for BWR's), stainless steel, and zircaloy. If as little as one material is specified, all default materials are ignored. If this card is not entered, then three materials are assumed. Material 1 is assumed to be Ag/In/Cd for PWR's, B₄C for BWR's, material 2 is assumed to be stainless steel, material 3 is assumed to be zircaloy. Other materials may be specified by using the material indices specified in Table 1, "User Specified Materials" on page A18-9.

This card is intended to specify materials for non-standard control rod configurations.

W1(I) ABSORBER MATERIAL INDEX. Material index for control rod absorber.

W2(I) SHEATH MATERIAL INDEX. Material index for control rod sheath.

WN(I) GUIDE TUBE MATERIAL INDEX. Material index for guide tube.

A.18.8.4 Card 4ccc0301 Through 4ccc0399, Control Rod Geometry

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) OUTER RADIUS OF CONTROL ROD ABSORBER (m, ft). The range is $0.0 < x < W2$.

W2(R) OUTER RADIUS OF STAINLESS STEEL SHEATH (m). The range is $W1 < x \leq W3$.

W3(R) INNER RADIUS OF ZIRCALLOY GUIDE TUBE (m). The range is $W2 \leq x < W4$.

W4(R) OUTER RADIUS OF ZIRCALLOY GUIDE TUBE (m). The range is $\frac{W3}{2} < x < \frac{pitch}{2}$.

W5(I) AXIAL NODE FOR SEQUENTIAL EXPANSION.

A.18.8.5 Card 4ccc0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 VOLUME LOCATED ABOVE CONTROL ROD.

W2(I) RELAP5 VOLUME LOCATED BELOW CONTROL ROD.

A.18.8.6 Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes

This card specifies the RELAP5 hydrodynamic volume, which provides the boundary conditions for the control rod. A hydrodynamic volume must be specified for each axial node of the component. The style of this card, i.e., specifying a hydrodynamic volume number and an increment, has been chosen to match the style used by RELAP5 to specify heat structure left and right boundary conditions. This card is required

for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 VOLUME NUMBER.
W2(I) INCREMENT
W3(I) AXIAL NODE. Sequential expansion applies.

A.18.8.7 Cards 4ccc0501 Through 4ccc0599, Radial Mesh Spacing

This card is required for NEW problems and cannot currently be input for RESTART problems.

This card may be entered in either Format 1 or 2, but you may not mix formats. A minimum of five radial nodes are required. Up to 20 radial nodes may be used. Nodes must be entered in consecutive order beginning with the first node at $r=0$. Other required radial nodes must be placed at the outer radius of absorber material, the outer radius of stainless steel sheath, and the inner and outer radius of the zircaloy guide tube.

Format 1:

W1(I) NUMBER OF EQUALLY SPACED INTERVALS ACROSS THE ABSORBER MATERIAL.
W2(I) NUMBER OF EQUALLY SPACED INTERVALS ACROSS THE STAINLESS STEEL SHEATH.
W3(I) NUMBER OF EQUALLY SPACED NODES ACROSS THE ZIRCALOY GUIDE TUBE.
W4(I) AXIAL NODE NUMBER FOR SEQUENTIAL EXPANSION.

Format 2:

W1(R) RADIAL MESH SPACING (m). Radial dimension of Node 1.
WN(R) RADIAL MESH SPACING (m). Radial dimension of Node n.
WN+1(I) AXIAL NODE NUMBER.

Sequential expansion applies to this input.

A.18.8.8 Cards 4ccc0601 Through 4ccc0699, Initial Temperatures

This card is required for fuel rod components and may not be change on RESTART calculations.

W1(R) TEMPERATURE (K, °F). Initial temperature at Radial Node 1. The range is $300.0\text{ K} \leq x \leq 3,123.0\text{ K}$.
Wn(R) TEMPRATURE N (K, °F). Enter an initial temperature for each radial node to radial node

n, which is the last radial node. The range is $300.0 \text{ K} \leq x \leq 3,123.0 \text{ K}$.

WN+1(I) AXIAL NODE. Input temperature at each radial node.

A.18.8.9 Card 4ccc0700, Internal Gas Pressure

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) INTERNAL GAS PRESSURE (Pa).

A.18.8.10 Card 4ccc0800, Mass of Silver

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) TOTAL MASS OF TIN IN ALL RODS OF THIS COMPONENT (kg).

W2(R) TOTAL MASS OF SILVER IN ALL RODS OF THIS COMPONENT (kg).

A.18.8.11 Card 4ccc1000, Power Data

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) SOURCE OF DATA ('table', 'cntrlvar', 'decay' or 'kinetics').

W2(I) TABLE OR CONTROL VARIABLE NUMBER (if necessary).

A.18.8.12 Card 4ccc1100, Power Multiplier

This card is required for NEW problems only if the source of the power data is table, or cntrlvar. This card cannot currently be input for RESTART problems.

W1(R) POWER MULTIPLIER. The default is 1.0.

A.18.8.13 Card 4ccc1200, Power Fractions For Reactor Kinetics Option

This card is required for NEW problems only if the kinetics option is specified. The card cannot currently be input for RESTART problems.

W1(R) FRACTION OF REACTOR FISSION POWER IN THIS COMPONENT. The range is $0.0 \leq x \leq 1.0$.

W2(R) FRACTION OF REACTOR FISSION PRODUCT DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

W3(R) FRACTION OF REACTOR ACTINIDE DECAY POWER. The range is $0.0 \leq x \leq 1.0$.

A.18.8.14 Card 4ccc13p0, Axial Power Profile Time

P axial power profile number (start with number 1). This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) END TIME(s).

A.18.8.15 Cards 4ccc13p1 Through 4ccc13p9, Axial Power Profile Data

This information is required for each profile.

W1.. (R) AXIAL POWER FACTOR AT AXIAL NODES. p axial power profile number. The range is $0.1 \leq x \leq 1.4$.

A.18.8.16 Cards 4ccc1401 Through 4ccc1499, Radial Power Profile

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) RADIAL POWER FACTOR.

W2(I) RADIAL NODE NUMBER AT ABSORBER SURFACE. The last radial node input must align with the outer radius of the absorber. The range is $x \leq 20$.

A.18.8.17 Cards 4ccc1501 Through 4ccc1599, Decay Power

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) PROMPT NEUTRON POWER (W/m^3).

W4(R) TRANSIENT POWER TIME (s).

A.18.8.18 Cards 4ccc1601 Through 4ccc1699, Previous Power History

This card is optional for NEW problems and may not currently be changed on RESTART problems. A prior power history can be defined for the decay heat calculation and is required to initialize the fission product inventory (PARAGRASS). The power is assumed to be a series of plateaus, with no interpolation. The last power density in this table is the transient power density, until the problem time exceeds the shutdown time. Time in this table is referenced to the start of the operation of the reactor and not to the start of the time in the transient analysis.

W1(R) POWER HISTORY (W/m^3). The range is $40.57 \times 10^6 \frac{\text{W}}{\text{m}^3} \leq x \leq 279.3 \times 10^6 \frac{\text{W}}{\text{m}^3}$.

W2(R) TIME (s).

A.18.9 BWR Control Rods

A.18.9.1 Card 4ccc0000, BWR Control Rod Component

W1(A) COMPONENT NAME. Descriptive of role in system.

W2(A) COMPONENT TYPE -- bwr.

A.18.9.2 Card 4ccc0100, Number of Rods

W1(I) NUMBER OF RODS IN COMPONENT.

A.18.9.3 Cards 4ccc0301 Through 4ccc0399, BWR Control Rod Geometry

W1(R) OUTER RADII FOR B₄C ABSORBER. The range is $0.0 \text{ m} < x < W2$.

W2(R) STAINLESS STEEL CLADDING OUTER RADII. The range is $W1 < x < 0.00935 \text{ m}$.

W3(I) AXIAL NUMBER FOR SEQUENTIAL EXPANSION.

A.18.9.4 Card 4ccc0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and may not be changed for RESTART problems.

