A1. INTRODUCTION

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

A1.1 Control Format

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

RELAP5-SCDAP attempts to read a 96-character record. If the actual input record is smaller, blank characters are added to the end of the input record to extend it to 96 characters. Each 96-character input record, preceded by a sequential card number starting at one and incrementing by one, is printed as the first part of a problem output. Only the first 80 characters are used for RELAP5-SCDAP 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-SCDAP as input, since RELAP5-SCDAP 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 do not store the line numbers. The line numbers, if saved, are listed in the output echo of the input data.

A1.2 Data Deck Organization

A RELAP5-SCDAP problem input deck consists of at least one title card, optional comment cards, data cards, and a terminator card. A listing of these input cards is printed at the beginning of each RELAP5-SCDAP 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 with a duplicated number is used. It is recommended that for a base deck, the title card be first, followed by data cards in card number order. Comment cards should be used freely to document the input. For parameter studies and for temporary changes, a new title card with the inserted, modified, and deleted data cards and identifying comment cards should be placed just ahead of the terminating card. In this manner, a base deck is maintained; yet changes are easily made.

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

A1.3 Title Card

A title card must be entered for each RELAP5-SCDAP 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.

A1.4 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.

A1.5 Data Cards

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

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

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

A numeric field must begin with either a digit (0 through 9), a sign (+ or -), or a decimal point (.). A comma or blank (with one exception subsequently noted) terminates the numeric field. The numeric field has a number part and optionally an exponent part. A numeric field without a decimal point or an exponent is an integer field; a number with either a decimal point, an exponent, or both is a real field. A real number without a decimal point (i.e., with an exponent) is assumed to have a decimal point immediately in front of the first digit. The exponent part denotes the power of 10 to be applied to the number part of the field. The exponent part has an E or D, a sign (+ or -), or both followed by a number giving the power of 10. These rules for real numbers are identical to those for entering data in FORTRAN E or F fields, except that no blanks (with one exception) are allowed between characters to allow real data written by FORTRAN programs to be read. The exception is that a blank following an E or D denoting an exponent is treated as a plus sign. Acceptable ways of entering real numbers, all corresponding to the quantity 12.45, are illustrated by the following six fields:

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

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

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

The total number of words on all cards may not exceed 2,097,151. The largest card number allowed is 536,870,911.

A1.6 Continuation Cards

A continuation card, indicated by a plus sign as the first non-blank 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 associated continuation cards.

A1.7 Terminator Cards

The input data are terminated by a slash or a period card. The slash and period cards have a slash (/) or a period (.) respectively as the first non-blank 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.

A1.8 Sequential Expansion Format

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

The first example is for 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 zero 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.

A1.9 Upper/Lower Case Sensitivity

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

A1.10 Data Card Requirements

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

A1.11 Input Error Trapping

Comparative checks will occur during input processing for variable type, number of words on a card, range of normal use, and physical/code limits Further checks will also be performed for consistency of input. For example, one consistency check will examine radial node placement and verify that radial nodes have been placed at material interfaces.

Input violations of variable type, number of words, physical limit, and consistency of input will result in an input error, but will not abort input processing. Error messages will be printed in the output file flagged with the character string "********". If the input is outside the range of normal use, a warning message will be printed in the output file and marked with the character string "$$$$$$$$."

To assist the user during deck building and input processing, selected ranges of allowable input will be identified with the card input descriptions. The range for a given input variable will be identified in the following manner:

Normal type - issue warning if out of range

$\underline{0.0\text{ m}} < x < 2.0\text{ m}$

Underline - input error if out of range

A2. MISCELLANEOUS CONTROL CARDS

A2.1 Card 1, Developmental Model Control

This card has been added to the code for the convenience of developers in testing model improvements or new models. This card is not a standard input feature of the code. The description of this card has been added to the input requirements because several laboratories are receiving test versions to assist in 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 99 options can be defined and the options are identified with a number from 1 through 99. 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 99 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 99 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.input.

The number 100 is an option that is always active [i.e., the logical variable n (=100) is always true] and can be used to activate coding which is being tested by a developer. The number 100 should not be entered on a card; if it is entered, an input error will occur

W1-100(I) Zero or an available option number as described above.

Option 2. Apply transient natural circulation model in calculation of heat transfer from interior to boundary of molten pool.

Option 11 This option changes oxidation and growth constants for zircaloy in matpro functions, coxthk and coxwtk. This option allows the user to apply the Leistkow-Schanz correlation to zircaloy oxidation.

Option 23. This options selects a boron transport algorithm that greatly reduces the numerical diffusion of boron compared to the standard algorithm.

Option 30. This option uses implicit coupling for the radiation exchange between SCDAP components and hydrodynamic volumes.

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 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. Invokes the modified Henry-Fauske critical flow model.

Option 54. This option changes the voidf limit in EQFINL from 1.0E-9 to 1.0E-9*(rhof/rhof). When this option is activated, it reduces the mass loss in low pressure cases many orders of magnitude.

Option 55. This option is a collection of modeling improvements designed to minimize numerical sources of oscillations for low pressure two-phase flow simulations. Specifically, this option affects:

Interfacial heat transfer for annular-mist, mist pre-CHF, and mist post-CHF flow regimes: the liquid-side interfacial heat transfer coefficient has been modified to replace “ad hoc” correlations with more physical models.

Option 57. This option modifies the phasic partitioning of the wall friction so that all of the wall friction is applied to the liquid film in the annular-mist flow regime. This option is necessary to compute realistic values of the liquid film thickness.

Option 58. This option changes the smoothing used for the bubbly flow interfacial heat transfer coefficient between the liquid superheat and subcooled regions.

Option 61. This option further modifies constitutive relationships to reduce numerical oscillations at low pressure. Specifically this option affects:

Vertical stratification: this model is used for the purpose of defining the character of the two-phase interface to evaluate the interfacial heat transfer coefficient and interface area. The criteria used to determine if the interface is “stratified” as opposed to a “normal” vertical flow regime such as slug flow have been modified.

Interfacial hat transfer for bubbly and slug flow regimes: the liquid-side interfacial heat transfer coefficient has been modified to replace “ad hoc” correlations with more physical models.

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 implements velocity squared instead of velocity * velocity-donored for momentum flux.

Option 68. This option implements velocity - j times (velocity - L - velocity - K) instead of velocity * velocity-donored for momentum flux.

Option 69. This option uses a momentum flux with a donored velocity calculated using the actual donored void fraction in the numerator instead of a floored value.

Option 70. This option selects modifications made to some of the MATPRO subroutines by the Russian Kurchatov Institute. This option is present only for testing and debugging.

Option 71. This option requires Option 70 to be set to be effective. The Kurchatov modifications started from a different MATPRO library from that now in the current code. Not entering this option uses the uses the "different" MATPRO library and sets a iwwer option to 1. This option is present only for testing and debugging.

Option 72. This option is similar to Option 71, but sets the iwwer option to 2. This option is present only for testing and debugging.

Option 73. This option requires Option 70 to be set to be effective. This option sets the imodel option to 1 from the default option 0. This option is present only for testing and debugging.

A2.2 Print Control

The following section describes the input by which the user can specify the contents of the printed output. The printed output is divided into blocks and an individual block may be added or deleted from the printed output. Blocks can be enabled by use of Card 4 or blocks can be disabled by use of Card 5. Either Card 4 or Card 5 but not both input cards may be included in an input deck. If neither card is included in an input deck, all available printout appears on the printed output file. In addition to specifying which blocks appear in the printed output, the volumes and/or junctions for which information is printed within each block can be specified on Cards 2 and 3 respectively.The print control information is not saved for restart. If the print control effect needs to be carried into a restart, these cards will need to be re-entered in the input deck.

A2.2.1 Card 2, Volume Print Control

This card is an optional card. If this card is present, the major edits and debug printouts contain information for only the volumes listed on this card. Single volume identifiers may be entered as well as pairs of volume identifiers. Pairs of volume identifiers specify a range of volumes to be printed and the second identifier in the pair must be a negative number and must be separated from the first number in the pair by a blank or a comma (i.e., each number of the pair must be a separate number). The volume identifiers in a pair must also be in increasing numerical order. There is no limit to the number of single volume identifiers or pairs of identifiers which may be listed on this card. Heat structures connected to the volumes listed on this card are printed on the major edits and debug printouts. If the entire heat structure print block of the major edit is suppressed by the action of either Card 4 or 5, no heat structure information is printed even if the volume to which a particular heat structure is attached is listed on this card. The same is true for the heat structure portion of the debug printout where the heat structure information for heat structures connected to volumes listed on this card is added to the debug printout unless that portion of the debug printout is suppressed by the action of Cards 4 or 5.

W1(I) Volume identifier.

W2(I) Volume identifier

A2.2.2 Card 3, Junction Print Control

This card is an optional card. If this card is present, the major edits and debug printouts contain information for only the junctions listed on this card. The rules for specifying junctions are the same as for specifying volumes on Card 2.

W1(I) Junction identifier.

W2(I) Junction identifier

A2.2.3 Card 4, Enable Printed Output Block

This is an optional card. If this card is present, printed output from the blocks listed on this card are added to the output file. All blocks not listed on this card are suppressed. The names of the blocks and a short description of the blocks are contained in Table 1.

W1(A) Name of first block of printout to be enabled.

W2(A) Name of second block of printout to be enabled.

A2.2.4 Card 5, Disable Printed Output Block

This is an optional card. The action of this card is similar to that of Card 4 except that blocks listed on this card are suppressed rather than being enabled. Blocks not listed on this card are enabled.

W1(A) Name of first block to be disabled.

W2(A) Name of second block to be disabled.

W3(A). Name of third block to be disabled.

Table 1:

Name	Description of Print Block
ACCUM	Debug printout from subroutine ACCUM
BRNTRN	Debug printout from subroutine BRNTRN
CCFL	Debug printout from subroutine CCFL
CHFCAL	Debug printout from subroutine CHFCAL
CONDEN	Debug printout from subroutine CONDEN
DITTUS	Debug printout from subroutine DITTUS
EQFINL	Debug printout from subroutine EQFINL
FPTRAN	Debug printout from fission product transport
FWDRAG	Debug printout from subroutine FWDRAG
HT1TDP	Debug printout from subroutine HT1TDP
HT2TDP	Debug printout from subroutine HT2TDP
HTADV	Debug printout from subroutine HTADV
HTFILM	Debug printout from subroutine HTFILM
HTFINL	Debug printout from subroutine HTFINL
HTRC1	Debug printout from subroutine HTRC1
HYDRO	Debug printout from subroutine HYDRO
IELVTN	Printout of coordinate positions.
ISTATE	Debug printout from subroutine ISTATE
JCHOKE	Debug printout from subroutine JCHOKE
JPROP	Debug printout from subroutine JPROP
LEVEL	Debug printout from subroutine LEVEL
NONCND	Debug printout from subroutine NONCOND

Table 1:

Name	Description of Print Block
PHANTV	Debug printout from subroutine PHANTV
PHANTJ	Debug printout from subroutine PHANTJ
PIMPLT	Debug printout from subroutine PIMPLT
PINTFC	Debug printout from subroutine PINTFC
PREDNB	Debug printout from subroutine PREDNB
PRESEQ	Debug printout from subroutine PRESEQ
PSTDNB	Debug printout from subroutine PSTDNB
QFMOV	Debug printout from subroutine QFMOV
SCDAP	Printout from SCDAP models
SIMPLT	Debug printout from subroutine SIMPLT
SSTCHK	Debug printout from subroutine SSTCHK
STACC	Debug printout from subroutine STACC
STATE	Debug printout from subroutine STATE
STATEP	Debug printout from subroutine STATEP
SUBOIL	Debug printout from subroutine SUBOIL
SYSITR	Debug printout from subroutine SYSITR
SYSSOL	Debug printout from subroutine SYSSOL
TSTATE	Debug printout from subroutine TSTATE
VALVE	Debug printout from subroutine VALVE
VEXPLT	Debug printout from subroutine VEXPLT
VFINL	Debug printout from subroutine VFINL
VIMPLT	Debug printout from subroutine VIMPLT
VLVELA	Debug printout from subroutine VLVELA
VOLVEL	Debug printout from subroutine VOLVEL
CONTROL	Section in major edit for results of control system components
FSNPRDTR	Section in major edit for results of fission product transport
HEATSTR	Section in major edit for results of heat structures

Table 1:

Name	Description of Print Block
IELVTN	Coordinate positions of volumes and junctions
INPUT	Printout of user input
JUNCTION	Section in major edit for results of junctions
MIEDT	Minor edits
POWER	Section in major edit for reactor kinetics results
RADHT	Section in major edit for radiation heat transfer
REFLOOD	Section in major edit for reflood model
SCDAP	Section in major edit for SCDAP results
TRIP	Section in major edit for trip results
VOLUME	Section in major edit for results of volumes

A2.3 Card 100, Problem Type and Option

This card is always required.

W1(A) Problem type. Enter one of the following: NEW, RESTART, PLOT, IN-COND, STRIP, CMPCOMS, UNCSETUP, or UNCPOST.

NEW specifies a new simulation problem. RESTART specifies continuation from some point in a previous problem using information from the RSTPLT file. PLOT specifies plotting results from a previous simulation run using the RSTPLT file. IN-COND specifies that initial conditions for hydrodynamic volumes and junctions, heat structures, and control systems are to be written to a disk 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. CMPCOMS specifies that a comparison is to be made between dump records on two files written in one or two previous runs. UNCSETUP specifies that the setup phase of the uncertainty option is to be executed. UNCPOST specifies that the post processing phase of the uncertainty option is to be executed.

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, enter either STDY-ST or TRANSNT to specify the type of simulation. Note the cautions discussed in Section 2.6, Card 103, Restart-Plot Input File Control Card on page 13, when the problem option is changed from STDY-ST to TRANSNT or vice versa. When STRIP is entered in W1, W2 may be optionally entered with BINARY or FMTOUT. BINARY is assumed if W2 is not entered. BINARY indicates unformatted records. FMTOUT indicates that the same information is to be written as 80-column formatted records. One use of this option is to allow simulation results to be transmitted to a different type of computer. Formats are:

STRIP Record 1. (5A8,10X,A8).

STRIP Record 2. (A10,3I10).

STRIP Record 3. (8A10).

STRIP Record 4. [A10,7I10/(8I10)].

STRIP Record 5 ..., N. [A10, 5X,1P,4E15.6/(5E15.6)].

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

A2.4 Card 101, Input Check or Run Option

This card is optional for all types.

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

A2.5 Card 102, Units Selection

This card is optional for all problem types. If the card is omitted, SI units are assumed for both input and output. If the card is used, enter either SI or BRITISH for each word. SI units used are the basic units, kg, m, s, and the basic combined units such as Pa = $kg - \frac{m}{s^2} \bullet m^2$.

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.

A2.6 Card 103, Restart Input File Control Card

This card is required for all problem types (W1 of Card 100) except NEW and is not allowed for type NEW. When the problem option (W2 on Card 100) is the same as the problem being restarted, the steady-state or transient is continued and data on the RSTPLT file up to the point of restart are saved. If the restart continues from the point the previous problem terminated, restart and plot information is added to the end of the previous RSTPLT file. If the restart is 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 zero, 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 number must be -1, 0, or a positive number. For a NEW problem type, the program's data bases are not defined, and the input data must contain all the information to define the data bases. For all problem types except for the STRIP option, the restart number indicates that simulation results from a specified time value is to be loaded into the data bases. Input processing can add to, delete from, or modify selected parts of the data base. Transient processing proceeds from the modified data base. Consult the users manuals for more detailed information on the modifications that can be made at restart. If the restart number is a positive number, it must be a number printed in one of the restart print messages and whose associated restart information is stored in the RSTPLT file. Not finding the restart number is an error, and the restart last read before detecting the error is used to continue input checking. If the restart number is -1, the restart record corresponding to the last time value of the previous simulation is used for restart. A zero can be entered for a restart run, but that reads the initial condition at the creation on the restart plot file, and there would be no difference in simulation results from simply starting from the original input deck. For INCOND and PLOT runs, the data bases are read and possibly modified by input processing in the same manner as for a RESTART run. For the INCOND run, initial conditions are printed from the resultant data base. For the PLOT run, the resultant data base is ignored, and plotting of transient information is done using data from the plot records included in the restart plot file. The restart number is usually entered as 0 for PLOT runs, so that only the first restart record need be read. No difference in plot results occurs if a positive restart number (but one that exists on the restart plot file) is entered. For STRIP runs, the restart number must be 0, and the restart plot file is read only to obtain plotting information.

W2(A) Compress flag. This optional flag indicates whether the restart-plot file is written in an uncompressed or compressed format. If the word is not entered or if NCMPRESS is entered, the restart plot file is assumed to be in uncompressed format. If CMPRESS is entered, the restart plot file is assumed to be in compressed format.

W3-7(A) Restart plot file name. This optional alphanumeric entry can be used to enter the file name of the restart plot file. Up to 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.

W7(A) Reset time flag. If the word RESET is the last word on this card, the problem time is reset to 0.0, This word can be W2, W3, W4, W5, W6, or W7, depending on whether the compress flag (W2) and restart-plot file name (W3-W7) are used.

A2.7 Card 104, Restart-Plot File Control Card

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

W1(A) Action. This word may not be blank. If the card is NONE, no restart-plot file is written. If this word is NCMPRESS, the restart-plot file is written in uncompressed format. If this word is CMPRESS, the file is written in compressed mode. The NCMPRESS and CMPRESS options may be entered only in NEW problems. In RESTART problems, this information is entered on the 103 card. Entering XMGR5CMP means that the title written to the restart-plot file is to be compatible with the XMGR5 plotting program.

W2-11(A) Restart plot file name. This optional alphanumeric entry can be used to enter the file name

A2.8 Card 105, CPU Time Remaining and Diagnostic Edit Card

Card 105 controls termination of transient advancement based on the CPU time remaining for the job. Some operating systems allow specification of the CPU time allocated for a job as part of the job control language and also provide a means to determine the CPU time remaining during job execution. As an alternative, Word 3 of this card may be entered as the CPU time allocated. An alternative CPU remaining time is computed by decrementing this quantity by the CPU used as measured by the program. If Word 3 is omitted or zero, the alternative CPU remaining time is assumed infinite. At the end of each time step, the CPU time remaining for the job is determined from the minimum of the system (if available) and alternative CPU remaining times. If the remaining CPU time is less than Word 1, the transient is immediately terminated. The advancement may not be at the end of a requested time step 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 a reduced time step. Major edits, minor edits, plot edits, and a restart record are forced. The transient can be restarted from this point as if the problem had not been interrupted. The transient is also terminated after successful advancement over a requested time step and the CPU time is less than Word 2. Word 2 should be larger than Word 1. The default values for Words 1 and 2 are 1.0 and 2.0 seconds. The default values are used if the card is not supplied or the entered numbers are less than default values. Word 2 is also forced to be 1.0 second larger than Word 1. The time values must include time for the final minor and major edits (very little time required), plotting, and any other processing that is to follow termination of SCDAP 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 zero, no debug options are in effect. If Word 4 is greater than zero, then Word 4 is the attempted advancement count number to start a diagnostic edit, and Word 5 is the attempted advancement count number to stop the diagnostic edit as well as the calculation. If Word 4 is -1, a dump file is written on the file specified by the -A option on the command line at the completion of the advancement given in Word 5. Entering 0 in Word 5 writes the dump file just before 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 from the drop file.

A2.9 Card 106, R5FORCE File Control

This card can be entered for NEW and RESTART options. If this card is omitted, NONE is assumed for W1.

W1(A) Action. This word may not be blank. If this word is NONE, no R5FORCE file is written. Currently, the use of any other entry for this word will force a R5FORCE file to be written.

W2-11(A) R5FORCE file name. This optional alphanumeric entry can be used to enter the file name of the R5FORCE file. Up to eighty characters may be entered as one alphanumeric field. (The code internally treats the field as up to ten eight-character words.) The default file name for the R5FORCE files is r5-r5f. This may be overwritten on Unix machines by using the -F option on the command line. Either the default name or the name from the command line may be overwritten by this field. This information can be entered on NEW or RESTART problems. For RESTART problems, the R5FORCE data are added to the end of the R5FORCE file.

A2.10 Card 107, Steady State Options

This card is optional. The values on this card are used to override the default options for the steady state mode. Without this card, trips and CHF are bypassed in steady state mode, the steady state solution is obtained using the nearly-implicit solution algorithm, the mass error time step control is disabled, the steady state checking routine is bypassed, and the heat conduction and hydrodynamic solutions are coupled implicitly and use the same time step size.

W1(I) Trip flag. If this word is one, the trip logic is enabled in steady state mode. The default value is zero.

W2(I) CHF flag. If this word is one, CHF is enabled in steady state mode. The default value zero.

W3(I) Solution controls flag. If this word in one, the solution controls found on the time stepcards are used instead of the default values for steady state mode. The default value is zero.

A2.11 Card 110, Noncondensable Gas Species

This card is required for all calculations that use noncondensable gas. Hydrogen must be included for RELAP5-SCDAP problems. 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, sf6 oxygen, CO2 or CO.

A2.12 Card 111, Metal Species

W1-W2(A) Metal species. Enter up to five words defining the metal species to be tracked. Species may be U, Zr, steel, Al, or O2.

A2.13 Cards 115 and 116, Noncondensible and Metal Species Mass Fractions

Card 115 is related to Card 110 and similarly Card 116 is related to Card 111. Card 115 is required if Card 110 is entered unless only one species is entered on Card 110 and then the mass fraction is set to 1.0. The number of words on Card 115 must equal the number of words on Card 110. A similar requirement holds for Card 116. The sum of the mass fractions on each card must sum to one. The mass fractions on these cards are default values and are used for initial conditions of active volumes and for values of time-dependent volumes unless mass fractions are entered in the hydrodynamic component data. These cards cannot be entered on a RESTART problem.

A2.13.1 Card 115, Noncondensable Gas Mass Fractions

W1-W2(R) Mass fraction for each noncondensable gas type.

A2.13.2 Card 116, Metal Mass Fractions

W1-WN(R) Mass fraction for each metal species.

A2.14 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. This card is not allowed in a RESTART problem.

W1(R) Gravitational constant (m/s^2, ft/s^2). A positive number, which must be greater than or equal to 1.0×10^{-6} m/s^2 (or $3.280839895 \times 10^{-6}$ 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.

A2.15 Cards 120 through 129, Hydrodynamic System Control Cards

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

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

A2.15.1 Hydrodynamic System Card

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 H_2O or D_2O.

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

W5(I) System information flag that specifies whether noncondensable gas is present for this system. This word is optional and if not entered, is assumed to be zero. This word being zero specifies that noncondensable gas is present for this system. This word being one specifies that noncondensable gas is not present for this system. If this word is one (no noncondensable in the system) and if the digit t = 4, 5, or 6 in the hydrodynamic volume component control word ebt (see Section 7 of this Appendix) is input an input error will result.

A2.16 Cards 140 through 147, Self-Initialization Option Control Cards

These cards are optional, are not needed, and are only used as a cross-check on the controllers specified in Section A14. 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 A14.

A2.16.1 Card 140, Self-Initialization Control Card

This card specifies the number and type of controllers desired.

W1(I) Number of pump controllers.

W2(I) Number of steam flow controllers.

W3(I) Number of feedwater controllers.

A2.16.2 Cards 141 through 142, Self-Initialization Pump Controller and Identification Cards

These cards establish the relationship between the pump number and the number of the pump controller. For each pump so referenced, the user must use the time-dependent pump velocity option. For pump component Card CCC6100, Words 2 and 3 must be the alphanumeric and numeric parts for the pump controller. The time-dependent pump velocity data (pump component Cards CCC6100 through CCC6199) should be input so that the search variable and pump velocity are related by a straight line through the origin with a slope of 1.

W1(I) Component number of pump number 1.

W2(I) Controller identification number for pump number 1.

W3(I) Component number of pump number 2.

W4(I) Controller identification number for pump number 2.

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

A2.16.3 Cards 143 through 144, Self-Initialization Steam Flow Controller Identification Cards

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

W1(I) Component number of steam flow control valve number 1.

W2(I) Controller number of steam flow controller for steam flow control valve number 1.

W3(I) Component number of steam flow control valve number 2.

W4(I) Controller number of steam flow controller for steam flow control valve number 2.

A maximum of six control valve/controller pairs may be entered. Note that in the above it is assumed that a valve component is the control component (junction). 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.

A2.16.4 Cards 145 and 146, Self-Initialization Feedwater Controller Identification Cards

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

W1(I) Component number of feedwater valve number 1.

W2(I) Controller id number of the feedwater controller for feedwater valve number 1.

W3(I) Component number of feedwater valve number 2.

W4(I) Controller id number of the feedwater controller for feedwater valve number 2. A maximum of six control valve/controller pairs may be entered. Note that in the above it is assumed that a valve component is the control junction. However, the user is not constrained to use a valve and may use a pump or time-dependent junction. CAUTION: Only a servo valve, a time-dependent junction, or a pump is allowed, or a diagnostic error will result, such as a time-dependent junction with the controller output used as the independent variable in place of time.

A2.16.5 Card 147, Pressure and Volume Control Component Identification Card

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

W1(I) Component number of time-dependent volume that replaces the pressurizer.

W2(I) Component number to which the above time-dependent volume is connected. CAUTION: Only a single-junction is allowed or an error will result.

W3(R) Desired steady-state pressure.

A2.17 Cards 191-199, Monitoring of Code Results

This input is provided to facilitate the verification and validation of new code versions by monitoring selected simulation results. For each result to be monitored, a general table is entered containing either values from an experiment or values from a prior version of the code. This value is compared to the simulation result from the current code using the COMPARE component in the control system. The COMPARE component computes the relative difference between its two input variables. This input specifies that the maximum relative error over the simulation time for up to nine simulation results be accumulated. At the end of the transient, the accumulated maximum errors are written to the print file. The input includes an input maximum error for each comparison and the accumulated maximum error is compared to the input maximum error for each selected simulation result. The result of these comparisons is summarized in a line printed on both the print file and the monitor screen. The line contains, "Overall tolerance test result:", followed by either successful or unsuccessful, where successful indicates that all measured relative errors were less than the associated input tolerance, and unsuccessful indicates that one or more measured errors exceeds the input tolerance.

This input is typically used only for test problems used in code verification and validation testing. These problems would also usually include plots showing the experimental or previous version result (general table), the simulation result, and the relative error (compare component).

The input for a comparison is entered on Card 19x where x ranges from 1 through 9. Card numbers need not be consecutive.

W1-2(A) Two user defined alphanumeric words are entered to identify the comparison. The first word could be used to identify the problem or test, and the second word would identify the quantity being compared.

W3(I) The control component number used for the comparison of the experimental or previous result with the simulation result. The control component must be a COMPARE component.

W4(R) Maximum relative error limit. If the measure relative error is greater than this quantity, the comparison is unsuccessful, otherwise the comparison is successful. This quantity must be greater than zero.

A3. CARDS 200 THROUGH 299, TIME STEP CONTROL CARDS

A3.1 Card 200, Initial Time Value

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 zero for a NEW problem, the advancement time at the point of restart for a RESTART problem, or zero 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 zero. 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 A2.6 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.

A3.2 Cards 201 through 299, Time Step Control

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

W1(R) Time end for this set (s). This quantity must increase with increasing card numbers.

W2(R) Minimum time step (s). This quantity should be a positive number $\leq$ 1.0E-6. If a larger number is entered, it is reset to 1.0E-6.

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

W4(I) Control option (see Section 5.2 for a discussion of this input). This word has the packed format <u>ssdtt.</u> It is not necessary to input leading zeros. The digits <u>ss</u>, that represent a number from 0 through 15, are used to control the printed content of the major edits. The number is treated as a four-bit binary number. If no bits are set (i.e., the number is 0), all the standard major printed output is given. If the first bit from the right is set (i.e., <u>ss</u> = 1 if the other bits are not set), the heat structure temperature blocks omitted. If the second bit from the right is set (i.e., <u>ss</u> = 2 if the other bits are not set), the second portion of the junction block is omitted. If the third bit from the right is set (i.e., <u>ss</u> = 4 if the other bits are not set), the third and fourth portions of the volume block are omitted. If the fourth bit from the right is set (i.e., ss = 8 if the other bits are not set), the statistics block is omitted.

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

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. If no bits are set (i.e., the number is 0), no error estimate time step control is used, and then a 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. If the first bit from the right is set (i.e., tt = 1 if the other bits are not 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. 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. 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. 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. 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. 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 hydrodynamic 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/transformed 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; 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/SCDAP 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.

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.

A4. CARDS 301 THROUGH 399, MINOR EDIT REQUESTS

These cards are optional for NEW and RESTART problems, are required for a REEDIT problem, and are not allowed for PLOT and STRIP problems. If these cards are not present, no minor edits reprinted. 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).

Words 1 and 2 form the variable request code pair. The quantities that can be edited and the input required input are listed below. For convenience, quantities that can be used in plotting requests, in trip specifications, as search variables in tables, and as operands in control statements are listed. Units for the quantities are also given. Interactive input variables described in Section A6. 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 totables 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 A4.1 through Section A4.14 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 that are followed with an asterisk are written to the restart-plot file only if requested on a 208XXXX card as described in Section A4.15.

A4.1 General Quantities

The quantities listed below are unique to the whole problem or to a particular system in the whole problem. The parameter required is indicated for each variable code.

Code	Quantity
COUNT	The current attempted advancement count number. The parameter is 0.
CPUTIME	The current CPU time for this problem (s). The parameter is zero.
DT	The current time step (s). The parameter is 0.
DTCRNT	The current Courant time step (s). The parameter is 0.
EMASS	Estimate of mass error in all the systems (kg, lb_m). The parameter is 0.
ERRMAX	The 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}).
NULL	Specifies null field. Allowed only on trip cards. The parameter is 0.
SYSTMS	Total mass of steam, water, and noncondensable in system n (kg, lb_m). Parameter is system number n.
STDTRN	Steady-state/transient flag. The parameter is 0. For steady-state, the value is 0.0. For transient, the value is 1.0.

SYSMER Estimate of mass error 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 zero, and programming must be inserted to set testda values. The usual purpose of this capability is to allow a simple method for debug information to be printed in minor edits or to be plotted.

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.

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

A4.2 System Quantities

The quantities listed below are unique to a particular computational system in the user's input model. The parameter is indicated for each quantity.

LEVHGT Height of two-phase level above bottom of level stack (m, ft). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVEL Two-phase level velocity (m/s, ft/s). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVDA Void fraction above two-phase level (-). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVD Void fraction below two-phase level (-). The parameter is nss where n is the system number and ss is the level stack index in the system.

LEVVNM Volume number of the volume containing the two-phase level. The parameter is nss where n is the system number and ss is the level stack index in the system.

SYSMER Estimate of mass error in system n (kg, lb_m). The parameter is system number n.

SYSTMS Total mass of steam, water, and noncondensable in system n (kg, lb_m). The parameter is system number n.

A4.3 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.

Code	Quantity
ACPGTG	Accumulator vapor specific heat, C_p, at vapor temperature (J/kg·K, Btu/lb_m· ^oF).
ACPNIT	Accumulator noncondensable specific heat, C_p, at vapor temperature (J/kg·K, Btu/lb_m· ^oF).
ACQTANK	Total energy transport to the gas by heat and mass transfer in the accumulator (W, Btu/s).
ACRHON	Accumulator noncondensable density (kg/m^3, lb_m/ft^3).
ACTTANK	Mean accumulator tank wall metal temperature (K, ^oF).
ACVDM	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_m· ^oF).
ACVLIQ	Liquid volume in the accumulator tank, standpipe, and surge line (m^3, ft^3).
AHFGTF	Accumulator heat of vaporization at liquid temperature (J/kg, Btu/lb_m).
AHFGTG	Accumulator heat of vaporization at vapor temperature (J/kg, Btu/lb_m).
AHFTG	Accumulator liquid enthalpy at vapor temperature (J/kg, Btu/lb_m).
AHGTF	Accumulator vapor enthalpy at liquid temperature (J/kg, Btu/lb_m).
AVGTG	Accumulator specific volume at vapor temperature (m^3/kg, ft^3/lb_m).
AVISCN	Accumulator noncondensable viscosity (kg/m·s, lb_m/ft·s).
BETAV	Accumulator steam saturation coefficient of expansion (K^{-1}, $^oF^{-1}$).
CDIM	GE mechanistic dryer critical inlet moisture quality.
CPREFF	Thermodynamic efficiency in the compressor component (-).
CPRHEAD	Head in the compressor component (Pa, lb_f/in^2).
CPRMT	Motor torque in the compressor component (N•m, lb_f•ft^2).
CPRNRT	Inertia in the compressor component (kg•m^2, lb_m•ft^2).
CPRTRQ	Sum of hydraulic torque and frictional torque in the compressor component (N•m, lb_f•ft).
CPRVEL	Rotational velocity in the compressor component (rad/s, rev/min).
DIM	GE mechanistic inlet moisture quality.
DMGDT	Accumulator/time rate of change in dome vapor mass (kg/s, lb_m/s).

GDRY GE mechanistic separator capacity factor.

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

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

PMPMT Pump motor torque (N·m, $lb_f \cdot ft$).

PMPNRT Calculated pump inertia ($kg \cdot m^2$, $lb_m \cdot ft^2$).

PMPTRQ Pump torque in the pump component (N·m, $lb_f \cdot ft$).

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

PRZLVL Pressurizer liquid level (m, ft)

THETA Inertial valve disk angular position (deg).

TUREFF The efficiency of the turbine component.

TURPOW The power developed in the turbine component (W, Btu/s).

TURTRQ The torque developed in the turbine component (N·m, $lb_f \cdot ft$).

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

VLVAREA This is the 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 This is the 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.

VOLSTEM Normalized volume of computational volume for variable volume model.

XCO GE mechanistic separator liquid carryover quality.

XCU GE mechanistic separator vapor carry under quality.

XI GE mechanistic separator inlet quality.

A4.4 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 is to be added to the volume number to form the parameter used with coordinate direction related quantities is 0 or the face number. When F is 0 (i.e., just the volume number), 1, or 2, the volume velocity is for coordinate 1. When F is 3 or 4, the volume velocity is for coordinate 2; and when F is 5 or 6, the volume velocity is for coordinate 3. The 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 A4.15. Input checks are made to ensure the parameter specifies a volume coordinate direction that is in use.

Code	Quantity
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_f, bulk conditions (K^{-1}, $^oF^{-1}$).
BORON	Spatial boron density, ρr_b (kg/m^3, lb_m/ft^3). This is 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.
CSUBPF	Liquid specific heat, C_{pf}, bulk conditions ($J/kg{\cdot}K$, $Btu/lb_m{\cdot}\,^oF$).
CSUBPG	Vapor specific heat C_{pg}, bulk conditions ($J/kg{\cdot}K$, $Btu/lb_m{\cdot}\,^oF$).
DRFDP	Partial derivative of ρ_f with respect to pressure (s^2/m^2, s^2/ft^2).
DRFDUF	Partial derivative of ρ_f with respect to U_f ($kg{\cdot}s^2/m^5$, $lb_m{\cdot}s^2/ft^2$).
DRGDP	Partial derivative of ρ_g with respect to pressure (s^2/m^2, s^2/ft^2).
DRGDUG	Partial derivative of ρ_g with respect to U_g ($kg{\cdot}s^2/m^5$, $lb_m{\cdot}s^2/ft^2$).
DRGDXA	Partial derivative of ρ_g with respect to X_n (kg/m^3, lb_m/ft^3).
DSNDDP	Steam specific enthalpy at bulk conditions using partial pressure of steam (J/kg, Btu/lb_m).
DTDP	Partial derivative of T_s with respect to pressure (K/Pa, $in^2 \cdot {}^oF/lb_f$).
DTDUG	Partial derivative of T_s with respect to U_g ($s^2 \cdot K/m^2$, $s^2 \cdot {}^oF/ft^2$).

DTDXA Partial derivative of T_s with respect to X_n (K, ^oF).

DTFDT Partial derivative of T_f with respect to pressure (K/Pa, $in^2 \cdot {}^oF/lb_f$).

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

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

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

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

FLOREG Flow regime number; the parameter is the volume number. A chart showing the meaning of each number is shown in Section 2 of this volume of the manual

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

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

GAMMAC Mass transfer rate per unit volume at the vapor./liquid interface in the boundary layer near the wall for condensation ($kg/m^3 \cdot s$, $lb_m/ft^3 \cdot s$).

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

GAMMAW Mass transfer rate per unit volume at the vapor/liquid interface in the boundary layer near the wall for vapor generation ($kg/m^3 \cdot s$, $lb_m/ft^3 \cdot s$).

GAMANHY Rate of addition of hydrogen to hydrodynamic volume ($kg/m^3 \cdot s$, $lb_m/ft^3 \cdot s$).

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

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

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

HSTEAM Vapor specific enthalpy at bulk conditions using partial pressure of vapor (J/kg, Btu/lb_m).

HVMIX Enthalpy of the liquid and vapor (J/kg, Btu/lb_m).

KAPPAF Liquid isothermal compressibility, κ_f, bulk conditions (Pa^{-1}, in^2/lb_f).

KAPPAG Vapor/gas isothermal compressibility, κ_g, bulk conditions (Pa^{-1}, in^2/lb_f).

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.
QUALAN1	Volume noncondensable mass fraction for the first species identified on Card 110.
QUALAN2	Volume noncondensable mass fraction for the second species identified on Card 110.
QUALAN3	Volume noncondensable mass fraction for the third species identified on Card 110.
QUALAN4	Volume noncondensable mass fraction for the fourth species identified on Card 110.
QUALE	Volume equilibrium quality. This quality uses phasic enthalpies and mixture quality, with the mixture enthalpy calculated using the flow quality.
QUALHY	Mass fraction of hydrogen in noncondensible part of the vapor in a volume.
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$_m$/ft^3).
RHOF	Liquid density (kg/m^3, lb$_m$/ft^3)
RHOG	Vapor density (kg/m^3, lb$_m$/ft^3).
RHOM	Total density for the mass error check (kg/m^3, lb$_m$/ft^3).
SATHF	Liquid specific enthalpy at saturation conditions using partial pressure of steam (J/kg, Btu/lb$_m$).
SATHG	Steam specific enthalpy at saturation conditions using partial pressure of steam (J/kg, Btu/lb$_m$).
SATTEMP	Volume saturation temperature based on the partial pressure of steam (K, ^{o}F).
SIGMA	Surface tension (N/m, lb$_f$ /ft).
SOUNDE	Volume sonic velocity (m/s, ft/s).
TEMPF	Volume liquid temperature (K, ^{o}F).
TEMPG	Volume vapor temperature (K, ^{o}F).
THCONF	Liquid thermal conductivity (W/m·K, Btu/s·ft· ^{o}F).
THCONG	Vapor thermal conductivity (W/m·K, Btu/s·ft· ^{o}F).
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$_m$).
TSATT	Volume saturation temperature based on the total pressure (K, ^{o}F).
UF	Liquid specific internal energy (J/kg, Btu/lb$_m$).

UG Vapor/gas specific internal energy (J/kg, Btu/lb_m).

VAPGEN 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 ($kg/m^3 \cdot s$, $lb_m/ft^3 \cdot s$).

