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MARS-KS CODE MANUAL
Volume II: Input Requirements

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VOLUME II:
Input Requirements

Thermal-Hydraulic Safety Research Department

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PREFACE

Within the nuclear industry, there has been a strong demand for realistic analysis tools based on best-estimate modeling for application in the thermal hydraulic analyses of nuclear reactor systems. This demand has led to the development of such advanced codes as RELAP5, COBRA-TF, TRAC, CATHARE, etc.

Korea Advanced Energy Research Institute (KAERI) conceived and started the development of MARS-KS code with the main objective of producing a state-of-the-art realistic thermal hydraulic systems analysis code with multi-dimensional analysis capability. MARS-KS achieves this objective by very tightly integrating the one dimensional RELAP5/MOD3 with the multi-dimensional COBRA-TF codes.

RELAP5 is a versatile and robust code based on one-dimensional two-fluid formulation, and the code includes many generic component and special process models. COBRA-TF is based on three-dimensional two-fluid, three-field formulation and was developed especially for the reflood thermal-hydraulics of large-break Loss of Coolant Accident (LOCA).

The method of integration of the two codes is based on the dynamic link library techniques, and the system pressure equation matrices of both codes are implicitly integrated and solved simultaneously. In addition, the Equation-Of-State (EOS) for the light water was unified by replacing the EOS of COBRA-TF by that of the RELAP5.

Other developmental objectives are to modernize the coding and to provide some user convenience by providing simple but effective Graphic User Interface (GUI). With some key programming techniques dating back to 1960's, the coding of RELAP5 lags behind the current level of the computer industry. By taking advantages of structured programming techniques provided in modern compiler, FORTRAN 90, the RELAP part of the MARS-KS code was thoroughly re-structured from the original RELAP coding with the objectives of improving the legibility, maintenance and ease of modification. The input scheme was unified whereby the original formatted input scheme of the COBRA-TF has been replaced with the free-format scheme of the RELAP. By this unification, a single free format input file is used for the two parts, one-dimensional and multi-dimensional. Some simple GUI are provided for the program execution and for the on-line showing of the calculation results. The MARS-KS code has been successfully developed and it is being used in many key areas of the nuclear industry.

This input manual provides a complete list of input required to run MARS-KS. The manual is divided largely into two parts, namely, the one-dimensional part and the multi-dimensional part. The inputs for auxiliary parts such as minor edit requests and graph formatting inputs are shared by the two parts and as such mixed input is possible. The overall structure of the input is modeled on the structure of the RELAP5 and as such the layout of the manual is very similar to that of the RELAP. This similitude to RELAP5 input is intentional as this input scheme will allow minimum modification between the inputs of RELAP5 and MARS-KS. MARS-KS development team would like to express its appreciation to the RELAP5 Development Team and the USNRC for making this manual possible.

RELAP5/MOD3.3 CODE MANUAL
VOLUME II:
APPENDIX A
INPUT REQUIREMENTS

Nuclear Safety Analysis Division

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Information Systems Laboratories, Inc.
Rockville, Maryland
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1 INTRODUCTION

This volume completely describes data deck MARS-KS organization and data card requirements for all problem types allowed in MARS-KS. The card numbers are in numerical order.

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 machine at most installations. Now, data are normally 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 in used extensively in this input description to mean an input record.

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 1 and incrementing by 1, is printed as the first part of a problem output. Only the first 80 characters are used for MARS-KS 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 RELAP5 as input, since 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.

1.2 Data Deck Organization

A RELAP5 problem input deck consists of at least one title card, optional comment cards, data cards, and a terminator card. A list of these input cards is printed at the beginning of each 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. We recommend 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 card format punctuation errors, such as an alphanumeric character in numeric fields are 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 RELAP5 problem is terminated at the end of input processing. A standard RELAP5 error message (error message preceded by eight asterisks (********) 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.

1.3 Title Card

A title card must be entered for each 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.

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.

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.

<ins>NOTE</ins>: For <ins>new</ins> problems, the recommended approach for deleting a model feature in the calculation input is to remove the appropriate cards or "comment" them out. Use of the "card number only" method mentioned above is not recommended. For <ins>restart</ins> problems, the recommended approach for deleting a model feature is to use the "delete" word that in typically input on the first data card for a model feature. The "card number only" method works only if the input cards previously appear in the <ins>restart</ins> input deck,

and in that is the case, it is recommended that the user either remove the appropriate cards or "comment" them out. In conclusion, the "card number only" method is not recommended for any problem.

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 ten to be applied to the number part of the field. The exponent part has an E or e or D or d, a sign (+ or -), or both followed by a number giving the power of ten. 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 e or D 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 eight fields:

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

When entering a decimal zero for either an integer or floating point quantity, the 0 can be written in either form. Thus a floating point zero can be entered simply as 0 without a decimal point.

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 the field from the next field.

Most computers (e.g., workstations, CRAY, and IBM) hold only eight characters per word. All alphanumeric words required by RELAP5, such as components types, system names, or processing options, have thus been limited to eight characters. We highly recommend 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.

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.

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.

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 1 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 1. 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.

The first example is 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 second example shows how the pipe volume friction data could be input. The input consists of three words per set for nv sets. The three words designate the wall roughness, hydraulic diameter (input of 0 causes the code to calculate it), and volume number. 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.

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, and some applications are case sensitive, others not. At the NRC, 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 (tr) and editors that can easily switch alphabetic characters to the desired case.

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 that are 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.

2 MISCELLANEOUS CONTROL

2.1 Developmental Model Control, 1

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 the development and testing of the code. Anyone using this card must realize that they are selecting experimental options still under development. Furthermore, these options may change more frequently than the revision of this input manual. Thus, before using the options, users should obtain the brief listing of current options from the code (described below) and verify those descriptions against this manual.

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 being used 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. Adding options or deactivating options is allowed at a restart; the previously defined options will remain. 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.

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.

W1-91. Option number as described above.

Option 0. This option lists out all the available options.

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

Option 2. This option sets the interfacial mass transfer to 0 and the direct heating heat transfer coefficient to 105. This option simulates the no mass transfer case in which the two phases are in thermal equilibrium.

Option 4. This option scales back the Courant limit to 75% of its calculated value so that the time step will always be less than or equal to 75% of the Courant limit.

Option 6. This option outputs information to the screen and to the screen file every time dtstep is called. It is useful for determining why the code is cutting the time step. The volume number for the volume that has the limiting Courant time step and the maximum mass error for each time step is printed on one line. In addition, the pressure and void fraction for each of these volumes are printed. If the time step is cut, the reason for the cut is given in the right-hand column.

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 .

Option 9. This option provides a 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 towards the condensation site. Instabilities occur that eventually cause the code to fail. This changes introduces a plug flow model that limits condensation to a value that is just large enough to condense all the vapor that can flow at the critical velocity, utilizing the full channel cross-sectional 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 12. This option provides a user controlled (on/off) water packer developed for horizontal reactors such as the Hanford N-Reactor. The interfacial friction coefficient term for the momentum equation, C_i, is adjusted as a function of vapor void fraction. For void fractions of 0.001 or less, C_i is forced to an arbitrarily large value of 10^{10}. For void fractions greater than 0.01, the regularly calculated C_i is used. For void fractions between 0.001 and 0.01, a cubic interpolation scheme is used to adjust C_i 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 upsteam 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 on to the next cell or impede the incoming liquid from an upstream cell. In either case, the model eases the overfilling and overpressurization of the cell.

Option 13. This option activates vertical stratification changes.

Option 14. This option turns off constitutive relations and should only be used for testing advancement of the basic advancement scheme for two-phase conditions. Do not use for single phase conditions.

Option 16. This option activates the velocity flip/flop logic for the nearly-implicit advancement scheme.

Option 17. This option allows the code to run at the Courant limit with a multiplication factor of four instead of two and a reduction factor of 0.25 instead of 0.5 used in the mass error check for the time step control.

Option 18. This option adds the sharp interface and reverse void profile logic from MOD2.5.

Option 19. This option uses the Bestion correlation (in MOD2.5) rather than the EPRI correlation (in MOD3) for bundles (when volume flag b = 1).

Option 20. This option uses the annulus multiplication factor for bubble rise velocity. This model change was raised due to downcomer boiling issue for LBLOCA of DVI plant.

Option 23. This option selects a boron transport algorithm (Godunov) that greatly reduces the numerical diffusion of boron compared to the standard algorithm.

Option 24. This option activates the original RELAP5 subcooled boiling model. The default subcooled boiling model is the SRL model, which is better at low pressures.

Option 25. This option linearizes the interfacial heat transfer for the nearly implicit scheme.

Option 32. This option activates the stretch logic for water packing model.

Option 36. Option 36 limits metastable extrapolation to 50 K.

Option 37. This option turns off the umbrella model. When the umbrella model is on, an upper limit is placed on the liquid interfacial heat transfer coefficient (H_{if}) when the liquid is subcooled. The limit is umbrella shaped so as to force the coefficient to small values as the void fraction approaches 0.0 or 1.0.

option 40. This option uses the KINS reflood model heat transfer correlations in subroutine PSTDNB. It can be invoked without having any KINS grid input (43000000 cards)

Option 41. This option includes energy dissipation due to form loss.

Option 42. This option applies a stronger unchoking test for junctions with an abrupt area change.

Option 43. This option uses iteration to calculate the hydrodynamic conditions at the throat for critical flow of vapor.

Option 44. This option turns on the AECL Look Up Table for CHF correlation

Option 45. This option selects the newly developed model for condensing interphase heat transfer.

Option 48. This option requests use of the level tracking model during moving problems.

Option 50. This option activates at all junctions where choking option is activated the original RELAP5 critical flow model instead of the default Henry-Fauske critical flow model. The code does not allow a user to switch between the two critical flow models in the middle of a problem, e.g. switching from the Henry-Fauske to the original critical flow model after a steady-state run at the beginning of a transient run.

Option 51. Normally, water packing is activated in all volumes unless specifically disabled by an input volume flag. This option disables water packing for all volumes.

Option 52. Normally, the choking model is activated for all junctions unless specifically disabled by an input junction flag. This option disables the choking model for all junctions.

Option 53. This option activates the Moody critical flow model. It is part of the CANDU package.

Option 54. This option activates the M.S.Chung modified mechanical critical flow model.

Option 55. This option activates the HF critical flow based on Enthapy Upstream.

Option 56. This option enforces $v_g = v_f$ at $_g = 1$ in BubbleDropDrag(FIDIS2).

Option 57 Turbulent viscous stress terms in 3D channel and gap module is activated.

Option 60. This option modifies the time step control for Courant limit. It is turned on automatically now.

Option 61 This option activates the Podowski subcooled boiling model instead of the Lahey method.

Option 62. This option uses newly developed changes to the Chen F factor in PREDNB to minimize oscillations.

Option 64. This option uses the old halving and doubling of the time step but the new Courant limit.

Option 65. This option changes the subcooled boiling model by modifying the fraction of nucleate boiling heat flux that generates vapor when the bulk liquid is subcooled. The modification minimizes the “on/off” behavior associated with low-pressure/low-flow conditions.

Option 66. This option implements donor/acceptor differencing in vertical stratification volumes.

Option 67. This option activate the lateral momentum flux.only for MULTID component. Using this option, the diffusion term of MULTID component is neglected.

Option 68. This option use serial X-Y volume-junction ID number for MULTID Component

Option 69 This option causes Two Step Method using IPF Model. Virtual Mass Force is deactivated

Option 70. This option use ASME 67 type Dynamic property instead of ASME 93 property.

Option 71. This option turns on the TMDPVOL momentum flux term.

Option 75. This option causes the vaporization smoothing.

Option 76. This option causes the default junction diameter as a min. volume hydaulic diameter.

Option 77. This option activates the SNU bubble regime model in annulus.

Option 78. This option deactivates 3D water-packing scheme.

Option 79. This option generates the plot record file for APTPLOT software.

Option 80. This option enables the moving reactor model by KAERI

Option 81. This option activates the Baker-Just metal water reaction equations. It is part of the CANDU package.

Option 82. This option activates 3D dial.

Option 83. This option activates generation of MARS-KS data file for interfacing with MIDAS severe accident code.

Option 84. This option activates implicit gravity head and horizontal stratification force due to the void gradient in the nearly implicit scheme.

Option 85. This option produce tecplt.dat file of MULTID output parameter for TECPLOT 3^{rd} party graphic software.

Option 86. This option deactivates option 60. It restores the old Courant time step calculation using void weighted volume averaged velocities with icoran = 1.

Option 87. This option deactivates the NC gas equation in the 3D module and a minimum internal energy of gas phase in the 1D module is set to 2.3E6 J/kg.

Option 88. uses KRB1 CHF correlation at P>50 bar rather than AECL Lookup Table

Option 89. uses KNOEBEL Annuli CHF correlation in annuli geometry (120)

Option 90. This option turns on the e-flag (modified PV term in the energy equation) for all applicable junctions. This includes all junctions except for time-dependent junctions, accumulator junctions, and junctions associated with separator, jetmixer, pump, turbine, and ECCMIXER components.

Option 97. This option turns on SCAN.DLL CANDU 3D Kinetic code

Option 99. This turns on Iterative Matrix solver for sparse matrix.

2.2 Multiplier for the Global Models, 10

This input card will be added for the multipliers of the global correlations in MARS-KS code. This feature is not implemented yet.

2.3 Multiplier for the Component-wise two phase wall friction, 11

This input card was added for implementing the multipliers for the two-phase wall friction for the specified components. Up to 9 components can be entered in card. If card is not entered, the default multipliers 1.0 are used.

W1(R) Multiplier.

W2(I) Component 1 identification number: CCC

W3(R) Component 2 identification number: CCC

W4(R) Component 3 identification number: CCC

...

WN(I) Component N identification number: CCC

2.4 Multiplier for the component-wise interfacial drag model, 12

This input card was added for implementing the multipliers for the interfacial drag model for the specified components. Up to 9 components can be entered in this card. If card is not entered, the default multipliers 1.0 are used.

W1(R) multiplier.

W2(I) Component 1 identification number: CCC

W3(R) Component 2 identification number: CCC

W4(R) Component 3 identification number: CCC

...

WN(I) Component N identification number: CCC

2.5 Multiplier for the component-wise interfacial heat transfer model,

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This input card was added for implementing the multipliers for the interfacial heat transfer model for the specified components. Up to 9 components can be entered in this card. If card is not entered, the default multipliers 1.0 are used.

W1(R) multiplier.

W2(I) Component 1 identification number: CCC

W3(R) Component 2 identification number: CCC

W4(R) Component 3 identification number: CCC

...

WN(I) Component N identification number: CCC

2.6 Problem Type and Option, 100

This card is always required.

W1(A) Problem type. Enter one of the following: NEW, RESTART, RESET, 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.

STRIP specifies that data are to be extracted (stripped) from the RSTPLT file, and only the data specified are written to the STRIP file.

W2(A) Problem option. This word is needed if W1 is NEW or RESTART and is optional if W1 is STRIP.

If NEW or RESTART is entered, in W1, enter either STDY-ST or TRANSNT in W2 to specify the type of simulation. Note the cautions discussed in Section 2.9 when the problem option is changed from STDY-ST to TRANSNT or vice versa.

When STRIP is entered in W1, enter either BINARY or FMTOUT or leave W2 blank. 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)).

The 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.

2.7 Input Check or Run Option, 101

This card is optional for all types.

W1(A) Option. Enter either INP-CHK or RUN; if this card is omitted, RUN is assumed. This card has no effect on a CMPCOMS problem

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.

2.8 Units Selection, 102

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 Pa = kg•m/s^2•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.

2.9 Restart Input File Control, 103

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 prior to 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 0, and the RSTPLT file will contain information as if this problem type were NEW.

Some cautions should be observed when the problem advancement time is changed by changing the problem option from STDY-ST to TRANSNT, or vice versa, or the problem advancement time is reset through W1 on card 200. Either or both of these could be specified at restart. When the advancement time is changed, the user is responsible for ensuring that models involving problem time will operate as intended. Affected models include trips using advancement time, control systems using time as an operand (does not include differentiation or integration with respect to time), and table lookup and interpolation using time as the independent variable. If necessary, trips, control systems, general tables, time-dependent volumes, junctions, and pump speed tables can all be reentered at restart. With normal modeling practices, little use of modeling features involving advancement time is needed for runs to steady-state and accordingly little effort should be needed in switching from STDY-ST to TRANSNT. Because of the frequent use of time in logic to initiate failures, as part of safety systems, and used in establishing the delay times allowed in most table lookup and interpolation tables, required changes to a transient run may be extensive.

The program does make a change to delay control components when the advancement time is changed. The delay control component operates by maintaining a tabular past history of the delayed functions and using table lookup and interpolating to evaluate the delayed function. The table consists of pairs of time values and the delayed function. When the problem time is changed, the time values in the history table and the time value to store the next point in the table are modified by adding the difference of the new advancement time and the old advancement time. The modified history table is as if the problem being restarted was run with the new advancement time. This may not be the desired change, and, in that case, the user can reenter the delay component.

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.

Alternately, a -1 may be specified instead of a specific restart number. This has the effect of restarting a problem from the last block in the restart file. Thus, the user can now set up a series of restart cases which begin from the end of a previous run without having to wait for the run to finish in order to get the actual restart number from which to restart.

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 forty 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.

2.10 Restart-Plot File Control, 104

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. Only the FILENAME option can be used. 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 this word is NONE, no restart-plot file is written. If this word is FILENAME, words 2-6 on this card contain the restart plot file name.

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 forty 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.

2.11 CPU Time Remaining and Diagnostic Edit, 105

Card 105 controls termination of the 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 0, 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 due to 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 seconds 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 that is to follow termination of RELAP5 execution. This card is optional, but we strongly recommend its use with Word 3 nonzero 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 0, no debug options are in effect. If Word 4 is greater than 0, 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 the 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.

2.12 Noncondensable Gas Species, 110

This card is required for all calculations that use noncondensable gas. Nitrogen must be included for any problem having accumulators. This card cannot be entered on a RESTART problem.

W1-WN(A) Noncondensable gas type. Enter any number N of words (maximum 5) of the following noncondensable gas types: ARGON, HELIUM, HYDROGEN, NITROGEN, XENON, KRYPTON, AIR or SF6.

2.13 Noncondensable Mass Fractions, 115

Card 115 is related to card 110. 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. The sum of the mass fractions must sum to 1.0. 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. This card cannot be entered on a RESTART problem.

W1-WN(R) Mass fraction for each noncondensable gas type.

2.14 Card 116, Convergence Criteria

W1(R) convergence criteria defined used in iteration matrix solver. default = $1.0e^{-6}$

2.15 Card 119, Gravity Constant

This card is optional and specifies the gravitational constant. If not entered, the earth gravitational constant of 9.80665 m/s^2 is used.

W1(R) Gravitational constant (m/s^2, ft/s^2). A positive number, which must be greater than or equal to $1.01.0x10^{-6}$ m/s^2 (or $3.2808x10^{-6}$ ft/s^2 if British input is used), is used as the gravitational constant. If -1.0 is entered, the earth gravitational constant is used.

2.16 Hydrodynamic System Control

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 were 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.

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 0. These cards should not be entered in a RESTART problem.

2.16.1 Hydrodynamic System, 120-129

W1(I) Reference volume number of the system. This must be a volume in the hydrodynamic system.

W2(R) Reference elevation of the volume center relative to a fixed z-axis for the system (m, ft).

W3(A) Fluid type for the system. Enter H2O or H2ONEW or D2O or HE for helium or CO2 for carbon dioxyde. If H2ONEW is entered, the code uses the newer steam tables and if H2O is entered, the code uses the older thermodynamically-consistent tables. The newer tables are based on the Helmholtz functional fit in the IAPWS-1995 document.

W4(A) Optional alphanumeric name of system used in output editing. *NONE* is used if this word not entered.

W5(I) System information flag. This word has the packed format g. This word is optional. If this word is not entered, g = 0 is used.

The digit g specifies whether noncondensable gas is present for this system. g = 0 specifies that noncondensable gas is present for this system. g = 1 specifies that noncondensable gas is not present for this system. If g = 1 (no noncondensable) in a system and if the digit t = 4, 5, or 6 in the hydrodynamic volume component control word εbt, an input error will result.

g = 2 specifies that pure noncondensable gas is present only. Others will result in error.

W6-9(A) Thermodynamic property file name of the system. This optional alphanumeric entry can be used to enter the file name of the thermodynamic property file of the system. Up to thirty-two characters may be entered as one alphanumeric field. (The code internally treats the field as up to four eight-character words.) The default file name for the thermodynamic property file is tpfh2o for H2O, tpfd2o for D2O, tpfh2onew for H2ONEW, tpfhe for helium, tpfco2 for CO_2, etc.

2.17 Self-Initialization Option Control

These cards are optional, are not needed, and are only used as a cross-check on the controllers specified in Section 14. Data supplied on these cards are used to invoke the self-initialization 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 14.

2.17.1 Self-Initialization Control, 140

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.

or

W1(A) DELETE or DISCARD. The command DELETE is allowed only in RESTART problems, and self-initialization control must be existing at the time of restart. The DELETE command deletes all controllers.

2.17.2 Self-Initialization Pump Controller and Identification, 141-142

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.

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.

2.17.3 Self-Initialization Steam Flow Controller Identification, 143-144

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 the valve component is assumed to be 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.

2.17.4 Self-Initialization Feedwater Controller Identification, 145-146

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.

2.17.5 Pressure and Volume Control Component Identification, 147

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.

3 TIME STEP CONTROL

3.1 Initial Time Value and User-Controlled Time Step, 200

This card is optional. See the description of each word on this card for the default values if this card is not entered.

W1(R) Initial time. If not entered, the simulation time at the start of the advancements is 0 for a NEW problem, the advancement time at the point of restart for a RESTART problem, or 0 for a RESTART problem in which the problem option switches from STDY-ST to TRANSNT or vice versa. If this card is entered, the simulation time is set to the entered value, which must be greater than or equal to 0. Setting the simulation time with this entry can be done on any NEW or RESTART problem but with most applications should only be used in NEW or RESTART problems that switch from the STDY-ST or TRANSNT options. See the cautions discussed in Section 2.9 for this capability. When needing to enter W2 but do not wish to enter a new initial time, enter -1.0, which is a flag to ignore this word.

W2(I) Control variable number for user-controlled time step. This word is optional. A nonzero number specifies a control variable whose value is used for user-specified time step control. The time step will be determined from the maximum of the value of the control variable and the current minimum time step entered on cards 201 through 299. The time step will be equal to or less than this value and depends on the current requested time step, the mass error and other error checks, the Courant limit, and the time-step reduction options.

3.2 Time Step Control, 201-299

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. The default action for the code is to stop at the first time step that is greater than or equal to this time. This means the code will probably not stop at the end time specified on this card, but will stop at some time larger than the end time. If the user wants to stop exactly at the end time, then the user needs to prefix the end time with a negative (-) sign.

W2(R) Minimum time step (s). The code starts out with this time step and increases by a factor 1.1 for the next step if the mass error is sufficiently low.

W3(R) Maximum time step (s). This quantity is also called the requested time step.

W4(I) Control option. This word has the packed format ssdtt. It is not necessary to input leading zeros.

ss. These digits 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. To decide how to set ss, pick some appropriate numbers from the set 0, 1, 2, 3, and 4, using the description below to decide which numbers to pick, then add the numbers together and set ss to that number.

ss = 0. NORMAL OUTPUT. If no bits are set (i.e., the number is 0), all the standard major printed output is given.

ss = 1. OMIT HEAT STRUCTURE TEMPERATURE BLOCK OUTPUT. 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.

ss = 2. OMIT SECOND PORTION OF THE JUNCTION BLOCK OUTPUT. 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.

ss = 4. OMIT THIRD AND FOURTH PORTIONS OF VOLUME BLOCK OUTPUT. If the third bit from the right is set (i.e., ss = 4 if the other bits are not set), the third and fourth portions of the volume block is omitted.

ss = 8. OMIT STATISTICS BLOCK. 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.

d. This digit 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. To decide how to set d, pick some appropriate numbers from the set 0, 1, 2, and 3, using the description below to decide which numbers to pick, then add the numbers together and set d to that number.

d = 0. NORMAL OUTPUT. 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 successful time step; and the bits indicate which output is obtained. These options should be used carefully, since considerable output can be generated.

d = 1. MAJOR EDITS EVERY TIME STEP. 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 successful time step.

d = 2. MINOR EDITS EVERY TIME STEP. If the second bit from the right is set (i.e., d = 2 if the other bits are not set), minor edits are obtained every successful time step.

d = 4. PLOT RECORDS EVERY TIME STEP. If the third bit from the right is set (i.e., d = 4 if the other bits are not set), plot records are written every successful time step. As a practical example, assume you made a run with d = 0 and discovered that the plot points were too far apart to tell what was happening in the transient. One solution would be to decrease the plot frequency W5, to 1 to get a plot point for each requested time step and decrease the maximum time step size to get the desired detail in the plot. An easier solution would be to set ¨d = 4 and get plot points out each successful time step, even if they are smaller than the requested time step. For example, if tt = 3, then changingW4 from a 3 to a 403 would do the trick.

The digits tt, that represent a number from 0 through 63, are used to control the time step. The number is treated as a six-bit binary number. The effect of no bits being set, i.e., 0 being entered, and the effect of each bit are first described followed by the recommended combination of bits. To decide how to set tt, pick some appropriate numbers from the set 0, 1, 2, 4, 8, 16, and 32 using the description below to decide which numbers to pick, then add the numbers together and set tt to that number.

tt = 0. NORMAL OUTPUT. 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 cases such as water property failures.

tt = 1. MASS ERROR CONTROLS THE TIME STEP. If the first bit from the right is set (i.e., tt = 1 if no other bits are set), the hydrodynamics advancement, 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.

tt = 2. HYDRODYNAMIC TIME STEP SAME AS HEAT CONDUCTION TIME STEP. If the second bit from the right is set (i.e., tt = 2 if the other bits are not set), the heat conduction/transfer time step is the same as the hydrodynamic time step; if the second bit from the right is not set, the heat conduction/transfer time step uses the maximum time step.

tt = 4. HEAT CONDUCTION AND HYDRODYNAMICS COUPLED IMPLICITLY. If the third bit from the right is set (i.e., tt = 4 if the other bits are not set), the heat conduction/transfer and hydrodynamics are coupled implicitly; if the third bit from the right is not set, the heat conduction/transfer and hydrodynamic advancements are done separately and the information between the models is coupled explicitly.

tt = 8. NEARLY-IMPLICIT TIME ADVANCEMENT. If the fourth bit from the right is set (i.e., tt = 8 if the other bits are not set), the nearly-implicit scheme is used to advance the hydrodynamics; if the fourth bit from the right is not set, the semi-implicit scheme is used to advance the hydrodynamics.

tt = 16. STEADY-STATE CONVERGENCE NOT CHECKED. If the fifth bit from the right is set (i.e., tt = 16 if the other bits are not set), the test for convergence of a steady-state calculation is not made; if the fifth bit from the right is not set, the test for convergence of a steady-state calculation is made.

tt = 32. AUTOMATIC SELECTION BETWEEN SEMI- AND NEARLY-IMPLICIT TIME ADVANCEMENT. If the sixth bit from the right is set (i.e., tt = 32 if the other bits are not set), the on-line algorithm selection of time migration is used to advance the hydrodynamics. The semi-implicit scheme will be used when the time step is below the Courant limit and the nearly-implicit will be used when a large time step can be taken.

We recommend not using tt equal to 0 except for special testing situations. The use of tt equal to 1 is possible if the maximum time step is kept sufficiently small to ensure that the explicit connection between the heat conduction/transfer and hydrodynamics calculations remains stable. If there is any doubt, use tt equal to or greater than 3 (sets first bit and second bit). Using tt equal to 3 or 11 specifies the semi-implicit or the nearly-implicit advancement scheme, respectively, with both schemes using time step control, the heat conduction and hydrodynamics use the same time step, and the heat conduction/transfer and hydrodynamics are advanced separately. Using tt equal to 7 or 15 specifies the same features as tt equal to 3 or 11 and, in addition, specifies the implicit advancement of the heat conduction/transfer with the hydrodynamics. We recommend the nearly-implicit scheme 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, though we advise the user that the answers may change somewhat from the semi-implicit scheme answers (depending on the time step size). The nearly-implicit advancement scheme is still under development and assessment; most of the verification and assessment for the code has been done with the semi-implicit advancement scheme. We did not recommend use of the implicit coupling of the heat conduction/transfer and hydrodynamics in prior versions since the implicit coupling was only partially implemented. With the implicit coupling now complete, we encourage the use of tt equal to 7 or 15. Users should be cautioned that the implicit coupling is a recent addition to RELAP5 and is still under assessment. When using the implicit coupling, the heat conduction time step must be the same as the hydrodynamic time step. This requirement is currently not enforced by the coding. In steady-state calculations, setting the fifth bit (adding 16) 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 to 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. Volume V, section 3.1.3.1 contains some recommendations for this and the following two words.This word has the packed format sssmmm. It is not necessary to input leading zeros. The mmm is the number of maximum or requested time advances per minor edit and the sss is the skip factor for the write of plot information. Thus sss*mmm is the number of maximum or requested time advances per plot-write on RSTPLT file. This feature enables to save the storage requirement for RSTPLT file. if no skip factor is set (sss=0), the default value is assigned, i.e. sss=1.

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.

4 MINOR EDITS, 301-399

CARDS 300, PLOT TIME SPAN

This card is optional for NEW and RESTART problems, are required for PC Window Plotting Case. If not entered, the initial time in CARD 2XX is set as a minimum value and final time is set as a maximum value.

W1(R) minimum X-value for X-Y Plot.

W2(R) Maximum X-Value for X-Y Plot.

CARDS 301 THROUGH 399, MINOR EDIT DATA 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.

W1(A) Variable code (alphanumeric).

W2(I) Parameter (numeric).

W3(R) Minimum Y Value for X-Y Plot (Optional Select for Window Plotting).

W4(R) Maximum Y Value for X-Y Plot (Optional Select for Window Plotting).

W5(I) Window Identification for multiple X-Y Plot.

W6(I) Color Pallet Identification for multiple X-Y Plot.

Words 1 and 2 form the variable request code pair. The quantities that can be edited and the input required 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 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. The quantities are listed in alphabetical order within each section.

The underlined quantities without an asterisk in Section 4.1 through Section 4.8 are always written to the restart-plot file (RSTPLT). Underlined quantities followed by an asterisk have only some of the quantities written to the restart-plot file and the text will indicate which quantities are written.

The quantities that are not underlined or some of the quantities underlined and followed with an asterisk are written to the restart-plot file only if requested on a 2080xxxx card as described in Section A4.9.

4.1 General Quantities

Variable	Description
COUNT	Current attempted advancement count number. The parameter is 0.
CPUTIME	Current CPU time for this problem (s). The parameter is 0.
DT	Current time step (s). The parameter is 0.
DTCRNT	Current Courant time step (s). The parameter is 0.
EMASS	Estimate of mass error in all the systems (kg, lb). The parameter is 0.
ERRMAX	Current estimate of the truncation mass error fraction. The parameter is 0. This is the maximum of the two types of computed mass error (ε_m or ε_{rms}).
EXTSNN	Extra system variables where NN goes from 01 to 20. These variables are output to the restart-plot file when RELAP5 is built using the "extra" flag on the dinstls command line. These variables are useful for debugging the code and for making temporary changes to the code. There is a similar set of variables for volumes called EXTVNN and for junctions called EXTJNN. Parameter is system number N.
NULL	Specifies null field. Allowed only on trip cards. The parameter is 0.
RKTPOW3D	Total reactor power for the MARS-KS/MASTER kinetics coupled code (W). It is the sum of the fission and decay powers (W) for all the core heat structures. This variable is written to the restart-plot file only when card 1 option 88 is used.
STDTRN	Steady-state/transient flag. The parameter is 0. For steady-state, the value is 0.0. For transient, the value is 1.0.
SYSERG	Total energy in system N (kJ, Btu). Parameter is system number N.
SYSMER	Estimate of mass error in system n (kg, lb). Parameter is system number N.

SYSTMS Total mass of steam, water, and noncondensable in system N (kg, lb). Parameter is system number N.

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 0.0, 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.

TIME Time (s). The parameter is 0. This request cannot be used for minor edit requests.

TIMEOF Time of trip occurring (s). The parameter is the trip number. This request is allowed only on trip cards.

<u>TMASS</u> Total mass of water, steam, and noncondensables in all the systems (kg, lb). The parameter is 0.

TOTHGEN Total hydrogen generation from metal-water reactions in all the systems (kg, lb). The parameter is 0.

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.

Variable	Description
ACPGTG	Accumulator vapor specific heat, C_p, at vapor temperature (J/kg•K, Btu/lb•^{o}F).
ACPNIT	Accumulator noncondensable specific heat, C_p, at vapor temperature (J/kg•K, Btu/lb•^{o}F).
<u>ACQTANK</u>	Total energy transport to the gas by heat and mass transfer in the accumulator (W, Btu/s).
<u>ACRHON</u>	Accumulator noncondensable density (kg/m^3, lb/ft^3).
<u>ACTTANK</u>	Mean accumulator tank wall metal temperature (K, ^{o}F).
<u>ACVDM</u>	Gas volume in the accumulator tank, standpipe, and surge line (m^3, ft^3).
ACVGTG	Accumulator vapor specific heat, C_v, at vapor temperature (J/kg•K, Btu/lb•^{o}F).

<u>ACVLIQ</u> Liquid volume in the accumulator tank, standipipe, and surge line (m^3, ft^3).

AHFGTF Accumulator heat of vaporization at liquid temperature (J/kg, Btu/lb).

AHFGTG Accumulator heat of vaporization at vapor temperature (J/kg, Btu/lb).

AHFTG Accumulator liquid enthalpy at vapor temperature (J/kg, Btu/lb).

AHGTF Accumulator vapor enthalpy at liquid temperature (J/kg, Btu/lb).

AVGTG Accumulator specific volume at vapor temperature (m^3/kg, ft^3/lb).

AVISCN Accumulator noncondensable viscosity (kg/m•s, lb/ft•s).

BETAV Accumulator steam saturation coefficient of expansion (K^{-1}, $^oF^{-1}$).

CDIM GE mechanistic dryer critical inlet moisture quality.

DIM GE mechanistic dryer inlet moisture quality.

DMGDT Accumulator/time rate of change in dome vapor mass (kg/s, lb/s).

GDRY GE mechanistic separator capacity factor.

OMEGA Inertial valve disk angular velocity (rad/s, rev/min).

<u>PMPHEAD</u> Pump head in the pump component (Pa, lb_f/ in^2).

PMPMT Pump motor torque (N•m, lb_f•ft).

PMPNRT Calculated pump inertia (kg•m^2, lb•ft^2).

<u>PMPTRQ</u> Pump torque in the pump component (N•m, lb_f•ft).

<u>PMPVEL</u> Pump rotational velocity in the pump component (rad/s, rev/min).

PRZLVL Pressurizer level in the PRIZER component (m, ft).

THETA Inertial valve disk angular position (deg).

<u>TUREFF</u> Efficiency of the turbine component.

<u>TURPOW</u> Power developed in the turbine component (W, Btu/s).

TURTRQ Torque developed in the turbine component (N•m, lb_f•ft).

TURVEL Rotational velocity of the turbine component (rad/s, rev/min).

VLVAREA Ratio of the current valve physical area to the junction area. The junction area is the fully open valve physical area for the smooth area option and the minimum of the two connecting volumes for the abrupt area change.

VLVSTEM Ratio of the current valve stem position to the fully open valve stem position for the motor and servo valves when the normalized stem position option is used. For the motor and servo valves when the normalized area option is used and for all the other valves, this is the ratio of the current valve physical area to the fully open valve physical area.

XCO GE mechanistic separator liquid carryover quality.

XCU GE mechanistic separator vapor carryunder quality.

XI GE mechanistic separator inlet quality.

4.3 Volume Quantities

For most of the following variable codes, the parameter is the volume number, i.e., the nine-digit number CCCNN0000 printed in the major edit. The parameter is CCC010000 for a single-volume; CCC010000 for a time-dependent volume; CCCNN0000 for a volume in a pipe component ($01 \leq NN \leq 99$); CCC010000 for the volume in a branch, separator, jetmixer, turbine, or ECC mixer component; CCC010000 for the volume in a pump component; and CCC010000 for the volume in an accumulator component. 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 (or x), respectively, faces 3 and 4 are inlet and outlet faces associated with coordinate 2 (or y), and faces 5 and 6 are inlet and outlet faces associated with coordinate 3 (or z). 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) or 1 or 2, the 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. For the underlined quantities followed by an asterisk in the list below, the coordinate-dependent quantities for coordinate 1 are automatically written to the restart-plot records using the parameter with F equal to 0. The other coordinate-dependent quantities can be written to the plot records using the 2080XXXX card series described in Section A4.9.Input checks are made to ensure the parameter specifies a volume coordinate direction that is in use.

Variable	Description
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, β_f, bulk conditions (K^{-1}, $^oF^{-1}$).
BETAGG	Vapor isobaric coefficient of the thermal expansion, β_g, bulk conditions (K^{-1}, $^oF^{-1}$).
BORON	Spatial boron density, ρ_b (kg/m^3, lb/ft^3). This is the volume liquid fraction (α_f) times the liquid density (ρ_f) times the boron concentration (C_b). Boron concentration is used for hydrodynamic input, and boron density is used for minor edits and plots.
BRNPPM	Boron concentration in ppm unit.
CSUBPF	Liquid specific heat, C_{pf}, bulk conditions (J/kg•K, Btu/lb•^{o}F).
CSUBPG	Vapor specific heat, C_{pg}, bulk conditions (J/kg•K, Btu/lb•^{o}F).
DRFDP	Partial derivative of ρ_f with respect to P (s^2/m^2, s^2/ft^2).
DRFDUF	Partial derivative of ρ_f with respect to U_f (kg•s^2/m^5, lb•s^2/ft^5).
DRGDP	Partial derivative of ρ_g with respect to P (s^2/m^2, s^2/ft^2).
DRGDUG	Partial derivative of ρ_g with respect to U_g (kg•s^2/m^5, lb•s^2/ft^5).
DRGDXA	Partial derivative of ρ_g with respect to X_n (kg/m^3, lb/ft^3).
DTDP	Partial derivative of T^s with respect to P (K/Pa, in^2•^{o}F/lb_f).
DTDUG	Partial derivative of T^s with respect to U_g (s^2•K/m^2, s^2•^{o}F/ft^2).
DTDXA	Partial derivative of T^s with respect to X_n (K, ^{o}F).
DTFDP	Partial derivative of T_f with respect to pressure (K/Pa, in^2•^{o}F/lb_f).

DTFDUF Partial derivative of T_f with respect to U_f ($s^2 \bullet K/m^2$, $s^2 \bullet {}^oF/ft^2$).

DTGDP Partial derivative of T_g with respect to P (K/Pa, $in^2 \bullet {}^oF/lb_f$).

DTGDUG Partial derivative of T_g with respect to U_g ($s^2 \bullet K/m^2$, $s^2 \bullet {}^oF/ft^2$).

DTGDXA Partial derivative of T_g with respect to X_n (K, ^oF).

EXTVNN Extra volume variables where NN goes from 01 to 20. These variables are output to the restart-plot file when RELAP5 is built using the “extra” flag on the dinstls command line. These variables are useful for debugging the code and for making temporary changes to the code. There is a similar set of variables for junctions called EXTJNN and for systems called EXTSNN.

FLOREG Flow regime number; the parameter is the volume number. A chart showing the meaning of each number is shown in Volume I, Section 3.1.3.

FWALF Liquid wall frictional drag coefficient ($kg/m^3 \bullet s$, $lb/ft^3 \bullet s$); the parameter is the volume number plus F.

FWALG Vapor wall frictional drag coefficient ($kg/m^3 \bullet s$, $lb/ft^3 \bullet s$); the parameter is the volume number plus F.

GAMMAC For explicit coupling of heat conduction/transfer and hydrodynamics, this is 0. For implicit coupling of heat conduction/transfer and hydrodynamics, this is the mass transfer rate per unit volume at the vapor/liquid interface in the boundary layer near the wall for condensation ($kg/m^3 \bullet s$, $lb/ft^3 \bullet s$).

GAMMAI Mass transfer rate per unit volume at the vapor/liquid interface in the bulk fluid for vapor generation/condensation ($kg/m^3 \bullet s$, $lb/ft^3 \bullet s$).

GAMMAW For explicit coupling of heat conduction/transfer and hydrodynamics, this is the mass transfer rate per unit volume at the vapor/liquid interface in the boundary layer near the wall for vapor generation/condensation ($kg/m^3 \bullet s$, $lb/ft^3 \bullet s$). For implicit coupling of heat conduction/transfer and hydrodynamics, this is the mass transfer rate per unit volume at the vapor/liquid interface in the boundary layer near the wall for vapor generation ($kg/m^3 \bullet s$, $lb/ft^3 \bullet s$).

HGF Direct heating heat transfer coefficient per unit volume ($W/m^3 \bullet K$, $Btu/s \bullet ft^3 \bullet {}^oF$).

HIF Liquid side interfacial heat transfer coefficient per unit volume ($W/m^3 \bullet K$, $Btu/s \bullet ft^3 \bullet {}^oF$).

HIG	Vapor side interfacial heat transfer coefficient per unit volume ($W/m^3•K$, $Btu/s•ft^3•^oF$).
HSTEAM	Steam specific enthalpy at bulk conditions using partial pressure of steam (J/kg, Btu/lb).
HVMIX	Enthalpy of the liquid and vapor (J/kg, Btu/lb).
P	Volume pressure (Pa, lb_f/in^2).
PECLTV	Peclet number.
PPS	Steam partial pressure (Pa, lb_f/in^2).
Q	Total volume heat source from the wall and direct moderator heating to liquid and vapor (W, Btu/s). This variable request is the same as "Q.wall.tot." in the major edits.
QUALA	Volume noncondensable mass fraction. The ratio of the mass of the noncondensable gas to the total mass of the vapor phase.
QUALE	Volume equilibrium quality. This quality uses phasic enthalpies and mixture quality, with the mixture enthalpy calculated using the flow quality.
QUALS	Volume static quality.
QWG	Volume heat source from the wall and direct moderator heating to vapor (W, Btu/s). This variable request is the same as "Qwg.wall.gas." in the major edits.
RHO	Total density (kg/m^3, lb/ft^3).
RHOF	Liquid density ρ_f (kg/m^3, lb/ft^3).
RHOG	Vapor density ρ_g (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 using partial pressure of steam (J/kg, Btu/lb).
SATHG	Steam specific enthalpy at saturation conditions using partial pressure of steam (J/kg, Btu/lb).
SATTEMP	Volume saturation temperature based on the partial pressure of steam (K, ^oF).