W1(I) RELAP5 VOLUME LOCATED ABOVE BWR ROD.

W2(I) RELAP5 VOLUME LOCATED BELOW BWR ROD.

A.18.9.5 Cards 4ccc0401 Through 4ccc0499, Hydraulic Volumes

This card is required for NEW problems and may not be changed for RESTART problems.

W1(I) RELAP5 VOLUME NUMBER. One word for each axial node.

A.18.9.6 Cards 4ccc0601 Through 4ccc0699, Initial Temperatures

This card is required for NEW problems and may not be changed for RESTART problems.

W1(R) B₄C ABSORBER TEMPERATURE. The range is $300.0 \text{ K} \leq x \leq 1,723.0 \text{ K}$.

W2(R) STAINLESS STEEL CLADDING TEMPERATURE. The range is $300.0 \text{ K} \leq x \leq 1,723.0 \text{ K}$.

W3(I) AXIAL NODE NUMBER.

A.18.10 BWR Blade/Box Component Input

These cards contain physical dimensions, hydraulic information, and initial conditions for each BWR blade component.

A.18.10.1 Card 4ccc0000, SCDAP Component Name and Type

This card is required for NEW problems and cannot currently be changed for RESTART problems.

W1(A) COMPONENT NAME. This is a descriptive name selected by the user. On most computers, there is an eight-character limit.

W2(A) COMPONENT TYPE. Specify the keyword "bladebox."

A.18.10.2 Card 4ccc0100, Number of Individual BWR Blade/Box Structures

This card is required for NEW problems and cannot currently be changed for RESTART problems.

- W1(I) NUMBER OF INDIVIDUAL BWR BLADE/BOX STRUCTURES IN THIS COMPONENT. An individual blade/box structure consists of half of a control blade (other half is symmetric) with length equal to Word 1 on Card 4ccc0300 and a channel box with length equal to the sum of Words 1 and 2 on Card 4ccc0300. The total mass represented by this component is equal to the mass of an individual blade/box structure multiplied by the value on this card. The range is $1 \leq x$.

A.18.10.3 Card 4ccc0200, Control Blade and Channel Box Radial Dimensions

This card is required for NEW problems and cannot currently be changed for RESTART problems.

- W1(I) NUMBER OF ABSORBER RODLETS IN A CONTROL BLADE WING. This variable is used only to specify the relative proportions of a control blade wing. The length (wetted perimeter) of a control blade is specified in Word 1 on Card 4ccc0300. The range is $1 \leq x$.
- W2(R) INSIDE DIAMETER OF STAINLESS STEEL ABSORBER RODLET (m, ft). The range is $0.0 \leq x \leq 0.0070$ m.
- W3(R) THICKNESS OF STAINLESS STEEL ABSORBER RODLET WALL (m, ft). The range is $0.0 \leq x \leq 0.0013$ m.
- W4(R) THICKNESS OF GAP BETWEEN ABSORBER RODLET AND CONTROL BLADE SHEATH (m, ft). The range is $0.0 \leq x \leq 0.0003$ m.
- W5(R) THICKNESS OF STAINLESS STEEL CONTROL BLADE SHEATH (m, ft). The range is $0.0 \leq x \leq 0.0030$ m.
- W6(R) DISTANCE BETWEEN CONTROL BLADE AND CHANNEL BOX (m, ft). The range is $0.0 \leq x \leq 0.0100$ m.
- W7(R) THICKNESS OF ZIRCALOY CHANNEL BOX WALL (m, ft). The range is $0.0 \leq x \leq 0.0050$ m.
- W8(R) DISTANCE BETWEEN CHANNEL BOX AND FIRST ROW OF FUEL RODS (m, ft). The range is $0.0 \leq x \leq 0.0080$ m.

A.18.10.4 Card 4ccc0300, Control Blade and Channel Box Lengths and View Factors

This card is required for NEW problems and cannot currently be changed for RESTART problems.

- W1(R) LENGTH (WETTED PERIMETER) OF CONTROL BLADE AND CHANNEL BOX SEGMENT NUMBER 1 (m, ft). The range is $0.0 \text{ m} \leq x$.
- W2(R) LENGTH (WETTED PERIMETER) OF CHANNEL BOX SEGMENT NUMBER 2 (m,

ft). This is the portion of the channel box not adjacent to a control blade. The range is $0.0 \leq x$.

W3(R) GEOMETRIC VIEW FACTOR FROM CHANNEL BOX SEGMENT NUMBER 1 TO CONTROL BLADE. This factor is based on the area of channel box segment Number 1. The range is $0.0 \leq x \leq 1.0$.

W4(R) GEOMETRIC VIEW FACTOR FROM CHANNEL BOX SEGMENT NUMBER 2 TO CONTROL BLADE. This factor is based on the area of channel box segment Number 2. The range is $0.0 \leq x \leq 1.0$.

A.18.10.5 Card 4ccc0400, Upper and Lower Volume Numbers

This card is required for NEW problems and cannot currently be changed for RESTART problems.

W1(I) VOLUME NUMBER OF HYDRAULIC VOLUME JUST ABOVE THE FUEL BUNDLE VOLUMES SPECIFIED IN WORD 1 ON CARDS 4CCC0401 THROUGH 4CCC0499.

W2(I) VOLUME NUMBER OF HYDRAULIC VOLUME JUST BELOW THE FUEL BUNDLE VOLUMES SPECIFIED IN WORD 1 ON CARDS 4CCC0401 THROUGH 4CCC0499.

A.18.10.6 Cards 4ccc0401 Through 4ccc0499, Fuel Bundle and Interstitial Volume Numbers

This card is required for NEW problems and cannot currently be changed for RESTART problems. A modified sequential expansion format is used where Words 1 and 2 are incremented by Word 3.

W1(I) VOLUME NUMBER OF HYDRAULIC VOLUME CONNECTED TO FUEL BUNDLE SIDE OF CHANNEL BOX AXIAL NODE. This is the first volume number used in the sequential expansion. Each subsequent volume number is generated by adding the increment specified in Word 3.

W2(I) VOLUME NUMBER OF HYDRAULIC VOLUME CONNECTED TO CONTROL BLADE AXIAL NODE AND INTERSTITIAL SIDE OF CHANNEL BOX AXIAL NODE. This is the first volume number used in the sequential expansion. Each subsequent volume number is generated by adding the increment specified in Word 3.

W3(I) VOLUME NUMBER INCREMENT. This increment may be positive, negative, or zero.

W4(I) AXIAL NODE NUMBER USED FOR THE SEQUENTIAL EXPANSION. The node numbers specified on these cards must be in ascending, but not necessarily consecutive order. The range is $1 \leq x \leq n$, where n is the number of axial nodes specified on Card 40000100.

A.18.10.7 Card 4ccc0500, Initial Oxide Thicknesses

This card is optional for NEW problems and cannot currently be changed for RESTART problems.

- W1(R) INITIAL THICKNESS OF ZrO_2 LAYER ON FUEL BUNDLE SIDE OF CHANNEL BOX (m, ft). The thicknesses for the two channel box segments and all axial nodes are identical. The default is 0.0 m and the range is $0.0\text{ m} \leq x \leq 0.5*W7$ on Card 4ccc0200.
- W2(R) INITIAL THICKNESS OF ZrO_2 LAYER ON INTERSTITIAL SIDE OF CHANNEL BOX (m, ft). The thicknesses for the two channel box segments and all axial nodes are identical. The default is 0.0 m and the range is $0.0\text{ m} \leq x \leq 0.5*W7$ on Card 4ccc0200.
- W3(R) INITIAL THICKNESS OF STAINLESS STEEL OXIDE LAYER ON CONTROL BLADE SURFACES (m, ft). The thicknesses for all axial nodes are identical. This thickness must be nonzero. The default is $1.0e-6\text{ m}$ and the range is $1.0e-6\text{ m} \leq x \leq \text{MIN}$ (W3 on Card 4ccc0200, $0.5*W5$ on Card 4ccc0200).