VELF* Volume-oriented liquid velocity (m/s, ft/s). The parameter is the volume number plus F.

VELG* Volume-oriented vapor velocity (m/s, ft/s). The parameter is the volume number plus F.

VISCF Liquid viscosity ($kg/m \cdot s$, $lb_m/ft \cdot s$).

VISCG Vapor viscosity ($kg/m \cdot s$, $lb_m/ft \cdot s$).

VOIDF Volume liquid fraction.

VOIDG 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).

A4.5 Junction Quantities

For the following variable request codes, the parameter is the junction number, i.e., the nine-digit number printed in the major edit. The parameter is CCC000000 for a single-junction; CCC000000 for a time-dependent junction; CCCXX0000 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.

Code Quantity

C0J Junction distribution coefficient. The 0 in C0J is the number zero and not the upper case letter O.

CCFLF Junction CCFL flag. The value is zero if the flow is not ccfl-limited, and the value is one if the flow is ccfl-limited.

CHOKEF Junction choking flag. The value is 0 if the flow is not choked, and is 1 if the flow is choked.

DLLPZK Junction elevation change pressure drop (from side) (Pa, lb_f/in^2).

DLLPZL Junction elevation change pressure drop (to side) (Pa, lb_f/in^2).

DPELJ Junction elevation change pressure drop (total) (Pa, lb_f/in^2).

DPFKJ	Junction wall friction and form loss pressure drop (total) (Pa, lb_f/in^2).
FIJ	Interphase friction ($N \cdot s/m^5$, $lb_f \cdot s^2/ft^5$).
FJUNFT	Total form loss coefficient for irreversible losses, forward.
FJUNRT	Total form loss coefficient for irreversible losses, reverse.
FLENTH	Total enthalpy flow rate in junction (includes liquid, vapor, and noncondensables) (J/s, Btu/s).
FLENTHA	Noncondensable gas enthalpy flow rate in junction (J/s, Btu/s).
FLENTHF	Liquid enthalpy flow rate in junction (J/s, Btu/s).
FLENTHG	Vapor/gas enthalpy flow rate in junction (J/s, Btu/s).
FLORGJ	Junction flow regime number.
FORMFJ	Liquid form loss factor (dimensionless).
FORMGJ	Vapor form loss factor (dimensionless).
FRICXK	Junction wall friction pressure drop (from side) (Pa, lb_f/in^2).
FRICXL	Junction wall friction pressure drop (to side) (Pa, lb_f/in^2).
FWALFJ	Non-dimensional liquid wall friction coefficient.
FWALGJ	Non-dimensional vapor wall friction coefficient
HLOSSX	Junction form loss pressure drop (total) (Pa, lb_f/in^2).
IREGJ	Vertical bubbly/slug flow junction flow regime number
MFLOWFJ	Junction liquid mass flow rate (kg/s, lb_m/s).
MFLOWGJ	Junction vapor/gas mass flow rate (kg/s, lb_m/s).
MFLOWJ	Combined liquid and vapor flow rate (kg/s, lb_m/s).
QUALAJ	Junction noncondensable mass fraction.
QUALNJ1	Junction noncondensable mass fraction for the first species identified on Card 110.
QUALNJ2	Junction noncondensable mass fraction for the second species identified on Card 110.
QUALNJ3	Junction noncondensable mass fraction for the third species identified on Card 110.
QUALNJ4	Junction noncondensable mass fraction for the fourth species identified on Card 110.
QUALNJ5	Junction noncondensable mass fraction for the fifth species identified on Card 110.
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.
TASAPK	Junction temporal and spatial variation of momentum pressure drop (from side) (Pa, lb_f/in^2).
TASAPL	Junction temporal and spatial variation of momentum pressure drop (to side) (Pa, lb_f/in^2).
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 drag.
XEJ	Junction equilibrium quality.

A4.6 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[i.e., 01 for the first mesh point (left boundary), 02 for the second mesh point, ..., np for the last mesh point(right boundary)]. 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.

Code	Quantity
HTCHF	Critical heat flux (W/m^2, $Btu/s{\cdot}ft^2$).
HTGAMW	Mass transfer rate per unit volume at the volume vapor/liquid interface in the boundary layer near this boundary (left or right) of the heat structure (wall) for vapor generation/condensation ($kg/m^3{\bullet}s$, $lb_m/ft^3{\bullet}s$). The parameter is the seven-digit heat structure number,
HTHTC	Heat transfer coefficient ($W/m^2 \cdot K$, $Btu/s\text{-}ft^2 \cdot {}^oF$)
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 number, CCCG0NN, with a two-digit number appended (00 for the left boundary and 01 for the right boundary). This same quantity is valid for the reflood heat structures. A chart showing the meaning of each number is shown in Section 3.2 of this volume of the manual.

HTPOWG Heat generated within a heat structure (i.e., internal heat source) (W, Btu/s.). The parameter is the seven-digit heat structure number, CCCG0NN.

HTRG Heat flux to vapor phase (W/m^2, Btu/s·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).

<u>HTRNR</u> Heat flux (W/m^2, Btu/s·ft^2).

<u>HTTEMP*</u> Mesh point temperature (K, ^{o}F). 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.

<u>HTVAT</u> Volume-averaged temperature in the heat structure (K, ^{o}F).

PECL Liquid Peclet number for the heat structures. The parameter is the heat structure geometry number CCCG00NN with a two-digit number appended (00 for the left boundary, and 01 for the right boundary).

H2GEN Heat structure hydrogen generated from the metal-water reaction model (kg, lb_m). The parameter is the seven-digit heat structure number, CCCG0NN.

OXTI Heat structure oxide thickness on the inside of the cladding from the metal-water reaction model (m, ft). The parameter is the seven-digit heat structure number, CCCG0NN.

OXTO Heat structure oxide thickness on the outside of the cladding from the metal-water reaction model (m, ft). The parameter is the seven-digit heat structure number, CCCG0NN.

STANT Stanton number. The parameter is the heat structure geometry number CCCG00NN with a two-digit number appended (00 for the left boundary, and 01 for the right boundary).

A4.7 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.

<u>Code</u>	<u>Quantity</u>
QFBOT	Elevation of bottom quench front (m, ft).
QFTOP	Elevation of top quench front (m, ft).
TCHFQF	Temperature at the critical heat flux (K, ^{o}F).
TREWET	Rewet or minimum film boiling temperature (K, ^{o}F).
FINES	Total number of axial mesh points for this CCGN

A4.8 Radiation/Conduction Enclosure Quantities

The parameter is the 4-digit number SSNN, where SS is the set number and NN is the surface number.

Code	Quantity
QRAD	Radiation/conduction enclosure heat flux for a surface in a set (W/m^2, Btu/s·ft^2).

A4.9 Reactor Kinetic Quantities

The following list is for point kinetics variables. The parameter is zero for the following reactor kinetics quantities except detector response.

Code Quantity

The following list is for point kinetics variables.

Code	Quantity
RDRES	Nuclear detector response. The parameter is the detector number.
RKACPOW	Total reactor power from actinide decay (W).
RKFIPOW	Total immediate (prompt and delayed neutron) fission power (W).
RKGAPOW	Total reactor power from decay of fission products and actinides (W).
RKREAC	Reactivity (dollars).
RKRECPER	Reciprocal period (s^{-1}).
RKTPOW	Total reactor power, i.e., sum of immediate (prompt and delayed neutron) fission power and decay (fission products and actinide) power (W).

The following list is for space dependent kinetics variables. The kinetics mesh consists of a user specified number of axial mesh planes with each mesh plane containing the same number of kinetics nodes. The kinetics mesh planes are numbered consecutively beginning from the bottom of the kinetics solution domain and proceeding upward to the top of the axial mesh. The kinetics nodes in an axial mesh plane are numbered consecutively starting from the upper left hand corner of the mesh plane (when viewed from the top of the kinetics mesh) and proceeding from left to right across each row of kinetics nodes in succession from the top row to the bottom row of kinetics nodes in the axial mesh plane. All nodes in the axial mesh plane are given a node number, including nodes that are not part of the kinetics solution domain. This numbering scheme holds for both Cartesian and hexagonal geometries. For Cartesian geometry, the underlying mesh is a rectangular mesh with a user specified number of rows and columns. For hexagonal geometry the underlying mesh is hexagonal with a user specified number of rings around a central node. The number of nodes on the first and subsequent rows for hexagonal geometry depends on the number of rows needed to accommodate the number of rings. The number of nodes on the first row is the number of rings plus one. Each subsequent row has one more node than the row above it down to the middle of the mesh below which the number of nodes in a row decreases by one relative to the row above it until the bottom row is reached. The bottom row of nodes has the same number of nodes as the top row of nodes. The total number of rows needed to accommodate the number of rings is twice the number of rings plus one. The middle row of nodes is numbered as the number of rings plus one. It is an error to request data from a kinetics node that is not part of the kinetics solution domain. For some space dependent kinetics alphanumeric codes, it is possible to enter -1 for the parameter (see below) on the 2080XXXX cards. This will cause all the data for this alphanumeric variable to be written to the restart-plot file. This option should be used carefully, since a large restart-plot file can be generated.

Code	Parameter	Quantity
RDRES	number	Nuclear detector response.
RKOBK	gllnnnn	Buckling in neutron group g for node nnnn on axial level ll (cm^{-2}). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL g groups and llnnnn nodes to be written to the restart plot file.
RKOBTB	ll	Bias buckling for the thermal neutron group axial level ll (cm^{-2}).
RKOCRACF	llrrrr	Control fraction of the active portion of control rod rrrr on axial level ll.
RKOCRDCF	llrrrr	Control fraction of the driver portion of control rod rrrr on axial level ll.
RKOCRPSN	rrrr	Insertion depth of control rod rrrr (m, ft).
RKOD	gllnnnn	Diffusion coefficient for neutron group g in node nnnn on axial level (cm). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL g groups and llnnnn nodes to be written to the restart-plot file.
RKOEGV	0	Eigenvalue (-).
RKOFIPOW	0	Total reactor immediate (prompt and delayed neutrons) fission power (W).
RKOGAPOW	0	Total reactor decay (fission products and actinide) power (W).
RKOPHI	gllnnnn	Neutron flux in neutron group g in node nnnn on axial level ll (n/cm^2-s). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL g groups and llnnnn nodes to be written to the restart-plot file.
RKOACPOW	0	Total reactor actinide decay power (W).
RKONDFIP	llnnnn	Fission power in node nnnn on axial level ll (W). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
RKONDFPD	llnnnn	Fission power density in node nnnn on axial level ll (W/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
RKONDRFP	llnnnn	Relative fission power density in node nnnn on axial level ll. Ratio

		of immediate (prompt and delayed neutrons) fission power density in node to average fission power density. Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
RKONRFP	llnnnn	Relative fission power in node nnnn on axial level ll. Ratio of immediate (prompt and delayed neutrons) fission power in node to average fission power. Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
RKORECPR	0	Reciprocal reactor period (s^{-1}).
RKOSIGA	gllnnnn	Macroscopic absorption cross-section in neutron group g in node nnnn on axial level ll (cm^{-1}). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL g groups and llnnnn nodes to be written to the restart-plot file.
RKOSIGF	gllnnnn	Macroscopic fission cross-section in neutron group g in node nnnn on axial level ll (cm^{-1}). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL g groups and llnnnn nodes to be written to the restart-plot file.
RKOSIGSj	gllnnnn	Macroscopic scattering cross-section from neutron group g to neutron group j in node nnnn on axial level ll (cm^{-1}). (j = 1, ..., number of neutron groups -1,). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL g groups and llnnnn nodes to be written to the restart-plot file.
RKOTPOW	0	Total reactor power, i.e., sum of immediate (prompt and delayed neutron) fission power and decay (fission products and actinide) power (W).
RKOZNALP	zzzzvv	Average void fraction in region vv of zone zzzz; only valid if RAMONA or GEN feedback selected. If RAMONA is selected, vv is omitted (-).
RKOZNBOR	zzzzvv	Average poison density in volume region vv of zone zzzz; if RAMONA feedback is selected, vv is omitted (kg/m^3, lb_m/ft^3).
RKOZNDEN	zzzzvv	Average fluid density in volume region vv of zone zzzz; only valid if HWR or GEN feedback selected (kg/m^3, lb_m/ft^3).
RKOZNFIP	zzzz	Total immediate (prompt and delayed neutrons) fission power in zone zzzz (W).
RKOZNGAP	zzzz	Total decay (fission products and actinide) power in zone zzzz (W).
RKOZNPWA	zzzz	Total actinide decay power in zone zzzz (W).
RKOZNPWK	zzzz	Total fission product decay power in zone zzzz (W).

RKOZNTF	zzzzss	Average structure temperature in structure region ss of zone zzzz; if RAMONA feedback is selected, ss is omitted (K, ^{o}F).
RKOZNTM RAMONA	zzzzvv	Average fluid temperature in volume region vv of zone zzzz; if feedback is used, vv is omitted (K, ^{o}F).
RKOZNTPW	zzzz	Total reactor power in zone zzzz (W).
CONXE	llnnnn	Xenon concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
CONI	llnnnn	Iodine concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
CONSM	llnnnn	Samarium concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
CONPM	llnnnn	Promethium concentration in node nnnn on axial level ll (a/cm^3). Entering -1 for the parameter on the 2080XXXX Cards will cause the data for ALL llnnnn nodes to be written to the restart-plot file.
USERVAR1	llnnnn	First user variable (-).
USERVAR2	llnnnn	Second user variable (-).
USERVAR3	llnnnn	Third user variable (-).
USERVAR4	llnnnn	Fourth user variable (-).

A4.10 General Table Values

The parameter is the general table number. Only general tables that had Word 6 of Card 202TTT00 set to one may be specified.

GNTBLVAL The units depend on the type of general table.

A4.11 Control System Quantities

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

CNTRLVAR These quantities are assumed dimensionless except for a SHAFT component.

A4.12 Interactive Variable Quantities

The parameter is 1000000000. The interactive variables are discussed in Section 6 of this Appendix A and can be used in batch or interactive jobs.

Code	Quantity
Variable name	Value of the interactive variable.

A4.13 Trip Quantities

The parameter is the trip number, i.e., the three-digit number NNN, or the four-digit number, NNNN, used in the input cards.

Code	Parameter	Quantity
TIMEOF	nnn or nnnn	Time of trip occurring (s). The parameter is the trip number.

A4.14 Radionuclide Transport Quantities

These quantities are available if the radionuclide transport model has been activated. The radionuclide specie identifier XXXXX in the variable request code is case sensitive (i.e., may be etherizer case, mixed case, or lower case). This is different from all of the other variable request codes that must be entered in the lower case.

Code	Parameter	Quantity
XXXXXcon	CCCNN0000	Concentration of radionuclide specie XXXXX in volume NN of component CCC (atoms/m^3). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
XXXXXmas	CCCNN0000	Mass of radionuclide specie XXXXX in volume NN of component CCC (kg). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
XXXXXact	CCCNN0000	Decay rate of radionuclide specie XXXXX in volume NN of component CCC (disintegrations/sec). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
XXXXXeng	CCCNN0000	Energy from decay of radionuclide specie XXXXX in volume NN of component CCC (W). The alphanumeric identifier XXXXX for the specie is Word 1 on Card 220MMM00 for radionuclide MMM.
rtzonphi	GZZZZ	Neutron flux-volume integral in group G of neutron kinetics zone ZZZZ $\left(\frac{n}{m^2 s}\right)$. This variable is only available if the nodal neutron kinetics model is activated.

A4.15 Cards 2080XXXX, Expanded Edit/Plot Variables

Several additional quantities have been added to the list of variables, which may be used in minor edits, plot requests, control systems, and trip logic. The additional variables and their associated parameters are listed in Section A4.15.1 through Section A4.17.

These additional request variables are not written to the restart-plot file (necessary for plotting) unless the user enters Cards 2080XXXX. The format of these cards is given below.

They are only required for the additional variables that the user wants to have written on the restart-plot file. The user can specify that between 1 and 9999 of these variables be written to the restart-plot file. The additional variables can be used in the usual manner on minor edit cards, trip cards, control system input cards, and on plot request cards.

The following cards are used to cause the requested variables to be written onto the RSTPLT file.

These cards are not to be used for the previously available variable request codes (see Section A4.1 through Section A4.14), since they are always written to the RSTPLT file.

The field XXXX need not be consecutive.

W1(A) Variable request code. See Section A4.15.1 through Section A4.17 for the valid request code.

W2(I) Parameter. Enter the parameter associated with the variable request code.

A4.15.1 General Quantities

Code	Quantity
COUNT	The current attempted advancement count number. The parameter is 0.
CPUTIME	Current CPU time for this problem (s). The parameter is 0
DT	The current time step (s). The parameter is 0.
DTCRNT	The current Courant time step (s). The parameter is 0.
ERRMAX	The current estimate of the truncation mass error. The parameter is 0.
STDTRN	Steady-state/transient flag. The parameter is 0. For steady-state, the value is 0.0. For transient, the value is 1.0.
TESTDA	An array testda of twenty quantities, [real testda(20)] has been defined for the convenience of program developers. This entry with a parameter ranging from 1 through 20 selects testda(parameter). The testda array is initially set to zero and programming must be inserted to set testda values. The usual purpose of this capability is to allow a simple method for debug information to be printed in minor edits or to be plotted.
TIME	Time (s). The parameter is 0. This request cannot be used for minor edit requests.
TMASS	Total mass of liquid, vapor, and noncondensable gases in all the systems (kg, lb_m). The parameter is 0.

A4.15.2 Component-Related Quantities

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

Code	Component Type	Quantity
ACPGTG	Accumulator	Vapor specific heat, C_p, at vapor temperature (J/kg·K, Btu/lb_m· ^oF).
ACPNIT	Accumulator	Noncondensable specific heat, C_p, at vapor

		temperature (J/kg·K, Btu/lb_m· °F).
ACVGTG	Accumulator	Vapor specific heat, C_v, at vapor temperature (J/kg·K, Btu/lb_m· °F).
AHFTG	Accumulator	Liquid enthalpy at vapor temperature (J/kg, Btu/lb_m).
AHFGTF	Accumulator	Heat of vaporization at liquid temperature (J/kg, Btu/lb_m).
AHFGT	Accumulator	Vapor enthalpy at liquid temperature (J/kg, Btu/lb_m).
AVISCN	Accumulator	Noncondensable viscosity (kg/m·s, lb_m/ft·s).
BETAV	Accumulator	Steam saturation coefficient of expansion (K^{-1}, $°F^{-1}$).
DMGDT	Accumulator	Time rate of change in dome vapor mass (kg/s, lb_m/s).
OMEGA	Inertial Valve	Pump motor torque (N·m, lb_f·ft).
PMPNRT	Pump	Calculated pump inertia (kg·m^2, lb·ft^2).
THETA	Inertial Valve	Valve disk angular position (deg).

A4.15.3 Volume-Related Quantities

For the following variable codes, the parameter is the volume number or the volume number plus F. See Section A4.4 for discussion of F. Quantities requiring the volume number plus F are so noted.

Code	Quantity
AHTCOFG	Heat transfer coefficient between slab and vapor (W/m^2·K, Btu/s·ft^2 · °F).
AVOL	Area of the volume (m^2, ft^2). The parameter is the volume number plus F.
BETAFF	Liquid isobaric coefficient of the thermal expansion (K^{-1}, $°F^{-1}$). 液体热膨胀系数
BETAGG	Vapor isobaric coefficient of the thermal expansion (K^{-1}, $°F^{-1}$).
CSUBPF	Liquid specific heat, C_p, bulk conditions (J/kg·K, Btu/lb_m· °F).
CSUBPG	Vapor specific heat, C_p, bulk conditions (J/kg·K, Btu/lb_m· °F).
DRFDP	Partial derivative of RHOF with respect to pressure (s^2/m^2, s^2/ft^2).
DRFDUF	Partial derivative of RHOF with respect to U_f (kg·s^2/m^5, lb·s^2/ft^5).
DRGDP	Partial derivative of RHOG with respect to pressure (s^2/m^2, s^2/ft^2).
DRGDUG	Partial derivative of RHOG with respect to U_g (kg· s^2/m^5, lb· s2 /ft^5).

DSNDDP	Partial derivative of SOUNDE with respect to pressure ($m^2 \cdot s/kg$, ft^2-s/lb_m).
DTDP	Partial derivative of T_{sat} with respect to pressure (K/Pa, $in^2 \cdot {}^oF/lb_f$).
DTDUG	Partial derivative of T_{sat} with respect to U_g ($s^2 \cdot K/m^2$, $s^2 \cdot {}^oF/ft^2$).
DTDXA	Partial derivative of T_{sat} with respect to X_n (K, ^oF).
DTFDP	Partial derivative of T_f with respect to pressure (K/Pa, $in^2 \cdot {}^oF/lb_f$).
DTFDUF	Partial derivative of T_f with respect to U_f ($s^2 \cdot K/m^2$, $s^2 \cdot {}^oF/ft^2$).
DTGDP	Partial derivative of T_g with respect to pressure (K/Pa, $in^2 \cdot {}^oF/lb_f$).
DTGDUG	Partial derivative of T_g with respect to U_g ($s^2 \cdot K/m^2$, $s^2 \cdot {}^oF/ft^2$).
DTGDXA	Partial derivative of T_g with respect to X_n (K, ^oF).
FLOREG	Flow regime number. The parameter is the volume number plus F.
FWALF	Liquid wall frictional drag coefficient ($kg/m^3 \cdot s$, $lb/ft^3 \cdot s$). The parameter is the volume number plus F.
FWALG	Vapor wall frictional drag coefficient ($kg/m^3 \cdot s$, $lb/ft^3 \cdot s$). The parameter is the volume number plus F.
GA	Liquid side interfacial heat transfer coefficient per unit volume ($W/m^3 \cdot K$, $Btu/s \cdot ft^3 \cdot {}^oF$).
HIG	Vapor side interfacial heat transfer coefficient per unit volume ($W/m^3 \cdot K$, $Btu/s \cdot ft^3 \cdot {}^oF$).
HTCOFF	Heat transfer coefficient between slab and liquid ($W/m^2 \cdot K$, $Btu/s \cdot ft^2 \cdot {}^oF$).
HVMIX	Enthalpy of the liquid and vapor (J/kg, Btu/lb_m).
PECLTV	Peclet number.
PPS	Vapor partial pressure (Pa, lb_f/in^2).
RGDXA	Partial derivative of RHOG with respect to X_n (kg/m^3, lb_m/ft^3).
RHOM	Total density for the mass error check (kg/m^3, lb/ft^3).
SATHF	Liquid specific enthalpy at saturation conditions (J/kg, Btu/lb_m).
SATHG	Vapor specific enthalpy at saturation conditions (J/kg, Btu/lb_m).
VISCF	Liquid viscosity ($kg/m \cdot s$, $lb_m/ft \cdot s$).
VISCG	Vapor viscosity ($kg/m \cdot s$, $lb_m/ft \cdot s$).
SIGMA	Surface tension (J/m^2, Btu/ft^2).
THCONF	Liquid thermal conductivity ($W/m \cdot K$, $Btu/s \cdot ft \cdot {}^oF$).

THCONG Vapor thermal conductivity (W/m·K, Btu/s·ft· ^{o}F).

TSATT Saturation temperature corresponding to total pressure (K, ^{o}F).

VELF Volume-oriented liquid velocity (m/s, ft/s). The parameter is the volume number plus F.

VELG Volume-oriented vapor velocity (m/s, ft/s). The parameter is the volume number plus F.

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

A4.15.4 Junction-Related Quantities

For the following variable codes, the parameter is the junction number, i.e. the nine-digit number CCCNN0000 printed in the major edit.

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

A4.15.5 Heat Structure-Related Quantities

Code	Quantity
HTGAMW	Wall vapor generation rate per unit volume (kg/m^3-s, lb/ft^3-s). The parameter is the heat structure geometry number CCCG0NN with a two-digit number appended (00 for the left boundary, and 01 for the right boundary).
HTMODE	Boundary heat transfer mode number (unitless). The mode number indicates which heat transfer regime is currently in effect. The parameter is the seven-digit heat structure geometry number CCCG0NN with a two-digit number appended. The two-digit appended Number 00 specifies the left boundary, and 01 specifies the right boundary. This same quantity is valid for the reflood heat structures.
HTRG	Heat flux to vapor phase (W/m^2, Btu/s-ft^2). The parameter is the heat structure geometry number CCCG0NN with a two-digit number appended (00 for left boundary, and 01 for right boundary).

A4.15.6 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.

Code	Quantity
FINES	Total number of axial mesh points for this CCGN
TCHFQF	Temperature at the critical heat flux (K, °F).
TREWET	Rewet or minimum film boiling temperature (K,°F).
ZQBOT	Elevation of bottom quench front (m, ft).
ZQTOP	Elevation of top quench front (m, ft)

A4.15.7 Reactor Kinetic-Related Quantities

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

Code	Parameter	Quantity
RKOBK1	ll	Buckling in fast neutron group in Axial Level ll (cm^{-2}).
RKOBK2	ll	Total buckling in thermal neutron group in Axial Level ll (cm^{-2}).
RKOBTB	ll	Bias thermal buckling in Axial Level ll (cm^{-2}).
RKOCRPSN	cc	Insertion depth of control rod cc (m, ft)
RKOD1	ll	Diffusion coefficient in fast neutron group in Axial Level ll (cm).
RKOD2	ll	Diffusion coefficient in thermal neutron group in Axial Level ll (cm).
RKOLVCFR	ll	Control fraction in Axial Level ll.
RKOLVFIP	ll	Fission power in Axial Level ll (W).
RKOLVGAP	ll	Total decay power in Axial Level ll (W).
RKOLVPWA	ll	Actinide decay power in Axial Level ll (W).
RKOLVP	ll	Neutron flux in fast neutron group in Axial Level ll (n/cm^2-s).
RKOPHI2	ll	Neutron flux in thermal neutron group in Axial Level ll (n/cm^2 -s).
RKOPOWA	0	Total reactor actinide decay power (W).
RKOPOWK	0	Total fission product decay power (W).
RKOSIGA1	ll	Macroscopic absorption cross-section in fast neutron group in Axial Level ll (cm^{-1}).
RKOSIGA2	ll	Macroscopic absorption cross-section in thermal neutron group in Axial Level ll (cm^{-1}).
RKOSIGR	ll	Macroscopic removal cross-section in fast neutron group in Axial Level ll (cm^{-1}).

RKOSIGF1	ll	Macroscopic fission cross-section in fast neutron group in Axial Level ll (cm^{-1}).
RKOSIGF2	ll	Macroscopic fission cross-section in thermal neutron group in Axial Level ll (cm^{-1}).
RKOZNALP	zz	Average void fraction in zone zz. Only valid if RAMONA feedback selected.
RKOZNBOR	zzvv	Average poison density in volume region vv of zone zz If RAMONA feedback is selected, vv is omitted (kg/m^3, lb/ft^3).
RKOZNDEN	zzvv	Average fluid density in volume region vv of zone zz. Only valid if HWR feedback selected (kg/m^3, lbm/ft^3).
RKOZNFIP	zz	Total fission power in zone zz (W).
RKOZNGAP	zz	Total decay power in zone zz (W).
RKOZNPWA	zz	Total actinide decay power in zone zz (W).
RKOZNPWK	zz	Total fission product decay power in zone zz (W).
RKOZNTF	zzss	Average structure temperature in structure region ss of zone zz. If RAMONA feedback is selected, ss is omitted (K, ^oF).
RKOZNTM	zzvv	Average fluid temperature in volume region vv of zone zz. If RAMONA feedback is used, vv is omitted (K, ^oF).
RKOZNTPW	zz	Total reactor power in zone zz (W).

A4.16 SCDAP Quantities

A4.16.1 SCDAP Bundle Quantities

This section describes variables that characterize the response of the bundle. The index is required for input, but is ignored. The underlined variables are default variables that are written to the plot file for every analysis, while 208 cards are required to save non-underlined variables for plotting, as documented in Section A15. It should be noted that if the default variables are requested on a 208 card, they will be written to the plot file twice.

BGNHG	0	Core nuclear heat generation (W).
BGMCT	0	Core maximum surface temperature (K).
BGTFPRN	0	Core cumulative noncondensable fission product release (kg).
BGTFPRS	0	Core cumulative soluble fission product release (kg).
BGTH	0	Core total hydrogen generation rate (kg/s).
BGTHQ	0	Core total oxidation heat generation (W).
BGTHQU	0	Core oxidation heat generation due to uranium oxidation (W).
BGTHU	0	Core hydrogen generation rate due to uranium oxidation
CRUCB	0	Indicator of whether crust supporting molten pool has failed: 0.0 no, 1.0 = yes.

REPOOL	0	Equivalent radius of the molten pool of core material (m).
SHQIN	0	Total heat flowing through the inside surface of the flow shroud (W). Available only if the shroud component is input.
SHQOUT	0	Total heat flowing through the outside surface of the flow shroud (W). Available only if the shroud component is input.

A4.16.2 SCDAP Component Quantities

This section describes the variables that characterize the response of each component. The index, jj, is the component number of interest. The underlined variables are default variables which are written to the plot file for every analysis, while 208 cards are required to save non-underlined variables for plotting, as documented in Section A4.15. It should be noted that if the default variables are requested on a 208 card, they will be written to the plot file twice.

Code	Index	Quantity
ACHDPN	jj	Temperature of the bottom surface of the cohesive debris layer for component jj (K).
PGAS	jj	Gas pressure inside component jj (MPa).
WDTQLP	jj	Thermal energy in the material from component jj that slumped below the bottom of component jj (J).
ZBTCOH	jj	Elevation of the bottom surface of the cohesive debris bed for component jj (m).
ZBTRUB	jj	Elevation of the bottom of the rubble debris bed for component jj (m).
ZTPCOH	jj	Elevation of the top surface of the cohesive debris bed for component jj (m).
ZTPRUB	jj	Elevation of the top of the rubble debris bed for component jj (m).

A4.16.3 SCDAP Axial Dependent Quantities

This section describes the variables that characterize the response of each axial node of each component. The index, kkjj, is the axial node, kk, and the component number, jj, of interest. The underlined variables are default variables which are written to the plot file for every analysis, while 208

Code	Index	Quantity
BRCHV	kkjj	Indicator of whether double-sided oxidation is taking place at axial node kk of component jj: 0.0 = no, 1.0 = yes.
DAMLEV	kkjj	Level of damage at axial node kk of component jj (unitless). See DAMLEV table
DZFRCQ	kkjj	Height of cohesive debris at axial node kk of component jj (m).
EFFOXD	kkjj	Effective oxide thickness at axial node kk of component jj. SCDAP/RELAP5 now uses two oxide thicknesses: the first is the physical oxide thickness, OXDEO, and the second is an effective

		thickness, used to calculate the oxidation rate.
H2OXD2	kkjj	Hydrogen production rate at axial node kk of component jj (kg/s).
HOOP	kkjj	Cladding hoop strain of component jj at axial node kk.
OXDEO	kkjj	Oxide thickness of the cladding at axial node kk of component jj (m).
RCI	kkjj	Inside radius of the cladding at axial node kk of component jj (m).
RCO	kkjj	Outside radius of the cladding (not including the crust of solidified material) at axial node kk of component jj (m).
RNALF	kkjj	Inner radius of the alpha oxide layer at axial node kk of component jj (m).
RNOXD	kkjj	Inner radius of the oxide layer at axial node kk of component jj (m).
ROCRST	kkjj	Outside radius of cladding (including the crust of the solidified material) of component jj at axial node kk (m).
RPEL	kkjj	Radius of fuel pellet of component jj at axial node kk (m).
RULIQ	kkjj	Outside radius of the solid part of the fuel pellet at axial node kk of component jj (m).
WFROSR	kkjj	Mass of stainless steel resolidified at axial node kk of component jj (kg).
WFROUO	kkjj	Mass of UO_2 resolidified at axial node kk of component jj (kg).
WFROZR	kkjj	Mass of zircaloy resolidified at axial node kk of component jj (kg).
WREMSR	kkjj	Mass of stainless steel remaining at axial node kk of component jj (kg).
WREMUO	kkjj	Mass of removed fuel of component jj at axial node kk (kg).
WREMZR	kkjj	Mass of removed cladding of component jj at axial node kk (kg).

A4.16.4 SCDAP General

The subfields of the index are explained for each variable in Table 2. The underlined variables are default variables which are written to the plot file for every analysis, while 208 cards are required to save non-underlined variables for plotting, as documented in Section A4.15. It should be noted that if the default variables are requested on a 208 card, they will be written to the plot file twice.

Table 2:

Code	Index	Quantity
CADCTa	iikkjj	Temperature of radial node number ii, axial node number kk, and component number jj (K).

Table 2:

Code	Index	Quantity
CGGIVY	kkjj	Inventory of fission product kk released into the fuel/clad gap of component jj. The index of each fission product species is shown in Table 3.
DCREPC	ii	Fraction of life expended for ii-th COUPLE heat structure identified for creep rupture calculation.
DCREPH	ii	Fraction of life expended for ii-th RELAP5 heat structure identified for creep rupture calculation.

[a] The component surface and centerline temperatures are always written to the restart/plot file at each minor edit frequency. A 208 card is required to save the temperature at any other radial node for plotting.

Table 3: Fission Product Indices

Index	Specie	Index	Specie
1	I		
2	CsI	10	Sn
3	CsOH	11	Fe
4	Te	12	Ru
5	HI	13	Ba
6	HTe	14	Sb
7	Cd	15	Zn
8	Ag	16	Xe
9	UO_2	17	Kr

Table 4: DAMLEV Damage state

DAMLEV	STATE
0.0	Intact geometry
0.1	Rupture due to ballooning
0.2	Rubble (fragmented)
0.4	Cohesive debris
1.0	Molten pool

A4.16.5 SCDAP Quantities for BWR Blade/Box Component

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

Code	Index	Quantity
CADCT	iikkjj	Temperatures (K) at radial node ii and axial node kk of component jj. For a BWR blade/box component, valid values of radial node ii are 1 - 14.
DAMLEV	kkjj	Level of damage (unitless) at axial node kk of component jj. For a BWR blade/box component, this indicates when the channel box wall has failed and a flow path has opened between the interstitial and fuel bundle coolant volumes.

DAMLEV	STATE
0.0	Both channel box segments intact.
0.1	Channel box segment 1 gone.
0.2	Channel box segment 2 gone.
0.3	Both channel box segments gone.

Code	Index	Quantity
H2OXD2	kkjj	Total hydrogen production rate (kg/s) at axial node kk of component jj. For a BWR blade/box component, this is the total hydrogen from the control blade and both sides of the channel box.
OXDEO	kkjj	Frozen crust thickness (m) on the interstitial side of channel box segment 2 at axial node kk of component jj.
RCI	kkjj	Equivalent thickness (m) of the intact control blade sheath at axial node kk of component jj.
RCO	kkjj	Frozen crust thickness (m) on the control blade at axial node kk of component jj.
ROCRST	kkjj	Thickness (m) of the intact channel box segment 1 at axial node kk of component jj.
RPEL	kkjj	Thickness (m) of the intact channel box segment 2 at axial node kk of component jj.
RULIQ	kkjj	Equivalent thickness (m) of the intact absorber rodlet (B_4C and stainless steel) at axial node kk of component jj.
WREMUO	kkjj	Frozen crust thickness (m) on the fuel bundle side of channel box segment 2 at axial node kk of component jj.
WREMZR	kkjj	Frozen crust thickness (m) on the fuel bundle side of channel box segment 1 at axial node kk of component jj.

A4.17 COUPLE Quantities

A4.17.1 Element or Node Specific Parameters

The expanded edit/plot element and node specific parameter variables underlined in the list below are written to the plot file for every analysis, while 208 cards are required to save non-underlined variables for plotting, as documented in Section A4.15. It should be noted that if the default variables are requested on a 208 card, they will be written to the plot file twice.

Code	Index	Quantity
AFBULK	jjkk	Indicator of type of material in element jj of COUPLE mesh kk. See Section A3.18.2
EVHTC	jj	Ex-vessel heat transfer coefficient at convection heat transfer node jj.
FPDEB	iijjkk	Fission product ii in element jj in COUPLE mesh number kk.
FRACML	jjkk	Fraction of COUPLE element jj in COUPLE mesh number kk that has melted.
PORE	jjkk	Porosity of debris in element jj of COUPLE mesh kk
POWDB	jjkk	Power in element jj of COUPLE mesh kk (W/m^3).
OXTHK	jjkk	Aluminum oxide thickness (m) in element jjj for COUPLE mesh kk.
TMLTEL	jjkk	Melting temperature of material in element kk of COUPLE mesh kk (K).
TMPCOU	jjkk	Debris bed temperature at node jj in COUPLE mesh number kk (K).

A4.17.2 COUPLE Mesh Quantities

The variables defined below describe the COUPLE mesh quantities. The underlined variables are default variables which are written to the plot file for every analysis, while 208 cards are required to save non-underlined variables for plotting, as documented in Section A4.15. It should be noted that if the default variables are requested on a 208 card, they will be written to the plot file twice.

Code	Index	Quantity
CSENRG	kk	Total internal energy in structural material that supports debris (J).
DEBQUP	kk	Total rate of heat transfer by convection from top surface of debris (W).
DENRGY	kk	Total internal energy of debris (J).
HGTDEB	kk	Debris bed height in COUPLE mesh kk (m).
INTPOW	kk	Integral with respect to time of total power in debris (J).

INTQ	kk	Integral with respect to time of total transfer from debris and structural material to fluid at boundaries of debris and structural material (J).
LIQAVG	kk	Average liquefied debris temperature (K).
LIQAG	kk	Mass of liquefied silver in mesh kk (kg).
LIQFE	kk	Mass of liquefied steel in mesh kk (kg).
LIQUO2	kk	Mass of liquefied UO_2 in mesh kk (kg).
LIQZO2	kk	Mass of liquefied ZrO_2 in mesh kk (kg).
LIQZR	kk	Mass of liquefied zirconium in mesh kk (kg).
MASLIQ	kk	Liquefied mass in mesh kk (kg).
MASSAG	kk	Total mass of silver in mesh kk (kg).
MASSAL	kk	Total mass of aluminum in mesh kk (kg).
MASB4C	kk	Total mass of B_4C in mesh kk (kg).
MASSCD	kk	Total mass of cadmium in mesh kk (kg).
MASSFE	kk	Total mass of stainless steel in mesh kk (kg).
MASSLI	kk	Total mass of lithium in mesh kk (kg).
MASSU	kk	Total mass of metallic uranium in mesh kk (kg).
MASUO2	kk	Total mass of uranium dioxide (UO_2) in mesh kk (kg).
MASSZR	kk	Total mass of zircaloy in mesh kk (kg).
MASZO2	kk	Total mass of zirconium oxide in mesh kk (kg).
MPPDEN	kk	Molten pool power density (W/m^3)
PDBTOT	kk	Total power in material that has slumped to lower head (W).
TMPDAV	kk	Average debris temperature in COUPLE mesh number kk (K).
TMPDMX	kk	Maximum debris bed temperature in COUPLE mesh number kk (K).
TWALMX	kk	Maximum temperature of structural material in COUPLE mesh kk (K)

A4.17.3 COUPLE material indicator.