SIGMA	Surface tension (N/m, lb_f/ft).
<u>SOUNDE</u>	Volume sonic velocity (m/s, ft/s).
<u>TEMPF</u>	Volume liquid temperature T_f (K, ^oF).
<u>TEMPG</u>	Volume vapor temperature T_g (K, ^oF).
TFSUB	Degree of subcooling for volume liquid (K, ^oF), <0.0.
TGSUP	Degree of superheating for volume vapor (K. ^oF), >0.0.
THCONF	Liquid thermal conductivity (W/m•K, Btu/s•ft•^oF).
THCONG	Vapor thermal conductivity (W/m•K, Btu/s•ft •^oF).
TIENGV	Total internal energy (of both phases and noncondensables) in volume (J, Btu).
TMASSV	Total mass (includes both phases and noncondensables) in volume (kg, lb).
TSATT	Saturation temperature corresponding to total pressure (K, ^oF).
<u>UF</u>	Liquid specific internal energy (J/kg, Btu/lb).
<u>UG</u>	Vapor specific internal energy (J/kg, Btu/lb).
<u>VAPGEN</u>	Total mass transfer rate per unit volume at the vapor/liquid interface in the bulk fluid for vapor generation/condensation and in the boundary layer near the wall for vapor generation/condensation (kg/m^3•s, lb/ft^3•s).
<u>VELF*</u>	Volume oriented liquid velocity (m/s, ft/s); the parameter is the volume number plus F.
<u>VELG*</u>	Volume oriented vapor velocity (m/s, ft/s); the parameter is the volume number plus F.
VISCF	Liquid viscosity (kg/m•s, lb/ft•s).
VISCG	Vapor viscosity (kg/m•s, lb/ft•s).
<u>VOIDF</u>	Volume liquid fraction.
<u>VOIDG</u>	Volume vapor fraction (void fraction).

VOIDLA Void above the level.

VOIDLB Void below the level.

VOLLEV Location of the level inside the volume (m, ft).

VVOL Volume of the volume (m^3, ft^3).

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. The parameter is CCC000000 for a single-junction; CCC000000 for a time-dependent junction; CCCMM0000 for a junction in a pipe component ($01 \leq MM \leq 99$); CCCMM0000 for a junction in a branch, separator, jetmixer, turbine, or ECC mixer component ($01 < MM \leq 9$); CCC000000 for a valve junction; CCC010000 for the inlet junction in a pump component; CCC020000 for the outlet junction in a pump component; CCCIINN00 for a junction in the multiple-junction component ($01 \leq II \leq 99$, $01 \leq NN \leq 99$); and CCC010000 for the junction in an accumulator component.

Variable	Description
C0J	Junction distribution coefficient. The 0 in C0J is the number 0 and not the upper case letter O.
CHOKEF	Junction choking flag. The value is 0 if the flow is not choked, and is 1 if the flow is choked.
EXTJNN	Extra junction variables where NN goes from 01 to 20. These variables are output to the restart-plot file when RELAP5 is built using the “extra” flag on the dinstls command line. These variables are useful for debugging the code and for making temporary changes to the code. There is a similar set of variables for volumes called EXTVNN and for systems called EXTSNN.
FIJ	Interphase friction coefficient ($N{\bullet}s^2/m^5$, $lb_f{\bullet}s^2/ft^5$).
FJUNFT	Total forward user input form loss coefficient for irreversible losses, including Re dependence (dimensionless).
FJUNRT	Total reverse user input form loss coefficient for irreversible losses, including Re dependence (dimensionless).
FLENTH	Total enthalpy flow in junction (includes both phases and noncondensables) (J/s, Btu/s).

FLORGJ	Junction flow regime number. A chart showing the meaning of each number is shown in Volume I, Section 3.
FORMFJ	Liquid abrupt area change model form loss factor (dimensionless).
FORMGJ	Vapor abrupt area change model form loss factor (dimensionless).
FWALFJ	Non-dimensional liquid wall friction coefficient (dimensionless).
FWALGJ	Non-dimensional vapor wall friction coefficient (dimensionless).
IREGJ	Vertical bubbly/slug flow junction flow regime number. A chart showing the meaning of each number is shown in Volume I, Section 3.
MFLOWJ	Combined liquid and vapor flow rate (kg/s, lb/s).
MFLOWFJ	Liquid flow rate (kg/s, lb/s).
MFLOWGJ	Vapor flow rate (kg/s, lb/s).
MFLOWNJ	Noncondensible gas 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).
SONICJ	Junction sound speed (m/s, ft/s). This speed is based on the physical junction area. It does not include the effects of the throat ratio and the discharge coefficients.
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). This velocity is based on the junction area A_j.
VELGJ	Junction vapor velocity (m/s, ft/s). This velocity is based on the junction area A_j.
VGJJ	Vapor drift velocity (m/s, ft/s).
VOIDFJ	Junction liquid fraction.

VOIDGJ Junction vapor fraction (void fraction).

VOIDJ Junction vapor fraction (void fraction) used in the interphase friction.

XEJ Junction equilibrium quality.

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 CCCG0NN with a two-digit number appended. For codes other than HTTEMP and HTVAT, 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. For HTVAT, omit the two appended digits and use only the seven digit number. Only the left and right 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.

Variable	Description
HTCHF	Critical (maximum) heat flux (W/m^2, $Btu/s{\bullet}ft^2$).
HTCHFR	Critical hat flux ratio (ratio of HTCHF to HTRNR). This variable can only be plotted and is set equal to the constant value of 12.34567 whenever HTCHF or HTRNR is equal to 0.0.
HTGAMW	Wall vapor generation rate per unit volume ($kg/m^3{\bullet}s$, $lb/ft^3{\bullet}s$). 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).
HTHTC	Heat transfer coefficient ($W/m^2{\bullet}K$, $Btu/s\text{-}ft^2{\bullet}{}^oF$).
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, $Btu/s{\bullet}ft^2$). 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).
HTRNR	Heat flux (W/m^2, $Btu/s{\bullet}ft^2$).

HTTEMP Mesh point temperature (K, ^oF). The parameter is the heat structure geometry number CCCG0NN with a two-digit number appended (mesh point number). The surface temperatures are written to the plot record but interior mesh point temperatures must be requested through the 2080XXXX cards.

HTTMAX Maximum of clad temperatures(K, ^oF). The parameter is the heat structure geometry number CCCG01 (last two word should be 01)

HTOMAX Maximum of (in+out) oxidation(m, ft). The parameter is the heat structure geometry number CCCG00 (last two word should be 00)

HTVAT Volume averaged temperature in the heat structure (K, ^oF).

PECL Liquid Peclet number for the heat structures. 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).

QRAD Heat flux (W/m^2, Btu/s.ft^2) due to radiation and contact heat transfer. 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).

STANT Stanton number. 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).

HGAP Total gap conductance, including radiation (W/m^2K, Btu/s-ft^{2o}F). This value is zero if the gap conductance model is turned off. The parameter is the heat structure geometry number CCCG0NN.

KGAP Effective gap thermal conductivity (W/mK, Btu/s-ft^oF). This value is zero if the gap conductance model is turned off. The parameter is the heat structure geometry number CCCG0NN.

PGAP Pressure of the gas gap (Pa, lb_f/in^2). This value is zero if the gap conductance model is turned off. The parameter is the heat structure geometry number CCCG0NN.

TGAP Temperature of the gas gap (K, ^oF). This value is zero if the gap conductance model is turned off. The parameter is the heat structure geometry number CCCG0NN.

CLSTRN Total cladding strain. This value is zero if the gap conductance model is turned off. The parameter is the heat structure geometry number CCCG0NN.

CLHOOP Cladding hoop stress (Pa, lb_f/in^2). This value is zero if the gap conductance model is turned off. The parameter is the heat structure geometry number CCCG0NN.

HTOXI Oxidation thickness of clad inside in the heat structure (m, ft)

HTOXO Oxidation thickness of clad outside in the heat structure (m, ft)

H2GEN Hydrogen generation in the heat structure (kg, lbm)

GAPWD Gap thickness in the heat structure (m, ft)

CLOUT Fuel cladding outer radius (m, ft)

4.6 Reflood-Related Quantities

For the following variable codes, the parameter is the heat structure geometry number, i.e., the four-digit number CCCG printed in the major edit.

Variable	Description
FINES	Current number of axial nodes on a reflood structure.
TCHFQF	Temperature at the critical (maximum) heat flux (K, ^oF).
TREWET	Rewet, quench, Leidenfrost, or minimum film boiling temperature (K, ^oF).
ZQBOT	Elevation of bottom quench front (m, ft).
ZQTOP	Elevation of top quench front (m, ft).

4.7 Reactor Kinetic Quantities

The parameter is 0 for the following reactor kinetic quantities.

Variable	Description
RKBORN	Reactivity feedback from boron density changes (dollars).
RKDOPP	Reactivity feedback from fuel temperature changes (dollars).
RKMOD	Reactivity feedback total from moderator (dollars). This is the sum of RKMODD and RKMODT.

RKMODD Reactivity feedback from moderator density changes (dollars).

RKMODT Reactivity feedback from moderator temperature (spectral) changes (dollars).

RKSCRAM Reactivity feedback from scram curve (dollars).

RKFIPOW Reactor power from fission (W).

<u>RKGAPOW</u> Reactor power from decay of fission products and actinides (W).

RKPOWA Reactor power from decay of actinides (W).

<u>RKPOWK</u> Reactor power from decay of fission products (W).

<u>RKREAC</u> Reactivity (dollars).

<u>RKRECPER</u> Reciprocal period (s^{-1}).

<u>RKTPOW</u> Total reactor power, i.e., sum of fission and decay powers (W).

4.8 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.

<u>CNTRLVAR</u> Control component number. These quantities are assumed dimensionless except for a SHAFT component.

4.9 Expanded Plot Variables, 2080XXXX

The underlined variables listed above are always available for plotting. The variables that are not underlined and some of the underlined variables followed by an asterisk are not written to the restart-plot file and are thus unavailable for plotting unless the user enters the desired variables on 2080XXXX cards. 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 field XXXX need not be consecutive.

W1(A) Variable. See the previous sections for valid variable names.

W2(I) Parameter. Enter the parameter associated with the variable request code. For example, for a single volume 567, the user would enter, 567010000.

-1 may be entered to plot a volume variable for all volumes or to plot a junction variable for all junctions. This feature was added to reduce the number of 2080XXXX cards the user has to enter in order. For example, to get the junction choking flag, CHOKEF, at all the junctions, instead of adding 2080XXXX cards for each junction, the user only has to enter one card:

20800001 CHOKEF -1

4.9.1 Plotting Additional 2080XXXX Variables from a Restart Run

If additional 2080XXXX cards are added to a restart run, these new variables are not available to XMGR5 for plotting until another variable that was on the original run has been plotted. The additional plot labels for the new variables requested on the 2080XXXX cards in the restart run are written to the restart/plot file after the restart edit, not at the front of the restart/plot file. Therefore, when XMGR5 reads the front end of the restart/plot file to get its labels, it does not know about these additional variables. However, once XMGR5 has plotted one of the original variables, it will encounter the new variables and add them to its list of variables that can be plotted.

5 TRIPS, 400-799 or 20600000-20620000

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 401-799 allow 199 variable trips and 199 logical trips. Card numbers 20600010 - 20620000 allow 1000 variable trips and 1000 logical trips.

5.1 Trips Cancellation, 400

This card is allowed only for RESTART problems. The 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.

5.2 Trip Series Type, 20600000

This card, if omitted, selects card numbers 401-599 for variable trips and 601-799 for logical trips. For this case, the trip numbers are equal to the card numbers.

If this card is entered, card numbers 206NNNN0 are used for entering trip data, where NNNN is the trip number. Trip numbers (NNNN) 1-1,000 are variable trips, and 1,001-2,000 are logical trips. Trip numbers do not have to be consecutive.

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

5.3 Variable Trips, 401-599 or 20600010-20610000

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 variables and parameters are the same as described for minor edits, Section 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. If the trip goes false, TIMEOF is set to -1.0.

W1(A) Variable. 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.

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 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 0 or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than 0 for NEW problems and must not be greater than the time of restart for RESTART problems.

W9(A) Auxiliary Input for Trip Message. This word is optional. If it is not entered, no message will be displayed. It must not greater than 24 character.

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.

5.4 Logical Trips, 601-799 or 20610010-20620000

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

W1(I) Trip number. The absolute value of this number must be one of the trip numbers defined by the variable or logical trips. 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 0.

W3(I) Trip number. This is similar to Word 1 (W1).

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 0 or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than 0 for NEW problems and must not be greater than the time of restart for RESTART problems.

W6(A) Auxiliary Input for Trip Message. This word is optional. If it is not entered, no message will be displayed. It must not greater than 24 character.

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

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

5.5 Trip Stop Advancement, 600

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.

6 INTERACTIVE INPUT, 801-999

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 RELAP5/MOD3.3Beta 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 RELAP5 coding, even if they are spelled the same. These user-defined variables can appear wherever variables listed in Section A4 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 variable 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(converted) = V(input)•W3. If negative, V(converted) = V(input)/1.8 -

W3. For temperature conversion from oF to K, Word 3 should be -255.3722222. If this word is missing, the conversion factor defaults to 1.0. If this word is 0, 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.

7 STRIP REQUESTS, 1001-1999

These cards are required only in STRIP-type problems. One or more cards are entered, each card containing one variable request. Card numbers need not be consecutive. Variables are ordered on the STRIPF file in the order of increasing card numbers. If an incorrect variable request code is entered, the value will be 0.0. It is not flagged as an input error, since at some later time in the transient, a renodalization may result in the variable request code becoming correct.

7.1 CARDS 1000, X-VALUE DATA FOR PLOTTING

W1(R) Minimum X-Value for Window X-Y Plot

W2(R) Maximum X-Value for Window X-Y Plot

7.2 CARDS 1001 THROUGH 1999, STRIP REQUEST DATA

These cards are required only in STRIP-type problems. One or more cards are entered, each card containing one variable request. Card numbers need not be consecutive. Variables are ordered on the STRIPF file in the order of increasing card numbers. If an incorrect variable request code is entered, the value will be 0.0. It is not flagged as an input error, since at some later time in the transient, a renodalization may result in the variable request code becoming correct.

W1(A) Alphanumeric part of the variable request code.

W2(I) Integer part of the variable request code.

W3(R) Minimum Y-Value for Window X-Y Plot

W4(R) Maximum Y-Value for Window X-Y Plot

8 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.

For junctions, an old format has been used in the past to connect volumes. In the old format, CCC000000 was used if the connection was to the inlet side of the component and CCC010000 was used if the connection was to the outlet side of the component. The use of this format is discouraged and the expanded connection format is preferred because it is more general and easier to understand. 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. The number N equal to 1 and 2 specifies the inlet and outlet faces, respectively, for the volume's coordinate direction (see Section 3.1.1.8 of Volume I). The number N equal to 3-6 specifies crossflow. The number 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. For example, in a 5 volume pipe component, the old format inlet connection code of CCC000000 is equivalent to CCC010001 in the expanded format, and the old outlet connection code of CCC010000 is equivalent to CCC050002 in the expanded format. In the following component descriptions, only the expanded format connection code will be used.

8.1 General Information

8.1.1 Component Name and Type, CCC0000

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 8 characters is allowed for most computers, e.g., workstations, CRAY, and IBM computers.

W2(A) Component type. Enter one of the following component types, SNGLVOL, TMDPVOL, SNGLJUN, TMDPJUN, PIPE, ANNULUS, PRIZER, CANCHAN, BRANCH, SEPARATR, JETMIXER, TURBINE, ECCMIX, VALVE, PUMP, CIRCLTR, MTPLJUN, ACCUM, SDBVOL, MULTID 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.

8.2 Single-Volume Component, SNGLVOL

A single-volume component is indicated by SNGLVOL for Word 2 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. For major edits, minor edits, and plot variables, the volume in the single-volume component is numbered as CCC010000.

8.2.1 Single-Volume X-Coordinate Volume Data, CCC0101-0109

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) Area (m^2, ft^2).

W2(R) Length (m, ft).

W3(R) Volume (m^3, ft^3). The program requires that the volume equals the area times the length ($W3 = W1 \bullet W2$). At least two of the three quantities, W1, W2, and W3, must be nonzero. If one of the quantities is 0, it will be computed from the other two. If none of the words are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

W4(R) Azimuthal angle (degrees). The absolute value of this angle must be $\leq$ 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 $\leq$ 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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used. When the ratio is greater than 45 degrees, the vertical flow regime map is used.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \frac{\text{area}}{\text{wetted perimeter}}$. If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made to ensure the pipe roughness is less than half the hydraulic diameter. See Word 1 for area.

W9(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag.

t-flag The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume.

l-flag The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume.

p-flag 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.

v-flag 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.

b-flag 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, b = 2 means that the ORNL ANS interphase friction model will be applied (see card CCC0111 in Section 8.2.2).

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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 with other codes.

8.2.2 Single-Volume ORNL ANS Interphase Model Values, CCC0111

This card is required if the interphase friction flag b in Word 9 on cards CCC0101-0109 is set to 2.

W1(R) Gap (distance between side walls, short length, pitch, channel width) (m, ft).

W2(R) Span (distance from one end to the other, long length) (m, ft).

W3(I) Volume number.

8.2.3 Single-Volume Additional Wall Friction, CCC0131

This card is optional. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.2.4 Single-Volume Initial Conditions, CCC0200

This card is required for a single-volume.

W1(I) Control word. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε =0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-9 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by cards 120-9 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-9 or these control words must be consistent (i.e., not specify different fluids). If cards 120-9 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid. It is recommended that the user use the 120-9 cards to set the fluid type in the systems.

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

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

$[P,U_f,U_g,\alpha_g]$ 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 internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

$[T,x_s]$ If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter boron in W4 if needed.

$[P,x_s]$ If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter boron in W4 if needed.

$[P,T]$ If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E\text{-}9 \leq x_s \leq 0.99999999$,

Single phase if $x_s < 1.0\ E\text{-}9$ or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option.

[T,x_s,x_n] If t = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[P,U_f,U_g,α_g,x_n] 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable), then the 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-W7(R) Quantities as described under Word 1 (W1). Depending on the control word, 2-6 quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass liquid) follows the last required word for thermodynamic conditions.

8.3 Time-Dependent Volume Component, TMDPVOL

This component is indicated by TMDPVOL for Word 2 on card CCC0000. For major edits, minor edits, and plot variables, the volume in the time-dependent volume component is numbered as CCC010000.

8.3.1 Time-Dependent Volume Geometry, CCC0101-0109

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) Area (m^2, ft^2). When a time-dependent volume is used to model a pressure boundary condition (i.e., the time-dependent volume is connected to the system through a normal junction), it is generally recommended that the cross-sectional area of the time-dependent volume be large compared to the area of the normal junction.

W2(R) Length (m, ft). After initialization, the length is set to 0.

W3(R) Volume (m^3, ft^3). The program requires that the volume equals the 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 0, it will be computed from the other two. If none of the words are 0, the volume must equal the area times the length within a relative error of 0.000001. After initialization, the volume is set to 0.

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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. As with the other components, this Word 6 is compared to the length (Word 2) to determine if the horizontal or vertical flow regime map is used. This is not important for this component, since the correlations that depend on the flow regime maps are not needed for this component. The volume conditions are prescribed through input cards CCC0201-0299. After initialization, the elevation change is set to 0.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made to ensure the pipe roughness is less than half the hydraulic diameter. See Word 1 for the area.

W9(I) Volume control flags. This word has the format tlpvbfe. For the time-dependent volume component, the volume control flag is restricted to the format 0000000. So enter 0 for this word.

8.3.2 Time-Dependent Volume Data Control Word, CCC0200

This card is required for a time-dependent volume.

W1(I) Control word for time-dependent data on CCC02NN cards. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-9 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by cards 120-9 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-9 or these control words within the hydrodynamic system must be consistent (i.e., not specify different fluids). If cards 120-129 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid. It is recommended that the user use the 120-129 cards to set the fluid type in the systems.

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

t-flag The digit t specifies how the words of the time-dependent volume data in cards CCC0201-0299 are to be used to determine the initial thermodynamic state. Entering t equal to 0-3 specifies one component (steam/water). Entering t equal to 4-6 allows the specification of two components (steam/water and noncondensable gas).

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

$[P,U_f,U_g,\alpha_g]$ If t = 0, the second, third, fourth, and fifth words of the time-dependent volume data on cards CCC0201-0299 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 internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

[T,x_s] If t = 1, the second and third words of the time-dependent volume data on cards CCC0201-0299 are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration follows the last required word for thermodynamic conditions. Enter boron in W4 if needed.

[P,x_s] If t = 2, the second and third words of the time-dependent volume data on cards CCC0201-0299 are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration follows the last required word for thermodynamic conditions. Enter boron in W4 if needed.

[P,T] If t = 3, the second and third words of the time-dependent volume data on cards CCC0201-0299 are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium conditions. Enter only the minimum number of words required. If entered, boron concentration follows the last required word for thermodynamic conditions. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E-9 \le x_s \le 0.99999999$,

Single phase if $x_s < 1.0$ E-9 or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the second, third, and fourth words of the time-dependent data on cards CCC0201-0299 are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter only the minimum number of words required. If entered, boron concentration follows the last required word for thermodynamic conditions. Enter boron in W5 if needed.

[T, x_s, x_n] If t = 5, the second, third, and fourth words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out. Enter boron in W5 if needed.

[$P, U_f, U_g, \alpha_g, x_n$] If t = 6, the second, third, fourth, fifth, and sixth words of the time-dependent data on cards CCC0201-0299 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable), then the 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. Enter only the minimum number of words required. If entered, boron concentration follows the last required word for thermodynamic conditions.

W2(I) Table trip number. This word is optional. If missing or 0 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 not present, time is the search argument. 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 0, 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. The variable MFLOWJ should not be used as a search variable; a user-initialized control variable that uses MFLOWJ should be used instead.

W4(I) Numeric part of variable request code. This is assumed 0 if missing. For example, to use the pressure in volume 567010000 for the search argument, the user would enter P for W3 and 567010000 in W4.

8.3.3 Time-Dependent Volume Data, CCC0201-0299

These cards are required for time-dependent volume components. A set of data is made up of the search variable (e.g., time) followed by the required data indicated by control Word 1 in card CCC0200. 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. Enter only the minimum number of words required. If entered, boron concentration follows the last required word for thermodynamic conditions. 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.

W1(R) Search variable (e.g., time).

W2-W7(R) Quantities as described under Word 1 in card 200. Depending on the control word, 2-5 quantities may be required. If entered, boron concentration (parts of boron per parts of liquid) follows the last required word for thermodynamic conditions.

As described above, sets may be entered one or more per card.

8.4 Single-Junction Component, SNGLJUN

A single-junction component is indicated by SNGLJUN for Word 2 on card CCC0000. For major edits, minor edits, and plot variables, the junction in the single-junction component is numbered CCC000000.

8.4.1 Single-Junction Geometry, CCC0101-0109

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. 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 component. 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. The number n equal to 1 and 2 specifies the inlet and outlet faces, respectively, for the volume's coordinate direction. The number n equal to 3 through 6 specifies crossflow. The number 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. For connecting to a time-dependent volume using the old format, both CCC000000 and CCC010000 are allowed. For connecting to a time-dependent volume using the expanded format, only the number N equal to 1 or 2 is allowed.

When this junction is used to connect a "FROM" 3D volume with a "TO" 1D volume, the connection code is cccvv000n, where ccc is the channel number of the 3D volume, vv is the mesh number (.ge. 2), and n indicates the face number. The numbers n equal to 7 and 8 specify the bottom and top faces, respectively. The number n equal to 9 specifies the side face.

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.

When this junction is used to connect a "FROM" 1D volume with a "TO" 3D volume, the connection code is cccvv000n. See the description for W1 above.

W3(R) Junction area (m2 , ft2). 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. Note: a variable loss coefficient may be specified. The interpretation and use of this loss coefficient vary based upon the “a” junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If the abrupt area change option is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. Note: a variable loss coefficient may be specified. See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. It is not necessary to input leading zeros.

j-flag The digit j specifies that this junction is a jet junction. Pool surface condensation is enhanced in the volume above the junction when this model is activated. This junction must be underneath the to volume.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag 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.

v-flag The digit v specifies horizontal stratification entrainment/pullthrough options. This model is for junctions connected to a horizontal volume. v = 0 means the model is not applied; v = 1 means an upward-oriented junction (offtake volume must be vertical); v = 2 means a downward-oriented junction (offtake volume must be vertical); and v = 3 means a centrally (side) located junction; v =4 means extended angled side located junction.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as

¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to volume and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume, but not in the from volume. s = 3 does not use momentum flux in either the to or the from volume.

W7(R) The meaning of this word is different, depending on which the critical flow model has been selected (see the c-flag under W6 above).

If the Henry-Fauske critical flow model is active, the discharge coefficient is entered. If W7 and W8 are missing, W7 is set to 1.0, and W8 is set to 0.14.

If the original RELAP5 critical flow model is active, the subcooled discharge coefficient is entered. This entry applies only to subcooled liquid choked flow calculations. The entry must be > 0.0 and < 2.0. If W7, W8, and W9 are missing, they are each set to 1.0.

W8(R) The meaning of this word is different, depending on which the critical flow model has been selected (see the c-flag under W6 above).

If the Henry-Fauske critical flow model is active, the thermal nonequilibrium constant is entered. If W7 is entered, and W8 is missing, W8 is set to 0.14. If W8 is < 0.01, the equilibrium option is used, and W8 is reset to 0.0. If W8 is >1000.0, the frozen option is used, and W8 is reset to 100.0.

If the original RELAP5 critical flow model is active, the two-phase discharge coefficient is entered. This entry applies only to two-phase choked flow calculations. The entry must be > 0.0 and < 2.0. If W7 is entered, and W8 and W9 are missing, W8 and W9 are each set to 1.0.

W9(R) The meaning of this word is different, depending on which the off-take model for an extended angled side junction has been selected (see the v-flag under W6 above) and which the critical flow model has been selected (see the c-flag under W6 above).

If -flag of W6(I) is 4, this word is the horizontal angle (degree) between from-volume and to-volume.

If the Henry-Fauske critical flow model is active, this word is not used and must not be entered. If it is entered, an input error results. This drastic action is to prevent the user from using an older deck with the new code without changing the three discharge coefficients from their values for the original RELAP5 critical flow model to an appropriate set for the Henry-Fauske critical flow model. W8 has a completely different meaning in the two models.

If the original RELAP5 critical flow model is active, the superheated discharge coefficient is entered. This entry applies only to superheated vapor choked flow calculations. The entry must be > 0.0 and < 2.0. If W7 and W8 are entered, and W9 is missing, then W9 is set to 1.0.

8.4.2 Single-Junction Diameter and CCFL Data, CCC0110

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation (i.e., $\underline{f} = 0$ in Word 6 of cards CCC0101-0109), then, the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If this card is being used for the CCFL model (i.e., $\underline{f} = 1$ in Word 6 of cards CCC0101-0109), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

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. This number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 3 of cards CCC0101-0109 for the area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1, the Kutateladze CCFL form is used. If between 0.0 and 1.0, 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.

8.4.3 Single-Junction Form Loss Data, CCC0111

This card is optional. The user-specified form loss is given in Words 4 and 5 of card CCC0101 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F} + KFJUNCV$$

$$K_R = A_R + B_R Re^{-C_R} + KRJUNCV$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of card CCC0101. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

W5(I) Control variable number for specifying a portion of the forward form loss (KFJUNCV). This quantity must be greater than or equal to 0. (Optional)

W6(I) Control variable number for specifying a portion of the reverse form loss (KRJUNCV). This quantity must be greater than or equal to 0. (Optional)

8.4.4 Single-Junction Initial Conditions, CCC0201

This card is required for single-junction components.

W1(I) Control word. If 0, the next two words are velocities; if 1, the next two words are mass flows.

W2(R) Initial liquid velocity or mass flow. This quantity is either velocity (m/s, ft/s) [W1 = 0] or mass flow (kg/s, lb/s) [W1 = 1].

W3(R) Initial vapor velocity or mass flow. This quantity is either velocity (m/s, ft/s) [W1 = 0] or mass flow (kg/s, lb/s) [W1 = 1].

W4(R) Interface velocity (m/s, ft/s). Enter 0.

8.5 Time-Dependent Junction Component, TMDPJUN

This component is indicated by TMDPJUN for Word 2 on card CCC0000. For major edits, minor edits, and plot variables, the junction in the time-dependent junction component is numbered as CCC000000.

8.5.1 Time-Dependent Junction Geometry, CCC0101

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. 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. The number N equal to 1 and 2 specifies the inlet and outlet faces, respectively, for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). If 0, the area is set to the minimum flow area of the adjoining volumes. There are no junction area restrictions for time-dependent junctions.

W4(I) Junction control flag. This word is optional and has the format jefvcahs. It is not necessary to input leading zeros. Only the e-flag can be set. The other flags have to be 0, so either 0 or 1000000 are the only two allowable entries.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

8.5.2 Time-Dependent Junction Data Control Word, CCC0200

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 0, the second and third words of the time-dependent junction data in cards CCC0201-0299 are velocities. If 1, the second and third words of the time-dependent junction data in cards CCC0201-0299 are mass flows. In both cases, the fourth word is interface velocity and should be entered as 0.

W2(I) Table trip number. This word is optional. If missing or 0 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 0, 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. The variable MFLOWJ should not be used as a search variable; a user-initialized control variable that uses MFLOWJ should be used instead.

W4(I) Numeric part of variable request code. This is assumed 0 if missing.

8.5.3 Time-Dependent Junction Data, CCC0201-0299

These cards are required for time-dependent junction components. A set of data consists of the search variable (e.g., time) followed by the required data indicated by control Word 1 on card CCC0200. 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 5000 sets may be entered. If the phase or material is not present, 0 may be entered for a velocity or flow. The interpolation and card formats for the time-dependent data are identical to that in Section 8.3.3 (cards CCC0201-0209, Time-Dependent Volume Data cards).

When doing a single-phase problem and entering velocities here, the same value should be entered for both liquid and vapor velocities. If entering mass flows, the correct value should be entered for either liquid or vapor (whichever single-phase is being modeled) and the other entry should be 0.

If the user wants to specify the vapor void fraction as a function of time in the time-dependent volume, and the total mass flow as a function of time in the time-dependent junction, then both the phasic (gas and liquid) mass flow rates must be calculated and entered in these cards.

W1(R) Search variable (e.g., time).

W2(R) 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 1 on card CCC0200.

W3(R) 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 1 on card CCC0200.

W4(R) Interface velocity (m/s, ft/s). This feature has not been implemented yet, so enter 0.

As described above, sets may be entered one or more per card.

8.6 Pipe Component, PIPE

A pipe component is indicated by PIPE. An annulus component is similar to a pipe component and is covered in the next section. The annulus component must be vertical and all the water is in the film on the wall (i.e., no drops) when in the annular mist flow regime.

More than one junction may be connected to the inlet or outlet of a pipe. If an end has no junctions, that end is considered a closed end. For major edits, minor edits, and plot variables, the volumes in the pipe component are numbered as CCCNN0000, where NN is the volume number ($01 \leq NN \leq 99$). The junctions in the pipe component are numbered as CCCJJ0000, where JJ is the junction number ($01 \leq JJ \leq 98$).

The general input for a pipe 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. In order to implement this special case, the user must set the number of volumes and the volume number on the volume cards to 1. In addition, the user should not input any of the junction cards. A single volume is much better suited for this type of component .

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 to any of the pipe volumes in the y- and z-coordinate directions (faces 3, 4, 5, or 6)using a form of the momentum equation that does or does not include momentum flux terms. It is also possible to connect external junctions to the x-coordinate direction faces (1 or 2) of any of the pipe volumes using a form of the momentum equation that does or does not include the momentum flux terms. It is also possible to include or not include the momentum flux terms in internal pipe junctions.

8.6.1 Pipe Information, CCC0001

This card is required.

W1(I) Number of volumes, nv. The number nv must be greater than 0 and less than 100. The number of associated junctions internal to these components is nv-1. The outer junctions are described by other components.

8.6.2 Pipe X-Coordinate Areas, CCC0101-0199

These cards are required, and the card numbers need not be consecutive. The format is two words per set in sequential expansion format for nv sets. (The corresponding y- and z-coordinate cards are CCC1601-1699 and CCC1701-1799). The words for one set are

W1(R) Area (m^2, ft^2).

W2(I) Volume number.

8.6.3 Pipe Junction Areas, CCC0201-0299

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 0, 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.

8.6.4 Pipe X-Coordinate Lengths, CCC0301-0399

These cards are required. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC1801-1899 and CCC1901-1999).

W1(R) Length (m, ft).

W2(I) Volume number.

8.6.5 Pipe Volumes, CCC0401-0499

These cards are optional, and if not entered, the volumes are set to 0. 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). The code requires that each volume equal the x-direction flow area times the x-direction length. If activated, the code also requires each volume equal the y-direction flow area times the y-direction length, and each volume equal the z-direction flow area times the z-direction length. For any volume, at least two of the three quantities, x-direction area, the x-direction length, or volume, must be nonzero. If one of the quantities is 0, it will be computed from the other two. If none of the quantities are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions. If both the y-direction area and y-direction length are not entered or are 0, the y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction area}}{\pi}\right)^{0.5}$ and the y-direction area is computed from $\frac{\text{volume}}{\text{y-direction length}}$. The same is true for the z-direction.

W2(I) Volume number.

8.6.6 Pipe Volume Azimuthal Angles, CCC0501-0599

These cards are optional, and if not entered, the angles are set to 0. The angles on these cards are used for the 3-D drawing programs, so it is recommended that the user enter these values if they are known. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

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

W2(I) Volume number.

8.6.7 Pipe Volume Vertical Angles, CCC0601-0699

These cards are required. 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 less than or equal to 90 degrees. This angle is used in the interphase drag calculation.

W2(I) Volume number.

8.6.8 Pipe X-Coordinate (Elevation) Changes, CCC0701-0799

These cards are optional. If these cards are missing, the coordinate changes or elevation changes are computed from the x-coordinate 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 1 or 3 coordinate changes per volume are provided. 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. (The corresponding y- and z-coordinate cards are CCC2101-2199 and CCC2201-2299).

1 coordinate change per volume format:

W1(R) Elevation change. This is the coordinate change along the fixed x-axis due to 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 length. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used; when the ratio is greater than 45 degrees, the vertical flow regime map is used.

W2(I) Volume number.

Three coordinate changes per volume format:

W1(R) Coordinate change along the fixed x-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{xx} (m, ft).

W2(R) Coordinate change along the fixed y-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{yx} (m, ft).

W3(R) Coordinate change along the fixed z-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{zx} (m, ft).

W4(I) Volume number.

8.6.9 Pipe Volume X-Coordinate Friction Data, CCC0801-0899

These cards are required. The card format is three words per set for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2301-2399 and CCC2401-2499).

W1(R) Wall roughness (m, ft).

W2(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made to ensure that the roughness is less than half the hydraulic diameter. See Word 1 on cards CCC0101-0109 for the area.

W3(I) Volume number.

8.6.10 Pipe Junction Loss Coefficients, CCC0901-0999

These cards are optional and if missing, the energy loss coefficients are set to 0. 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. Note: a variable loss coefficient may be specified. The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected for this junction on cards CCC1101-1199. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area (from cards CCC0201-0299). If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction (from cards CCC0101-0199). If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W2(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. Note: a variable loss coefficient may be specified. See information for the previous word regarding interpretation and use of this loss coefficient.

W3(I) Junction number.

8.6.11 Pipe Volume X-Coordinate Control Flags, CCC1001-1099

These cards are required. The card format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2701-2799 and CCC2801-2899).

W1(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. These words enter the scalar oriented flags and the x-coordinate flags for each volume in the component.

t-flag. The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The thermal front tracking model can only be applied to vertically-oriented components.

l-flag The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. The mixture level tracking model can only be applied to vertically-oriented components.

p-flag 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.

v-flag 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.

b-flag 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, b = 2 means that the ORNL ANS interphase friction model will be applied (see card ccc3101 in Section 8.6.20).

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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.

8.6.12 Pipe Junction Control Flags, CCC1101-1199

These cards are required. 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 format jefvcahs. It is not necessary to input leading zeros. For the pipe component, the junction control flag is limited to the format 0ef0cahs.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag 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.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and contains Option 50, the original RELAP5 critical flow model is active. Unlike junctions for certain other hydrodynamic components, only the default values of discharge coefficients and factors used in the critical flow models are allowed for junctions in PIPE components. Problem renodalization should be used to circumvent this limitation should it prove to be significant. For the Henry-Fauske critical flow model, the default value for the discharge coefficient is 1.0 and the default value for the thermal nonequilibrium constant is 0.14. For the original RELAP5 critical flow model, the default values for the subcooled, two-phase and superheated discharge coefficients each are 1.0.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to volume and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume but not in the from volume. s = 3 does not use momentum flux in either the to or the from volume. For this component, the option s = 0 is the usual recommendation (momentum flux in both volumes). The other options s = 1, 2, and 3 are included to allow consistency for this flag for other components (single-junction, branch junction, etc.).

W2(I) Junction number.

8.6.13 Pipe Volume Initial Conditions, CCC1201-1299

These cards are required. 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 format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-9 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-9 or these control words must be consistent (i.e., not specify different fluids). If cards 120-9 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid. It is recommended that the user use the 120-9 cards to set the fluid type in the systems.

b-flag The digit b specifies whether boron is present or not. b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered on the CCC2001-2099 cards.

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

[P,U_f,U_g,α_g] 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 internal energies used to define the thermodynamic state. W6 should be 0.0.

One Component (Steam/Water), Equilibrium

[T,x_s] If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. W4, W5, and W6 should be 0.0.

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

[P,T] If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. W4, W5, and W6 should be 0.0.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E-9 \leq x_s \leq 0.99999999$,

Single phase if $x_s < 1.0 E-9$ or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

$[P,T,x_s]$ If $\underline{t} = 4$, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option.

$[T,x_s,x_n]$ If $\underline{t} = 5$, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. W5 and W6 should be 0.0. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

$[P,U_f,U_g,\alpha_g,x_n]$ If $\underline{t} = 6$, 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 ($\underline{t} = 0$). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Five quantities must be entered, and zeros should be entered for unused quantities. If any control word (Word 1) indicates that boron is present, cards CCC2001-2099 must be entered to define the initial boron concentrations. Boron concentrations are not entered in Words 2-6 for pipe components.

W7(I) Volume number.

8.6.14 Pipe Junction Conditions Control Words, CCC1300

This card is optional, and, if missing, velocities are assumed on cards CCC1301-1399.

W1(I) Control word. If 0, the first and second words of each set on cards CCC1301-1399 are velocities. If 1, the first and second words of each set on cards CCC1301-1399 are mass flows.

8.6.15 Pipe Junction Initial Conditions, CCC1301-1399

These cards are required.

W1(R) Initial liquid velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). This capability has not yet been implemented, so enter 0.

W4(I) Junction number.

8.6.16 Pipe Junction Diameter and CCFL Data, CCC1401-1499

These cards are optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, (i.e., $\underline{f} = 0$ in Word 1 of cards CCC1101-1199) then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If this card is being used for the CCFL model (i.e., $\underline{f} = 1$ in Word 1 of cards CCC1101-1199), then enter all four words for the appropriate CCFL model if values different from the default value are desired.

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. The number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 1 of cards CCC0201-0299 for the area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1, the Kutateladze CCFL form is used. If between 0.0 and 1.0, 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.

8.6.17 Pipe Initial Boron Concentrations, CCC2001-2099

These cards are required only if boron is specified in one of the control words (Word 1) in cards CCC1201-1299. The card format is two words per set in sequential expansion format for nv sets. Boron concentrations must be entered for each volume, and 0 should be entered for those volumes whose associated control word did not specify boron.

W1(R) Boron concentration (mass of boron per mass of liquid).

W2(I) Volume number.

8.6.18 Pipe Volume Additional Wall Friction Data, CCC2501-2599

These cards are optional. If these cards are not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.6.19 Pipe Junction Form Loss Data, CCC3001-3099

These cards are optional. The user-specified form loss is given in Words 1 and 2 of cards CCC0901-0999 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 1 and 2 of cards CCC0901-0999. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all five words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

W5(I) Junction number.

8.6.20 Pipe ORNL ANS Interphase Model Values, CCC3101-3199

These cards are required of any of the interphase friction flags b in the volume control flags entered on cards CCC1001-1099 are set to 2.

W1(R) Gap (distance between side walls, short length, pitch, channel width) (m, ft).

W2(R) Span (distance from one end to the other, long length) (m, ft).

W3(I) Volume number.

8.7 Annulus Component, ANNULUS

An annulus component is indicated by ANNULUS for Word 2 on card CCC0000. The annulus and pipe 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.

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. For major edits, minor edits, and plot variables, the volumes in the annulus component are numbered as CCCNN0000, where NN is the volume number ($01 \leq NN \leq 99$). The junctions in the annulus component are numbered as CCCJJ0000, where JJ is the junction number ($01 \leq JJ \leq 98$).

The general input for a annulus component assumes that the annulus has at least two volumes with one junction separating the two volumes. It is possible to input a one-volume annulus. In order to implement this special case, the user must set the number of volumes and the volume number on the volume cards to 1. In addition, the user should not input any of the junction cards.

The volumes in an annulus are usually considered one-dimensional components and flow in the volumes is along the x-coordinate (face 1 or 2). Crossflow junctions can connect to any of the annulus volumes in the y- and z-coordinate directions (faces 3, 4, 5, or 6) using a form of the momentum equation that does or does not include momentum flux terms. It is also possible to connect external junctions to the x-coordinate direction faces of any of the annulus volumes using a form of the momentum equation that does or does not include the momentum flux terms. It is also possible to include or not include the momentum flux terms in internal annulus junctions.

8.7.1 Annulus Information, CCC0001

This card is required.

W1(I) Number of volumes, nv. The number nv must be greater than 0 and less than 100. The number of associated junctions internal to these components is nv-1. The outer junctions are described by other components.

8.7.2 Annulus X-Coordinate Areas, CCC0101-0199

These cards are required, and the card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC1601-1699 and CCC1701-1799). The format is two words per set in sequential expansion format for nv sets. The words for one set are

W1(R) Area (m^2, ft^2).

W2(I) Volume number.

8.7.3 Annulus Junction Areas, CCC0201-0299

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 0, 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.

8.7.4 Annulus X-Coordinate Lengths, CCC0301-0399

These cards are required. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC1801-1899 and CCC1901-99).

W1(R) Length (m, ft).

W2(I) Volume number.

8.7.5 Annulus Volumes, CCC0401-0499

These cards are optional, and, if not entered, the volumes are set to 0. 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). The code requires that each volume equal the x-direction flow area times the x-direction length. If activated, the code also requires each volume equal the y-direction flow area times the y-direction length, and each volume equal the z-direction flow area times the z-direction length. For any volume, at least two of the three quantities, x-direction area, the x-direction length, or volume, must be nonzero. If one of the quantities is 0, it will be computed from the other two. If none of the quantities are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions. If both the y-direction area and y-direction length are not entered or are 0, the y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction area}}{\pi}\right)^{0.5}$ and the y-direction area is computed from $\frac{\text{volume}}{\text{y-direction length}}$. The same is true for the z-direction.

W2(I) Volume number.

8.7.6 Annulus Volume Azimuthal Angles, CCC0501-0599

These cards are optional, and, if not entered, the angles are set to 0. The angles on these cards are used for the 3-D drawing programs, so it is recommended that the user enter these values if they are known. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(R) Azimuthal angle (degrees). The absolute value of the angle must be $\leq$ 360 degrees.

W2(I) Volume number.

8.7.7 Annulus Volume Vertical Angles, CCC0601-0699

These cards are required. 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). Since an annulus component is vertical, the angle must be ± 90.0 . This angle is used in the interphase drag calculation.

W2(I) Volume number.

8.7.8 Annulus X-Coordinate (Elevation) Changes, CCC0701-0799

These cards are optional. If these cards are missing, the coordinate changes or elevation changes are computed from the x-coordinate 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. Since an annulus component is vertical, any elevation changes entered on these cards have to consistent with the length of the component and the vertical angle entered on the previous card. Two formats entering 1 or 3 coordinate changes per volume are provided. 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. (The corresponding y- and z-coordinate cards are CCC2101-2199 and CCC2201-2299).