A.18.10.8 Cards 4ccc0601 Through 4ccc0699, Initial Temperatures of Control Blade and Channel Box

This card is required for NEW problems and cannot currently be changed for RESTART problems. A sequential expansion format is used.

- W1(R) INITIAL TEMPERATURE OF CONTROL BLADE (K, °F). The temperatures of the three control blade radial nodes are identical at each axial node. The range is $300\text{ K} \leq x \leq 1,505\text{ K}$.
- W2(R) INITIAL TEMPERATURE OF CHANNEL BOX (K, °F). The temperatures of the two channel box segments are identical at each axial node. The range is $300\text{ K} \leq x \leq 1,523\text{ K}$.
- W3(I) AXIAL NODE NUMBER USED FOR THE SEQUENTIAL EXPANSION. The node numbers specified on these cards must be in ascending, but not necessarily consecutive order. The range is $1 \leq x \leq n$, where n is the number of axial nodes specified on Card 40000100.

A.18.11 SCDAP Radiation Enclosure Grouping

CCC now stands for the radiation bundle number. The only restrictions on these is that they must not conflict with the component numbers used in the previous sections of this document.

A.18.11.1 Card 4ccc0000, Bundle Components

This card is required for NEW problems and cannot currently be input for RESTART problems.

- W1(A) KEYWORD '*bundle*,'

Either the 1000 or 2000 series Cards are needed, but not both. The 1000 series Cards must be used if the bundle includes a BWR blade/box component.

A.18.11.2 Card 4ccc1000, Number of Components in Bundle

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1..(I) COMPONENT NUMBERS OF BUNDLE COMPONENTS.

A.18.11.3 Cards 4ccc1001 Through 4ccc1099, View Factors

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1..(R) VIEW FACTORS. This input can be considered a square matrix of view factors, where, for example, the third word of the second row is the view factor from the third component specified on Card 4ccc1000 to the second component specified on Card 4ccc1000.

A.18.11.4 Cards 4ccc1101 Through 4ccc1199, Radiation Path Length

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1..(R) RADIATION PATH LENGTHS. Just as in Card 4ccc1001, this input should be considered a square matrix.

A.18.11.5 Card 4ccc2000, Pitch of Rods

W1(R) PITCH (m). Pitch of rods in bundle.

W2(I) SHROUD COMPONENT NUMBER. This word is optional. If missing, then no shroud is modeled.

A.18.11.6 Cards 4ccc2001 Through 4ccc2099, Matrix of Components of the Bundle

W1..(I) MATRIX OF INTEGERS IDENTIFYING THE COMPONENT IN EACH SLOT OF THE BUNDLE. The maximum is 20 x 20.

A.18.12 Core Slumping Cards

A.18.12.1 Card 4ccc0000, Core Slumping

W1(A) KEYWORD '*slump*.'

A.18.12.2 Card 4ccc0100, COUPLE Mesh

W1(I) COUPLE MESH NUMBER TO DEFINE HISTORY. Either use the 03, 04, and 05 Cards, or the 05, 06, and 07, depending on the value of NSLHPS variable on Card 103N.

NSLHPS = 1 -> use 03 and 04.

NSLHPS = -1 -> use 06 and 07. Uses only one time period.

A.18.12.3 Cards 4ccc0301 Through 4ccc0399, User-Defined Core Slumping

W1(R) TIME AT WHICH CORE SLUMPING BEGINS.

W2(R) TIME AT WHICH CORE SLUMPING ENDS. Repeat for each time period.

A.18.12.4 Cards 4ccc0401 Through 4ccc0499, Mass of Each Material That Slumped

W1(R) MASS OF ZIRCALOY THAT SLUMPED DURING PERIOD.

W2(R) MASS OF METALLIC URANIUM.

W3(R) MASS OF STAINLESS STEEL.

W4(R) MASS OF SILVER.

W5(R) MASS OF BORON CARBIDE.

W6(R) MASS OF URANIUM DIOXIDE.

W7(R) MASS OF OXIDIZED ZIRCALOY.

W8(R) MASS OF ALUMINUM.

W9(R) MASS OF LITHIUM.

W10(R) MASS OF CADMIUM.

Repeat for each time period.

A.18.12.5 Cards 4ccc0501 Through 4ccc0599, Characteristics of Slumped Material

W1(R) TEMPERATURE OF SLUMPED MATERIAL.

W2(R) RADIUS OF PARTICLES OF SLUMPED MATERIAL.

W3(R) POROSITY OF SLUMPED MATERIALS.

W4(R) TOTAL POWER (HEAT GENERATION RATE) IN SLUMPED MATERIAL.

Repeat for each time period.

A.18.12.6 Card 4ccc0600, Mass Fractions

W1(R) MASS FRACTION OF ZIRCALOY IN MATERIAL 1.

W2(R) MASS FRACTION OF METALLIC URANIUM IN MATERIAL 1.

W3(R) MASS FRACTION OF STAINLESS STEEL IN MATERIAL 1.

W4(R) MASS FRACTION OF SILVER IN MATERIAL 1.

W5(R) MASS FRACTION OF BORON CARBIDE IN MATERIAL 1.
W6(R) MASS FRACTION OF URANIUM DIOXIDE IN MATERIAL 1.
W7(R) MASS FRACTION OF OXIDIZED ZIRCALLOY IN MATERIAL 1.
W8(R) MASS FRACTION OF ALUMINUM IN MATERIAL 1.
W9(R) MASS FRACTION OF LITHIUM IN MATERIAL 1.
W10(R) MASS FRACTION OF CADMIUM IN MATERIAL 1.
W11(R) MASS FRACTION OF SOIL IN MATERIAL 1.

A.18.12.7 Card 4ccc0700, Characteristics of Material 1

W1(R) RADIUS OF PARTICLES IN COUPLE MATERIAL 1.
W2(R) POROSITY OF COUPLE MATERIAL 1.
W3(R) EFFECTIVE HEIGHT (DEPTH) OF MATERIAL 1.
W4(R) MULTIPLIER OF POWER DENSITY FROM TABLE W5.
W5(I) RELAP5 GENERAL TABLE OF POWER DENSITY IN COUPLE MATERIAL 1.

A.18.12.8 Cards 4ccc1001 Through 4ccc1099, Data for Species

W1..(R) MASS OF SPECIE. Mass of fission products to track.

Debris, input in the following order: i, csi, csoh, te, hi, hte, cd, ag, uo2, sn, fe, ru, ba, sb, cs*, i*, zn, xe, kr .

Repeat for each time period.

A.19 COUPLE INPUT

The ability to enter data in both the formatted ("old style") and free format ('new style') has been maintained for the convenience of the user. Many of the supporting software which can automatically generate a COUPLE mesh, have the ability to generate an output file which can be input to the old style input, either directly or through a filter. The development staff also believe that a code user using a hand generated COUPLE mesh, should have the benefits of the free form RELAP5 style card number input. For these reasons, both styles of COUPLE input will be allowed.

A.19.1 COUPLE Control Cards

These cards are input whenever a COUPLE calculation is begun. These cards can be entered on either NEW or RESTART problems. Every COUPLE calculation must begin with a 50000000 card. Cards 5m001000 through 5m0030000 may be entered for each COUPLE mesh 'm'.

A.19.1.1 Card 50000000 COUPLE Control

This card is entered, whenever COUPLE input is present.

- W1(A) keyword 'couple'
- W2(A) INPUT FORMAT. Enter the keyword 'old' for old-style input (with formatted input), or 'new' for unformatted, RELAP5 card number style input.

A.19.1.2 Card 50004000 Ex-Vessel Heat Transfer Control

This card is used to control ex-vessel heat transfer correlations.

- W1(I) CONTAINMENT VOLUME. This volume is the number of a hydrodynamic volume representing the containment. The ex-vessel heat transfer correlations DO NOT actually use this volume for heat transfer conditions. Instead, any COUPLE node which has this volume specified as the hydrodynamic volume for convective heat transfer will use the ex-vessel heat transfer correlations.
- W2(R) HEAT TRANSFER COEFFICIENT. The heat transfer coefficient to use for vapor phase heat transfer, when the node is modelled as being uncovered.
- W3(R) CONTAINMENT TEMPERATURE. The temperature used for the sink temperature in the ex-vessel heat transfer correlations.
- W4(I) CONTAINMENT LEVEL CONTROL VARIABLE. The control variable which specifies the containment liquid level.