AFBULK	Type of material
0.3	Mostly Ag-In-Cd
0.4	Mostly stainless steel
0.5	Mostly Zr
0.6	Mostly ZrO_2
0.7	More than 50% UO_2
1.0	More than 70% UO_2

A5. Cards 400 through 799 or 20600000 through 20620000, Trip Input Data

These cards are optional for NEW and RESTART type problems and are not used for other problem types. Two different card series are available for entering trip data, but only one series type may be used in a problem. Card numbers 401 through 799 allow 199 variable trips and 199 logical trips. Card numbers 20600010 through 20620000 allow 1000 variable trips and 1000 logical trips.

A5.1 Card 400, Trip Cancellation Card

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.

A5.2 Card 20600000, Trip Card Series Type

This card, if omitted, selects card numbers 401 through 599 for variable trips and 601 through 799 for logical trips. 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, and nnnn is the trip number. Trip numbers (nnnn) 1 through 1000 are variable trips, and 1001 through 2000 are logical trips. Trip numbers do not have to be consecutive.

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

A5.3 Cards 401 through 599 or 20600010 through 20610000, Variable Trip Cards

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

The variable codes and parameters are the same as described for minor edits, Section A4. 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 true. If the trip goes false, TIMEOF is set to -1.0.(i.e., the trip is false), the evaluation of the variable trip is bypassed. Thus, the value of the variable trip remains the same as the value on the previous time step. Quantities compared in variable trips must have the same units if neither quantity is a control variable. Either SI units or British units can be used, depending on Card 102, Word 1. The control variables use the code's internal units (SI).

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

W2(I) Parameter

W3(A) Relationship. This may be either EQ, NE, GT, GE, LT, or LE, where the symbols have the standard FORTRAN meaning.Do not enter periods as part of the designator. Thus, use EQ rather than .EQ. to specify *equal to*, use NE rather than .NE. to specify *not equal to*, use GT rather than .GT. to specify *greater than*, use GE rather than .GE. to specify *greater than or equal to*, use LT rather than .LT. to specify *less than*, or use LE rather than .LE. to specify *less than or equal to*.

W4(A) Variable code.

W5(I) Parameter.

W6(R) Additive constant.

W7(A) Latch indicator. If L, the trip once set true remains true even if the condition later is not met. If N, the trip is tested at each time advancement.

W8(R) Time of quantity (s). This word is optional. If it is not entered, the trip is initialized as false and the associated TIMEOF quantity is set to -1.0. If -1.0 is entered, the trip is initialized as false. If zero or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than zero for NEW problems and must not be greater than the time of restart for RESTART problems.

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

A5.4 Cards 601 through 799 or 20610010 through 20620000, Logical Trip Cards

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

W1(I) Trip number. The absolute value of this number must be one of the trip numbers defined by the variable or logical trip cards. A negative trip number indicates that the complement of the trip is to be used in the test.

W2(A) Operator. The operator may be AND, OR, or XOR. For RESTART problems, this quantity may also contain DISCARD or RESET. DISCARD deletes the trip and RESET sets the trip to false. If DISCARD or RESET are entered, no further words are entered on the card and Word 1 (W1) may be zero.

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

W4(A) Latch indicator. If L, the trip when set remains set. If N, the trip is tested each time advancement.

W5(R) TIMEOF quantity (s). This word is optional. If not entered, the trip is initialized as false and the associated TIMEOF quantity is set to -1.0. If -1.0 is entered, the trip is initialized as false. If zero or a positive number is entered for TIMEOF, the trip is initialized as true. TIMEOF must not be greater than zero for NEW problems and must not be greater than the time of restart for RESTART problems.

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

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

A5.5 Card 600, Trip Stop Advancement Card

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

W1(I) Trip number. A zero can be entered on restart to remove the effects of the this card entered in the previous run.

W2(I) Trip number. A second trip number need not be entered.

A6. CARDS 801 THROUGH 1999, INTERACTIVE INPUT DATA

An interactive and color display capability exists when the code is interfaced with Nuclear Plant Analyzer (NPA) software. This capability allows a user to view selected results on a color graphics terminal and to modify user-defined input quantities. A user can view RELAP5-SCDAP 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-SCDAP 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 request code and 1000000000 is the numerators.

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.E+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 ^{o}F to K, Word 3 should be -255.3722222. If this word is missing, the conversion factor defaults to 1.0. If this word is zero, the next two words(W4 and W5) must contain the alphanumeric part and the numeric part of a variable request code. The conversion factor (for the case of Word 3 equal to zero) appropriate for this interactive variable is set to the conversion factor for the variable specified by W4 and W5. If SI units are in use for input, the supplied conversion factor is 1.0. If British units are in use for input, the appropriate conversion factor is set to the conversion factor for the variable specified by W4 and W5.

W4(A)	Alphanumeric part of the variable request code. The alphanumeric name CNTRLVAR cannot be used.
W5(A)	Numeric part of the variable request code. The numeric part must be omitted if zero.

A7. CARDS CCCXXNN, HYDRODYNAMIC COMPONENTS

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

A7.1 Card CCC0000, Component Name and Type

This card is required for each component.

W1(A) Component name. Use a name descriptive of the component's use in system. A limit of 8 characters is allowed for other computers, e.g., workstations, CRAY, Cyber-205, and IBM computers.

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

A7.2 Single-Volume Component

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 number is CCC010000.

A7.2.1 Cards CCC0101 through CCC0109, Single-Volume Geometry Cards

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

W1(R) Volume flow area (m^2, ft^2).

W2(R) Length of volume (m, ft).

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length ($W3 = W1 \cdot W2$). At least two of the three quantities, W1, W2, and W3 must be nonzero. If one of the quantities is zero, it will be computed from the 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 $\leq$ 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 volume length. If the vertical angle orientation is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign.When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the volume 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 $4.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\text{x-direction wetted perimeter}}\right)$. If zero, the hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. A check is made to ensure the pipe roughness is less than half the hydraulic diameter. See Word 1 for volume flow area.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler 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 scaler oriented flags and the x-coordinate 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 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 the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer.

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

The vertical stratification model is recommended when modeling a pressurizer.

The digit b specifies the interphase friction 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.

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.

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.

A7.2.2 Cards ccc0181 through ccc0189, Single Volume Y-Coordinate Volume Data

These cards are optional. These cards are used when the user specifies a y-face in junction connections. The volume of the volume is the same for the x-, y-, and z-directions. If this card is entered, either W1 or W2 must be nonzero.

W1(R) Flow area of the volume along the y-coordinate (m^2, ft^2). If this card is missing or this word is zero, the y-direction flow area is computed from $\frac{\text{volume of volume}}{\text{y-direction length}}$.

W2(R) Length of volume along y-coordinate (m, ft). If this card is missing, the y-direction length is computed from $2.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. If this word is zero, the y-direction length is computed from $\left(\frac{\text{volume of volume}}{\text{y-direction flow area}}\right)$.

W3(R) Roughness (m, ft).

W4(R) Hydraulic diameter (m, ft). If this card is missing or this word is zero, the y-direction hydraulic diameter is computed from $4.0 \bullet \left(\frac{\text{y-direction volume flow area}}{\pi \bullet \text{x-direction volume flow area}}\right)^{0.5}$. 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 packed format tlpvbfe, but tis word is limited to 00000f0 since it enters only the coordinated oriented flags for the y-direction.

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 of the volume, and f = 1 specifies that wall friction effects are not to be computed along the y-coordinate direction of the volume.

W6(R) This and the following two words are optional. If these words are not entered, the position changes are obtained from the flow length in the y-direction and the two volume orientation angles. This word is the position change in the x-fixed direction as the flow passes from the y-inlet face to the y-outlet face (m, ft). This quantity affects only moving problems.

W7(R) This word is the position change in the y-fixed direction as flow passes from the y-inlet face to the y-outlet face (m, ft). This quantity affects results only in moving problems.

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 non-moving problems if connections are made to the y-faces.

A7.2.3 Cards ccc0191 through ccc0199, Single Volume Z-Coordinate Volume Data

These cards are optional. These cards are used when the user specifies a z-face in junction connections. The volume of the volume is the same for the x-, y-, and z-directions. If this card is entered, either W1 or W2 must be nonzero.

W1(R) Flow area of the volume along the z-coordinate (m^2, ft^2). If this card is missing or this word is zero, the z-direction flow area is computed from $\left(\frac{\text{volume of volume}}{\text{z-direction length}}\right)$.

W2(R) Length of volume along z-coordinate (m, ft). If this card is missing, the z-direction length is computed from $2.0 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. If this word is zero, the z-direction length is computed from $\left(\frac{\text{volume of volume}}{\text{z-diection flow area}}\right)$.

W3(R) Roughness (m, ft).

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

W5(I) Volume control flags. This word has the general packed format <u>tlpvbfe</u>, but tis word is limited to 00000f0 since it enters only the coordinated oriented flags for the z-direction.

W6(R) This and the following two words are optional. If these words are not entered, the position changes are obtained from the flow length in the z-direction and the two volume orientation angles. This word is the position change in the x-fixed direction as the flow passes from the z-inlet face to the z-outlet face (m, ft). This quantity affects only moving problems.

W7(R) This word is the position change in the y-fixed direction as flow passes from the z-inlet face to the z-outlet face (m, ft). This quantity affects results only in moving problems.

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 non-moving problems if connections are made to the z-faces.

A7.2.4 Card ccc0111, ORNL ANS Interphase Model Pitch and Span Values

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

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

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

A7.2.5 Card CCC0131, Additional Laminar Wall Friction Card

This card is optional. If this card is not entered, the default values are 1.0 for the 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.

A7.2.6 Card ccc0141, Alternate Turbulent Wall Friction Data

This card is optional. This card allows the specification of user defined turbulent friction factor for each coordinate direction. The turbulent friction factor has the form $f = A + B(R_e)^{-C}$, where A, B, and C are entered for each coordinate of the volume. If this card is not entered, the standard turbulent friction factor is used for all coordinates. If the card is entered, the standard turbulent friction factor can be selected for a particular coordinate by entering zeros for the three quantities. Three, six, or nine quantities may be entered on the card, and the data not entered are set to zeros.

W1(R) *A* for x-coordinate.

W2(R) *B* for x-coordinate.

W3(R) *C* for x-coordinate.

W4(R) *A* for y-coordinate.

W5(R) *B* for y-coordinate.

W6(R) *C* for y-coordinate.

W7(R) *A* for z-coordinate.

W8(R) *B* for z-coordinate.

W9(R) *C* for z-coordinate.

A7.2.7 Card CCC0200, Single-Volume Initial Conditions

This card is required for a single-volume.

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

The digit e specifies the fluid. e = 0 is the default fluid, e = 1 specifies H_2O and e = 2 specifies D_2O. 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 H_2O is assumed as the fluid.

The digit b specifies whether boron is present or not. The digit b = 0 specifies that the volume fluid does not contain boron; b = 1 specifies that a boron concentration in 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 the 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, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/lb_m), 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.

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

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

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for static quality are: $1.0E\text{-}9 \leq$ static quality ≤ 0.99999999, two-phase conditions, and static quality < 1.0 E-9 or quality > 0.99999999, single-phase. The static quality is given by $M_g / (M_g + M_f)$, where $M_g = M_s + M_n$.

Noncondensable options are:

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.

If t = 5, the next three words are interpreted as temperature (K, ^oF), static quality, and noncondensable quality in equilibrium condition. Both the equilibrium and noncondensable qualities are restricted to be between 1.0 E-9 and 0.99999999. 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, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/ lb_m), vapor void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium 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.

If t = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, ^oF), vapor/gas temperature (K, ^oF), vapor/gas void fraction, and noncondensable quality.These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. 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 the thermodynamic conditions.

W2-W6(R) Quantities as described under Word 1 (W1). Depending on the control word, two through five quantities may be required. Enter only the minimum number required. If entered, boron concentration (mass of boron per mass liquid) follows the last required word for thermodynamic conditions.

A7.2.8 Card CCC0300, Single-Volume Variable Volume Control

This card is optional. The presence of this card in the input deck signals that the variable volume option is to be activated for this single-volume component. The items on the card specify how the computational volume of this single-volume component is to be determined. The volume specified on the CCC0101 card for this volume is the maximum value of the computational volume.

W1(I) Control variable number. The value of the indicated control variable is used as either the normalized volume of the computational volume (if Word 2 is not entered on this card) or as the normalized stem position (if Word 2 is entered on this card). This word must be entered as zero if no control variable is to be used.

W2(I) General table number. The input argument for the table is either the value (normalized stem position) of the control variable (entered as Word 1) or time (if Word 1 is entered as zero). If the input argument comes from a control variable, no trip should be specified in the input for the general table.

A7.2.9 Card CCC0301 Single Volume Noncondensable Mass Fraction

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions for the noncondensable species entered on Card 110. The number of words on this card should be the same as on Card 110. The noncondensable mass fractions must sum to one within a relative error of 1.0×10^{-10}.

A7.3 Time-Dependent Volume Component

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.

A7.3.1 Cards CCC0101 through CCC0109, Time-Dependent Volume Geometry Cards

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

W1(R) Volume flow area (m^2, ft^2). 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 of volume (m, ft). After initialization, the length is set to zero.

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length (W3 = W1·W2). At least two of the three quantities, W1, W2, and W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001. After initialization, the volume is set to zero.

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 volume length. If the vertical angle orientation is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. As with the other components, this Word 6 is compared to the volume 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 through CCC0299. After initialization, the elevation change is set to zero.

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

W8(R) Hydraulic diameter (m, ft). This should be computed from

$4.0 \bullet \left(\frac{\text{volume flow area}}{\text{wetted perimeter}}\right)$. If zero, the hydraulic diameter is computed from

$2.0 \bullet \left(\frac{\text{volume flow area}}{\pi}\right)^{0.5}$. A check is made to ensure the pipe roughness is less than half the hydraulic diameter.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler 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 scaler oriented flags and the x-coordinate flag. The y- and z-coordinate data (wall friction flag f) are not read in for the time-dependent component because the wall friction is not used for time-dependent volumes.

The digit t is not used and should be input as zero (t = 0). The thermal stratification model is not used in a time-dependent volume.

The digit l is not used and should be input as zero (l = 0). The level tracking model is not used in a time-dependent volume.

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

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

The digit b specifies the interphase friction that is used. b = 0 means that the pipe interphase friction model will be applied, and b = 1 means that the rod bundle interphase friction model will be applied. The interphase friction models are not used for time-dependent volumes, so either b = 0 or b = 1 can be inputted and the output will show the digit entered.

The digit f specifies whether wall friction is to be computed. f = 0 specifies that wall friction effects are to be computed for the volume, and f = 1 specifies that wall friction effects are not to be computed for the volume. The wall friction model is not used for time-dependent volumes, so either f = 0 or f = 1 can be inputted and the output will show the digit entered.

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. The nonequilibrium and equilibrium options are not used for time-dependent volumes, so either e = 0 or e = 1 can be used.

A7.3.2 Card CCC0200, Time-Dependent Volume Data Control Word

This card is required for a time-dependent volume.

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

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

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

The digit t specifies how the words of the time-dependent volume data in Cards CCC0201 through CCC0209 are to be used to determine the initial thermodynamic state. Entering t equal to 0 through 3 specifies one component (steam/water). Entering t equal to 4 through 6 allows the specification of two components (steam/water and noncondensable gas). With options 4 through 6, names of the components of the noncondensable gas must be entered on Card 110, and mass fractions of the components are entered on 115. Entering t = 7 specifies three components, liquid/steam, noncondensable gas, and a molten metal. Option 7 requires Card 110 and Card CCC0301 or Card 115 similarly to options 4 through 6. In addition, option 7 requires Card 111 defining components of the metal. The mass fractions are defined by Card CCC0302 if entered or from Card 116.

If t = 0, the second, third, fourth, and fifth words of the time-dependent volume data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/lb_m), 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 follows the last required word for thermodynamic conditions.

If t = 1, the second and third words of the time-dependent volume data on Cards CCC0201 through CCC0299 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.

If t = 2, the second and third words of the time-dependent volume data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2) and 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.

If t = 3, the second and third words of the time-dependent volume data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium conditions. Enter only the minimum number of words required. If entered, boron concentration 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 $\leq$ static quality $\leq$ 0.99999999, two-phase conditions, and static quality < 1.0E-9 or static quality > 0.99999999, single-phase. The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

Noncondensable options are:

If t = 4, the second, third, and fourth words of the time-dependent data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2), temperature (K, ^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.

If t = 5, the second, third, and fourth words of the time-dependent data on Cards CCC0201 through CCC0299 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 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 second, third, fourth, fifth, and sixth words of the time-dependent data on Cards CCC0201 through CCC0299 are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/lb_m), 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 follows the last required word for thermodynamic conditions.

If t = 8, the next seven words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb), vapor specific internal energy (J/kg, Btu/lb_m), vapor void fraction, noncondensable quality, metal internal energy (J/kg, Btu/lb_m), and metal void fraction The sum of the vapor void fraction and the metal void fraction must be greater than or equal to zero and less than or equal to one. The noncondensable quality must be greater than or equal to zero and less than or equal to one. 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.

W2(I) Table trip number. This word is optional. If missing or zero and Word 3 is missing, no trip is used and the time argument is the advancement time. If nonzero and Word 3 is missing, this number is the trip number and the time argument is -1.0 if the trip is false and the advancement time minus the trip time if the trip is true.

W3(A) Alphanumeric part of variable request code. This quantity is optional. If 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 zero, the specified argument is used. If the trip number is nonzero, -1.0E+75 is used if the trip is false and the specified argument is used if the trip is true. TIME can be selected, but note that the trip logic is different than if this word were omitted. 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 zero if missing.

A7.3.3 Cards CCC0201 through CCC0299, Time-Dependent Volume Data Cards

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, two through five 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.

A7.3.4 Card CCC0301, Noncondensible Mass Fraction Card

This card is optional. If entered, the mass fractions on this card replace those entered on the default mass fraction cards, Card 115. See the description for Cards 110 and 115 for further information on this card.

W1-5(R) Mass fraction for each noncondensible type in the same order as noncondensible species entered on Card 110.

A7.4 Single-Junction Component

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.

A7.4.1 Cards CCC0101 through CCC0109, Single-Junction Geometry Cards

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

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect 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 expanded format, only the number N equal to 1 or 2 is allowed

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum volume flow area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) 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 zero. Note: a variable loss coefficient may be specified (see Section A7.4.3). The interpretation and use of the coefficient depends on whether the smooth or An abrupt area change option is specified or grid spacers are modeled.

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 Section A7.4.3). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change is specified or grid spacers are modeled.

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

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.

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.

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

The digit 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; v = 2 means a downward-oriented junction; and v = 3 means a centrally (side) located junction.

The digit c specifies choking options. c = 0 means that the choking model will be applied, and c = 1 means that the choking model will not be applied and c = 2 specifies that the modified Henry-Fauske choking model will be 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, (K_{loss}, area apportioning at branch, restricted junction area, and extra interphase drag), and a = 2 means a partial abrupt area change model (no K_{loss}, 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 = 2), the major edit printout will show a 1.

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.

The meaning of the following three words are different depending on the choking model chosen with the c junction control flag. If c = 0, then the following definitions are used:

W7(R) Subcooled discharge coefficient. This quantity is applied only to subcooled liquid choked flow calculations. The quantity must be > 0.0 and ≤ 2.0. If W7, W8, and W9 are missing, then W7, W8, and W9 are set to 1.0.

W8(R) Two-phase discharge coefficient. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0.0 and ≤ 2.0. If W7 is entered, and W8, and W9 are missing, then W8 and W9 are set to 1.0.

W9(R) Superheated discharge coefficient. This quantity is applied only to superheated vapor choked flow calculations. The quantity must be > 0.0 and ≤ 2.0. If W7 and W8 are entered, and W9 is missing, then W9 is set to 1.0.

If c = 2, then the following definitions are used:

W7(R) This word is the discharge coefficient. The quantity must be > 0.0 and 2.0. If W7 and W8 are missing, then W7 is set to 1.0 and W8 is set to 0.14.

W8(R) This word is the thermal nonequilibrium constant. 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 1000.0. If W7 is entered and W8 is missing, then W8 is set to 0.14.

W9(R) This word in not used. (do not enter).

A7.4.2 Card CCC0110, Single-Junction Diameter and CCFL Data Card

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 6 of Cards CCC0101 through CCC0109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model (i.e., f = 1 in Word 6 of Cards CCC0101 through CCC0109), 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 $4 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If zero is entered or if the default is used, the junction diameter is computed from $2 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 3 of Cards CCC0101 through CCC0109 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1. The default value is 0 (Wallis form).

W3(R) Gas intercept, c. This quantity is the gas intercept used in the CCFL correlation (when $h_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This quantity is the slope used in the CCFL correlation and must be > 0. The default value is 1.

A7.4.3 Card CCC0111, Single-Junction Form Loss Data Card

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

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

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

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 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.

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

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

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

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

A7.4.4 Card CCC0113, Single-Junction Face Placement

This card is optional. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the "from" volume and entering the "to" volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates in the remaining two directions. Four words are entered on the card; two words for the coordinates for the "from" face, and two words for the two coordinates for the "to" face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0.

W1(R) First remaining coordinate value for the "from" face (dimensionless).

W2(R) Second remaining coordinate value for the "from" face (dimensionless).

W3(R) First remaining coordinate value for the "to" face (dimensionless).

W4(R) Second remaining coordinate value for the "to" face (dimensionless).

A7.4.5 Card CCC0201, Single-Junction Initial Conditions

This card is required for single-junction components.

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

W2(R) Initial liquid velocity or mass flow. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb_m/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_m/s), depending on the control word.

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

A7.5 Time-Dependent Junction Component

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 asCCC000000.

A7.5.1 Card CCC0101, Time-Dependent Junction Geometry Card

This card is required for time-dependent junction components.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format, use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the volume.In the 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, or 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 expanded format, only the number N equal to 1 or 2 is allowed.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum flow area of the adjoining volumes. There are no junction area restrictions for time-dependent junctions.

W4(I) Junction control flags. This word has the packed format jefvcahs. It is not necessary to input leading zeros. This word is optional. If this word is not entered, jefvcahs is set to 00000000.

The digit j is not used and should be input as zero (j = 0). The jet junction model is not used.

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

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

The digit v is not used and should be input as zero (v = 0). The stratification entrainment/pullthrough model is not used.

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

The digit a is not used and should be input as zero (a = 0). The abrupt area change model is not used.

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

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

A7.5.2 Card CCC0113, Time-Dependent Junction Face Placement Data

This card is optional. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the “from” volume and entering the “to” volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates on the remaining two directions. Four words are entered on the card; two words for the coordinates for the “from” face, and two words for the two coordinates for the “to” face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0

W1(R) First remaining coordinate value for the “from” face (dimensionless).

W2(R) Second remaining coordinate value for the “from” face (dimensionless).

W3(R) First remaining coordinate value for the “to” face (dimensionless).

W4(R) Second remaining coordinate value for the “to” face (dimensionless).

A7.5.3 Card CCC0200, Time-Dependent Junction Data Control Card

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

W1(I) Control word. If zero, the second and third words of the time-dependent junction data in Cards CCC0201 through CCC0299 are velocities. If one, the second and third words of the time-dependent junction data in Cards CCC0201 through CCC0299 are mass flows. In both cases, the fourth word is interface velocity and should be entered as zero.

W2(I) Table trip number. This word is optional. If missing or zero and Word 3 is missing, no trip is used and the time argument is the advancement time. If nonzero and Word 3 is missing, this number is the trip number and the time argument is -1.0 if the trip is false and the advancement time minus the trip time if the trip is true.

W3(A) Alphanumeric part of variable request code. This quantity is optional. If present, this word and the next are a variable request code that specifies the search argument for the table lookup and interpolation. If the trip number is zero, the specified argument is always used. If the trip number is nonzero, -1.0E75 is used if the trip is false, and the specified argument is used if the trip is true. TIME can be selected, but note that the trip logic is different than if this word is omitted. 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 zero if missing.

A7.5.4 Cards CCC0201 through CCC0299, Time-Dependent Junction Data Cards

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 5,000 sets may be entered. Zero may be entered for a velocity of flow if the phase or material is not present. The interpolation and card formats for the time-dependent data are identical to that in Section.

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 zero.

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_m/s), depending on the 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_m/s), depending on control Word 1 on Card CCC0200.

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

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

A7.6 Pipe, Annulus Component

A pipe component is indicated by PIPE, and an annulus component is indicated by ANNULUS for Word 2 on Card CCC0000. The PIPE and ANNULUS components are similar, except that the ANNULUS component must be vertical and all the water is in the film (i.e., no drops) when in the annular-mist flow regime. The remaining input for both components is identical. 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 pipe or annulus component are numbered as CCCNN0000, where NNN is the volume number (greater than 00 and less than 100). The junction in the pipe or annulus component are numbered as CCCMM0000, where MM is the junction number (greater than 00 and less than 99).

The input for a pipe or annulus component assumes that the pipe or annulus has at least two volumes with one junction separating the two volumes. It is possible to input a one-volume pipe or 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 one. In addition, the user should not input any of the junction cards.

The volumes in a pipe or annulus 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 or annulus volumes in the y- and z-coordinate directions using a form of the momentum equation that does or does not include momentum flux terms. It is also possible to include or not include the momentum flux terms in internal pipe or annulus junctions.

A7.6.1 Card CCC0001, Pipe, Annulus Information Card

This card is required for pipe components.

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

W2(I) Surgeline connection junction number of the junction connecting the bottom volume of the pressurizer to the surge line volume. This word must have the same format as in the major edits, minor edits, and plot variables. The bottom volume of the pressurizer must be the “from” volume and the surgeline volume must be the “to” volume when specifying this surgeline connection junction connecting the two. This input is required for a PRIZER component and must not be entered for PIPE or ANNULUS components.

W3(R) User-specified constant interfacial heat transfer coefficient for liquid (W/m^2-K, Btu/hr-ft^2- ^{o}F) in the vertically stratified flow regime and the level tracking flow regime. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. If this word is less than or equal to zero, the interfacial heat transfer coefficient for liquid from the correlation is used. The default value is zero.

W4(R) User-specified constant interfacial heat transfer coefficient for vapor/gas (W/m^2-K, Btu/hr-ft^2-^{o}F) in the vertically stratified flow regime and the level tracking flow regime. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. If this word is less than or equal to zero, the interfacial heat transfer coefficient for vapor/gas from the correlation is used. The default value is zero.

W5(I) User-specified identifier for a multiplier on the code calculated fraction of the liquid in the film in the annular-mist flow regime. This word is optional for a PRIZER component and must not be entered for PIPE and ANNULUS components. A value of 1 through 999 indicates a general table of type REAC-T for use to specify the multiplier whose number is the entered number (Note: A general table of type REAC-T is used to prevent undesirable units conversion, since no British or SI units conversion is done for REAC-T entries). A value of 10001 through 19999 indicates the multiplier will be obtained from a control variable whose identification number is the entered number minus 10000. A value of zero means that the multiplier of 1.0 will be used. A value of zero from the table or control variable means that all of the available liquid is in droplets in the annular-mist flow regime. The default value is zero.

W6(I) User-specified identifier for a multiplier on the interfacial heat transfer coefficients for both liquid and vapor/gas in the vertically stratified flow regime and the level tracking flow regime. This word is optional for the PRIZER component and may not be entered for PIPE and ANNULUS components. A value of 1 through 999 indicates a general table of type REAC-T for use to specify the multiplier (Note: A general table of type REAC-T is used to prevent undesirable units conversion, since no British or SI units conversion is done for REAC-T entries). A value of 10001 through 19999 indicates the multiplier will be obtained from a control variable whose identification number is the entered value minus 10000. A value of zero means that a multiplier of 1.0 will be used. The default value is zero.

W7(I) Pressurizer spray droplet diameter. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. This word specifies the droplet diameter in the annular-mist and mist flow regimes. A value of zero specifies that the value computed from the correlations in the code are to be used. The default value is zero.

W8(I) Pressurizer spray junction identifier. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. This word specifies the identifier of the pressurizer spray junction. This word must have the same format as in the major edits, minor edits, and plot variables. A volume in the pressurizer component must be the "to" volume for this junction so that positive flow in the junction is into the pressurizer component. A non-zero value for this input activates the spray induced, enhanced condensation model in the vertical stratification and level tracking flow regimes. These flow regimes are active for the pressurizer volume containing the liquid level. The default value is zero.

W9(R) Pressurizer spray mixing coefficient. This word is optional for a PRIZER component and must not be entered for PIPE or ANNULUS components. This word specifies the spray mixing coefficient used in the spray induced, enhanced condensation model. The default value is zero.

A7.6.2 Card ccc0002, Pipe Angles and Elevation Options

This card is optional for pipe components.

W1(A) Angles option. Enter EULER for Euler angles, PYR for pitch, yaw, and roll angles, and SPH for spherical angles. Each volume of a pipe is initially assumed to have its local x-axis (the one dimensional flow coordinate) aligned with the fixed x-axis. The volume is then rotated using the two or three input angles before being placed within the hydrodynamic system. This quantity states how the angles are interpreted. If this card is missing, spherical angles are used.

W2(I) Elevation change option. This word is optional. Nine quantities, Δ_{xx}, Δ_{yx}, Δ_{zx}, Δ_{xy}, Δ_{yy}, Δ_{zy}, Δ_{xz}, Δ_{yz}, and Δ_{zz} need to be defined. The Δ's are changes along the fixed space coordinate given by the first subscript due to traversing the local coordinate given by the second subscript from its inlet to its outlet. For regular volumes such as sections of a circular pipe, these quantities can be computed by the code from the volume's volume, flow area, and flow length. For irregularly shaped volumes, input is provided to enter all nine Δ quantities. If x-coordinate data only (the standard one dimensional input) is entered, the flow lengths and flow areas in the y- and z-coordinate directions are computed from the x-coordinate data and the volume of the volume, assuming a right circular pipe. Flow areas and flow lengths for the y- and z-coordinates may be entered using optional input similar to that used for the x-coordinate. Initially, Δ_{xx}, Δ_{yy}, and Δ_{zz} are set to the flow lengths for the x-, y-, and z-coordinates, respectively, and the Δ's with unequal subscripts are set to zero. The Δ's are then re-evaluated due to the effects of any rotations. The Δ's can be overwritten using optional input. No rotation effects are applied to the data entered in these cards and, thus, the data on these cards must reflect the desired orientation of the volume. Enter 1 to indicate that the elevation changes on the x-coordinate change data are entered in the original format of one elevation change (Δ_{zx}) per volume. Enter 3 to indicate that three coordinate changes (Δ_{xx}, Δ_{yx}, and Δ_{zx} are entered for each volume. The coordinate changes for the y- and dz-coordinates are always three coordinate changes per volume. This quantity is assumed 1 if this word is not entered.

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

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

A7.6.3 Cards CCC0101 through CCC0199, Pipe, Annulus X-Coordinate Volume Flow Areas

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

W1(R) Volume flow area (m^2, ft^2).

W2(I) Volume number.

A7.6.4 Cards ccc1601 through ccc1699, Pipe or Annulus Y-Coordinate Volume Flow Areas

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

W1(R) Volume flow area (m^2, ft^2).

W2(I) Volume number.

A7.6.5 Cards ccc1701 through ccc1799, Pipe or Annulus Z-Coordinate Volume Flow Areas

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

W1(R) Volume flow area (m^2, ft^2).

W2(I) Volume number.

A7.6.6 Cards CCC0201 through CCC0299, Pipe, Annulus Junction Flow Areas

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

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

W2(I) Junction number.

A7.6.7 Cards CCC0301 through CCC0399, Pipe, Annulus X-Coordinate Volume Lengths

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

W1(R) Pipe or annulus volume length (m, ft).

W2(I) Volume number.

A7.6.8 Cards CCC1801 through CCC1899, Pipe, Annulus Y-Coordinate Volume Lengths

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

W1(R) Pipe volume length (m, ft).

W2(I) Volume number.

A7.6.9 Cards CCC1901 through CCC1999, Pipe, Annulus Z-Coordinate Volume Lengths

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

W1(R) Pipe volume length (m, ft).

W2(I) Volume number.

A7.6.10 Cards ccc2901 through ccc2999, Pipe, Annulus Elbow/Spiral Angle/Radius of Curvature

This section of input is proposed only and has not been implemented.

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

W1(R) Angle of curved pipe if a positive number (degrees) or radius of curvature (m, ft) if entered as a negative number. A zero indicates a straight section of pipe. The angle of the curved pipe is the angle formed by the radius of curvature drawn from the center of the inlet face to the radius of curvature drawn from the center of the outlet face. The radius of curvature is a positive number; the minus sign is only to distinguish it from the angle input. Using ζ for the angle of curved pipe, r for the radius of curvature, and l for the volume length, these quantities are related by $l = r\zeta\frac{\pi}{180}$.

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

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

W3(I) Volume number.

A7.6.11 Cards CCC0401 through CCC0499, Pipe, Annulus Volume Volumes

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

W1(R) Volume (m^3, ft^3). If these cards are missing, volumes equal to zero are assumed. The code requires that each volume equal the 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 zero, it will be computed from the other two. If none of the quantities are zero, 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 zero, the y-direction length is computed from $2.0\left(\frac{\text{x-direction flow area}}{\pi}\right)^{0.5}$ and the y-direction flow area is computed from $\frac{\text{volume of volume}}{\text{y-direction length}}$. The same is true for the z-direction.

.W2(I) Volume number.

A7.6.12 Cards CCC0501 through CCC0599, Pipe, Annulus Volume First or Azimuthal Angles

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

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

W2(I) Volume number.

A7.6.13 Cards CCC0601 through CCC0699, Pipe, Annulus Volume Second or Vertical Angles

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

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

W2(I) Volume number.

A7.6.14 Cards ccc1501 through 1599, Pipe, Annulus Third Angle

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

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

W2(I) Volume number.

A7.6.15 Cards CCC0701 through CCC0799, Pipe, Annulus X-Coordinate (Elevation) Changes

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

One coordinate change per volume format:

W1(R) Elevation change. That is the coordinate change along fixed z-axis 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 volume length. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the volume 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}.

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

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

W4(I) Volume number.

A7.6.16 Cards CCC2101 through CCC2199, Pipe, Annulus Y-Coordinate (Elevation) Changes

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

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

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

W3(R) Coordinate change along the fixed y-axis due to traverse from inlet to outlet along the local y-coordinate, Δ_{zy}.

W4(I) Volume number.

A7.6.17 Cards CCC2201 through CCC2299, Pipe, Annulus Z-Coordinate (Elevation) Changes

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

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

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

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

W4(I) Volume number.

A7.6.18 Cards CCC0801 through CCC0899, Pipe, Annulus Volume X-Coordinate Friction Data

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

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

W2(R) Hydraulic diameter (m, ft). This should be computed from

If zero, the hydraulic diameter is computed

from $2.0 \cdot \left(\frac{x\text{-direction volume flow area}}{\pi}\right)^{0.5}$. A check is made to ensure that the roughness is less than half the hydraulic diameter. See Word 1 on Cards CCC0101 through CCC0109 for the volume flow area.

W3(I) Volume number.

A7.6.19 Cards CCC2301 through CCC2399, Pipe, Annulus Volume Y-Coordinate Friction Data

These cards are optional and may be entered if volume flow area or volume length data was entered for the y-coordinate. If the cards are not entered, the wall roughness defaults to zero and the default hydraulic diameter is computed from

$4.0 \cdot \left(\frac{\text{y-direction volume flow area}}{\pi \bullet \text{x-direction volume flow area}}\right)^{0.5}$. The format for these cards is the same as for the friction data for the x-coordinate. A check is made to ensure that the y-direction roughness is less than half the y-direction hydraulic diameter.

W1(R) Wall roughness in the y-direction (m, ft). The y-direction wall roughness is limited to be greater than or equal to $1.0\text{x}10^{-9}$ times the y-direction hydraulic diameter. If zero, the y-direction wall roughness is computed from $1.0\text{x}10^{-9}$ times the y-direction hydraulic diameter.

W2(R) Hydraulic diameter in the y-direction (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{y-direction volume flow area}}{\text{y-direction wetted perimeter}}\right)$ If zero, the y-direction hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{y-direction volume flow area}}{\pi \bullet \text{x-direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure that the y-direction wall roughness is less than half the y-direction hydraulic diameter. See Word 1 on cards CCC1601 through CCC1699 for the y-direction volume flow area.

W3(R) Volume number.

A7.6.20 Cards CCC2401 through CCC2499, Pipe, Annulus Volume Z-Coordinate Friction Data

These cards are optional and may be entered if volume flow area or volume length data was entered for the z-coordinate. If the cards are not entered, the wall roughness defaults to zero and the default hydraulic diameter is computed from

$4.0 \bullet \left(\frac{\text{z-direction volume flow area}}{\pi \bullet \text{x-direction volume flow area}}\right)^{0.5}$. The format for these cards is the same as for the friction data for the x-coordinate. A check is made to ensure that the z-direction roughness is less than half the y-direction hydraulic diameter

W1(R) Wall roughness in the z-direction (m, ft). The z-direction wall roughness is limited to be greater than or equal to 1.0×10^{-9} times the z-direction hydraulic diameter. If zero, the z-direction wall roughness is computed from 1.0×10^{-9} times the z-direction hydraulic diameter.

W2(R) Hydraulic diameter in the z-direction (m, ft). This should be computed from $4.0 \bullet \left(\frac{\text{z-direction volume flow area}}{\text{z-direction wetted perimeter}}\right)$ If zero, the z-direction hydraulic diameter is computed from $2.0 \bullet \left(\frac{\text{z-diection volume flow area}}{\pi \bullet \text{x-direction volume flow area}}\right)^{0.5}$. See Section 2.4 of this volume of the manual. A check is made to ensure that the z-direction wall roughness is less than half the z-direction hydraulic diameter. See Word 1 on cards CCC1701 through CCC1799 for the z-direction volume flow area.

W3(R) Volume number.

A7.6.21 Cards ccc2501 through ccc25999, Pipe, Annulus Volume Additional Laminar Wall Friction Data

These cards are optional. If these cards are not entered, the default values are 1.0 for the 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 for x-coordinate.

W3(R) Shape factor for y-coordinate.

W4(R) Viscosity ratio for y-coordinate.

W5(R) Shape factor for y-coordinate.

W6(R) Viscosity ratio for y-coordinate.

W7(I) Volume number.

A7.6.22 Cards ccc2601 through ccc2699, Pipe, Annulus Alternate Turbulent Wall Friction Data

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

W1(R) *A* for x-coordinate.

W2(R) *B* for x-coordinate.

W3(R) *C* for x-coordinate.

W4(R) *A* for y-coordinate.

W5(R) *B* for y-coordinate.

W6(R) *C* for y-coordinate.

W7(R) *A* for z-coordinate.

W8(R) *B* for z-coordinate.

W9(R) *C* for z-coordinate.

W10(I) Volume number.

A7.6.23 Cards CCC0901 through CCC0999, Pipe, Annulus Junction Loss Coefficients

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

W1(R) 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 zero. Note: a variable loss coefficient may be specified (see Section A7.6.33). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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 A7.6.33). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

W3(I) Junction number.