1 coordinate change per volume format:

W1(R) Elevation change. This is the coordinate change along the fixed x-axis due to 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 the length.

W2(I) Volume number.

Three coordinate changes per volume format:

W1(R) Coordinate change along the fixed x-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{xx} (m, ft).

W2(R) Coordinate change along the fixed y-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{yx} (m, ft).

W3(R) Coordinate change along the fixed z-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{zx} (m, ft).

W4(I) Volume number.

8.7.9 Annulus Volume X-Coordinate Friction Data, CCC0801-0899

These cards are required. The card format is three words per set for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2301-2399 and CCC2401-2499).

W1(R) Wall roughness (m, ft).

W2(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made to ensure that the roughness is less than half the hydraulic diameter. See Word 1 on cards CCC0101-0109 for the area.

W3(I) Volume number.

8.7.10 Annulus Junction Loss Coefficients, CCC0901-0999

These cards are optional and if missing, the energy loss coefficients are set to 0. 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. Note: a variable loss coefficient may be specified (see Section 8.6.19). The interpretation and use of this loss coefficient vary based upon the “a” junction control flag selected for this junction on cards CCC1101-1199. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area (from cards CCC0201-0299). If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction (from cards CCC0101-0199). If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W2(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. Note: a variable loss coefficient may be specified (see Section 8.6.19). See information for the previous word regarding interpretation and use of this loss coefficient.

W3(I) Junction number.

8.7.11 Annulus Volume X-Coordinate Control Flags, CCC1001-1099

These cards are required. The card format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2701-2799 and CCC2801-2899).

W1(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. These words enter the scalar oriented flags and the x-coordinate flags for each volume in the component.

t-flag. The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The thermal front tracking model can only be applied to vertically-oriented components.

l-flag The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. The mixture level tracking model can only be applied to vertically-oriented components.

p-flag 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.

v-flag 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.

b-flag 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, b = 2 means that the ORNL ANS interphase friction model will be applied (see card ccc3101 in Section 8.6.20).

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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.

8.7.12 Annulus Junction Control Flags, CCC1101-1199

These cards are required. 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 format jefvcahs. It is not necessary to input leading zeros. For the annulus component, the junction control flag is limited to the format 0ef0cahs.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag 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.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and contains Option 50, the original RELAP5 critical flow model is active. Unlike junctions for certain other hydrodynamic components, only the default values of discharge coefficients and factors used in the critical flow models are allowed for junctions in ANNULUS components. Problem renodalization should be used to circumvent this limitation should it prove to be significant. For the Henry-Fauske critical flow model, the default value for the discharge coefficient is 1.0 and the default value for the thermal nonequilibrium constant is 0.14. For the original RELAP5 critical flow model, the default values for the subcooled, two-phase and superheated discharge coefficients each are 1.0.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to volume and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume but not in the from volume. s = 3 does not use momentum flux in either the to or the from volume. For this component, the option s = 0 is the usual recommendation (momentum flux in both volumes). The other options s = 1, 2, and 3 are included to allow consistency for this flag for other components (single-junction, branch junction, etc.).

W2(I) Junction number.

8.7.13 Annulus Volume Initial Conditions, CCC1201-99

These cards are required. 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 format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-9 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-9 or these control words must be consistent (i.e., not specify different fluids). If cards 120-9 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid. It is recommended that the user use the 120-9 cards to set the fluid type in the systems.

b-flag The digit b specifies whether boron is present or not. b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered on the CCC2001-2099 cards.

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

[P,U_f,U_g,α_g] 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 internal energies used to define the thermodynamic state. W6 should be 0.0.

One Component (Steam/Water), Equilibrium

[T,x_s] If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. W4, W5, and W6 should be 0.0.

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

[P,T] If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. W4, W5, and W6 should be 0.0.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E-9 \leq x_s \leq 0.99999999$,

Single phase if $x_s < 1.0$ E-9 or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option.

[T, x_s, x_n] If t = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. W5 and W6 should be 0.0. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[$P, U_f, U_g, \alpha_g, x_n$] 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Five quantities must be entered, and zeros should be entered for unused quantities. If any control word (Word 1) indicates that boron is present, cards CCC2001-2099 must be entered to define the initial boron concentrations. Boron concentrations are not entered in Words 2-6 for annulus components.

W7(I) Volume number.

8.7.14 Annulus Junction Conditions Control Words, CCC1300

This card is optional, and if missing, velocities are assumed on cards CCC1301-99.

W1(I) Control word. If 0, the first and second words of each set on cards CCC1301-1399 are velocities. If 1, the first and second words of each set on cards CCC1301-1399 are mass flows.

8.7.15 Annulus Junction Initial Conditions, CCC1301-1399

These cards are required.

W1(R) Initial liquid velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). The feature is not implemented yet, so enter 0.

W4(I) Junction number.

8.7.16 Annulus Junction Diameter and CCFL Data, CCC1401-1499

These cards are optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, (i.e., f = 0 in Word 1 of cards CCC1101-1199) then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If this card is being used for the CCFL model (i.e., f = 1 in Word 1 of cards CCC1101-1199), then enter all four words for the appropriate CCFL model if values different from the default value are desired.

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. The number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 1 of cards CCC0201-0299 for the area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1, the Kutateladze CCFL form is used. If between 0.0 and 1.0, 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.

8.7.17 Annulus Initial Boron Concentrations, CCC2001-2099

These cards are required only if boron is specified in one of the control words (Word 1) in cards CCC1201-1299. The card format is two words per set in sequential expansion format for nv sets. Boron concentrations must be entered for each volume, and 0 should be entered for those volumes whose associated control word did not specify boron.

W1(R) Boron concentration (mass of boron per mass of liquid).

W2(I) Volume number.

8.7.18 Annulus Volume Additional Wall Friction Data, CCC2501-2599

These cards are optional. If these cards are not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.7.19 Annulus Junction Form Loss Data, CCC3001-3099

This card is optional. The user-specified form loss is given in Words 1 and 2 of cards CCC0901-0999 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 1 and 2 of cards CCC0901-0999. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all five words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

W5(I) Junction number.

8.7.20 Annulus ORNL ANS Interphase Model Values, CCC3101-3199

These cards are required of any of the interphase friction flags b in the volume control flags entered on cards CCC1001-1099 are set to 2.

W1(R) Gap (distance between side walls, short length, pitch, channel width) (m, ft).

W2(R) Span (distance from one end to the other, long length) (m, ft).

W3(I) Volume number.

8.8 Pressurizer Component, PRIZER

A pressurizer component is indicated by PRIZER for Word 2 on CCC0000.

More than one junction may be connected to the inlet or outlet of a pressurizer. If an end has no junctions, that end is considered a closed end. For major edits, minor edits, and plot variables, the volumes in the pressurizer component are numbered as CCCNN0000, where NN is the volume number ($01 \leq NN \leq 99$). The junctions in the pressurizer component are numbered as CCCJJ0000, where JJ is the junction number ($01 \leq JJ \leq 98$).

The volumes in a pressurizer are usually considered one-dimensional components and flow in the volumes is along the x-coordinate. Crossflow junctions can connect to any of the pressurizer volumes in the y- and z-coordinate directions (faces 3, 4, 5, or 6)using a form of the momentum equation that does or does not include momentum flux terms. It is also possible to connect external junctions to the x-coordinate direction faces (1 or 2) of any of the pressurizer volumes using a form of the momentum equation that does or does not include the momentum flux terms. It is also possible to include or not include the momentum flux terms in internal pressurizer junctions.

8.8.1 Pressurizer Information, CCC0001

This card is required.

W1(I) Number of volumes, nv. The number nv must be greater than 0 and less than 100. The number of associated junctions internal to these components is nv-1. The outer junctions are described by other components.

W2(I) Surgeline junction connection number. This word must the same 9-digit format as printed in the output.

W3(R) User specified interfacial heat transfer coefficient from liquid to saturation state (W/m2-K, Btu/hr-ft2-F). This word is optional. If it is not supplied, a value equal to $\dfrac{k_f[\max(0.15Ray^{0.333}, 2.0Nu)]}{D_{Hyd}}$ is used.

W4(R) User specified interfacial heat transfer coefficient from vapor to saturation state (W/m2-K, Btu/hr-ft2-F). This word is optional. If it is not supplied, a value equal to $\dfrac{k_g[\max(0.15Ray^{0.333}, 2.0Nu)]}{D_{Hyd}}$ is used.

W5(R) Spray droplet diameter (m, ft). This is used to compute the interphase drag term for bubbles and droplets. This word is optional and the code computed value is used if this word is not input.

8.8.2 Pressurizer X-Coordinate Areas, CCC0101-0199

These cards are required, and the card numbers need not be consecutive. The format is two words per set in sequential expansion format for nv sets. (The corresponding y- and z-coordinate cards are CCC1601-1699 and CCC1701-1799). The words for one set are

W1(R) Area (m^2, ft^2).

W2(I) Volume number.

8.8.3 Pressurizer Junction Areas, CCC0201-0299

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 0, 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.

8.8.4 Pressurizer X-Coordinate Lengths, CCC0301-0399

These cards are required. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC1801-1899 and CCC1901-1999).

W1(R) Length (m, ft).

W2(I) Volume number.

8.8.5 Pressurizer Volumes, CCC0401-0499

These cards are optional, and if not entered, the volumes are set to 0. 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). The code requires that each volume equal the x-direction flow area times the x-direction length. If activated, the code also requires each volume equal the y-direction flow area times the y-direction length, and each volume equal the z-direction flow area times the z-direction length. For any volume, at least two of the three quantities, x-direction area, the x-direction length, or volume, must be nonzero. If one of the quantities is 0, it will be computed from the other two. If none of the quantities are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions. If both the y-direction area and y-direction length are not entered or are 0, the y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction area}}{\pi}\right)^{0.5}$ and the y-direction area is computed from $\frac{\text{volume}}{\text{y-direction length}}$. The same is true for the z-direction.

W2(I) Volume number.

8.8.6 Pressurizer Volume Azimuthal Angles, CCC0501-0599

These cards are optional, and if not entered, the angles are set to 0. The angles on these cards are used for the 3-D drawing programs, so it is recommended that the user enter these values if they are known. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(R) Azimuthal angle (degrees). The absolute value of the angle must be $\leq$ 360 degrees.

W2(I) Volume number.

8.8.7 Pressurizer Volume Vertical Angles, CCC0601-0699

These cards are required. 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 less than or equal to 90 degrees. This angle is used in the interphase drag calculation.

W2(I) Volume number.

8.8.8 Pressurizer X-Coordinate (Elevation) Changes, CCC0701-0799

These cards are optional. If these cards are missing, the coordinate changes or elevation changes are computed from the x-coordinate 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 1 or 3 coordinate changes per volume are provided. 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. (The corresponding y- and z-coordinate cards are CCC2101-2199 and CCC2201-2299).

1 coordinate change per volume format:

W1(R) Elevation change. This is the coordinate change along the fixed x-axis due to 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 length. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used; when the ratio is greater than 45 degrees, the vertical flow regime map is used.

W2(I) Volume number.

Three coordinate changes per volume format:

W1(R) Coordinate change along the fixed x-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{xx} (m, ft).

W2(R) Coordinate change along the fixed y-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{yx} (m, ft).

W3(R) Coordinate change along the fixed z-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{zx} (m, ft).

W4(I) Volume number.

8.8.9 Pressurizer Volume X-Coordinate Friction Data, CCC0801-0899

These cards are required. The card format is three words per set for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2301-2399 and CCC2401-2499).

W1(R) Wall roughness (m, ft).

W2(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made to ensure that the roughness is less than half the hydraulic diameter. See Word 1 on cards CCC0101-0109 for the area.

W3(I) Volume number.

8.8.10 Pressurizer Junction Loss Coefficients, CCC0901-0999

These cards are optional and if missing, the energy loss coefficients are set to 0. 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. Note: a variable loss coefficient may be specified (see Section 8.6.19). The interpretation and use of this loss coefficient vary based upon the “a” junction control flag selected for this junction on cards CCC1101-1199. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area (from cards CCC0201-0299). If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction (from cards CCC0101-0199). If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W2(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. Note: a variable loss coefficient may be specified (see Section 8.6.19). See information for the previous word regarding interpretation and use of this loss coefficient.

W3(I) Junction number.

8.8.11 Pressurizer Volume X-Coordinate Control Flags, CCC1001-1099

These cards are required. The card format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2701-2799 and CCC2801-2899).

W1(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. These words enter the scalar oriented flags and the x-coordinate flags for each volume in the component.

t-flag. The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The thermal front tracking model can only be applied to vertically-oriented components.

l-flag The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. The mixture level tracking model can only be applied to vertically-oriented components.

p-flag 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.

v-flag 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.

b-flag The digit b specifies the interphase friction that is used. b = 0 means that the pressurizer interphase friction model will be applied, b = 1 means that the rod bundle interphase friction model will be applied, b = 2 means that the ORNL ANS interphase friction model will be applied (see card ccc3101 in Section 8.6.20).

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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.

8.8.12 Pressurizer Junction Control Flags, CCC1101-1199

These cards are required. 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 format jefvcahs. It is not necessary to input leading zeros. For the pressurizer component, the junction control flag is limited to the format 0ef0cahs.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag 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.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and contains Option 50, the original RELAP5 critical flow model is active. Unlike junctions for certain other hydrodynamic components, only the default values of discharge coefficients and factors used in the critical flow models are allowed for junctions in PRESSURIZER components. Problem renodalization should be used to circumvent this limitation should it prove to be significant. For the Henry-Fauske critical flow model, the default value for the discharge coefficient is 1.0 and the default value for the thermal nonequilibrium constant is 0.14. For the original RELAP5 critical flow model, the default values for the subcooled, two-phase and superheated discharge coefficients each are 1.0.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to volume and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume but not in the from volume. s = 3 does not use momentum flux in either the to or the from volume. For this component, the option s = 0 is the usual recommendation (momentum flux in both volumes). The other options s = 1, 2, and 3 are included to allow consistency for this flag for other components (single-junction, branch junction, etc.).

W2(I) Junction number.

8.8.13 Pressurizer Volume Initial Conditions, CCC1201-1299

These cards are required. 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 format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-9 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-9 or these control words must be consistent (i.e., not specify different fluids). If cards 120-9 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid. It is recommended that the user use the 120-9 cards to set the fluid type in the systems.

b-flag The digit b specifies whether boron is present or not. b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered on the CCC2001-2099 cards.

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

[P,U_f,U_g,α_g] 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 internal energies used to define the thermodynamic state. W6 should be 0.0.

One Component (Steam/Water), Equilibrium

[T,x_s] If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. W4, W5, and W6 should be 0.0.

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

[P,T] If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. W4, W5, and W6 should be 0.0.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E-9 \le x_s \le 0.99999999$,

Single phase if $x_s < 1.0$ E-9 or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option.

$[T,x_s,x_n]$ If t = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. W5 and W6 should be 0.0. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

$[P,U_f,U_g,\alpha_g,x_n]$ 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Five quantities must be entered, and zeros should be entered for unused quantities. If any control word (Word 1) indicates that boron is present, cards CCC2001-2099 must be entered to define the initial boron concentrations. Boron concentrations are not entered in Words 2-6 for pressurizer components.

W7(I) Volume number.

8.8.14 Pressurizer Junction Conditions Control Words, CCC1300

This card is optional, and, if missing, velocities are assumed on cards CCC1301-99.

W1(I) Control word. If 0, the first and second words of each set on cards CCC1301-1399 are velocities. If 1, the first and second words of each set on cards CCC1301-1399 are mass flows.

8.8.15 Pressurizer Junction Initial Conditions, CCC1301-1399

These cards are required.

W1(R) Initial liquid velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). This capability has not yet been implemented, so enter 0.

W4(I) Junction number.

8.8.16 Pressurizer Junction Diameter and CCFL Data, CCC1401-1499

These cards are optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, (i.e., $\underline{f} = 0$ in Word 1 of cards CCC1101-1199) then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If this card is being used for the CCFL model (i.e., $\underline{f} = 1$ in Word 1 of cards CCC1101-1199), then enter all four words for the appropriate CCFL model if values different from the default value are desired.

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. The number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 1 of cards CCC0201-0299 for the area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1, the Kutateladze CCFL form is used. If between 0.0 and 1.0, 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.

8.8.17 Pressurizer Initial Boron Concentrations, CCC2001-2099

These cards are required only if boron is specified in one of the control words (Word 1) in cards CCC1201-1299. The card format is two words per set in sequential expansion format for nv sets. Boron concentrations must be entered for each volume, and 0 should be entered for those volumes whose associated control word did not specify boron.

W1(R) Boron concentration (mass of boron per mass of liquid).

W2(I) Volume number.

8.8.18 Pressurizer Volume Additional Wall Friction Data, CCC2501-2599

These cards are optional. If these cards are not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.8.19 Pressurizer Junction Form Loss Data, CCC3001-3099

These cards are optional. The user-specified form loss is given in Words 1 and 2 of cards CCC0901-0999 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 1 and 2 of cards CCC0901-0999. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all five words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F ($\geq$ 0). This quantity must be greater than or equal to 0.

W2(R) C_F ($\geq$ 0). This quantity must be greater than or equal to 0.

W3(R) B_R ($\geq$ 0). This quantity must be greater than or equal to 0.

W4(R) C_R ($\geq$ 0). This quantity must be greater than or equal to 0.

W5(I) Junction number.

8.8.20 Pressurizer ORNL ANS Interphase Model Values, CCC3101-3199

These cards are required of any of the interphase friction flags b in the volume control flags entered on cards CCC1001-1099 are set to 2.

W1(R) Gap (distance between side walls, short length, pitch, channel width) (m, ft).

W2(R) Span (distance from one end to the other, long length) (m, ft).

W3(I) Volume number.

8.9 CANDU Channel Component, CANCHAN

A CANDU channel component is indicated by CANCHAN for Word 2 on CCC0000.

More than one junction may be connected to the inlet or outlet of a CANDU channel. If an end has no junctions, that end is considered a closed end. For major edits, minor edits, and plot variables, the volumes in the CANDU channel component are numbered as CCCNN0000, where NN is the volume number (01 ≤ NN ≤ 99). The junctions in the CANDU channel component are numbered as CCCJJ0000, where JJ is the junction number (01 ≤ JJ ≤ 98).

The volumes in a CANDU channel are usually considered one-dimensional components and flow in the volumes is along the x-coordinate. Crossflow junctions can connect to any of the CANDU channel volumes in the y- and z-coordinate directions (faces 3, 4, 5, or 6)using a form of the momentum equation that does or does not include momentum flux terms. It is also possible to connect external junctions to the x-coordinate direction faces (1 or 2) of any of the CANDU channel volumes using a form of the momentum equation that does or does not include the momentum flux terms. It is also possible to include or not include the momentum flux terms in internal CANDU channel junctions.

8.9.1 CANDU Channel Information, CCC0001

This card is required.

W1(I) Number of volumes, nv. The number nv must be greater than 0 and less than 100. The number of associated junctions internal to these components is nv-1. The outer junctions are described by other components.

W2(I) Surgeline connection number. This word must the same format as printed in the output.

W3(R) User specified interfacial heat transfer coefficient from liquid to saturation state (W/m2-K, Btu/hr-ft2-F). This word is optional.

W4(R) User specified interfacial heat transfer coefficient from vapor to saturation state (W/m2-K, Btu/hr-ft2-F). This word is optional.

8.9.2 CANDU Channel X-Coordinate Areas, CCC0101-0199

These cards are required, and the card numbers need not be consecutive. The format is two words per set in sequential expansion format for nv sets. (The corresponding y- and z-coordinate cards are CCC1601-1699 and CCC1701-1799). The words for one set are

W1(R) Area (m^2, ft^2).

W2(I) Volume number.

8.9.3 CANDU Channel Junction Areas, CCC0201-0299

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 0, 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.

8.9.4 CANDU Channel X-Coordinate Lengths, CCC0301-0399

These cards are required. The format is two words per set in sequential expansion format for nv sets. Card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC1801-1899 and CCC1901-1999).

W1(R) Length (m, ft).

W2(I) Volume number.

8.9.5 CANDU Channel Volumes, CCC0401-0499

These cards are optional, and if not entered, the volumes are set to 0. 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). The code requires that each volume equal the x-direction flow area times the x-direction length. If activated, the code also requires each volume equal the y-direction flow area times the y-direction length, and each volume equal the z-direction flow area times the z-direction length. For any volume, at least two of the three quantities, x-direction area, the x-direction length, or volume, must be nonzero. If one of the quantities is 0, it will be computed from the other two. If none of the quantities are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions. If both the y-direction area and y-direction length are not entered or are 0, the y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction area}}{\pi}\right)^{0.5}$ and the y-direction area is computed from $\frac{\text{volume}}{\text{y-direction length}}$. The same is true for the z-direction.

W2(I) Volume number.

8.9.6 CANDU Channel Volume Azimuthal Angles, CCC0501-0599

These cards are optional, and if not entered, the angles are set to 0. The angles on these cards are used for the 3-D drawing programs, so it is recommended that the user enter these values if they are known. The format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive.

W1(R) Azimuthal angle (degrees). The absolute value of the angle must be $\leq$ 360 degrees.

W2(I) Volume number.

8.9.7 CANDU Channel Volume Vertical Angles, CCC0601-0699

These cards are required. 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 less than or equal to 90 degrees. This angle is used in the interphase drag calculation.

W2(I) Volume number.

8.9.8 CANDU Channel X-Coordinate (Elevation) Changes, CCC0701-0799

These cards are optional. If these cards are missing, the coordinate changes or elevation changes are computed from the x-coordinate 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 1 or 3 coordinate changes per volume are provided. 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. (The corresponding y- and z-coordinate cards are CCC2101-2199 and CCC2201-2299).

1 coordinate change per volume format:

W1(R) Elevation change. This is the coordinate change along the fixed x-axis due to 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 length. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used; when the ratio is greater than 45 degrees, the vertical flow regime map is used.

W2(I) Volume number.

Three coordinate changes per volume format:

W1(R) Coordinate change along the fixed x-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{xx} (m, ft).

W2(R) Coordinate change along the fixed y-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{yx} (m, ft).

W3(R) Coordinate change along the fixed z-axis due to traverse from inlet to outlet along the local x-coordinate, Δ_{zx} (m, ft).

W4(I) Volume number.

8.9.9 CANDU Channel Volume X-Coordinate Friction Data, CCC0801-0899

These cards are required. The card format is three words per set for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2301-2399 and CCC2401-2499).

W1(R) Wall roughness (m, ft).

W2(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made to ensure that the roughness is less than half the hydraulic diameter. See Word 1 on cards CCC0101-0109 for the area.

W3(I) Volume number.

8.9.10 CANDU Channel Junction Loss Coefficients, CCC0901-0999

These cards are optional and if missing, the energy loss coefficients are set to 0. 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. Note: a variable loss coefficient may be specified (see Section 8.6.19). The interpretation and use of this loss coefficient vary based upon the “a” junction control flag selected for this junction on cards CCC1101-1199. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area (from cards CCC0201-0299). If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction (from cards CCC0101-0199). If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W2(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. Note: a variable loss coefficient may be specified (see Section 8.6.19). See information for the previous word regarding interpretation and use of this loss coefficient.

W3(I) Junction number.

8.9.11 CANDU Channel Volume X-Coordinate Control Flags, CCC1001-1099

These cards are required. The card format is two words per set in sequential expansion format for nv sets, and card numbers need not be consecutive. (The corresponding y- and z-coordinate cards are CCC2701-2799 and CCC2801-2899).

W1(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. These words enter the scalar oriented flags and the x-coordinate flags for each volume in the component.

t-flag. The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The thermal front tracking model can only be applied to vertically-oriented components.

l-flag The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. The mixture level tracking model can only be applied to vertically-oriented components.

p-flag 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.

v-flag 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.

b-flag The digit b specifies the interphase friction that is used. b = 0 means that the CANDU channel interphase friction model will be applied, b = 1 means that the rod bundle interphase friction model will be applied, b = 2 means that the ORNL ANS interphase friction model will be applied (see card ccc3101 in Section 8.6.20).

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate of the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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.

8.9.12 CANDU Channel Junction Control Flags, CCC1101-1199

These cards are required. 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 format jefvcahs. It is not necessary to input leading zeros. For the CANDU channel component, the junction control flag is limited to the format 0ef0cahs.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag 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.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and contains Option 50, the original RELAP5 critical flow model is active. Unlike junctions for certain other hydrodynamic components, only the default values of discharge coefficients and factors used in the critical flow models are allowed for junctions in CANDU channel components. Problem renodalization should be used to circumvent this limitation should it prove to be significant. For the Henry-Fauske critical flow model, the default value for the discharge coefficient is 1.0 and the default value for the thermal nonequilibrium constant is 0.14. For the original RELAP5 critical flow model, the default values for the subcooled, two-phase and superheated discharge coefficients each are 1.0.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to volume and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume but not in the from volume. s = 3 does not use momentum flux in either the to or the from volume. For this component, the option s = 0 is the usual recommendation (momentum flux in both volumes). The other options s = 1, 2, and 3 are included to allow consistency for this flag for other components (single-junction, branch junction, etc.).

W2(I) Junction number.

8.9.13 CANDU Channel Volume Initial Conditions, CCC1201-1299

These cards are required. 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 format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-9 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-9 or these control words must be consistent (i.e., not specify different fluids). If cards 120-9 are not entered and all control words use the default ε = 0, then H_2O is assumed as the fluid. It is recommended that the user use the 120-9 cards to set the fluid type in the systems.

b-flag The digit b specifies whether boron is present or not. b = 0 specifies that the volume liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered on the CCC2001-2099 cards.

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

$[P,U_f,U_g,\alpha_g]$ 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 internal energies used to define the thermodynamic state. W6 should be 0.0.

One Component (Steam/Water), Equilibrium

[T,x_s] If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. W4, W5, and W6 should be 0.0.

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

[P,T] If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. W4, W5, and W6 should be 0.0.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E\text{-}9 \leq x_s \leq 0.99999999$,

Single phase if $x_s < 1.0\ E\text{-}9$ or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option.

[T,x_s,x_n] If t = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. W5 and W6 should be 0.0. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[P,U_f,U_g,α_g,x_n] If $\underline{t}$ = 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 ($\underline{t}$ = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Five quantities must be entered, and zeros should be entered for unused quantities. If any control word (Word 1) indicates that boron is present, cards CCC2001-2099 must be entered to define the initial boron concentrations. Boron concentrations are not entered in Words 2-6 for CANDU channel components.

W7(I) Volume number.

8.9.14 CANDU Channel Junction Conditions Control Words, CCC1300

This card is optional, and, if missing, velocities are assumed on cards CCC1301-1399.

W1(I) Control word. If 0, the first and second words of each set on cards CCC1301-1399 are velocities. If 1, the first and second words of each set on cards CCC1301-1399 are mass flows.

8.9.15 CANDU Channel Junction Initial Conditions, CCC1301-1399

These cards are required.

W1(R) Initial liquid velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). This capability has not yet been implemented, so enter 0.

W4(I) Junction number.

8.9.16 CANDU Channel Junction Diameter and CCFL Data, CCC1401-1499

These cards are optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation, (i.e., $\underline{f} = 0$ in Word 1 of cards CCC1101-1199) then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If this card is being used for the CCFL model (i.e., $\underline{f} = 1$ in Word 1 of cards CCC1101-1199), then enter all four words for the appropriate CCFL model if values different from the default value are desired.

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. The number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 1 of cards CCC0201-0299 for the area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1, the Kutateladze CCFL form is used. If between 0.0 and 1.0, 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.

8.9.17 CANDU Channel Initial Boron Concentrations, CCC2001-2099

These cards are required only if boron is specified in one of the control words (Word 1) in cards CCC1201-1299. The card format is two words per set in sequential expansion format for nv sets. Boron concentrations must be entered for each volume, and 0 should be entered for those volumes whose associated control word did not specify boron.

W1(R) Boron concentration (mass of boron per mass of liquid).

W2(I) Volume number.

8.9.18 CANDU Channel Volume Additional Wall Friction Data, CCC2501-2599

These cards are optional. If these cards are not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.9.19 CANDU Channel Junction Form Loss Data, CCC3001-3099

These cards are optional. The user-specified form loss is given in Words 1 and 2 of cards CCC0901-0999 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 1 and 2 of cards CCC0901-0999. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all five words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

W5(I) Junction number.

8.9.20 CANDU Channel ORNL ANS Interphase Model Values, CCC3101-3199

These cards are required of any of the interphase friction flags b in the volume control flags entered on cards CCC1001-1099 are set to 2.

W1(R) Gap (distance between side walls, short length, pitch, channel width) (m, ft).

W2(R) Span (distance from one end to the other, long length) (m, ft).

W3(I) Volume number.

8.10 Branch Component, BRANCH

A branch component is indicated by BRANCH for Word 2 on card CCC0000. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N is the face number. 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. If more than one junction is connected on one end of a branch, each junction should be modeled as an abrupt area change. For major edits, minor edits, and plot variables, the volume in the branch component is numbered as CCC010000. The junctions associated with the branch component are numbered as CCCJJ0000, where JJ is the junction number ($01 \leq JJ \leq 09$).

8.10.1 Branch Component Information, CCC0001

This card is required.

W1(I) Number of junctions, nj. The variable nj is the number of junctions described in the input data for this component ($0 \leq nj \leq 9$). Not all junctions connecting to the branch need 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, circulators, separators, jetmixers, ECC mixers, 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 card CCCN201 are assumed to be velocities. If 0, velocities are assumed; if nonzero, mass flows are assumed.

8.10.2 Branch X-Coordinate Volume Data, CCC0101-0109

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

W1(R) Area (m^2, ft^2).

W2(R) Length (m, ft).

W3(R) Volume (m^3, ft^3). The code requires that the volume equals the 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 0, it will be computed from the other two. If none of the words are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used. When the ratio is greater than 45 degrees, the vertical flow regime map is used.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made that the pressurizer roughness is less than half the hydraulic diameter. See Word 1 for the area.

W9(I) Volume control flags. This word has the format <u>tlpvbfe</u>. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate

oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag.

t-flag The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume.

l-flag The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume.

p-flag 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.

v-flag 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.

b-flag The digit b specifies the interphase friction that is used. b = 0 means that the pressurizer interphase friction model will be applied, b = 1 means that the rod bundle interphase friction model will be applied, b = 2 means that the ORNL ANS interphase friction model will be applied (see card ccc0111 in Section 8.10.3).

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate direction in the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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.

8.10.3 Branch ORNL ANS Interphase Model Values, CCC0111

This card is required if the interphase friction flag b in Word 9 of card CCC0101-0109 is set to 2.

W1(R) Gap (distance between side walls, short length, pitch, channel width) (m, ft).

W2(R) Span (distance from one end to the other, long length) (m, ft).

W3(I) Volume number.

8.10.4 Branch Additional Wall Friction, CCC0131

This card is optional. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.10.5 Branch Y-Coordinate Volume Data, CCC0181-0189

These cards are optional. These cards are used when the user specifies the y-direction connection with the crossflow model. The volume of the volume is the same for the x-, y-, and z-directions. If these cards are entered, either W1 or W2 must be nonzero.

W1(R) Area (m^2, ft^2). If these cards are missing or if this word is 0, this y-direction area is computed from $\frac{\text{volume}}{\text{y-direction length}}$.

W2(R) Length (m, ft). If these cards are missing, this y-direction length is computed from $2.0 \bullet \left(\frac{\text{x} - \text{direction area}}{\pi}\right)^{0.5}$. If this word is 0, this y-direction length is computed from $\frac{\text{volume}}{\text{y-direction area}}$.

W3(R) Roughness (m, ft).

W4(R) Hydraulic diameter (m, ft). If these cards are missing or if this word is 0, this y-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{\text{y} - \text{direction area}}{\pi \bullet \text{x} - \text{direction area}}\right)^{0.5}$. A check is made to ensure the y-direction roughness is less than half the y-direction hydraulic diameter.

W5(I) Volume control flags. This word has the general format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the y-direction.

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the y-coordinate direction in the volume, and f = 1 specifies that wall friction effects are not to be computed along the y-coordinate direction.

W6(R) This word is not used. Enter 0.

W7(R) This word is not used. Enter 0.

W8(R) This word is the position change in the z-fixed (vertical) direction as the flow passes from the y-inlet face to the y-outlet face (m, ft). This quantity affects problems if connections are made to the y-faces.

8.10.6 Branch Z-Coordinate Volume Data, CCC0191-0199

These cards are optional. These cards are used when the user specifies the z-direction connection with the crossflow model. The volume of the volume is the same for the x-, y-, and z-directions. If these cards are entered, either W1 or W2 must be nonzero.

W1(R) Area (m^2, ft^2). If these cards are missing or if this word is 0, this z-direction area is computed from $\frac{\text{volume}}{\text{z-direction length}}$.

W2(R) Length (m, ft). If these cards are missing, this z-direction length is computed from $2.0 \bullet \left(\frac{x - \text{direction area}}{\pi}\right)^{0.5}$. If this word is 0, this z-direction length is computed from $\frac{\text{volume}}{\text{z-direction area}}$.

W3(R) Roughness (m, ft).

W4(R) Hydraulic diameter (m, ft). If these cards are missing or if this word is 0, this z-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{z - \text{direction area}}{\pi \bullet x - \text{direction area}}\right)^{0.5}$. A check is made to ensure the z-direction roughness is less than half the z-direction hydraulic diameter.

W5(I) Volume control flags. This word has the general format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the z-direction.

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the z-coordinate direction in the volume, and f = 1 specifies that wall friction effects are not to be computed along the z-coordinate direction.

W6(R) This word is not used. Enter 0.

W7(R) This word is not used. Enter 0.

W8(R) This word is the position change in the z-fixed (vertical) direction as the flow passes from the z-inlet face to the z-outlet face (m, ft). This quantity affects problems if connections are made to the z-faces.

8.10.7 Branch Volume Initial Conditions, CCC0200

This card is required.

W1(I) Control word. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-129 or these control words must be consistent (i.e., not specify different fluids). If cards 120-129 are not entered and all control words use the default ε = 0, then water is assumed to be the fluid. It is recommended that the user use the 120-129 cards to set the fluid type in the systems.

b-flag The digit b specifies whether boron is present. b = 0 specifies that the volume liquid does not contain boron, and b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered after the other required thermodynamic information.

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

$[P, U_f, U_g, \alpha_g]$ 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 the internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

$[T, x_s]$ If $\underline{t} = 1$, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter boron in W4 if needed.

$[P, x_s]$ If $\underline{t} = 2$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter boron in W4 if needed.

$[P, T]$ If $\underline{t} = 3$, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E{-}9 \le x_s \le 0.99999999$,

Single phase if $x_s < 1.0\ E{-}9$ or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

$[P, T, x_s]$ If $\underline{t} = 4$, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality greater than 0.0 and less than or equal to 1.0, saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter boron in W5 if needed.

$[T, x_s, x_n]$ If $\underline{t} = 5$, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Enter boron in W5 if needed. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

$[P, U_f, U_g, \alpha_g, x_n]$ If $\underline{t}$ = 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 ($\underline{t}$ = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Enter boron in W7 if needed.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, 2-6 quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

8.10.8 Branch Junction Geometry, CCCN101-N109

These cards are required if nj is greater than 0. cards with N equal to 1-9 are entered, one for each junction. For a BRANCH component, N need not be consecutive, but nj cards must be entered. The card format for Words 1-6 is listed below and is identical to Words 1-6 on card CCC0101 of the Single-Junction Geometry Card, except that N instead of 0 is used in the fourth digit.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). If 0, the area is set to the minimum area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.10.10). The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.10.10). See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. For the branch component, the junction control flag is limited to the format 0efvcahs.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag 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.

v-flag The digit v specifies horizontal stratification entrainment/pullthrough options. This model is for junctions connected to a horizontal volume. v = 0 means the model is not applied; v = 1 means an upward oriented junction (offtake volume must be vertical); v = 2 means a downward oriented junction (offtake volume must be vertical); and v = 3 means a centrally (side) located junction.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume, but not in the from volume. s = 3 does not use momentum flux in either the to volume or the from volume.

W7(R) The meaning of this word is different, depending on the critical flow model which has been selected (see W6).

If the Henry-Fauske critical flow model is active, the discharge coefficient is entered. If W7 and W8 are missing, W7 is set to 1.0 and W8 is set to 0.14.

If the original RELAP5 critical flow model is active, the subcooled discharge coefficient is entered. This entry applies only to subcooled liquid choked flow calculations. The entry must be > 0.0 and < 2.0. If W7, W8 and W9 are missing, they are each set to 1.0.

W8(R) The meaning of this word is different, depending on the critical flow model which has been selected (see W6).

If the Henry-Fauske critical flow model is active, the thermal nonequilibrium constant is entered. If W7 is entered and W8 is missing, W8 is set to 0.14. If the entry is < 0.01, the equilibrium option is used and W8 is reset to 0.0. If the entry is >1000.0, the frozen option is used and W8 is reset to 100.0.

If the original RELAP5 critical flow model is active, the two-phase discharge coefficient is entered. This entry applies only to two-phase choked flow calculations. The entry must be > 0.0 and < 2.0. If W7 is entered and W8 and W9 are missing, W8 and W9 are each set to 1.0.

W9(R) If the Henry-Fauske critical flow model is active, this word is not used and should not be entered.

If the original RELAP5 critical flow model is active, the superheated discharge coefficient is entered. This entry applies only to superheated vapor choked flow calculations. The entry must be > 0.0 and < 2.0. If W7 and W8 are entered and W9 is missing, then W9 is set to 1.0.

8.10.9 Branch Junction Diameter and CCFL Data, CCCN110

These cards are optional. The value N should follow the same approach as used in cards CCCN101-N109. The defaults indicated for each word are used if the card is not entered. If these cards are being used to specify only the junction hydraulic diameter for the interphase drag calculations (i.e., f = 0 in Word 6 of cards CCCN101-N109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If these cards are being used for the CCFL model (i.e., f = 1 in Word 6 of cards CCCN101-N109), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

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. This number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$ of the respective junction. See Word 3 of cards CCCN101-N109 for the junction area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1, the Kutateladze CCFL form is used. f between 0.0 and 1.0, 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.

8.10.10 Branch Junction Form Loss Data, CCCN112

These cards are optional. The values of N should follow the same approach as used in cards CCCN101-N109. The user-specified form loss is given in Words 4 and 5 of cards CCCN101-N109 if these cards are not entered. If these cards are entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F} + KFJUNCV$$

$$K_R = A_R + B_R Re^{-C_R} + KRJUNCV$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of cards CCCN101-N109. Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

W5(I) Control variable number for specifying a portion of the forward form loss (KFJUNCV). This quantity must be greater than or equal to 0. *(Optional)*

W6(I) Control variable number for specifying a portion of the reverse form loss (KRJUNCV). This quantity must be greater than or equal to 0. *(Optional)*

8.10.11 Branch Junction Initial Conditions, CCCN201

These cards are required depending on the value of nj as described for cards CCCN101-N109. The values of N should follow the same approach as used in cards CCCN101-N109.

W1(R) Initial liquid or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). Enter 0.

8.11 Separator Component, SEPARATR

A steam separator component is indicated by SEPARATR for Word 2 on card CCC0000. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N is the face number. For major edits, minor edits, and plot variables, the volume is numbered as CCC010000. The junctions associated with the separator component are numbered as CCCJJ0000, where JJ is the junction number ($01 \leq JJ \leq 03$).

A separator component is a specialized branch component having three junctions. The number of junctions nj defined below must be 3, and no junctions may connect to this component. The variable N defined below must have values of 1, 2, and 3. For the junctions, N = 1 is the vapor outlet junction, N = 2 is the liquid fall back junction, and N = 3 is the separator inlet junction. The from part of the vapor outlet junction must refer to the outlet of the separator (CCC010002), and the from part of the liquid fall back must refer to the inlet of the separator (CCC010001). 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. We recommend that choking be turned off for all three junctions. The vapor outlet and liquid fall back junctions should use the nonhomogeneous option.

8.11.1 Separator Component Information, CCC0001

This card is required.

W1(I) Number of junctions, nj. The variable nj is the number of junctions described in the input data for this component and must be 3.

W2(I) Initial condition control. This word is optional and, if missing, the junction initial velocities in the first and second words on card CCCN201 are assumed to be velocities. If 0, velocities are assumed; if nonzero, mass flows are assumed.

8.11.2 Separator Options, CCC0002

This card is optional. The first word specifies the separator option while the second word specifies the number of actual separator components represented by this RELAP5 SEPARATOR component. The second word is needed if the user uses the General Electric separator options

W1(I) Separator option, ISEPST. A value of 0 specifies the simple separator contained in previous versions of RELAP5 (default), a value of 1 specifies the General Electric dryer model, a value of 2 specifies a General Electric two-stage separator, and a value of 3 specifies a three-stage General Electric separator.

W2(I) Number of separator components represented by this RELAP5 component. The number is needed only if Word 1 has a value of 2 or 3.

8.11.3 Separator X-Coordinate Volume Data, CCC0101-0109

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

W1(R) Area (m^2, ft^2).

W2(R) Length (m, ft).

W3(R) Volume (m^3, ft^3). The code requires that the volume equals the 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 0, it will be computed from the other two. If none of the words are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

W4(R) Azimuthal angle (degrees). The absolute value of this angle must be $\leq$ 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 $\leq$ 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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used. When the ratio is greater than 45 degrees, the vertical flow regime map is used.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made that the pipe roughness is less than half the hydraulic diameter. See Word 1 for the area.

W9(I) Volume control flags. This word has the format <u>tlpvbfe</u>. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag. For the SEPARATR component, the volume control flag is limited to the format <u>000001e</u>.

e-flag The digit <u>e</u> specifies if nonequilibrium or equilibrium is to be used. <u>e</u> = 0 specifies that a nonequilibrium (unequal temperature) calculation is to be used, and <u>e</u> = 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.

8.11.4 Separator Additional Wall Friction, CCC0131

This card is optional. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.11.5 Separator Volume Initial Conditions, CCC0200

This card is required.

W1(I) Control word. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-129 or these control words must be consistent (i.e., not specify different fluids). If cards 120-129 are not entered and all control words use the default ε = 0, then water is assumed to be the fluid. It is recommended that the user use the 120-129 cards to set the fluid type in the systems.

b-flag The digit b specifies whether boron is present. b = 0 specifies that the volume liquid does not contain boron, and b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered after the other required thermodynamic information.

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

[P,U_f,U_g,α_g] 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 internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

[T,x_s] If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter boron in W4 if needed.

[P,x_s] If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter boron in W4 if needed.

[P,T] If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E-9 \leq x_s \leq 0.99999999$,

Single phase if $x_s < 1.0$ E-9 or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality greater than 0.0 and less than or equal to 1.0, saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter boron in W5 if needed.

[T,x_s,x_n] If t = 5, the next three words are interpreted as steam saturation temperature (K, ^{o}F), static quality, and noncondensable quality in equilibrium condition. Enter boron in W5 if needed. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[P,U_f,U_g,α_g,x_n] 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Enter boron in W7 if needed.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, 2-6 quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

8.11.6 Separator Junction Geometry, CCCN101-N109

These cards are required. Cards with N equal to 1, 2 and 3 are entered, one for each junction.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). If 0, the area is set to the minimum area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.10.10). The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.10.10). See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. For this component, the junction control flag format is limited to 0000cahs.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as

¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume, but not in the from volume. s = 3 does not use momentum flux in either the to volume or the from volume.