A.19.1.3 Card 5m001000, COUPLE Debris Bed Model Control Card

One of these cards is read for each COUPLE mesh "m", where "m" is between 1 and the allowed maximum number of meshes. The maximum allowed number of meshes is defined by

COUPLE INPUT

parameter 'maxcpm' in common block 'cpmdat'. The maximum in the unmodified transmittal is 5.

W1(I) COUPLE flag and input indicator.

0 = Used on a restart run to turn off the COUPLE model for mesh "m".

-1 = Used on a restart run to replace some of the values on this card for mesh "m".

1 = Read COUPLE input for mesh "m".

This option can be used on RESTART to add or change a COUPLE mesh, unless word 3 is 0 and core slumping into the mesh has already started.

For a restart run, if this word is 1, then the problem type on Card 100 must be RESTARTS instead of RESTART.

W2(I) Number of the RELAP5 volume to receive COUPLE debris. On a restart run, this word may not be changed, but a 0 may be entered as input.

If word 3 is 0, then word 2 must be the same number as word 1 on Card 108.

W3(I) Debris source indicator for COUPLE mesh "m":

-1 No slumping. Debris material is already present at the start of the application.

0 LWR meltdown (default).

1 User-defined slumping.

2 Depends on components above mesh (non LWRs).

3 Corium hydro model (not yet available).

Only 1 mesh of type 0 is allowed.

W4(I) Flag for breakup of COUPLE debris:

0 Debris may be broken up (default).

1 Debris is never broken up.

W5(I) Maximum number of SCDAP/RELAP5 hydraulic time steps to use per COUPLE time steps. Default = 200.

W6(R) Maximum COUPLE time step. Default = 10.0 seconds. If word 5 is 1, this input is not used.

W7(I) Print flag. If greater than 1, print out this COUPLE mesh.

A.19.1.4 Card 5m002000, COUPLE Debris Bed Model Control Card

For each new COUPLE mesh "m" for which a card 5m001000 was entered with word 2 equal

to 2 or 3, this card is needed to specify 1 to 6 connected SCDAP components. On restart, this card is read if, and only if, word 1 on Card 5m001000 is 1.

W1(I) Identification number of first SCDAP component connected to COUPLE mesh "m".

Wn(I) Identification number of n'th SCDAP component connected to COUPLE mesh "m", if any.

A.19.1.5 Card 5m003000, COUPLE Power Card

This card is used for each new COUPLE mesh "m" for which a Card 5m001000 is entered with word 3 equal to 2. It is optional on both NEW and RESTART problems.

W1(I) Power source indicator.

- 0 Constant power from slumping material at time of slumping (default).
- 1 Power is determined by RELAP5 reactor kinetics power in the associated SCDAP components.
- 2 Power is determined by power other than RELAP5 reactor kinetics power in the associated SCDAP components.

If word 1 is 0, then none of the following values on this card are used.

W2(R) Multiplier for fission power in the COUPLE mesh if the associated SCDAP components obtain their power from RELAP5 reactor kinetics. Default = 1.0.

W3(R) Multiplier for fission product decay power in the COUPLE mesh. Used only if the associated SCDAP components obtain their power from RELAP5 reactor kinetics. The default = 1.0.

W4(R) Multiplier for actinide decay power in the COUPLE mesh. Used only if the associated SCDAP components obtain their power from RELAP5 reactor kinetics. The default = 1.0.

A.19.1.6 Cards 5m003001 Through 5m003009, COUPLE Fission Product Decay Power Fractions

These cards are used only for each new COUPLE mesh "m" for which a card 5m003000 with word 1 equal to 2. These cards are optional on both NEW and RESTART problems. The default = 0.0.

The fission product species, in this order are: i, csi, csoh, te, hi, htc, cd, ag, uo2, sn, fe, ru, ba, sb, cs*, i*, zn, xe, and kr.

W1(R) Fraction of fission product decay heat from first species.

COUPLE INPUT

W19(R) Fraction of fission product decay heat from 19th species.

These fractions are used only if the SCDAP components associated with this COUPLE mesh obtain their power from RELAP5 reactor kinetics.

For those species to be tracked in the COUPLE mesh, the fractions are used to account for fission product decay power decreases from fission product loss. A zero fraction value for a given species will mean no power decrease from any loss of that species.

Since not all species need be tracked in the COUPLE mesh, the sum of these fractions does not need to be 1, but it should probably not exceed 1.

Currently when material relocates to a lower axial node in a SCDAP component with power, the power calculated at each axial node is not exactly correct, unless the axial power profile is flat. The same is true then for the power slumped out of such a SCDAP component into a COUPLE mesh. All or none of the powered SCDAP components listed on Card 5m002000 must obtain their power from RELAP5 reactor kinetics.

A.19.2 Formatted COUPLE Input

The old style COUPLE input data consist of a series of ordered input blocks or input data sections. Those data blocks that do not apply to a particular job may be omitted without affecting other sections of input. Each data block consists of an initial block header card, several data cards, and a block terminator blank card. No units are built into the program, and the user must be careful to be consistent throughout. The input is not freeform and must be properly positioned within the specified columns (spaces) of 80-character records (cards). Integer and exponential types of input data must be right-hand justified. The required type of input data is indicated by A for alphanumeric, I for integer, and R for real. The columns for each piece of input data are specified by the two numbers to the left of the definition of the piece of input data. The type of input data is indicated by the character in parentheses to the right of the column specifier.

A.19.3 Title Block

A.19.3.1 Header for Title Block

1-5(A) BLOCK HEADER. Since only the first four characters (Columns 1 through 4) are actually checked on each block header card for each section, the rest may be used as a comment card.

Always input the following word: title.

A.19.3.2 Title Card

1-80(A) FIRST TITLE CARD.

A.19.3.3 Title Card

- | 1-80(A) SECOND TITLE CARD. This is a good place to list the unit set employed.

A.19.3.4 Block Terminator

BLOCK TERMINATOR (blank card).

A.19.4 Mesh Generation Block

A.19.4.1 Header for Mesh Generation Block

- | 1-8(A) HEADER FOR MESH GENERATION BLOCK. Always input the following word: automesh.

A.19.4.2 Mesh Generator Control Card

- | 1-5(I) MAXIMUM VALUE OF I IN MESH. This is the maximum number of nodes in the horizontal direction.
- | 6-10(I) MAXIMUM VALUE OF J IN MESH. This is the maximum number of nodes in the vertical direction.
- | 11-15(I) NUMBER OF MATERIAL BLOCKS TO BE ASSIGNED. This is the number of different material regions specified on the material block assignment Card(s).
- | 16-20(I) GEOMETRIC CODE.
- 0 = r, z axisymmetric.
- 1 = x, y plane body.
- | 21-30(R) MULTIPLIER. This multiplier operates on dimensions that are input on the line segment Card(s) and elsewhere in the input. The multiplier allows the COUPLE input to use inches as the unit for length even though the calculations use meters as the unit for length. (This word) x (value of input number) = (dimension in m).

A.19.4.3 Line Segment Cards

Line segment cards. Any reasonable combination of internal and external line segments that represent circular arcs, straight lines, or points in the r, z (or x, y) plane can be used to generate a finite element mesh. The line segments are defined by the location of the end points. Circular line segments are defined by one intermediate point, or the center, in addition to the end points. The line segment cards can be input in any order. Any given (i, j) pair can be input only once.

The elements that may be filled by relocated material must be quadrilateral and not triangular in shape. Two of the sides must be perpendicular to the direction in which material is transported into the element.