A7.6.24 Cards CCC1001 through CCC1099, Pipe, Annulus Volume X-Coordinate Control Flags

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

W1(I) Volume control flags. This word has the packed format <u>tlpvbfe</u>. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler 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 <u>f</u> flag is the only coordinate direction oriented flag. These words enter the scaler oriented flags and the x-coordinate flags for each volume in the pipe or annulus.

The digit <u>t</u> specifies whether the thermal front tracking model is to be used; <u>t</u> = 0 specifies that the front tracking model is not to be used for the volume, and <u>t</u> = 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.

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.

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

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

The digit b specifies the interphase friction 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.

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.

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.

A7.6.25 Cards ccc2701 through ccc2799, Pipe, Annulus Y Coordinate Control Flags

W1(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the y-coordinate direction.

The digit f specifies whether wall friction is 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.

W2(I) Volume number.

A7.6.26 Cards ccc2801 through ccc2899, Pipe, Annulus Y Coordinate Control Flags

W1(I) Volume control flags. This word has the general packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the z-coordinate direction.

The digit f specifies whether wall friction is 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.

W2(I) Volume number.

A7.6.27 Cards CCC1101 through CCC1199, Pipe, Annulus Junction Control Flags

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

W1(I) Junction control flags. This word has the packed format efvcahs. It is not necessary to input leading zeros.

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

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

The digit v is not used and should be input as zero (v = 0). The horizontal stratification entrainment/pullthrough model cannot be used.

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

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means full abrupt area change model (K_{loss} area apportioning at branch, restricted junction area, and extra interphase drag), and a = 2 means a partial abrupt area change model (no K_{loss} 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 = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 1 or 2), the major edit printout will show a one.

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 either the to or the from volume. For the case of a pipe or annulus, 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.

A7.6.28 Cards CCC1201 through CCC1299, Pipe, Annulus Volume Initial Conditions

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

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

The digit e specifies the fluid. e = 0 is the default fluid, e = 1 specifies H_2O and e = 2 specifies D_2O. 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 H_2O is assumed as the fluid.

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 zero) is being entered after the other required thermodynamic information.

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

With options t equal to 4 through 6, names of the 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, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/lb_m), 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.

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.

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.

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.

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, two-phase conditions, and static quality < $1.0E^{-9}$ or static quality > 0.99999999, single-phase. The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$.

Noncondensable options are:

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.

If t = 5, the next three words are interpreted as temperature (K, ^{o}F), 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. W5 and W6 should be 0.0. 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, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/lb_m), 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 > 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.

If t = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, ^{o}F), vapor/gas temperature (K, ^{o}F), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature.

W2-W6(R) Quantities as described under Word 1. Five quantities must be entered, and zeros should be entered for unused quantities. If any control word (Word1) indicates that boron is present, Cards CCC2001 through CCC2099 must be entered to define the initial boron concentrations. Boron concentrations are not entered in Words 2 through 6.

W7(I) Volume number.

A7.6.29 Cards CCC2001 through CCC2099, Pipe, Annulus Initial Boron Concentrations

These cards are required only if boron is specified in one of the control words (Word 1) in Cards CCC1201 through CCC1299. The card format is two words per set in sequential expansion format for nv sets. Boron concentrations must be entered for each volume, and zero should be entered for those volumes whose associated control word did not specify boron.

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

W2(I) Volume number.

A7.6.30 Card CCC1300, Pipe, Annulus Junction Conditions Control Words

This card is optional, and, if missing, velocities are assumed on Cards CCC1301 through CCC1399.

W1(I) Control word. If zero, the first and second words of each set on Cards CCC1301 through CCC1399 are velocities. If one, the first and second words of each set on Cards CCC1301 through CCC1399 are mass flows.

A7.6.31 Cards CCC1301 through CCC1399, Pipe, Annulus Junction Initial Conditions

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

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

W3(R) Interface velocity (m/s, ft/s). Enter zero.

W4(I) Junction number.

A7.6.32 Cards CCC1401 through CCC1499, Pipe, Annulus Junction Diameter and CCFL Data Cards

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 through CCC1199), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model, (i.e., $\underline{f}$ = 1 in Word 1 of Cards CCC1101 through CCC1199), 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. The number should be computed from $4.0 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If a zero is entered or if the default is used, the junction diameter is computed from

. See Word 1 of Cards CCC0201 through CCC0299 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1. The default value is 0 (Wallis form).

W3(R) Gas intercept, C This quantity is the gas intercept used in the CCFL correlation (when) 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.

A7.6.33 Cards CCC3001 through CCC3099, Pipe, Annulus Junction Form Loss Data Card

This card is optional. The user-specified form loss is given in Words 1 and 2 of Cards CCC0901 through CCC0999 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 through CCC0999. Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss coefficient, then enter all five words for the appropriate expression.

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

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

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

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

W5(I) Junction number.

A7.6.34 Cards ccc3101 through ccc3199, ORNL ANS Interphase Model Pitch and Span Values

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

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

W#(I) Volume number.

A7.6.35 Cards CCC3201 through CCC3299, Pipe, Accumulator, or Pressurizer VolumeNon-condensable Mass Fractions.

These cards are optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-W5(R) Mass fractions for the noncondensable species entered on Card 110. Five quantities must be entered, and zeros should be entered for species not present in the volumes. The noncondensable mass fractions must sum to one within a relative error of 1.0×10^{-10}.

W6(I) Volume number.

A7.7 Branch, Separator, Jetmixer, Turbine, Or ECC Mixer Component

A branch component is indicated by BRANCH, a steam separator is indicated by SEPARATR, a jetmixer is indicated by JETMIXER, a turbine is indicated by TURBINE, and an ECC mixer is indicated by ECCMIX for Word 2 on Card CCC0000. In junction references using the old format, the code for the component inlet is CCC000000 and the code for the component outlet is CCC010000. In the junction references using the expanded format, 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. Normally, only a branch has more than one junction connected to a volume end. Multiple junctions may connect to the ends of pipes and single-volumes except that a warning message is issued even though the connections are handled correctly. Limiting multiple connections to branch components allows the warning message to indicate probable input error. If 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 wit the branch component are numbered as CCCMM0000, where MM is the junction number (greater than 00 and less than 10).If multiple junctions are connected on one end of a branch, each junction should be modeled as an abrupt area change.

A separator component is a specialized branch component having three junctions. The number of junctions nj defined below must be three, and no junctions in other components 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, N = 2 is the liquid fall back, and N = 3 is the separator inlet. The <u>from</u> part of the vapor outlet junction must refer to outlet of the separator (old format is CCC010000, and expanded format is CCC010002), and the from part of the liquid fall back must refer to the inlet of the separator (old format is CCC000000, and expanded format is 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 recommended that choking be turned off for all three junctions. The vapor outlet and liquid fall back junctions should use the nonhomogeneous option. The CCFL flag must be turned off (<u>f</u> = 0) for all three junctions. The horizontal stratification flag is not used for separator junctions and should be set to zero (<u>v</u> = 0). The rod bundle interphase friction flag must be turned off (<u>b</u> = 0) in the separator volume. The vertical stratification model flag is not used in the separator volume and should be set to zero (<u>v</u> = 0). The water packing scheme flag is not used in the separator volume and should be set to zero (<u>p</u> = 0).

A jetmixer component is a specialized branch using three junctions numbered in the same manner as the separator. For the junctions, N = 1 represents the drive, N = 2 represents the suction, and N = 3 represents the discharge. The <u>to</u> part of the drive and suction junctions must refer to the inlet end of the jetmixer (old format is CCC000000, and the expanded format is CCC010001), and the <u>from</u> part of the discharge junction must refer to the outlet end of the jetmixer (old format is CCC010000, and expanded format is CCC010002). To model a jet pump properly, the junction flow areas of the drive and suction should equal the volume flow area. The CCFL flag must be turned off (<u>f</u> = 0) for all three junctions. The horizontal stratification entrainment/pullthrough flag is not used for jetmixer junctions and should be set to zero (<u>v</u> = 0). The rod bundle interphase friction flag must be turned off (<u>b</u> = 0) in the jetmixer volume. The vertical stratification model flag is not used in the jetmixer volume and should be set to zero (<u>v</u> = 0). The water packing scheme flag is not used in the jetmixer volume and should be set to zero (<u>p</u> = 0).

A turbine component is a specialized branch with additional input to describe the turbine characteristics. A simple turbine might use only one turbine component. A multistage turbine with steam extraction points might require several turbine components. The number of junctions, nj, must be equal to 1 or 2. For the junctions, N = 1 is the turbine junction that models the stages, and N = 2 is the steam extraction (bleed) junction that should be crossflow. The primary steam inlet junction (N = 1) is a normal junction, and the steam extraction line (N = 2) should be modeled as a crossflow junction. The turbine junction (N = 1) must be the only entrance junction, and there must be only one exit junction (part of another component). The to part of the steam inlet junction (N = 1) must refer to the inlet end of the turbine volume (old format is CCC000000, and expanded format is CCC0100001). 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. The horizontal stratification entrainment/pullthrough flag must be turned off (<u>v</u> = 0). 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). If a steam extraction (bleed) junction is present, it must be a crossflow junction. The CCFL flag must be turned off (<u>f</u> = 0) for both junctions. The rod bundle interphase friction flag must be turned off (<u>b</u> = 0) in the turbine volume. The vertical stratification model flag is not used in the turbine volume and should be set to zero (<u>v</u> = 0). The water packing scheme flag is not used in the turbine volume and should be set to zero (p = 0).

An ECC mixer (ECCMIX) component is a specialized branch that requires three junctions with a certain numbering order. The physical extent of the ECC mixer is a length of the cold leg, or any other horizontal pipe, centered around the position of the ECC injection location. The length of this pipe segment should be equal to three times the inside diameter of the pipe (if the physical arrangement of the system permits). Junction number one (the lowest numbered junction) must be the ECC connection. This is, in some respects, similar to the drive junction of a jetmixer component. Junction number two (the junction with higher number than the first one) should be the one that is the flow inlet to this component in normal operation. The geometrical angle between the axis of junctions one and two is one of the necessary inputs, as will be specified later. The third, or discharge, junction is the normal outlet of flow through this pipe segment. The to part of junctions one and two must refer to the inlet end of the ECC mixer (old format CCC00000, and expanded format is CCC010001), and the from part of the discharge junction must refer to the outlet end of the ECC mixer (old format CCC010000, and expanded format is CCC010002).

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.

The component identification word on Card CCC0000 should be ECCMIX for the ECC mixer. This word directs the code to use a specific flow regime map and a specific interfacial heat transfer package for steam condensation.

A7.7.1 Card CCC0001, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Information Card

This card is required for branch, separator, jetmixer, turbine, or ECC mixer components.

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 equal to or greater than zero and less than ten. This number must be 3 for SEPARATR, JETMIXER, and ECCMIX components and must be 1 or 2 for TURBINE components. For BRANCH components, not all junctions connecting to the branch need to be described with this component input, and nj is not necessarily the total number of junctions connecting to the branch. Junctions described in single-junctions, time-dependent junctions, pumps, separators, jetmixers, and other branches can be connected to this branch.

W2(I) Initial condition control. This word is optional and, if missing, the junction initial velocities in the first and second words on Cards CCCN201 are assumed to be velocities. If zero, velocities are assumed; if nonzero, mass flows are assumed.

A7.7.2 Card CCC0002, Separator Component Options Card

This card is an optional card for a separator component. The first word specifies the separator option while the second word specifies the number of actual separator components by this RELAP5 SEPARATR 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 two or three.

A7.7.3 Card CCC0003, Feedwater Heater Data

This card is optional for the feedwater heater component. It is not allowed for branch, separator, jetmixer, turbine, or ECC mixer components. Word 1 is the number of a table that specifies the relationship between the non-dimensional water level and the void on the shell side of the feedwater heater. The non-dimensional water level is equal to the water level divided by the shell diameter, The table must be a REAC-T type table, which has no units conversion. If this card is missing, the code uses the liquid volume fraction (1 - void) as the default value for the non-dimensional water level.

W1(I) Table number specifying non-dimensional water level for the table function value (Cards 202TTT01-202TTT99, Word 2) versus void for the table argument value (Cards 202TTT01-202TTT99, Word 1) in the shell side of the feedwater heater.

A7.7.4 Cards CCC0101 through CCC0109, Branch, Separator, Jetmixer, Turbine, or ECC Mixer X-Coordinate Volume Data

This card (or cards) is required for branch, separator, jetmixer, turbine, and ECC mixer components. The nine words can be entered on one or more cards, and the card numbers need not be consecutive.

W1(R) Volume flow area (m^2, ft^2).

W2(R) Length of volume (m, ft).

W3(R) Volume of volume (m^3, ft^3). The code requires that the volume equals the volume flow area times the length ($W3 = W1 \cdot W2$). At least two of the three quantities, W1, W2, and W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the 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. For ECCMIX, the allowable inclination angle is less than + 15 degrees. Any other value will be considered an input error.

W6(R) Elevation change (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be less than or equal to the volume length. If the vertical angle orientation is zero, this quantity must be zero. If the vertical angle is nonzero, this quantity must also be nonzero and have the same sign. When the absolute value of the elevation angle determined by the ratio of the elevation change (this Word 6) and the volume 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. 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

$4 \bullet \left(\frac{\text{x-direction volume flow area}}{\text{x-direction wetted perimeter}}\right)$. If zero, the hydraulic diameter is computed from $2 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. A check is made to ensure the pipe roughness is less than half the hydraulic diameter. See Word 1 for the volume flow area.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler 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 scaler oriented flags and the x-coordinate 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. This model is not used for SEPARATR, JETMIXER, TURBINE, or ECCMIX components and the flag if entered is considered an input error.

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. This model is not used for SEPARATR, METMIXER, TURBINE, or ECCMIX components and the flag if entered as 1 is considered an input error.

The digit p specifies whether the water packing scheme is to be used. p = 0 specifies that the water packing scheme is to be used for the volume, and p = 1 specifies that the water packing scheme is not to be used for the volume. The water packing scheme is recommended when modeling a pressurizer. This digit is used for the BRANCH and ECCMIX components. For the SEPARATR, JETMIXER, and TURBINE components, the water packing scheme is not allowed, the digit is not used and may be input as 0 or 1. The major edit will show p = 1.

The digit v specifies whether the vertical stratification model is to be used. v = 0 specifies that the vertical stratification model is to be used for the volume, and v = 1 specifies that the vertical stratification model is not to be used for the volume. The vertical stratification model is recommended when modeling a pressurizer. This digit is used for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, and ECCMIX components, the vertical stratification model is not allowed, the digit is not used and may be input as 0 or 1. The major edit will show v = 1.

The digit b specifies the interphase friction that is used. b = 0 means that the pipe interphase friction model will be applied, b = 1 means that the rod bundle interphase friction model will be applied. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, and ECCMIX, the rod bundle interphase friction is not allowed, the digit is not used, and must be input as 0.

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. For a SEPARATR component, either 0 or 1 may be entered; the code will set f = 1 and no wall friction will be calculated. The digit f must be entered as 1 for a TURBINE component.

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 than 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.

W10(I) Optional control word for elevation (or position) changes. This word is normally used only for motion problems. The elevation change in W6 is the change in the vertical direction as the flow passes from the x-inlet face to the x-outlet face. This is the only elevation change needed for the x-coordinate for non-moving problems. For moving problems, position change information is needed in the other two horizontal directions. This control word may be 0, 1, or 2. If not entered, the default value is 1. If this word is entered as 0, the position changes for the x-coordinate are computed from the x-volume length (W2) and the azimuthal and vertical angles, and W6 is not used. If 1 is entered, W6 is used, but W11 and W12 are not used and the corresponding values are computed from the flow lengths and the angles. If 2 is entered, W6, W11, and W12 are used for the position changes.

W11(R) Position change in fixed x-direction as flow passes from x-inlet to x-outlet (m, ft). This quantity does not affect simulation results from non-moving problems.

W12(R) Position change in fixed y-direction as flow passes from x-inlet to x-outlet (m, ft). This quantity does not affect simulation results from non-moving problems.

A7.7.5 Cards CCC0181 through CCC0189, Branch, Separator, Jetmixer, or ECC Mixer Y-Coordinate Volume Data

These cards are optional for BRANCH, SEPARATR, JETMIXER, or ECCMIXER components but are not allowed for TURBINE components. These cards are used when the user specifies the y-direction connection with the cross flow 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 of the volume (m^2, ft^2). If these cards are missing or if this word is zero, this y-direction volume flow area is computed from

$$\frac{\text{volume of volume}}{\text{y-direction length}}.$$

W2(R) Length of the crossflow volume (m, ft). If these cards are missing, this y-direction length is computed from. $2 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$.

W3(R) Roughness (m, ft).

W4(R) Hydraulic diameter (m, ft). If these cards are missing or if this word is zero, this y-direction hydraulic diameter is computed from

$\cdot 4 \bullet \left(\frac{\text{y-direction volume flow area}}{\pi \bullet \text{x-direction volume flow area}}\right)^{0.5}$ · 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 packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the y-direction.

The digit f specifies whether wall friction is to be computed. f = 0 specifies that was friction effects are not to be computed along the y-coordinate direction.

W6(R) This and the following two words are optional. If these words are not entered, the position changes are obtained from the flow length in the y-direction and the two volume orientation angles. This word is the position change in the x-fixed direction as the flow passes from the y-inlet face to the y-outlet face (m, ft). This quantity affects results only in moving problems.

W7(R) This word is the position change in the y-fixed direction as flow passes from the y-inlet face to the y-outlet face (m, ft). This quantity affects results only in moving problems.This quantity affects non-moving problems if connections are made to the y-faces.

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 results only in moving problems.

A7.7.6 Cards CCC0191 through CCC0199, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Z-Coordinate Volume Data

These cards are optional for BRANCH, SEPARATR, JETMIXER, TURBINE, and ECCMIXER. These cards are used when the user specifies the z-direction connection with the cross flow 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 of the volume (m^2, ft^2). If these cards are missing or if this word is zero, this z-direction volume flow area is computed from $\left(\frac{\text{volume of volume}}{\text{z-direction length}}\right)$.

W2(R) Length of the crossflow volume (m, ft). If these cards are missing, this z-direction length is computed from $2 \bullet \left(\frac{\text{x-direction volume flow area}}{\pi}\right)^{0.5}$. If this word is zero, this z-direction length is computed from $\frac{\text{volume of volume}}{\text{z-direction volume flow area}}$.

W3(R) Roughness (m, ft).

W4(R) Hydraulic diameter (m, ft). If these cards are missing or if this word is zero, this y-direction hydraulic diameter is computed from

$4 \bullet \left(\frac{\text{y-direction volume flow area}}{\pi \bullet \text{x-direction volume flow area}}\right)^{0.5}$. 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 packed format tlpvbfe, but this word is limited to 00000f0 since it only enters the coordinate oriented flags for the z-direction.

The digit f specifies whether wall friction is to be computed. f = 0 specifies that was friction effects are not to be computed along the z-coordinate direction.

W6(R) This word is not used. This and the following two words are optional. If these words are not entered, the position changes are obtained from the flow length in the y-direction and the two volume orientation angles. This word is the position change in the x-fixed direction as the flow passes from the z-inlet face to the z-outlet face (m, ft). This quantity affects results only in moving problems.

W7(R) This word is not used. Enter 0. This is the position change in the y-fixed direction as flow passes from the z-inlet face to the z-outlet face (m, ft). This quantity affects results only in moving problems.This quantity affects non-moving problems if connections are made to the y-faces.

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 non-moving problems is connections are made to the z-faces.

A7.7.7 Card ccc0111, ORNL ANS Interphase Model Pitch and Span Values

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

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

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

A7.7.8 Card CCC0131, Additional Laminar Wall Friction Card

This card is optional except for a TURBINE component. If this card is not entered, the default values are 1.0 for the 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

A7.7.9 Card CCC0141, Branch, Separator, Jetmixer, Feedwater Heater, or ECC Mixer Alternate Turbulent Wall Friction

This card is optional for the BRANCH, SEPARATR, JETMIXER, FWHTR, and ECCMIX components, and it is not allowed for a TURBINE component. This card allows the specification of a user defined turbulent friction factor for each coordinate direction. The turbulent friction factor has the form $f = A + B(Re)^{-C}$ where A, B, and C are entered for each coordinate of each volume. If this cards is not entered, the standard turbulent friction factor is used for all coordinates. If the card is entered, the standard turbulent friction factor can be selected for a particular coordinate direction by entering zeros for the three quantities. Three, six, or nine quantities may be entered on the card, and the data not entered are set to zeros.

W1(R) *A* for coordinate direction 1.

W2(R) *B* for coordinate direction 1

W3(R) *C* for coordinate direction 1.

W4(R) *A* for coordinate direction 2.

W5(R) *B* for coordinate direction 2.

W6(R) *C* for coordinate direction 2.

W7(R) *A* for coordinate direction 3.

W8(R) *B* for coordinate direction 3.

W9(R) *C* for coordinate direction 3.

A7.7.10 Card CCC0200, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Volume Initial Conditions

This card is required for branch, separator, jetmixer, turbine, and ECC mixer components.

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

The digit e specifies the fluid; e = 0 is the default fluid, e = 1 specifies H_2O and e = 2 specifies D_2O. 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 water is assumed to be the fluid.

The digit b specifies whether boron is present. b = 0 specifies that the volume fluid does not contain boron, and b = 1 specifies that a boron concentration in 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. t = 0 through 3 specifies one component (steam/water); 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 the 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, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/lb_m), 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.

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

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

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K,^oF) in equilibrium condition.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for static quality are: 1.0E-9 $\leq$ static quality $\leq$ 0.99999999, two-phase conditions, and static quality < 1.0E-9 or static quality > 0.99999999, single-phase. The static quality is given by $Mg/(M_g + M_f)$, where $M_g = M_s + M_n$. Noncondensable options are:

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 $\leq$ 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.

If t = 5, the next three words are interpreted as temperature (K, ^oF), equilibrium quality, and noncondensable quality. Both the equilibrium and noncondensable qualities are restricted to be between 1.0E-9 and 0.99999999. 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, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor specific internal energy (J/kg, Btu/lb_m), 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.

If t = 8,the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K,°F), vapor/gas temperature (K, °F), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. 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.

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

A7.7.11 Cards CCCN101 through CCCN109, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Geometry Card

These cards are required if nj is greater than zero. Cards with N equal to 1 through 9 are entered, one for each junction. The variable N equal to 1, 2, and 3 must be used for SEPARATR, JETMIXER, and ECCMIX components. For a BRANCH component, N need not be consecutive, but nj cards must be 4.0 volume flow area wetted perimeter entered. The card format for Words 1 through 6 is listed below and is identical to Words 1 through 6 on Card CCC0101 of the Single-Junction Geometry Card, except that N instead of 0 is used in the fourth digit. Word 7 is not used for JETMIXER and TURBINE components. Word 7 is defined for SEPARATR and ECCMIX components. Words 7, 8, and 9 are defined BRANCH components.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or expanded format can be used to connect volumes. in the old format, use CCC000000 if the connections to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the volume. In the 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 expanded format, only the number N equal to 1 or 2 is allowed.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum volume area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) 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 zero. A variable loss coefficient may be specified (see Section A7.7.13). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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 A7.7.13). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

W6(I) Junction control flags. This word has the packed format efvcahs.

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. This digit is only for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, and ECCMIX components, this digit is not used and should be set to 0. The major edit output will show e = 0.

The digit f specifies CCFL options. f = 0 means that the CCFL model will not be applied, and f = 1 means that the CCFL model will be applied. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, and ECCMIX components, the CCFL model is not allowed, this digit is not used and should be set to 0. The major edit output will show f = 0.

The digit v specifies horizontal stratification entrainment/pullthrough options. 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; v = 2 means a downward oriented junction; and v = 3 means a centrally (side) located junction. This digit is only used for the BRANCH component. For the SEPARATR, JETMIXER, TURBINE, and ECCMIX components, the horizontal stratification entrainment/pullthrough model is not allowed, this digit is not used and should be set to 0.

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

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, a = 1 means full abrupt area change model (K_{loss}, area apportioning at branch, restricted junction area, and extra interphase drag), and a = 2 means a partial abrupt area change (no K_{loss}, 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 h = 1.

The digit s specifies momentum flux options. This digit is used for the BRANCH, SEPARATR, and TURBINE components. 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 or the from volume. For the JETMIXER and ECCMIX components, this digit is not used and should be input as 0.

W7(R) Void fraction limit (for SEPARATR). Angle (for ECCMIX), and subcooled discharge coefficient (for BRANCH). This word is needed only for a SEPARATR or an ECCMIX component. For SEPARATR, this word is void fraction limit. For the vapor exit junction (N = 1), this quantity (VOVER) is the vapor void fraction above which flow out of the vapor outlet is pure vapor. If the word is missing, a default value of 0.5 is used. For the liquid fall back junction (N = 2), this quantity (VUNDER) is the liquid void fraction above which flow out of the liquid fall back is pure liquid. If the word is missing, a default value of 0.15 is used. For the separator inlet, this word is not used. For ECCMIX, this word is angle and is the angle between the axis of the ECC injection line and the main pipe (or the angle between Junctions 1 and 2). This angle must be between 0 and 180 degrees. If missing, a 90-degree connection for the ECC pipe is assumed. For BRANCH, this word is subcooled discharge coefficient. This quantity is applied only to subcooled choked flow calculations. The quantity must be > 0 and ≤ 2.0. If W7, W8, and W9 are missing, then W7, W8, and W9 are set to 1.0

W8(R) For BRANCH, this word is two-phase discharge coefficient. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 and ≤ 2.0. If W7 is entered and W8 and W9 are missing, then W8, and W9 are set to 1.0

W9(R) For BRANCH, this word is superheated discharge coefficient. This quantity is applied only to superheated choked flow calculations. The quantity must be > 0 and ≤ 2.0. If W7 and W8 are entered and W9 is missing, then W9 is set to 1.0

A7.7.12 Cards CCCN110 Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Diameter And CCFL Data Cards

These cards are optional. The value N should follow the same approach as used in Cards CCCN101 through CCCN109. 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 through CCCN109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If these cards are being used for the CCFL model (i.e., f = 1 in Word 6 of Cards CCCN101 through CCCN109), 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 $4 \bullet \left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)^{0.5}$. If a zero is entered or if the default is used, the junction diameter is computed from $2 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$ of the respective junction. See Word 3 of Cards CCCN101 through CCCN109 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 0 and $\leq$ 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.

A7.7.13 Cards CCCN112, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Form Loss Data Card

These cards are optional. The user-specified form loss is given in Words 4 and 5 of Cards CCCN101 through CCCN109 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 through CCCN109. 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.

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

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

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

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

A7.7.14 Card CCCN113, Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Junction Face Placement Data

These cards are optional for the BRANCH, SEPARATR, JETMIXER, FWHTR, and ECCMIX components, and they are not allowed for a TURBINE component. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the “from” volume and entering the “to” volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates on the remaining two directions. Four words are entered on the card; two words for the coordinates for the “from” face, and two words for the two coordinates for the “to” face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0.

W1(R) First remaining coordinate value for the “from” face (dimensionless).

W2(R) Second remaining coordinate value for the “from” face (dimensionless).

W3(R) First remaining coordinate value for the “to” face (dimensionless).

W4(R) Second remaining coordinate value for the “to” face (dimensionless).

A7.7.15 Cards CCCN201, Branch, Separator, Jetmixer, Turbine, or ECC Mixer Junction Initial Conditions

These cards are required depending on the value of NJ as described for Cards CCCN101 through CCCN109. The values of N should follow the same approach as used in Cards CCCN101 through CCCN109. A 90% extraction limit during input processing is tested for the vapor at the vapor outlet junction and for the liquid at 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_m/s).

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

W3(R) Interface velocity (m/s, ft/s). Enter zero.

A7.7.16 Card CCC0300, Turbine/Shaft Geometry Card

This card is used only for TURBINE components.

W1(R) Turbine stage shaft speed, ω (rad/s, rev/min). This speed should equal the shaft speed used in the SHAFT component.

W2(R) Inertia of rotating stages in stage group, I_i. (kg· m^2, lb$_m$·ft^2).

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 zero, the turbine is always connected to the shaft. If nonzero, the turbine is connected to the shaft when the trip is false and disconnected when the trip is true.

W6(I) Drain flag. At the present time, this is not used and can be neglected or set to zero.

A7.7.16.1 Card CCC0302, Turbine/Shaft Variable Frictional Torque.

This card is used only for TURBINE components and is optional. If this card is not entered, the frictional torque equals $f_i\ \omega$, where f_i is obtained from Word 3 of Card CCC0300. If this card is entered, the frictional torque is computed from

$$\tau_{fr} = \pm\left(\tau_{fr0} + \tau_{fr1}\left|\frac{\omega}{\omega_R}\right| + \tau_{fr2}\left|\frac{\omega}{\omega_R}\right|^{x2} + \tau_{fr3}\left|\frac{\omega}{\omega_R}\right|^{x3} + f_i\omega\right)$$

where ω is the turbine speed and ω_R is the rated speed of the turbine and is obtained from Card CCC0400.

The turbine frictional torque is negative if, $\frac{\omega}{\omega_R} > 0$ and it is positive if $\frac{\omega}{\omega_R} < 0$. Fewer than seven words may be entered. Entering a total of one word, three words, five words, or seven words in allowed. Entering a total of two words, four words, or six words is not allowed. The default values are 0.0 for the coefficients.

W1(R) Constant frictional torque coefficient, τ_{fr0} (N-m, lb$_f$-ft).

W2(R) First frictional torque coefficient, τ_{fr1} (N-m, lb$_f$-ft).

W3(R) First exponent, x1. This is used on the speed ratio used with the frictional torque coefficient τ_{fr1}. If not entered, a default value of 1.0 is used.

W4(R) Second frictional torque coefficient, τ_{fr2} (N-m, lb$_f$-ft).

W5(R) Second exponent, x2. This is used on the speed ratio used with the frictional torque coefficient τ_{fr2}. If not entered, a default value of 2.0 is used.

W6(R) Third frictional torque coefficient, τ_{fr3} (N-m, lb$_f$-ft).

W7(R) Third exponent, x3. This is used on the speed ratio used with the frictional torque coefficient τ_{fr3}. If not entered, a default value of 3.0 is used.

A7.7.17 Card CCC0308, Turbine Variable Inertia

This card is used only for the TURBINE components and is optional. If this card is not entered, the moment of inertia of the turbine stage is constant and is given by Word 2 of Card CCC0300. If this card is entered, the moment of inertia, I_t, of the turbine is calculated as

$$I_t = I_{tn} \quad \text{for} \quad \left|\frac{\omega}{\omega_R}\right| < S_{TI}$$

$$I_t = I_{t0} + I_{t1}\left|\frac{\omega}{\omega_R}\right| + I_{t2}\left|\frac{\omega}{\omega_R}\right|^2 + I_{t3}\left|\frac{\omega}{\omega_R}\right|^3 \quad \text{for} \quad \left|\frac{\omega}{\omega_R}\right| \geq S_{TI}$$

where ω is the turbine speed, ω_R is the rated turbine speed and is obtained from Word 6 of Card CCC0400. Fewer than five words may be entered. The default values of the coefficients are 0.0.

W1(R) Turbine inertia critical speed ratio, S_{TI}. When the absolute value of the turbine speed ratio is greater than or equal to S_{TI}, the cubic expression for the inertia is used. When the absolute value of the turbine speed ratio is less than S_{TI}, the inertia (I_{tn}) from Word 2 of Card CCC0300 is used.

W2(R) Constant inertia coefficient, I_{t0} (kg-m^2, lb$_m$-ft^2).

W3(R) Linear inertia coefficient, I_{t1} (kg-m^2, lb$_m$-ft^2).

W4(R) Quadratic inertia coefficient, I_{t2} (kg-m^2, lb$_m$-ft^2).

W5(R) Cubic inertia coefficient, I_{t3} (kg-m^2, lb$_m$-ft^2).

A7.7.18 Cards CCCN901 through CCCN909, Separator Junction Maximum Volume Fractions

These cards are optional for the SEPARATR component, and they are not allowed for the BRANCH, JETMIXER, TURBINE, FWHTR, and ECCMIX components. The value N should follow the same approach as used for Cards CCCN101 through CCCN109. The defaults indicated for each word are used if no cards are entered.

W1(R) Enter 1.0. The default value is 1.0.

W2(R) Enter 1.0. The default value is 1.0.

W3(R) Maximum volume fraction. This entry is for the SEPARATR component. This is only used for the simple separator. For the output junction (N=1), this quantity (VGMAX) is the vapor/gas volume (void) fraction used when the vapor/gas volume (void) fraction in the separator exceeds VOVER (Cards CCC1101 through CCC1109, Word 7). For the liquid fallback junction (N=2), this quantity (VFMAX) is the liquid volume fraction used when the liquid volume fraction in the separator exceeds VUNDER (Cards CCC2101 through CCC2109, Word 7). This word is not used for the separator inlet junction (N=3).The default value is

1.0.

A7.7.19 Card CCC0400, Turbine Performance Data Card

This card is used only for TURBINE components.

W1(I) Turbine type.

0= Two-row impulse stage group.

1 = General impulse-reaction stage group.

2 = Constant efficiency stage group.

W2(R) Actual efficiency ho 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).

A7.7.20 Card CCC0500, GE Separator Data

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.

A7.7.21 Card CCC0501, GE Separator First Stage Data

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 bespectacled.

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 coefficient. Default = 450.0 for two-stage separator and 53.44 for three-stage separator.

A7.7.22 Card CCC0502, GE Separator Second Stage Data

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 and0.10794 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 coefficient. Default = 95.85 for two-stage separator and 194.64 for three-stage separator.

A7.7.23 Card CCC0503, GE Separator Third Stage Data

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 coefficient. Default = 424.96.

A7.7.24 Card CCC0600, GE Dryer Data

This card is optional for the GE dryer. 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% 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.

A7.7.25 Card CCC0701 Branch, Separator, Jetmixer, Turbine, Feedwater Heater, or ECC Mixer Volume Noncondensable Mass Fractions

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions for the noncondensable species entered on Card 110. The number of words should be the same as on Card 110. The noncondensable mass fractions must sum to one within a relative error of 1.0×10^{-10}.

A7.8 Valve Junction Component

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.

A7.8.1 Cards CCC0101 through CCC0109, Valve Junction Geometry Cards

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

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or expanded format can be used to connect volumes. In the old format, use CCC000000 if the connection is the inlet side of the component, and CCC010000 if the connection is the outlet side of the volume. 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 expanded format, only the number N equal to 1 or 2 is allowed.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). This quantity is the full open area of the valve except in the case of a relief valve. For valves other than relief valves, if this area is input as zero, the area is set to the minimum area of adjoining volumes. If nonzero, this area is used. For relief valves, this term is the valve inlet throat area. If this term is input as zero, it will default to the area calculated from the inlet diameter term input on Cards CCC0301 through CCC0309, in which case the inlet diameter term cannot be input as zero. If both this area and the inlet diameter are input as nonzero, this area will be used but must agree with the area calculated from the inlet diameter within 10^{-5} m^2. However, if this area is input as nonzero and the inlet diameter is input as zero, the inlet diameter will default to the diameter calculated from this area. When an abrupt area change model is specified, the area must be less than or equal to the minimum of the adjoining volume areas.

W4(R) 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 zero. A variable loss coefficient may be specified (see Section A7.8.3). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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 A7.8.3). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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

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.

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

The digit v 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; v = 2 means a downward-oriented junction; and v = 3 means a centrally (side) located junction.

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

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means full abrupt area change model (K_{loss}, area apportioning at branch, restricted junction area, and extra interphase drag), and a = 2 means a partial abrupt area change model (no K_{loss}, but includes area apportioning at branch, restricted junction area, and extra interphase drag). 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 must be input. For all other valves, one of the abrupt area change options must be input.

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.

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) Subcooled discharge coefficient. This quantity is applied only to subcooled choked flow calculations. The quantity must be > 0 and $\leq$ 2.0. If W7, W8, and W9 are missing, then W7, W8, and W9 are set to 1.0.

W8(R) Two-phase discharge coefficient. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 or $\leq$ 2.0. If W7 is entered, and W8 and W9 are missing, then W8 and W9 are set to 1.0

W9(R) Superheated discharge coefficient. This quantity is applied only to superheated choked flow calculations. The quantity must be > 0 and $\leq$ 2.0. If W7 and W8 are entered, and W9 is missing, then W9 is set to 1.0.

A7.8.2 Card CCC0110, Valve Junction Diameter and CCFL Data Card

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 through CCC0109), then the diameter should be entered in Word 1 and any allowable values should be entered in Words 2 through 4 (will not be used). If this card is being used for the CCFL model (i.e., f = 1 in Word 6 of Cards CCC0101 through CCC0109), then enter all four words for the appropriate CCFL model if values different from the default values are used.

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 $4 \bullet \frac{\text{junction area}}{\text{wetted perimeter}}$. If a zero is entered or if the default is used, the junction diameter is computed from $2 \bullet \left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 3 of Cards CCC0101 through CCC0109 for the junction area.

W2(R) Flooding correlation form, b. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 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 of f is 1.

W4(R) Slope, m. This is the slope used in the CCFL correlation and must be > 0. The default value is 1.

A7.8.3 Card CCC0111, Valve Junction Form Loss Data Card

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

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

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

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 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.

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

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

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

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

A7.8.4 Card CCC0113, Valve Junction Face Placement Data

This card is optional. It is used to improve the graphical display of the hydrodynamic nodes. It is used to resolve problems with converging and diverging flows, that is, multiple junctions attached to the same face of a volume. With the standard input, each junction attached to the same face of a volume would be superimposed on the graphical display since each junction would be attached to the center of the volume face. For junctions with this card, the point of leaving the "from" volume and entering the "to" volume is allowed to be other than the center of the faces. The volume face is perpendicular to one of the coordinate directions. The attachment position is given by specifying the coordinates on the remaining two directions. Four words are entered on the card; two words for the coordinates for the "from" face, and two words for the two coordinates for the "to" face. The coordinates are entered in the order x, then y, then z, skipping the coordinate direction perpendicular to the face. The values are dimensionless. The actual coordinates are given by these values times the position change in moving from the volume center to the face in that direction. A value of 0.0 means no change from the center of the volume in that direction, and 1.0 means move to the edge of the volume in that direction. Positive or negative numbers can be entered, and the sign indicates moving in the positive or negative direction along that coordinate. A value greater than 1.0 can be used to get separation; the maximum allowed value is 25.0. The default is 0.0.

W1(R) First remaining coordinate value for the "from" face (dimensionless).

W2(R) Second remaining coordinate value for the "from" face (dimensionless).

W3(R) First remaining coordinate value for the "to" face (dimensionless).

W4(R) Second remaining coordinate value for the "to" face (dimensionless).

A7.8.5 Card CCC0201, Valve Junction Initial Conditions

This card is required for valve junction components.

W1(I) Control word. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) Initial liquid velocity or initial liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lbm/s), depending on the control word.

W3(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lbm/s), depending on the control word.

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

A7.8.6 Card CCC0300, Valve Type Card

This card is required to specify the valve type.