W7(R) 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.

8.11.7 Separator Junction Form Loss Data, CCCN112

These cards are optional. The values of N should follow the same approach as used in cards CCCN101-N109. The user-specified form loss is given in Words 4 and 5 of cards CCCN101-N109 if these cards are not entered. If these cards are entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of cards CCCN101-N109. Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

W5(I) Control variable number for specifying a portion of the forward form loss (KFJUNCV). This quantity must be greater than or equal to 0. (Optional)

W6(I) Control variable number for specifying a portion of the reverse form loss (KRJUNCV). This quantity must be greater than or equal to 0. (Optional)

8.11.8 Separator Junction Initial Conditions, CCCN201

These cards are required depending on the value of nj as described for cards CCCN101-N109. The values of N should follow the same approach as used in cards CCCN101-N109. A 90% extraction limit during input processing is tested for the vapor at the vapor outlet junction and for the liquid fall back junction. If greater than 90%, an input error occurs.

W1(R) Initial liquid or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). Enter 0.

8.11.9 GE Separator Data, CCC0500

This card is optional for the GE separator. If this card is missing and the GE separator has been specified on card CCC0002, the default values will be used. If the card is present, all eight values must be specified.

W1(R) Radius of larger pickoff ring at first stage of a two-stage separator (m, ft). (Default = 0.0857208 m).

W2(R) Standpipe flow area (m^2, ft^2). Default = 0.018637 m^2.

W3(R) Separator nozzle exit area (m^2, ft^2). Default = 0.01441 m^2.

W4(R) Radius of separator hub at inlet (m, ft). Default = 0.0809585 m.

W5(R) Swirl vane angle relative to the horizontal (deg). Default = 48 deg.

W6(R) Liquid carryover coefficient for upper separating stages. Default = 0.009 for two-stage separator and 0.110 for three-stage separator.

W7(R) Vapor carryunder coefficient for upper separating stages. Default = 0.0004.

W8(R) Axial distance between exit of first stage discharge passage and swirl vanes (m, ft). Default = 0.2127 m for two-stage separator and 0.45083 m for three-stage separator.

8.11.10 GE Separator First Stage Data, CCC0501

This card is optional for the GE separator. If this card is missing and the GE separator has been specified on card CCC0002, the default values will be used. If the card is present, all nine values must be specified.

W1(R) Liquid film void profile coefficient. Default = 110.0.

W2(R) Vapor core void profile coefficient. Default = 0.5.

W3(R) Separator wall inner radius (m, ft). Default = 0.10794 m.

W4(R) Pickoff ring inner radius (m, ft). Default = 0.069875 m for two-stage separator and 0.0857208 m for three-stage separator.

W5(R) Discharge passage flow area (m^2, ft^2). Default = 0.0415776 m^2 for two-stage separator and 0.0096265 m^2 for three-stage separator.

W6(R) Discharge passage hydraulic diameter (m, ft). Default = 0.045558 m for two-stage separator and 0.025399 m for three-stage separator.

W7(R) Separating barrel length (m, ft). Default = 0.877845 m for two-stage separator and 1.0699 m for three-stage separator.

W8(R) Discharge passage loss coefficient. Default = 10.0 for two-stage separator and 2.5 for three-stage separator.

W9(R) Discharge passage effective L/D coefficient. Default = 450.0 for two-stage separator and 53.44 for three-stage separator.

8.11.11 GE Separator Second Stage Data, CCC0502

This card is optional for the GE separator. If this card is missing and the GE separator has been specified on card CCC0002, the default values will be used. If the card is present, all nine values must be specified.

W1(R) Liquid film void profile coefficient. Default = 20.0.

W2(R) Vapor core void profile coefficient. Default = 0.25.

W3(R) Separator wall inner radius (m, ft). Default = 0.06985 m for two-stage separator and 0.10794 m for three-stage separator.

W4(R) Pickoff ring inner radius (m, ft). Default = 0.06032 m for two-stage separator and 0.0952453 m for three-stage separator.

W5(R) Discharge passage flow area (m^2, ft^2). Default = 0.0029133 m^2 for two-stage separator and 0.0096265 m^2 for three-stage separator.

W6(R) Discharge passage hydraulic diameter (m, ft). Default = 0.0121699 m for two-stage separator and 0.025399 m for three-stage separator.

W7(R) Separating barrel length (m, ft). Default = 0.16255 m for two-stage separator and 0.384156 m for three-stage separator.

W8(R) Discharge passage loss coefficient. Default = 0.5 for two-stage separator and 1.429 for three-stage separator.

W9(R) Discharge passage effective $\frac{L}{D}$ coefficient. Default = 95.85 for two-stage separator and 194.64 for three-stage separator.

8.11.12 GE Separator Third Stage Data, CCC0503

This card is optional for the GE separator. If this card is missing and the GE three-stage separator has been specified on card CCC0002, the default values will be used. If the card is present, all nine values must be specified.

W1(R) Liquid film void profile coefficient. Default = 20.0.

W2(R) Vapor core void profile coefficient. Default = 0.55.

W3(R) Separator wall inner radius (m, ft). Default = 0.10794 m.

W4(R) Pickoff ring inner radius (m, ft). Default = 0.0984201 m.

W5(R) Discharge passage flow area (m^2, ft^2). Default = 0.0096265 m^2.

W6(R) Discharge passage hydraulic diameter (m, ft). Default = 0.025399 m.

W7(R) Separating barrel length (m, ft). Default = 0.384156 m.

W8(R) Discharge passage loss coefficient. Default = 2.563.

W9(R) Discharge passage effective L/D coefficient. Default = 424.96.

8.11.13 GE Dryer Data, CCC0600

This card is optional for the GE separator. If this card is missing and the GE dryer has been specified on card CCC0002, the default values will be used. If the card is present, all three values must be specified.

W1(R) Vapor velocity at dryer inlet below which there is 0% liquid carryover (m/s, ft/s). Default = 1.5 m/s.

W2(R) Vapor velocity at dryer inlet above which there is 100% liquid carryover (m/s, ft/s). Default = 6.0 m/s.

W3(R) Range of dryer inlet quality where dryer carryover changes from 0 to 100% when dryer inlet vapor velocity is between lower and upper values. Default = 0.05.

8.12 Jetmixer Component, JETMIXER

A jetmixer component is indicated by JETMIXER for Word 2 on card CCC0000. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N is the face number. Each junction should be modeled as an abrupt area change. For major edits, minor edits, and plot variables, the volume is numbered as CCC010000. The junctions associated with the jetmixer component are numbered as CCCJJ0000, where JJ is the junction number ($00 \leq JJ \leq 09$).

A JETMIXER component is a specialized branch using three junctions. For the junctions, N = 1 represents the drive junction, N = 2 represents the suction junction, and N = 3 represents the discharge junction. The <u>to</u> part of the drive and suction junctions (N = 1 and 2) must refer to the inlet end of the jetmixer (CCC010001), and the <u>from</u> part of the discharge junction (N = 3) must refer to the outlet end of the jetmixer (CCC010002). To model a jet pump properly, the junction flow areas of the drive and suction should equal the volume flow area.

8.12.1 Jetmixer Component Information, CCC0001

This card is required.

W1(I) Number of junctions, nj. Enter 3.

W2(I) Initial condition control. This word is optional and, if missing, the junction initial velocities in the first and second words on card CCCN201 are assumed to be velocities. If 0, velocities are assumed; if nonzero, mass flows are assumed.

8.12.2 Jetmixer X-Coordinate Volume Data, CCC0101-0109

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

W1(R) Area (m^2, ft^2).

W2(R) Length (m, ft).

W3(R) Volume (m^3, ft^3). The code requires that the volume equals the 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 0, it will be computed from the other two. If none of the words are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used. When the ratio is greater than 45 degrees, the vertical flow regime map is used.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made that the pipe roughness is less than half the hydraulic diameter. See Word 1 for the area.

W9(I) Volume control flags. This word has the format <u>tlpvbfe</u>. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate

oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag. The jetmixer volume control flag is restricted to the format 00000fe.

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate direction in the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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.

8.12.3 Jetmixer Additional Wall Friction, CCC0131

This card is optional. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.12.4 Jetmixer Volume Initial Conditions, CCC0200

This card is required.

W1(I) Control word. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-129 or these control words must be consistent (i.e., not specify different fluids). If cards 120-129 are not entered and all control words use the default $\underline{\varepsilon}$ = 0, then water is assumed to be the fluid. It is recommended that the user use the 120-129 cards to set the fluid type in the systems.

b-flag — The digit $\underline{b}$ specifies whether boron is present. $\underline{b}$ = 0 specifies that the volume liquid does not contain boron, and $\underline{b}$ = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered after the other required thermodynamic information.

t-flag — The digit $\underline{t}$ specifies how the following words are to be used to determine the initial thermodynamic state. $\underline{t}$ = 0-3 specifies one component (steam/water); $\underline{t}$ = 4-6 allows the specification of two components (steam/water and noncondensable gas).

With options $\underline{t}$ equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

$[P,U_f,U_g,\alpha_g]$ — 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 the internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

$[T,x_s]$ — If $\underline{t}$ = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter boron in W4 if needed.

$[P,x_s]$ — If $\underline{t}$ = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter boron in W4 if needed.

$[P,T]$ — If $\underline{t}$ = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if 1.0E-9 $\leq x_s \leq$ 0.99999999,

Single phase if x_s < 1.0 E-9 or x_s > 0.99999999

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality greater than 0.0 and less than or equal to 1.0, saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter boron in W5 if needed.

[T,x_s,x_n] If t = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Enter boron in W5 if needed. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[P,U_f,U_g,α_g,x_n] 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Enter boron in W7 if needed.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, 2-6 quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

8.12.5 Jetmixer Junction Geometry, CCCN101-N109

These cards are required. Cards with N equal to 1, 2 and 3 are required, one for each junction.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). If 0, the area is set to the minimum area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.10.10). The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.10.10). See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. For the JETMIXER, the junction control flag format is limited to 0000cah0.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-

Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

8.12.6 Jetmixer Junction Form Loss Data, CCCN112

These cards are optional. The values of N should follow the same approach as used in cards CCCN101-N109. The user-specified form loss is given in Words 4 and 5 of cards CCCN101-N109 if these cards are not entered. If these cards are entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of cards CCCN101-N109. Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

8.12.7 Jetmixer Junction Initial Conditions, CCCN201

These cards are required depending on the value of nj as described for cards CCCN101-N109. The values of N should follow the same approach as used in cards CCCN101-N109.

W1(R) Initial liquid or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). Enter 0.

8.13 Turbine Component, TURBINE

A turbine component is indicated by TURBINE for Word 2 on card CCC0000. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N is the face number. 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.

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. The number of junctions, nj, must be equal to 1 or 2. Junction N = 1 is the turbine junction that models the stages, and junction N = 2 is the steam extraction (bleed) junction that should be a crossflow junction. Junction N = 1 must be the only entrance junction, and there must be only one exit junction (part of another component). The <u>to</u> part of the steam inlet junction (N = 1) must refer to the inlet end of the turbine volume (CCC010001). 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, with efficiency = 0, turbine with <u>h</u> = 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. If several turbine components are in series, the choking flag should be left on (<u>c</u> = 0) for the first component but turned off for the other components (<u>c</u> = 1). The smooth junction option (<u>a</u> = 0) should be used at both inlet and outlet junctions. The inlet and outlet junctions must be input as homogeneous junctions (<u>h</u> = 1 or 2).

8.13.1 Turbine Component Information, CCC0001

This card is required.

W1(I) Number of junctions, nj. The variable nj must be 1 or 2.

W2(I) Initial condition control. This word is optional and, if missing, the junction initial velocities in the first and second words on card CCCN201 are assumed to be velocities. If 0, velocities are assumed; if nonzero, mass flows are assumed.

8.13.2 Turbine X-Coordinate Volume Data, CCC0101-0109

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

W1(R) Area (m^2, ft^2).

W2(R) Length (m, ft).

W3(R) Volume (m^3, ft^3). The code requires that the volume equals the 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 0, it will be computed from the other two. If none of the words are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the length (Word 2) is less than or equal to 45 degrees, the horizontal flow regime map is used. When the ratio is greater than 45 degrees, the vertical flow regime map is used.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made that the pipe roughness is less than half the hydraulic diameter. See Word 1 for the area.

W9(I) Volume control flags. This word has the format <u>tlpvbfe</u>. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate

oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag. For the TURBINE component the volume control flag is limited to the format 000001e.

e-flag 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.

8.13.3 Turbine Volume Initial Conditions, CCC0200

This card is required.

W1(I) Control word. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-129 or these control words must be consistent (i.e., not specify different fluids). If cards 120-129 are not entered and all control words use the default ε = 0, then water is assumed to be the fluid. It is recommended that the user use the 120-129 cards to set the fluid type in the systems.

b-flag The digit b specifies whether boron is present. b = 0 specifies that the volume liquid does not contain boron, and b = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered after the other required thermodynamic information.

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

[P,U_f,U_g,α_g] 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 internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

[T,x_s] If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter boron in W4 if needed.

[P,x_s] If t = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter boron in W4 if needed.

[P,T] If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E\text{-}9 \leq x_s \leq 0.99999999$,

Single phase if $x_s < 1.0\ E\text{-}9$ or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality greater than 0.0 and less than or equal to 1.0, saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter boron in W5 if needed.

[T,x_s,x_n] If t = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Enter boron in W5 if needed. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[P,U_f,U_g,α_g,x_n] If $\underline{t}$ = 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 ($\underline{t}$ = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Enter boron in W7 if needed.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, 2-6 quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

8.13.4 Turbine Junction Geometry, CCCN101-N109

Two or three cards are required. Cards with N equal to 1 and/or 2 are entered, one for each junction.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). If 0, the area is set to the minimum area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.10.10). The interpretation and use of this loss coefficient vary based upon the “a” junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.10.10). See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. For the TURBINE component, the junction control flag format is limited to 0000cahs.

c-flag 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. Turn off the choking (c =1) for the second and succeeding turbines in a series of turbines. The choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume.

s = 2 uses momentum flux in the to volume, but not in the from volume. s = 3 does not use momentum flux in either the to volume or the from volume.

8.13.5 Turbine Junction Form Loss Data, CCCN112

These cards are optional. The values of N should follow the same approach as used in cards CCCN101-N109. The user-specified form loss is given in Words 4 and 5 of cards CCCN101-N109 if these cards are not entered. If these cards are entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of cards CCCN101-N109. Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

8.13.6 Turbine Junction Initial Conditions, CCCN201

These cards are required depending on the value of nj as described for cards CCCN101-N109. The values of N should follow the same approach as used in cards CCCN101-N109.

W1(R) Initial liquid or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). Enter 0.

8.13.7 Turbine Shaft Geometry, CCC0300

This card is required.

W1(R) Turbine stage shaft speed, w (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, (kg•m^2, lb_f •ft · s).

W3(R) Shaft friction coefficient, f_i (N•m•s, lb•ft•s). The frictional torque equals $f_i\omega$. This fractional 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 0, 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 0.

8.13.8 Turbine Performance Data, CCC0400

This card is required.

W1(I) Turbine type

0 = Two-row impulse stage group.

1 = General impulse-reaction stage group.

2 = Constant efficiency stage group.

3 = Gas turbine. Turbine performance data are required in cards CCC0401-450 and CCC0451-0499.

W2(R) Actual efficiency h_o 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).

8.13.9 Efficiency Data, CCC0401-0450

These cards are required only if W1 of CCC0400 is 3.

W1(R) Enter the pressure ratio. it must be larger than unity.

W2(R) Enter the efficiency.

W3(R)~W40(R) Additional pressure ratio and efficiency pairs. Up to 20 pairs can be entered.

8.13.10 Mass flow rate data, CCC0451-0499

These cards are required only if W1 of CCC0400 is 3.

W1(R) Enter the pressure ratio. it must be larger than unity.

W2(R) Enter the corrected mass flow rate.

W3(R)~W40(R) Additional pressure ratio and corrected mass flow rate pairs. Up to 20 pairs can be entered.

8.14 ECC Mixer Component, ECCMIX

An ECC mixer is indicated by ECCMIX for Word 2 on card CCC0000. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N is the face number.

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 1 is the ECC connection. Junction number 2 is the flow inlet to the ECC mixer component in normal operation. The geometrical angle between the axis of junctions 1 and 2 is input on the ECC Mixer Junction Geometry card for junction number 1. Junction number 3 is the discharge, junction in normal operation. The to part of junctions 1 and 2 must refer to the inlet end of the ECC mixer (CCC010001), and the from part of the discharge junction must refer to the outlet end of the ECC mixer (CCC010002). Note that junction 1 is not a crossflow junction. Two or more ECCMIX components may be considered in modeling some piping. These may be connected in tandem and require at least one normal volume between them.

8.14.1 ECC Mixer Component Information, CCC0001

This card is required.

W1(I) Number of junctions, nj. This number must be 3 for ECCMIX components.

W2(I) Initial condition control. This word is optional and, if missing, the junction initial velocities in the first and second words on card CCCN201 are assumed to be velocities. If 0, velocities are assumed; if nonzero, mass flows are assumed.

8.14.2 ECC Mixer X-Coordinate Volume Data, CCC0101-0109

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

W1(R) Area (m^2, ft^2).

W2(R) Length (m, ft).

W3(R) Volume (m^3, ft^3). The code requires that the volume equals the 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 0, it will be computed from the other two. If none of the words are 0, the volume must equal the x-direction area times the x-direction length within a relative error of 0.000001. The same relative error check is done for the y- and z-directions.

W4(R) Azimuthal angle (degrees). The absolute value of this angle must be $\leq$ 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 value of this angle must be less than $\pm$ 15 degrees. Any other value will be considered an input error. 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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. For ECCMIX, the ECC mixer flow regimes are used.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made that the pipe roughness is less than half the hydraulic diameter. See Word 1 for the area.

W9(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag. For the ECCMIX component, the volume control flags are limited to a format of 00p00fe.

p-flag 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.

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed along the x-coordinate direction in the volume, and f = 1 specifies that wall friction effects are not to be computed along the x-coordinate.

e-flag 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.

8.14.3 ECC Mixer Additional Wall Friction, CCC0131

This card is optional. If this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 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.

8.14.4 ECC Mixer Volume Initial Conditions, CCC0200

This card is required.

W1(I) Control word. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-129 cards (i.e., ε

= 1 specifies H_2O, $\underline{\varepsilon}$ = 2 specifies D_2O etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-129 or these control words must be consistent (i.e., not specify different fluids). If cards 120-129 are not entered and all control words use the default $\underline{\varepsilon}$ = 0, then water is assumed to be the fluid. It is recommended that the user use the 120-129 cards to set the fluid type in the systems.

b-flag The digit $\underline{b}$ specifies whether boron is present. $\underline{b}$ = 0 specifies that the volume liquid does not contain boron, and $\underline{b}$ = 1 specifies that a boron concentration in mass of boron per mass of liquid (which may be 0) is being entered after the other required thermodynamic information.

t-flag The digit $\underline{t}$ specifies how the following words are to be used to determine the initial thermodynamic state. $\underline{t}$ = 0-3 specifies one component (steam/water); $\underline{t}$ = 4-6 allows the specification of two components (steam/water and noncondensable gas).

With options $\underline{t}$ equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

$[P, U_f, U_g, \alpha_g]$ 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 the internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

$[T, x_s]$ If $\underline{t}$ = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter boron in W4 if needed.

$[P, x_s]$ If $\underline{t}$ = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter boron in W4 if needed.

[P,T] If $\underline{t}$ = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if 1.0E-9 $\leq x_s \leq$ 0.99999999,

Single phase if $x_s <$ 1.0 E-9 or $x_s >$ 0.99999999

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If t = 4, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static quality greater than 0.0 and less than or equal to 1.0, saturated noncondensables will result. Also, the temperature is restricted to be less than the saturation temperature at the input pressure. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter boron in W5 if needed.

[T,x_s,x_n] If t = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Enter boron in W5 if needed. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[P,U_f,U_g,α_g,x_n] 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Enter boron in W7 if needed.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, 2-6 quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

8.14.5 ECC Mixer Junction Geometry, CCCN101-N109

These cards are required. Cards with N equal to 1, 2, and 3 are entered, one for each junction. For the first junction, the ECC injection connection, enter 7 words, and for junctions 2 and 3, enter 6 words.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). If 0, the area is set to the minimum area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining areas. For smooth area changes, there are no restrictions.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.10.10). The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.10.10). See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. For the ECCMIX component, the format is restricted to 0000cah0.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

W7(R) Angle (degrees) 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. Enter W7 only for the first junction.

8.14.6 ECC Mixer Junction Form Loss Data, CCCN112

These cards are optional. The values of N should follow the same approach as used in cards CCCN101-N109. The user-specified form loss is given in Words 4 and 5 of cards CCCN101-N109 if these cards are not entered. If these cards are entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of cards CCCN101-N109. Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

8.14.7 ECC Mixer Junction Initial Conditions, CCCN201

Three cards are required. The values of N should be 1, 2, and 3.

W1(R) Initial liquid or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W2(R) Initial vapor velocity or mass flow (velocity in m/s, ft/s or mass flow in kg/s, lb/s).

W3(R) Interface velocity (m/s, ft/s). Enter 0.

8.15 Valve Component, VALVE

A valve junction component is indicated by VALVE for Word 2 on card CCC0000. For major edits, minor edits, and plot variables, the junction in the valve junction component is numbered CCC000000.

8.15.1 Valve Junction Geometry, CCC0101-0109

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. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). 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 0, 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 0, it will default to the area calculated from the inlet diameter term input on cards CCC0301-0309, in which case the inlet diameter term cannot be input as 0. 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 10^{-5} m^2. However, if this area is input as nonzero and the inlet diameter is input as 0, 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 areas.

W4(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.15.3). The interpretation and use of this loss coefficient vary based upon the “a” junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.15.3). See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. It is not necessary to input leading zeros. For the VALVE component, the junction control flag is limited to the format 0efvcahs

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag 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.

v-flag The digit v specifies horizontal stratification entrainment/pullthrough options. This model is for junctions connected to a horizontal volume. v = 0 means the model is not applied; v = 1 means an upward-oriented junction (offtake volume must be vertical); v = 2 means a downward-oriented junction (offtake volume must be vertical); and v = 3 means a centrally (side) located junction.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag — The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied. All options 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 one of the abrupt area change options (a = 1 or 2) must be input. All options may be input for check valves, but if a nonzero leak ratio is entered, then one of the abrupt area change options (a = 1 or 2) must be input. All options may be input for a trip valve. For inertial and relief valves, one of the abrupt area change options (a = 1 or 2) must be input.

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

s-flag — The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to volume and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume, but not in the from volume. s = 3 does not use momentum flux in either the to or the from volume.

W7(R) — The meaning of this word is different, depending on the critical flow model which has been selected (see W6).

If the Henry-Fauske critical flow model is active, the discharge coefficient is entered. If W7 and W8 are missing, W7 is set to 1.0 and W8 is set to 0.14.

If the original RELAP5 critical flow model is active, the subcooled discharge coefficient is entered. This entry applies only to subcooled liquid choked flow calculations. The entry must be > 0.0 and < 2.0. If W7, W8 and W9 are missing, they are each set to 1.0.

W8(R) — The meaning of this word is different, depending on the critical flow model which has been selected (see W6).

If the Henry-Fauske critical flow model is active, the thermal nonequilibrium constant is entered. If W7 is entered and W8 is missing, W8 is set to 0.14. If the entry is < 0.01, the equilibrium option is used and the entry is reset to 0.0. If the entry is >1000.0, the frozen option is used and the entry is reset to 100.0.

If the original RELAP5 critical flow model is active, the two-phase discharge coefficient is entered. This entry applies only to two-phase choked flow calculations. The entry must be > 0.0 and < 2.0. If W7 is entered and W8 and W9 are missing, W8 and W9 are each set to 1.0.

W9(R) If the original RELAP5 critical flow model is active, the superheated discharge coefficient is entered. This entry applies only to superheated vapor choked flow calculations. The entry must be > 0.0 and < 2.0. If W7 and W8 are entered and W9 is missing, then W9 is set to 1.0. If the Henry-Fauske critical flow model is active, this word is not used and should not be entered.

8.15.2 Valve Junction Diameter and CCFL Data, CCC0110

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify the junction hydraulic diameter for the interphase drag calculation (i.e., f = 0 in Word 6 of cards CCC0101-0109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If this card is being used for the CCFL model (i.e., f = 1 in Word 6 of cards CCC0101-0109), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

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 $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 3 of cards CCC0101-0109 for the area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1, the Kutateladze CCFL form is used. If between 0.0 and 1.0, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 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.

8.15.3 Valve Junction Form Loss Data, CCC0111

This card is optional. The user-specified form loss is given in Words 4 and 5 of cards CCC0101-0109 if card CCC0111 is not entered. If card CCC0111 is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of cards CCC0101-0109. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

8.15.4 Valve Junction Initial Conditions, CCC0201

This card is required for valve junction components.

W1(I) Control word. If 0, the next two words are velocities; if 1, 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 0.

8.15.5 Valve Type, CCC0300

This card is required to specify the valve type.

W1(A) Valve type. This word must contain one of the variables from the following table.

Table 8.15-1 Valve Types

Valve Name	Type of Valve
CHKVLV	Check valve
TRPVLV	Trip valve
INRVLV	Inertial swing check valve
MTRVLV	Motor valve
SRVVLV	Servo valve,
RLFVLV	Relief valve

8.15.6 Check Valve Data and Initial Conditions, CCC0301-0399

These cards are required for a check valve. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The check valve 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). It is recommended that 0 be used for most calculations, as it is more stable (i.e., less noisy and less oscillations) than +1 or -1.

W2(I) Check valve initial position. The valve is initially open if 0, closed if 1.

W3(R) Closing back pressure (Pa, lb_f/in^2). Additive closing ΔP to model spring-loaded valves.

W4(R) Leak ratio. This defines the flow area for leakage when the valve is nominally closed. If omitted or input as 0, then any of the area change models (a = 0, 1 or 2) may be specified for the check valve. If input as nonzero, then one of the abrupt area change models (a = 1 or 2) must be specified for the check valve. The leak ratio is specified as the fraction of the "junction area" through which leakage occurs. Because nonzero leak ratios require use of an abrupt area change model, the "junction area" is taken to mean the minimum of the flow areas in the two hydrodynamic volumes connected by the valve.

8.15.7 Trip Valve Data and Initial Conditions, CCC0301-0399

These cards are required for a trip valve. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The trip valve 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) 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.

8.15.8 Inertial Valve Data and Initial Conditions, CCC0301-0399

These cards are required for an inertial valve. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The inertial value 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 0. When W1 = 1, the valve either opens or closes only once if the initial angle is between the maximum and minimum. If the flapper starts at either the maximum or minimum angle it will not move. When W1 = 2, the flapper will latch only at the maximum position. If it starts at the maximum, it will not move.

W2(I) Valve initial condition. The valve is initially open if 0, initially closed if 1.

W3(R) Cracking pressure (Pa, lb_f/in^2).

W4(R) Leakage fraction. Fraction of the “junction area” for leakage when the valve is nominally closed. Because an abrupt area change option must be used, the “junction area” is the minimum of the flow areas in the two hydrodynamic volumes connected by the valve.

W5(R) Initial flapper angle (degrees). The flapper angle must be within the minimum and maximum angles specified in Words 6 and 7.

W6(R) Minimum flapper angle (degrees). This must be greater than or equal to 0.

W7(R) Maximum flapper angle (degrees).

W8(R) Moment of inertia of valve flapper ($kg\bullet m^2$, $lb\bullet ft^2$).

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).

8.15.9 Relief Valve Data and Initial Conditions, CCC0301-0399

These cards are required for a relief valve. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The relief valve area varies, considering the hydrodynamic forces and the valve mass, momentum, and acceleration. One of the abrupt area change models (a =1 or 2) must be specified. The junction area input by cards CCC0101-0199 is the valve inlet area.

W1(I) Valve initial condition. The valve is initially closed if 0, open if 1.

W2(R) Inlet diameter (m, ft). This is the inside diameter of the valve inlet. If this term is input as 0, it will default to the diameter calculated from the junction area input on cards CCC0101-0109. 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 10^{-5} m^2. If the junction area is input as 0, 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 0, 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 0, it will default to the valve seat diameter; in which case W7, following, must be input as 0. 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, is allowed. Also refer to the warning stated for W9.

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 0 value is required if W6 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.

W8(R) Minimum inside diameter of the outer adjustment ring (m, ft). If this input is 0, it will default to the valve piston diameter, in which case W9 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 is allowed only if this diameter is greater than the valve piston diameter. Also refer to the warning stated for W9.

W9(R) Height of inside bottom edge relative to the valve seat for outer adjustment ring (m, ft). This may be input as positive, 0, or negative. If this input is negative, then W8 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, W7, and W8 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 0, 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 0.

W16(R) Initial stem position. This is the fraction of total lift and is required if W1 is input as 1. Total lift is input as W5.

W17(R) Initial valve piston velocity (m/s, ft/s). This must be 0 or omitted if W1 is input as 0

8.15.10 Motor Valve Data and Initial Conditions, CCC0301-0399

These cards are required for a motor valve. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The motor valve 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=0), a table of flow coefficients must also be input as described in cards CCC0400-0499, CSUBV Table Section 8.15.12. If an abrupt area change model is selected (a = 1 or 2), 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 opening (or closing) 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. If Word 6 is entered, this quantity is the rate of change of the normalized valve area as the valve opens only. This word must be greater than 0.

W4(R) Initial position. This number is the initial normalized valve area or the initial normalized stem position depending on Word W5. This quantity must be between 0.0 and 1.0.

W5(I) Valve table number. If this word is omitted or input as 0, 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.

W6(R) Valve closing change rate (s^{-1}). This word is optional and if it is not entered, the valve closing change rate is the same as the valve opening change rate.

Input for general tables is discussed in cards 202TTTNN, General Table Data, Section 12. For this case, the normalized stem position is input as the *argument value* and the normalized valve area is input as the *function value*.

8.15.11 Servo Valve Data and Initial Conditions, CCC0301-0399

These cards are required for a servo valve. The following words may be placed on one or more cards, and the card numbers need not be consecutive. The servo valve 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 14. 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.

8.15.12 Motor or Servo Valve CSUBV Table Factors, CCC0400

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 cards (cards CCC0101-0109). If the smooth area change model is specified, a CSUBV table must be input.

This card is optional for a motor or servo valve. 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 (See Section 8.15.10 for motor valve and Section 8.15.11 for servo valve).

W2(R) Flow coefficient factor.

8.15.13 Motor or Servo Valve CSUBV Table Entries, CCC0401-0499

These cards are required if the motor or servo valve requests a CSUBV table as part of its input. The CSUBV table contains forward and reverse flow coefficients as a function of normalized flow area or normalized stem position. These cards are required for a motor or servo valve.

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 0. If the valve is fully open, the normalized term is 1.0. Any value may be input that is between 0.0 and 1.0. The forward and reverse flow coefficients are W2 and W3, respectively. The code internally converts flow coefficients to energy loss coefficients by the formula $K = 2 \bullet A_j^2 / (\rho \bullet CSUBV^2)$, where ρ is a reference density of 991.091 kg/m^3 (62.3706 lb$_m$/ft^3), 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 (See Section 8.15.10 for motor valve and Section 8.15.11 for servo valve).

W2(R) Forward CSUBV $\{(gal/min)/[(lb_f/in^2)^{0.5}]\}$. The CSUBV is input in British units only and is converted automatically by the code to SI units [(m$^{7/}$kg)$^{0.5}$] using a multiplier of 7.598055E-7 as the conversion factor.

W3(R) Reverse CSUBV $\{(gal/min)/[(lb_f/in^2)^{0.5}]\}$.

The user is cautioned that when CSUBV = 0.0, the valve acts like a check valve and no flow occurs through the valve even if the normalized stem position is 1.0 or open.

8.16 Pump Component, PUMP

A pump component is indicated by PUMP for Word 2 on card CCC0000. A pump consists of one volume and two junctions, one attached to each end of the volume. For major edits, minor edits, and plot variables, the volume in the pump component is numbered as CCC010000. The pump junctions are numbered CCC010000 for the inlet junction and CCC020000 for the outlet junction.

8.16.1 Pump Volume Geometry, CCC0101-0107

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) Area (m^2, ft^2).

W2(R) Length (m, ft).

W3(R) Volume (m^3, ft^3). The program requires that the volume equals the 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 0, it will be computed from the other two. If none of the words are 0, 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 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 length. If the vertical angle orientation is 0, this quantity must be 0. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. For this component, this Word 6 is not compared to the length (Word 2) to decide if the horizontal or vertical flow regime is used. Rather, the pump flow regime map is used.

W7(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag. The pump component forces all volume flags except for the e digit, and y- and z-coordinate flags are not read. The effective format is 000000e.

e-flag The equilibrium 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.

8.16.2 Pump Inlet Junction, CCC0108

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. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, only the number N equal to 1 or 2 is allowed.

W2(R) Area (m^2, ft^2). If 0, the area is set to the minimum area 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.16.6). The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected in W5. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W2. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W4(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.16.6). See information for the previous word regarding interpretation and use of this loss coefficient.

W5(I) Junction control flags. This word has the format jefvcahs. It is not necessary to input leading zeros. For the PUMP inlet junction, the junction control flag is restricted to the format 00f0cah0.

f-flag 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.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

Unlike junctions for certain other hydrodynamic components, only the default values of discharge coefficients and factors used in the critical flow models are allowed for junctions in the PUMP component. Problem renodalization should be used to circumvent this limitation should it prove to be significant.

For the Henry-Fauske critical flow model, the default value for the discharge coefficient is 1.0 and the default value for the thermal nonequilibrium constant is 0.14. For the original RELAP5 critical flow model, the default values for the subcooled, two-phase and superheated discharge coefficients each are 1.0.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

8.16.3 Pump Outlet Junction, CCC0109

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.

This card is required for a pump component.

W1(I) Volume code of connecting volume on outlet side. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

W2(R) Area (m^2, ft^2). If 0, the area is set to the minimum area 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.16.6). The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected in W5. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W2. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W4(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.16.6). See information for the previous word regarding interpretation and use of this loss coefficient.

W5(I) Junction control flags. This word has the format jefvcahs. It is not necessary to input leading zeros. For the PUMP outlet junction, the junction control flag is restricted to the format 00f0cah0.

f-flag 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.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

Unlike junctions for certain other hydrodynamic components, only the default values of discharge coefficients and factors used in the critical flow models are allowed for junctions in the PUMP component. Problem renodalization should be used to circumvent this limitation should it prove to be significant.

For the Henry-Fauske critical flow model, the default value for the discharge coefficient is 1.0 and the default value for the thermal nonequilibrium constant is 0.14. For the original RELAP5 critical flow model, the default values for the subcooled, two-phase and superheated discharge coefficients each are 1.0.

a-flag The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

8.16.4 Pump Inlet Junction Diameter and CCFL Data, CCC0110

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to specify only the junction hydraulic diameter for the interphase drag calculation (i.e., f = 0 in Word 5 of card CCC0108), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If the card is being used for the CCFL model (i.e., f = 1 in Word 5 of card CCC0108), then enter all four words for the appropriate CCFL model if values different from the default values are desired.

W1(R) Inlet 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 $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 2 of card CCC0108 for the junction area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1.0, the Kutateladze CCFL form is used. If between 0.0 and 1.0, 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.

8.16.5 Pump Outlet Junction Diameter and CCFL Data, CCC0111

This card is optional. The defaults indicated for each word are used if the card is not entered. If this card is being used to just specify the junction hydraulic diameter for the interphase drag calculation (i.e., f = 0 in Word 5 of card CCC0109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If the card is being used for the CCFL model (i.e., f = 1 in Word 5 of card CCC0109), then enter all four words for the appropriate CCFL model if values different from the default values are desired. The format for this card is identical to card CCC0110 except that data are for the outlet junction.

W1(R) Outlet 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. This number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 2 of card CCC0108 for the junction area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1.0, the Kutateladze CCFL form is used. If between 0.0 and 1.0, 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.

8.16.6 Pump Inlet Junction Form Loss Data, CCC0112

This card is optional. The user-specified form loss is given in Words 3 and 4 of card CCC0108 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 3 and 4 of card CCC0108. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

8.16.7 Pump Outlet Junction Form Loss Data, CCC0113

This card is optional. The user-specified form loss is given in Words 3 and 4 of card CCC0109 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 3 and 4 of card CCC0109. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all four words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R. The format of this card is identical to card CCC0112 except data are for the outlet junction.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

8.16.8 Pump Volume Initial Conditions, CCC0200

This card is required for a pump component.

W1(I) Control word. This word has the format εbt. It is not necessary to input leading zeros.

e-flag The digit ε specifies the fluid, where ε = 0 is the default fluid. The value for ε > 0 corresponds to the position number of the fluid type indicated on the 120-129 cards (i.e., ε = 1 specifies H_2O, ε = 2 specifies D_2O, etc.). The default fluid is that set for the hydrodynamic system by cards 120-129 or this control word in another volume in this hydrodynamic system. The fluid type set on cards 120-129 or these control words must be consistent (i.e., not specify different fluids). If cards 120-129 are not entered and all control words use the default ε = 0, then H_2o is assumed to be the fluid. It is recommended that the user use the 120-129 cards to set the fluid type in the systems.

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

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

With options t equal to 4-6, names of the components of the noncondensable gas must be entered on card 110, and mass fractions of the noncondensable gas components are entered on card 115.

One Component (Steam/Water), Equilibrium or Non-equilibrium

[P,U_f,U_g,α_g] 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 the internal energies used to define the thermodynamic state. Enter boron in W6 if needed.

One Component (Steam/Water), Equilibrium

[T,x_s] If $\underline{t}$ = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter boron in W4 if needed.

[P,x_s] If $\underline{t}$ = 2, the next two words are interpreted as pressure (Pa, lb_f/in^2) and static quality in equilibrium condition. Enter boron in W4 if needed.

[P,T] If $\underline{t}$ = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition. Enter boron in W4 if needed.

Two Components (Steam/Water/Air), Non-equilibrium

The following options are used for input of non-equilibrium two-phase and/or noncondensable states. In all cases, the criteria used for determining the range of values for static quality (x_s) are

Two-phase if $1.0E\text{-}9 \leq x_s \leq 0.99999999$,

Single phase if $x_s < 1.0\ E\text{-}9$ or $x_s > 0.99999999$

The static quality is given by $x_s = M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

[P,T,x_s] If $\underline{t}$ = 4, the next three words are interpreted as pressure (Pa, $lb_f/in.^2$), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensables (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter boron in W5 if needed.

[T,x_s,x_n] If $\underline{t}$ = 5, the next three words are interpreted as steam saturation temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Enter boron in W5 if needed. Both the static and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. The liquid will be subcooled. The input temperature determines the steam partial pressure, and the total pressure may be greater than the critical pressure, which will cause an input processing error. Little experience has been obtained using this option, and it has not been checked out.

[P,U_f,U_g,α_g,x_n] If $\underline{t}$ = 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. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 ($\underline{t}$ = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Enter boron in W7 if needed.

W2-W7(R) Quantities as described under word 1. Depending on the control word, 2-6 quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

8.16.9 Pump Inlet Junction Initial Conditions, CCC0201

This card is required for a pump component.

W1(I) Control word. If 0, the next two words are velocities; if 1, 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 0.

8.16.10 Pump Outlet Junction Initial Conditions, CCC0202

This card is required for a pump component. This card is similar to card CCC0201 except that data are for the outlet junction.

W1(I) Control word. If 0, the next two words are velocities; if 1, 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 0.

8.16.11 Pump Index and Option, CCC0301

This card is required for a pump component.

W1(I) Pump table data indicator. If 0, 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. If -3, use built-in data for the Wolsong pump.

W2(I) Two-phase index. Enter -1 if the two-phase option is not to be used. Enter 0 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 0 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.

W4(I) Pump motor torque table index. If -1, no table is used. If 0, 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 0, 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 0. If the pump trip number is 0, no trip is tested and the pump trip is assumed to always be off.

W7(I) Reverse indicator. If 0, no reverse is allowed; if 1, reverse is allowed.

8.16.12 Pump Description, CCC0302-0304

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 (N·m, lb_f-ft).

W6(R) Moment of inertia (kg·m^2, lb·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 0, initial density is used. This is the density used to generate homologous data.

W8(R) Rated pump motor torque (N·m, lb_f-ft). If this word is 0, 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 (N·m, lb_f·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 (N·m, lb_f·ft). This is constant frictional torque.

W11(R) TF1, friction torque coefficient (N·m, lb_f·ft). This multiplies the speed ratio to the first power.

W12(R) TF3, friction torque coefficient. (N·m, lb_f·ft). This multiplies the speed ratio to the third power.

8.16.13 Pump Variable Inertia, CCC0308

This card is optional, and if this card is not entered, the pump inertia is given by Word 6 of card CCC0302 . If this card is entered, pump inertia is computed from

$$I = I_3S^3 + I_2S^2 + I_1S^1 + I_0$$

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 (kg/m ^{2}, lb·ft ^{2}).

8.16.14 Pump-Shaft Connection, CCC0309

This card is optional, and 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 0, 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.

8.16.15 Pump Stop Data, CCC0310

If this card is optional, and if this card is not entered, 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.

8.16.16 Pump Single-Phase Homologous Curves, CCCXX00-XX99

These cards are required only if W1 of card CCC0301 is 0. There are sixteen 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 sixteen curves is not necessary, but an error will occur from an attempt to reference one that has not been entered.

card numbering is CCC1100-1199 for the first curve, CCC1200-1299 for the second curve, and CCC2600-2699 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 1 for a head curve; enter 2 for a torque curve.

W2(I) Curve regime. 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/a for W2(I) = 1, 3, 5, or 7 and a/v for W2(I) = 2, 4, 6, or 8. If the tabular data does 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/a^2 or b/a^2 for W2(I) = 1, 3, 5, or 7 and h/v^2 or b/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.

8.16.17 Pump Two-Phase Multiplier Tables, CCCXX00-XX99

These cards are required only if W2 of card CCC0301 is 0; 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 0.

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.

8.16.18 Pump Two-Phase Difference Tables, CCCXX00-XX99

These cards are required only if W3 of card CCC0301 is 0. The two-phase difference tables are homologous curves entered in a similar manner to the single-phase homologous data. Card numbering is CCC4100-4199 for the first curve, CCC4200-4299 for the second curve, … CCC5600-5699 for the sixteenth 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.

8.16.19 Relative Pump Motor Torque Data, CCC6001-6099

These cards are required only if W4 of card CCC0301 is 0. 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 0.

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.

8.16.20 Time-Dependent Pump Velocity Control, CCC6100

This card is required only if W5 of card CCC0301 is 0. 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 0, the pump velocity is always computed from this table. If the trip number is nonzero, the trip determines which table is to be used. If the trip is off, the pump velocity is set from the trip, the pump motor torque data, and the torque-inertia equation as if this table had not been entered. If the trip is on, the pump velocity is computed from this table. If Word 2 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 0 if missing.

8.16.21 Time-Dependent Pump Velocity, CCC6101-6199

These cards are required only if W5 of card CCC0301 is 0.

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.

8.17 Multiple Junction Component, MTPLJUN

A multiple junction component is indicated by MTPLJUN for Word 2 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. For major edits, minor edits, and plot variables, the junctions in the multiple junction component are numbered CCCJJNN00, where NN is the set number and JJ is the junction number within the set. The quantity NN may be 01-99; JJ is 01 for the first junction described in a set and incremented by 1 for each additional junction ($01 \leq JJ \leq 99$).