COUPLE INPUT

1-3(I) I COORDINATE OF 1ST POINT.
 4-6(I) J COORDINATE OF 1ST POINT.
 4-14(R) R COORDINATE OF 1ST POINT.
 15-22(R) Z COORDINATE OF 1ST POINT.
 23-25(I) I COORDINATE OF 2ND POINT.
 26-28(I) J COORDINATE OF 2ND POINT.
 29-36(R) R COORDINATE OF 2ND POINT.
 37-44(R) Z COORDINATE OF 2ND POINT.

If the line segment type (Columns 67 to 71) is 0 or 1, then omit the input in Columns 45 through 66.

45-47(I) I COORDINATE OF 3RD POINT.
 48-50(I) J COORDINATE OF 3RD POINT.
 51-58(R) R COORDINATE OF 3RD POINT.
 59-66(R) Z COORDINATE OF 3RD POINT.
 67-71(I) LINE SEGMENT TYPE OF PARAMETER.

0 = Point (input only 1st i, j, r, z).
 1 = Straight line (input only 1st and 2nd set of i, j, r, z as end point of line).
 3 = Circular arc with midpoint of arc specified (input 1st and 3rd sets of i, j, r, z as end points of arc and 2nd set as midpoint on arc).
 4 = Circular arc with center of radius of curvature specified (input 1st and 2nd sets of i, j, r, z as end points of arc and 3rd set of r, z as coordinates of center of radius of curvature).

Straight or curved lines segments in the r, z plane must correspond to either a straight line (i or j constant along line) or a stepped diagonal segment $[ABS(vI)=ABS(vJ)]$ in that i, j plane. Note on a stepped diagonal segment that i is incremented first and then j.

Repeat the line segment Card until the finite element mesh has been completely defined by the specification of line segments. In general, a finite-element mesh can be completely defined by inputting a line segment Card for each segment of the surface of the mesh.

For modeling gap resistances, input two consecutive values of i or j that have identical coordinates.

A.19.4.4 Mesh Generation Block Terminator

BLOCK TERMINATOR (blank card).

A.19.5 Material Block

A.19.5.1 Material Block Assignment

Material block assignment. A card is needed for each block specified. Each card assigns a material definition number to a block of elements defined by the i, j coordinates.

1-5(I) MATERIAL IDENTIFICATION NUMBER. The COUPLE model considers up to 15 different materials. The materials and their identification numbers are:

<u>Material</u>	<u>ID No.</u>
Relocated debris	1
Stainless steel	2
Inconel	3
Carbon steel	4
Coolant	5
Null material	6
MHTGR graphite	7
MHTGR fuel compact	8
MHTGR target	9
MHTGR smeared (homogenized)	10
User-specified materials	11-15

For user-specified materials, the user supplies constant property values by entering the values on the material properties and material data Cards. For user-specified materials, the code will not model phase change.

Each element defined to have relocated debris is considered to contain coolant until the coolant has been displaced by relocated debris that has slumped into the element. The exception to this is the "no slumping" case (NSLPHS = -1 on RELAP5 Card 103N), in which Material 1 is already present at the start of the problem. If on the fission products Card(s) the gap heat transfer is not specified for nodes that are part of null element, then no heat transfer will occur across the null element. Null elements are used to differentiate between two regions with different heat generation rates and to model heat transfer between two materials with a possible gap between them.

6-10(I) MINIMUM I.

COUPLE INPUT

- 11-15(I) MAXIMUM I.
- 16-20(I) MINIMUM J.
- 21-25(I) MAXIMUM J.
- 26-35(R) ALWAYS INPUT 0.0.
- 36-45(R) POROSITY OF MATERIAL IN THESE ELEMENTS. If material type is 1 and element is at start of analysis, input 1.
- 46-50(I) MATERIAL FLAG. For materials other than material type 1 (relocated material), always input the integer 0. For material Type 1, indicate as follows whether relocated material is in the mesh at the start of the analysis.
- 0 = No material in region.
- 2 = Material in region.

These flags are not used for the case of no fluid flow in the debris.

- 51-55(I) INDICATOR FOR DEBRIS.
- 0 = None
- 1 = Partially full
- 2 = Full.

- 56-65(R) PARTICLE DIAMETER.

A.19.5.2 Material Block Terminator

BLOCK TERMINATOR (blank card).

A.19.6 Material Block

A.19.6.1 Material Block Header

- 1-8(A) BLOCK HEADER. Always input the following word: material.

A.19.6.2 Material Data Information

- 1-5(I) NUMBER OF DIFFERENT MATERIALS TO BE DEFINED. Materials that do not exist in the finite element mesh can be defined. In the current version of COUPLE input, if Material 5 is to be used, Materials 1, 2, 3, and 4 need also to be defined.

A.19.6.3 Emissivity

- | 1-10(R) EMISSIVITY. Emissivity for internal radiation in material with ID No. 1. The standard value is 0.8.

A.19.6.4 Material Properties

- | 1-5(I) MATERIAL IDENTIFICATION NUMBER. If material identification number greater than 11 is input, then properties are defined as input on this card (density) and on the material data Card, but materials properties do not change with temperature.
- | 11-20(R) DENSITY OF MATERIAL (kg/m^3). If null material (an element used to model gap resistance), then leave these columns blank.
- | 21-52(A) MATERIAL TITLE INFORMATION. For example, if stainless steel material, input "stainless steel."

A.19.6.5 Material Data

These data are used as default values in case built-in procedures (derivative method in COUPLE) fail to meet specified criteria. If data are not available, low-temperature default data given in the following table should be input. These default values are required. If the input columns are left blank, the code does not automatically set the input variable to the default value.

- | 1-10(R) HORIZONTAL THERMAL CONDUCTIVITY, KR (J/m-s-K). Input 0.0 for null material.
- | 11-20(R) AXIAL THERMAL CONDUCTIVITY, KZ (J/m-s-K). Input 0.0 for null material.
- | 21-30(R) SPECIFIC HEAT CAPACITY, CP (J/kg-K). Input 0.0 for null material.
- | 31-80 BLANK. Unless material = 7, then input next word.
- | 31-40(R) FAST NEUTRON FLUENCE (n/cm^{**2}).

Default values

Material ID	Material	Density (kg/m^{**3})	Specific Heat capacity (J/kg-K)	Thermal conductivity (J/m-s-K)
2	Stainless	7,894	300	13.0
3	Inconel	8,000	427	11.0
4	Carbon steel	8,000	489	42.0

COUPLE INPUT

7	Graphite	1,730	2,000	30.0
8	Fuel compact	1,900	1,200	10.5
9	Target	1,560	1,200	7.0
10	Smeared MHTGR	1,730	2,000	30.0

Repeat the two previous cards until each type of material in the mesh has been defined.

If material = 10, then MHTGR is a smeared core, and insert the next card.

A.19.6.6 MHTGR Material Data

- 1-10(R) CROSS-SECTION AREA OF GRAPHITE (m**2).
- 11-20(R) CROSS-SECTION AREA OF FUEL COMPACT (m**2).
- 21-30(R) CROSS-SECTION AREA OF TARGET (m**2).
- 31-40(R) CROSS-SECTION AREA OF HELIUM COOLANT CHANNELS (m**2).
- 41-50(R) FAST NEUTRON FLUENCE (n/cm**2).

The cross-section areas are in the plane perpendicular to longitudinal axis of the reactor core.

A.19.6.7 Material Block Terminator

BLOCK TERMINATOR (blank card).

A.19.7 Time Step Data

A.19.7.1 Time Step Data Block Header

- 1-4(A) TIME STEP DATA BLOCK HEADER. Always input the following word: step.

A.19.7.2 Temperature Control Card

- 31-40(R) INITIAL TEMPERATURE OF FINITE ELEMENT MESH (K).
- 41-50(R) RELAXATION PARAMETER IN NUMERICAL SOLUTION. Recommended value is 0.5.
- 51-60(R) CONVERGENCE PARAMETER IN NUMERICAL SOLUTION. Recommended value is 1.0. If gap elements (elements with null material) are being modeled, then the computer run time can be very sensitive to this input value. To avoid excessive run time, it may be necessary to define the convergence parameter to be greater than 1.0, perhaps as large as 5.0.
- 61-70(R) INNER RADIUS OF LOWER HEAD OF VESSEL. Use the same units as the

coordinates on the line segment Card. If a spherical lower head is not being modeled, input 0.0.