W1(A) Valve type. This word must contain one of the following: CHKVLV for a check valve, TRPVLV for a trip valve, INRVLV for an inertial swing check valve, MTRVLV for a motor valve, SRVVLV for a servo valve, or RLFVLV for a relief valve.

A7.8.7 Cards CCC0301 through CCC0399, Valve Data and Initial Conditions

These cards are required for valve junction components. Six different types of valves are allowed.The following words may be placed on one or more cards, and the card numbers need not be consecutive.The card format of these cards depends on the valve type.

A7.8.7.1 Check Valve. This behaves as an on, off switch. If the valve is on, then it is fully open; and if the valve is off, it is fully closed.

W1(I) Check valve type. Enter +1 for a static pressure-controlled check valve (no hysteresis), 0 for a static pressure/flow-controlled check valve (has hysteresis effect), or -1 for a static/ dynamic pressure-controlled check valve (has hysteresis effect). 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 zero, closed if one.

W3(R) Closing back pressure (Pa, lb_f/in^2).

W4(R) Leak ratio. This is the fraction of the junction area for the leakage when the valve is nominally closed. If omitted or input as zero, then either the smooth or the abrupt area change model may be specified. If input as nonzero, then the abrupt area change model must be specified.

A7.8.7.2 Trip Valve. This behaves as an on, off switch as described for the check valve.

W1(I) Trip number. This must be a valid trip number. If the trip is false, the valve is closed; if the trip is true, the valve is open.

A7.8.7.3 Inertial Valve. This behaves realistically in that the valve area varies considering the hydrodynamic forces and the flapper inertia, momentum, and angular acceleration. The abrupt area change model must be specified.

W1(I) Latch option. The valve can open and close repeatedly if the latch option is zero. 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 = W2, 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 zero, initially closed if one.

W3(R) Closing back pressure (Pa, lb_f/in^2).

W4(R) Leakage fraction. Fraction of the junction area for leakage when the valve is nominally closed.

W5(R) Initial flapper angle (degrees). The flapper angle must be within the minimum and maximum angles specified in Words 6 and 7.

W6(R) Minimum flapper angle (degrees). This must be greater than or equal to zero.

W7(R) Maximum flapper angle (degrees). This must be greater than the minimum angle specified in Word 6.

W8(R) Moment of inertia of valve flapper ($kg \cdot m^2$, $lb_m \cdot ft^2$).

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_m).

A7.8.7.4 Motor Valve. This behaves realistically in that the valve area varies as a function of time by either of two models specified by the user. The user must also select the model for valve hydrodynamic losses by specifying either the smooth or the abrupt area change model. If the smooth area change model is selected, a table of flow coefficients must also be input as described in Cards CCC0400 through CCC0499, CSUBV Table Section A7.8.8. If the abrupt area change model is selected, a flow coefficient table cannot be input.

W1(I) Open trip number.

W2(I) Close trip number. Both the open and close trip numbers must be valid trips. When both trips are false, the valve remains at its current position. When one of the trips is true, the valve opens or closes depending on which trip is true. The transient will be terminated if both trips are true at the same time.

W3(R) Valve change rate (s^{-1}). If Word 5 is not entered, this quantity is the rate of change of the normalized valve area as the valve opens or closes. If Word 5 is entered, this quantity is the rate of change of the normalized valve stem position. This word must be greater than zero.

W4(R) Initial position. This number is the initial normalized valve area or the initial normalized stem position depending on Word 5. This quantity must be between 0.0 and 1.0.

W5(I) Valve table number. If this word is omitted or input as zero, the valve area is determined by the valve change rate and the trips. If this word is input as nonzero, the valve stem position is determined by the valve change rate and the trips; and the valve area is determined from a general table containing normalized valve area versus normalized stem position. Input for general tables is discussed in Cards 202TTTNN, General Table Data, Section A11. For this case, the normalized stem position is input as the argument value and the normalized valve area is input as the function value.

A7.8.7.5 Servo Valve. This behaves as described for a motor valve except that the valve flow area or stem position is calculated by a control system. Input for control systems is discussed in Section A14. 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.

A7.8.7.6 Relief Valve. The valve area varies considering the hydrodynamic forces and the valve mass, momentum, and acceleration. The abrupt area change model must be specified. The junction area input by Cards CCC0101 through CCC0199 is the valve inlet area.

W1(I) Valve initial condition. The valve is initially closed if zero, open if one.

W2(R) Inlet diameter (m, ft). This is the inside diameter of the valve inlet. If this term is input as zero, it will default to the diameter calculated from the junction area input on Cards CCC0101 through CCC0109. If both this diameter and the junction area are input as nonzero, care must be taken that these terms are input with enough significant digits so that the areas agree within 10^{-5} m^2. If the junction area is input as zero, then this diameter must be input as nonzero.

W3(R) Valve seat diameter (m, ft). Nonzero input is required. This term is the outside diameter of the valve seat, including the minimum diameter of the inner adjustment ring. This term must also be greater than or equal to the inlet diameter.

W4(R) Valve piston diameter (m, ft). If input as zero, the default is to the valve seat diameter.

W5(R) Valve lift (m, ft). Nonzero input is required. This is the distance the valve piston rises above the valve seat at the fully open position.

W6(R) Maximum outside diameter of the inner adjustment ring (m, ft). If this input is zero, it will default to the valve seat diameter; in which case W7, following, must be input as zero. If this input is nonzero, the value must be greater than or equal to the valve seat diameter. If input is greater than the valve seat diameter, a nonzero input of W7, 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 zero 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 zero, 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, zero, 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 zero, it will default to the valve piston diameter, resulting in a model not containing a bellows for which the valve bonnet region is vented to the atmosphere.

W11(R) Valve spring constant (N/m, lb_f/ft). Positive, nonzero input is required.

W12(R) Valve set point pressure (Pa, lb_f/in^2). Positive input is required.

W13(R) Valve piston, rod, spring, bellows mass (kg, lb_m). Nonzero input is required.

W14(R) Valve damping coefficient (N·s/m, $lb_f \cdot s/ft$).

W15(R) Bellows inside pressure (Pa, lb_f/in^2). Defaults to standard atmospheric pressure if omitted or input as zero.

W16(R) Initial stem position. This is the fraction of total lift and is required if W1 is input as one. Total lift is input as W5.

W17(R) Initial valve piston velocity (m/s, ft/s). This must be zero or omitted if W1 is input as zero.

A7.8.8 Cards CCC0400 through CCC0499, Valve CSUBV Table

The CSUBV table may be input only for motor and servo valves. If the CSUBV table is input, the smooth area change model must be specified on the valve junction geometry card (Cards CCC0101 through CCC0109). If the smooth area change model is specified, a CSUBV table must be input.

The CSUBV table contains forward and reverse flow coefficients as a function of normalized flow area or normalized stem position.

A7.8.8.1 Card CCC0400, Factors. This card is optional. The factors apply to the flow area or the stem position and the flow coefficient entries in the CSUBV table.

W1(R) Normalized flow area or normalized stem position.

W2(R) Flow coefficient factor.

A7.8.8.2 Cards CCC0401 through CCC0499, Table Entries.. The table is entered by using three-word sets. W1 is the flow area or stem position and must be normalized. The factor W1 on Card CCC0400 can be used to normalize the flow area or stem position. In either case, the implication is that if the valve is fully closed, the normalized term is zero. If the valve is fully open, the normalized term is one. Any value may be input that is between zero and one. The forward and reverse flow coefficients are W2 and W3, respectively. The code internally converts flow coefficients (CSUBV) to energy loss coefficients (K) by the formula,

$K = \dfrac{2CA_j^2}{\rho_o CSUBV^2}$ where ρ_o r is density of water at 60 ^oF (288.71 K), 14.7 lb_f/in^2 (1.0 x 10^5 Pa), C is $9.3409X10^8 \dfrac{\left(\frac{gal}{min}\right)^2 lb_m}{ft^7 \frac{lb_f}{in^2}}$, A_j is the full open valve area, and CSUBV is the flow coefficient. On Card CCC0400, W2 may be used to modify the definition of CSUBV. A smooth area change must be specified in W6 on Card CCC0101 to use the CSUBV table. CSUBV is entered in British units only.

W1(R) Normalized flow area or normalized stem position.

W2(R) Forward CSUBV $\{gal/[min \cdot (lb_f/in^2)^{0.5}]\}$. The CSUBV is input in British units only and is converted to SI units using 7.598055E-7 as the conversion factor.

W3(R) Reverse CSUBV $\{gal/[min \cdot (lb_f/in^2)^{0.5}]\}$.

A7.9 Pump Component

A pump component is indicated by PUMP on 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 CCC010000. The pump junctions are numbered CCC010000 for the inlet junction and CCC020000 for the outlet junction.

A7.9.1 Cards CCC0101 through CCC0107, Pump Volume Geometry Cards

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

W1(R) Volume flow area (m^2, ft^2).

W2(R) Length of volume (m, ft).

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length ($W3 = W1 \cdot W2$). At least two of the three quantities, W1, W2, W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.

W4(R) 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 volume length. If the inclination (vertical) angle orientation is zero, this quantity must be zero. If the inclination (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 volume 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 packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler 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 scaler 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.

The digit t is not used and must be input as zero (t = 0). Thermal stratification is not used in a pump component.

The digit l is not used and must be entered as zero (l = 0). Level tracking is not used in a pump component.

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

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

The digit b is not used and should be input as 0 (b = 0). The major edit will show b = 0. The rod bundle interphase friction is not used.

The digit f that normally specifies whether wall friction is to be computed is not used and a 0 must be entered. No wall friction is computed for a pump, since it is included in the homologous pump data. The major edit output will show f = 1, which indicates that no friction flag is set.

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.

A7.9.2 Card CCC0108, Pump Inlet (Suction) Junction Card

This card is required for a pump component.

W1(I) Volume code of connecting volume on inlet side. This refers to the component from which the junction coordinate direction originates. An old or expanded format can be used to connect volumes. In the old format, use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the volume. In the 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 expanded format, only the number N equal to 1 or 2 is allowed. With the old format, connections are possible only to the inlet or crossflow faces of the first pipe volume or to the outlet or crossflow faces of the last pipe volume. With the expanded format, connections can be made to any face of any pipe volume. Output edits use the expanded format regardless of the input format.

W2(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum of the volume areas of adjacent volumes. If an abrupt area change, the area must be equal to or less than the minimum of the adjacent volume areas. If a smooth area change, no restrictions exist. Note: a variable loss coefficient may be specified. See Section A7.9.6.

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 zero. A variable loss coefficient may be specified (see Section A7.9.6). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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 Card 103, Restart-Plot Input File Control Card on page 13,Card 103, Restart-Plot Input File Control Card on page 13, Card 103, Restart-Plot Input File Control Card on page 13,). The interpretation and use of the coefficient depends on whether the smooth or abrupt are change option is specified or grid spacers are modeled.

W5(I) Junction control flags. This word has the packed format efvcahs. It is not necessary to input leading zeros.

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 will not be applied, and f = 1 means that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0). The horizontal stratification entrainment/pullthrough model is not used.

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

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means full abrupt area change model (K_{loss}, area apportioning at branch, restricted junction area, and extra interphase drag), and a = 2 means a partial abrupt area change (no K_{loss}, 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; h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit printout will show a 1.

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

A7.9.3 Card CCC0109, Pump Outlet (Discharge) Junction Card

This card is required for a pump component. The format for this card is identical to Card CCC0108 except data are for the outlet junction.

A7.9.4 Card 103, Restart-Plot Input File Control Card on page 13, Card CCC0110, Pump Inlet (Suction) Junction Diameter and CCFL Data Card

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 through 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) 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 $4.0\left(\frac{\text{junction area}}{\text{wetted perimeter}}\right)$. If a zero is entered or the default is used, the junction diameter is computed from $2.0\left(\frac{\text{junction area}}{\pi}\right)^{0.5}$. See Word 2 of Card CCC0108 for the junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be ≥ 0 and ≤ 1. The default value is 0 (Wallis form).

W3(R) Gas intercept, c. This is the gas intercept used in the CCFL correlation (when $H_f^{1/2} = 0$) and must be > 0. The default value is 1.

W4(R) Slope, m. This is the slope used in the CCFL correlation and must be > 0. The default value is 1.

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A7.9.5 Card CCC0111, Pump Outlet (Discharge) Junction Diameter and CCFL Data Card

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 through 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.

A7.9.6 Card CCC0112, Pump Inlet (Suction) Junction Form Loss Data Card

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

$$K_f = A_f + B_f R_e^{-C_f}$$

$$K_r = A_r + B_r R_e^{-C_r}$$

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. R_e 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 zero.

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

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

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

A7.9.7 Card CCC0113, Pump Outlet (Discharge) Junction Form Loss Data Card

This card is optional. The user-specified form loss is given in Words 3 and 4 of Card CCC0109 is this card is not entered. If this card is entered, the form loss coefficient is calculated from

$$K_f = A_f + B_f R_e^{-C_f}$$

$$K_r = A_r + B_r R_e^{-C_r}$$

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. R_e 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. The format of this card is identical to Card CCC0112 except data are for the outlet junction.

A7.9.8 Card CCC0200, Pump Volume Initial Conditions

This card is required for a pump component.

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

The digit e specifies the fluid; e = 0 is the default fluid, e = 1 specifies H_2O and e = 2 specifies D_2O. 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 H_2O is assumed to be the fluid. The digit b specifies whether boron is present. b = 0 specifies that the volume fluid does not contain boron; 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. t = 0 through 3 specifies 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 the 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, 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.

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

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

If t = 3, the next two words are interpreted as pressure (Pa, lb_f/in^2) and temperature (K, ^oF) in equilibrium condition.

The following options are used for input of noncondensable states only. In all cases, the criteria used for determining the range of values for static quality are: 1.0E-9 $\leq$ static quality $\leq$ 0.99999999, two-phase conditions, and static quality < 1.0E-9 or static quality > 0.99999999, single-phase.

Noncondensable options are as follows:

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 $\leq$ 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.

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. Little experience has been obtained using this option, and it has not been checked out.

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. Depending on the control word, two through five 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.

A7.9.9 Card CCC0201, Pump Inlet (Suction) Junction Initial Conditions

This card is required for a pump component.

W1(I) Control word. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) Initial liquid velocity or mass flow. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s).

W3(R) Initial vapor velocity or mass flow. This quantity is either velocity (m/s, ft/s) or mass flow (kg/s, lb/s).

W4(R) Initial interface velocity (m/s, ft/s). Enter zero.

A7.9.10 Card CCC0202, Pump Outlet (Discharge) Junction Initial Conditions

This card is similar to Card CCC0201 except that data are for the outlet junction.

A7.9.11 Card CCC0300, Pump Volume Noncondensable Mass Fractions

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions of the noncondensable species entered on Card 110. The number of words on this card should be the same as on Card 110.The noncondensable mass fractions must sum to one within a relative error of $1.0x10^{-10}$

A7.9.12 Card CCC0301, Pump Index and Option Card

This card is required for a pump component.

W1(I) Pump table data indicator. If zero, single-phase homologous tables are entered with this component. A positive nonzero number indicates that the single-phase tables are to be obtained from the pump component with this number. If -1, use built-in data for the Bingham pump. If -2, use built-in data for the Westinghouse pump.

W2(I) Two-phase index. Enter -1 if the two-phase option is not to be used. Enter zero if the two-phase option is desired and two-phase multiplier tables are entered with this component. Enter nonzero if the two-phase option is desired and the two-phase multiplier table data are to be obtained from the pump component with the number entered. There are no built-in data for the two-phase multiplier table.

W3(I) Two-phase difference table index. Enter -3 if the two-phase difference table is not needed (i.e., if W2 is -1). Enter zero if a table is entered with this component. Enter a positive nonzero number if the table is to be obtained from pump component with this number. Enter -1 for built-in data for the Bingham pump. Enter -2 for built-in data for the Westinghouse pump.

W4(I) Pump motor torque table index. If -1, no table is used. If zero, a table is entered for this component. If nonzero, use the table from the component with this number.

W5(I) Time-dependent pump velocity index. If -1, no time-dependent pump rotational velocity table is used and the pump velocity is always determined by the torque-inertia equation. If zero, a table is entered with this component. If nonzero, the table from the pump component with this number is used. A pump velocity table cannot be used when the pump is connected to a shaft control component.

W6(I) Pump trip number. When the trip is off, electrical power is supplied to the pump motor; when the trip is on, electrical power is disconnected from the pump motor. The pump velocity depends on the pump velocity table and associated trip, the pump motor torque data, and this trip. If the pump velocity table is being used, the pump velocity is always computed from that table. If the pump velocity table is not being used, the pump velocity depends on the pump motor torque data and this trip. If the trip is off and no pump motor torque data are present, the pump velocity is the same as for the previous time step. This will be the initial pump velocity if the pump trip has never been set. Usually the pump trip is a latched trip, but that is not necessary. If the trip is off and a pump motor torque table is present, the pump velocity is given by the torque-inertia equation where the net torque is given by the pump motor torque data and the homologous torque data. If the trip is on, the torque-inertia equation is used and the pump motor torque is set to zero. If the pump trip number is zero, no trip is tested and the pump trip is assumed to always be off.

W7(I) Reverse indicator. If zero, no reverse is allowed; if one, reverse is allowed.

A7.9.13 Cards CCC0302 through CCC0304, Pump Description Card

This card (or cards) is required for a pump component.Words 1-12 must be entered. Words 13-17 are optional. Words 1, 9, 10, 11, 12, 13, 14, 15, 16, and 17 are used for the pump frictional torque (τ_{fr}, which is modeled as a constant or a four-term function of the pump rotational velocity and is given by

$$\text{for } \left|\frac{\omega}{\omega_R}\right| < S_{PF}$$

and

$$\tau_{fr} = \pm\left(\tau_{fr0} + \tau_{fr1}\left|\frac{\omega}{\omega_R}\right|^{x1} + \tau_{fr2}\left|\frac{\omega}{\omega_R}\right|^{x2} + \tau_{fr3}\left|\frac{\omega}{\omega_R}\right|^{x3}\right) \text{ for } \left|\frac{\omega}{\omega_R}\right| \geq S_{PF}$$

where ω is the pump rotational velocity; ω_R is the rated pump rotational velocity; and τ_{frn}, τ_{fr0}, τ_{fr1}, τ_{fr2}, τ_{fr3}, x1, x2, x3, and S_{PF} (pump friction critical speed ratio) are input data. The pump frictional torque is negative if $\frac{\omega}{\omega_R} > 0$, and it is positive if $\frac{\omega}{\omega_R} < 0$.

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 zero, 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 zero, the rated pump motor torque is computed from the initial pump velocity and the pump torque that is computed from the initial pump velocity, initial volume conditions, and the homologous curves. This quantity must be nonzero if the relative pump motor torque table is entered.

W9(R) TF2, friction torque coefficient (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.

W13(R) First exponent, x1. This is used on the speed ratio used with frictional torque coefficient τ_{fr1}. If zero or not entered, a default value of 1.0 is used.

W14(R) Second exponent, x2. This is used on the speed ratio used with frictional torque coefficient τ_{fr2}. If zero or not entered, a default value of 2.0 is used.

W15(R) Third exponent, x3. This is used on the speed ratio used with frictional torque coefficient τ_{fr3}. If zero or not entered, a default value of 3.0 is used.

W16(R Pump friction torque, τ_{frn}, to be used below the pump friction critical speed ratio (N·m, lb_f·ft). If not entered, a default value of τ_{fr0} is used.

W17(R) Pump friction critical speed ratio, S_{PF}. When the absolute value of the pump speed ratio is greater than or equal to S_{PF}, the four-term expression for frictional torque is used. When the absolute value of the pump speed ratio is less than S_{PF}, the frictional torque (τ_{frn}) from Word 16 is used.

A7.9.14 Card CCC0308, Pump Variable Inertia Card

Pump inertia is given by Word 6 of Card CCC0302 if this card is not entered. If this card is entered, pump inertia is computed from

$$I = I_3S^3 + I_2S^2 + I_1S + I_0$$

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).

A7.9.15 Card CCC0309, Pump-Shaft Connection Card

If this card is entered, the pump is connected to a SHAFT component. The pump may still be driven by a pump motor that can be described in this component, by a turbine also connected to the SHAFT component, or from torque computed by the control system and applied to the SHAFT component. The pump speed table may not be entered if this card is entered.

W1(I) Control component number of the shaft component.

W2(I) Pump disconnect trip. If this quantity is omitted or zero, the pump is always connected to the SHAFT. If nonzero, the pump is connected to the shaft when the trip is false and disconnected when the trip is true.

A7.9.16 Card CCC0310, Pump Stop Data Card

If this card is omitted, the pump will not be stopped by the program.

W1(R) Elapsed problem time for pump stop (s).

W2(R) Maximum forward velocity for pump stop (rad/s, rev/min).

W3(R) Maximum reverse velocity for pump stop (rad/s, rev/min). Reverse velocity is a negative number.

A7.9.17 Cards CCCXX00 through CCCXX99, Single-Phase Homologous Curves

These cards are needed only if W1 of Card CCC0301 is zero. 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 through CCC1199 for the first curve, CCC1200 through CCC1299 for the second curve, through CCC2600 to CCC2699 for the sixteenth curve. Data for each individual curve are input on up to 99 cards, which need not be numbered consecutively.

W1(I) Curve type Enter one for a head curve; enter two for a torque curve.

W2(I) Curve regime. 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 do not span the entire range of the independent variable, end point values are used for data outside the table. This usually leads to incorrect pump performance data. Thus entering data to cover the complete range is recommended.

W4(R) Dependent variable. The variable is h/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.

A7.9.18 Cards CCCXX00 through CCCXX99, Two-Phase Multiplier Tables

These cards are needed only if W2 of Card CCC0301 is zero; XX is 30 and 31 for the pump head multiplier table and the pump torque multiplier table, respectively.

W1(I) Extrapolation indicator. This is not used, enter zero.

W2(R) Void fraction.

W3(R) Head or torque difference multiplier depending on table type.

Additional pairs of data as needed are entered on this or additional cards as needed, up to a limit of 100 pairs. Void fractions must be in increasing order.

A7.9.19 Cards CCCXX00 through CCCXX99, Two-Phase Difference Tables

These cards are required only if W3 of Card CCC0301 is zero. The two-phase difference tables are homologous curves entered in a similar manner to the single-phase homologous data. Card numbering is CCC4100 through CCC4199 for the first curve, CCC4200 through CCC4299 for the second curve, through CCC5600 to CCC5699 for the 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.

A7.9.20 Cards CCC6001 through CCC6099, Relative Pump Motor Torque Data

These cards are required only if W4 of Card CCC0301 is zero. If the pump velocity table is not being used and these cards are present, the torque-inertia equation is used. When the electrical power is supplied to the pump motor (the pump trip is off), the net torque is computed from the rated pump motor torque times the relative pump motor torque from this table and the torque from the homologous data. If the electrical power is disconnected from the pump (the pump trip is on), the pump motor torque is zero.

W1(R) Pump velocity (rad/s, rev/min).

W2(R) Relative pump motor torque.

Additional pairs as needed are added on this or additional cards, up to a maximum of 100 pairs.

A7.9.21 Card CCC6100, Time-Dependent Pump Velocity Control Card

This card is required only if W5 of Card CCC0301 is zero. The velocity table, if present, has priority in setting the pump velocity over the pump trip, the pump motor torque data, and the torque-inertia equation.

W1(I) Trip number. If the trip number is zero, the pump velocity is always computed from this table. 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 zero if missing.

A7.9.22 Cards CCC6101 through CCC6199, Time-Dependent Pump Velocity

These cards are required only if W5 of Card CCC0301 is zero.

W1(R) Search variable. Units depend on the quantity selected for the search variable.

W2(R) Pump velocity (rad/s, rev/min).

Additional pairs as needed are added on this or additional cards, up to a maximum of 100 pairs. Time values must be in increasing order.

A7.10 Compressor Component

A compressor component is indicated by CPRSSR for Word 2 on Card CCC0000. A compressor consists of one volume and at least one junction, attached to the inlet end of the volume. Optionally, a junction can be attached to the outlet end of the volume. For major edits, minor edits, and plot variables, the volume in the compressor component is numbered as CCC010000. The compressor junctions are numbered CCC010000 for the inlet junction and CCC020000 for the outlet junction, if it is supplied with the component.

A7.10.1 Card CCC0001, Compressor Information

This card is required for a compressor component.

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 either 1 or 2. If nj = 1, then a junction is specified only at the compressor inlet. If nj = 2, then junctions are specified with the compressor component at both the inlet and the outlet. The outlet junction, if not specified with this component, can be either the inlet junction of another compressor component or a non-compressor junction.

A7.10.2 Cards CCC0101 through CCC0107, Compressor Volume Geometry

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

W1(R) Volume flow area ($m^{2,}$ ft^2).

W2(R) Length of volume (m, ft).

W3(R) Volume of volume (m^3, ft^3). The program requires that the volume equals the volume flow area times the length (W3 = W1•W2). At least two of the three quantities, W1, W2, W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. If none of the words are zero, the volume must equal the area times the length within a relative error of 0.000001.

W4(R) Azimuthal (horizontal) angle (degrees). The absolute value of this angle must be < 360 degrees and is defined as a positional quantity. This angle is in the horizontal x-y plane. The angle 0 degrees is on the x axis, and the angle 90 degrees is on the y axis. Positive angles are rotated from the x axis toward the y axis. This quantity is not used in the calculation but is specified for automated drawing of nodalization diagrams.

W5(R) Inclination (vertical) angle (degrees). The absolute value of this angle must be <90 degrees. The angle 0 degrees is horizontal; 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 and for automated drawing of nodalization diagrams. For this component, this angle is not used to decide if the horizontal or vertical flow regime is used. Rather, the high mixing flow regime map is used.

W6(R) Elevation change (m, ft). A positive value is an increase in elevation. The absolute value of this quantity must be equal to or less than the volume length. If the inclination (vertical) angle orientation is zero, this quantity must be zero. If the inclination (vertical) angle is nonzero, this quantity must also be nonzero and have the same sign. The elevation change is used in the gravity head and in checking loop closure. See Section of Volume II of the manual for further discussion. A calculated elevation angle is determined by the arcsin of the ratio of the elevation change (this word) and the volume length (Word 2). This calculated elevation angle is used in the additional stratified force term. For moving problems, see the discussion in W8. If W8 is 1 (default) or 2, this word is the position change in the fixed z direction as flow passes from the x inlet face to the x outlet face.

W7(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented lags. Only one value for a scaler 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 scaler oriented flags and the x-coordinate flag. The compressor component forces all volume flags except for the e digit, and y- and z-coordinate flags are not read. The effective format is 000000e.

The digit t is not used and must be input as zero (t = 0). Thermal stratification is not used in a compressor component.

The digit l is not used and must be entered as zero (l = 0). Level tracking is not used in a compressor component.

The digit p is not used and must be input as zero (p = 0). The major edit output will show p = 1. The water packing scheme is not used.

The digit v is not used and must be input as zero (v = 0). The major edit output will show v = 1. The vertical stratification model is not used.

The digit b is not used and must be input as zero (b = 0). The major edit will show b = 0. The rod bundle interphase friction is not used.

The digit f that normally specifies whether wall friction is to be computed is not used and a 0 must be entered. No wall friction is computed for a compressor, since it is included in the homologous compressor data. The major edit output will show f = 1, which indicates that the no friction flag is set.

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.

W8(I) Optional control word for elevation (or position) changes. This word is normally used only for moving problems. The elevation change in W6 is the change in the vertical direction as the flow passes from the x inlet face to the x outlet face. This is the only elevation change needed for the x coordinate for non-moving problems. For moving problems, position change information is needed in the other two horizontal directions. This control word may be 0, 1, or 2. If not entered, the default value is 1. If this word is entered as 0, the position changes for the x coordinate are computed from the x volume length (W2) and the azimuthal and inclination angles, and W6, W9, and W10 are not used. If this word is entered as 1, the position changes for the x coordinate are the elevation change (W6) for the change in the fixed z direction, from the x volume length (W2) and the azimuthal and inclination angles for the change in the fixed x and y directions, and W9 and W10 are not used. If this word is entered as 2, the position changes for the x coordinate are the elevation change (W6), W9, and W10.

W9(R) Position change in the fixed x direction as flow passes from the x inlet face to the x outlet face (m, ft). This quantity does not affect simulation results for non-moving problems. If not entered, the default value is 0.0.

W10(R) Position change in the fixed y direction as flow passes from the x inlet face to the x outlet face (m, ft). This quantity does not affect simulation results for non-moving problems. If not entered, the default value is 0.0.

A7.10.3 Card CCC0108, Compressor Inlet (Suction) Junction

This card is required for a compressor component.

W1(I) Volume code of connecting volume on inlet side. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format (only allowed for connection to 1-D components), 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 for 1-D components is CCCXX000F [where CCC is the component number, XX is the volume number (greater than 00 and less than 100) for 1-D pipes/annuli/pressurizers, XX is 01 for all other 1-D components, and F indicates the face number], and the connection code for 3-D components is CCCXYYZZF (where CCC is the component number, X is the first coordinate direction position number, YY is the second coordinate direction position number, ZZ is the third coordinate direction position number, and F indicates the face number). A nonzero F specifies the expanded format. The number F equal to 1 and 2 specifies the inlet and outlet faces for the first coordinate direction, which is a 1-D volume's coordinate direction (see Section 2.1 of Volume II of this manual). The number F equal to 3 through 6 specifies crossflow for 1-D volumes. The number F equal to 3 and 4 would specify inlet and outlet faces for the second coordinate direction; F 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 F equal to 1 or 2 is allowed. Section 4.4 in this Appendix discusses this further.

W2(R) Junction flow area (m^2, ft^2). If zero, the junction flow area is set to the minimum of the volume flow areas of adjoining volumes. For abrupt area changes, the junction flow area must be equal to or smaller than the minimum of the adjoining volume flow areas. For smooth area changes, there are no restrictions.

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 zero. A variable loss coefficient may be specified (see Section 7.9.6 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

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 7.9.6 of this Appendix). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled (see Section 2.4.1 of Volume II of this manual). This quantity must be greater than or equal to zero.

W5(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 = 1). 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 specifies that the CCFL model will not be applied, and f = 1 specifies that the CCFL model will be applied.

The digit v is not used and should be input as zero (v = 0). The stratification entrainment/pullthrough model is not used.

The digit c specifies choking options; c = 0 specifies that the standard choking model will be applied, c = 1 specifies that neither choking model will be applied, and c = 2 specifies that the modified Henry-Fauske choking model will be applied.

The digit a specifies area change options; a = 0 specifies either a smooth area change or no area change, a = 1 specifies full abrupt area change model (code-calculated K_{loss}, area apportioning at a branch, restricted junction area, and extra interphase drag), and a = 2 specifies a partial abrupt area change (no code-calculated K_{loss}, but includes area apportioning at a 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 one.

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

A7.10.4 Card CCC0109, Compressor Outlet (Discharge) Junction

This card is optional for a compressor component. The format for this card is identical to Card CCC0108 except data are for the outlet junction, if one is supplied with the component.

A7.10.5 Card CCC0110, Compressor Inlet (Suction) Junction Diameter and CCFL Data

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 through 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) Junction hydraulic diameter, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation, interphase drag, and form loss Reynolds number. This number must be > 0. This number should be computed from

$$4.0 \bullet \left(\frac{\text{Volume flow area}}{\text{Wetted perimeter}}\right).$$

.If a zero is entered or the default is used, the junction diameter is computed from

$$2.0 \bullet \left(\frac{\text{Volumes flow area}}{\pi}\right).$$ See Word 2 of Card CCC0108 for the junction area.

W2(R) Flooding correlation form, b. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be > 0 and < 1. The default value is 0 (Wallis form). See Section 3 of Volume I for details of the model.

W3(R) Vapor/gas intercept, c. This is the vapor/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.

A7.10.6 Card CCC0111, Compressor Outlet (Discharge) Junction Diameter and CCFL Data

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 through 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.

A7.10.7 Card CCC0112, Compressor Inlet (Suction) Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Card CCC0108 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

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

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

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC0108; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 of this card (CCC0112); and Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculations, then enter all four words for the appropriate expression.

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

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

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

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

A7.10.8 Card CCC0113, Compressor Outlet (Discharge) Junction Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Cards CCC0109 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

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

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

where K_F and K_R are the forward and reverse form loss coefficients; A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC0109; B_F, B_R, C_F, and C_R are Words 1, 2, 3, and 4 on this card (CCC0113); and Re is the Reynolds number based on mixture fluid properties. If these cards are being used for the form loss calculations, then enter all four words for the appropriate expression. The format for this card is identical to Card CCC0112 except data are for the outlet junction.

A7.10.9 Card CCC0200, Compressor Volume Initial Conditions

This card is required for a compressor component.

W1(I) Control word. This word has the packed format ε<u>bt</u>. It is not necessary to input leading zeros. The digit ε specifies the fluid, where $\varepsilon = 0$ is the default fluid. The value for $\varepsilon > 0$ corresponds to the position number of the fluid type indicated on the 120 - 129 cards (i.e., $\varepsilon = 1$ specifies H_2O, $\varepsilon = 2$ specifies D_2O, 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 $\varepsilon = 0$, then H_2O is assumed to be the fluid.

The digit b specifies whether boron is present or not. Entering 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 equal to 0 through 3 specifies one component (vapor/liquid). Entering t equal to 4, 5, 6, or 8 allows the specification of two components (vapor/liquid and noncondensable gas).

With options t equal to 4, 5, 6, or 8, the names of the components of the noncondensable gas must be entered on Card 110, and the mass fractions of the components of the noncondensable gas are entered on Card 115. Card CCC0300 may be used for the mass fractions of the components of the noncondensable gas.

If t = 0, the next four words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), and vapor/gas void fraction. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific 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, °F) 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, lb_f/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, lb_f/in^2) and temperature (K, °F) in nonequilibrium or equilibrium conditions depending on the pressure and temperature 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.

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

1. 1.0E-9 < static quality < 0.99999999, two phase conditions

2. static quality < 1.0E-9 or static quality > 0.99999999, single-phase conditions.

The static quality is given by $M_g/(M_g + M_f)$, where $M_g = M_s + M_n$. Section 3.2 of Volume I of the manual discusses this further.

Noncondensable options are as follows:

If $\underline{t}$ = 4, the next three words are interpreted as pressure (Pa, lb_f/in^2), temperature (K, °F), and static quality in equilibrium condition. Using this input option with static quality > 0.0 and < 1.0, saturated noncondensables (100% relative humidity) will result. The temperature is restricted to be less than the saturation temperature at the input pressure and less than the critical temperature; otherwise an input error will occur. Setting static quality to 0.0 is used as a flag that will initialize the volume to all noncondensables (dry noncondensable, 0% relative humidity) 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 $\underline{t}$ = 5, the next three words are interpreted as temperature (K, °F), 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. Little experience has been obtained using this option, and it has not been checked out. 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 $\underline{t}$ = 6, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid specific internal energy (J/kg, Btu/lb_m), vapor/gas specific internal energy (J/kg, Btu/lb_m), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the specific internal energies used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the 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/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas 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/gas 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.

If $\underline{t}$ = 8, the next five words are interpreted as pressure (Pa, lb_f/in^2), liquid temperature (K, °F), vapor/gas temperature (K, °F), vapor/gas void fraction, and noncondensable quality. These quantities will be interpreted as nonequilibrium or equilibrium conditions depending on the temperatures used to define the thermodynamic state. This option can be used to set the relative humidity to less than or equal to 100%. The combinations of vapor/gas void fraction and noncondensable quality must be thermodynamically consistent. If the noncondensable quality is set to 0.0, noncondensables are not present and the input processing branches to that type of processing. If noncondensables are present (noncondensable quality greater than 0.0), then the vapor/gas void fraction must also be greater than 0.0. If the noncondensable quality is set to 1.0 (pure noncondensable, 0% relative humidity), then the vapor/gas void fraction must also be 1.0. When both the vapor/gas void fraction and the noncondensable quality are set to 1.0, the volume specific internal energy is calculated from the noncondensable energy equation using the input vapor/gas temperature. 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.

W2-W7(R) Quantities as described under Word 1. Depending on the control word, two through five thermodynamic 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.

A7.10.10 Card CCC0201, Compressor Inlet (Suction) Junction Initial Conditions

This card is required for a compressor component.

W1(I) Control word. If zero, the next two words are velocities; if one, the next two words are mass flow rates.

W2(R) Initial liquid velocity or initial liquid mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W3(R) Initial vapor/gas velocity or initial vapor/gas mass flow rate. This quantity is either velocity (m/s, ft/s) or mass flow rate (kg/s, lb_m/s), depending on the control word.

W4(R) Initial interface velocity (m/s, ft/s). Enter zero.

A7.10.11 Card CCC0202, Compressor Outlet (Discharge) Junction Initial Conditions

This card is optional for the compressor component. This card is similar to Card CCC0201 except that data are for the outlet junction, if supplied with the compressor component.

A7.10.12 Card CCC0300, Compressor Volume Noncondensable Mass Fractions

This card is optional. If omitted, the noncondensable mass fractions are obtained from the noncondensable mass fractions entered on Card 115.

W1-WN(R) Mass fractions of the noncondensable species entered on Card 110. The number of words on this card should be the same as on Card 110. The noncondensable mass fractions must sum to one within a relative error of 1.0x10-10.

A7.10.13 Card CCC0301, Compressor Index and Option

This card is required for a compressor component.

W1(I) Compressor performance table data indicator. If zero, compressor performance data tables are entered with this component. A positive nonzero number indicates that the data tables are to be obtained from the compressor component with this number.

W2(I) Compressor motor torque table index. If -1, no compressor motor torque table is used. If zero, a compressor motor torque table is entered for this compressor component. If positive nonzero, use the motor torque table from the compressor component with this number.

W3(I) Time-dependent compressor rotational velocity index. If -1, no time-dependent compressor rotational velocity table is used and the compressor rotational velocity is always determined by the torque-inertia equation. If zero, a rotational velocity table is entered with this component. If positive nonzero, the rotational velocity table from the compressor component with this number is used. A compressor rotational velocity table cannot be used when the compressor is connected to a shaft control component.

W4(I) Compressor motor trip number. When the motor trip is off, electrical power is supplied to the compressor motor; when the motor trip is on, electrical power is disconnected from the compressor motor. If the compressor rotational velocity table is being used during a time step (i.e., a compressor rotational velocity table has be entered in the input deck, and the compressor rotational velocity table trip number is zero or the compressor rotational velocity table trip number is nonzero and the compressor rotational velocity table trip is on), the compressor rotational velocity is computed from the compressor rotational velocity table. If the compressor rotational velocity table is not being used during a time step (i.e., a compressor rotational velocity table has not been entered in the input deck or the compressor rotational velocity table has be entered in the input deck, the compressor rotational velocity table trip number is not zero, and the compressor rotational velocity table trip is off), the compressor rotational velocity depends on the compressor motor torque data and this trip. If the motor trip is off and no compressor motor torque data are present, the compressor rotational velocity is the same as for the previous time step. This will be the initial compressor rotational velocity if the compressor trip has never been set. Usually the compressor motor trip is a latched trip, but that is not necessary. If the motor trip is off and a compressor motor torque table is present, the compressor rotational velocity is given by the torque-inertia equation where the net torque is given by the compressor motor torque data, the hydraulic torque from the compressor performance tables, and the frictional torque data. If the compressor motor trip is on, the torque-inertia equation is used and the compressor motor torque is set to zero. If the compressor motor trip number is zero, no motor trip is tested and the compressor motor trip is assumed to be off.