8.17.1 Multiple Junction Information, CCC0001

This card is required.

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 0. If 0 is entered, the initial conditions on cards CCC1NNM are velocities; if 1 is entered, the initial conditions are mass flows.

8.17.2 Multiple Junction Geometry, CCC0NNM

These cards are required. 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 CCCJJNN00, where JJ is 01 for the first junction described in a set and increments by 1 for each additional junction. The quantity NN may be 01-99, and M may be 1-9. 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. The connection code is CCCVV000N, where CCC is the component number, VV is the volume number, and N indicates the face number. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

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) Area (m^2, ft^2). If 0, the area is set to the minimum area of the adjoining volumes. For abrupt area changes, the 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) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. A variable loss coefficient may be specified (see Section 8.17.5). The interpretation and use of this loss coefficient vary based upon the "a" junction control flag selected in W6. If the smooth area change option is selected (a = 0), the entry here is the loss coefficient appropriate for the junction flow area resulting from the entry made in W3. If one of the abrupt area change options is selected (a = 1 or 2), the entry here is the loss coefficient appropriate for the minimum flow area between the two hydrodynamic volumes connected by this junction. If the a = 1 option is selected, a loss coefficient entered here is considered to be additive with the abrupt area change flow energy loss coefficient, which is calculated separately by the code.

W5(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. A variable loss coefficient may be specified (see Section 8.17.5). See information for the previous word regarding interpretation and use of this loss coefficient.

W6(I) Junction control flags. This word has the format jefvcahs. It is not necessary to input leading zeros. For the multiple junction, the junction control flag is limited to the format 0ef0cahs.

e-flag The digit e specifies the modified PV term in the energy equations. e = 0 means that the modified PV term will not be applied, and e = 1 means that it will be applied.

f-flag
: 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.

c-flag
: 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active.

a-flag
: The digit a specifies area change options. a = 0 means a smooth area change and only the user supplied K_{loss} is applied. a = 1 means full abrupt area change model and the code calculates forward and reverse contraction/expansion K_{loss} terms and adds them to the user supplied K_{loss} terms. In addition, the code includes extra interphase drag to account for the vena contracta. a = 2 means a partial abrupt area change model and it is the same as ¨a = 1 except no code calculated forward and reverse contraction/expansion K_{loss} is applied.

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

s-flag
: The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to and from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume, but not in the from volume. s = 3 does not use momentum flux in either the to volume or the from volume.

W7(R)
: The meaning of this word is different, depending on the critical flow model which has been selected (see W6).

  If the Henry-Fauske critical flow model is active, the discharge coefficient is entered. The recommended default value for this coefficient is 1.0.

  If the original RELAP5 critical flow model is active, the subcooled discharge coefficient is entered. This entry applies only to subcooled liquid choked flow calculations. The entry must be > 0.0 and < 2.0. The recommended default value for this coefficient is 1.0.

W8(R)
: The meaning of this word is different, depending on the critical flow model which has been selected (see W6).

  If the Henry-Fauske critical flow model is active, the thermal nonequilibrium constant is entered. The recommended default value for this coefficient is 0.14. If the entry is < 0.01, the equilibrium option is used and the entry is reset to 0.0. If the entry is >1000.0, the frozen option is used and the entry is reset to 100.0.

If the original RELAP5 critical flow model is active, the two-phase discharge coefficient is entered. This entry applies only to two-phase choked flow calculations. The entry must be > 0.0 and < 2.0. The recommended default value for this coefficient is 1.0.

W9(R) The meaning of this word is different, depending on the critical flow model which has been selected (see W6).

If the Henry-Fauske critical flow model is active, enter 0.0 (this word is not used).

If the original RELAP5 critical flow model is active, the superheated discharge coefficient is entered. This entry applies only to superheated vapor choked flow calculations. The entry must be > 0.0 and < 2.0. The recommended default value for this coefficient is 1.0.

W10(I) From 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 10 and 11. The increments may be positive, negative, or 0. Junctions are defined up to the limit in Word 13. Words 3-9 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 13 for the second and following sets must be greater than Word 13 of the preceding set, and Word 13 of the last set must equal nj. A new set is used whenever a new increment is needed, Words 3-9 need to be changed, or a change in junction numbering is desired.

W11(I) To volume increment. See description for Word 10.

W12(I) Enter 0. This is reserved for future capability.

W13(I) Junction limit. Described above.

8.17.3 Multiple Junction Initial Condition, CCC1NNM

These cards are required. Initial velocities are entered using one or more sets of data. The processing of sets of data is identical to that described in Section 8.17.2 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) 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.

8.17.4 Multiple Junction Diameter and CCFL Data, CCC2NNM

These cards are optional. The defaults indicated for each word are used if the card is not entered. If the card is being used to specify only the junction hydraulic diameter for the interphase drag calculation (i.e., $\underline{f}$ = 0 in Word 6 of cards CCC0NNM), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2-4 (will not be used). If this card is being used for the CCFL model (i.e., $\underline{f}$ = 1 in Word 6 of cards CCC0NNM), then enter all four words for the appropriate CCFL model if values different from the default values are desired. The processing of sets of data is identical to that described in Section 8.17.2 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 $\geq$ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$. If a 0 is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. See Word 3 of card CCC0NNM for area.

W2(R) Flooding correlation form, β. If 0, the Wallis CCFL form is used. If 1.0, the Kutateladze CCFL form is used. If between 0.0 and 1.0, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 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.

W5(I) Junction limit number.

8.17.5 Multiple Junction Form Loss Data, CCC3NNM

These cards are optional. The user-specified form loss is given in Words 4 and 5 of card CCC0NNM if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficient. A_F and A_R are the Words 4 and 5 of card CCC0NNM. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all five words for the appropriate expression. See the discussion regarding the flow area basis assumed for A_F and A_R; the same information applies for B_F and B_R.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

W5(I) Junction limit number.

8.18 Accumulator Component, ACCUM

An accumulator component is indicated by ACCUM for Word 2 on card CCC0000. For major edits, minor edits, and plot variables, the volume in the accumulator component is numbered CCC010000, and the junction in the accumulator component is numbered CCC010000.

An accumulator is a lumped parameter component treated by special numerical techniques that model both the tank and surgeline 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. The junction initial conditions may not be input i.e., initial liquid and gas velocities are set to 0 in the code. The noncondensable gas in the accumulator is nitrogen and that the gas and liquid are initially in equilibrium. No other junctions should be connected to the accumulator volume. The geometry of the tank may be cylindrical or spherical. The standpipe/surge line inlet refers to the end of the pipe inside the tank itself.

8.18.1 Accumulator Volume Geometry, CCC0101-0109

This card is required.

W1(R) Area (m^2, ft^2). This is the flow area of a cylindrical tank, or the maximum flow area of a spherical tank. In the case of a spherical tank, the flow area and the tank radius are related by the formula $A = \pi R^2$.

W2(R) Length (m, ft). This is the length of the tank above the standpipe/surgeline inlet, where this inlet refers to the end of the pipe inside the tank itself.

W3(R) Volume (m^3, ft^3). This is the volume of the tank above the standpipe/surgeline inlet, where this inlet refers to the end of the pipe inside the tank itself. The code requires that the volume, area, and length are consistent. For a cylindrical tank, $W3 = W1 \bullet W2$, and at least two of the three quantities, W1, W2 or W3, must be nonzero. If one of the quantities is 0, it will be computed from the other two. For a spherical tank, W1 and W2 must be nonzero. If W3 is 0, it will be computed from the other two. If none of the words are 0, they must satisfy the consistency condition within a relative error $\pm$ 0.000001.

W4(R) Azimuthal angle (degrees). The absolute value of this angle must be $\leq$ 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/surgeline inlet (where this inlet refers to the end of the pipe inside the tank itself) 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/surgeline inlet (where this inlet refers to the end of the pipe inside the tank itself) 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 length, and have the same sign as the angle for vertical orientation. As with other components, this Word 6 is compared to the length (Word 2) to decide if the horizontal or vertical flow regime map is used. This is not important for this component, since the correlations that depend on the flow regime map are not needed for this component. The volume conditions are determined from the accumulator's special model.

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{area}}{\text{wetted perimeter}}\right)$.

If 0, the hydraulic diameter of the tank is computed from $2.0 \bullet \left(\frac{\text{area}}{\pi}\right)^{0.5}$. A check is made that the pipe roughness is less than half the hydraulic diameter of the tank. See Word 1 for the area.

W9(I) Volume control flags. This word has the format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scalar oriented and coordinate direction oriented flags. Only one value for a scalar oriented flag is entered per volume but up to three coordinate oriented flags can be entered for a volume, one for each coordinate direction. At present, the f flag is the only coordinate direction oriented flag. This word enters the scalar oriented flags and the x-coordinate flag. The accumulator component forces all volume flags except for the x-coordinate f digit, and y- and z-coordinate flags are not read. For the accumulator volume control flag, the format is restricted to 00110f0.

f-flag The digit f specifies whether wall friction is to be computed. f = 0 specifies the wall friction effects are to be computed along the x-coordinate; and f = 1 specifies the friction effects are not to be computed along the x-coordinate.

W10(I) Geometry flag (optional). To specify a cylindrical tank, set the flag equal to 0 (default). To specify a spherical tank, set the flag equal to 1. To specify a cylindrical tank with fluidic device, set the flag equal to 2.

8.18.2 Accumulator Additional Laminar Wall Friction, CCC0131

This card is optional. and if this card is not entered, the default values are 1.0 for the laminar shape factor and 0.0 for the viscosity ratio exponent.

W1(R) Shape factor for x-coordinate.

W2(R) Viscosity ratio exponent for x-coordinate.

8.18.3 Accumulator Alternate Wall Friction Data, CCC0141

This card is optional. The input on this card, which does no distinguish between forward and reverse loss coefficients, has been superseded by the CCC1101-1102 cards. If this card is entered, the form loss coefficient is calculated from

$$K = A + B Re^{-C}$$

where K is the form loss coefficients. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all three words.

W1(R) A (≥ 0). This quantity must be greater than or equal to 0.

W2(R) B (≥ 0). This quantity must be greater than or equal to 0.

W3(R) C (≥ 0). This quantity must be greater than or equal to 0.

8.18.4 Accumulator Tank Initial Thermodynamics Conditions, CCC0200

This card is required.

W1(R) Pressure (Pa, lb_f/in^2).

W2(R) Temperature (K, ^oF).

W3(R) Boron concentration (mass of boron per mass of liquid). This word is optional.

8.18.5 Accumulator Junction Geometry, CCC1101

This card is required.

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. 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. The number N equal to 1 and 2 specifies the inlet and outlet faces respectively for the volume's coordinate direction. The number N equal to 3-6 specifies crossflow. The number 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. For connecting to a time-dependent volume, N is restricted to 1 or 2.

W2(R) Area (m^2, ft). This is the average area of the surgeline and standpipe.

W3(R) Reynolds number independent forward flow energy loss coefficient, A_F. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is positive or 0. Because the smooth area change model (control flag a = 0, see W5) must be used for the junction in the ACCUM component, the loss coefficient entered here should be consistent with the junction flow area entered in W2.

W4(R) Reynolds number independent reverse flow energy loss coefficient, A_R. This quantity will be used in each of the phasic momentum equations when the junction velocity of that phase is negative. See information for the previous word regarding interpretation and use of this loss coefficient.

W5(I) Junction control flags. This word has the format jefvcahs. It is not necessary to input leading zeros. For the accumulator, the junction control flag is restricted to the format 0000c0hs.

The accumulator model automatically disables the following flags 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 flags are then enabled and used as defined.

c-flag 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 choking model used is based on input on card 1. If card 1 is missing or it does not contain Option 50, the Henry-Fauske critical flow model is active. If card 1 is present and it contains Option 50, the original RELAP5 critical flow model is active. Unlike junctions for certain other hydrodynamic components, only the default values of discharge coefficients and factors used in the critical flow models are allowed for the junction in the ACCUM component. Problem renodalization should be used to circumvent this limitation should it prove to be significant. For the original RELAP5 critical flow model, the default values for the subcooled, two-phase and superheated discharge coefficients each are 1.0. For the Henry-Fauske critical flow model, the default value for the discharge coefficient is 1.0 and the default value for the thermal nonequilibrium constant is 0.14.

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

s-flag The digit s specifies momentum flux options. s = 0 uses momentum flux in both the to volume and the from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 or 3 is not allowed for an accumulator.

8.18.6 Accumulator Junction Form Loss Data, CCC1102

This card is optional. The user-specified form loss is given in Words 3 and 4 of card CCC1101 if this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_F = A_F + B_F Re^{-C_F}$$

$$K_R = A_R + B_R Re^{-C_R}$$

where K_F and K_R are the forward and reverse form loss coefficients. A_F and A_R are the Words 3 and 4 of card CCC1101. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculation, then enter all four words for the appropriate expression.

W1(R) B_F (≥ 0). This quantity must be greater than or equal to 0.

W2(R) C_F (≥ 0). This quantity must be greater than or equal to 0.

W3(R) B_R (≥ 0). This quantity must be greater than or equal to 0.

W4(R) C_R (≥ 0). This quantity must be greater than or equal to 0.

8.18.7 Accumulator Miscellaneous Parameters, CCC2200

This card is required.

W1(R) Liquid volume in tank (m^3, ft^3). This is the volume of water contained in the tank above the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank).

W2(R) Liquid level in tank (m, ft). This is the liquid level of water contained in the tank above the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank) entrance. For a cylindrical tank, either W1 or W2 must be specified as nonzero. For a spherical tank, W2 must be specified as nonzero. If one of the words is 0, it is computed from the other two.

W3(R) Length of surgeline and standpipe (m, ft). If input as 0, then the surgeline and standpipe are not modeled.

W4(R) Elevation drop of surgeline and standpipe (m, ft). This is the elevation drop from the standpipe/surgeline inlet (where this inlet refers to the end of the pipe inside the tank) 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 0.

W6(I) Heat transfer flag. If 0, heat transfer will be calculated. If 1, no heat transfer will be calculated.

W7(R) Tank density (kg/m^3, lb/ft^3). If 0, the density will default to that for carbon steel.

W8(R) Tank volumetric heat capacity (J/kg•K, Btu/lb•^{o}F). If 0, the heat capacity will default to that for carbon steel.

W9(I) Trip number. If 0 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.

8.18.8 Fluidic Device Geometry, CCC2201

This cars is required if the geometry flag(W10) of accumulator geometry card CCC0101-0109 is set to 2 (cylindrical tank with fluidic device).

W1(R) Length of the stand pipe of fluidic device (m, ft). This value shlould be less than the length of tank.

W2(R) Reynolds number independent forward energy loss coefficient due to vortex motion. This quantity will be added to junction loss coefficient.

W3(R) Reynolds number independent reverse energy loss coefficient due to vortex motion. This quantity will be added to junction loss coefficient.

8.19 Sub-Domain Boundary Volume (SDBVOL) Component

A sub-domain boundary volume represents the three-dimensional cell that is connected to a one-dimensional cell.

This component is indicated by SDBVOL on card ccc0000. For major edits, minor edits, and plot variables, the volume in the sub-domain boundary volume components is numbered as ccc010000.

8.19.1 CARD ccc0101 through ccc0109, Sub-domain Boundary Volume Geometry Cards

This card (or cards) is required for a sub-domain boundary 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 (m2, ft2).

W2(R) Length of volume (m, ft).

W3(R) Volume of volume (m3, ft3).

W4(R) Azimuthal angle (degrees).

W5(R) Inclination angle (degrees). If a 1D cell is vertically connected to the top of the 3D cell represented by this sdbvol, this number is - 90.0.

If a 1D cell is vertically connected to the bottom of the 3D cell represented by this sdbvol, this number is 90.0.

If a 1D cell is horizontally connected to the 3D cell represented by this sdbvol, this number is 0.0 or 90.0. If the angle is 90.0, horizontal 1-D pipe is connected to this SDBVOL component using a cross flow junction.

W6(R) Elevation change (m, ft).

W7(R) Wall roughness (m, ft).

W8(R) Hydraulic diameter (m, ft).

W9(I) Volume control flags, tlpvbfe (See RELAP5/MOD3.2 Code Input Model).

8.19.2 CARD ccc0300, Sub-domain Boundary Volume Connection Cards

This card is required for a sub-domain boundary volume component.

W1(I) Channel number. This number is the channel number of the three-dimensional cell represented by this sdbvol.

W2(I) Mesh number. This number is the mesh number of the three-dimensional cell represented bythis sdbvol.

W3(I) Connection mode.

If a 1D cell is vertically connected to the top of the 3D cell represented by this sdbvol, this number is 1.

If a 1D cell is vertically connected to the bottom of the 3D cell represented by this sdbvol, this number is -1.

If a 1D cell is horizontally connected to the 3D cell represented by this sdbvol, this number is 0.

Additional three words (W4, W5 and W6) should be entered in case of horizontal connection (i.e., W3 is 0).

W4(I) Gap number 1.This number is the gap number facing the 1D/3D interface surface represented by this sdbvol.

This number is zero if there is no gap facing the 1D/3D interface surface.

W5(I) Gap number 2. This number is the left gap number normal to the 1D/3D interface represented by this sdbvol.

This number is zero if there is no gap normal to the 1D/3D interface surface.

W6(I) Gap number 3. This number is the right gap number normal to the 1D/3D interface.

This number is zero if there is no gap normal to the 1D/3D interface surface. The sequence of W5 and W6 is meaningless.

8.20 Multi-Dimensional Input

A multi-dimensional 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 multi-dimensional 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, volumes are defined. The number of volumes in a threedimensional component is limited to 9999 volumes. Volumes are numbered CCCXYYZZ0 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 z in both Cartesian and cylindrical 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. Positive θ direction is counterclockwise. The r-θ plane is in the same plane as the x-y plane.

The volume face number is given by CCCXYYZZF 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 z-coordinate, 3 and 4 for the inlet and outlet faces for the x- or r- coordinate, and 5 and 6 for the inlet and outlet faces for the y- or θ- 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 . 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 CCCXYYZZF 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.

MULTID component can be connected to 1-D components externally via either a normal junction or a crossflow junction, depending on the actual flow paths. The 1-D to MULTID external junction connection to an external MULTID face should be restricted to 1 junction for each external MULTID face. The MULTID component can also be connected to MULTID components externally via either a normal junction or a crossflow junction. The MULTID to MULTID connection is restricted to the same direction (i.e., radial to radial, axial to axial,etc.).

8.20.1 Card CCC0001, Multi-Dimensional 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. If this word is zero, Cartesian geometry is indicated; 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 of the word is negative, θ is assumed to extend to less than 360 degrees. Input checking uses 360 + 0.0005 degrees for the region that represents 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 or Cartesian geometry. A nonzero value allows the specification of a cylinder with a hollow center in cylindrical geometry. This word is not used in Cartesian geometry.

W7(I) Three-dimensional flag. This word is optional and if missing is assumed to be zero. Not used yet, it has been reserved for future application.

8.20.2 Card CCC0002, Multi-Dimensional Rotation Angle Data Card

This card is optional and if missing, the angles for W1, W2, and W3 are assumed to be zero and W4 is dummy card.

W1(R) First rotation angle (degrees).

W2(R) Second rotation angle (degrees).

W3(R) Third rotation angle (degrees).

W4(A) dummy, not used.

The angles used in MULTID are Euler angles. 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-, r- and θ-coordinates are in the horizontal plane with the $\theta = 0$ line coinciding with the x-axis. The coordinate system of the multi-dimensional component is initially aligned with the reference coordinates. For the Euler angles, 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 and pitch-yaw-roll angle is from 0.0 through plus or minus 360 degrees. The effects of the spherical first and second angles of the pipe and single volumes and the Euler and pitch-yaw-roll angles are similar, except that the spherical angle first angle is not used and the second angle is limited to 90 degrees. An example of usage of the Euler angle data is to move the axial coordinate in cylindrical geometry from the vertical direction to the horizontal plane.

8.20.3 Cards CCC0XNN, Multi-Dimensional 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, sequence 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 X. 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. Input checking uses 360 °+– 0.0005 degrees for the region that represents 360 degrees. Presently a further restriction exists on the q 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.

8.20.4 Cards CCC1NNN, Multi-Dimensional Volume Option Cards

These cards are required. The NNN digits range 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 consists of volumes where the x- or rcoordinate 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 is stored in volumes not referenced by an overlay.

W1(I) x1

W2(I) x2

W3(I) y1

W4(I) y2

W5(I) z1

W6(I) z2

W7(R) Volume porosity factor. Default is 1.0. This quantity must be greater than zero and less than or equal to one. The original volume of each volume is computed from the mesh interval data. The actual volumes'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 which 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) Scaler volume control flag. This word has the general packed format tlpvbfe but this word is limited to tlpvb0e. It is not necessary to input leading zeros. This word applies to the scaler oriented options for a volume.

W9(I) Dummy value. It is not used.

W10(I) Y- or θ-coordinate volume control flag. This word has the general packed format tlpvbfe but this word is limited to 00000f0. It is not necessary to input leading zeros. This word applies to the coordinate options.

W11(I) Z-coordinate volume control flag. This word has the general packed format tlpvbfe. It is not necessary to input leading zeros. This word applies to the coordinate options.

The digit t specifies whether the thermal front tracking model is to be used; t = 0 specifies that the front tracking model is not to be used for the volume, and t = 1 specifies that the front tracking model is to be used for the volume. The digit l specifies whether the mixture level tracking model is to be used; l = 0 specifies that the level model not be used for the volume, and l = 1 specifies that the level model be used for the volume. 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 that volume, and p = 1 specifies that the water packing scheme is not to be used. 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, and v = 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. If this word is 2, all the water volume is in the film (i.e., no drops) when in the annular mist flow regime.

8.20.5 Cards CCC2NNN, Multi-Dimensional Volume Friction Data Cards

These cards are required. The NNN digits range 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 and 18 or 27 words may be entered. Words 13 through 18 enter additional wall friction data which specify laminar shape factors and viscosity ratio exponents. Words 19 through 27 specify data for an alternate turbulent friction factor model. The alternate turbulent 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. 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). Default value is zero.

W8(R) Hydraulic diameter for the x- or r-coordinate (m, ft). Default value is zero. If zero, the hydraulic diameter is computed from four times the total flow area in that direction divided by the associated wetted perimeter. The flow area and wetted perimeter are appropriate for the geometry and the coordinate direction. This represents the default for a tank.

W9(R) Wall roughness for the y- or θ-coordinate (m, ft). Default value is zero.

W10(R) Hydraulic diameter for the y- or theta-coordinate (m, ft). Default value is zero. If zero, the hydraulic diameter is computed from four times the total flow area in that direction divided by the associated wetted perimeter. The flow area and wetted perimeter are appropriate for the geometry and the coordinate direction. This represents the default for a tank.

W11(R) Wall roughness for the z-coordinate (m, ft). Default value is zero.

W12(R) Hydraulic diameter for the z-coordinate (m, ft). Default value is zero. If zero, the hydraulic diameter is computed from four times the total flow area in that direction divided by the associated wetted perimeter. The flow area and wetted perimeter are appropriate for the geometry and the coordinate direction. This represents the default for a tank.

W13(R) Shape factor for x- or r-coordinate. Default value is 1.0.

W14(R) Viscosity ratio exponent for x- or r-coordinate. Default value lis 0.0.

W15(R) Shape factor for y- or θ-coordinate. Default value is 1.0.

W16(R) Viscosity ratio exponent for y- or θ-coordinate. Default value lis 0.0.

W17(R) Shape factor for z-coordinate. Default value is 1.0.

W18(R) Viscosity ratio exponent for z-coordinate. Default value lis 0.0.

W19(R) A for x- or r-coordinate. Default value is zero.

W20(R) B for x- or r-coordinate. Default value is zero.

W21(R) C for x- or r-coordinate. Default value is zero.

W22(R) A for y- or q-coordinate. Default value is zero.

W23(R) B for y- or q-coordinate. Default value is zero.

W24(R) C for y- or q-coordinate. Default value is zero.

W25(R) A for z-coordinate. Default value is zero.

W26(R) B for z-coordinate. Default value is zero.

W27(R) C for z-coordinate. Default value is zero.

8.20.6 Cards CCC3001 Through CCC5999, Multi-Dimensional Junction Data and Initial

Condition Cards

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. Not all junctions need to be referenced by these cards.

A totally blocked internal MULTID junction (i.e., the junction that is not defined in this card) is treated as a wall with no flow. If all the internal MULTID junctions associated with a MULTID volume are blocked (i.e., all the junctions are not defined), then that MULTID volume is treated as another system.

W1(I) x1

W2(I) x2

W3(I) y1

W4(I) y2

W5(I) z1

W6(I) z2

W7(A) Face direction. The face direction is limited to x, y, or z.

W8(R) Junction area factor. Default value is one. This quantity must be greater than or equal to zero and less than or equal to 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) Reynolds number independent forward flow energy loss coefficient. Default value is zero.

W10(R) Reynolds number independent reverse flow energy loss coefficient. Default value is zero.

W11(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

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

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 stratification entrainment/pullthrough options. v = 0 means the model is not applied; v = 1 means an upward-oriented junction (offtake volume must be vertical); v = 2 means a downward-oriented junction (offtake volume must be vertical); 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, a = 1 means full abrupt area change model, (Kloss, area apportioning at branch, restricted junction area, and extra interphase drag), and a = 2 means a partial abrupt area change model (no Kloss, but includes area apportioning at branch, restricted junction area, and extra interphase drag).

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

The digit s specifies momentum flux option. s = 0 uses momentum flux in both the to and from volume. s = 1 uses momentum flux in the from volume, but not in the to volume. s = 2 uses momentum flux in the to volume but not in the from volume. s = 3 does not use momentum flux in either the to volume or the from.

W12(R) Junction hydraulic diameter (m, ft). This word is optional. Default value is zero. If zero is entered, hydraulic diameter is set to four times the total junction area in that direction divided by the associated wetted perimeter. This represents the default for a tank.

W13(R) Initial liquid velocity or mass flow (m/sec, ft/sec or kg/sec, lb/sec).

W14(R) Initial vapor velocity or mass flow (m/sec, ft/sec or kg/sec, lb/sec).

W15(R) This word is optional. If digit f of W11(I) is 1, this means CCFL data, β.

W16(R) This word is optional. If digit f of W11(I) is 1, this means CCFL data, C_m.

W17(R) This word is optional. If digit f of W11(I) is 1, this means CCFL data, C_0.

8.20.7 Cards CCC6NNN, Multi-Dimensional Volume Initial Condition Cards

These cards are required. The NNN digits range 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 ebt. It is not necessary to input leading zeros. The digit e specifies the fluid, where e = 0 is the default fluid. The value for e > 0 corresponds to the position number of the fluid type indicated on the 120 - 129 cards (i.e., e = 1 specifies H2O, e = 2 specifies D2O, etc.). 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 e = 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 liquid does not contain boron; b = 1 specifies that a boron concentration in mass of boron per mass 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). With options t equal to 4 through 6, names of components of the noncondensable gas must be entered on Card 110, and mass fractions of the components are entered on Card 115.

If t = 0, the next four words are interpreted as pressure (Pa, lbf/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 internal energies used to define the thermodynamic state. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 1, the next two words are interpreted as temperature (K, ^oF) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 2, the next two words are interpreted as pressure (Pa, lbf/in^2) and static quality in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 3, the next two words are interpreted as pressure (Pa, lbf/in^2) and temperature (K, ^oF) in equilibrium condition. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic 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 static quality are: 1.0E-9 < static quality < 0.99999999 implies two phase conditions; static quality < 1.0E9 or quality > 0.99999999 implies single phase. The static quality is given by Mg / (Mg + Mf), where Mg = Ms + Mn. Noncondensable options are:

If t = 4, the next three words are interpreted as pressure (Pa, lbf/in^2), temperature (K, ^oF), and static quality in equilibrium condition. Using this input option with static 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 static quality to 0.0 is used as a flag that will initialize the volume to all noncondensable (dry noncondensable) with no temperature restrictions. Static quality is reset to 1.0 using this dry noncondensable option. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

If t = 5, the next three words are interpreted as temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the static and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions. Little experience has been obtained using this option, and it has not been checked out.

If t = 6, the next five words are interpreted as pressure (Pa, lbf/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb), vapor void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the internal energies used to define the thermodynamic state. 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 (t = 0). If noncondensables are present (noncondensable quality greater than 0.0), then the vapor void fraction must also be greater than 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. Enter only the minimum number of words required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

W8-W13(R) Quantities described under Word 7 (W7). Depending on the control word, two through five thermodynamic quantities may be required. Enter only the minimum required. If entered, boron concentration (mass of boron per mass of liquid) follows the last required word for thermodynamic conditions.

8.20.8 Cards CCC7001, Turbulent Mixing Length Cards

These cards are optional and if missing, the mixing length for W1 is set to be 0.1 m. The turbulent mixing length scale(m, ft) is used to calculate the turbulent viscosity for 1D module component CCC by Prandtl's mixing model.

W1(R) Enter the turbulent mixing length(m, ft). A real number should be required. if this card not exists, default 0.1(m, ft) is entered. **Table 8.20-1** suggests some useful guidelines to calculate the quantity. The viscous fluid shear stresses are obtained by multiplying the velocity gradient and the sum of the dynamic viscosity and turbulent viscosity.

Table 8.20-1 Mixing length models for various flow conditions and geometries

Flow	**turbulent length scale, l_m**	**hydraulic length scale, L**
Mixing layer	$0.07L$	layer width
Jet	$0.09L$	jet half width
Wake	$0.16L$	wake half width
Axisymmetric jet	$0.075L$	jet half width
Boundary layer	$0.09L$	layer thickness
Channel	$L\left[0.14-0.08(1-y/L)^2-0.06(1-y/L)^4\right]$	channel half width

8.20.9 Cards CCC8NNN, Output Control Cards

These cards are optional. The NNN digits range 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 major output activation. MULTID junctions between activated volumes also appears in the major output.

W1(I) x1.

W2(I) x2.

W3(I) y1.

W4(I) y2.

W5(I) z1.

W6(I) z2.

W7(I) control word. This word is dummy value and seserved for future use. enter 0.

9 HEAT STRUCTURES

These are used in NEW and RESTART type problems and are required only if heat structures are described. The heat structure card numbers are of the form 1CCCGXNN where the fields are defined as follows:

CCC is a heat structure number. The heat structure numbers need not be consecutive. We suggest, but the system does not require, 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.

9.1 General Heat Structure Data, 1CCCG000

This card is required for heat structures. Use 8 words for new data input or 1 word for deleting a heat structure.

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 or metal water reaction 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 0 if the desired initial condition temperatures are entered on input cards 1CCCG401-G499; use 1 if the steady-state initial condition temperatures are to be calculated by the code. If option 1 is chosen, the user is still required to enter temperatures on cards 1CCCG402-G499. In this case, the temperatures are used as starting points for the steady-state solutions. The user should therefore enter temperatures either below or above the minimum film boiling point to assure the respective pre-DNB or post-DNB steady-state condition is calculated. This is because the boiling curve is multi-valued.

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 0, 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. If the heat structure is fuel pins or heat exchanger tubes, the length factor (Word 5 on cards 1CCCG501-G509) is the product of the hydrodynamic volume length and the number of pins or tubes. 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 $2 \bullet nh + 1$ 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 in this heat structure geometry when the average pressure in the connected hydrodynamic volumes is less than 1.2×10^6 Pa, and the average void fraction in the interconnected hydrodynamic volumes is greater than 0.9 (i.e., nearly empty).

If 2 is entered, the reflood calculation is initiated in this heat structure geometry when the average pressure in the connected hydrodynamic volumes is less than 1.2×10^6 Pa and the average void fraction in the interconnected hydrodynamic volumes is greater than 0.1 (i.e., 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 0 or 1 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.

9.2 Heat Structure Deletion, 1CCCG000

This card can only be entered for RESTART problems. If entered, all heat structures associated with the heat structure geometry number CCCG are deleted.

W1(A) Enter DELETE.

9.3 Gap Data, 1CCCG001

This card is optional and is needed only if the gap conductance model is to be used. If the card is entered, Word 1 of card 1CCCG100 must be 0, cards 1CCCG011-G099, and cards 1CCCG201-G299 are required. Word 2 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 201MMM01-49).

W1(R) Initial gap internal pressure (Pa, lb_f/in^2).

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 $P(t) = P(0)/T(0) \bullet T(t)$, where P(t) is the pressure in the fuel pin and T(t) is the temperature in the reference volume. P(0) is Word 1 above, and T(0) 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 hydrodynamic volume (i.e., the nine-digit number CCCNN0000) most closely associated with the nonfuel region in a fuel pin at the top of a stack of fuel pellets.

W3(R) Gap conductance multiplier. This word is optional. The default value is 1.0.

9.4 Metal-Water Reaction Control, 1CCCG003

This card is optional, and if this card is not present, no metal-water reaction will be calculated. The initial oxide thickness is assumed to be 0 on the inner surface. It remains 0 unless cladding rupture occurs. CCCG is a heat structure geometry number.

W1(R) Initial oxide thickness on cladding's outer surface (m, ft).

W2(I) Hydrogen addition control word. This word is optional and defaults to 0 if not entered. If 0, hydrogen from metal-water reaction will not be added to the noncondensables in the attached volume. If 1, hydrogen from metal-water reaction will be added to the noncondensables in the attached volume.

W3(R) Coefficient kocp in oxide thickness equation. This word is optional and defaults to 2.252E-6 m^2/s if not entered. The Baker-Just value for kocp,7.9848E-5 m^2/s, can be obtained by using the CANDU option, Card 1, Option 81 (m^2/s, ft^2/s).

W4(R) Coefficient aocp in oxide thickness equation. This word is optional and defaults to 18062.0 K if not entered. The Baker-Just value for aocp, 22900.0 K, can be obtained by using the CANDU option, Card 1, Option 81 (K, R).

9.5 Fuel Cladding Deformation Model Control, 1CCCG004

If this card is optional, and if it is not present, no deformation calculations will be done. If this card is present, then card 1CCCG001 must also be present. CCCG is a heat structure geometry number.

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.

9.6 Gap Deformation Data, 1CCCG011-G099

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 0. 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 due to fission gas-induced fuel swelling and densification (m, ft). This number must be ≥ 0. A negative entry is reset to 0. An appropriate value can be obtained from calculations using FRAPCON-2 or FRAP-T6.

W4(R) Radial displacement due to cladding creepdown (m, ft). The value is normally negative. A positive entry is reset to 0. An appropriate value can be obtained from calculations using FRAPCON-2 or FRAP-T6.

W5(I) Heat structure number.

9.7 Heat Structure Mesh Flags, 1CCCG100

This card is required for heat structure input.

W1(I) Mesh location flag. If 0, 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 9.7-Section 9.10 is not entered.

W2(I) Mesh format flag. This word is needed only if Word 1 is 0, though no error occurs if it is present when Word 1 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-G199. If this word is 1 (format 1 on cards 1CCCG101-G199), the pairs of numbers contain the number of 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 Word 5 of card 1CCCG000; for succeeding pairs, the left coordinate is the right coordinate of the previous pair. If this word is 2 (format 2 on cards 1CCCG101-G199), the format is a sequential expansion of mesh intervals; i.e., the distance in Word 1 on cards 1CCCG101-G199 is used for each interval starting from the leftmost, as yet unspecified, interval to and including the interval number specified in Word 2.

9.8 Format 1 Number of Mesh Intervals, 1CCCG101-G199

These cards are required if Word 1 of card 1CCCG100 is 0. The sum of the numbers of intervals must be np-1. The card numbers need not be sequential.

W1(I) Number of intervals. Enter the number of intervals, not the interval number.

W2(R) Right coordinate (m, ft).

9.9 Format 2 Mesh Intervals, 1CCCG101-G199

These cards are required if Word 1 of card 1CCCG100 is 0. The sequential expansion must be for np-1 intervals. The card numbers need not be sequential.

W1(R) Mesh interval (m, ft.)

W2(I) Interval number.

9.10 Heat Structure Composition Data, 1CCCG201-G299

These cards are required if Word 1 of card 1CCCG100 is 0 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 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.

9.11 Fission Product Decay Heat Flag, 1CCCG300

This card is required if fission product decay heat is used on this heat structure. This card sets the fission product decay heat flag. The code will then treat card 1CCCG301 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.

9.12 Heat Structure Source Distribution Data, 1CCCG301-G399

These cards are required if Word 1 of card 1CCCG100 is 0 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 1CCCG300 is entered, then card 1CCCG301 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.

9.13 Initial Temperature Flag, 1CCCG400

This card is optional; if missing, Word 1 is assumed to be 0.

W1(I) Initial temperature flag. If this word is 0 or -1, initial temperatures are entered with the input data for this heat structure geometry. If greater than 0, initial temperatures for this heat structure geometry are taken from the heat structure geometry number in this word, and the initial temperature distribution from Section 9.14 or Section 9.15 is not needed.

9.14 Format 1 Initial Temperature Data, 1CCCG401-99

These cards are required if Word 1 of card 1CCCG400 is 0. 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, ^oF).

W2(I) Mesh point number.

9.15 Format 2 Initial Temperature Data, 1CCCG401-499

These cards are required if Word 1 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, ^oF). Enter the np mesh point temperatures in order from left to right.

9.16 Left Boundary Condition, 1CCCG501-599

These cards are required. 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 CCCNN000F) or general table associated with the left surface of this heat structure. These are used to specify the sink temperature. If 0, 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 0 temperature gradient at the boundary), or a temperature of 0 is used for a surface temperature or a sink temperature in boundary conditions. A boundary volume number is entered as a positive number. If F is 0 or 4, the volume coordinate associated values such as average volume velocity are taken from the x-coordinate; if F is 2 or 1, volume coordinate associated values are taken from the y- or z-axes, respectively. Specifying a volume coordinate not in use is an input error. A general table is entered as a negative number (-1 through -999).If F is 7, the 3D hydraulic volume is used. Then ccc is a channel number and nn is a mesh number

W2(I) Increment. This word and Word 1 of this card are treated differently from the standard sequential expansion. Word 1 of the first set applies to the first heat structure of the heat structure geometry set. The increment (normally 10000) is added to Word 1, which results in the hydraulic cell number associated with heat structure 2; etc. The increment is applied up to the limit in Word 6 of a set. Word 1 of the next set applies to the next heat structure, and increments are applied as for the first set. The increment may be 0 or nonzero, positive or negative. If Word 1 is 0, this word should be 0.

W3(I) Boundary condition type.

If 0, a symmetry or insulated boundary condition is used (i.e., a 0 temperature gradient is used at the boundary). 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. The allowed values of nn are shown in **Table 9.16-1**. The sink temperature is the temperature of the boundary volume. Word 1 must specify a boundary volume with this boundary condition type. The boundary volume cannot be a time-dependent volume.

There are several numbers allowed for Word 3 to activate convective boundary conditions for nonstandard geometries. A 1, 100, or 101 give the default values. The numbers 1, 100, and 101 use the same correlations. The number 101 is recommended; the numbers 1 and 100 are allowed so that the code is backwards compatible with previous input decks. The default convection and boiling correlations were derived mainly based on data from internal vertical pipe flow. Other possible input values are shown in **Table 9.16-1**. When modeling a vertical bundle, the rod or tube pitch-to-diameter ratio should be input on the 801 card. This has the effect of increasing the convective part of heat transfer such that users can input the true hydraulic diameter and get reasonable predictions.

Table 9.16-1 Card 501 Word 3 Convection Boundary Type

Word 3	Geometry Type
1, 100, 101	Default
102	Parallel plates (ORNL, ANS reactor; set gap and span on CCC3101-3199 hydro cards for pipes and CCC0111 hydro card for single volumes and branches, set b = 2 in volume control flag on CCC1001-1099 hydro cards for pipes and CCC0101-0109 hydro cards for single volumes and branches).
109	HANARO fuel
110	Vertical bundle without crossflow (set P/D on 801 card)
111	Vertical bundle with crossflow (set P/D on 801 card)
114	Helical S/G tube side (set Dc/di on 801/901 card Word 10)
115	Parallel plates large gaps - uses Petukhov-Gnielinski heat transfer correlation with Swanson-Catton multiplier for mixed convection
124	CANDU fuel bundle element heat transfer

Table 9.16-1 Card 501 Word 3 Convection Boundary Type

Word 3	Geometry Type
130	Flat plate above fluid
131	HANARO horizontal plate heat exchanger
134	Horizontal bundle
135	Helical S/G shell side (set P/D on 801/901 card Word 10)

If 1000, the temperature of the boundary volume or the temperature from the general table (as specified in Word 1) is used as the left surface temperature. If Word 1 is 0, the surface temperature is set to 0.

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 Word 1. If Word 1 is 0, the sink temperature is set to 0.

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 Word 1. If Word 1 is 0, the sink temperature is set to 0.

If reflood is specified, the left boundary condition type must be 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 1000 or 1xxx.

W4(I) Surface area code. If 0, Word 5 is the left surface area. If 1, Word 5 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 Word 4, 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 (Word 3 = 0), this word must still be entered nonzero.

W6(I) Heat structure number.

9.17 Right Boundary Condition, 1CCCG601-G699

These cards are required. The left and right surface areas must be compatible with the geometry. 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 CCCNN000F) or general table associated with the right surface of this heat structure. These are used to specify the sink temperature. If 0, no volume or general table is associated with the right surface of this heat structure, and a symmetry or insulated boundary condition is used (i.e., a 0 temperature gradient at the boundary), or a temperature of 0 is used for a surface temperature or a sink temperature in boundary conditions. A boundary volume number is entered as a positive number. If F is 0 or 4, the volume coordinate associated values such as average volume velocity are taken from the x-coordinate; if F is 2 or 1, volume coordinate associated values are taken from the y- or z-axes, respectively. Specifying a volume coordinate not in use is an input error. A general table is entered as a negative number (-1 through -999). If F is 7, the 3D hydraulic volume is used. Then ccc is a channel number and nn is a mesh number

W2(I) Increment. This word and Word 1 of this card are treated differently from the standard sequential expansion. Word 1 of the first set applies to the first heat structure of the heat structure geometry set. The increment (normally 10000) is added to Word 1, which results in the hydraulic cell number associated with heat structure 2; etc. The increment is applied up to the limit in Word 6 of a set. Word 1 of the next set applies to the next heat structure, and increments are applied as for the first set. The increment may be 0 or nonzero, positive or negative. If Word 1 is 0, this word should be 0.

W3(I) Boundary condition type.

If 0, a symmetry or insulated boundary condition is used (i.e., a 0 temperature gradient is used at the boundary). 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. The allowed values of nn are shown in **Table 9.17-1**. The sink temperature is the temperature of the boundary volume. Word 1 must specify a boundary volume with this boundary condition type. The boundary volume cannot be a time-dependent volume.

There are several numbers allowed for Word 3 to activate convective boundary conditions for nonstandard geometries. A 1, 100, or 101 give the default values. The numbers 1, 100, and 101 use the same correlations. The number 101 is recommended; the numbers 1 and 100 are allowed so that the code is backwards compatible with previous input decks. The default convection and boiling correlations were derived mainly based on data from internal vertical pipe flow. Other possible input values are shown in **Table 9.17-1**. When modeling a vertical bundle, the rod or tube pitch-to-diameter ratio should be input on the 901 card. This has the effect of increasing the convective part of heat transfer such that users can input the true hydraulic diameter and get reasonable predictions.