A.19.7.3 Description of Lower Head of Vessel

- | 1-10(R) OUTER RADIUS OF REGION IN FINITE ELEMENT MESH THAT CAN FILL WITH SLUMPING MATERIAL. Use the same units as the coordinates on the line segment Card. If a spherically shaped lower head is being modeled, input 0.0. If a cylindrically shaped lower head is being modeled or plane coordinates are being used, then this input is used. If plane coordinates are being used, this input specifies the inner radius of pipe being modeled in plane geometry.

- | 11-20(R) THICKNESS OF LOWER HEAD OF VESSEL OR ELEVATION OF TOP SURFACE OF STRUCTURAL MATERIAL SUPPORTING DEBRIS. Use the same units as the coordinates on the line segment Card. If a spherical lower head is not being modeled, then input the distance from the bottom of the finite element mesh to the surface that supports the slumping material.

- | 21-25(I) SPHERICAL LOWER HEAD MODELING FLAG.
 - 0 = Spherical lower head of vessel is not being modeled.
 - 1 = Spherical lower head of vessel is being modeled.

- | 26-30(I) MAXIMUM NUMBER OF ITERATIONS. Recommended value is 10.

- | 31-40(R) INNER RADIUS OF REGION THAT CAN FILL IN WITH SLUMPING MATERIAL. Use the same units as for the line segment Card. Omit for the case of spherical lower head. Omit this input for the SCDAP/RELAP5/MOD2 version of the code. For the case of plane geometry, input 1.0.

- | 41-50(R) DEPTH (THICKNESS) OF PLANE. Use the same units as for the line segment Card. Omit this input for axisymmetric geometry.

- | 51-55(I) TRANSIENT CONFIGURATION OF DEBRIS SLUMPING FLAG.
 - 0 = Debris slumping is self-leveling throughout the COUPLE mesh.
 - 1 = Configuration of slumped debris is defined by the user.

If this flag is set, the order in which elements receive slumped debris is defined by the user. The user can divide the elements into layers, which will fill sequentially as the debris slumps. Within each layer the debris is assumed to self-level across all elements in that layer. The user defines the layers of elements by adding cards immediately after this one; one card for each layer. The code limits the inputs to 25 elements per layer for up to 25 layers. The last card in the list should contain a single 0 to indicate the end of the list. Each card that defines a layer must conform to the format as defined below.

COUPLE INPUT

A.19.7.4 User-Defined Layer of the COUPLE Mesh

- 1-4(I) NUMBER OF ELEMENTS IN THIS LAYER.
- 5-10(I) THE ELEMENT NUMBERS IN THIS LAYER. Five spaces for each element, continued on the next card if necessary.

The last card in the list must contain a single 0.

A.19.7.5 Block Terminator

BLOCK TERMINATOR (blank card).

A.19.8 Internal Heat Generation Block

A.19.8.1 Internal Heat Generation Block Header

- 1-10(A) BLOCK HEADER. Always input the following word: generation. The generation block is required input.

A.19.8.2 Number of Materials Without Internal Generation

- 1-5(I) NUMBER OF MATERIALS FOR WHICH INTERNAL GENERATION IS NOT POSSIBLE. If relocated debris is being considered, input the number that is one less than the input in Columns 1 through 5 of the material data information Card. Otherwise, input the same number.
- 6-10(I) NAF. The number of pairs of lines of mass fractions input.
- 11-15(I) NFP. The number of lines of fission products input.

A.19.8.3 Power Densities

These cards are optional for the "no slumping" COUPLE case (NSLPHS = -1 on the RELAP5 Card 103N), and are not allowed otherwise. Each card defines a power density for a specified group of consecutive nodes. This input can be used for selected nodes to override the power density option set for all COUPLE Material 1 by SCDAP.

- 1-5(I) I1I of first node in the group.
- 6-10(I) J1J of first node in the group.
- 11-15(I) I2I of last node in the group.
- 16-20(I) J2J of last node in the group.
- 21-30(R) X204 Multiplier of power density from Table N402. If N402 = 0, then X204 = constant power density (W/m^3).

31-35(I) N402 Number of RELAP5 general tables of power density (W/m^3).

A.19.8.4 Block Terminator

BLANK CARD.

A.19.8.5 Material Numbers Without Internal Generation

1-5(I) FIRST MATERIAL NUMBER.

6-10(I) SECOND MATERIAL NUMBER.

Continue in Columns 11-15, 16-20, etc., until all materials defined in the material properties Card have been identified. Null material must be defined as material with no internal heat generation.

A.19.8.6 Mass Fractions

These cards are optional for the "no slumping" COUPLE case ($\text{NSLPHS} = -1$ on the RELAP5 Card 103N) and are not allowed otherwise. Each pair of cards defines the mass fractions for the constituents in a consecutive group of COUPLE elements with Material 1. These fractions are converted to atomic fractions and stored as such.

Card 1:

1-5(I) NEL1. Number of first element in the group.

6-10(I) NEL2. Number of last element in the group.

11-20(R) MASS FRACTION OF ZIRCALOY.

21-30(R) MASS FRACTION OF METALLIC URANIUM.

31-40(R) MASS FRACTION OF STAINLESS STEEL.

41-50(R) MASS FRACTION OF SILVER.

51-60(R) MASS FRACTION OF BORON CARBIDE

61-70(R) MASS FRACTION OF URANIUM DIOXIDE

71-80(R) MASS FRACTION OF OXIDIZED ZIRCALOY.

Card 2:

1-10(R) MASS FRACTION OF ALUMINUM.

11-20(R) MASS FRACTION OF LITHIUM.

21-30(R) MASS FRACTION OF CADMIUM.

COUPLE INPUT

31-40(R) MASS FRACTION OF SOIL.

This input overrides the SCDAP values for the elements specified.

A.19.8.7 Fission Products

These cards are optional for the "no slumping" COUPLE case (NSLPHS = -1 on the RELAP5 Card 103N) and are not allowed otherwise. They cannot change the fission product species selected on the SCDAP fission products input Card, but the cards can be used to override the masses for selected elements. Each set of these cards (which may consist of 1, 2, or 3 cards, depending on the number of fission products selected in the SCDAP input) redefines the initial fission product masses for a group of elements with Material 1. The values in a set must be in the same order as those in the SCDAP input.

1-5(I) NEL1 Number of first element in the group.

6-10(I) NEL2 Number of last element in the group.

11-20(R) FIRST IN THE LIST OF SPECIFIED FISSION PRODUCT (kg/m^3).

21-30(R) SECOND IN THE LIST OF SPECIFIED FISSION PRODUCT (kg/m^3).

The remaining fission products are specified in 10-column fields on this card and on a second (and third) card as needed.

A.19.8.8 Block Terminator

BLOCK TERMINATOR (blank card).

A.19.9 Convection Data Block

A.19.9.1 Convection Data Block Header

1-11(A) BLOCK HEADER. Always input the following word: convectsets.

A.19.9.2 Number of Nodes with Convection

1-5(I) NUMBER OF NODES IN FINITE ELEMENT MESH AT WHICH CONVECTION HEAT TRANSFER CAN OCCUR. Nodes specified twice on the fission product Card(s) count as two nodes for this input. Nodes that are part of finite elements that receive relocated material should be defined as nodes at which convection heat transfer occurs. Otherwise, convective heat transfer will not be modeled at the surface of the relocated material. Nodes at both surfaces of gap modeled as null material must be defined.

6-10(I) INPUT THE INTEGER 1.

A.19.9.3 Boundary Conditions at Start of Analysis for Finite Elements That Can Fill With Slumping Debris

1-10(R) ALWAYS INPUT 1,000.0.

11-20(R) ALWAYS INPUT 500.0.