W5(I) Reverse indicator. If zero, no reverse is allowed; if one, reverse is allowed.

A7.10.14 Cards CCC0302 through CCC0304, Compressor Description

This card (or cards) is required for a compressor component. Note that for the compressor component, rated values for pressure ratio and efficiency are not entered. The data for these quantities are entered directly on cards CCCXX00 through CCCXX99 (11 < XX.< 99).

W1(R) Rated compressor rotational velocity, ω_R (rad/s, rev/min).

W2(R) Ratio of initial compressor rotational velocity to rated compressor rotational velocity. Used for calculating initial compressor rotational velocity.

W3(R) Rated compressor mass flow, (kg/s, lb_m/sec).

W4(R) Rated stagnation sonic speed, a0,R (m/s, ft/s).

W5(R) Moment of inertia, I_{cn} (kg-m^2, lb_m-ft^2). This includes all direct coupled rotating components, including the motor for a motor driven compressor.

W6(R) Rated stagnation fluid density, $\rho_{0,R}$ (kg/m^3, lb_m/ft^3).

W7(R) Rated compressor motor torque (N·m, lb_f·ft). If this word is zero, the rated compressor motor torque is computed from the initial compressor velocity and the compressor torque that is computed from the initial compressor velocity, initial volume conditions, and the torque from the compressor performance data. This quantity must be nonzero if the relative compressor motor torque table is entered.

W8(R) t_{fr2}, friction torque coefficient (N·m, lb_f·ft). This parameter multiplies the absolute value of the speed ratio (compressor speed/rated compressor speed) to the second power. The friction torque factors are summed together.

W9(R) t_{fr0}, friction torque coefficient (N·m, lb_f·ft). This is constant frictional torque.

W10(R) t_{fr1}, friction torque coefficient (N·m, lb_f·ft). This multiplies the absolute value of the speed ratio to the first power.

W11(R) t_{fr3}, friction torque coefficient. (N·m, lb_f·ft). This multiplies the absolute value of the speed ratio to the third power.

A7.10.15 Card CCC0308, Compressor Variable Inertia

Compressor inertia is given by Word 5 of Card CCC0302-CCC0304 if this card is not entered. If this card is entered, the compressor inertia is computed from

$$I = I_{cn} \quad \text{for} \left|\frac{\omega}{\omega_R}\right| \quad \text{for} < S_{CI}$$

and

$$I = I_{c0} + I_{c1}\left|\frac{\omega}{\omega_R}\right| + I_{c2}\left|\frac{\omega}{\omega_R}\right|^2 + I_{c3}\left|\frac{\omega}{\omega_R}\right|^3 \quad \text{for} \left|\frac{\omega}{\omega_R}\right| > S_{CI}$$

where ω is the compressor speed and ω_R is the rated compressor speed from Word 1 of Cards CCC0302-CCC0304, and I_{cn} is from Word 5 of Cards CCC0302-CCC0304. If this card is entered, all five words must be input.

W1(R) Compressor inertial critical speed ratio, S_{CI}. When the absolute value of the compressor speed ratio is greater than or equal to S_{CI}, the cubic expression for inertial is used. When the absolute value of the compressor speed ratio is less than S_{CI}, the inertia (I_{cn}) from Word 5 of Card CCC0302-CCC0304 is used.

W2(R) Cubic inertial coefficient, I_{c3} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

W3(R) Quadratic inertial coefficient, I_{c2} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

W4(R) Linear inertial coefficient, I_{c1} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

W5(R) Constant inertial coefficient, I_{c0} ($kg{\cdot}m^2$, $lb_m{\cdot}ft^2$).

A7.10.16 Card CCC0309, Compressor-Shaft Connection

If this card is entered, the compressor is connected to a SHAFT component. The compressor may still be driven by a compressor 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 compressor speed table may not be entered if this card is entered.

W1(I) Control component number of the shaft component.

W2(I) Compressor-shaft disconnect trip. If this quantity is omitted or zero, the compressor is always connected to the SHAFT. If nonzero, the compressor is connected to the shaft when the trip is false and disconnected when the trip is true.

A7.10.17 Card CCC0310, Compressor Stop Data

If this card is omitted, the compressor will not be stopped by the program.

W1(R) Elapsed problem time for compressor stop (s).

W2(R) Maximum forward velocity for compressor stop (rad/s, rev/min).

W3(R) Maximum reverse velocity for compressor stop (rad/s, rev/min). Reverse velocity is a negative number.

A7.10.18 Card CCC0401 through CCC0499, Compressor Relative Motor Torque Data

These cards are required only if W2 of Card CCC0301 is zero. If the compressor 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 compressor motor (the compressor trip is off), the net torque is computed from the rated compressor motor torque times the compressor relative motor torque from this table and the torque from the compressor performance data. If the electrical power is disconnected from the compressor (the compressor trip is on), the compressor motor torque is zero.

W1(R) Compressor rotational velocity (rad/s, rev/min).

W2(R) Compressor relative motor torque.

Additional pairs as needed are added on this or additional cards, up to a limit of 100 pairs. Compressor velocities must be in increasing order.

A7.10.19 Card CCC0500, Compressor Time-Dependent Rotational Velocity Control

This card is required only if W3 of Card CCC0301 is zero. The compressor rotational velocity table, if present, has priority in setting the compressor rotational velocity over the compressor motor trip, the compressor motor torque data, and the torque-inertia equation.

W1(I) Rotational velocity table trip number. If the table trip number is zero, the compressor rotational velocity is always computed from this table, and the search argument is the advancement time. If the table trip number is nonzero, the state of the table trip determines when the table is to be used. If the table trip is off, the compressor rotational velocity is set from the state of the compressor motor trip (Word 4 on Card CCC0301), the compressor motor torque data, and the torque-inertia equation as if this table had not been entered. If the table trip is on, the compressor rotational velocity is computed from this table. If the table trip is on and Words 2 and 3 are not entered on this card, the search variable in the table is time, and the search argument is advancement time minus the table trip activation time. If this word is used, it takes precedence over the compressor motor trip number used in Word 4 of the CCC0301 card.

W2(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. TIME can be selected, but the trip activation time is not subtracted from the advancement time.

W3(I) Numeric part of variable request code. This is assumed to be zero if missing.

A7.10.20 Cards CCC0501-CCC0599, Compressor Time-Dependent Rotational Velocity Data

These cards are required only if W3 of Card CCC0301 is zero.

W1(I) Search variable. Units depend on the quantity selected for the search variable.

W2(A) Compressor rotational velocity (rad/s, rev/min).

Additional pairs as necessary are added on this or additional cards, up to a limit of 100 pairs. Search variable values must be in increasing order.

A7.10.21 Cards CCC0901-CCC0999, Compressor Relative Rotational Velocity Data

These cards are required for the compressor component. Pairs of numbers are entered. The first number of the pair is the rotational velocity relative to the rated rotational velocity specified in Word 1 of Card CCC0302. The second number is the number of triples of data (relative flow, pressure ratio, and efficiency) entered on Cards CCCXX00 through CCCXX99, which correspond to this relative rotational velocity entry.

W1(R) Relative rotational velocity.

W2(I) Number of data triples associated with this relative rotational velocity.

A7.10.22 Cards CCCXX00 through CCCXX99 (10 < XX < 99), Compressor Performance Data.

These cards are required for the compressor component, which contain the performance data corresponding to each value of relative rotational velocity entered on Cards CCC0901-CCC0999. The card numbering is CCC1000 through CCC1099 for the first data set, CCC1100 through CCC1199 for the second data set, up to a maximum of CCC9900 through CCC9999 for the 90th data set. The data are entered in triples, which correspond to relative corrected flowrate, pressure ratio, and efficiency.

W1(R) Relative corrected mass flowrate (kg/s, lb_m/s).

W2(R) Pressure ratio.

W3(R) Efficiency

A7.11 Multiple Junction Component

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 CCCIINN00, where NN is the set number and II is the junction number within the set. The quantity NN may be 01 through 99; II is 01 for the first junction described in a set and incremented by one for each additional junction ($01 \leq II \leq 99$).

A7.11.1 Card CCC0001, Multiple Junction Information Card

W1(I) Number of junctions, nj. This number must be > 0 and < 100.

W2(I) Initial condition control. This word is optional and, if missing, is assumed to be zero. If zero is entered, the initial conditions on Cards CCC1NNM are velocities; if one is entered, the initial conditions are mass flows.

A7.11.2 Cards CCC0NNM, Multiple Junction Geometry Card

Junctions are described by one or more sets of data; NN being the set number and M being the card number within a set. The junctions are numbered as CCCIINN00, where II is 01 for the first junction described in a set and increments by one for each additional junction. The quantity NN may be 01 through 99, and M may be 1 through 9. Cards are processed by increasing set number NN, and cards within a set by increasing M. Neither NN or M need be strictly consecutive.

W1(I) From connection code to a component. This refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format, use CCC000000 if the connection is to the inlet side of the component and use CCC010000 if the connection is to the outlet side of the volume. In the 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 expanded format, only the number N equal to 1 or 2 is allowed.

W2(I) To connection code to a component. This refers to the component at which the junction coordinate direction ends. See the description for W1 above.

W3(R) Junction area (m^2, ft^2). If zero, the area is set to the minimum volume area of the adjoining volumes. For abrupt area changes, the junction area must be equal to or smaller than the minimum of the adjoining volume areas. For smooth area changes, there are no restrictions.

W4(R) 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 zero. A variable loss coefficient may be specified (see Section A7.11.5). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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 A7.11.5). The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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

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.

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

The digit v is not used and should be input as zero (v = 0). The horizontal stratification entrainment/pullthrough model is not used.

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

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 means full abrupt area change model (K_{loss}, area apportioning at branch, restricted junction area, and extra interphase drag), and a = 2 means a partial abrupt area change (no K_{loss}, 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; h = 2 specifies the homogeneous (single-velocity momentum equation) option. For the homogeneous option (h = 2), the major edit printout will show h = 1.

The digit s specifies 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) Subcooled discharge coefficient. This quantity is applied only to subcooled liquid choked flow calculations. The quantity must be > 0 and $\leq$ 2.0.

W8(R) Two-phase discharge coefficient. This quantity is applied only to two-phase choked flow calculations. The quantity must be > 0 and $\leq$ 2.0.

W9(R) Superheated discharge coefficient. This quantity is applied only to superheated vapor choked flow calculations. The geometry must be > 0 and $\leq$ 2.0.

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 zero. Junctions are defined up to the limit in Word 13. Words 3 through 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 through 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 zero. This is reserved for future capability.

W13(I) Junction limit. Described above.

A7.11.3 Cards CCC1NNM, Multiple Junction Initial Condition Cards

Initial velocities are entered using one or more sets of data. The processing of sets of data is identical to that described in Section A7.9.2 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_m/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_m/s), depending on control Word 2 of Card CCC0001.

W3(I) Junction limit number.

A7.11.4 Cards CCC2NNM, Multiple Junction Diameter and CCFL Data Cards

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., 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 through 4 (will not be used). If this card is being used for the CCFL model (i.e., 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 A7.9.2 except that there need be no relationship in the division of junctions within sets between these cards (CCC1NNM) and the multiple junction geometry cards (CCC0NNM). Likewise, these cards do not affect the numbering of the junctions.

W1(R) Junction hydraulic diameter, D_j (m, ft). This is the junction hydraulic diameter used in the CCFL correlation equation and interphase drag and must be ≥ 0. This number should be computed from $4.0 \bullet \left(\frac{\text{Junction area}}{\text{Wetted Perimeter}}\right)$. If a zero is entered or if the default is used, the junction diameter is computed from $2.0 \bullet \left(\frac{\text{Junction area}}{\pi}\right)^{0.5}$. See Word 3 of Card CCC0NNMM for junction area.

W2(R) Flooding correlation form, β. If zero, the Wallis CCFL form is used. If one, the Kutateladze CCFL form is used. If between zero and one, Bankoff weighting between the Wallis and Kutateladze CCFL forms is used. This number must be $\geq$ 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) and must be > 0. The default value of f is 1.

W4(R) Slope, m. This is the slope used in the CCFL correlation and must be > 0. The default value is 1.

W5(I) Junction limit number.

A7.11.5 Card CCC3NNM, Multiple Junction Form Loss Data Card

This card is 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

$$K_f = A_f + B_f R_e^{-C_f}$$
$$K_r = A_r + B_r R_e^{-C_r}$$

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.

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

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

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

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

W5(I) Junction limit number.

A7.12 Accumulator Component

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 surgeline but may or may not occupy the tank. It is further assumed that the accumulator is not initially in the injection mode. Hence, the initial pressure must be input lower than the injection point pressure, including elevation head effects; and junction initial conditions may not be input (i.e., initial hydrodynamic velocities are set to zero in the code). It is further assumed that the noncondensable gas in the accumulator is nitrogen and that the gas and liquid are initially in equilibrium. No other junctions (except the accumulator junction) should be connected to the accumulator volume. The geometry of the tank may be cylindrical or spherical. The standpipe/surgeline inlet refers to the end of the pipe inside the tank itself.

A7.12.1 Cards CCC0101 through CCC0199, Accumulator Volume Geometry Cards

W1(R) Volume flow 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 of volume (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 of 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, volume flow area, and length are consistent. For a cylindrical tank, $W3 = W1 \cdot W2$, and at least two of the three quantities, W1, W2, or W3, must be nonzero. If one of the quantities is zero, it will be computed from the other two. For a spherical tank, W1 and W2 must be nonzero. If W3 is zero, it will be computed from the other two. If none of the words are zero, they must satisfy the consistency condition within a relative error ± 0.000001.

W4(R) Azimuthal angle (degrees). The absolute value of this angle must be ≤ 360 degrees. This quantity is not used in the calculation but is specified for possible automated drawing of nodalization diagrams.

W5(R) Inclination angle (degrees). Only +90 or -90 degrees is allowed. The accumulator is assumed to be a vertical tank with the standpipe/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 volume length, and have the same sign as the angle for vertical orientation. As with other components, this Word 6 is compared to the volume 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 $4.0 \bullet \left(\frac{\text{Junction area}}{\text{Wetted Perimeter}}\right)$. If zero, the hydraulic diameter of the tank is computed from $2.0 \bullet \left(\frac{\text{Junction area}}{\pi}\right)^{0.5}$ A check is made that the pipe roughness is less than half the hydraulic diameter of the tank.See Word 1 for the volume flow area.

W9(I) Volume control flags. This word has the packed format tlpvbfe. It is not necessary to input leading zeros. Volume flags consist of scaler oriented and coordinate direction oriented flags. Only one value for a scaler 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 scaler oriented flags and the x-coordinate flag. The accumulator component forces all volume flags except for the f digit and y- and z-coordinate flags are not read. The effective format is 00110f0 where 0 and 1 indicate fields as set by the accumulator component. The user must enter 0 in the digits marked with 0 and may enter 0 or 1 in the digits marked with 1.

The t flag is not used and must be input as zero (t = 0). The thermal stratification is not used for an accumulator component.

The l flag is not used and must be input as zero (l = 0). The level tracking model is not used for an accumulator component.

The flag p is not used and may be input as zero or one (p = 0 or 1). The water packing scheme is not used.

The flag v is not used and may be input as zero or one (v = 0 or 1). The major edit will show v = 1. The vertical stratification model is not used.

The flag b is not used and must be input as zero (b = 0). The rod bundle interphase friction model is not used.

The flag f specifies wall friction. Enter f = 0 if wall friction is to be computed, and enter f = 1 if wall friction is not to be computed.

The flag e must be specified zero, since only a nonequilibrium (unequal temperature) calculation is allowed.

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.

A7.12.2 Card CCC0131, Accumulator Additional Wall Friction

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 quantities must be entered on the card. A description of this input is presented in Section 3 of Volume I. The accumulator model automatically does not use the following words 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 words are then used as defined.

W1(R) Shape factor.

W2(R) Viscosity ratio exponent.

A7.12.3 Card CCC0141, Accumulator Alternate Turbulent Wall Friction

This card is optional. This card allows the specification of a user-defined turbulent friction factor. The turbulent friction factor has the form $f = A + B(Re)^{-C}$, where A, B, and C are entered for the accumulator volume. If this card is not entered, the standard turbulent friction factor is used. If the card is entered, the standard turbulent friction factor can be selected by entering zeros for the three quantities. Three quantities must be entered on the card. The accumulator model automatically does not use the following words 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 words are then used as defined.

W1(R) A.

W2(R) B.

W3(R) C.

A7.12.4 Card CCC0200, Accumulator Tank Initial Thermodynamics Conditions

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.

A7.12.5 Card CCC1101, Accumulator Junction Geometry Card

W1(I) To connection code to a component. The from connection is not entered, since it is always from the accumulator. The to connection code refers to the component from which the junction coordinate direction originates. An old or an expanded format can be used to connect volumes. In the old format, use CCC000000 if the connection is to the inlet side· of the component and use CCC010000 if the connection is to the outlet side of the volume. In the 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. For connecting to a time-dependent volume using the expanded format, only the number N equal to 1 or 2 is allowed.

W2(R) Junction area (m^2, ft^2). 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 zero. The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

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. The interpretation and use of the coefficient depends on whether the smooth or abrupt area change option is specified or grid spacers are modeled.

W5(I) Junction control flags. This word has the packed format efvcahs. It is not necessary to input leading zeros.

The accumulator model automatically disables the following terms as long as liquid remains in the accumulator. However, when the accumulator empties of liquid, the model is automatically converted to an active normal volume. The following terms are then enabled and used as defined.

The digit e is not used and should be input as zero (e = 0). The modified energy model is not used.

The digit f is not used and should be input as zero (f = 0). The major edit output will show f = 0. The CCFL model is not used.

The digit v is not used and should be input as zero (v = 0). The horizontal stratification entrainment/pullthrough model is not used.

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

The digit a specifies area change options. a = 0 means either a smooth area change or no area change, and a = 1 and a = 2 are not allowed for an accumulator.

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

The digit s specifies 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.

A7.12.6 Card CCC1102, Accumulator Form Loss Data

This card is optional. The user-specified form loss coefficients are given in Words 3 and 4 of Card CCC1101 if this card is not entered. If this card is entered, the form loss coefficients depend on the flow conditions and are calculated from

$$K_f = A_f + B_f Re^{-C_{Ff}}$$

$$K_r = A_r + B_r Re^{-C_{Rf}}$$

where K_F and K_R are the forward and reverse loss coefficients: A_F, A_R, B_F, B_R, C_F, and C_R are user-specified constants. A_F and A_R are Words 3 and 4 of Card CCC1101, B_F, B_R, C_F, C_R are Words 1, 2, 3, and 4 of this card (CCC1102): and Re is the Reynolds number based on mixture fluid properties. If this card is being used for the form loss calculations, then enter all four words for the appropriate expression. The accumulator model automatically does not use the following words 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 words are then used as defined.

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

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

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

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

A7.12.7 Card CCC2200, Accumulator Tank Initial Fill Conditions, Standpipe/Surgeline Length/Elevation, and Tank Wall Heat Transfer Terms

W1(R) Liquid volume in tank (m^3, ft^3). This is the volume of water contained in the tank above the standpipe/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 zero, it is computed from the other two.

W3(R) Length of surgeline and standpipe (m, ft). If input as zero, 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 zero.

W6(I) Heat transfer flag. If zero, heat transfer will be calculated. If one, no heat transfer will be calculated.

W7(R) Tank density (kg/m^3, lb_m/ft^3). If zero, the density will default to that for carbon steel.

W8(R) Tank volumetric heat capacity (J/kg·K, Btu/lb_m· ^{o}F). If zero, the heat capacity will default to that for carbon steel.

W9(I) Trip number. If zero or if no number is input, then no trip test is performed. If nonzero then this must be a valid trip number, the operations performed are similar to those performed for a trip valve. If the trip is false, then the accumulator is isolated and no flow through the junction can occur. If the trip is true, then the accumulator is not isolated and flow through the junction will occur in the normal manner for an accumulator.

A8. CARDS 1CCCGXNN, HEAT STRUCTURE INPUT

These cards are used in NEW and RESTART type problems and are required only if heat structures are described. The heat structure card numbers are divided into fields where: CCC is a heat structure number. The heat structure numbers need not be consecutive. 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.

A8.1 Card 1CCCG000, General Heat Structure Data

This card is required for heat structures. Use eight words for new data input or one word for deleting a heat structure.

A8.1.1 General Heat Structure Data Card

W1(I) Number of axial heat structures with this geometry, nh. This number must be > 0 and < 100. radial

W2(I) Number of axial 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 zero if the desired initial condition temperatures are entered on input cards 1CCCG401 through 1CCCG499; use one if a steady-state initial condition temperatures are to be calculated by the code. If option one is chosen, the user is still required to enter temperatures on cards 1CCCG402 through 1CCCG499. 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 zero, no reflood calculation is to be performed. If nonzero, all the heat structures in this heat structure/geometry are assumed to form a two-dimensional representation of a fuel pin. The radial mesh is defined on Card 1CCCG1NN. Each heat structure represents an axial level of the fuel pin, with the first heat structure being the bottom level. Each heat structure should be connected to a hydrodynamic volume representing the same axial section of the coolant channel. The length of the axial mesh in the fuel pin is given by the height of the connected hydrodynamic volume. If the heat structure is fuel pins or heat exchange tubes, the length factor (Word 5 on Cards 1CCCG501 through 1CCCG509) 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*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 zero or one to indicate that reflood heat transfer applies to the left or right boundary, respectively.

W8(I) Maximum number of axial intervals. Enter 2, 4, 8, 16, 32, 64, or 128 to indicate the maximum number of axial subdivisions a heat structure can have. Storage is allocated for the number indicated, even though a transient may not require that level of subdivision.

A8.1.2 Heat Structure Delete Card

This card is entered only for RESTART problems. If entered, all heat structures associated with the heat structure geometry number CCCG are deleted.

W1(A) Enter DELETE.

A8.2 Card 1CCCG001, Gap Conductance Model Initial Gap Pressure Data

This card is needed only if the gap conductance model is to be used. If the card is entered, W1 of Card 1CCCG100 must be zero, Cards 1CCCG011 through 1CCCG099, and Cards 1CCCG201 through 1CCCG299 are required. W2 of Card 201MMM00 must be 3, and a table of the gas component name and mole fraction must be specified in the gap material data (Cards 201MMM01 through 201MMM49).

W1(R) Initial gap internal pressure (Pa, lb_f/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(O)/T(O)*T(t), where P(t) is the pressure in the fuel pin and T(t) is the temperature in the reference volume. P(O) is W1 above, and T(O) is the initial value if the volume is also being defined with these input data or the value from the restart block. The reference volume is usually the volume most closely associated with the nonfuel region in a fuel pin at the top of a stack of fuel pellets.

A8.3 Card 1CCCG003, Metal-Water Reaction Control Card

CCCG is a heat structure geometry number. If this card is not present, no metal-water reaction will be calculated. The initial oxide thickness is assumed to be zero on the inner surface. It remains zero unless cladding rupture occurs.

W1(R) Initial oxide thickness on cladding's outer surface.

A8.4 Card 1CCCG004, Fuel Cladding Deformation Model Control Card

CCCG is a heat structure geometry number. If this card is not present, no deformation calculations will be done. If this card is present, then Card 1CCCG001 must also be present.

W1(I) Form loss factor flag. Enter 0 if no additional form loss factors are to be calculated after a rod ruptures. Enter 1 if additional form loss factors are to be calculated. Either a 0 or a 1 must be entered.

A8.5 Cards 1CCCG011 through 1CCCG099, Gap Deformation Data

These cards are required for the gap conductance model only. The card format is sequential format, five words per set, describing nh heat structures.

W1(R) Fuel surface roughness (m, ft). This number must be ≥ 0. An appropriate value is 10^{-6} m. A negative entry is reset to 10^{-6} m with no errors.

W2(R) Cladding surface roughness (m, ft). This number must be either positive or zero. An appropriate value is 2 x 10^{-6} m. A negative entry is reset to 2 x 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 zero. 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 zero. An appropriate value can be obtained from calculations using FRAPCON-2 or FRAP-T6.

W5(I) Heat structure number.

A8.6 Card 1CCCG100, Heat Structure Mesh Flags

This card is required for heat structure input.

W1(I) Mesh location flag. If zero, geometry data including mesh interval data, composition data, and source distribution data, are entered with this heat structure input. If nonzero, that information is taken from the geometry data from the heat structure geometry (CCCG) number in this word. If this word is nonzero, the remaining geometry information described in Section A8.7 through Section A8.10 is not entered.

W2(I) Mesh format flag. This word is needed only if Word 1 is zero, 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 through 1CCCG199. If this word is 1 (format 1 on Cards 1CCCG101 through 1CCCG199), 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 through 1CCCG199), the format is a sequential expansion of mesh intervals; i.e., the distance in Word 1 on Cards 1CCCG101 through 1CCCG199 is used for each interval starting from the left most, as yet unspecified, interval to and including the interval number specified in Word 2.

A8.7 Cards 1CCCG101 through 1CCCG199, Heat Structure Mesh Interval Data (Radial)

These cards are required if Word 1 of Card 1CCCG100 is zero. In Format 1, the sum of the numbers of intervals must be np-1. In Format 2, the sequential expansion must be for np-1 intervals. The card numbers need not be sequential.

A8.7.1 Format 1

W1(I) Number of intervals. Enter the number of intervals, not the interval number.

W2(R) Right coordinate (m, ft).

A8.7.2 Format 2

W1(R) Mesh interval (m, ft.).

W2(I) Interval number.

A8.8 Cards 1CCCG201 through 1CCCG299, Heat Structure Composition Data (Radial)

These cards are required if Word 1 of Card 1CCCG100 is zero and must not be entered otherwise.The card format is two numbers per set in sequential expansion format for np-1 intervals. The card numbers need not be in sequential order.

W1(I) Composition number. The absolute value of this quantity is the composition number, and it must be identical to the subfield MMM used in Heat Structure Thermal Property Data, Section A-10. The sign indicates whether the region over which this composition is applied is to be included or excluded from the volume averaged temperature computation. If positive, the region is included; if negative, the region is not included. The option to exclude regions from the volume averaged temperature integration is to limit the integration to fuel regions only for use in reactivity feedback calculations. Gap and cladding regions should not be included in this case. If the gap conductance model is used, only one interval can be used for the gap model.

W2(I) Interval number.

A8.9 Card 1CCCG300, Fission Product Decay Heat Flag

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.

A8.10 Cards 1CCCG301 through 1CCCG399, Heat Structure Source Distribution Data (Radial)

These cards are required if Word 1 of Card 1CCCG100 is zero and must not be entered otherwise. The card format is two numbers per set in sequential expansion format for np-1 intervals. The card numbers need not be in sequential order. 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 the 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.

A8.11 Card 1CCCG400, Initial Temperature Flag

This card is optional; if missing, Word 1 is assumed to be zero.

W1(I) Initial temperature flag. If this word is zero or -1, initial temperatures are entered with the input data for this heat structure geometry. If greater than zero, initial temperatures for this heat structure geometry are taken from the heat structure geometry number in this word.

A8.12 Cards 1CCCG401 through 1CCCG499, Initial Temperature Data

These cards are required if Word 1 on Card 1CCCG400 is zero or -1.

A8.12.1 Format 1 (Word 1 on Card 1CCCG400 = 0)

If Word 1 is zero, one temperature distribution is entered, and the same distribution is applied to all of the nh heat structures. The card format is two numbers per set in sequential expansion format for np mesh points.

W1(R) Temperature (K, ^{o}F).

W2(I) Mesh point number.

A8.12.2 Format 2 (Word 1 on Card 1CCCG400 = -1)

If W1 of Card 1CCCG400 is -1, a separate temperature distribution must be entered for each of the nh heat structures. The distribution for the first heat structure is entered on Card 1CCCG401, the distribution for the second heat structure is entered on Card 1CCCG402, and the remaining distributions are entered on consecutive card numbers. Continuation cards can be used if the data do not fit on one card.

W1-WNP(R) Temperature (K, ^{o}F). Enter the np mesh point temperatures in order from left to right.

A8.13 Cards 1CCCG501 through 1CCCG599, Left Boundary Condition Cards

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 zero, no volume or general table is associated with the left surface of this heat structure, and a symmetry or insulated boundary condition is used (i.e., a zero temperature gradient at the boundary), or a temperature of zero is used for a surface temperature or a sink temperature in boundary conditions. A boundary volume number is entered as a positive number. 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. These numbers define the flow direction parallel with tube bundles. Any flow in other directions is vectorally added to give the crossflow mass flux. Specifying a volume coordinate not in use is an input error. A general table is entered as a negative number (-1 through -999).

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 is (normally 10,000) 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 zero or nonzero, positive or negative. If Word 1 i zero, this word should be zero.

W3(I) Boundary condition type.

If 0, a symmetry or insulated boundary condition is used (i.e., a zero 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 5. 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 5. 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 5: Card 501and 601 Word 3 convection boundary

Word 3	**Geometry Type**
1, 100, 101	Default
110	Vertical bundle without crossflow (set P/D on 801/901 card)
111	Vertical bundle with crossflow (set P/D on 801/901 card)
130	Flat plate above fluid
134	Horizontal bundle

If 1,000, 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 zero, the surface temperature is set to zero.

If 1xxx, the temperature in general Table xxx is used as the left surface temperature.

If 2xxx, the heat flux from Table xxx is used as the left boundary condition.

If 3xxx, a convective boundary condition is used where the heat transfer coefficient as a function of time is obtained from general Table xxx. The sink temperature is the temperature of the boundary volume or from the table specified in Word 1. If Word 1 is zero, the sink temperature is set to zero.

If 4xxx, a convective boundary condition is used where the heat transfer coefficient as a function of surface temperature is obtained from general Table xxx. The sink temperature is the temperature of the boundary volume or from the table specified in Word 1. If Word 1 is zero, the sink temperature is set to zero. If reflood is specified, the left boundary condition type must be the same for all nh heat structures and, similarly, for the right boundary condition type. The left and right boundary types need not be the same, but neither can be 1,000 or 1xxx.

W4(I) Surface area code. If zero, Word 5 is the left surface area. If one, 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.

A8.14 Cards 1CCCG601 through 1CCCG699, Right Boundary Condition Cards

These cards are required. These cards are the same as Cards 1CCCG501 through 1CCCG599, except for the right boundary. The left and right surface areas must be compatible with the geometry.

A8.15 Cards 1CCCG701 through 1CCCG799, Source Data Cards

These cards are required for heat structure data. The card format is sequential expansion format, five words per set, describing nh heat structures.

W1(I) Source type. If zero, no source is used. If a positive number is less than 1,000, power from the general table with this number is used as the source. If 100,000 through 1999949, the number has the form 1zzzzt and the source is taken from a reactor kinetics calculation. The field zzzz must be 0000 for point reactor kinetics and is the zone number for nodal reactor kinetics. The zone number specified must be in use in the nodal kinetics model. The field t = 0 specifies total reactor power, t = 1 specifies total decay power, t = 2 specifies fission power, t = 3 specifies fission product decay power, and t = 4 specifies actinide decay power. If 10,001 through 19999, the source is the control variable whose number is this quantity minus 10000.

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.

W5(I) Heat structure number.

A8.16 Card 1CCCG800, Additional Left Boundary Option

W1(I) If this card is not entered or if this word is zero, the nine-word format is used on Cards 1CCCG801 through 1CCCG899. If this word is one, the twelve-word format is used on the cards. If this word is two, the thirteen-word format is used on the cards (needed for PG-CHF correlation).

A8.17 Cards 1CCCG801 through 1CCCG899, Additional Left Boundary Cards

These cards are required whenever the left boundary communicates energy with the left hand fluid volume. The cards are in sequential expansion format, nine 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 through 8 are used for the CHF correlation.

Nine-word format:

W1(R) Heat transfer hydraulic diameter (i.e., heated equivalent diameter) (m, ft). This is $4.0 \bullet \frac{\text{flow area}}{\text{heated perimeter}}$ 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 zero. 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 zero. 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 zero, 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 effect of a grid spacer in rod bundles. This is used only for the CHF correlation. If the grid K_{loss} (Word 7) is zero, 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 zero. This is used only for the 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 calculation.

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 zero). This is the local heat flux/average heat flux from start of boiling. If the power profile is not flat, a steady-state run may help determine this number. This number must be greater than 0.0.

W9(R) Heat structure number.

Twelve-word format (Word 1 = 1 on Card 1CCCG800). The first eight words of this format are identical to the nine-word format.

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. It is not used unless Word 3 on the 501 card is 110 or 111.

W11(R) Fouling factor. This factor is applied to the heat transfer correlations and may be used to represent fouling or to sun 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.

Thirteen-word format (Word 1 = 2 on Card 1CCCG800). Set Word 1 = 0. Words 9, 10, and 11 of this format are identical to the twelve-word format.

W2(R) Reduced heated length forward (m, ft). This is the product (y * 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 zero. 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:

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$$y \bullet T_a = \frac{1}{q(y)}\int_0^y q(z)dz$$

W3(R) Reduced heated length reverse (m, ft). This is the product (y * 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 vaneless grid spacers, then Word 4 must be input as W4 = 1.0. Either as W4 = $\frac{1}{\bar{R}}$, if the statistical evaluation data for the rod bundle are available ($\bar{R}$ 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 4 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 must be input either as W5 = $\frac{1}{\bar{R}}$ if the statistical evaluation data for the rod bundle are available ($\bar{R}$ 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:

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$$T_r = q\frac{\sum_i r_i}{\sum_i r_i q_i}$$

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 component which represents the outlet for the heated channel. It applies when the flow reverses.

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 the 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.

A8.18 Card 1CCCG900, Additional Right Boundary Option

This card is the same as Card 1CCCG800 but applies to the right boundary.

A8.19 Cards 1CCCG901 through 1CCCG999, Additional Right Boundary Cards

These cards are the same as Cards 1CCCG801 through 1CCCG899 but apply to the right boundary.

A9. CARD 60000000, RADIATION MODEL CONTROL CARD

Any heat structure may radiate to any other heat structure or set of heat structures in a user-defined enclosure. An enclosure is a set of heat structures that communicate via thermal radiation. The calculation ignores fluid in the enclosure.

This card is required.

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.

A9.1 Card 6SS00000, Radiation Set Card

SS is the set number. One of these cards must be input for each radiating set. The first word is required, the other three are optional.

W1(I) Number of radiating heat slabs, nrh. This word is the number of radiating heat slabs (surfaces) that participate in radiation heat transfer in set SS. The maximum is 99.

W2(R) Minimum temperature, trmin (K, ^{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 (1,160.33 ^{o}F).

W3(R) Minimum void fraction, voidmm. This word is the minimum void fraction below which radiation will no longer be calculated. The default value is 0.75. Each volume connected to any of the radiating surfaces in the set is checked and if any have a void fraction greater than Word 3, radiation stays on in the enclosure set.

W4(I) View factor set, refset. If input, this is the number of the set (SS) from which view factors are to be obtained. If no number is found here, the view factors must be input for this set.

A9.2 Cards 6SSNN001 through 6SSNN099, Radiation Heat Structure Data

For these cards, SS must take on every value from 1 to nset (Word 1 in Card 60000000) and NN must take on every value from 1 to nrh (Word 1 on Card 6ss00000) 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.

A9.3 Cards 6SSNN101 through 6SNN199, Radiation View Factors

There are nrh-nrh values in each set. SS is the set number (from 1 to net). 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 Word 2.

W2(I) Radiation surface number to which NN radiates. Repeat the above two words until view factors to all nhr surfaces from all surfaces are entered. Sequential expansion is used.

A10. CARDS 201MMMNN, HEAT STRUCTURE THERMAL PROPERTY DATA

These cards are used in NEW or RESTART problems. These cards are required if Cards 1CCCGXNN, Heat Structure Input Cards, Section A8., 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 through 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.

A10.1 Card 201MMM00, Composition Type and Data Format

This card is required.

W1(A) Material type. Thermal properties for four materials are stored within the program: carbon steel (C-STEEL), stainless steel (S-STEEL), uranium dioxide (UO_2), and zirconium (Zr). These properties are selected by entering the name in parentheses for this word. If a user-supplied table or function is to be used, enter TBL/FCTN for this word. At present, the data are primarily to demonstrate capability. The user should check whether the data are satisfactory. The word DELETE may be entered in RESTART problems to delete a composition.

The next two words are required only if TBL/FCTN is entered for Word 1.

W2(I) Thermal conductivity format flag or gap mole fraction flag. Enter 1 if a table containing temperature and thermal conductivity is to be entered; enter 2 if functions are to be entered. Enter 3 if the gap conductance model is used, and thus a table containing gas component names and mole fractions is to be entered.

W3(I) Volumetric heat capacity flag. Enter 1 if a table containing temperature and volumetric heat capacity is to be entered; enter -1 if a table containing only volumetric heat capacities is to be entered and the temperature values are identical to the thermal conductivity table; enter 2 if functions are to be entered.

A10.2 Cards 201MMM01 through 201MMM49, Thermal Conductivity Data or Gap Mole Fraction Data

These cards are required if W1 of Card 201MMM00 contains TBL/FCTN. For a table, enter pairs of temperatures and thermal conductivities or pairs of gas component names and mole fractions according to the specification of Word 2 of Card 201MMM00. One to 7 pairs of gas names and their mole fractions can be entered. The gas component names that may be entered are: helium, argon, krypton, xenon, nitrogen, hydrogen, and oxygen. No particular order of the pairs is required. Do not enter any gas component with a zero mole fraction. Normalization of the total mole fraction to one is performed if the sum of the mole fractions entered is not one. The table of gas composition data is applicable to any gap and is required if Card 1CCCG001 is present.

A10.2.1 Table Format

If only one word is entered, that word contains the thermal conductivity that is assumed constant. Otherwise, pairs of temperatures and thermal conductivities are entered. The number of pairs is limited to 100. The temperatures must be in increasing order. The end-point temperatures must bracket the expected temperatures during a transient. That is, if the temperature is outside the bracketed range, a failure will occur and a diagnostic edit will be printed.

W1(R) Temperature (K, ^oF) or gas name. The allowed gas names are HELUIM, ARGON, KRYPTON, XENON, NITROGEN, HYDROGEN, and OXYGEN.

W2(R) Thermal conductivity (W/m·K, Btu/s·ft· ^oF) or mole fraction.

A10.2.2 Functional Format

In the functional format, sets of nine quantities are entered, each set containing one function and its range of application. The function is

$$k = A0 + A1(TX) + A2(TX)^2 + A3(TX)^3 + A4(TX)^4 + A5(TX)^{-1}$$

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, ^oF).

W2(R) Upper limit temperature (K, ^oF).

W3(R) A0 (W/m·K, Btu/s·ft· ^oF).

W4(R) A1 (W/m·K^2, Btu/s·ft· $^oF^2$).

W5(R) A2 (W/m·K^3, Btu/s·ft· $^oF^3$).