Table 9.17-1 Card 601 Word 3 Convection Boundary Type

Word 3	Geometry Type
1, 100, 101	Default
102	Parallel plates (ORNL, ANS reactor; set gap and span on CCC3101-3199 hydro cards for pipes and CCC0111 hydro card for single volumes and branches, set b = 2 in volume control flag on CCC1001-1099 hydro cards for pipes and CCC0101-0109 hydro cards for single volumes and branches).
109	HANARO fuel
110	Vertical bundle without crossflow (set P/D on 901 card)
111	Vertical bundle with crossflow (set P/D on 901 card)
114	Helical S/G tube side (set Dc/di on 801/901 card Word 10)
115	Parallel plates large gaps - uses Petukhov-Gnielinski heat transfer correlation with Swanson-Catton multiplier for mixed convection
124	CANDU fuel bundle element heat transfer
130	Flat plate above fluid
131	HANARO horizontal plate heat exchanger
134	Horizontal bundle
135	Helical S/G shell side (set P/D on 801/901 card Word 10)

If 1000, the temperature of the boundary volume or the temperature from the general table (as specified in Word 1) is used as the right surface temperature. If Word 1 is 0, the surface temperature is set to 0.

If 1xxx, the temperature in general Table xxx is used as the right surface temperature.

If 2xxx, the heat flux from Table xxx is used as the right 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 Word 1. If Word 1 is 0, the sink temperature is set to 0.

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 Word 1. If Word 1 is 0, the sink temperature is set to 0.

If reflood is specified, the right boundary condition type must be same for all nh heat structures and, similarly, for the left boundary condition type. The left and right boundary types need not be the same, but neither can be 1000 or 1xxx.

W4(I) Surface area code. If 0, Word 5 is the right surface area. If 1, Word 5 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 Word 4, 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 (Word 3 = 0), this word must still be entered nonzero.

W6(I) Heat structure number.

9.18 Source Data, 1CCCG701-G799

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 0, no source is used. If a positive number is less than 1000, power from the general table with this number is used as the source. If 1000-1004, the number has the form 100t, and the source is taken from a point kinetics calculation. 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 10001-19999, the source is the control variable whose number is this quantity minus 10000. If -3 is entered, the source of the heat structure is taken from the 3D kinetics module, MASTER. In this case, Input Cards 61100001 and 61100002 should be provided. In addition, MASTER input files and mapping data ("MAS_MAP" file) should be also prepared [KAERI/TR-2232/2002].

To run the RELAP5/PARCS 3-D kinetics code, the user must enter option 88 on card 1. During the heat structure initialization, PARCS is not called, so it is up to RELAP5 to supply the initial power and heat structure temperatures. Depending on how the user models the initial heat structure temperature, the user may need to input an initial power. If the steady-state initialization flag W4 on card 1CCCG000 is a 0, the initial temperatures are entered on cards 1CCCG401-G499, and it is not necessary to enter a power source. If the steady-state initialization flag W4 on card 1CCCG000 is a 1, the steady-state initial temperatures are calculated by the code, and the user needs to enter an initial power. The initial power can be entered using any of the methods discussed in the previous paragraph. After the RELAP5 initial power calculation, PARCS will supply the power, and the RELAP5 power calculations is skipped.

It is acceptable to restart a RELAP5/PARCS 3-D kinetics coupled code calculation from a RELAP5 stand-alone restart file in which the user can use any of the heat source types. However, the reverse case, restarting a RELAP5 stand-alone calculation from a RELAP5/PARCS coupled code restart file, is not allowed.

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 Word 1 to obtain the total power generated in this heat structure. These factors are not relative factors.

W3(R) Direct moderator heating multiplier for left boundary volume.

W4(R) Direct moderator heating multiplier for right boundary volume.

W5(I) Heat structure number.

9.19 Additional Left Boundary Option, 1CCCG800

W1(I) If this card is not entered or if this word is 0, the nine-word format is used on cards 1CCCG801-G899. If this word is 1, the twelve-word format is used on the cards. If this word is 2, the thirteen-word format is used on the cards (needed for PG-CHF correlation). If this word is 3, the nine-word format is used on the cards and model multiplier inputs are required. If this word is 4, the twelve-word format is used on the cards and model multiplier inputs are required.

W2(R) Multiplier for liquid Dittus-Boelter correlation (default = 1.0)

W3(R) Multiplier for Chen nucleate boiling model (default = 1.0)

W4(R) Multiplier for AECL CHF value (default = 1.0)

W5(R) Multiplier for Chen transition boiling model (default = 1.0)

W6(R) Multiplier for Bromley film boiling model (default = 1.0)

W7(R) Multiplier for vapor Dittus-Boelter correlation (default = 1.0)

W8(R) Multiplier for Zuber CHF correlation (default=1.0)

W9(R) Multiplier for Modified Weismann correlation (default=1.0)

W10(R) Multiplier for QF film boiling correlation (default=1.0)

W11(R) Multiplier for Forslund-Rohsenow correlation (default=1.0)

W12(R) Multiplier for Reflood superheated vapor correlation (default=1.0)

W13(I) Trip number to activate multipliers. The 11 multipliers are applied only during the period when trip is true.

9.20 9-Word Format Additional Left Boundary, 1CCCG801-G899

These cards are required whenever the left boundary communicates energy with the left hand fluid volume, and Word 1 = 0 on card 1CCCG800. The cards are in sequential expansion format, nine words per set, describing nh heat structures. Sequential expansion would only be used where the critical heat flux value was not of importance, since the length to all heat structures in the expansion would be the same. Words 2-8 are used for the CHF correlation.

W1(R) Heat transfer hydraulic diameter (i.e., heated equivalent diameter) (m, ft). This is $4\left(\frac{\text{flow area}}{\text{heated perimeter}}\right)$ and is recommended to be greater than or equal to the volume hydraulic diameter since (heated perimeter) $\leq$ (wetted perimeter). It is possible to input this diameter to be less than the volume hydraulic diameter. If Word 1 equals 0.0, the volume hydraulic diameter is used.

W2(R) Heated length forward (m, ft). Distance is from the heated inlet to the center of this slab. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W3(R) Heated length reverse (m, ft). Distance is from the heated outlet to the center of this slab. This quantity will be used when the liquid volume velocity is negative. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W4(R) Grid spacer length forward (m, ft). Distance is from the center of this slab to the nearest grid or obstruction upstream. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the boundary layer disturbance and atomization effect of a grid spacer in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 6) is 0, Word 4 is not used.

W5(R) Grid spacer length reverse (m, ft). Distance is from the center of the slab to the nearest grid or obstruction downstream. This quantity will be used when the liquid volume velocity is negative. This is used to get the boundary layer disturbance and atomization affect of a grid space in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 7) is 0, Word 5 is not used.

W6(R) Grid loss coefficient forward. Used for forward flow in rod bundles. This quantity is used when the liquid volume velocity is positive or 0. This is used only for CHF calculation.

W7(R) Grid loss coefficient reverse. Used for reverse flow in rod bundles. This quantity is used when the liquid volume velocity is negative. This is used only for the CHF correlation.

W8(R) Local boiling factor. Enter 1.0 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 0). 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. This number must be greater than 0.0.

W9(I) Heat structure number.

9.21 12-Word Format Additional Left Boundary, 1CCCG801-G899

These cards are required whenever the left boundary communicates energy with the left hand fluid volume, and Word 1 = 1 on card 1CCCG800. The cards are in sequential expansion format, twelve words per set, describing nh heat structures.

W1(R) Heat transfer hydraulic diameter (i.e., heated equivalent diameter) (m, ft). This is $4\left(\frac{\text{flow area}}{\text{heated perimeter}}\right)$ and is recommended to be greater than or equal to the volume hydraulic diameter since (heated perimeter) $\leq$ (wetted perimeter). It is possible to input this diameter to be less than the volume hydraulic diameter. If Word 1 equals 0.0, the volume hydraulic diameter is used.

W2(R) Heated length forward (m, ft). Distance is from the heated inlet to the center of this slab. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W3(R) Heated length reverse (m, ft). Distance is from the heated outlet to the center of this slab. This quantity will be used when the liquid volume velocity is negative. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W4(R) Grid spacer length forward (m, ft). Distance is from the center of this slab to the nearest grid or obstruction upstream. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the boundary layer disturbance and atomization effect of a grid spacer in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 6) is 0, Word 4 is not used.

W5(R) Grid spacer length reverse (m, ft). Distance is from the center of the slab to the nearest grid or obstruction downstream. This quantity will be used when the liquid volume velocity is negative. This is used to get the boundary layer disturbance and atomization affect of a grid space in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 7) is 0, Word 5 is not used.

W6(R) Grid loss coefficient forward. Used for forward flow in rod bundles. This quantity is used when the liquid volume velocity is positive or 0. This is used only for CHF calculation.

W7(R) Grid loss coefficient reverse. Used for reverse flow in rod bundles. This quantity is used when the liquid volume velocity is negative. This is used only for the CHF correlation.

W8(R) Local boiling factor. Enter 1.0 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 0). 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. This number must be greater than 0.0.

W9(R) Natural circulation length (m, ft). This should be the height of a hydraulic natural convection cell. For a heated vertical plate, this is the total height of the plate. For inside a horizontal tube, this should be the inside tube diameter. For the outer surface of vertical or horizontal bundles, it is suggested to use the heated bundle height in the vertical direction. When using the nine word format, this quantity is set to Word 1, the heat transfer hydraulic diameter.

W10(R) Rod or tube pitch-to-diameter ratio. The default is 1.1. The maximum is 1.6 ft. It is not used unless Word 3 on the 501 card is 110, 111, 114, or 135. If CANDU geometry (124 option on Card 1CCCG5XX) was selected, this value is the relative height of the fuel element, and its value should be within ± 1.0 .Rod or tube pitch-to-diameter ratio (P/D). The default is 1.1. The maximum is 1.6. It is not used unless Word 3 on the 501 card is 110, 111, 114, 124 or 135. If Helical geometry (114 option on 501 CARD)was selected, this value is Helical Circle Diameter-to-Tube Inner Diameter Ratio (Dc/di), and unlimited maximum value can be entered

W11(R) Fouling factor. This factor is applied to the heat transfer correlations and may be used to represent fouling or to run sensitivity studies. This quantity must be a positive nonzero number. When using the nine-word format, this quantity is set to 1.0.

W12(I) Heat structure number.

9.22 13-Word Format Additional Left Boundary, 1CCCG801-G899

These cards are required whenever the left boundary communicates energy with the left hand fluid volume, and Word 1 = 2 on card 1CCCG800. The cards are in sequential expansion format, thirteen words per set, describing nh heat structures.

W1(R) Not used, enter 0.0.

W2(R) Reduced heated length forward (m, ft). This is the product $(y \bullet T_a)$. The first term is the distance from the heated channel inlet to the point of the predicted CHFR when the liquid volume velocity is positive or 0. The second term is the ratio of average heat flux from the heated channel inlet to the axial coordinate y (m, ft), i.e., at the point of the predicted CHFR, to local heat flux q at y. Word 2 should be determined as follows:

$$y \bullet T_a = \frac{1.}{q(y)}\int_0^y q(z)dz \ .$$

W3(R) Reduced heated length reverse (m, ft). This is the product $(y \bullet T_a)$. The first term is the distance from the heated channel outlet to the point of the predicted CHFR when the liquid volume velocity is negative. The second term is the ratio of average heat flux from the heated channel outlet to the axial coordinate y (m, ft), i.e., at the point of the predicted CHFR, to local heat flux q at y. Word 3 should be determined as follows:

$$y \bullet T_a = \frac{1.}{q(y)}\int_0^y q(z)dz \ .$$

W4(R) Grid spacer factor forward. This should be input as follows:

If Word 12 = 11, 12, 21, 22, 31, 32, 41, or 42, i.e., CHFR for the tube or the internally heated annulus, then Word 4 must be input as W4 = 1.0.

If Word 12 = 13, 23, 33, or 43, i.e., CHFR for the rod bundle with <u>vaneless</u> grid spacers, then Word 4 should be input either as W4 = 1.0 / $\overline{R}$, if the statistical evaluation data for the rod bundles are available ($\overline{R}$ is the mean of variable R. R is the statistical random variable representing CHFR, i.e., predicted CHF to measured CHF ratio), or as W4 = 1.0, if the statistical evaluation data for the rod bundle are not available.

If Word 12 = 14, 24, 34, or 44, i.e., CHFR for the rod bundle with <u>vane</u> grid spacers, then Word 4 should be input as: W4 could be determined from statistical evaluation data of specific fuel design.

If Word 12 = 15, then W4 should be input as W4 = 1.0.

W5(R) Grid spacer factor reverse. This should be input as follows:

If Word 12 = 11, 12, 21, 22, 31, 32, 41, or 42, i.e., CHFR for the tube or the internally heated annulus, then Word 5 must be input as W5 = 1.0.

If Word 12 = 13, 23, 33, or 43, i.e., CHFR for the rod bundle with <u>vaneless</u> grid spacers, then Word 5 should be input either as W5 = 1.0 / $\overline{R}$, if the statistical evaluation data for the rod bundles are available ($\overline{R}$ is the mean of variable R. R is the statistical random variable representing CHFR, i.e., predicted CHF to measured CHF ratio), or as W5 = 1.0, if the statistical evaluation data for the rod bundle are not available.

If Word 12 = 14, 24, 34, or 44, i.e., CHFR for the rod bundle with <u>vane</u> grid spacers, then Word 5 should be input as: W5 could be determined from statistical evaluation data of specific fuel design.

If Word 12 = 15, then W5 should be input as W5 = 1.0.

W6(R) Factor of the radial heat flux distribution. This should be input as:

$$T_r = q\frac{\sum_i r_i}{\sum_i r_i q_i}$$

This is the ratio of local heat flux on referred perimeter to average heat flux on perimeters pertaining to the subchannel (or the annulus).

W7(I) Heated channel upstream hydrodynamic volume number. This refers to the hydrodynamic components which represents the inlet for the heated channel. This is to get the heated channel inlet quality in the case of forward flow direction.

W8(I) Heated channel downstream hydrodynamic volume number. This refers to the hydrodynamic components which represents the outlet for the heated channel. It applies when the flow reverses.

W9(R) Natural circulation length (m, ft). This should be the height of a hydraulic natural convection cell. For a heated vertical plate, this is the total height of the plate. For inside a horizontal tube, this should be the inside tube diameter. For the outer surface of vertical or horizontal bundles, it is suggested to use the heated bundle height in the vertical direction. When using the nine word format, this quantity is set to Word 1, the heat transfer hydraulic diameter.

W10(R) Rod or tube pitch-to-diameter ratio. The default is 1.1. The maximum is 1.6 ft. It is not used unless Word 3 on the 501 card is 110, 111, 114, or 135. If Helical geometry (114 option on 501 CARD)was selected, this value is Helical Circle Diameter-to-Tube Inner Diameter Ratio (Dc/di), and unlimited maximum value can be entered. If CANDU geometry (124 option on Card 1CCCG5XX) was selected, this value is the relative height of the fuel element, and its value should be within ±1.0

W11(R) Fouling factor. This factor is applied to the heat transfer correlations and may be used to represent fouling or to run sensitivity studies. This quantity must be a positive nonzero number. When using the nine-word format, this quantity is set to 1.0.

W12(I) CHFR correlation option. This is input in mn format. The first digit specifies the CHFR correlation form.

If m = 1, then the basic form of PG CHFR correlation is used.

If m = 2, then the flux form of the PG CHFR correlation is used.

If m = 3, then the geometry form of PG CHFR correlation is used.

If m = 4, then the power form of PG CHFR correlation is used.

The second digit specifies the geometry of heated structure. If this is the rod bundle, it specifies if and how the statistical evaluation data are applied for the grid spacer factor (see Word 4 and Word 5).

If n = 1, then this is the tube.

If n = 2, then this is the internally heated annulus.

If n = 3, then this is the rod bundle. The use of an isolated subchannel model is recommended. This is used if the applicable PG CHFR correlation statistical evaluation data are not available.

If n = 4, then this is the rod bundle. The use of an isolated subchannel model is recommended. An extended use of the PG CHFR statistical evaluation data is enabled.

If n = 5, then this is the rod bundle. This is only used in combination with m = 1. Applicable for a subchannel code respecting lateral mixing.

W13(I) Heat structure number.

9.23 Additional Right Boundary Option, 1CCCG900

This card is optional, and if it is not entered, the nine-word format is used on cards 1CCCG901-G999.

W1(I) If this word is 0, the nine-word format is used on cards 1CCCG901-G999. If this word is 1, the twelve-word format is used on the cards. If this word is 2, the thirteen-word format is used on the cards (needed for PG-CHF correlation). If this word is 3, the nine-word format is used on the cards and model multiplier inputs are required. If this word is 4, the twelve-word format is used on the cards and model multiplier inputs are required.

W2(R) Multiplier for liquid Dittus-Boelter correlation (default = 1.0)

W3(R) Multiplier for Chen nucleate boiling model (default = 1.0)

W4(R) Multiplier for AECL CHF value (default = 1.0)

W5(R) Multiplier for Chen transition boiling model (default = 1.0)

W6(R) Multiplier for Bromley film boiling model (default = 1.0)

W7(R) Multiplier for vapor Dittus-Boelter correlation (default = 1.0)

W8(R) Multiplier for Zuber CHF correlation (default=1.0)

W9(R) Multiplier for Modified Weismann correlation (default=1.0)

W10(R) Multiplier for QF film boiling correlation (default=1.0)

W11(R) Multiplier for Forslund-Rohsenow correlation (default=1.0)

W12(R) Multiplier for Reflood superheated vapor correlation (default=1.0)

W13(I) Trip number to activate multipliers. The 11 multipliers are applied only during the period when trip is true.

9.24 9-Word Format Additional Right Boundary1CCCG901-G999

These cards are required whenever the right boundary communicates energy with the right hand fluid volume, and Word 1 = 0 on card 1CCCG900. The cards are in sequential expansion format, nine words per set, describing nh heat structures. Sequential expansion would only be used where the critical heat flux value was not of importance, since the length to all heat structures in the expansion would be the same. Words 2-8 are used for the CHF correlation.

W1(R) Heat transfer hydraulic diameter (i.e., heated equivalent diameter) (m, ft). This is $4\left(\frac{\text{flow area}}{\text{heated perimeter}}\right)$ and is recommended to be greater than or equal to the volume hydraulic diameter since (heated perimeter) $\leq$ (wetted perimeter). It is possible to input this diameter to be less than the volume hydraulic diameter. If Word 1 equals 0.0, the volume hydraulic diameter is used.

W2(R) Heated length forward (m, ft). Distance is from the heated inlet to the center of this slab. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W3(R) Heated length reverse (m, ft). Distance is from the heated outlet to the center of this slab. This quantity will be used when the liquid volume velocity is negative. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W4(R) Grid spacer length forward (m, ft). Distance is from the center of this slab to the nearest grid or obstruction upstream. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the boundary layer disturbance and atomization effect of a grid spacer in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 6) is 0, Word 4 is not used.

W5(R) Grid spacer length reverse (m, ft). Distance is from the center of the slab to the nearest grid or obstruction downstream. This quantity will be used when the liquid volume velocity is negative. This is used to get the boundary layer disturbance and atomization affect of a grid space in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 7) is 0, Word 5 is not used.

W6(R) Grid loss coefficient forward. Used for forward flow in rod bundles. This quantity is used when the liquid volume velocity is positive or 0. This is used only for CHF calculation.

W7(R) Grid loss coefficient reverse. Used for reverse flow in rod bundles. This quantity is used when the liquid volume velocity is negative. This is used only for the CHF correlation.

W8(R) Local boiling factor. Enter 1.0 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 0). 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. This number must be greater than 0.0.

W9(I) Heat structure number.

9.25 12-Word Format Additional Right Boundary, 1CCCG901-G999

These cards are required whenever the right boundary communicates energy with the right hand fluid volume, and Word 1 = 1 on card 1CCCG900. The cards are in sequential expansion format, twelve words per set, describing nh heat structures.

W1(R) Heat transfer hydraulic diameter (i.e., heated equivalent diameter) (m, ft). This is $4\left(\frac{\text{flow area}}{\text{heated perimeter}}\right)$ and is recommended to be greater than or equal to the volume hydraulic diameter since (heated perimeter) $\leq$ (wetted perimeter). It is possible to input this diameter to be less than the volume hydraulic diameter. If Word 1 equals 0.0, the volume hydraulic diameter is used.

W2(R) Heated length forward (m, ft). Distance is from the heated inlet to the center of this slab. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W3(R) Heated length reverse (m, ft). Distance is from the heated outlet to the center of this slab. This quantity will be used when the liquid volume velocity is negative. This is used to get the hydraulic entrance length effect. This is used only for the CHF correlation. It must be > 0. To ignore the length effect, put in a large number (i.e., $\geq$ 10.0).

W4(R) Grid spacer length forward (m, ft). Distance is from the center of this slab to the nearest grid or obstruction upstream. This quantity will be used when the liquid volume velocity is positive or 0. This is used to get the boundary layer disturbance and atomization effect of a grid spacer in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 6) is 0, Word 4 is not used.

W5(R) Grid spacer length reverse (m, ft). Distance is from the center of the slab to the nearest grid or obstruction downstream. This quantity will be used when the liquid volume velocity is negative. This is used to get the boundary layer disturbance and atomization affect of a grid space in rod bundles. This is used only for the CHF correlation. If the grid K loss (Word 7) is 0, Word 5 is not used.

W6(R) Grid loss coefficient forward. Used for forward flow in rod bundles. This quantity is used when the liquid volume velocity is positive or 0. This is used only for CHF calculation.

W7(R) Grid loss coefficient reverse. Used for reverse flow in rod bundles. This quantity is used when the liquid volume velocity is negative. This is used only for the CHF correlation.

W8(R) Local boiling factor. Enter 1.0 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 0). 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. This number must be greater than 0.0.

W9(R) Natural circulation length (m, ft). This should be the height of a hydraulic natural convection cell. For a heated vertical plate, this is the total height of the plate. For inside a horizontal tube, this should be the inside tube diameter. For the outer surface of vertical or horizontal bundles, it is suggested to use the heated bundle height in the vertical direction. When using the nine word format, this quantity is set to Word 1, the heat transfer hydraulic diameter.

W10(R) Rod or tube pitch-to-diameter ratio. The default is 1.1. The maximum is 1.6 ft. It is not used unless Word 3 on the 601 card is 110, 111, 114, or 135. If CANDU geometry (124 option on Card 1CCCG6XX) was selected, this value is the relative height of the fuel element, and its value should be within ± 1.0. Rod or tube pitch-to-diameter ratio (P/D). The default is 1.1. The maximum is 1.6. It is not used unless Word 3 on the 501 card is 110, 111, 114 or 135. If Helical geometry (114 option on 501 CARD)was selected, this value is Helical Circle Diameter-to-Tube Inner Diameter Ratio (Dc/di), and unlimited maximum value can be entered. If CANDU geometry (124 option on Card 1CCCG5XX) was selected, this value is the relative height of the fuel element, and its value should be within ± 1.0

W11(R) Fouling factor. This factor is applied to the heat transfer correlations and may be used to represent fouling or to run sensitivity studies. This quantity must be a positive nonzero number. When using the nine-word format, this quantity is set to 1.0.

W12(I) Heat structure number.

9.26 13-Word Format Additional Right Boundary, 1CCCG901-G999

These cards are required whenever the right boundary communicates energy with the right hand fluid volume, and Word 1 = 2 on card 1CCCG900. The cards are in sequential expansion format, thirteen words per set, describing nh heat structures.

W1(R) Not used, enter 0.0.

W2(R) Reduced heated length forward (m, ft). This is the product $(y \bullet T_a)$. The first term is the distance from the heated channel inlet to the point of the predicted CHFR when the liquid volume velocity is positive or 0. The second term is the ratio of average heat flux from the heated channel inlet to the axial coordinate y (m, ft), i.e., at the point of the predicted CHFR, to local heat flux q at y. Word 2 should be determined as follows:

$$y \bullet T_a = \frac{1.}{q(y)}\int_0^y q(z)dz \quad .$$

W3(R) Reduced heated length reverse (m, ft). This is the product $(y \bullet T_a)$. The first term is the distance from the heated channel outlet to the point of the predicted CHFR when the liquid volume velocity is negative. The second term is the ratio of average heat flux from the heated channel outlet to the axial coordinate y (m, ft), i.e., at the point of the predicted CHFR, to local heat flux q at y. Word 3 should be determined as follows:

$$y \bullet T_a = \frac{1.}{q(y)} \int_0^y q(z)dz \quad .$$

W4(R) Grid spacer factor forward. This should be input as follows:

If Word 12 = 11, 12, 21, 22, 31, 32, 41, or 42, i.e., CHFR for the tube or the internally heated annulus, then Word 4 must be input as W4 = 1.0.

If Word 12 = 13, 23, 33, or 43, i.e., CHFR for the rod bundle with vaneless grid spacers, then Word 4 should be input either as W4 = 1.0 / $\overline{R}$, if the statistical evaluation data for the rod bundles are available ($\overline{R}$ is the mean of variable R. R is the statistical random variable representing CHFR, i.e., predicted CHF to measured CHF ratio), or as W4 = 1.0, if the statistical evaluation data for the rod bundle are not available.

If Word 12 = 14, 24, 34, or 44, i.e., CHFR for the rod bundle with vane grid spacers, then Word 4 should be input as: W4 could be determined from statistical evaluation data of specific fuel design.

If Word 12 = 15, then W4 should be input as W4 = 1.0.

W5(R) Grid spacer factor reverse. This should be input as follows:

If Word 12 = 11, 12, 21, 22, 31, 32, 41, or 42, i.e., CHFR for the tube or the internally heated annulus, then Word 5 must be input as W5 = 1.0.

If Word 12 = 13, 23, 33, or 43, i.e., CHFR for the rod bundle with vaneless grid spacers, then Word 5 should be input either as W5 = 1.0 / $\overline{R}$, if the statistical evaluation data for the rod bundles are available ($\overline{R}$ is the mean of variable R. R is the statistical random variable representing CHFR, i.e., predicted CHF to measured CHF ratio), or as W5 = 1.0, if the statistical evaluation data for the rod bundle are not available.

If Word 12 = 14, 24, 34, or 44, i.e., CHFR for the rod bundle with vane grid spacers, then Word 5 should be input as: W5 could be determined from statistical evaluation data of specific fuel design.

If Word 12 = 15, then W5 should be input as W5 = 1.0.

W6(R) Factor of the radial heat flux distribution. This should be input as:

$$T_r = q\frac{\sum_i r_i}{\sum_i r_i q_i}$$

This is the ratio of local heat flux on referred perimeter to average heat flux on perimeters pertaining to the subchannel (or the annulus).

W7(I) Heated channel upstream hydrodynamic volume number. This refers to the hydrodynamic components which represents the inlet for the heated channel. This is to get the heated channel inlet quality in the case of forward flow direction.

W8(I) Heated channel downstream hydrodynamic volume number. This refers to the hydrodynamic components which represents the outlet for the heated channel. It applies when the flow reverses.

W9(R) Natural circulation length (m, ft). This should be the height of a hydraulic natural convection cell. For a heated vertical plate, this is the total height of the plate. For inside a horizontal tube, this should be the inside tube diameter. For the outer surface of vertical or horizontal bundles, it is suggested to use the heated bundle height in the vertical direction. When using the nine word format, this quantity is set to Word 1, the heat transfer hydraulic diameter.

W10(R) Rod or tube pitch-to-diameter ratio. The default is 1.1. The maximum is 1.6 ft. It is not used unless Word 3 on the 601 card is 110, 111, 114, or 135. If CANDU geometry (124 option on Card 1CCCG6XX) was selected, this value is the relative height of the fuel element, and its value should be within ±1.0

W11(R) Fouling factor. This factor is applied to the heat transfer correlations and may be used to represent fouling or to run sensitivity studies. This quantity must be a positive nonzero number. When using the nine-word format, this quantity is set to 1.0.

W12(I) CHFR correlation option. This is input in mn format. The first digit specifies the CHFR correlation form.

If m = 1, then the basic form of PG CHFR correlation is used.

If m = 2, then the flux form of the PG CHFR correlation is used.

If m = 3, then the geometry form of PG CHFR correlation is used.

If m = 4, then the power form of PG CHFR correlation is used.

The second digit specifies the geometry of heated structure. If this is the rod bundle, it specifies if and how the statistical evaluation data are applied for the grid spacer factor (see Word 4 and Word 5).

If n = 1, then this is the tube.

If n = 2, then this is the internally heated annulus.

If n = 3, then this is the rod bundle. The use of an isolated subchannel model is recommended. This is used if the applicable PG CHFR correlation statistical evaluation data are not available.

If n = 4, then this is the rod bundle. The use of an isolated subchannel model is recommended. An extended use of the PG CHFR statistical evaluation data is enabled.

If n = 5, then this is the rod bundle. This is only used in combination with m = 1. Applicable for a subchannel code respecting lateral mixing.

W13(I) Heat structure number.

10 HEAT STRUCTURE THERMAL PROPERTIES

These cards are used in NEW or RESTART problems. These cards are required if cards 1CCCGXNN, Heat Structure Input cards, Section 9 are entered. These data, if present, are processed and stored even if no cards 1CCCGXNN 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 1CCCG201-1CCCG299 correspond to this subfield. A set of cards 201MMMNN 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.

10.1 Composition Type and Data Format, 201MMM00

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. At present, the data are primarily to demonstrate capability. The user should check whether the data are satisfactory.

If a user-supplied table or function is to be used, enter TBL/FCTN for this word.

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 only volumetric heat capacities is to be entered and the temperature values are identical to the thermal conductivity table.

Enter 1 if a table containing temperature and volumetric heat capacity is to be entered.

Enter 2 if functions are to be entered.

10.2 Constant Thermal Conductivity, 201MMM01-49

One of these cards is required if W1 of card 201MMM00 contains TBL/FCTN, W2 of contains a 1, and the thermal conductivity is constant for all temperatures.

W1(R) Constant thermal conductivity (W/m•K, Btu/s•ft•^{o}F).

10.3 Temperature-Thermal Conductivity, 201MMM01-49

These cards are required if W1 of card 201MMM00 contains TBL/FCTN and W2 of contains a 1. In this case, the thermal conductivity varies with temperature, so the user has to enter pairs of temperatures and thermal conductivities. More than one pair can be entered on a single card. The total number of pairs is limited to 100. The temperatures must be in increasing order. The first and last temperatures must bracket the expected temperatures during the calculation. A code failure will occur if the calculated material temperature is outside the bracketed range.

W1(R) Temperature (K, ^{o}F).

W2(R) Thermal conductivity (W/m•K, Btu/s•ft•^{o}F).

10.4 Thermal Conductivity Function, 201MMM01-49

These cards are required if W1 of card 201MMM00 contains TBL/FCTN and W2 contains a 2. Sets of nine quantities are entered, each set containing one function and its range of application. The function is

k = A0 + A1*TX + A2*TX**2 + A3*TX**3 + A4*TX**4+ A5*TX**(-1)

where TX = T - C, T is the temperature argument, and C is a constant. 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, ^{o}F).

W2(R) Upper limit temperature (K, ^{o}F).

W3(R) A0 (W/m•K, Btu/s•ft•^{o}F).

W4(R) A1 (W/m•K^2, Btu/s•ft•^{o}F^2).

W5(R) A2 (W/m•K^3, Btu/s•ft•^{o}F^3).

W6(R) A3 (W/m•K^4, Btu/s•ft•$^oF^4$).

W7(R) A4 (W/m•K^5, Btu/s•ft•$^oF^5$).

W8(R) A5 (W/m, Btu/s•ft).

W9(R) C (K, ^{o}F).

10.5 Gap Mole Fraction, 201MMM01-49

These cards are required if W1 of card 201MMM00 contains TBL/FCTN and W2 contains a 3, Enter pairs of gas component names and mole fractions. More than one pair can be entered on a single card. 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.

W1(R) Gas name. Possible names include HELIUM, ARGON, KRYPTON, XENON, NITROGEN, HYDROGEN, and OXYGEN.

W2(R) Mole fraction.

10.6 Volumetric Heat Capacity, 201MMM51-99

These cards are required if W1 of card 201MMM00 contains TBL/FCTN and W3 contains a -1. The card numbers need not be consecutive. More than one value can be entered on a single card. Since this format assumes the temperatures are identical to the values in the temperature-thermal conductivity table, only the volumetric heat capacities need be entered. The number of entries must be the same as the number of pairs in the temperature-thermal conductivity table, which is limited to 100.

W1(R) Volumetric heat capacity (J/m^3K, Btu/ft^3 ^{o}F). This is ρC_p, where ρ is density (kg/m^3, lb/ft^3) and C_p is specific heat capacity (J/kg·K, Btu/lb·^{o}F).

10.7 Constant Volumetric Heat Capacity, 201MMM51-99

One of these cards is required if W1 of card 201MMM00 contains TBL/FCTN, W2 of contains a 1, and the volumetric heat capacity is constant for all temperatures.

W1(R) Constant volumetric heat capacity (J/m^3K, Btu/ft^3 ^{o}F). This is ρC_p, where ρ is density (kg/m^3, lb/ft^3) and C_p is specific heat capacity (J/kg·K, Btu/lb·^{o}F).

10.8 Temperature-Volumetric Heat Capacity, 201MMM51-99

These cards are required if W1 of card 201MMM00 contains TBL/FCTN and W3 contains a 1. The card numbers need not be consecutive. More than one pair can be entered on a single card. Since the volumetric heat capacity varies with temperature, enter pairs of temperatures and volumetric heat capacities. More than one pair can be entered on a single card. The total number of pairs is limited to 100. The temperatures must be in increasing order. The first and last temperatures must bracket the expected temperatures during the calculation. A code failure will occur if the calculated material temperature is outside the bracketed range.

W1(R) Temperature (K, ^oF).

W2(R) Volumetric heat capacity (J/m^3K, $Btu/ft^3\ ^oF$). This is ρC_p, where ρ is density (kg/m^3, lb/ft^3) and C_p is specific heat capacity ($J/kg{\cdot}K$, $Btu/lb{\cdot}{}^oF$).

10.9 Volumetric Heat Capacity Function, 201MMM51-99

These cards are required if W1 of card 201MMM00 contains TBL/FCTN and W3 contains a 2. The card numbers need not be consecutive. Sets of nine quantities are entered, each set containing one function and its range of application. More than one set can be entered on a single card. The function is

ρc_r = 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, ^oF).

W2(R) Upper limit temperature (K, ^oF).

W3(R) A0 ($J/m^3\ K$, $Btu/ft^3\ ^oF$).

W4(R) A1 ($J/m^3\ K^2$, $Btu/ft^3\ ^oF^2$).

W5(R) A2 ($J/m^3\ K^3$, $Btu/ft^3\ ^oF^3$).

W6(R) A3 ($J/m^3\ K^4$, $Btu/ft^3\ ^oF^4$).

W7(R) A4 ($J/m^3\ K^5$, $Btu/ft^3\ ^oF^5$).

W8(R) A5 ($J/m^{3\cdot}$, Btu/ft^3).

W9(R) C (K, ^oF).

11 RADIATION HEAT TRANSFER

Most of the MARS-KS variables for the radiation heat transfer model are stored in the "rstplt"" file. Thus, a restart calculation with the same radiation heat transfer input is possible using the "rstplt" file of the previous run. A complete change of the radiation heat transfer input is also allowed in "restart" calculations. However, "partial" changes of the radiation heat transfer input are not allowed in "restart" calculations.

11.1 CARD 70000000, Radiation Heat Transfer Model Control Card

Any heat structure may radiate or contact 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 and contact. 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.

11.2 Card 7SS00000, Radiation Set Card

SS is the set number. One of these cards must be input for each radiation 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 heat slabs (surfaces) that participate in radiation heat transfer in set SS. The maximum is 99.

W2(R) Minimum temperature, trmin (K, ^{o}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.

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.

11.3 Cards 7SSNN001 through 7SSNN099, 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 CCCG0ZZ, 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.

11.4 Cards 7SSNN101 through 7SSNN199, 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/contact surface number to which NN radiates or contacts. Repeat the above two words until view factors to all nhr surfaces from all surfaces are entered. Sequential expansion is used.

12 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 that is 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.

12.1 Table Type and Multiplier Data, 202TTT00

W1(A) Table type.In RESTART problems, DELETE can be entered to delete general table TTT. For non restart problems, the names in the following table can be used.

Table 12.1-1 Types of General Tables

Table Type	Quantity in Table
POWER	Power versus time
HTRNRATE	Heat flux versus time
HTC-T	Heat transfer coefficient versus time
HTC-TEMP	Heat transfer coefficient versus temperature
TEMP	Temperature versus time
REAC-T	Reactivity versus time or Control system variable versus time (prevents undesirable unit conversion)
NORMAREA	Normalized area versus normalized stem position

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 flux, heat transfer coefficient, normalized stem position, and normalized area; a multiplier and additive constant are used for temperature as T = M*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. Note that the temperature can be either the argument (HTC-TEMP table type) or the function (TEMP table type). When factors are used for a table involving temperature as the argument, the first two factors apply to the temperature. The second and third factors apply to the temperature when temperature is the function.

W2(I) Table trip number. This number is optional unless factors are entered. If missing or 0, no trip is used, and the time argument in the following table is the time supplied to the table for interpolation. If nonzero, the number is the trip number, and the time argument in the following table 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 0 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.

12.2 General Table Data, 202TTT01-99

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, ^oF, if temperature; dimensionless, if normalized stem position).

W2(R) Function value (W, MW, if power; K, ^oF, if temperature; W/m^2, $Btu/s{\bullet}{\bullet}ft^2$, if heat flux; $W/m^2{\bullet}K$, $Btu/s{\bullet}ft^2$,^oF, 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.

13 PLOT REQUESTS, 20300000-203499999

The plotting capability that was built into RELAP5 is not currently active. Besides not being converted to machine-dependent form from the original CDC-7600 version, a proprietary plotting package was required. Users can 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 or they can use the XMGR5 interactive plotting program that is distributed with RELAP5.

The plotting capability is provided for 2D map, contour line, and vector window plot. 3D vector and scalar plot capabilities also provided using OpenGL graphic library. This plot option card is valid for Windows system.

13.1 Card 20300000, Plot Identification Card

This card is required.

W1(I) total number of plot windows

13.2 Card 203nnn00, Plot Type Information Card

W1(A) graphic type

line : 2D contour line plot

bitmap :2D contour map plot

vectmap : 2D rectangle geometry map

hexamap : 2D hexagonal geometry map

grapmap : 2D graphic geomtery map

vector : 2D vector plot

surf3d : 3D surface plot

vector3d: 3D vector plot

scalar3d : 3D scalar bitmap plot

W2(A) 1D module or 3D module : "1D" if 1D module variables, "3D" if 3D module variables, bitmap file name if graphic type is grapmap

W3(A) alphabetic name of requesting variables

W4(R) minimum value of plot (BLUE color)

W5(R) maximum value of plot (RED color)

W6(I) numbers of X-grid point (NX)

W7(I) numbers of Y-grid point (NY)

W8(I) numbers of Z-grid point (NZ) if 3D vector and scalar graph is requested.

skip factor of color if Bitmap graph is requested (Default = 3).

number of Lines if line graph is requested (Default = 16).

selection number of 2D vector plane if MULTID vector graph is requested (Default = 3: z-y(θ) plane). If this value is 1, x-y(θ) plane is selected. And if 3, z-y(θ) plane. And if 5, z-x plane is selected

13.3 Card 203nnn01 ~ 203nnn99, Plot Request Information Card

W1(I) numeric part of requesting variables

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WN(I) numeric part of requesting variables

The sequence of data should be arranged to X-grid first. Total number of variables must be same as define in Card 203nnn00:

N = NX*NY for 2D graph, NX*NY*NZ for 3D graph

14 CONTROL SYSTEM

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 205CCCNN allows 999 control variables, where CCC ranges from 001-999. The card format 205CCCCN allows 9999 control variables, where CCCC ranges from 1-9999.

If the self-initialization option is selected, the data cards described in Section 14.3.19, Section 14.3.20, and Section 14.3.21 must be included. If loop flow control is to be included, the data cards described in Section 14.3.19 must also be included.

14.1 Control Variable Card Type, 20500000

If this card is omitted, card type 205CCCNN 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) Enter 999 to select the 205CCCNN format or 9999 (4095 also allowed) to select the 205CCCCN format.

14.2 Control Component Type, 205CCC00 or 205CCCC0

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, FEEDCTL DIGITAL, or the command, DELETE. If DELETE is entered, enter any alphanumeric word in Word 1 and zeros in Words 3-8. No other control system cards are needed when DELETE is entered.

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-CCC09 or

205CCCC1-CCCC9 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. 0 means no initial condition calculation and W4 is used as the initial condition; 1 means compute initial condition.

W6(I) Limiter control. Enter 0, 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.

W9(A) ’1D’ or ’3D’. If not entered, this value is assumed as ’1D’.

14.3 Control Component Data, 205CCC01-CCC98 or 205CCCC1-CCCC8

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,...,J, represent constants defined by the control component input data. The variables V_j, j = 1,2,...,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.

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

$$Y = S(A_0 + A_1V_1 + A_2V_2 + \ldots + A_jV_j) \ .$$

W1(R) Constant A_0.

W2(R) Constant A_1.

W3(A) Alphanumeric name of variable request code for V_1.

W4(I) Integer 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 2-4 can be entered for additional product terms up to twenty 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.

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

$$Y = SV_1V_2...V_j \ .$$

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.

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

$$Y = \frac{S}{V_1} \quad \text{or} \quad Y = \frac{SV_2}{V_1}$$

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 0 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.

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

$$Y = S\frac{dV_1}{dt} \quad .$$

This is evaluated by

$$Y = \frac{2S}{\Delta t}(V_1 - V_{10}) - Y_o \qquad \text{(DIFFERENI)}$$

$$Y = S\frac{(V_1 - V_{10})}{\Delta t} \qquad \text{(DIFFREND)}$$

where Δt is the time step, and V_{10} and Y_0 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 and is not consistent with the integration approximation, but does not require an initial value. For these reasons, 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.

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,

$$Y(s) = \frac{SV_1(s)}{s} \quad .$$

This is evaluated by

$$Y = Y_o + S \bullet (V_1 + V_{10})\frac{\Delta t}{2}$$

where Δt is the time step and Y_o and V_{10} are 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.

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 that is 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.

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

$Y = S[\text{FNCTN}(V_1, V_2, ...)]$

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 twenty 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.

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 $\leq$ 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 $d_{TM} = \frac{t_d}{h}$. 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_dT or d_{TM} relative to the time steps on cards 2NN. When a change in advancement time is made at a restart, the time values in this table are changed to have time values as if the problem in the restart had run to the new advancement time.

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

$$Y = S \bullet U(\pm T_1)$$

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. A minus sign may prefix the trip number to indicate that the complement of the trip is to be used.

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

$$Y = ST_{rptim}\,(T_1)$$

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 0 or a positive number.

W1(I) Trip number, T_1.

14.3.11 Integer Power Component

This component is indicated by POWERI in Word2 of card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1^{I} \ .$$

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.

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

$$Y = SV_1^{R} \ .$$

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.

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

$$Y = SV_1^{V_2} \quad .$$

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.

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

$$Y = S[A_1V_1 + A_2\int_0^t V_1 dt]$$

or in Laplace transform notation,

$$Y(s) = S\left[A_1 + \frac{A_2}{s}\right]V_1(s) \quad .$$

If the control variable is initialized,

$$Y(t_0) = SA_1V_1(t_0) \quad .$$

If it is desired that the output quantity Y remain constant as long as the input quantity remains constant, V_1 must initially be 0 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.

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,

$$Y(s) = \frac{S}{1 + A_1 s} V_1(s) \quad .$$

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, 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.