A.19.9.4 Identification of Surfaces With Convective and Radiative Heat Transfer

All convective boundary data should be input for a line of points (that is, i2 equal i1, j2 not equal j1 or i2 not equal i1, j2 equal j1) with the nodal coordinates increasing from the first to the second node. The program will automatically assign values at nodal points intermediate to the first and second defined nodal points. Each line must contain a minimum of two points. Nodes that are on a surface and not listed on the fission product Card are treated as being part of an adiabatic surface.

1-5(I) I COORDINATE OF 1ST NODE.

6-10(I) J COORDINATE OF 1ST NODE.

11-15(I) I COORDINATE OF 2ND NODE.

16-20(I) J COORDINATE OF 2ND NODE.

21-30(R) IF THESE CONVECTIVE NODES ARE NOT MODELING HEAT TRANSFER ACROSS THE GAP, LEAVE THESE COLUMNS BLANK. Otherwise, input gap heat transfer coefficient for case of materials in both sides of the gap being solid state.

55-60(I) IF THESE CONVECTIVE NODES ARE NOT MODELING HEAT TRANSFER ACROSS THE GAP, LEAVE THESE COLUMNS BLANK. Otherwise, input -1.

A.19.9.5 Number of Interfacing SCDAP/RELAP5 Volumes

Omit this card if -1 is input in columns 55-60 on the fission products Card.

1-10(I) NUMBER OF SCDAP/RELAP5 VOLUMES THAT INTERFACES THESE NODES. Input the full nine-digit number.

The fission product and block terminator cards are repeated as many times as necessary to define all the convection boundary data.

A.19.9.6 Block Terminator

BLOCK TERMINATOR (blank card).

A.19.10 Initial Temperature

A.19.10.1 Initial Temperature Block Header

1-8(A) BLOCK HEADER. Always input the following word: tempsets.

A.19.10.2 Number of Temperature Nodes

5-10(I) NUMBER OF NODES IN MESH AT LOCATIONS THAT MAY BE FILLED WITH SLUMPING DEBRIS. Always input the integer 0.

16-20(I) ALWAYS INPUT THE INTEGER 0.

21-30(R) ALWAYS INPUT 0.0.

A.19.10.3 Block Terminator

BLOCK TERMINATOR (blank card).

A.19.11 Plot Control

A.19.11.1 Plot Control Header

1-5(A) BLOCK HEADER. Always input the following word: plots.

A.19.11.2 Plot Control Card

1-5(I) ALWAYS INPUT THE INTEGER 1.

6-10(I) ALWAYS INPUT THE INTEGER 0.

11-15(I) ALWAYS INPUT THE INTEGER 2.

A.19.11.3 Plot Control Block Terminator

BLOCK TERMINATOR (blank card).

A.19.12 Solution Control

A.19.12.1 Solution Control Header

1-6(A) BLOCK HEADER. Always input the following word: couple.

A.19.12.2 Solution Control Block Terminator

BLOCK TERMINATOR (blank card).

A.19.12.3 Problem Termination Card

1-11(A) PROBLEM TERMINATION CARD. Always input the following words: end of

data.

Input data for next COUPLE mesh being modeled.

A.20 NEW STYLE COUPLE INPUT

The couple input in the card number format consists of selecting one value for ccc and designating this as the couple data. It may not be the same as the numbers used for any component, or other input, or each couple mesh; use a different value for ccc.

A.20.1 COUPLE Control

W1(A) KEYWORD 'couple' 50000010 - First Title Card.

W1(A) FIRST TITLE CARD. 64 characters maximum.

| A.20.1.1 Card 50000020, Second Title Card

W1(A) SECOND TITLE CARD. 64 characters maximum.

A.20.2 Mesh Generator

| A.20.2.1 Card 5ccc0100, Mesh Generator Control Card

W1(I) MAXIMUM VALUE OF I IN COUPLE MESH.

W2(I) MAXIMUM VALUE OF J IN COUPLE MESH.

W3(I) NUMBER OF MATERIAL BLOCKS.

W3(I) GEOMETRIC CODE.

W4(R) MULTIPLIER.

This multiplier operates on dimensions input on the 200 cards and elsewhere in the input. The multiplier allows the couple input to use inches as the unit for length even though the calculations use meters for length. (This word) x (value of input number) = dimension.

| A.20.2.2 Cards 5ccc0201 Through 5ccc0299, Line Segment Cards

W1(I) LINE SEGMENT TYPE PARAMETER.

0 = point.

1 = straight line.

2 = Circular arc with second point as midpoint.

3 = Circular arc with third point as center of radius of curvature (Note: only input one point for a point, two for a line, and three for an arc).

W2(I) I COORDINATE OF 1ST POINT.

W3(I) J COORDINATE OF 1ST POINT.

W4(R) R COORDINATE OF 1ST POINT.

NEW STYLE COUPLE INPUT

W5(R)	Z COORDINATE OF 1ST POINT.
W6(I)	I COORDINATE OF 2ND POINT.
W7(I)	J COORDINATE OF 2ND POINT.
W8(R)	R COORDINATE OF 2ND POINT.
W9(R)	Z COORDINATE OF 2ND POINT.
W10(I)	I COORDINATE OF 3RD POINT.
W11(I)	J COORDINATE OF 3RD POINT.
W12(R)	R COORDINATE OF 3RD POINT.
W13(R)	Z COORDINATE OF 3RD POINT.

A.20.3 Material Input

| A.20.3.1 Cards 5ccc0401 Through 5ccc0499, Material Block Assignment

W1(I)	MATERIAL IDENTIFICATION NUMBER.
W2(I)	MINIMUM I.
W3(I)	MAXIMUM I.
W4(I)	MINIMUM J.
W5(I)	MAXIMUM J.
W6(R)	POROSITY OF MATERIALS IN ELEMENTS.
W7(I)	MATERIAL FLAG.
W8(I)	INDICATOR FOR DEBRIS.

| A.20.3.2 Card 5ccc0500, Emissivity

W1(R)	EMISSIONITY.
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| A.20.3.3 Cards 5ccc0501 Through 5ccc0599, Material Properties

W1(I)	MATERIAL IDENTIFICATION NUMBER.
W2(R)	DENSITY OF MATERIAL.
W3(R)	HORIZONTAL THERMAL CONDUCTIVITY.

W4(R)	AXIAL THERMAL CONDUCTIVITY.
W5(R)	SPECIFIC HEAT CAPACITY.
W6(R)	FAST NEUTRON FLUENCE.
W7(R)	CROSS-SECTION AREA OF GRAPHITE.
W8(R)	CROSS-SECTION AREA OF FUEL COMPACT.
W9(R)	CROSS-SECTION AREA OF TARGET.
W10(R)	CROSS-SECTION AREA OF HELIUM COOLANT CHANNELS.

Note: Words 8 through 10 are only input if Word 1 is 10. Word 7 is only used if Word 1 is 7 or 10. For null material, Words 3 through 6 should be 0.0

A.20.3.4 Card 5ccc0600, Temperature Control Card

W1(I)	MELT PROGRESSION AND NATURAL CIRCULATION MODEL OPTION.
W2(R)	RELAXATION PARAMETER IN NUMERICAL SOLUTION.
W3(R)	CONVERGENCE PARAMETER IN NUMERICAL SOLUTION.
W4(R)	INNER RADIUS OF LOWER HEAD OF VESSEL.

A.20.3.5 Cards 5ccc0601 Through 5ccc0699, Initial Mesh Temperature

W1(R)	INITIAL TEMPERATURE OF MESH.
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A.20.4 Geometry

A.20.4.1 Card 5ccc0700, Description of Lower Head of Vessel

W1(R)	OUTER RADIUS OF REGION IN FINITE ELEMENT MESH THAT CAN FILL WITH SLUMPING MATERIAL.
W2(R)	THICKNESS OF LOWER HEAD OF VESSEL OR ELEVATION OF TOP SURFACE OF STRUCTURAL MATERIAL SUPPORTING DEBRIS.
W3(I)	SPHERICAL LOWER HEAD MODELING FLAG.
W4(I)	MAXIMUM NUMBER OF ITERATIONS.
W5(R)	INNER RADIUS OF REGION THAT CAN FILL IN WITH SLUMPING MATERIAL.
W6(R)	DEPTH (THICKNESS) OF PLANE.