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, ^oF).

A10.3 Cards 201MMM51 through 201MMM99, Volumetric Heat Capacity Data

These cards are required if Word 1 of Card 201MMM00 contains TBL/FCTN. The card numbers need not be consecutive.

A10.3.1 Table Format

If only one word is entered, that word contains the volumetric heat capacity that is assumed constant. Pairs of temperatures and volumetric heat capacities are entered if the temperatures are different than the thermal conductivity table or if functions are used for thermal conductivity. If the temperature values are identical, only the volumetric heat capacities need be entered. The number of pairs or single entries is limited to 100. The temperatures must be in increasing order. The end-point temperatures must bracket the expected temperatures during the transient. That is, if the temperature is outside the bracketed range, a failure will occur and a diagnostic edit will be printed.

W1(R) Temperature (K, ^oF). If only volumetric heat capacities are being entered, this word is not entered.

W2(R) Volumetric heat capacity ($J/m^3 \cdot {}^oK$, $Btu/ft^3 \cdot {}^oF$). This is ρC_p, where ρ is the density (kg/m^3, lb_m/ft^3) and C_p is specific heat capacity ($J/kg{\cdot}K$, $Btu/lb_m, {}^oF$).

A10.3.2 Functional Format

In the functional format, sets of nine quantities are entered, each set containing one function and its range of application. The function is

$$\rho C_p = A0 + A1(TX) + A2(TX)^2 + A3(TX)^3 + A4(TX)^4 + A5(TX)^{-1}$$

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 ($J/m^3 \cdot K$, $Btu/ft^3 \cdot {}^oF$).

W4(R) A1 ($J/m^3 \cdot K^2$, $Btu/ft^3 \cdot {}^oF^2$).

W5(R) A2 ($J/m^3 \cdot K^3$, $Btu/ft^3 \cdot {}^oF^3$).

W6(R) A3 ($J/m^3 \cdot K^4$, $Btu/ft^3 \cdot {}^oF^4$).

W7(R) A4 ($J/m^3 \cdot K^5$, $Btu/ft^3 \cdot {}^oF^5$).

W8(R) A5 (J/m^3, Btu/ft^3).

W9(R) C (K, ^oF).

A11. CARDS 202TTTNN, GENERAL TABLE DATA

These cards are used only in NEW or RESTART type problems and are required only if any input references general tables. TTT is the table number, and table references such as for power, heat transfer coefficients, and temperatures refer to this number. Data must be entered for each table referenced, but TTT need not be consecutive. Tables entered but not referenced are stored, and this is not considered an error. During RESTART, general tables may be added, existing tables may be deleted, or existing tables may be modified by entering new data.

A11.1 Card 202TTT00, Table Type and Multiplier Data

W1(A) TABLE TYPE. Enter POWER for power versus time; enter HTRNRATE for heat flux versus time; enter HTC-T for heat transfer coefficient versus time; enter HTC-TEMP for heat transfer coefficient versus temperature; enter TEMP for temperature versus time; enter REAC-T for reactivity versus time; enter NORMAREA for normalized area versus normalized stem position; (enter SP-HEAT for specific heat versus temperature; enter DENSITY for density versus temperature; enter TH-COND for thermal conductivity versus temperature). In RESTART problems, DELETE can be entered to delete general table TTT. When a general table is used to define a FUNCTION type control system variable, table type REAC-T can be used to prevent undesirable units conversion, since no British to SI units conversion is done for REAC-T entries.

(The type names are suggestive of their typical use. The POWER type can be used to enter the time dependent portion of the volumetric heat source in heat structures. The HTRNRATE, HTC-T, HTC-TEMP, and TEMP types can be used for heat structure boundary conditions. The REAC-T type is used for reactivity in reactor kinetics calculations. The NORMAREA type is used with valves. The SP-HEAT, DENSITY, and TH-COND types are used to define user specified materials in SCDAP components.)

The following two, three, or four words are optional and allow trips and factors or units changes to be applied to the table entries. If the factors are omitted, the data are used as entered. One multiplier is used for time, power, heat transfer flux, heat transfer coefficient, normalized length, and normalized area; a multiplier and additive constant are used for temperature as $T = M^2 \cdot TX + C$, where M is the multiplier, C is the additive constant, and TX is the temperature entered. The first one or two factors apply to the argument variable, time or temperature; one factor is applied if the argument is time, and two factors are used if the argument is temperature. The remaining one or two factors are used for the function; two factors being used if temperature is the function.

W2(I) Table trip number. This number is optional unless factors are entered. If missing or zero, no trip is used; and the time argument 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 zero or blank for tables that are not a function of time.

W3-W5(R) Factors. As described above, enter factors such that when applied to the table values entered, the resultant values have the appropriate units. For the NORMAREA table, the resultant values for both the normalized length and area must be ≥ 0 and ≤ 1.0.

W6(I) Flag. This word is optional, and if not entered zero is assumed. If this word is to be entered, unneeded words in W3 through W5 should have -1.0 entered. In standard use of a general table, the table is evaluated as needed by the various models using general tables. Some of the models include power and boundary conditions for heat structures, reactivity for reactor kinetics, and valve positions. A function control component forces evaluates a general table and the tabular value is then available as CNTRLVAR nnn where nnn is the control component number. This capability is available if this flag is 0. This flag, if set to 1, forces an evaluation of the general table at the end of the time step advancement (just before evaluation of the control components). In addition, the value of this evaluation is available as a minor edit quantity, GNTBLVAL nnn, where nnn is the general table number. This value is also written to the plot records in the restart-plot file. A typical use of this capability is to enter experimental data or data from previous versions in a general table, and then plot the computed value and value from the general table on the same graph to facilitate graphical comparisons. Use of this word saves the use off a control component to gain the same result.

A11.2 Cards 202TTT01 through 202TTT99, General Table Data

The card numbers need not be consecutive. The units given are the units required after the factors on Card 202TTT00 have been applied. Pairs of numbers are entered; the limit on the number of pairs is 10000.

W1(R) Argument value (s, if time; K, ^{o}F, if temperature; dimensionless, if normalized stem position).

W2(R) Function value (W, MW, if power; K, ^{o}F, if temperature; W/m^2, Btu/s· ft^2, if heat flux; W/m^2 · K, Btu/s·ft^2 · ^{o}F, if heat transfer coefficient; dollars, if reactivity; dimensionless, if normalized area, J/kg-K, Btu/lb$_m$, ^{o}F if specific heat, kg/m^3, lb/ft^3 if density, W/m-K, Btu/s-m-^{o}F).

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.

A12. CARDS 30000000 THROUGH 30399999, REACTOR KINETICS INPUT

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.

A12.1 Card 30000000, Reactor Kinetics Type Card

This card is required.

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 reactor 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 through 30000899. 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 through 30002999. 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.

A12.2 Card 30000001, Reactor Kinetics Information Card

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.

W3(R) Initial reactivity (dollars). This quantity must be ≤ 0.0.

W4(R) Delayed neutron fraction over prompt neutron generation time (s^{-1}).

W5(R) Fission product yield factor. This is usually 1.0 for best-estimate problems, and 1.2 has been used with ANS73 data for conservative mode problems. The factor 1.0 is assumed if this word is not entered.

W6(R) ^{239}U yield factor. This is the number of ^{239}U atoms produced per fission times any conservative factor desired. The factor 1.0 is assumed if this word is not entered.

W7(R) Fissions per initial fissile atom, ψ. Used in factor

$G(t) = 1.0 + (3.24\times10^{-6} + 5.23\times10^{-10}t)T^{0.4}\psi$ 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 zero. 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 an 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 ≥ 1.0 and ≤ 3.0.

W8(R) Reactor operating time T. This quantity is the T in the expression given in Word 7 above. The unit for this quantity is given in the next word. If not entered or entered as zero, this quantity defaults to 52 wk. This quantity is used only if the power history data in Section A12.7 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 zero to determine the *G* factor at the start of the simulation. The limit for this quantity is $1.2614\cdot10^{8}$ seconds.

W9(A) Units for Word 8 above. Must be sec, min, hr, day, wk.

A12.3 Card 30000002, Fission Product Decay Information

This card is entered for POINT problems if Word 1 of Card 30000001 contains GAMMA or GAMMA-AC. If this card is not entered, the proposed 1973 ANS standard fission product data are used if default data are used.

W1(A) Fission product type. Enter ANS73, ANS79-1, or ANS79-3. If default fission product data are used, ANS73 specifies the proposed 1973 ANS standard data, ANS79-1 specifies the 1979 standard data for 235 U, and ANS79-3 specifies the 1979 ANS standard data for the three isotopes, ^{235}U, ^{238}U, and ^{239}Np. ANS79-3 also requires that power fractions for each isotope must be entered. If fission product data are entered, ANS73 and ANS79-1 specify only one isotope and ANS79-3 specifies three isotopes and also requires that the number of decay heat groups for each isotope be entered.

W2(R) Energy release per fission (MeV/fission). If not entered or zero, the default value of 200 MeV/fission is used.

W3-W5(R) If ANS79-3 is specified in Word 1. The fraction of power generated in ^{235}U, ^{238}U, and ^{239}Pu must be entered in these three words. The sum of the fractions must add to one.

W6-W8(I) Number of groups per isotope. If ANS79-3 is entered in Word 1 and default data are not being used, the number of decay groups for ^{235}U, ^{238}U, and ^{239}Pu must be entered in these words. The number of groups for each isotope must be ≤ 50.

A12.4 Cards 30000101 through 30000199, Delayed Neutron Constants

If these cards are missing, constants for the six generally accepted delayed neutron groups are supplied. Otherwise, two numbers for each delay group are entered, one or more pairs per card. Card numbers need not be consecutive. The number of pairs on these cards defines the number of delay groups. Up to 50 delay groups may be entered.

W1(R) Delayed neutron precursor yield ratio.

W2(R) Delayed neutron decay constant (s^{-1}).

A12.5 Cards 30000201 through 30000299, Fission Product Decay Constants

These cards are not needed if Word 1 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 Word 1 of Card 30000002 are supplied. Up to 50 fission product groups may be entered. Data are entered on cards similarly to Cards 30000101 through 30000199. The factor in Word 5 of Card 30000001 is applied to the yield fractions.

W1(R) Fission product yield fraction (MeV).

W2(R) Fission product decay constant (s^{-1}).

A12.6 Cards 30000301 through 30000399, Actinide Decay Constants

These cards are not needed unless Word 1 of Card 30000001 is GAMMA-AC. If GAMMA-AC is entered, data from these cards or default data are used to define actinide decay. If the cards are missing, default data are supplied.

W1(R) Energy yield from ^{239}U decay (MeV).

W2(R) Decay constant of ^{239}U (s^{-1}).

W3(R) Energy yield from ^{239}Np (MeV).

W4(R) Decay constant of ^{239}Np (s^{-1}).

A12.7 Cards 30000401 through 30000499, Power History Data

If these cards are not present, initial conditions for fission product and actinide groups are for steady-state operation at the power given in Word 2 of Card 30000001. This is equivalent to operation at that power for an infinite time. If these cards are present, the power history consisting of power and time duration is used to determine the fission product and actinide initial conditions. The power from gamma and actinide decay is assumed to be zero at the beginning of the first time duration. Data are entered in three- or six-word sets, one or more sets per card. Card numbers need not be consecutive.

W1(R) Reactor power (W). This quantity is the total reactor power, that is, the sum of fission power and decay power, and must be ≥ 0. If a decay power obtained from the power history exceeds this quantity, the fission power is assumed to be zero.

W2(R) Time duration. Units are as given in next word. This quantity must be ≥ 0.

W3(A) Time duration units. Must be sec, min, hr, day, or wk.

W4-W6(R) Power fractions. If ANS79-3 is entered in Word 1 of Card 30000002, the power fractions for ^{235}U, ^{238}U, and ^{239}Pu must be entered in these words.

A12.8 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 zero.

A12.8.1 Cards 30000011 through 30000020, Reactivity Curve or Control Variable Numbers

Reactivity (or scram) curves from the general tables (Cards 202TTTNN) or control variables that contribute to reactivity feedback are specified on these cards. These cards are not used if there are no references to reactivity contributions from general tables or control variables. Tables and control variables referenced must be defined. No error is indicated if reactivity curves are defined but not referenced on this card, but memory space is wasted. Curve numbers, which are the TTT of the general table card number or control variable number code, are entered one or more per card. Card numbers need not be consecutive.

W1(I) Table or control variable number. Up to 20 numbers may be entered. Numbers from 1 through 999 indicate general table numbers. Numbers > 10,000 indicate the control variable whose number is the entered number minus 10,000.

A12.8.2 Cards 30000501 through 30000599, Density Reactivity Table

This table is required if the SEPARABL option is being used and if Cards 30000701 through 30000799 are entered. One or more pairs of numbers are entered to define reactivity as a function of moderator density. Data are entered one or more pairs per card, and card numbers need not be consecutive. Up to 100 pairs may be entered. 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.

W1(R) Moderator density (kg/m^3, lb/ft^3).

W2(R) Reactivity (dollars).

A12.8.3 Cards 30000601 through 30000699, Doppler Reactivity Table

This table is required if the SEPARABL option is being used and if Cards 30000801 through 30000899 are entered. One or more pairs of numbers are entered to define Doppler reactivity as a function of volume-averaged fuel temperature. Heat structure composition data Cards 1CCCG201 through 1CCCG209 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.

W1(R) Temperature (K, ^oF).

W2(R) Reactivity (dollars).

A12.8.4 Cards 30000701 through 30000799, Volume Weighting Factors

These cards are used only if the SEPARABL option is being used and are omitted if no reactor kinetics feedback from hydrodynamics is present. Each card contains the input for reactivity feedback 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, $W_{\rho i}$.

W4(R) Water temperature coefficient, a_{Wi} (dollars/K, dollars/^oF). The weighting factor in Word 3 is not applied to this quantity.

A12.8.5 Cards 30000801 through 30000899, Heat Structure or SCDAP Component Weighting Factors

These cards are used only if the SEPARABL option is being used and are omitted if no reactor kinetics feedback from heat structures or SCDAP components are present. Each card contains the input for reactivity feedback due to conditions in one or more heat structures or SCDAP components representing fueled portions of the reactor. Data are entered in a manner similar to Cards 30000701 through 30000799. For each heat structure specified on these cards, input on the heat structure data Cards 1CCCG2NN must define the fueled region as the region over which the volume-average temperature is computed. Usually, either Word 3 or 4 is zero.

W1(I) Heat structure number or SCDAP component iijj. ii equals the axial node, and jj equals the component number.

W2(I) Increment.

W3(R) Weighting factor for doppler feedback, W_{Fi}.

W4(R) Fuel temperature coefficient, a_{Fi} (dollars/K, dollars/^oF). The weighting factor in Word 3 is not applied to this quantity.

A12.8.6 Cards 30001701 through 30001799, Volume Weighting Factors

These cards are used only if the TABLE3, TABLE3A, TABLE4, or TABLE4A option is not 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 the 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 A12.8.5.

W1(I) Hydrodynamic volume number.

W2(I) Increment.

W3(R) Weight factor, $W_{\rho i}$.

A12.8.7 Cards 30001801 through 30001899, Heat Structure or SCDAP Component Weighting Factors

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 temperature in one or more heat structures or SCDAP components. At least three quantities must be entered on each card. The use of the increment field is similar to that in Section A12.8.5.

W1(I) Heat structure number or SCDAP component iijj. ii is the axial node, and jj is the component number.

W2(I) Increment.

W3(R) Weight factor, W_{Fi}.

A12.8.8 Cards 300019C1 through 300019C9, Feedback Table Coordinate Data

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 Word 2, Card 30000000 in Section 12.1). 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.

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).

A12.8.9 Cards 30002001 through 30002999, Feedback Table Data

Values defining the table are entered in pairs. The first is a coded number defining the position of the table entry. The second number is the table entry. One or more pairs may be entered on one or more cards as needed. Card numbers need not be consecutive. There is no required ordering for the coded number, but a coded number may be entered only once.

W1(I) Coded number. The coded number has the form ddmmffbb, where the letter pairs represent coordinate numbers of the independent variables of the table. The dd pair refers to moderator density 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.

A13. CARDS 20300000 THROUGH 20300999, PLOT REQUEST INPUT DATA

Cards 20300nnm contain the plot requests and these cards may be entered in new, restart, or plot runs. Each set of 20300nnm cards generates one graph, with one or more variables shown on each graph. At present, time is always placed along the x axis, and one or two y axes may be used. Thirty nine graphs should be allowed, but some computer systems have run out of resources when more than 30 graphs have been attempted. Any of the quantities listed in Appendix A, Section A4, "Minor Edit Requests," of the RELAP5 or SCDAP/RELAP5 input manuals may be entered. The plot request variables are tested for validity as part of input checking. The data for the plots are obtained from the restart-plot file, and the desired plot variables must be present on that file. For new or restart runs, plot variables appearing in the plot requests that are not automatically written to the restart-plot file or were not added to the restart-plot file through 2080xxxx cards are added to the restart-plot file as part of input processing of the plot requests. Thus plot requests that pass successfully through input checking will always generate graphs. For plot runs, plots requests for quantities not present on the restart-plot file are ignored.

As part of the coding for the integrated plot capability, an improvement was added to the processing of 2080xxxx cards. The purpose of the 2080xxxx cards is to add to the plot records variables that are not automatically written to the plot records. In prior versions, if 2080xxxx cards were input for variables automatically written to the file, those variables were duplicated on the file. Now, the 2080xxxx cards are checked and no duplicate variables are written. A warning message is issued to the print file that unneeded cards have been entered. With the addition of many SCDAP variables to those automatically written, many SCDAP input decks have unneeded input.

As execution starts, whether from commands entered into a command line window or information entered into the run window, a new window and a child window within the new window appears. The child window shows the standard text written to the monitor during code execution. The user will normally wish to extend the width of the child window and perhaps the main window. The window can be extended to full screen by using the view option, but then no other information appears.

Also the window must be manually scrolled to see the last entered results once the top of the window is filled. At the conclusion of the advancements, the requested graphs appear, stacked in child windows on top of the monitor child window.

The title on the window is Graph nn, where nn is from the 20300nnm card. This title also appears on the graph. Standard Windows mouse clicks can iconify the graphs (hit minus sign in right end of task bar) or restore them (hit square(s) in right end of task bar). By hitting the view command near the left end of the task bar, the pull down menu includes a full screen command. Hitting this expands the graph to full screen and allows viewing the entire graph. Entering ESC or clicking the left mouse button returns from the full screen. By hitting the file command in the left end of the task bar, save and print options appear in a pull down menu. Hitting print will generate a hard copy of the graph. The graphs in the child windows are temporary and are lost when the top window is closed. Use the save option to allow further access to the graphs. The permanent copy of the graph has a file suffix of bmp. The graph in the saved file can be viewed through the Windows Explorer program. The full graph can be viewed by hitting View, then View Bitmap that appears in the pull down window.

Note that these operations on the temporary graphs or the saved graphs are standard Window operations and further information can be obtained through the help command.

The limit of 39 graphs can be overcome by making multiple plot runs using the same restart plot file with different 20300nnm cards.

The plot request information for each graph nn is entered on cards 20300nnm. The graph number, nn, may range from 1 through 99, but the total number of graphs must be less than 40. The m is a sequence number. The information for each graph consists of one or more sets of three words, one set for each variable to be shown on the graph. The sets may be entered on one or more cards, using m ranging from 0 through 4. No more than nine plots may be on one may be on a single graph.

W1(A) Alphanumeric part of variable name.

W2(I) Parameter part of variable name.

W3(I) Axis number.

W1(A) Alphanumeric part of variable name.

W2(I) Parameter part of variable name.

W3(I) Axis number and linear/logarithmic scale indicator. Allowed values are plus or minus 1, plus or minus 2, or zero.

Each graph contains a left y axis and optionally a right y axis. The absolute value of W3 specifies the y axis, 1 for the left y axis, 2 for the right y axis. The sign of W3 specifies the scaling, plus for linear scaling, minus for logarithmic scaling. A zero may be entered for W3 and is interpreted the same as plus 1. Scaling for the y axes is such that all values of all the variables specified for the left axis will fit within the left y axis, and similarly for the right y axis. The labeling for both the left and right y axes are the units of the first variable specifying that axis. A power of 10^3 may be included to allow reasonable axis numbers. The selection between linear and logarithmic scaling is similarly based on the first set of input specifying an axis and the selections in other sets of input specifying that axis are ignored. If any of the values of the variables selected for logarithmic scaling contain a zero or negative value, the scaling is switched to linear scaling. The scaling for the left and right axes are not related in any manner, and the selection between linear and logarithmic scaling need not be the same. Grid lines are generated for the major tic marks on the left y axis and only tic marks are used on the right y axis. Lines with no marking to show actual data points are used to display the values. Different colors and a different line pattern are used for each variable. The variables are listed in a table beneath the x axis with a segment of the line to enable matching of the line plots with the variables. In the input of the three word sets, the last word or the last two words of the last set may be omitted and zeros will be supplied as default input. If none of the sets of input specify the right y axis, only the left axis is used. If none of the sets of input specify the left axis, the specified right y axis will be switched to the left axis. The previous version of the plot capability allowed only a single variable to be plotted on each graph. The three word set specifying the variable and axis and with the last two words able to be omitted matches the previous input but unfortunately the card number is slightly different. Hopefully the increased capability is worth the bother of modifying existing plot input. To obtain reasonable graphs, the variables specifying the same y axis should be closely related and probably have the same units. A common practice in input decks used for validation is to enter experimental results into general tables, and use a control variable to evaluate the general table. The computed result and the experimental result from the control variable could be shown on the same axis to allow graphical comparison. No units are available for control variables, so the computed variable should be specified first so that units will appear on the y axis labeling.

A14. CARDS 205CCCNN OR 205CCCCN, CONTROL SYSTEM INPUT DATA

These cards are used in NEW and RESTART problems if a control system is desired. They are also used to define the generic control components employed with the self-initialization option. Input can also be used to compute additional quantities from the normally computed quantities. These additional quantities can then be output in major and minor edits and plots. Two different card types are available for entering control system data, but only one type can be used in a problem. The digits CCC or CCCC form the control variable number (i.e., control component number). The card format 205CCCNN allows 999 control variables, where CCC ranges from 001 through 999. The card format 205CCCCN allows 9999 control variables, where CCCC ranges from 1 through 9999. If the self-initialization option is selected, the data cards described in Section A2.16, Section A2.16, and Section A2.16 must be included. If loop flow control is to be included, the data cards described in Section A2.16 must also be included.

A14.1 Card 20500000, Control Variable Card Type

If this card is omitted, Card 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.

A14.2 Card 205CCC00 or 205CCCC0, Control Component Type Card

This card must be entered for each control component. The self-initialization option if used requires use of generic control components as specified in the self-initialization input. Generic components can also be used independently of the self-initialization option.

W1(A) Alphanumeric name. Enter a name of up to eight characters descriptive of the component. This name will appear in the printed output along with the component number.

W2(A) Control component type. Enter one of the component names, SUM, MULT, DIV, DIFFRENI, DIFFREND, INTEGRAL, FUNCTION, STDFNCTN, DELAY, TRIPUNIT, TRIPDLAY, POWERI, POWERR, POWERX, PROP-INT, LAG, LEAD-LAG, CONSTANT, SHAFT, PUMPCTL, STEAMCTL, or FEEDCTL, or the command, DELETE. If DELETE is entered, enter any alphanumeric word in Word 1 and zeros in the remaining words. No other cards are needed when deleting a component.

W3(R) Scaling factor. For a CONSTANT component, this quantity is the constant value. No additional words are entered on this card, and Cards 205CCC01 through 205CCC09 or 205CCCC1 through 205CCCC9 are not entered. For the PUMPCTL, STEAMCTL, or FEEDCTL components, this is the gain multiplier (G) for the output signal.

W4(R) Initial value.

W5(I) Initial value flag. Zero means no initial condition calculation and Word 4 is used as the initial condition; one means compute initial condition.

W6(I) Limiter control. Enter zero or omit this and the following words if no limits on the control variable are to be imposed. Enter 1 if only a minimum limit is to be imposed, 2 if only a maximum limit is to be imposed, and enter 3 if both minimum and maximum limits are to be imposed.

W7(R) Minimum or maximum value. This word is the minimum or maximum value if only one limit is to be imposed or is the minimum value if both limits are to be imposed.

W8(R) Maximum value. This word is used if both limits are to be imposed.

A14.3 Cards 205CCC01 through 205CCC98 or 205CCCC1 through 205CCCC8, Control Component Data Cards

The format of these cards depends on the control component type. An equation is used to describe the processing by each component. The symbol Y represents the control variable defined by the component. The symbols A_j, $j = 1, 2, \ldots, J$ represent constants defined by the control component input data. The variables V_j, $j = 1, 2, \ldots, J$ 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.

A14.3.1 Sum-Difference Component

This component is indicated by SUM in Word 2 of Card 205CCC00 or 205CCCC0. The sum-difference component is defined by

$$Y = S(A_0 + A_1 V + A_2 V_2 + \ldots + A_J V_j)$$

W1(R) Constant A_0.

W2(R) Constant A_1.

W3(A) Alphanumeric name of variable request code for V_1.

W4(I) 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 through 4 can be entered for additional product terms up to 20 product terms. One or more cards may be used as desired. Card numbers need not be strictly consecutive. The sign of A_j determines addition or subtraction of the product terms.

A14.3.2 Multiplier Component

This component is indicated by MULT in Word 2 of Card 205CCC00 or 205CCCC0. The multiplier component is defined by

$$Y = SV_1V_2 \ldots V_J$$

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.

A14.3.3 Divide Component

This component is indicated by DIV in Word 2 of Card 205CCC00 or 205CCCC0. The divide component is defined by

$$Y = \frac{S}{V_1} \text{ or } Y = \frac{SV_2}{V_1}.$$

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 zero is attempted.

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

A14.3.4 Differentiating Components

These components are indicated by DIFFRENI or DIFFREND in Word 2 of Card 205CCC00 or

205CCCC0. The differentiating component is defined by

$$Y = S\frac{dV_1}{dt}.$$

This is evaluated by

$$Y = \frac{2S(V_1 - V_{10})}{\Delta t} - Y_0 \quad \text{(DIFFRENI)}$$

$$Y = \frac{S(V_1 - V_{10})}{\Delta t} \quad \text{(DIFFREND)}$$

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, is not consistent with the integration approximation, but does not require an initial value. Use of DIFFRENI is not recommended.

Since differentiation, especially numerical differentiation, can introduce noise into the calculation, it should be avoided if possible. When using control components to solve differential equations, the equations can be arranged such that INTEGRAL components can handle all indicated derivatives except possibly those involving noncontrol variables.

W1(A) Alphanumeric name of variable request code for V_1.

W2(I) Integer name of variable request code for V_1.

A14.3.5 Integrating Component

This component is indicated by INTEGRAL in Word 2 of Card 205CCC00 or 205CCCC0. The integrating component is defined by

$$Y = \int_0^t V_1 dt$$

or, in Laplace notation,

$$Y(s) = \frac{SV_1(s)}{s}.$$

This is evaluated by

$$Y = Y_0 + S(V_1 + V_{10})\frac{\Delta t}{2}$$

where Δt is the time step and Y_0 and V_{10} are the values at the beginning of the time step.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Integer name of the variable request code for V_1.

A14.3.6 Functional Component

This component is indicated by FUNCTION in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = S[\mathrm{FUNCTION}(V_1)]$$

where FUNCTION is defined by a general table. This allows the use of any function conveniently defined by a table lookup and linear interpolation procedure. The function component can also be used to set limiting values.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Integer name of the variable request code for V_1.

W3(I) General table number of the function.

A14.3.7 Standard Function Component

This component is indicated by STDFNCTN in Word 2 of Card 205CCC00 or 205CCCC0.

The component is defined by

$$Y = S[\mathrm{FNCTN}(V_1, V_2, \ldots)]$$

where FNCTN is ABS (absolute value), SQRT (square root), EXP (e raised to power), LOG (natural logarithm), SIN (sine), COS (cosine), TAN (tangent), ATAN (arc tangent), MIN (minimum value), or MAX (maximum value). All function types except MIN and MAX must have only one argument; MIN and MAX function types must have at least two arguments and may have up to 20 arguments. If the control variable being defined also appears in the argument list of MIN or MAX, the old time value is used in the comparison.

W1(A) FNCTN.

W2(A) Alphanumeric name of the variable request code for V_1.

W3(I) Integer name of the variable request code for V_1.

W2 and W3 are repeated as necessary to enter the arguments.

A14.3.8 Delay Component

This component is indicated by DELAY in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1(t - t_d)$$

where t is time and t_d is the delay time.

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Integer name of the variable request code for V_1.

W3(R) Delay time, t_d (s).

W4(I) Number of hold positions. This quantity, h, must be > 0 and ≤ 100. This quantity determines the length of the table used to store past values of the quantity V_1. The maximum number of time-function pairs that can be stored is $h + 2$. The delay table time increment, d_{TM}, is $d_{TM} = \frac{t_d}{h}$. 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 $t_d T$ 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.

A14.3.9 Unit Trip Component

This component is indicated by TRIPUNIT in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by where U is 0.0 if the trip, T_1, is false and is 1.0 if the trip is true. If the complement of T_1 is specified, U is 1.0 if the trip is false and 0.0 if the trip is true.

W1(I) Trip number, T_1. A minus sign may prefix the trip number to indicate that the complement of the trip is to be used.

A14.3.10 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 zero or a positive number.

W1(I) Trip number, T_1.

A14.3.11 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.

A14.3.12 Real Power Component

This component is indicated by POWERR in Word 2 of Card 205CCCc00 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.

A14.3.13 Variable Power Component

This component is indicated by POWERX in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = SV_1^{V_2}.$$

W1(A) Alphanumeric name of the variable request code for V_1.

W2(I) Integer name of the variable request code for V_1.

W3(A) Alphanumeric name of the variable request code for V_2.

W4(I) Integer name of the variable request code for V_2.

A14.3.14 Proportional-Integral Component

This component is indicated by PROP-INT in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = S\left[A_1 V_1 + A_2 \int_0^t V_1 dt\right]$$

or in Laplace transform notation,

$$Y(s) = S\left[A_1 + \frac{A_2}{s}\right] V_1(s).$$

If the control variable is initialized,

$$Y(t_0) = SA_1 V_1(t_0).$$

If it is desired that the output quantity Y remain constant as long as the input quantity remains constant, V_1 must initially be zero regardless of the initialization flag.

W1(R) A_1.

W2(R) A_2.

W3(A) Alphanumeric name of the variable request code for V_1.

W4(I) Integer name of the variable request code for V_1.

A14.3.15 Lag Component

This component is indicated by LAG in Word 2 of Card 205CCC00 or 205CCCC0. This component is defined by

$$Y = \int_0^t \left(\frac{SV_1 - Y}{A_1}\right) dt$$

or, in Laplace transform notation,

$$Y(s) = \frac{S}{1 + A_1 s} V_1(s).$$

If the control variable is initialized,

$$Y(t_0) = SV_1(t_0)$$

If the initialization flag is set on and if the initial values of Y and V_1 satisfy a specified relationship, 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.

A14.3.16 Lead-Lag Component

This component is indicated by LEAD-LAG in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = \frac{A_1 S V_1}{A_2} + \int_0^t \left(\frac{S V_1 - Y}{A_2}\right) dt$$

or, in Laplace transform notation,

$$Y(s) = S\left(\frac{1 + A_1 s}{1 + A_2 s}\right) V_1(s) .$$

If the control variable is initialized,

$$Y(t_0) = S V_1(t_0)$$

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_2 (s).

W3(A) Alphanumeric name of the variable request code for V_1.

W4(I) Integer name of the variable request code for V_1.

A14.3.17 Constant Component

Cards 205CCC01 through 205CCC09 or 205CCCC1 through 205CCCC9 are not entered. The quantity in Word 3 of Card 205CCC00 or 205CCCC0 is the constant value used for this component.

A14.3.18 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

$$\sum_i I_i \frac{\mathrm{d}\omega}{\mathrm{d}t} = \sum_i \tau_i - \sum_i f_i \omega + \tau_c$$

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.

A14.3.19 Card 205CCC01 through 205CCC05 or 205CCC1 through 205CCCC5, Shaft Description Card.

W1(I) Torque control variable number. If zero, there is no contribution to torque from the control system. If nonzero, the control variable with this number is assumed to be a torque and is added to the torques from the other components attached to the shaft. The torque must be in SI units.

W2(R) Shaft moment of inertia, I_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 10 components. Only one generator, the one defined as part of this SHAFT component, may be attached.

A14.3.20 Card 205CCC06 or 205CCCC6, Generator Description Card.

Each SHAFT component may optionally define an associated GENERATR component.

W1(R Initial rotational velocity (rad/s, rev/min).

W2(R) Synchronous rotational velocity (rad/s, rev/min).

W3(R) Moment of inertia, I_i (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 zero, the generator is always connected to the shaft. If nonzero, the generator is connected to the shaft when the trip is false and disconnected when the trip is true.

A14.3.21 PUMPCTL Component

This component is specified when using the self-initialization option and loop flow control is desired but is not limited to that use. For each PUMPCTL component enter:

W1(A) Alphanumeric name of 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. Word 1 and Word 2 contain CNTRLVAR and CCC (or CCCC), respectively, where CCC (or CCCC) is a CONSTANT type control element containing the desired (setpoint) flow rate. Word 3 is MFLOWJ, and Word 4 is the junction number at which the flow is to be sensed and compared to the setpoint. Word 5 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 zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. Word 6 and Word 7 are the T_2 and T_1 values, respectively. All variables having units must be in SI units.

A14.3.22 STEAMCTL Component

This component is specified when using the self-initialization option to control steam flow from one or more steam generators but is not limited to that use. For each STEAMCTL component enter:

W1(A) Alphanumeric name of 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. Word 1 and Word 2 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). Word 3 would be TEMPF (for suboptions A and B) or P (for suboptions C and D), and Word 4 would be the volume number where the temperature (suboptions A and B) or pressure (suboptions C and D) is sensed. Word 5 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 zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. Word 6 and Word 7 are the T_4 and T_3 values, respectively. All variables having units must be in SI units.

A14.3.23 FEEDCTL Component

This component is specified when using the self-initialization option to control feedwater flow to a steam generator but is not limited to that use. For each FEEDCTL component enter:

W1(A) Alphanumeric name of first 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 set point.

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. Word 1 and Word 2 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. Word 3 and Word 4 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). Word 5 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. Word 6 is MFLOWJ, and Word 7 is the junction number of the steam exit junction from the steam generator. Word 8 is MFLOWJ, and Word 9 is the junction number of the feedwater inlet junction. Word 10 is the S_m value used to divide the difference between the sensed steam flow and sensed feedwater flow to produce the second portion of the error signal E_3. E_3 must be initially zero if it is intended to have the controller output remain constant as long as the input quantities remain constant. Word 11 and Word 12 are the T_6 and T_5 values, respectively. All variables having units must be in SI units.

A14.3.24 Compare Component

This component is indicated by COMPARE in Word 2 of Card 205CCC00 or 205CCCC0. The component is defined by

$$Y = S\left[abs\left(\frac{(V_1 - V_2)}{\frac{V_1 + V_2}{2}}\right) \right].$$

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.

A15. CARDS 20700000 THROUGH 20799999, FISSION PRODUCT AND AEROSOL TRANSPORT

These cards are required only when the fission product aerosol behavior models are desired while performing a severe accident analysis. These cards are optional and may be entered in NEW or RESTART problems.

A15.1 Card 20700000, Aerosol Size Bins

W1(I) Number of bins or delete flag. Zero may be entered in a RESTART problem having a fission product transport model and indicates that the model is to be terminated and all fission product data are to be deleted. No other cards in the range 20700001 through 20799999 may be entered. A positive nonzero quantity may be entered in a RESTART problem with a fission product model to indicate that the current fission product data are to be discarded and a new model entered. A positive nonzero number in a NEW problem or a RESTART without a fission product transport model indicates that the fission product transport model is to be started. The nonzero number is the number of aerosol bins. The number of bins must be greater than 1 and less than 50.

A15.2 Cards 20700001 Through 20700005, Hydrodynamic System Specification

These cards specify the hydrodynamic systems for which the fission product transport calculation is to be made. These cards may be entered in NEW or RESTART problems. A hydrodynamic system is selected by entering one of the volumes in the hydrodynamic system. Only one volume per system may be entered on these cards. A positive volume number indicates that a fission product transport calculation is to be added to the hydrodynamic system. A negative volume number means that the fission product transport model is to be terminated for the hydrodynamic system and the associated data discarded. An input error results if an attempt is made to specify the fission product transport model for a hydrodynamic system already having the model. If in a RESTART, no hydrodynamic systems with fission transport remain, all fission product data are discarded. If Card 20700000 with W1 nonzero is entered, an input error results if no hydrodynamic systems with fission product transport are present.

If volumes are added or deleted in the hydrodynamic systems with fission product transport, fission product data corresponding to those volumes are similarly added or deleted. If an entire hydrodynamic system is deleted, the corresponding fission product system is deleted. All fission product systems may be deleted in this manner, but an input error results if this occurs and Card 20700000 with W1 nonzero is entered. If hydrodynamic systems are merged (by junctions connecting them), the fission product systems are similarly merged.

Data may be entered one or more words per card, one or more cards as needed.

W1(I) Volume number of selected hydrodynamic system. This number is plus or minus, as described above.

A15.3 Card 20700010, Convergence Criteria

This card may be entered whenever Card 20700000 with W1 nonzero is entered or in any RESTART problem with an existing fission product model. Default values or previously entered values are used if this card is omitted.

W1(R) First convergence value (E_1).

W2(R) Second convergence value (E_2).

A15.4 Cards 20700011 Through 20700018, Species Selection Cards

These cards must be entered whenever Card 20700000 with W1 nonzero is entered and are not entered otherwise. Each word specifies a species to be tracked, and a species may be entered only once. At least one species must be entered, and all species may be entered if desired.

The allowed symbols and species are: I (iodine), CsI (cesium iodide), CsOH (cesium hydroxide), Te (tellurium), HI (hydrogen iodide), HTe (hydrogen telluride), Cd (cadmium), Ag (silver), UO_2 (uranium dioxide), Sn (tin), Fe (iron), Ru (ruthenium), B (barium), and Sr (strontium). These symbols are entered, one or more symbols per card, on one or more cards as desired for the desired species. Use upper and lower case as indicated above for the symbols.

W1(A) Species symbol.

A15.5 Cards 2070nnnm, Initial Conditions

Whenever a hydrodynamic volume is associated with the fission product transport model, whether by the specification of a system or by the addition of volumes through renodalization, the initial aerosol masses are assumed zero. These cards can be entered in NEW or RESTART problems to set different initial values or to reset values in existing volumes. Since the fission product aerosol masses are zero for undamaged fuel, these cards a generally not needed. Entering data for a volume not involved in a fission product transport calculation is an error.

In the card numbering, nnn ranges from 002 through 999, and each nnn contains the initial condition for one volume or a range of volumes. The cards are processed in order of increasing nnn. The initial conditions for a volume may be set in one specification and overridden in a subsequent specification. Not all species need to be entered in each specification, and if not entered, the initial specification remain at the previously set value or the default value.