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,

$$Y(s) = S \frac{1 + A_1 s}{1 + A_2 s} V_1(s) \quad .$$

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, Y remains constant as long as V_1 retains its initial value.

W1(R) Lead time, A_1 (s).

W2(R) Lag time, A_1 (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.

14.3.17 Constant Component

Cards 205CCC01-CCC09 or 205CCCC1-CCCC9 are not entered. The quantity in Word 3 of card 205CCC00 or 205CCCC0 is the constant value used for this component.

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 that are 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.

14.3.18.1 Shaft Description, 205CCC01-CCC05 or 205CCCC1-CCCC5.

W1(I) Torque control variable number. If 0, 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_i (kg•m^2, lb•ft^2).

W3(R) Friction factor for the shaft, f_i (N•m•s, lb_f•ft•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 ten components. Only one generator, the one which is defined as part of this SHAFT component, may be attached.

14.3.18.2 Generator Description, 205CCC06 or 205CCCC6. 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 (kg•m^2, lb•ft^2).

W4(R) Friction factor, f_i (N•m•s, lb_f•ft•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 0, 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.

14.3.19 PUMPCTL Component

This component is specified when using the self-initialization option and loop flow control is desired, but it is not limited to that use. For each PUMPCTL component enter:

W1(A) Alphanumeric name of setpoint variable.

W2(I) Parameter part of setpoint variable.

W3(A) Alphanumeric name of sensed variable.

W4(I) Parameter part of sensed variable.

W5(R) 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 (setpoint) flow rate. W3 is MFLOWJ, and W4 is the junction number at which the flow is to be sensed and compared to the setpoint. W5 is the S_i value used to divide the difference between the desired (setpoint) and sensed flow rate to produce the error signal E_1. E_1 must be initially 0 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.

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 it is not limited to that use. For each STEAMCTL component enter:

W1(A) Alphanumeric name of setpoint variable.

W2(I) Parameter part of setpoint variable.

W3(A) Alphanumeric name of sensed variable.

W4(I) Parameter part of sensed variable.

W5(R) Scale factor(s) applied to sensed and setpoint 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 (setpoint) 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 (setpoint) 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 0 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.

14.3.21 FEEDCTL Component

This component is specified when using the self-initialization option to control feedwater flow to a steam generator, but it is not limited to that use. For each FEEDCTL component enter:

W1(A) Alphanumeric name of first setpoint variable.

W2(I) Parameter part of first setpoint variable.

W3(A) Alphanumeric name of sensed variable to be compared with first setpoint.

W4(I) Parameter part of sensed variable to be compared with first setpoint.

W5(R) Scale factor applied to sensed and setpoint values (first setpoint), S_k. Must be nonzero.

W6(A) Alphanumeric name of second setpoint variable.

W7(I) Parameter part of second setpoint variable.

W8(A) Alphanumeric name of sensed variable to be compared with second setpoint.

W9(I) Parameter part of sensed variable to be compared with second setpoint.

W10(R) 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 (setpoint) 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 (setpoint) 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 0 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.

14.3.22 DIGITAL Component

This component is indicated by DIGITAL in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1 f\{t_s\}(t - t_d)$$

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) Sampling time, t_s (s).

W4(R) Delay time, t_d (s).

15 CARDS 2200000, CONTAINMENT INPUT

These cards are used optionally in NEW and RESTART problems when containment function is desired. If these cards exist, the CONTEMPT4/MOD5/PCCS (CONTL.DLL) module or CONTAIN 2.0 (contain20.dll) module, is loaded dynamically. If this card is omitted, the containment function is deactivated and containment data should not be entered.

15.1 Card 22000000, Control Card

W1(A) contempt or contain.

If you choose contempt, contl.dll will be loaded and CONTEMPT4/MOD5 module is used. If you choose contain, contain20.dll will be loaded and CONTAIN 2.0 module is used.

W2(A) new or restart

Restart function was not provided yet. If you want to run after system steady calculation, use 'new' option in the start of initial transient calculation

15.2 Card 22000001 ~ 22000099, Volume Linkage Identification Card

W1(I) volume identification number of time-dependent volume for containment

W2(I) compartment number of containment

The number of card should be total number of connections between system and containment

15.3 CHANGED PART FOR CONTAINMENT CODE INPUT

These cards are used for "inputc" file data of CONTEMPT4/MOD5/PCCS code. In unified calculation, the file names have been fixed by follows and cannot be changed by user.

Function File name

Input : inputc

Output : outputc

Plot: plotflc

Screen: screenc

15.3.1 Card 1000501, Tagami Boundary Condition Card

W1(A)	time unit
W2(R)	TPEAK
W3(I)~W5(I)	Single transaction table number
W5(A)	heat transfer coefficient unit
W6(A)	blowdown energy unit
W7(R)	Total blowdown energy

15.3.2 Card 1YY1100 , Boundary Condition Card

W1(I)	ISHL : Heat Transfer Control for Nominal Left Boundary
	= 53 : Tagami Model
	= 70 : Almenas Correlation
W2(I)	ISTL
W3(I)	ISHR : Heat Transfer Control for Nominal Right Boundary
	= 53 : Tagami Model
	= 70 : Almenas Correlation
W4(I)	ISTR

16 REACTOR KINETICS

These cards are required if a space-independent (point) reactor kinetics or a nodal 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.

16.1 Reactor Kinetics Type, 30000000

This card is required. Read in by rrkin.

W1(A) Kinetics type. Enter POINT or DELETE. Enter POINT for the point reactor 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, TABLE3A, or TABLE4A. If Word 2 is not entered, a default value is assumed. If the kinetics type is POINT, the default is SEPARABL. If SEPARABL is entered, reactor kinetics feedback due to moderator density, void fraction weighted moderator temperature, and fuel temperature is assumed to be separable, and feedback data are entered on cards 30000501-0899. If SEPARA3D is entered, reactor kinetics feedback due to 3D volume moderator and fuel temperature is assumed. IF SEPARA3M is entered, reactor kinetics feedback due to 3D volume moderator and 1D fuel is assumes.If TABLE3, TABLE4, TABLE3A, or TABLE4A is entered, reactivity is obtained from a table defining reactivity as a function of three or four variables using cards 30001001-2999. If TABLE3 or TABLE4 are entered, the variables are moderator density, void fraction weighted moderator temperature, fuel temperature, and boron density. If TABLE3A or TABLE4A is entered, the variables are void fraction, liquid moderator temperature, volume average fuel temperature, and boron concentration. If TABLE3 or TABLE3A is entered, the first three of the variables in one of the sets defined above are used, and if TABLE4 or TABLE4A is entered, all four variables are used.

16.2 Reactor Kinetics Information, 30000001

Read in by rrkin.

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. This must be > 0.0. If SEPARA3D or SEPARA3M is entered, this value is meaningless. Then the total power is given by the 3D input convention.

W3(R) Initial reactivity (dollars). This quantity must be less than or equal to 0.0. It is recommended that this quantity be less than or equal to -1.0E-60; otherwise, the CPU time may increase dramatically.

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.

W7(R) Fissions per initial fissile atom, ψ. Used in factor G(t) [$= 1.0 + (3.24 \cdot 10^{-6} + 5.23 \cdot 10^{-10} t) T^{0.4} \psi$] to account for neutron capture in fission products when using ANS79-1 or ANS79-3 option. Entering this quantity as a nonzero includes the G factor as part of the decay heat. The factor is not included if this quantity is not entered or is entered as 0. Entering this word as a positive quantity indicates that the equation is to be used for shutdown time up to 10^4 seconds, and the table is to be used from that time on. Entering this word as a negative number indicates that the table is to be used for all shutdown times. Note that there is a discontinuity in G(t) when switching between and equation and the table. The standard indicates that the table can be used for all shutdown times and that would result in a higher neutron absorption capture effect. The magnitude of this quantity if nonzero must be greater than or equal to 1.0 and less than or equal to 3.0.

W8(R) Reactor operating time T. This quantity is the T in the expression given in W7 above. The unit for this quantity is given in the next word. If not entered or entered as 0, this quantity defaults to 52 wk. This quantity is used only if the power history data in Section 16.7 are not entered. When the power history data are entered, the reactor operating time is obtained from that data. When the power history data are not entered, an infinite operating time is assumed in initializing the decay heat variables, and if the equation form of G(T) is being used, the quantity in this word is used with the shutdown period t set to 0 to determine the G factor at the start of the simulation. The limit for this quantity is $1.2614 \cdot 10^8$ seconds.

W9(A) Units for W8 above. Must be sec, min, hr, day, wk.

W10(R) Differential boron worth in \$/ppm. This value is normally given in core design reports in units of pcm/ppm. The abbreviation pcm stands for per cent mille or 10^{-5} of $(\Delta k)/k$, while dollars are measured in units of the delayed neutron fraction, $\$ = (\Delta k)/(k\beta)$.

16.3 Fission Product Decay Information, 30000002

This card is optionally entered for POINT 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. Read in by rrkin.

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. ANS2005 specifies the 2005 ANS Standard data for the four isotopes, ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu. ANS79-3 and ANS2005 also require that power fractions for each isotope must be entered. If fission product data are entered, ANS73 and ANS79-1 specify only one isotope. ANS79-3 specifies three isotopes and ANS2005 specifies four isotopes. Both ANS79-3 and ANS2005 require the number of decay heat groups for each isotope be entered.

W2(R) Energy release per fission (MeV/fission). If not entered or 0, the default value of 200 MeV/fission is used.

If using ANS79-3 Data:

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 1.0.

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 less than or equal to 50.

If using ANS94-4 Data:

W3-W6(R) If ANS94-4 is specified in W1, the fraction of power generated in ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu must be entered in these four words. The sum of the fractions must add to one.

W7-W10(I) Number of groups per isotope. If ANS94-4 is entered in W1 and default data are not being used, the number of decay groups for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu must be entered in these words. The number of groups for each isotope must be less than or equal to 50.

16.4 Delayed Neutron Constants, 30000101-0199

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. Read in by rrkin.

W1(R) Delayed neutron precursor yield ratio.

W2(R) Delayed neutron decay constant (s^{-1}).

16.5 Fission Product Decay Constants, 30000201-0299

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 30000101-0199. The factor in W5 of card 30000001 is applied to the yield fractions. Read in by rrkin.

W1(R) Fission product yield fraction.

W2(R) Fission product decay constant (s^{-1}).

16.6 Actinide Decay Constants, 30000301-0399

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. Read in by rrkin.

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}).

16.7 Power History Data, 30000401-0499

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 0 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. Read in by rrkin.

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 0.

W2(R) Time duration. Units are as given in next word. This quantity must be ≥ 0.

W3(A) Time duration units. Must be sec, min, hr, day, or wk.

W4-W7(R) Power fractions. If ANS79-3 or ANS94-4 is entered in W1 of Card 30000002, enter the power fractions for ^{235}U, ^{238}U, and ^{239}Pu in Words 4, 5, and 6. W7 is not entered if using ANS79-3

If ANS94-4 is entered in W1 of Card 30000002, enter the power fractions for ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu in Words 4, 5, 6, and 7.

16.8 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 0.

16.8.1 Reactivity Curve or Control Variable Numbers, 30000011-0020

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. Read in by rrkin.

W1(I) Table or control variable number. Up to 20 numbers may be entered. Numbers from 1-999 indicate general table numbers. Numbers greater than 10000 indicate the control variable whose number is the entered number minus 10000.

16.8.2 Density Reactivity Table, 30000501-0599

This table is required if the SEPARABL option is being used and if cards 30000701-0709 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. The table uses linear interpolation for segments between table search argument values. For search arguments beyond the range of entered data, the end-point values are used. Read in by rrkinp.

W1(R) Moderator density (kg/m^3, lb/ft^3).

W2(R) Reactivity (dollars).

16.8.3 Doppler Reactivity Table, 30000601-0699

This table is required if the SEPARABL option is being used and if cards 30000801-0899 are entered. One or more pairs of numbers are entered to define Doppler reactivity as a function of volume-averaged fuel temperature. Heat structure composition data cards 1CCCG201-9 need to exclude the gap and the cladding for the volume-average fuel temperatures. Data are entered one or more pairs per card, and card numbers need not be consecutive. Up to 100 pairs may be entered. The table uses linear interpolation for segments between table search argument values. For search arguments beyond the range of entered data, the end-point values are used. Read in by rrkinp.

W1(R) Temperature (K, ^oF).

W2(R) Reactivity (dollars).

16.8.4 Volume Weighting Factors, 30000701-0799

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 due to 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, $W_{\rho i}$. See Volume 1 of this manual for a discussion of the symbols.

W4(R) Water temperature coefficient, a_{Wi} (dollars/K, dollars/^oF). As defined in Volume 1, the weighting factor in Word 3 is not applied to this quantity.

16.8.5 Heat Structure Weighting Factors, 30000801-0899

These cards are used only if the SEPARABL option is being used and are omitted if no reactor kinetics feedback from heat structures are present. Each card contains the input for reactivity feedback due to conditions in one or more heat structures representing fueled portions of the reactor. Data are entered in a manner similar to cards 30000701-0799. Read in by rrkinp.

For each heat structure specified on these cards, input on the heat structure data cards 1CCCG2NN must define the fueled region as the region over which the volume-average temperature is computed.

Usually, either Word 3 or 4 is 0.

W1(I) Heat structure number.

W2(I) Increment.

W3(R) Weighting factor for doppler feedback, W_{Fi}.

W4(R) Fuel temperature coefficient, a_{Fi} (dollars/K, dollars/^{o}F). As defined in Volume 1, the weighting factor in Word 3 is not applied to this quantity.

16.8.6 Volume-Weighting Factors, 30001701-1799

These cards are used only if the TABLE3, TABLE3A, TABLE4, or TABLE4A option is being used. Each card contains the weighting factor for reactivity feedback due to moderator density (void fraction), void weighted moderator temperature (liquid moderator temperature), and spatial boron density (boron concentration) in one or more hydrodynamic volumes. The quantities preceding the quantities within parentheses are used if TABLE3 or TABLE4 has been entered; the quantities within parentheses are used if TABLE3A or TABLE4A has been entered. 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 16.8.4. Read in by rrkinp.

W1(I) Hydrodynamic volume number.

W2(I) Increment.

W3(R) Weight factor, $W_{\rho i}$.

16.8.7 Heat Structure Weighting Factors, 30001801-1899

These cards are used only if the TABLE3, TABLE 3A, TABLE4, or TABLE4A option is being used. Each card contains the weighting factor for reactivity feedback due to temperature in one or more heat structures. At least three quantities must be entered on each card. The use of the increment field is similar to that in Section 16.8.4. Read in by rrkinp.

W1(I) Heat structure number.

W2(I) Increment.

W3(R) Weight factor, W_{Fi}.

16.8.8 Feedback Table Coordinate Data, 300019C1-19C9

If the TABLE3 or TABLE3A option is being used, the feedback table is a function of three variables: moderator density or void fraction (C = 1), void weighted moderator temperature or liquid moderator temperature (C = 2), and fuel temperature (C = 3). If the TABLE4 or TABLE4A option is being used, the feedback table is a function of four variables: the three above and spatial boron density or boron concentration (C = 4). Which variables are used depend on the feedback option used (see W2, card 30000000 in Section 16.1). 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 twenty points may be entered for each variable. The table uses multi-dimensional interpolation for values between table coordinate values. For values beyond the range of the entered coordinate values, the end-point coordinate values are used. 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. Read in by rrkinp.

W1(R) Coordinate value (kg/m^3, lb/ft^3 for moderator and spatial boron densities; K, ^{o}F for moderator and heat structure temperatures; void fractions and boron concentrations are dimensionless).

16.8.9 Feedback Table Data, 30002001-2999

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. Read in by rrkinp.

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 or void fraction, mm refers to void weighted moderator temperature or liquid moderator temperature, ff refers to heat structure temperature, and bb refers to spatial boron density or boron concentration. 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. (A future version may allow gaps that are filled in by interpolation.)

W2(R) Table value.

17 GRID MODEL

These cards are required if the KINS grid model is desired.

17.1 Basic Input, 43000000

This card is required. It is read in by subroutine W1rgrid. The presence of this card activates the grid model.

W1(A) NGRID, the number of grid information cards to be input. Must be less than or equal to 20 (maxgrd parameter in /grid/definition).

W2(R) Fuel rod pitch (m, ft)

W3(R) Fuel rod diameter (m, ft)

W4(R) Grid material density (kg/m^3, lbm/ft^3)

W5(I) Grid material property number. Must be material number that is defined in the input.

17.2 Grid Information, 43000XX00

Currently, the value of XX must be less than 21.

W1(R) Grid material thickness (m, ft)

W2(R) Height of the grid (m, ft). Distance from the bottom of the grid to the top.

W3(R) Grid flow blockage (-). The ratio of the flow area in the grid and upstream flow area.

W4(R) Axial location of the bottom of the grid (m, ft)

W5(I) The hydrodynamic cell number where the grid is located (CCCXX0000)

W6(I) The heat structure node whose heat transfer is affected by the grid (CCCGXXXYY). CCCG is the HS-geometry number, XXX is the HS axial node number, and YY is the radial mesh point number.

W7(I) Number of fuel rods associated with this grid (-).

18 VESSEL COMPONENT INPUT DATA

This chapter describes input data card requirements for the problems allowed in the 3-D Vessel part of MARS-KS code.

18.1 CARD 60000000, Main Problem Control Data

The three words can be entered on this card.

W1(I)	init	Enter the vessel initialization option. Valid entries are:
		0 = initial start with automatic initialization of the 3D module.
		1 = initial start without automatic initialization of the 3D module.
		2 = initial start without automatic initialization of the 3D module.
		Card 61600NNN should be entered, which are used to specify initial void fractions of the 3D cells.
		4 = fill vessel arrays with data obtained from a restart file
W2(I)	dstep	Enter the time step number of the dump to be used for restarting.
		Enter zero(0) if this is not a restart.
W3(R)	timet	Enter the restart time for the problem.
		Enter zero (0.0) if this is not a restart.

18.2 CARDS 60000101 THROUGH 60000199, Plot File 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.

W1(A)	Variable code (alphanumeric).
W2(I)	Parameter (numeric).

W3(R) Minimum Y Value for X-Y Plot (Optional Select for Window Plotting).

W4(R) Maximum Y Value for X-Y Plot (Optional Select for Window Plotting).

W5(I) Window Identification for multiple X-Y Plot.

W6(I) Color Pallet Identification for multiple X-Y Plot.

Words 1 and 2 form the variable request code pair. The quantities that can be edited and the input required 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 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. The quantities are listed in alphabetical order within each section.

18.2.1 Channel/Node Quantities

The quantities listed below are unique to certain components; for example, three-digit number ccc used for channel number and xx for node number in the input cards (for cccxx0000 numeric field)

AE Entrained liquid volume fraction.

AL Vapor volume fraction.

ALIQ Liquid volume fraction.

FEM Vertical entrained liquid momentum flow.

FGM Vertical vapor momentum flow.

FLM Vertical liquid momentum flow.

GAMA Vapor generation rate

P Old time pressure

HL Liquid enthaphy.

HV Vapor enthaphy.

RL Liquid density.

RV Vapor density.

PMGAS Gas partial pressure.

RMGAS Gas density.

QCHFF Cell critical heat flux

QLIQ Heat transfer rate to liquid

QVAP Heat transfer rate to vapor

TEMP_F Liquid temperature

TEMP_G Vapor temperature

QUALF Flow quality

18.2.2 Heat Rod Quantities

The quantities listed below are unique to certain components; for example, three-digit number mmm used for rod number, and 0nn for node number from the bottom of 3D model, and rr for radial mesh number in input card (for mmm0nnrr numeric field) If radial mesh is not available, then use final 2 digit as null number, i.e. mmm0nn00.

TROD Rod mesh temperature

XC Axial node elevation for each rod.

QROD Heat Flux for each rod at certain node.

HTCL Heat Transfer Coefficient to the liquid

HTCV Heat transfer coefficient to vapor

TLIQ Liquid temperature seen by rod

TVAP Vapor temperature seen by rod

TFAVG Fuel temperature averaged radially over pellet and axially over fluid node.

18.2.3 Channel Quantities

The quantities listed as unique to a certain component; for example, three digit number ccc used for channel number:

LVL_LIQ Collapsed liquid level for a channel

18.2.4 Gap Qualtities

WGM Vapor mass flow rate in transverse momentum cell

WEM Entrained liquid mass flow rate in transverse momentum cell

WLM Liquid mass flow rate in transverse momentum cell

18.3 Calculation Variables and Initial Conditions

In case of a 'restart problem', following data cards are skipped.

18.3.1 CARD 60100000, Fluid Initial Condition Card

The seven words have to be entered on this card.

W1(R) pref Enter the initial 3D region operating pressure (psi or N/m^2).

W2(R) hin Enter the temperature for fluid initialization (^{o}F or K).

W3(R) gin Enter the vertical mass velocity for flow initialization.(lbm/ft^{2}sec or kg/m^{2}sec).

W4(R) aflux Enter the average linear heat rate per active rod (kW/ft or kW/m).

W5(R) vfrac(1) Volume fraction of liquid

W6(R) vfrac(2) Volume fraction of vapor in gas mixture

W7(R) rbsf Rod bundle scaling factor. Enter 1.0 for ideal subchannel

18.3.2 CARD 60110000, Noncondensible Gas

W1(I) ngas Number of noncondensible gases (minimum of one).

18.3.3 CARD 60110001 through 60110099, Noncondensible Gas Fraction

The two words have to be entered on each card.

W1(A) gtype(i) Enter name of gas (left justified).

Examples: air, argon, helium, hydro, kryto, nitro, oxyge, xneno.

W2(R) vfrac(i+2) Volume fraction of gtype(i) in gas mixture.

18.4 CARD 602xxxxx, Channel Description

18.4.1 CARD 60200000

W1(I) nchanl Enter the number of channels in the problem.

18.4.2 CARD 6020NN00, Channel Geometric Data(NN=1, W1 of 60200000)

The six words have to be entered on each card. The seventh and eighth words may not be entered. NN does not need to be consecutive, however, has to be the same number as the NN of Section 18.4.1.

W1(I) i Enter the channel identification number.

(Note : Channel index numbers must be unique, but they do not have to be sequential Skipping numbers is permitted, so long as exactly nchanl of 60200000 channels are identified.)

W2(R) an(i) Enter the nominal channel area (in^2 or m^2). (Do not enter zero.)

W3(R) pw(i) Enter the channel wetted perimeter (inches or m). (Do not enter zero.)

W4(R) abot(i) Enter the area of the bottom of the channel for use in the momentum equation. Units are in^2 or m^2. If abot(i)is entered as zero (0.0), it is set to an(i).

W5(R) atop(i) Enter the area on the top of the channel for use in the momentum equation. Units are in^2 or m^2. If atop(i) is entered as zero (0.0), it is set to an(i).

W6(I) namgap Enter the number of gaps for which the vertical velocity of channel i convects transverse momentum between sections.

W7(R) rufnes Enter wall roughness for the wall friction of channel i or gaps connected with the channel i.

W8(R) dhydn Enter hydraulic diameter of the channel (inches or m). dhydn is always greater than 0.0.

18.4.3 CARD 6020NNMM, Channel Geometric Data(MM=1,namgap of 6020NN00)

The three words have to be entered on each card. MM did not need to be consecutive, however, NN has to be the same as the NN of Section 18.4.1.

NOTE : This card is read only namgap of 6020NN00 > 0. Omit this card if namgap of 6020NN00 is zero (0).

W1(I) inode(i,mm) Enter the index number of the node where the vertical velocity of channel described in 6020NN00 convects transverse momentum across a section boundary.

(Note : inode will be either at the bottom of the channel inode=1, or the top of the channel, inode=nonode+1), where nonode is the number of axial levels in the section containing channel 6020NN00. inode is defined in the section where the vertical momentum equation is solved.)

W2(I) kgapb(i,mm) Enter the index number of the gap below the section boundary. Enter zero if there is no gap below the section boundary.

(Note : If kgapb is not zero, the positive velocity of channel 6020NN00 at inode convects transverse momentum out of kgapb into kgapa. The negative velocity of channel i at inode convects transverse momentum from kgapa into kgapb; but if kgapb is zero, this momentum is dissipated.)

W3(I) kgapa(i,mm) Enter the index number of the gap above the section boundary. Enter zero if there is no gap above the section boundary.

(Note : If kgapa is not zero, the positive velocity of channel i at inode convects transverse momentum from kgapb (if kgapb is not equal 0) into kgapa. If kgapa is zero, this momentum is dissipated. The negative velocity of channel i at inode convects transverse momentum from kgapa to kgapb, if kgapb is not equal 0; if kgapb is zero, this momentum is dissipated.)

18.5 CARD 603XXXXX, Transverse Channel Connection (Gap) Data

These cards are omitted if there are no transverse connections between channels.

18.5.1 CARD 60300000

W1(I) nk Enter the number of transverse connections (gaps).

18.5.2 CARD 603NNN00 through 603NNN99 (NNN=1,nk < 200)

The eighteen words have to be entered on one or more card. NNN does not need to be consecutive.

W1(I) k Enter the gap identification number. (Note: Gap numbers must be unique but they do not have to be sequential. nk gaps must be input.)

W2(I) ik(k) Enter the identification number of the lower-numbered channel of the pair that connects through gap k.

W3(I) jk(k) Enter the identification number of the higher-numbered channel of the pair that connects through gap k.

W4(R) gapn(k) Enter the nominal gap width (in. or m).

W5(R) length(k) Enter the distance between the center of channel ik(k) and the center of channel jk(k) (in. or m).

W6(R) wkr(k) Enter the loss coefficient (velocity head) for gap k.

W7(R) fwall(k) Enter the wall friction factor for the gap. Valid entries are : 0.0 = no walls, 0.5 = one wall, 1.0 = two walls

W8(I) igapb(k) Enter the index number of the gap below gap k. Enter zero if there is no gap below gap k. (NOTE: The velocity of igapb(k) convects vertical momentum at node i into (or out of) channel ik(k) out of (or into) jk(k).)

W9(I) igapa(k) Enter the index number of the gap above gap k. Enter zero if there is no gap above gap k. (NOTE: The velocity of igapa(k) convects vertical momentum at the top node of the section into (or out of) channel ik(k) out of (or into) jk(k).)

W10(R) factor(k) Enter 1.0 if gap positive flow (from channel ik(k) to channel jk(k)) is in the same direction as positive flow for the global coordinate system. Enter -1.0 if gap positive flow is opposite to positive flow for the global coordinate system. (Default=1.0).

W11(I) igap(k,1) Enter the index numbers of gaps facing the ik(k) side of gap k. If the gap faces a wall, enter -1.

W12(I) jgap(k,1) Enter the index numbers of gaps facing the jk(k) side of gap k. If the gap faces a wall, enter -1.

W13(I) igap(k,2)

W14(I) jgap(k,2)

W15(I) igap(k,3)

W16(I) jgap(k,3)

Three sets of (W13(igap)~W14(jgap)) and (W15(igap)~W16(jgap)) have to be entered.

Note : The input for W10~W16 is required only if the three-dimensional form of the transverse momentum equation is desired.

W17(R) gmult(k) Enter the number of actual gaps modeled by gap k.

W18(R) etanr(k) Enter the crossflow de-entrainment fraction.

18.6 CARD 60320000

W1(I) nlmgap Enter the number of gaps that convect orthogonal transverse momentum. (This is required only for the three-dimensional form of the transverse momentum equation.) Enter zero if the three-dimensional form of the transverse momentum equation is not desired.

18.6.1 CARD 60320100 through 60329900

Read only if nlmgap of 60320000 > 0. These card numbers have to be consecutive.

W1(I) kgap1(n) Enter the index number of a gap whose velocity transports transverse momentum from one gap to another.

W2(I) kgap2(n) Enter the index number of the gap that receives the transverse momentum convected by the positive velocity of gap kgap1. A nonzero value must be entered.

W3(I) kgap3(n) Enter the index number of the gap that the positive velocity of kgap1 transports the transverse momentum out of. A nonzero number must be entered.

(Note : The positive velocity of kgap1 transports momentum from kgap3 to kgap2. The negative velocity of kgap1 will transport transverse momentum in the opposite direction; i.e., from kgap2 into kgap3.)

18.7 CARD 604XXXXX, Vertical Channel Connection Data

18.7.1 CARD 60400000

A word has to be entered on this card.

W1(I) nsects Enter the number of sections in this problem.

18.7.2 CARD 604K0000, 604K00MM, 604KNN00, 604KNN01, 604KNN11 (K=1, nsects)

The K does not need to be consecutive, however, all cards of the 604K0000, 604K00MM, and 604KNN00 must have the same K.

18.7.2.1 CARD 604K0000

The five words have to be entered on each card.

W1(I) isec Enter the section identification number. If this number is positive, Cards 604KNN00 (old format) should be entered. If this number is negative, Cards 604KNN01 and 604KNN11 (new format) should be entered. And WI(I) of other 604K0000 cards should be negative.

W2(I) nchn Enter the number of channels in section isec.

W3(I) nonode Enter the number of vertical levels in section isec.

W4(R) dxs(isec,1) Enter the vertical node length in this section (in.or m).

W5(I) ivardx Flag for variable node length in this section. For constant node length, this word is 0(default). If this word is greater than 0, DX table is read ivardx pairs in variable.

18.7.2.2 CARD 604K00MM (MM=1,ivardx)

The two words have to be entered on each card.

W1(I) jlev(i) Last axial level in section to have a node length of vardx(i) of this card. jlev(ivardx) of the last card (604k00MM,MM=W5 of 604K0000) must be greater than or equal to nonode+1.

W2(R) vardx(i) Axial node length (in. or m).

18.7.2.3 CARD 604KNN00 (NN=1,nchn)

These cards have to be entered only when W1 of Card 604K0000 is positive. The thirteen words have to be entered on each card.

W1(I) i Enter the identification number of a channel in section isec.

W2~7(I) kchana(i,j) Enter the indices of channels in the section above isec that connect to channel i of this card. If channel i of this card does not connect to any channels above, enter i of this card in W2(I).

W8~13(I) kchanb(i,j) Enter the indices of channels in the section below isec that connect to channel i of this card. If channel W1 of this card does not connect to any channels below, enter i of this card in W9(I).

18.7.2.4 CARD 604KNN01 (NN=1,nchn)

These cards have to be entered only when W1 of Card 604K0000 is negative. Forty one words may be entered on each card.

W1(I) i Enter the identification number of a channel in section isec.

W2~41(I) kchana(i,j) Enter the indices of channels in the section above isec that connect to channel i of this card. If channel i of this card does not connect to any channels above, enter i of this card in W2(I).

18.7.2.5 CARD 604KNN11 (NN=1,nchn)

These cards have to be entered only when W1 of Card 604K0000 is negative. Forty one words may be entered on each card.

W1(I) i Enter the identification number of a channel in section isec.

W2~41(I) kchanb(i,j) Enter the indices of channels in the section below isec that connect to channel i of this card. If channel W1 of this card does not connect to any channels below, enter i of this card in W2(I).

18.8 CARD 605XXXXX, Geometry Variation Data

The input for these cards allows the user to specify vertical variations in the continuity area, momentum area, or wetted perimeter for channels, and in the transverse width for gaps. It can be omitted if such variations are not needed.

18.8.1 CARD 60500000

W1(I) nafact Enter the number of geometry variation tables to be entered.

18.8.2 CARD 6050NN00, 6050NNMM

These cards are repeated nafact times

18.8.2.1 CARD 6050NN00 (NN=1, nafact)

The NN has to be consecutive.

W1(I) nxl(nn) Enter the number of points in this variation table.

18.8.2.2 CARD 6050NNMM (MM=1, nxl(nn))

The MM has to be consecutive.

W1(I) jaxl(nn,mm) Enter the node number at which to apply the area variation factor for table NN, point MM.

W2(R) afact(nn,mm) Enter the variation factor for table NN, point MM.

Area = afact(nn,mm) X an(i), or

Gap width = afact(nn,mm) X gapn(k)

Gap loss coefficient = afact(nn,mm) X wkr(k)

18.9 CARD 606XXXXX, Channels and Gaps Affected by Variation Tables

18.9.1 CARD 60600000

W1(I) n1 Enter the total number of channel and gap variation table cards to be read.

18.9.2 CARD 6060NN00 through 6060NN99 (NN=1,n1)

The fifteen word have to be entered on one or more cards.

W1(I) iact Enter a positive integer corresponding to a variation table number, for channel continuity area variation. Enter a negative integer, whose absolute value corresponds to a variation table number, for gap width variation. Enter zero (0) if iamt is negative.

W2(I) iamt Enter a variation table number for channel momentum area variation. Enter a negative integer, whose absolute value corresponds to a variation table number, for gap loss coefficient variation. Enter zero (0) if iact is negative.

W3(I) ipwt Enter a variation table number for wetted perimeter variation. Enter zero (0) if iact or iamt is negative.

W4~15(I) icrg(m) Enter the index numbers of the channels (or gaps if iact(iamt) is negative) that the tables identified in iact, iamt and ipwt are to be applied to.

18.10 CARD 607XXXXX, Local Loss Coefficient and Grid Spacer Data.

This card can be omitted if they are not needed.

18.10.1 CARD 60700000

The eight words have to be entered on this card

W1(I) ncd Enter the number of loss coefficient specifications to be read. (These include vertical momentum losses only. Transverse losses are specified in 603NNN00)

W2(I) ngt Number of grid types to be read.

W3(I) ifgqf Flag for grid quench front model (1=on, 0=off).

W4(I) ifsdrp Flag for small drop model (1=on, 0=off).

W5(I) ifespv Flag for grid convective enhancement (1=on, 0=off).

W6(I) iftpe Flag for two-phase enhancement of dispersed flow heat transfer (1=on, 0=off).

W7(I) igtemp Number of the sets of grid temperature corresponding to grid elevation

W8(I) nfbs Number of flow blockages

18.10.2 CARD 607001NN (NN=1,ncd), Loss Coefficient Data

The fourteen words can be entered on each card. This card is repeated W1 of 60700000 times. The card numbers have to be consecutive.

W1(R) cdl Enter the loss coefficient (velocity head).

W2(I) j Enter the node number where the loss coefficient is applied. (NOTE: The vertical node number is relative to the beginning of the section containing the channel(s) listed in icdum(i).)

W3~14(I) icdum(i) Enter the index number(s) of channel(s) the loss coefficient will be applied to at node j. (Up to twelve channels may use the specified loss coefficient cdl at vertical node j.)

18.10.3 CARD 607002NN(NN=1,igtemp), Grid Temperature Data(UNIDENTIFIED)

The two words can be entered on each card. This is repeated in igtemp times.

W1(R)	tgrid	Enter the grid temperature at elevation W2. (^{o}F or K)
W2(R)	qfgrid	Enter the grid elevation (in. or m).

18.10.4 CARD 6070KXXX (K=1,W8 of 60700000), Flow Blockages Data

18.10.4.1 CARD 6070K000

The ten words have to be entered on this card. This card is repeated W8 of 60700000 times.

W1(I)	i	Flow blockage index number
W2(I)	ifb	Channel index number
W3(I)	jsfb	Axial node index number
W4(I)	nrfb	Number of rods that block this channel
W5(R)	spoint	Axial position of the flow separation point.
W6(R)	dsep	Channel diameter at separation point,
W7(R)	throat	Diffuser diameter at exit
W8(R)	aflblk	Area for DBM (fraction of channel) x 0.25
W9(R)	cdfb	Loss coefficient (Rehme multiplier)
W10(R)	ablock	Blockage area ratio

18.10.4.2 CARD 6070K00N (Nn=1, W4 of 6070K000(nrfb))

W1(I)	nrodfb(n)	Index number of rod.
W2(I)	krodfb(n)	Surface number.
W3(R)	angiht(n)	Angle for impact heat transfer (degree).
W4(R)	araiht(n)	Area for impact heat transfer(in^2/per rod).

18.10.5 CARD 607KXXXX (k=1,ngt), Grid Type Data

607k0000, 607k00xx, and 607knn00 have to be specified ngt times

18.10.5.1 CARD 607K0000

The eight words have to be entered on each card.

W1(I)	ing	Grid type number. (must be sequential starting with 1)
W2(I)	ngal(ing)	Number of axial locations for grid type ing.
W3(I)	ngcl(ing)	Number of channels containing grid ing at levels ngal(ing).
W4(I)	igmat(ing)	Grid material table index (MMM) . Refer 1-D material table (201MMMNN).
W5(R)	gloss(ing)	Loss coefficient multiplier (suggest 1.0 for round edge grids; 1.4 for square edge grids)
W6(R)	gabloc(ing)	Fraction of channel area blocked by grid
W7(R)	glong(ing)	Grid length (in. or m)
W8(R)	gperim(ing)	Grid perimeter (in. or m)

18.10.5.2 CARD 607K0001 through 607K0099

The number of words are equal to ngal(ing)

W1~NN(I)	nngl(ing)	Axial node number of momentum cells containing grid type ing.

18.10.5.3 CARD 607KNN00 (nn=1, ngcl(ing))

The fourteen words have to be entered on each card. This card is repeated ngcl(ing) times per ing.

W1(I)	ncngl(ing,nn)	Channel ID number with grid type ing at axial levels nngl(ing) (specified above).
W2(R)	gmul(ing,nn)	Number of grids contained in channel ncngl(ing,nn).
W3,5,7,(I)	ngrod(*)	Whole rod number with surface surrounding grid(maximum of six)
W4,6,8,(I)	ngsurf(*)	Rod surface index of whole rod ngrod surrounding grid ing. * : 3-dimensional variable, (ing, nn, m). Here m =1,6.

(Note: average temperature of all surfaces surrounding grid is used to transport heat between grid and heater rods.)

18.11 CARD 608XXXXX, Rod and Unheated Conductor Data

This card can be omitted if they are not needed.

18.11.1 CARD 60800000

The eight words can be entered on this card. Rods and unheated conductors are both used to model solid coducting structures in vessel. Rods can model either active or passive element, but unheated conductors are always passive. Unheated conductors can not have internal heat sources.

W1(I) nrod Enter number of active or passive conducting rods, including fuel rods.

W2(I) nsrod Enter number of unheated conductors.

W3(I) nc Conduction model flag;

nc =1 : for radial conduction only.

nc =2 : for radial and axial conduction.

nc =3 : for radial, axial, and azimuthal conduction.

W4(I) nrtab Enter number of temperature initialization tables to be read.

W5(I) nrad Enter number of radiation channels.

W6(I) nltyp Enter number of location types.

W7(I) nsrad Enter total number of rod or slab surfaces with radiation.

W8(I) nxf Enter number of time steps between radiation calculations (Default=1).

18.11.2 CARD 6080NN00 (NN=1,nrod), Rod Geometry Data

The cards in Section 18.11.2 is specified to define the geometry of structures that generate heat, including nuclear fuel rods. It is repeated nrod times. The eleven words can be entered on each card.

W1(I) n Enter rod identification number. (Note: Rod index numbers must be entered sequentially, from 1 to W1 of 60800000. Skipping numbers is not permitted.)

W2(I) iftyp(n) Enter geometry type identification number. (Refer to 609xxxxx card for geometry type input data.)

W3(I) iaxp(n) Enter axial power profile table identification number. (Refer to 611xxxxx card for axial power profile input data.) If 0 is entered, the source of the heat structure is taken from the 3D kinetics module, MASTER. In this case, Input Cards 61100001 and 61100002 should be provided. In addition, MASTER input files and mapping data ("MAS_MAP" file) should be also prepared. [see Appendix A, or KAERI/TR-2232/2002]. If a negative integer is entered, the source of the heat structure is taken from the nuclear rod, of which rod number is "-iaxp(n)."

W4(I) nrenode(n) Enter renoding flag for heat transfer solution for rod n.

= 0 : no fine mesh renoding

> 0 : renoding every this word time steps

< 0 : renoding every this word time steps, based on inside surface temperatures

W5(R) daxmin(n) Enter minimum axial node size (in. or m). (This is used only if fine mesh renoding is used.)

W6(R) rmult(n) Enter rod multiplication factor (number of rods modeled by rod n). (This number can contain fractional parts.)

W7(R) radial(n) Enter radial power factor (normalized to average power).

W8(R) hgap(n) Enter constant gap conductance (Btu/hr-ft^2-^{o}F or W/m^2-^{o}C). (This parameter is used only for nuclear fuel rods that do not have the dynamic gap conductance model specified by their geometry type.)

Enter 0 if the rod n does not model a nuclear fuel rod.

W9(I) isecr(n) Number of sections containing rod n.

W10(R) htamb(n) Heat transfer coefficient for heat loss to ambient from surface not connected to a channel (Btu/hr-ft^2-^{o}F or W/m^2-^{o}C).

W11(R) tamb(n) Sink temperature for ambient heat loss (^{o}F or ^{o}K).

18.11.3 CARD 6080NNK0 (K=1,isecr(n))

The eight words can be entered on each card. This card is repeated isecr(n).

W1(I) nischc(n,k) Negative of channel number connected to the inside of rod n.

18.11.4 CARD 6080NNK1 through 6080NNK9

The sixteen words can be entered on each card. This card is repeated isecr(n).

W1(I) nschc(k) Channel number with thermal connections to rod n. Enter 0 if no channels are connected to the outside of rod n.

W2(R) pie(k) Fraction of rod n thermally connected to channel nschc(k).

Odd words are the same as the Word 1(nschc(k)), and even words are the same as the Word 2 (pie(k)). The eight pairs can be specified.

18.11.5 CARD 6081NN00 (NN=1, nsrod), Unheated Conductor Data

This card is read for each of the nsrod conductor rods (also called heat slabs).

Specify only if nsrod > 0.

W1(I) n Enter unheated conductor identification number. (Note : Unheated conductor index numbers must be entered sequentially, from 1 to nsrod. Skipping numbers is not permitted.)

W2(I) istyp(n) Enter geometry type identification number. (Refer to 609xxxxx card for geometry type input data.)

W3(R) hperim(n) Enter wetted perimeter on outside surface (in. or m).

W4(R) hperimi(n) Enter wetted perimeter on inside surface (in. or m). Enter zero for a solid cylinder.

W5(R) rmuls(n) Enter multiplication factor (number of elements modeled by unheated conductor n).

(This number can contain fractional parts.)

W6(I) nslchc(n) Channel number on inside of slab.

W7(I) ndslch(n) Channel number on outside of slab.

W8(R) htambs(n) Heat transfer coefficient for heat loss to the ambient (Btu/hr-ft^2-^{o}F or W/m^2-^{o}C)

W9(R) tambs(n) Sink temperature for ambient heat loss (^{o}F or K)

18.11.6 CARD 6082XXXX, Rod Temperature Initialization Tables

Cards 6082XXXXX are specified which temperature tables apply to which rods and unheated conductors. The sequence is repeated nrtab times, and all rods and conductors must be accounted for.

18.11.6.1 CARD 6082NN00

The four words have to be entered on each card.

W1(I) i Enter identification number of temperature table.

W2(I) nrt1 Enter number of rods using table i.

W3(I) nst1 Enter number of unheated conductors using table i.

W4(I) nrax1 Enter number of pairs of elements in table i.

In case of a tube inside, use a negative number.

18.11.6.2 CARD 6082NN01 through 6082NN05

Specify only if nrt1 > 0. The number of words are nrt1.

W1,2,3,(I) irtab(i,l) Enter identification numbers of rods using table i for temperature initialization.

Note : The steady-state conduction equation is solved for these rods using the temperatures from this table as a boundary condition on the rod surface.

18.11.6.3 CARD 6082NN06 through 6082NN10

Specify only if nst1 > 0. This card has to contain nst1 words.