A.20.4.2 Cards 5ccc0701 Through 5ccc0799, User-Defined Layer of the COUPLE Mesh

W1(I) NUMBER OF ELEMENTS IN THIS LAYER.
W2..(I) THE ELEMENT NUMBERS IN THIS LAYER.

A.20.5 Power

A.20.5.1 Card 5ccc0800, Number of Materials Without Internal Heat Generation

W1..(I) NUMBER OF MATERIALS FOR WHICH INTERNAL HEAT GENERATION IS NOT POSSIBLE.

A.20.5.2 Cards 5ccc0801 Through 5ccc0899, Power Densities

W1(I) I OF FIRST NODE IN GROUP.
W2(I) J OF FIRST NODE IN GROUP.
W3(I) I OF LAST NODE IN GROUP.
W4(I) J OF LAST NODE IN GROUP.
W5(R) MULTIPLIER FOR TABLE SPECIFIED ON NEXT CARD. If zero, constant power density.
W6(I) NUMBER OF RELAP5 GENERAL TABLE OF POWER DENSITY.

A.20.5.3 Cards 5ccc0901 Through 5ccc0999, Mass Fractions

W1(I) NUMBER OF THE FIRST ELEMENT IN THE GROUP.
W2(I) NUMBER OF THE LAST ELEMENT IN THE GROUP.
W3(R) MASS FRACTION OF ZIRCALOY.
W4(R) MASS FRACTION OF METALLIC URANIUM.
W5(R) MASS FRACTION OF STAINLESS STEEL.
W6(R) MASS FRACTION OF SILVER.
W7(R) MASS FRACTION OF BORON CARBIDE.
W8(R) MASS FRACTION OF URANIUM DIOXIDE.
W9(R) MASS FRACTION OF OXIDIZED ZIRCALOY.
W10(R) MASS FRACTION OF ALUMINUM.

W11(R) MASS FRACTION OF LITHIUM.
W12(R) MASS FRACTION OF CADMIUM.
W13(R) MASS FRACTION OF SOIL.

A.20.5.4 Cards 5ccc1001 Through 5ccc1099, Fission Products

W1(I) NUMBER OF THE FIRST ELEMENT IN THE GROUP.
W2(I) NUMBER OF THE LAST ELEMENT IN THE GROUP.
W3..(R) DENSITY OF THE FISSION PRODUCTS. Input in the same order as done
in the SCDAP cards. You can't change the species selected in the SCDAP fis-
sion product input, but you can override the initial masses.

A.20.5.5 Cards 5ccc1101 Through 5ccc1199, Surfaces with Convective and Radiative Heat Transfer Identification

W1(I) I COORDINATE OF 1ST NODE.
W2(I) J COORDINATE OF 1ST NODE.
W3(I) I COORDINATE OF 2ND NODE.
W4(I) J COORDINATE OF 2ND NODE.
W5(R) GAP HEAT TRANSFER COEFFICIENT.
W6(I) NUMBER OF SCDAP/RELAP5 VOLUMES THAT INTERFACE THESE
NODES.

A.21 CARDS 1001 THROUGH 1999, STRIP REQUEST DATA

These cards are required only in STRIP-type problems. One or more cards are entered, each containing one variable request. Card numbers need not be consecutive. Variables are ordered on the STRIPF file in the order of increasing card numbers.

W1(A) ALPHANUMERIC PART OF THE VARIABLE REQUEST CODE.

W2(I) INTEGER PART OF THE VARIABLE REQUEST CODE.

A.22 CARDS 1001 THROUGH 1999, COMPARE DUMP FILES CONTROL DATA

These cards are required only in CMPCOMS problems. One or more cards are entered, each containing one request to compare dump blocks on the files specified with the -A and -B options on the command line. Card numbers need not be consecutive.

W1(I) DUMP FILE NUMBER FROM FILE SPECIFIED ON -A COMMAND LINE
 OPTION.

W2(I) DUMP FILE NUMBER FROM FILE SPECIFIED ON -B COMMAND LINE
 OPTION.

The values in Words 1 and 2 on a succeeding card must be greater than the values on the preceding card. The values in Words 1 and 2 are the advancement number when the dump block was written. This information is written as a line in the printed output of the run writing the dump file. The form of the line is, "---Dmpcom no. nnn written, block no. mmm on unit u---," where nnn is the advancement count number, mmm is the count of the number of blocks written, and u is A or B indicating the file specified by the -A or -B option.

A.23 SCDAP/RELAP5 OPERATING PROCEDURES

When operating on Unix systems, the SCDAP/RELAP5 program can interpret a Unix style command line. The command line below is written with all of the allowed options (prefixed by a minus sign), and each option is followed by its default value.

```
relap5.x -f ftb1 -i indta -o outdta -p plotfl -r rstplt -s stripf -j jbinfo \
-n null -c cdffile -a coupfl -X -C 0 -A dumpfil1 -B dumpfil2 \
-w tpfh2o -d tpfh2o -h tpfh2 -l tpfli -k tpfk -b tpfhe -e tpfh2 -m tpfna \
-q tpfnak -t tpfli -u tpfh3
```

If an option and its parameter are not entered, the default is used. With the exception of the X option, an option character must always be followed with a file name, and an option may not be repeated. The f option specifies a scratch word addressable file used only on CRAY versions. This file is a word addressable file and the I/O is done by CRAY library subroutines, which have successfully resisted external open and close statements. This file is small and can fit in most directories. The file should be removed after execution, but no error occurs in subsequent calculations if it is not removed. The file *indta* contains input data, *outdta* contains printed output, *plotfl* contains plotter information, *rstplt* is the restart plot file, and *stripf* is the strip file. The files *dumpfil1* and *dumpfil2* are files used to dump common and dynamic blocks for debugging purposes. The files beginning with *tpf* (e.g., *tpfh2o*) are thermodynamic property files where the characters following the *tpf* are chemical names of the material. The SCDAP/RELAP5 code uses only the light and heavy water (H₂O and D₂O) materials. The file *jbinfo* is an optional file created by the user who wishes to place some additional information on the output file (such as a listing of the control cards used to run the job). The *indta* file must be available and the *outdta* file must not exist or else a diagnostic message followed by immediate termination will follow. The *rstplt* must not exist for a NEW problem and must exist for other problems. The *dumpfil1* and *dumpfil2* must not exist for the run that creates them and must exist for the CMPCOMS run. Most of the other options are for operation with the Nuclear Plant Analyzer (NPA).

The command line capability eliminates the need to have all files needed for execution in the same directory or to copy/rename files to match the default names. For example, the command:

```
relap5.x -i myprob.i -o /usr/tmp/rjw/myprob.o \
-r /usr/tmp/rjw/myprob.r -w /u2/rjw/SCDAP/RELAP5/tpfh2o
```

takes the executable file and input file from the current directory, uses a temporary disk for the output and restart-plot files, and uses a water property file from a different directory.

For operating systems other than UNIX, the default file names must be used.

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11. ABSTRACT (200 words or less)

The SCDAP/RELAP5 code has been developed for best estimate transient simulation of light-water-reactor coolant systems during a severe accident. The code models the coupled behavior of the reactor coolant system, core, fission products released during a severe accident transient as well as large and small break loss-of-coolant accidents, operational transients such as anticipated transient without SCRAM, loss of offsite power, loss of feedwater, and loss of flow. A generic modeling approach is used that permits as much of a particular system to be modeled as necessary. Control system and secondary system components are included to permit modeling of plant controls, turbines, condensers, and secondary feedwater conditioning systems.

This volume, Volume III, provides guidelines to code users based upon lessons learned during the developmental assessment process. A description of problem control and the installation process is included. Appendix A contains the description of the input requirements.

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