W1,2,3,(I) istab(i,l) Enter identification numbers of unheated conductors using table i described in 6082NN00 for temperature initialization.

Note : A flat radial temperature profile is assumed initially in unheated conductors.

18.11.6.4 CARD 6082NN11 through 6082NN99

This card are required if W4 of card 6082NN00(nrax1) is not zero. In format 1(W4 of card 6082NN00 > 0), each data set has two words. In format 2(W4 of card 6082NN00 < 0), each data set has three words. These cards have to contain data sets of | nrax1 |.

<u>Format1</u>

W1(R) axialt(i,l) Enter the vertical position relative to the bottom of the lowest section (in. or m).

W2(R) trinit(i,l) Enter the temperature to be applied at axialt(i,l) (^{o}F or K).

<u>Format2</u>

W1(R) axialt(i,l) Enter the vertical position relative to the bottom of the lowest section (in. or m).

W2(R) trinit(i,l) Enter the temperature to be applied at axialt(i,l) (^{o}F or K). In tube, inner side temperature are specified.

W3(R) tronit(i,l) Enter the temperature to be applied at axialt(i,l) (^{o}F or K). In tube, outer side temperature are specified.

18.11.7 CARD 6083XXXX though 6084XXXX, Radiation Initialization Tables

Cards 6083XXXX through 6084XXXX are read in to specify orientation and which location type tables apply to which fluid channels, rods, and unheated conductors if W5 of 60800000 > 0.

18.11.7.1 CARD 6083NN00(NN=1,nrad), Channel Orientation and Location Type

This card repeated W5 of 60800000(nrad) times. The ten words are entered on each card.

W1(I) idcard(nn) Radiation channel ID number

W2(I) nsidr(nn) Number of fluid channel which contains idcard(nn).

W3(I) locate(nn) Location type for radiation channel idcard(nn) :

<0 : contains no unheated conductors.

>0 : has both rods and unheated conductors.

W4(I) nrrad(nn) Number of contributing radiation surfaces for idcard(nn):

= 20: location types 1,2,3,7,8

= 16: location types 4,5

= 9: location type 6

= 14: location type 9

W5(I) nsymf(nn) Enter flag for fluid channel or rod lumping.

= 0 : no lumping

= 1 : lumped fluid channels

W6(R) mltf(1,nn) Enter surface lumping factor for surface position 1. Ratio of total calculated to actually modeled surface areas of this rod type contained in location type idcard(nn) times the ratio of total surface areas in all channels of this rod type to this surface area (Default=1.0).

W7(R) mltf(2,nn) Enter surface lumping factor for surface position 2. Ratio of total calculated to actually modeled surface areas of this rod type contained in location type idcard(nn) times the ratio of total surface areas in all channels of this rod type to this surface area (Default=1.0).

W8(R) mltf(3,nn) Enter surface lumping factor for surface position 3. Ratio of total calculated to actually modeled surface areas of this rod type contained in location type idcard(nn) times the ratio of total surface areas in all channels of this rod type to this surface area (Default=1.0).

W9(R) mltf(4,nn) Enter surface lumping factor for surface position 4. Ratio of total calculated to actually modeled surface areas of this rod type contained in location type idcard(nn) times the ratio of total surface areas in all channels of this rod type to this surface area (Default=1.0).

W10(R) vdmlt(nn) Vapor/droplet multiplication factor. Total number of radiation channels being modeled by this location type (Default=1.0).

18.11.7.2 CARD 6083NN01 through 6083NN99, Radiation Channel Orientation Array

The number of words are W4 of 6083NN00(nrrad(nn)). j=1,nrrad(nn)

W1,2,3..(I) lrad(nn,j) Rod number in position "j" for appropriate radiation channel idcard(nn). Negative for inside surface. (See text for proper rod orientation.)

18.11.7.3 CARD 6084K000(K=1,W6 of 60800000(nltyp)), Radiation Location Type Information

This card is repeated nltyp times.

W1(I) idtyp(k) Location type to be input

> 0 : manual input to follow.

< 0 : auto view factor routine to be used.

If W1 of 6084K000(idtyp(k)) < 0 skip the manual input cards

18.11.7.4 CARD 6084K101 through 6084K110, Area input, j=1,jtop

The jtop is total number surfaces for location type idtyp(k).

W1,2,..,jtop(R) arad(j) Surface area of position "j" for location type idtyp(k) (in. or centimeter)

= 40 : (idtyp(k) : 1)

= 38 : (idtyp(k) : 2)

= 36 : (idtyp(k) : 3)

= 26 : (idtyp(k) : 4)

= 25 : (idtyp(k) : 5)

= 16 : (idtyp(k) : 6)

= 38 : (idtyp(k) : 7)

= 36 : (idtyp(k) : 8)

= 23 : (idtyp(k) : 9)

18.11.7.5 CARD 6084K111 through 6084K120, Emissivity input, j=1,jtop

The jtop is total number surfaces for location type idtyp(k).

W1,2,..,jtopt(R) erad(j) Enter the emissivity of position "j" for location type idtyp(k)

18.11.7.6 CARD 6084K121 through 6084K380, View Factor input, m=j,jl

jl = Total number of radiant surfaces in location type idtyp(k).

This card number is increased by 20 from 6084K121 after entering a series of data set.

W1,2,(R) frad(j,m) Enter radiation view factor between one surface and another surface.

Ex.) 6084K121 through 608K140, W11,W12,W13,...,W1N

6084K141 through 608K160, W22,W23,...,W2N

6084K161 through 608K180, W33,...,W3N

6084KXX1 through 608KXX0, ...,WNN.

Where Wij is view factor between surface "i" and surface "j". Subscript N is total number of radiant surfaces in location type W1 6084K000(idtyp(k)) :

= 12: (idtyp(k) : 1, 2, 3)

= 9 : (idtyp(k) :4, 5)

= 6 : (idtyp(k) :6)

= 12: (idtyp(k) :7, 8)

= 7 : (idtyp(k) :9)

18.11.7.7 CARD 6084K421 through 6084K680, Beam Length input

This card number is increased by 20 from 6084K421 after entering a series of data set.

W1,2,(R) drad(j,m) Enter radiation beam length between one surface and another surface (in. or cm).

These input formats are the same as view factor input except for the card number.

18.11.7.8 CARD 6084k701, Auto View Factor input

Omit if W1 of 6084K000(idtyp(k)) > 0.

W1(R) apar(1) Enter first parameter for auto view factor input according to location type.

	(d)	Enter nominal rod diameter(inches or centimeters).
W2(R)	apar(2)	Enter second parameter for auto view factor input according to location type.
	(em1)	Enter emissivity of rod(inches or centimeters).
W3(R)	apar(3)	Enter third parameter for auto view factor input.
	(d1)	If location type=1, enter rod diameter of rod in oversized rod location.
	(g)	Enter gap width between rod and wall (inches or centimeters).
	(cld)	If location type=4,5 and W5>0, Enter position of centerline (unidentified)
		If location type=8,9 and $W5 \neq 0$, Enter position of centerline (unidentified)
	(disx)	If location type=6 and $W5 \neq 0$, Enter displacement from centerline axis to rod position 1 (inches or centimeters)
W4(R)	apar(4)	Enter fourth auto view factor input parameter.
	(p)	Enter pitch of rods.
W5(R)	apar(5)	Enter fifth auto view factor input parameter.
	(rad)	Enter radius of curvature of wall.
W6(R)	apar(6)	Enter sixth auto view factor input parameter.
	(disx)	Enter displacement from centerline axis to rod position 1(inches or centimeters)
W7(R)	apar(7)	Enter seventh auto view factor input parameter.
	(em2)	Enter emissivity of the wall. If location type=4,5, enter 0.0
W8(R)	apar(8)	Enter eighth auto view factor input parameter.
	(d1)	If location type=1,2,3, enter rod diameter of rod in oversized rod location. Enter emissivity of the wall.
	(fg)	If location type=7,8,9, enter fg.

If location type=4,5,6, Enter 0.0

W9(R) apar(9) Enter nineth auto view factor input parameter.

(d1) If location type=7, enter rod diameter of rod in oversized rod location. enter emissivity of the wall.

(fw) If location type=8,9, enter fg. If location type=1,2,3,4,5,6, enter 0.0

18.12 CARD 609XXXXX, Conductor Geometry Description

The geometry types are read in these cards. The geometry types are numbered sequentially in the order they are read in. Nuclear rod geometry types are read using cards 609nn000 through 609nn3xx. All other geometry types are read using cards 609nn000 and 60nn4xx.

18.12.1 CARD 60900000

The four words can be entered on this card.

W1(I) nfuelt Enter number of geometry types to be read in. Note: A geometry type may be used by both rods and unheated conductors, but for the unheated conductor, any heat generation specified for the type will be ignored.

W2(I) irelf Fuel relocation flag (1=on, 0=off) (This is used only for nuclear fuel rods using the dynamic gap conductance model).

W3(I) iconf Fuel degradation flag (1=on, 0=off) (NOTE : if irelf = 1, then iconf = 1.)

W4(I) imwr Flag for metal-water reaction. (zirconium dioxide only)

= 0, off

= 1, Cathcart (for best-estimate analysis)

= 2, Baker-Just (for evaluation model analysis)

18.12.2 CARD 60900NN0

W1(I) i Enter the geometry type identification number. (Note : Geometry type index numbers must be entered sequentially, from 1 to W1 of 60900000(nfuelt). Skipping numbers is not permitted.)

W2(A) ftype(i) Enter the one of the following four words.

nucl : Nuclear fuel geometry

hrod : Solid cylinder

tube : Hollow tube

wall : Flat plate.

The following cards are divided into FORMAT1 and FORMAT2 according to geometry type. Format1 is the information for the nuclear fuel geometry(nucl) geometry type. Format2 is the information for the other geometry types (hrod, tube, wall).

FORMAT 1 : 609NN000 through 609NN3XX (W2 of 60900NN0(ftype(i)) = nucl)

18.12.2.1 CARD 609NN000 through 609NN009

The twelve words have to be entered on each card. Specify only if ftype(i) =nucl.

W1(R) drod(i) Enter rod outside diameter (in. or m)

W2(R) dfuelt(i) Enter fuel pellet diameter (in. or m)

W3(I) nfuel(i) Enter number of radial nodes in fuel pellet.

W4(I) imatf(i) Fuel material properties flag.

Enter zero (0) for built-in U02 properties.

Enter a positive integer corresponding to the identification number of a material properties tables for user-input properties. (Refer 1-D material tables (201MMMNN).)

W5(I) imatc(i) Clad material properties flag :

Enter zero (0) for built-in zirconium properties.

Enter a positive integer corresponding to the identification number of a material properties table for user-input properties. (Refer 1-D material tables (201MMMNN).)

W6(I) imatox(i) Clad oxide property flag:

Enter zero (0) for built-in zirconium dioxide properties.

Enter a positive integer corresponding to the identification number of a material properties table for user-input properties (Refer 1-D material tables (201MMMNN)).

W7(R) dcore(i) Enter diameter of central void for cored fuel (in. or m). Enter zero for uncored fuel.

W8(R) tclad(i) Enter clad thickness (in. or m).

W9(R) ftdens(i) Enter fuel theoretical density as a fraction (used only if built-in U02 properties have been flagged; i.e., if imatf(i) = 0). Note : Do not enter zero.

W10(I) igpc(i) Gap conductance option flag:

Enter zero (0) for constant gap conductance (as specified by W8 on card 6080nn00(hgap(n))).

Enter a positive integer for user-specified non-uniform gap conductance (entered on card 609NN2XX in a table of igpc(i) elements).

Enter a negative integer for the dynamic gap conductance model. (| igpc(i) | is the number of entries in the cold gap width vs axial location table, read on card 609NN2XX)

W11(I) igforc(i) Flag for temporal forcing function on gap conductance (valid only if igpc(i) > 0:

Enter zero (0) for constant gap conductance.

Enter a positive integer for a temporal forcing function with igforc(i) table entries.

W12(I) iradp(i) Enter number of entries in radial power profile table for the fuel pellet.

Enter zero (0) for a uniform radial power profile.

18.12.2.2 CARD 609NN101 through 609NN110

Specify only if W2 of 60900NN0(ftype(i)) = nucl and W10 of 609NN00X(igpc(i)) < 0. The eleven words have to be entered on this card.

W1(R) pgas(i) Enter cold pin gas pressure for nuclear fuel rod geometry type (psia or N/ m^2).

W2(R) vplen(i) Enter gas plenum volume (in^3 or m^3).

W3(R) rouff(i) Enter fuel pellet surface roughness (in. or m).

W4(R) roufc(i) Enter surface roughness of clad inner surface (in. or m).

(Note: Fuel and clad surface roughness should correspond to those used in FRAPCON-2 since the correlation is empirical.)

Fuel surface rouff(i) = 0.000085 inches

Clad surface roufc(i) = 0.000045 inches

W5(R) gsfrac(1) Enter molar fraction of helium gas present.

W6(R) gsfrac(2) Enter molar fraction of xenon gas present.

W7(R) gsfrac(3) Enter molar fraction of argon gas present.

W8(R) gsfrac(4) Enter molar fraction of krypton gas present.

W9(R) gsfrac(5) Enter molar fraction of hydrogen gas present.

W10(R) gsfrac(6) Enter molar fraction of nitrogen gas present.

Note: sum of gas fractions = 1.0

W11(R) oxidet(i) Enter initial oxide thickness for the zircaloy metal-water reaction rate equation(in. or m).

(Used only if W4 of 60900000(imwr) > 0.)

18.12.2.3 CARD 609NN2MM (MM = 1, | W10 of 609NN00X(igpc(i)) |)

Specify only if ftype(i) = nucl and | igpc(i) | > 0. The two words have to be entered on each card.

W1(R) axj(i,mm) Enter topmost vertical position, measured from the bottom of the rod, at which the cold gap width (or gap conductance) agfact(i,mm) is applied. (All vertical levels below axj(i,mm) and above axj(i,mm-1) will have agfact(i,mm) for gap width or gap conductance.) Units on axj(i,mm) are inches or meters.

W2(R) agfact(i,mm) Enter cold gap width if igpc(i) is negative. Units are inches or meters.

Enter gap conductance if igpc(i) is positive. Units are Btu/hr-ft^2-^{o}F or W/m^2-K.

18.12.2.4 CARD 609NN3MM (MM = 1, | W12 of 609NN00X |)

Specify only if W2 of 60900NN0(ftype(i)) = nucl and W12 of 609NN00X(iradp(i)) > 0. The two words have to be entered on each card.

W1(R) radp(mm) Enter the relative radial location (r/ro) where corresponding power factor powr(mm) is applied.

W2(R) powr(mm) Enter the relative power factor (i.e., the ratio of local power at location radp(mm) to total rod power).

FORMAT 2 : 609NN000 and 609NN4XX (W2 of 60900NN0(ftype(i)) = hrod or tube or wall)

18.12.2.5 CARD 609NN000

These data are read for all geometry types that do not describe nuclear fuel. The five words have to be entered on this card. Specify only if W2 of 60900NN0(ftype(i)) ≠ nucl

W1(R) drod(i) Enter outside diameter for hrod or tube geometries (inches or meters).

Enter the wetted perimeter for wall geometries (inches or meters).

W2(R) din(i) Enter inside diameter for tube geometries (inches or meters).

Enter thickness for wall geometries (inches or meters).

Enter zero (0.0) for hrod solid cylinder geometries.

W3(I) nfuel(i) Enter the number of regions within the conductor. (Each region has a uniform power profile and consists of one material.)

W4(I) imatox(i) Enter material property table identification number for oxide on outside surface.

(Refer 1-D material tables (201MMMNN), Default is zirconium oxide; imatox(i) = 0).

Enter the index number of the material property table for material in region nfuel(i) if there is no oxide present.

W5(I) imatix(i) Enter material property table identification number for oxide on inside surface

(Refer 1-D material tables (201MMMNN), Default is zirconium oxide; (imatix(i) = 0); applies only to tube or wall.)

Enter the index number of the material property table for material in region 1 if there is no oxide present.

Data sets for the regions spcified in W3 of 609NN000(nfuel(i)) of geometry type specified in W1 of 60900NN0(i) are entered starting at the centerline for hrod types and at the inside surface for tube and wall types. Data sets are entered in sequence moving radially toward the outside surface.

18.12.2.6 CARD 609NN4MM (MM = 1, | W3 of 609NN000(nfuel(i)) |)

Specify only if W2 of 60900NN0(ftype(i)) ≠ nucl. The four words have to be entered on each card.

W1(I) noder(mm) Enter the number of radial heat transfer nodes in a region.

W2(I) matr(mm) Enter the material property table identification number for the region (Refer 1-D material tables (201MMMNN),.

W3(R) treg(mm) Enter the thickness of the region (inches or meters).

Note : For tube and hrod geometry types,

W4(R) qreg(mm) Enter radial power factor for the region. (This profile is automatically normalized to unity.)

18.13 CARD 611XXXXX, Axial Power Tables and Forcing Functions

These input cards can be omitted if they are not needed. The power forcing functions cards are replaced at restart problem.

18.13.1 CARD 61100000

The one word has to be entered on this card

W1(I) naxp Enter number of axial power profile tables to be read. (Minimum of one.)

18.13.2 CARD 61100001, MARS-KS/MASTER or MARS-KS/CORDAX coupling data

If the 1D hydrodynamic module is used:

W1(I) Axial mesh number (NN) of the lower axial reflector region.

W2(I) Axial mesh number (NN) of the upper axial reflector region.

W3(I) Component number (CCCNN or CCCXYYZZ) of the bottom volume of the radial reflector region.

W4(R) Starting time of the transient advancement of MASTER (sec).

W5(I) Trip number (reactor trip card number).

W6(R) Total core power (W).

Note: The radial reflector region should be modeled with a "pipe" or "annulus" component. The vertical nodding of the radial reflector should be consistent with that of the active core.

If the 3D hydrodynamic module is used:

W1(I) Axial level for the lower axial reflector region (greater than 1).

W2(I) Axial level for the upper axial reflector region. The lower & upper reflector should be included in the same section. That is, the whole core should be modeled with a single section.

W3(I) Radial reflector channel number.

W4(R) Starting time of the transient advancement of MASTER (sec).

W5(I) Trip number (reactor trip card number).

18.13.3 CARD 61100002, Control variable numbers for "control rod bank position" control

(Maximum 10 words can be entered)

W1(I) Control variable number for control rod bank 1. The bank position is represented in cm.

W2(I) Control variable number for control rod bank 2. The bank position is represented in cm.

18.13.4 CARD 6110NNXX, Axial Power Tables

This is repeated naxp times

18.13.4.1 CARD 6110NN00

W1(I) i Enter axial power profile table identification number.

W2(I) naxn(i) Enter number of pairs of elements in axial power profile table i.

18.13.4.2 CARD 6110NN01 through 6110NN99

W1(R) y(i,n) Enter vertical location, relative to bottom of the section 1, where axial power factor axial(i,n) is applied. Use inches or meters.

W2(R) axial(i,n) Enter relative power factor (the ratio of local power to average power) at vertical location y(i,n).

All rods using the same table should start and end at the same vertical locations. In the table, y(i,n) must be the vertical location of the beginning of the rods, and y(i,naxn(i)) must be the vertical location of the end of the rods.

18.13.5 CARD 6111XXXX, Power Forcing Function

18.13.5.1 CARD 61110000

The one word has to be entered on this card.

W1(I) nq Enter 1-D general table number for power forcing function .

Note: The power forcing function is still effective when the 3D heat structures use the point kinetics model with "SEPARA3D" module. For a steady-state calculation, users can use this function for regulating the total core power when using the point kinetics model. But, for transient calculations using the point kinetics model, this function should be always 1.0.

18.13.6 CARD 6112XXXX, Gap Conductance Forcing Function

18.13.6.1 CARD 61120000

The one word has to be entered on this card

W1(I) ngpff Enter 1-D general table number for gap conductance forcing function .

18.13.7 CARD 6113xxxx, Direct Moderator Heating

This card must be entered if SEPARA3D option is selected on W2(A) in Card 3000000

18.13.7.1 CARD 61130000

W1(I)	ndht_tot	Total numeber of nodes for direct heating
W2(R)	direct_f	Direct heating fraction to total heating power

18.13.7.2 CARD 61130001 through 61130099

W1(I)		Channel/node volume number (CCCNN0000)
W2(I)	iskp	Volume increament
W3(R)	qdirect	Fraction to total direct heating
W4(R)		Numbers of volumes

18.14 CARD 612XXXXX, Turbulent Mixing Data

18.14.1 CARD 61200000

W1(I)	n1	Enter number of sections in which turbulence will be applied.

18.14.2 CARD 6120NN00 (NN=1, n1)

Three words have to be entered on each card.

W1(I)	i	Section index number.
W2(R)	beta(i)	Mixing coefficient (=w'/G-S)
W3(R)	aaak(i)	Equilibrium distribution weighting factor in void drift model. Suggested value=1.0.

18.15 CARD 613XXXXX, Boundary Condition Data

18.15.1 CARD 61300000

W1(I)	nibnd	Enter the total number of vertical mesh cell boundary conditions.
W2(I)	nkbnd	Enter the total number of transverse momentum cells for which crossflow will be set to zero.

W3(I) nfunct Enter the number of forcing functions for the boundary conditions.

W4(I) ngbnd Enter the number of groups of contiguous transverse momentum cells for which crossflows will be set to zero.

Note: The inlet of the lowest channels and the exit of the highest channels in the 3D hydrodynamic input model are automatically blocked. Other boundary conditions specified by users on these cells are effective (overwritten).

In the earlier versions of MARS-KS (e.g., MARS-KS 1.3.1), appropriate boundary conditions should have been provided for all the vertical mesh cells at the inlet of the lowest channels and the exit of the highest channels. Old input data can be run without modification, but it is not efficient.

18.15.2 Forcing Function

18.15.2.1 CARD 61300001 through 61300009 (k=1,nfunct)

Specify Word 3 of 61300000 (nfunct) words. The card numbers range from 61300001 to 61300009 which need not be in sequential order.

W1,2,..,k(I) npts(k) Enter the number of points (pairs of values) in each forcing function table.

18.15.2.2 CARD 6130NN00 through 6130NN99 (NN= 1, nfunct)

Specify the data sets corresponding to Word k(npts(k)) of 6130000X. i=1,npts(k)

W1(R) abscis(nn,i) Enter the time in seconds, the factor is applied

W2(R) ordnit(nn,i) Enter the forcing function factor to be applied at W1 time.

.

.

Wnpts(R) abscis(nn,npts)

Wnpts+1(R) ordnit(nn,npts)

18.15.3 Vertical Mesh Cell Boundary Condition Data

Specify only if W1 of 61300000(nibnd) > 0.

This card is repeated nibnd times.

18.15.3.1 CARD 6131NN00 (NN=1,nibnd)

W1(I) ibound(1,nn) Enter the index number of the channel which boundary condition specified on this card applies to.

W2(I) ibound(2,nn) Enter the vertical node number at which this boundary condition is applied. (NOTE: The node number is referenced to the beginning of the section that the channel identified in W1 resides in.)

W3(I) ispec(nn) Enter the boundary condition type. Valid options are:

1 = pressure and enthalpy boundary condition

2 = flow and enthalpy

3 = flow only

4 = mass source (flow rate and enthalpy)

5 = pressure sink and enthalpy

W4(I) npfn(nn) Enter the index number of the forcing function table by which the first parameter of the boundary condition will be varied. (NOTE: The forcing function tables are numbered sequentially in the order they are read in on card 6130NNXX) For example: If W3(ispec(nn))= 1 and W4(npfn(nn)) = 3, the specified pressure will be adjusted according to the third forcing function entered on 6130NNXX. Enter zero if the boundary condition is constant.

W5(I) nhfn(nn) Enter the index number of the forcing function table by which the second parameter of the boundary condition will be varied. (For example: If W3(ispec(nn)) = 1 and W5(nhfn(nn)) = 6, the specified enthalpy will be adjusted according to the 6th forcing function specified on 6130NNXX.) Enter zero if the boundary condition is constant.

W6(R) pvalue(nn) Enter the first boundary value.

If W3(ispec(nn)) = 1 or 5, enter pressure (psia or N/m^2).

If W3(ispec(nn)) = 2,3 or 4, enter flow rate (lbm/sec or kg/sec).

W7(R) hvalue(nn) Enter enthalpy (Btu/lbm or J/kg). Enter zero (0) if W3(ispec(nn)) = 3.

W8(R) xvalue(nn) Pressure (psia or N/m^2) must be input for W3(ispec(nn)) = 2, 3 or 4.

18.15.3.2 CARD 6131NN10

k = W1(ngas) on 60110000 + 2. Specify only if W3 of 6131NN00(ispec(nn)) ≠ 3.

W1(R) hmga(nn) Enthalpy of noncondensable gas mixture.

W2,3,..,k(R) gvalue(nn) Volume fraction of gas in vapor-gas mixture. (specify in same order as in card 601XXXXX)

Ex) 61310110 H_ncg vf_liq vf_steam vf_gas1 vf_gas2 ..., .

H: Enthalpy, ncg: Non-Condensible Gas, vf: Volume Fraction

18.15.3.3 CARD 6131NN20

W1(I) nhmfn(nn) Index number of forcing function applied to gas mixture enthalpy.

W2,3,..,k(I) ngfn(nn) Index number of forcing function applied to volume fraction of each gas.

18.15.3.4 CARD 6131NN30

Specify only if some W3 of 6131NN00(ispec(nn)) = 4.

W1(R) ainjt(nn) Enter the flow area of the mass injection (in^2 or m^2).

18.15.3.5 CARD 6131NN40

Specify only if some W3 of 6131NN00(ispec(nn)) = 5.

W1(R) asink(nn) Enter the flow area of the pressure sink (in^2 or m^2).

W2(R) sinkk(nn) Enter the loss coefficient (velocity head) of the pressure sink.

W3(R) dxsink(k) Enter the length of the momentum control volume for the sink (inches or meters).

18.15.4 CARD 6132NN00, Gap Boundary Condition Data

18.15.4.1 CARD 6132NN00

This card is read W4 of 61300000(ngbnd) times.

W1(I) k Enter the gap number to which a zero (0.0) crossflow is to be applied.

W2(I) jstart Enter the continuity cell number at which to start applying the zero crossflow.

W3(I) jend Enter the continuity cell number at which to stop applying the zero crossflow.

Note: The crossflow will be set to zero for gap k between nodes W2(jstart) and W3(jend). The node numbers are given relative to the beginning of the section containing gap W1(k).

This card may be repeated as many times as necessary for a given gap W1(k), to identify all axial levels that have zero crossflow. The total number of transverse momentum cells with zero crossflow boundary conditions specified by card 6132NN00 must sum to W2 of 61300000(nkbnd).

18.16 CARD 614XXXXX, Output Option.

18.16.1 CARD 61400000

W1(I) n1 Enter the general vessel output option. Valid entries are:

1 = print channels only

2 = print channels and gaps only

3 = print rods and unheated conductors only

4 = print rods, unheated conductors, and channels only

5 = print channels, gaps, rods, and unheated conductors

W2(I) nout1 Enter the number of channels to be printed (used if W1(n1)=1, 2, 4, or 5).

If W2(nout1) = 0, all channels will be printed.

If W2(nout1) > 0, an array of W2(nout1) channel numbers must be entered on card 614100XX.

W3(I) nout2 Enter the number of rods to be printed (used if W1(n1) > 2).

If W3(nout2) = 0, all rods will be printed.

If W3(nout2) > 0, an array of W3(nout2) rod numbers must be entered on card 614200XX.

W4(I) nout3 Enter the number of gaps to be printed (used if W1(n1) = 2 or 5).

If W4(nout3) = 0, all gaps will be printed.

If W4(nout3) > 0, an array of W4(nout3) gap numbers must be entered on card 614300XX.

W5(I) nout4 Enter the number of unheated conductors to be printed (used if W1(n1) > 2).

If W5(nout4) = 0, all unheated conductors will be printed.

If W5(nout4) > 0, an array of W5(nout4) unheated conductor numbers must be entered on card 614400XX.

W6(I) ipropp Enter the property table print option.

Valid entries are:

0 = do not print the property table

1 = print the property table

W7(I) iopt Enter the debug print option. Valid entries are:

0 = normal printout only

2 = debug printout (print extra data for channels, rods and gaps)

18.16.2 CARD 6141000N, Channel Option.

Specify only if W1 of 61400000(n1) is not 3 and W2 of 61400000(nout1) is greater than 0.

W1,2,..,k(I) ptintc(i) Enter the index numbers of channels to be printed.

Repeat this card until nout1 values have been entered.

18.16.3 CARD 6142000N, Gap Option.

Specify only if W1 of 61400000(n1) is not 3 and W4 of 61400000(nout3) is greater than 0.

W1,2,..,k(I) ptintg(i) Enter the index numbers of gaps to be printed.

Repeat this card until nout3 values have been entered.

18.16.4 CARD 6143000N, Rod Option.

Specify only if W1 of 61400000(n1) is not 3 and W3 of 61400000(nout2) is greater than 0.

W1,2,..,k(I)	ptintr(i)	Enter the index numbers of rods to be printed.

Repeat this card until nout2 values have been entered.

18.16.5 CARD 6144000X, Unheated Conductor Option.

Specify only W5 of 61400000(n1) is greater than 0.

W1,2,..,k(I)	ptints(i)	Enter the index numbers of unheated conductors to be printed.

Repeat this card until nout5 values have been entered.

18.17 CARD 615XXXXX, Graphic Option.

18.17.1 CARD 61500000

This card is optional for all problem types. If the card is omitted, default values are assumed (W1=1000, W2=0, and W3=0).

W1(I) mxgdmp Enter the maximum number of time steps for which graphics data will be saved. Absolute maximum is 1000. Note: This cannot be changed on a restart.

W2(I) igrfop Enter zero (0).

W3(I) nllr Enter the number of liquid level calculations. (Number of 61500100 cards.)

(Valid only if W2 > 0.)

18.18 CARD 616XXXXX, Initial Condition Data.

These cards can be specified if W2 of card 60000000 is 2.

18.18.1 CARD 61600NNN, INITIAL VOID FRACTIONS

The three words are entered on this card, where NNN =1, 2, 3,..., (Total number of the 3D cells).

W1(I)	i	Enter the channel number (sequential number).
W2(I)	j	Enter the mesh number, where j=2,3,...,jnodes+1.

W3(R)	al	Enter the void fraction.

19 INSTALLATION AND OPERATING PROCEDURES

This section briefly describes the basic installation procedure for MARS-KS and the program execution steps. The platforms supported for the current (and most probably for the future) release of MARS-KS are MS Windows O/S systems, i.e., Windows 95, Windows 98, Windows NT, and Windows 2000, all of them running on PC. A version for the Linux operating system is under development.

19.1 MARS-KS Code Installation

The files released with MARS-KS and their functions are:

1. MARS-KS.exe: MARS-KS main program

2. contl.dll: Windows DLL for CONTEMPT4 coupled run

3. tpfh20: Steam table data for light water

4. tpfd20: Steam table data for heavy water

5. grfx.exe: post-plot data processor of 3-D grafout file

MARS-KS can be installed by simply following the procedure below.

1. Copy all the distributed files in any of the directory preferred. (eg. C:\MARS-KS)

2. Create a shortcut for MARS-KS31.exe file on the desktop.

19.2 MARS-KS Code Execution Steps

Once MARS-KS has been installed and input data file is ready, proceed as follow to execute the program. It is assumed that MARS-KS has been installed in C:\MARS-KS and user's input files reside in D:\Project_1\Case_1.

1. User may create the input data file in whichever directory location preferred. However, when the directory other than MARS-KS main directory (C:\MARS-KS in our example) is used as a working directory, steam table file should be also copied from the MARS-KS main directory. The working directory also needs contl.dll if MARS-KS/CONTEMPT4 coupled analysis is performed. The contain.dll or master.dll is necessary for the similar coupled analysis, such as containment analysis or 3-D kinetics calculations.

2. Click the right mouse button on the MARS-KS shortcut, and then choose registration button. You will see the dialog window similar to **Fig. 19-1**. Specify your MARS-KS working directory (eg. d:\Project_1\Case_1) as a 'Starting directory' and close the window by clicking OK. This step needs to be performed only once, unless any other directory is used as a working directory.

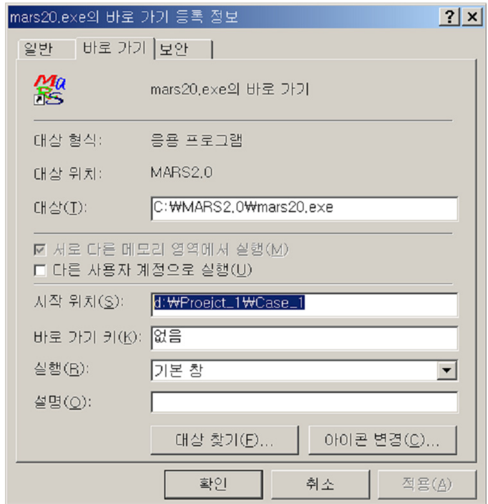

Figure 19-1. A View of MARS-KS Execution Setting Dialog Window

3. Now, double click the MARS-KS shortcut on your desktop. Three new windows as shown in **Fig. 19-2** will appear. In the top dialog window you can specify input and output data file names if the default file names provided are not appropriate. When 3-D module is used, one can also specify i/o data file names for 3-D analysis by clicking 'More 3D' button. Once the data file names are assigned properly, you are ready to the start analysis run by clicking 'Start Run' button. But if the output files are already present (if it is not the very first run in this directory), the program terminates by file opening error. Users, therefore, have to remove the previously generated output files by clicking 'Delete Files' button before the execution. The ’delete files’ button pops up another window where you can select the problem type. For instance, if ’new’ problem type is selected, all the file generated in the previous run will be deleted. The ’rstplt’ file could be remained undeleted if ’restart’ button is clicked on. The window provides file delete functions for coupled analysis as well.

4. Once analysis run starts, you may want maximize the MARS-KS main window by clicking max button on the right upper corner of the window. Also rearranging the graph windows and the text info window to 'tile' form will enhance your interaction with several windows (See **Fig. 19-3**). The graph windows show the minor edit variables specified in the input file, and the text info box displays various information as the run proceeds.

Beside above procedure, data file named 'inputc' should exist when CONTEMP4 module is invoked by the input data. The input file name is currently fixed as 'inputc' and the dialog box does not allow for any change. In running the MARS-KS/CONTEMPT4 coupled problem, users should manually remove the CONTEMPT4 output files before the execution. Refer to CONTEMP4 manual for the preparation of 'inputc'.

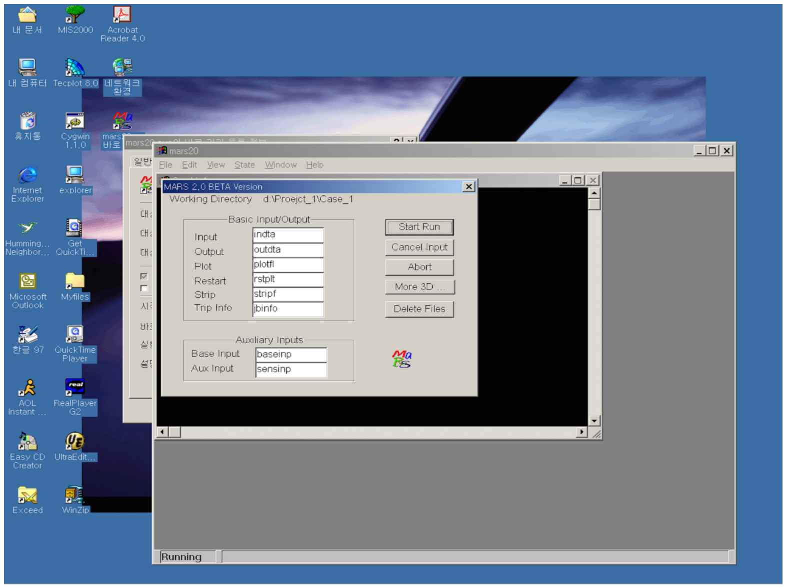

Figure 19-2. A View of Dialog Box Listing the Input and Output Files to Use

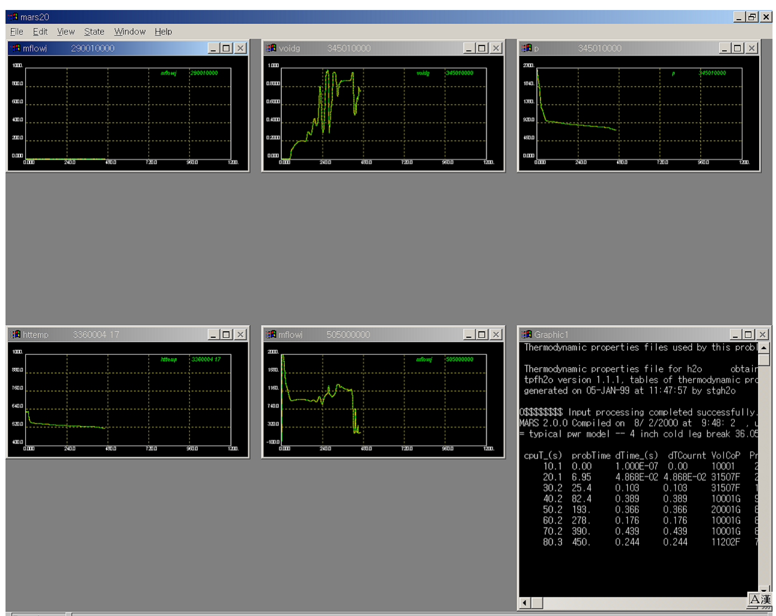

Figure 19-3. A View of MARS-KS Running in Qwin Mode.

19.3 MARS-KS I/O Files

The input and output file names provided by default are as below. These names can be overridden by the user using the dialog box, as mentioned in Section 19.2.

Files related with both 1-D and 3-D Vessel modules

indta	input data
plotfl	minor edit data for plot
jbinfo	trip information data
coupfl	contour plot data

Files related with 1-D module only

outdta	printed output
rstplt	restart plot file
stripf	the strip file
screen	text sub-window output

Files related with 3-D module only

restart	restart file
grafout	plot data (needed for restart run)
mserr	mass error data
output	printed out for
mvyout	text sub-window output

Files related with CONTEMPT4 module

inputc	input file for CONTEMPT4 module
ouputc	text output file
plotflc	plot data file

screenc text sub-window output

Files related with CONTAIN2.0 module

inputc	input file for CONTAIN module
ouputc	text output file
plotflc	plot data file

Files related with 3D kinetics MASTER module

MAS_INP	input file for MASTER Module

Note: Other I/O files for MASTER Modules are specified in 'MAS_INP'.

Files related with MIDAS connection

Trip4Midas.dat	trip data file
kinetic4Midas.dat	reactor kinetics data file
VolJun4Midas.dat	volume/junction/component data file
Heat4Midas.dat	heat structure data file
MWR4Midas.dat	metal-water reaction data file
reflood4Midas.dat	reflood data file
control4Midas.dat	control variable data file

APPENDIX A: "MAS_MAP" Input Data Generation

In general, the mesh structures used for the neutronic and thermal/hydraulic (T/H) calculations are different from each other. In such cases, the correspondence between the neutronic and T/H nodes is no longer one-to-one and a special input is required to define the correspondence. In the MARS-KS/ MASTER coupled code, the correspondence is established through the MAS_MAP file in which the schemes of mapping a neutronic node onto T/H nodes are specified. It is assumed in the mapping input scheme described by MAS_MAP that the same radial node structure is applied in all axial levels. Due to this assumption, it is not necessary to provide the mapping information for every neutronic node in the three-dimensional domain. Instead, it is sufficient to specify only the radial and the axial mapping information separately.

The MAS_MAP file consists of three sets of data with each set starting with a comment card. The first set has nothing to do with the mapping, but it defines the fuel surface temperature weighting factor, ω, that is used to obtain the effective fuel temperature out of the fuel centerline (T_f^{CL}) and surface (T_f^S) temperatures as:

$$T_f^{Dop} = \omega T_f^S + (1-\omega) T_f^{CL} .$$

The second and third sets provide the radial and axial mapping information, respectively. The same rule to define the mapping scheme described below applies to both directions. Each line in the mapping input represents a neutronic node, either radially or axially. The line starts with a neutronic node number and lists pairs of two numbers consisting of a heat structure (fuel rod) number in the T/H input and the volume fraction of the neutronic node belonging to the heat structure. Note that a neutronic node can belong to only one heat structure node or different parts of the node can belong to different heat structure nodes. The sum of the fractions of a neutronic node belonging to different heat structure nodes must 1.0. The radial mapping information must be given from the first radial node to the last. The same rules are applied to the axial mapping information as well.

Consider a reactor core, of which neutronics is modeled by 9 radial meshes and 3 vertical meshes (See **Figure A1**) and of which T/Hs is modeled by 4 radial meshes and 2 vertical meshes (See **Figure A2**). A sample MAS_MAP file is given in **Figure A3** for the neutronic-to-T/H mapping scheme.

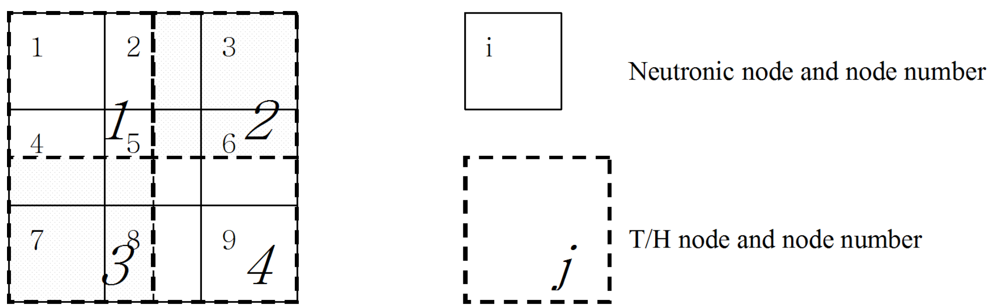

Figure A1. Radial Mapping Example

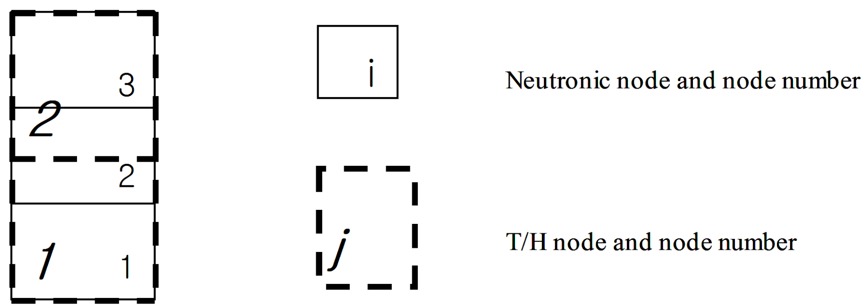

Figure A2. Axial Mapping Example

```
pellet surface temp weighting factor
 0.7
radial mapping (neutnode, (thnode(i),frac(i)),i=1,nth))
    1      1   1.0000
    2      1   0.5000   2   0.5000
    3      2   1.0000
    4      1   0.5000   3   0.5000
    5      1   0.2500   2   0.2500   3   0.2500   4   0.2500
    6      2   0.5000   4   0.5000
    7      3   1.0000
    8      3   0.5000   4   0.5000
    9      4   1.0000
axial mapping (neutnode, (thnode(i),frac(i)),i=1,nth)) 3 neutronic and 2 t/h planes
    1      1   1.0000
    2      1   0.5000   2   0.5000
    3      2   1.0000
```

Figure A3. Sample MAS_MAP file

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