A15.6 Card 2070nnn0, Initial Volume Number

W1(I) Initial volume number.

W2(I) Final volume number. Both W1 and W2 must specify hydrodynamic volumes in the problem. These volumes and all volumes with volume numbers between these words are initialized to the aerosol masses on Cards 2070nnn1 through 2070nnn9. All the volumes specified must be part of systems having fission product transport. If this word is omitted or is equal to W1, the initial conditions are for the volume specified in W1.

A15.7 Cards 2070nnn1 Through 2070nnn9, Masses of Species

W1(A) Species symbol. The allowed species are limited to those entered on Cards 2070011 through 20777718.

W2(R) Mass of species in liquid form (kg, lb).

W3(R) Mass of species in vapor form (kg, lb).

W4...(R) Mass of species for the aerosols in each bin (kg, lb).

A16. ADDITIONAL PLOT VARIABLES

These cards put variables on a restart tape so their history from start of analysis is plotted. These variables do not need to be listed as variables printed in minor edits. Some SCDAP variables are written to the plot file by default, others must be listed on a 20800NNN card to be plotted. Refer to "SCDAP Quantities" on page A4-18.

A16.1 Cards 20800NNN, Additional Plot Variables

These cards consist of the card number, followed by the variable name as specified in Section A4., Minor Edit Requests. Example input:

20800001 CADCT 000060201.
20800278 GAMMAW 231010000.

A17. CREEP RUPTURE

The following cards are used to activate the creep rupture model. The temperature for this model may either come from a RELAP5-SCDAP heat structure, or from the COUPLE debris bed model. Card 21000000 and cards 21000001 through 21000009 are used to link the creep rupture model to the COUPLE debris bed, while cards 21000101 through 21000110 link the model to a RELAP5-SCDAP heat structure. Either or both types of cards may be entered. These cards are optional for either a NEW or RESTART problem. If the creep rupture model is linked to a COUPLE debris bed, then the COUPLE debris bed model must be activated.

A17.1 CARD 21000000, COUPLE Creep Rupture Control

This card is optional if the COUPLE model is used but cannot be present if the COUPLE model is not used. All three values may be changed on RESTART.

W1(I) IMAT. Material index for COUPLE wall:

1 = A-508 Class 2 carbon steel (default).

2 = 316 stainless steel.

3 = Inconel 600.

W2(I) Containment volume. If specified as non-zero this volume is used as the containment volume. Default is zero.

W3(R) External pressure (Pa, lb_f/in^2). If W2 is > 0, then this value is ignored and the external pressure is taken from the containment volume, otherwise this value is the constant external pressure. Default is atmospheric pressure.

A17.2 Cards 21000001 through 21000009, Creep Rupture at COUPLE Wall

Creep rupture may be modeled at a maximum of nine COUPLE locations (defined by parameter nrlcmx). At each creep rupture location, a maximum of eleven COUPLE mesh points may be used to define the temperature for the creep rupture model. The temperature at each mesh points is used to produce an average temperature, which is then used as the single temperature of that creep rupture location.

One Card 2100000I is read for each COUPLE wall creep rupture calculation location I, and the specification of all mesh points for that location must be contained on that card. If entered on a restart run, any Card 2100000I will cause the mesh points identifying the average temperature of location i to be replaced for that I. The creep rupture damage term for location I will also be reset to 0.0 at the time of restart. Therefore the user should not re-enter any creep rupture locations which the user does not wish to replace. On a restart run, one may also add new locations by specifying previously unused values of I. To remove location i on restart without replacement, specify W1 on Card 2100000I as 0. Each Card 2100000I lists N (1 to 11) elements of the COUPLE grid, which describe location I on the COUPLE wall.

W1(I) ELEMENT 1.

WN(I) ELEMENT N.

A17.3 Cards 21000101 through 21000110, Creep Rupture at Heat Structures

Creep rupture may be modeled at up to ten RELAP5-SCDAP heat structures. A COUPLE mesh need not be entered to model creep at a heat structure. These cards are optional for either NEW or RESTART calculations. One Card 210001II is read for each creep rupture calculation location II, where the location is at the given heat structure. If entered on a restart run, any Card 210001II will cause the mesh points identifying the average temperature of location II to be replaced. The creep rupture damage term for location II will also be reset to 0.0 at the time of restart. Therefore the user should not re-enter any creep rupture locations which the user does not wish to replace. On a restart run, one may also add new locations by specifying previously unused values of II. To remove location II on restart without replacement, specify W1 on Card 210001II as 0.

W1(I) Heat structure number. The heat structure for which creep rupture failure calculation is to be done. The format is CCCG00X, where CCC is the heat structure number and G is its geometry.

W2(I) Material index.

1 = A-508 Class 1 carbon steel.

2 = 316 stainless steel.

3 = Inconel 600.

W3(R) Inner (left) pressure (Pa, lb_f/in^2). If non-zero, this constant pressure is used. If zero, pressure is from adjacent volume. Default is zero.

W4(R) Outer (left) pressure (Pa, lb_f/in^2). If non-zero, this constant pressure is used. If zero, pressure is from adjacent volume. Default is zero.

A18. GENERAL CORE INPUT

The presence of these cards activates the SCDAP (Severe Core Damage Analysis) portion of the code. Each card number begins with the digit ‘4’.

Input Error Trapping

Comparative checks will occur during input processing for variable type, number of words on a card, range of normal use, and physical/code limits. Further checks will also be performed for consistency of input. For example, one consistency check will examine radial node placement and verify that radial nodes have been placed at material interfaces.

Input violations of variable type, number of words, physical limit, and consistency of input will result in an input error, but will not abort input processing. Error messages will be printed in the output file flagged with the character string “********”. If the input is outside the range of normal use, a warning message will be printed in the output file and marked with the character string “$$$$$$$$.” To assist the user during deck building and input processing, selected ranges of allowable input will be identified with the card input descriptions. The range for a given input variable will be identified in the following manner:

Normal type - issue warning if out of range

$0.0m < x \leq 2.0m$

Underline - input error if out of range

A18.1 Severe Accident Core Behavior Input

The first set of cards describe general core geometry, and are also used to input core-wide parameters. They are unique since they begin with the four digits ‘4000’.

A18.1.1 Card 40000100, SCDAP Control

This card is used to define general control parameters and to control the types of facility dependent phenomena to be modeled. This card is required for NEW problems, and cannot be changed for RESTART problems.

W1(I) Number of axial nodes. Number of axial nodes. The range is greater than or equal to 2 and less than or equal to 20.

W2(I) Heat conduction flag. Always input the integer 1.

W3(I) Reactor environment.

This flag identifies phenomena for modeling fuel component meltdown and fission product release.

1 = PWR.

2 = BWR.

4 = ATR.

5 = Electrically heated core.

W4(I) Power history type. This flag is used to specify the decay power reduction caused by the release of volatile fission products after fuel disruption. Six different built-in correction relations are provided, as follows:

1 = Generic PWR (33,800 MWD/tU).

2 = TMI (3,250 MWD/tU).

3 = PBF Severe Fuel Damage Test Series.

4 = PBF (other test series).

5 = Full decay power.

6 = No decay power.

W5(I) Oxide shattering trip. If present, this trip number causes all the oxide in-core to be shattered when the trip becomes true. If specified as nonzero, the default logic to determine oxide shattering on reflood is not used.

A18.1.2 Cards 40000201 through 40000299, Axial Node Heights

This card is required for a NEW problem and cannot currently be changed for RESTART problems. The card format is two words per set in sequential expansion format.

W1(R) Axial node height (m, ft). There must be a one-to-one correspondence between axial node heights and connected RELAP5 volume heights. The default is 0.1 m and the range is 0.0 m < x ≤ 2.0 m.

W2(I) Axial node. Node number used for sequential expansion.

A18.1.3 Card 40000300, Oxide Shell Stability Parameters

This card is optional for a NEW or RESTART problems. This card has been added to allow the user the ability to perform parametric studies on significant parameters. This card is not required for a best-estimate calculation.

W1(R) Temperature for failure of oxide shell on outer surface of fuel and cladding (K, ^{o}F). If the cladding surface temperature is less than this temperature, the oxide shell does not fail. Default value is 2,500 K.

W2(R) Fraction of oxidation of fuel rod cladding for stable oxide shell. If extent of oxidation of cladding (expressed as fraction of cladding oxidized) is greater than this value, then the oxide shell does not fail even if cladding surface temperature exceeds the temperature specified in W1. Default value: 0.6. Value of 0.2 is recommended for analyses of full-sized nuclear power plants and value of 0.6 is recommended for analyses of severe accident experiments.

W3(R) Hoop strain threshold for double-sided oxidation. If cladding hoop strain is greater than this value at a location and the fuel rod cladding has ruptured, then double-sided oxidation of cladding occurs at that location. Default value: 0.07.

W4(I) Indicator of models for failure of cladding oxide shell, dissolution of fuel, slumping of previously frozen drops of relocated cladding, and slumping of liquefied material; default value = 0, which invokes model defining cladding oxide shell to only fail where double-sided oxidation and where relocated material has not solidified, invokes model defining fuel dissolution to not occur at location with double-side oxidation, invokes model constraining a second slumping of drops of relocated material that have frozen, and invokes model for slumping of liquefied cladding with dissolved fuel based on some superheat in slumping material; value of 1 invokes model for cladding oxide shell to fail also at locations with single-sided oxidation and with relocated material frozen on outside surface of cladding, fuel dissolution to occur to at locations with either single-sided or double-sided oxidation, drops of relocated material at temperature that exceeds failure temperature of oxide shell to slump again, and slumping model based on absence of superheat in slumping material (at the beginning of slumping material is slushy rather than completely liquefied, which results in smaller distance of slumping than for case of some superheat in material at start of slumping).

A18.1.4 Card 40000310, Metallic Meltdown Parameters

This card is optional for a NEW or RESTART problems. This card has been added to allow the user the ability to perform parametric studies on significant parameters, and is not required for a best-estimate calculation.

W1(R) Fraction of surface area covered with drops that results in blockage that stops local oxidation. Default value: 0.2.

W2(R) Surface temperature for freezing of drops of liquefied/slumping fuel rod cladding, (K, ^{o}F). If 0.0, then the location of freezing is calculated by the heat transfer model for the drops. Otherwise, the slumping drops freeze and stop motion as soon as they encounter fuel rod surface temperature less than this value. Default value: 1,750 K. If W4(I) of Card 40000300 is equal to one, this input variable is not used.

W3(R) Velocity of drops of cladding material slumping down outside surface of fuel rod (m/s). Default value: 0.5.

A18.1.5 Card 40000320, Molten Pool Parameters

This card is optional for a NEW or RESTART problems. This card has been added to allow the user the ability to perform parametric studies on significant parameters, and is not required for a best-estimate calculation.

W1(R) Multiplication factor on fuel pellet diameter that defines minimum thickness that crust at bottom of molten pool must have in order to support and seal the molten pool. Default value: 1.0.

W2 (R) Minimum fractional flow area for outer-most flow channel in reactor core after fuel rods in this channel have become molten. This parameter is intended to provide a means of comparing analyses to severe accident results which may exhibit non-symmetrical molten pools. Refer to Figure 1. Default value: 0.0.

Figure 1. Definition of user-defined residual flow area after fuel melting for outermost flow channel in reactor core.

A18.1.6 Card 40000330 Core Fragmentation Parameters

This card is optional for a NEW or RESTART problems. This card has been added to allow the user the ability to perform parametric studies on significant parameters, and is not required for a best-estimate calculation.

W1(I) Define criteria for disintegration of fuel rods during quench. Default value: 1

1 = Criteria does not use maximum fuel temperature at the axial node in period from start of accident to present time.

2 = Criteria does use maximum fuel temperature at the axial node in period from start of accident to present time.

W2(R) Temperature above saturation at which rod fragmentation occurs during quench. Default value: 100.

Figure A17-1. Definition of user-defined residual flow area after fuel melting for outermost flow channel in reactor core.

A18.1.7 Card 40000400, Gamma Heating

This card is optional for a NEW problem, and cannot currently be changed for RESTART problems.

W1(R) Gamma heat fraction. The fraction of power used to directly heat the coolant by gamma heating. The default is 0.026, and the range a is $0.0 \leq x \leq 0.057$. The upper limit is based on the fission of ^{235}U.

A18.1.8 Card 40000500, Cladding Deformation

This card is optional for either NEW or RESTART problems and is used to define cladding ballooning parameters. Strain values must be input as real hoop strain, $\varepsilon = \dfrac{r - r_i}{r}$ where r is the radius of the fuel rod and r_i is the initial radius of the fuel rod.

W1(R) Rupture strain. The strain at which the cladding will rupture. The default is 0.18 and the range is 0.0 < x < W3.

W2(R) Transition strain. Strain for transition from sausage type deformation to localized deformation. The default is 0.20 and the range is 0.0 < transition strain ≤ W3, W2(R) must be greater than W1(R).

W3(R) Limits strain. Strain limit for rod-to-rod contact. The default is 0.33 and the range[1] is $0.0 \geq \text{range} \leq \dfrac{p-2r}{p}$ where p is pitch of the fuel rods and r is the fuel rod radius. The strain limit is based on rod to rod contact.

W4(I) Pressure drop flag. Flag for modeling pressure drop due to ballooning. The default is 0.

0 = Pressure drop caused by ballooning is modeled.

1 = Pressure drop caused by ballooning is not modeled.

A18.1.9 Card 40000600, Source of Component Power Data

This card is required for NEW problems, and may be changed for RESTART problems. The purpose of this card is to specify how the time-dependent core power is specified to RELAP5-SCDAP. A subsequent component-specific card (40CC1100) specifies the fraction of core power to be deposited in each component. Power in either molten pool or porous debris will be modified according to core power.

W1(A) Source of data (‘table’, ‘cntrlvar’ or ‘kinetics’).

W2(I) Table or control variable number (if necessary).

If the ‘kinetics’ option is specified, then the component power is calculated by the RELAP5 kinetics model. If the time-dependent core power is specified with either reactor kinetics or general table the units will be handled internally. If specified by a control variable, the power should be calculated in watts.

A18.1.10 Card 40001000, Grid Spacer Elevation

This card is optional and is used to define the elevation of each grid spacer. If this card is not used, then no grid spacers will be modeled. It may not be changed on RESTART.

W1(R) Elevation (m, ft). Elevation of the first grid spacer. The bottom of the core is at elevation zero.

WN(R) Elevation (m, ft). Elevation of the grid spacer n. The bottom of the core is at elevation zero. The range is 0.0 m < x ≤ 10.0 m.

1. Based on rod-to-rod contact.

A18.1.11 Cards 40001001 through 40001099, Grid Spacer Description

This card is required for a NEW problem only if a grid spacer elevation has been specified. This card cannot be changed for RESTART problems. Sequential expansion format is used.

W1(I) Grid spacer material. Input one word per spacer.

0 = Zircaloy.

1 = Inconel.

W2(R) Mass of grid spacer (kg, lb_m). Mass per rod. Total mass of spacer divided by number of rods in array. The range is 0.0 kg < x $\leq$ 0.004 kg.

W3(R) Height of grid spacer (m, ft). The range is 0.0 m < x < 0.125 m.

W4(R) Plate thickness of grid spacer (m, ft). The range is 0.0 m < x $\leq$ 0.01 m.

W5(R) Radius of contact (m, ft). The radius of a circle which will have the same area as the contact area between the grid spacer and the fuel rod cladding. The range is 0.0 m < x $\leq$ 0.002 m.

W6(I) Grid spacer number. Sequential expansion applies.

A18.1.12 Card 40001100, Definition of Core Slumping Model

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

W1(I) Indicator of model for determining when a pool of molten material in the core region slumps.

0 = Model that results in latest possible slumping (default).

1 = Model that results in earliest possible slumping.

A18.1.13 Cards 40001101 through 40001199, Core Bypass Volume Identification

These cards are used to specify the core bypass hydrodynamic volume, which are used by model for radial spreading of core melt. These cards are required for a NEW problem and may not be changed during RESTART problems.

W1(I) RELAP5 hydrodynamic volume.

WN(I) RELAP5 hydrodynamic volume.

A18.1.14 Cards 40001201 through 40001299, Core Bypass Volume Elevations

These cards are used to specify the elevations of the core bypass volumes identified on Cards 40001101 through 40001199. The elevations are referenced from the bottom of the core to the top of each RELAP5 control volume.

W1(R) Elevation of bypass volume 1 (m, ft). Distance from bottom of core to top of bypass volume 1.

WN(R) Elevation of bypass volume n (m, ft). Distance from bottom of core to top of bypass volume n.

A18.1.15 Card 40002000, Core Slumping Control Card

For a NEW RELAP5-SCDAP problem, this card is required with at least the first two words present. A default value is provided for the remaining input. For a RESTART run, this card is optional. For Words 2 through 8, if input values are absent or are < 1×10^{-9}, respective constants will be obtained from the restart file.

W1(I) Number of the RELAP5 control volume to receive any slumped core material.

W2(I) RELAP5 volume at top center of core. The bottom of this volume should be contiguous with the top of the core. This word may not be changed on RESTART.

W3(R) Minimum flow area per fuel rod in cohesive debris in core region (m^2). The default is 1.4×10^{-6} m^2. This parameter is used as follows: Let $A_0 = (\text{pitch}^2 - \pi d_r^2)/4$ where d_r = diameter of rods, then if W3/A_o > 0.1, cohesive debris formation does not result in complete flow blockage; otherwise it does. If the total number of flow channels are two or less, W7(R) ≤ $0.5A_0$.

A18.1.16 Card 40002200, User Defined Core Slumping

This card is optional in a NEW problem, and may not be used in a RESTART problem. This card allows the user to input a slump of molten material, either to the lower plenum or into an in-core molten pool.

W1(R) Time at which material from upper plenum or core plate slumps (s).

W2(R) Mass of material that slumps from upper plenum region or core plate at time of Word 1 (kg). This material is assumed to be stainless steel at its liquidus temperature of 1,727 K.

W3(I) Parameter controlling user-definition of material slumping to lower head.

1 = Material slumps to lower head.

2 = Material slumps to in-core molten pool. If in-core molten pool does not exist, material slumps to lower head.

A18.2 User Defined Options

A limited number of options have been implemented within the RELAP5-SCDAP code to allow the development staff to enable or disable specific models during model assessment, as well as to debug problems. These options are activated (or deactivated) by entering a card with a sequence number equal to or greater than 40004001 and less than or equal to 40004999. The first word should be a recognized keyword from Table 6. and the second word should be a value as described by the second column. The default value for all keywords is ‘off’. It should be noted that the keywords and their actions are subject to change, and therefore should be used with caution. These cards are optional on either NEW or RESTART problems.

Table 6: User Defined Options

hydrogen	on/off	When ’off’, all oxidation calculations are performed but hydrogen is not released to the coolant stream.
balloon	on/off	When ’off’, cladding deformation calculations are disabled.
truncate	on/off	When ’off’, heat flux to coolant is limited.
convect	on/off	When ’off’, convection heat transfer is disabled.
radiate	on/off	When ’off’, radiation heat transfer is disabled.
oxidate	on/off	When ’off’, oxidation models are disabled.
svecha	on/off	IBRAE developed component models.

A18.3 Debris Bed Characteristics

The debris cards are optional and may be entered for NEW problems only. The debris bed cards allow the formation of a user-specified debris bed at a user-specified problem time. These cards are intended to be used for debris bed model assessment only. Enter one card for each fuel rod component. All debris cards will self-expand i.e., if there are not a sufficient number of words on a card, the last word entered will be repeated to fill the required words needed for that card during input processing. It is recommended that component numbers be ordered in the sequence that they are located in the reactor core, with the sequence beginning at the center of the core and advancing to the periphery of the core. This ordering makes the printed core degradation map easy to understand. The group of fuel rods at the center of the core should be identified as component number 1 (CCC = 001), and the group of fuel rods at the periphery of the core should have the largest component number for fuel rods. Control rods should be assigned a component number that is one digit greater than the component number of the fuel rods that surround them. Water rods (represented by SCDAP as fuel rods with no fuel pellets), should be assigned a component number that is two digits greater than the component number of the fuel rods that surround them.

A18.3.1 Cards 40002001 through 40002020, Time

W1(R) Time of debris bed formation (s). Enter the time of debris bed formation for each axial node 1.

WN(R) Time of debris bed formation (s). Enter the time of debris bed formation for each axial node n. The default value is 1×10^{30}.

A18.3.2 Cards 40002021 through 40002040, Porosity

W1(R) Porosity. Enter the debris bed porosity at each axial node 1.

WN(R) Porosity. Enter the debris bed porosity at each axial node n. The range is $0.0 \leq x \leq 1.0$. The default value is 0.54.

A18.3.3 Cards 40002041 through 40002060, Particle Diameter

W1(R) Particle diameter (m). Enter the particle diameter at each axial node.

WN(R) Particle diameter (m). Enter the particle diameter at each axial node. The default value is 0.00087 m.

A18.3.4 Cards 40002061 through 40002080, Stainless Steel Mass

This card is optional. If entered the mass of UO_2 will be reset to zero.

W1(R) Mass of stainless steel (kg). The mass of stainless steel at each axial node 1 per fuel rod.

WN(R) Mass of stainless steel (kg). The mass of stainless steel at axial node n per fuel rod.

A18.3.5 Cards 40002081 through 40002099, Zircaloy Mass

W1(R) Mass of zircaloy (kg). Enter the mass of zircaloy at each axial node, 1 per fuel rod.

WN(R) Mass of zircaloy (kg). Enter the mass of zircaloy at axial node n per fuel rod.

A18.4 User-Specified Materials

Indices for material properties are listed in Table 7. Most of the material properties are defined within the code and the user does not define the properties through input data. But if the user specifies material properties for Material Indices 9, 10, 11, or 12, on Card 40CC0300 for a "shroud" type of component, the user must define the properties through input data. Materials 50 through 59 if used must also be defined by the user through input data. Materials 50 through 59 are entered as pairs, the even index being the material and the odd index being the oxide.

Table 7: User-Specified Material

Index	Material
1	Zircaloy
2	Zr-U-O mixture (liquid)

Index	Material
3	Zr-U-O mixture (frozen)
4	Tungsten
5	ZrO_2
6	Unirradiated fuel, UO_2
7	Cracked fuel, UO_2
8	Relocated fuel, UO_2
9	Steam-gas atmosphere. User may specify properties.
10	User-specified properties.
11	User-specified properties.
12	User-specified properties.
13	Metallic uranium
14	Disabled
15	Aluminum
16	Al_2O_3
17	Lithium
18	Stainless steel 3304
19	Stainless steel oxide
20	Control rod absorber material (Ag/In/Cd or B_4C)
59-59	User specified material properties

Two formats are provided for entering user specified materials, a fixed table format and a general table format. Each material may use either format.

For the fixed table format, material properties as a function of temperature are defined by a table of ten pairs of values, with the material temperature as the independent variable and the material property as the dependent variable. All materials use ten pairs and the temperatures are built into the code and not entered as user input. The temperatures in degrees Kelvin are defined in the table as follows:

300, 550, 700, 873, 1,083, 1,173, 1,248, 1,700, 2,100, 2,500

The general table format uses general tables to define the properties. This format allows the user to select the number of pairs and the temperature distribution.

Cards 40009NN0, 40009NN1, 40009NN2, and 40009NN3 are used for each material to be specified, where NN is the material number whose properties are being specified.

A18.4.1 Card 40009NN1, Specific Heat

This card is required for the fixed format in NEW problems and cannot currently be input for RESTART problems. Note that the user may specify properties only for Materials 9, 10, 11, 12, and 50 through 59. This card is not used when the general table format is used.

W1(R) Material specific heat at the ten values of temperatures shown above (J/kg·K).

A18.4.2 Card 40009NN2, Density

This card is required for the fixed format in NEW problems and cannot currently be input for RESTART problems. Note that the user may specify properties only for Materials 9, 10, 11, 12 and 50 through 59. This card is not used when the general table format is used.

W1(R) Material densities at the ten values of temperatures shown above (kg/m^3).

A18.4.3 Card 40009NN3, Thermal Conductivity

This card is required for the fixed format in NEW problems and cannot currently be input for RESTART problems. Note that the user may specify properties only for Materials 9, 10, 11, 12 and 50 through 59. This card is not used when the general table format is used.

W1(R) Material thermal conductivity at the ten values of temperatures shown above (W/m·K).

A19. CORE COMPONENTS

The reactor core is described by a group of components. Each component may represent one or more core elements.

A19.1 Fuel Rod Component

This component describes a group of UO_2 fuel rods. All of the fuel rods that are described by this component are assumed to behave identically. Multiple groups of fuel rods may be described.

A19.1.1 Card 40CC0000, Fuel Rod Component

This card is required for fuel rod components and may not be input for RESTART calculations.

W1(A) Component name. An eight-character name that should be descriptive of this component.

W2(A) Component keyword. Enter the four-character word “fuel.”

A19.1.2 Card 40CC0100, Number of Rods

This card is required for fuel rod components, and may not be input for RESTART calculations.

W1(I) Number of rods. Number of rods simulated by this component. All rods simulated by a single component are assumed to behave identically.

W2(R) Fuel rod pitch (m, ft.). The distance from fuel rod center to fuel rod center of adjacent fuel rods. The range[11] is 0.0126 M $\leq x \leq$ 0.0187 m.

W3(R) Average burnup of fuel (MW-s/kg). This word is optional. The default is 0.0 and the range is $0.0 \leq x \leq 4752000.0$ (MW-s/kg).

A19.1.3 Card 40CC0200, Fuel Rod Plenum Geometry

This card is required for fuel rod components and may not be input for RESTART calculations. The volume input is used in the calculation of internal gas pressure.

W1(R) Plenum length (m, ft.). The range is between 3% and 11% of the rod length.

W2(R) Plenum void volume (m^3, ft^3). Enter the plenum volume less the volume occupied by the spring. The range is $0.0 < x < 0.000049$ m^3.

W3(R) Lower plenum void volume (m^3, ft^3). Enter the gas volume of the lower fuel rod plenum.

A19.1.4 Cards 40CC0301 through 40CC0399, Fuel Rod Dimensions

This card is required for fuel rod components, and may not be input for RESTART calculations. Radial dimensions of the fuel rod materials are specified for each axial node.

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1. All fuel performance and rod geometry values are based on NUREG/CR-3950, PNL-5210, Vol.

W1(R Fuel pellet radius (m, ft.). The range is 0.00385 m $\leq$ x $\leq$ 0.00685 m. If this component represents a water rod, then define a fuel pellet radius of 1 x 10^{-4} m.

W2(R) Inner cladding radius (m, ft.). The range is W1 < x < W3 and 0.003935 m $\leq$ x $\leq$ 0.00634 m.

W3(R) Outer cladding radius (m, ft.). The range is $W2 < x < \frac{\text{W2-Card4ccc0100}}{2}$ and 0.00457 m $\leq$ x $\leq$ 0.00715 m.

W4(I) Axial node.

A19.1.5 Card 40CC0400, Upper and Lower Hydraulic Volumes

This card is required for fuel rod components and may not be input for RESTART calculations. Specified on this card are the RELAP5 control volumes which will act as heat sinks for bottom crust of a molten pool or for top crust of a molten pool.

W1(I) RELAP5 control volume located just above fuel rod.

W2(I) RELAP5 control volume located just below fuel rod.

A19.1.6 Cards 40CC0401 through 40CC0499, Hydraulic Volumes

This card is required for fuel rod components and may not be input for RESTART calculations. It specifies the RELAP5 hydraulic volumes that provide the boundary conditions for the core component. A hydraulic volume must be specified for each axial node of the component, but the same hydraulic volume may be specified for a number of axial nodes. The style of this card, specifying a volume number and an increment, has been designed to match the style RELAP5 uses to specify left and right boundary conditions for the heat structures. The user is referred to Cards 1CCCG501, in the RELAP5 heat structure specification, for further information.

W1(I) RELAP5 control volume number. This word specifies the hydrodynamic control volume number (of the form CCCNN0000) associated with the surface of this component. One volume number must be specified for each axial node of the component, starting with the bottom node (Node 1).

W2(I) Increment. This word (of the form NN0000) and W1 of this card are treated differently from the standard sequential expansion. W1 applies to the first axial node within a set. The increment is applied to W1 to obtain the volume connected to the next axial node. The increment is repeated up to the axial node identified by W3. W1 of the next set applies to the next axial node, and increments are applied as for the first set. The increment may be zero or nonzero, positive or negative.

W3(I) Axial node.

A19.1.7 Cards 40CC0501 through 40CC0599, Radial Mesh Spacing

This card is required for fuel rod components and may not be input for RESTART calculations. This card specifies the radial nodalization. To correctly interpret the nodalization, all numbers for a specific axial node must be specified with a single card number. Use continuation cards if necessary. The radial nodalization may be specified by either of two formats, but not both.

Format 1

Specify the number of intervals to be used across each material. The code will divide the radial distance across each material into the number of equally spaced mesh intervals specified. The number of radial nodes will be n+1, which is the total number of intervals plus one.

W1(I) Number of equally spaced intervals across fuel.

W2(I) Number of intervals across gap. One interval is recommended.

W3(I) Number of equally spaced intervals across cladding.

W4(I) Axial node number.

Format 2

Specify the radial position of each radial node for each axial node. In this format, the user must be careful to input the same number of radial nodes for each axial node, although the position of the radial nodes may be changed for each axial node.

W1(R) Radius to radial node 1 (m, ft). Enter pellet center radius of 0.0.

WN(R) Radius to radial node N (m, ft.). Enter radial node N. Radial nodes must be placed at least at the material interfaces (i.e., fuel pellet radius, and cladding inner radius). Radial nodes must be entered in ascending order and end with the last node placed on the cladding outer surface.

WN+1(I) Axial node.

A19.1.8 Cards 40CC0601 through 40CC0699, Initial Temperatures

This card is required for fuel rod components, and may not be changed on RESTART calculations.

W1(R) Temperature (K, ^{o}F). Initial temperature at Radial Node 1. The range is 300 K $\leq$ x $\leq$ 3,123 K.

W (R) Temperature N (K, ^{o}F). Enter an initial temperature for each radial node to radial node N, which is the last radial node. The range is 300 K $\leq$ x $\leq$ 3,123 K.

WN+1(I) Axial node. Input temperature at each radial node.

A19.1.9 Card 40CC0801 through 40CC0899, Material Specification

This card is optional for NEW, and may not be changed on RESTART calculations. The user may specify material indices for the components. At least three material indices should be input.

W1(I) Material index for material layer closest to center of rod.

W2(I) Material index for next material layer.

WN(I) Material index for nth material layer.

The defaults for a fuel rod component are UO_2 (index=6), Gap (index=9), and Zircaloy (index=1).

Refer to Table 7 for a list of material indices.

A19.1.10 Card 40CC1100, Power Multiplier

This card is optional for NEW and RESTART problems, and specifies the fraction of total core power which is generated in this component. The approach to specify power is as follows. First, a total core time-dependent power is specified (Section A18.1.9). Then a component power multiplier (this card) is used to determine the fraction of core power deposited in this fraction. The power in a single fuel rod can then be determined by dividing the component power by the number of fuel rods represented by this component. The linear heat generation rate at an individual axial node is determined by multiplying the rod power by an axial power profile factor (Section A19.1.11 & Section A19.1.12) and dividing by the axial node length. The power density at a specific radial node can then be determined by multiplying the local linear heat generation rate by the radial power factor (Section A19.1.13) and dividing by the cross-sectional area associated with that radial node.

W1(R) Fraction. This is the fraction of the core power in this component. The range for this power multiplier is $0.0 \leq x \leq 1.0$, and the default is 0.0.

A19.1.11 Card 40CC13P0, Axial Power Profile Time

In the card number, "P" is axial power profile number (start with Number 1). This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) End time for which this axial power profile applies (s).

A19.1.12 Cards 40CC13P1 through 40CC13P9, Axial Power Profile Data

Card numbering is specified similarly to the previous card, with "P" in the card number indicating the axial power profile number. This information is required for each profile and must be specified for each axial node of the component. This input specifies the fraction of rod power which is deposited at the axial node. The axial power fraction will be normalized over the length of the component.

W1... (R) Axial power factor at axial nodes. The range is $0.1 \leq x \leq 1.4$, and the default is 1.0.

A19.1.13 Cards 40CC1401 through 40CC1499, Radial Power Profile

This card is required for NEW problems and cannot currently be input for RESTART problems. The radial power factor is used to determine the power density at each radial node, based upon the local heat generation rate.

W1(R) Radial power factor.

W2(I) Radial node at which W1(R) applies. The last radial node that is input must align with the outer radius of the fuel pellet. The range is $x \leq 20$, and the default power factor is 1.0.

A19.1.14 Card 40CC1500, Shutdown Time and Fuel Density

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) Time of reactor shutdown (s). This word is required.

W2(R) Fraction of fuel theoretical density. This word is required. The range of the faction of fuel theoretical density is $0.94 \leq x \leq 0.96$.

A19.1.15 Cards 40CC1601 through 40CC1699, Previous Power History

This card is optional for NEW problems and may not currently be changed on RESTART problems. A prior power history is required to initialize the fission product inventory (PARAGRASS). It is assumed that either a prior power history or the initial fission product inventory (see next card) will be specified prior to enabling the PARAGRASS calculation. The power is assumed to be a series of plateaus, with no interpolation. The last power density in this table is the transient power density until the problem time exceeds the shutdown time. Time in this table is referenced to the start of the operation of the reactor and not to the start of the time in the transient analysis.

W1(R) Power history (W/m^3). The range is 40.57×10^6 $W/m^3 \leq x \leq 279.3\times10^6$ W/m^3.

W2(R) Time (s).

A19.1.16 Card 40CC2000, Fission Products Tracked by PARAGRASS Model

This card is optional for fuel rod components and may not be input for RESTART calculations. This card is entered when initial inventory of fission products is not to be calculated by the code based on prior power history.

W1... (A) Species name. Enter the species (Xe, Kr, Cs, I) to be tracked.

A19.1.17 Cards 40CC2001 through 40CC2099, PARAGRASS Species Mass

This card is required only if Card 40CC2000 above is entered.

W1(R) Mass of species (kg, lb/m). Enter the initial mass of the first species specified on Card 40CC2000.

WN(R) Mass of species N (kg, lb/m). Enter the initial mass of the next species specified on Card 40CC2000 and repeat until all species masses specified on Card 40CC2000 have been entered.

A19.1.18 Card 40CC2100, Fission Products to be Tracked by CORSOR Model

This card is optional and may not be changed on RESTART calculations.

W1... (A) Species name. Enter the species (Te, Zr, Sr, Fe, Ru, Zr*, Ba) to be tracked.

A19.1.19 Cards 40CC2101 through 40CC2199, Initial Fuel Fission Product Mass

This card is required only if Card 40CC2100 above is present.

W1(R) Mass of species (kg, lb/m). Enter the initial mass of the first species specified on Card 40CC2100.

WN(R) Mass of species N (kg, lb/m). Enter the initial mass of the next species specified on Card 40CC2100 and repeat until all species masses specified have been entered.

A19.1.20 Card 40CC2200, Gap Fission Products

This card is optional and may not be changed on RESTART calculations. This card is normally omitted so that inventory of fission products in fuel-cladding gap is defined by the codes' fission gas release model.

W1... (A) Species name. Enter the species (Xe, Kr, Cs, I, Te) to be tracked.

A19.1.21 Cards 40CC2201 through 40CC2299, Initial Gap Fission Product Mass

This card is required only if Card 40CC2200 is present.

W1(R) Mass of species (kg, lb/m). Enter the initial mass of the first species specified on Card 40CC2200.

WN(R) Mass of species N (kg, lb/m). Enter the initial mass of the next species specified on Card 40CC2200 and repeat until all species masses specified have been entered.

A19.1.22 Card 40CC3000, Gas Internal Pressure

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) Helium gas as-fabricated inventory in an individual fuel rod in this component group (kg).

W2(R) Internal gas pressure in rod (Pa). (This value is used only to define a first guess of initial internal pressure for iteration procedure, so accurate values not required.)

A19.1.23 Cards 40CC3201 through 40CC3299, Time-Temperature-Pressure Profile

This card is optional for NEW problems. If omitted, no variation occurs in boundary conditions for calculating temperature distribution in fuel rod during burnup period before transient. This card cannot currently be input for RESTART problems. This card is normally omitted.

W1(R) Time (s). The time to which the axial surface temperature profile and fuel average hydrostatic pressure are used

W2(R) Cladding surface temperature (K).

W3(R) Fuel hydrostatic pressure (Pa).

A19.1.24 Card 40CC4000, Option Definition

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1(A) Keyword to identify optional model to be applied.

W2(A) Flag specifying whether to apply model. ('on' or 'off').

The default for each model is 'off'. See Table 8.

Table 8: Component Optional Models

Keyword	Value	Meaning if On
limit	on/off	oxidation is limited due to rate of steam diffusion through hydrogen

A19.1.25 Cards 40CC5101 through 40CC5199, Gap Conductance

This card is optional and may not be changed on RESTART. The intended use is to allow the SCDAP calculated steady-state temperature profile to better match an independent steady-state temperature profile by specifying the steady-state gap conductance. If this card is not entered, the gap conductance will be calculated by the code. Sequential expansion applies.

W1(R) Gap conductance at steady-state conditions just before start of transient ($W/m^2 \cdot K$, $Btu/ s \cdot ft^2, {}^oF$)

W2(I) Axial node.

A19.1.26 Cards 40CC5201 through 40CC5299, Fuel Thermal Conductivity

This card is optional and may not be changed on RESTART. Sequential expansion applies.

W1(R) Fuel thermal conductivity multiplier. The default is 1.0.

W2(I) Axial node.

A19.2 Simulator Component

This input describes a group of electrically heated fuel rod simulators.

A19.2.1 Card 40CC0000, Simulator Component

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) Component name.

W2(A) Component type -- cora.

A19.2.2 Card 40CC0100, Number of Rods

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) Number of rods.

W2(R) Rod pitch (m). The range is $0.0126 \text{ m} \leq x \leq 0.0187 \text{ m}$.

W3(R) Radius of tungsten filament (m).

A19.2.3 Card 40CC0200, Simulator Rod Geometry

This card is required for NEW problems and cannot currently be input for RESTART problems.

W2(R) Plenum volume (m^3). The range is $0.0 \leq x \leq 0.000049$ m^3.

A19.2.4 Card 40CC0250, Upper Plenum Boundary Conditions

This card describes the source of sink temperature data to be used to model axial heat conduction calculations from the top of the simulator rod. This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1(A) Keyword. The default is no axial heat conduction is modeled.

control = sink temperature defined by control variable

table = sink temperature define by general table

W2(I) Upper boundary control variable or RELAP5 table number.

A19.2.5 Card 40CC0251, Lower Plenum Boundary Conditions

This card describes the source of sink temperature data to be used to model axial heat conduction calculations from the bottom of the simulator rod. This card is optional for NEW problems, and cannot currently be input for RESTART problems.

W1(A) Keyword. The default is no axial heat conduction is modeled.

control = sink temperature defined by control variable.

table = sink temperature define by general table.

W2(I) Lower boundary control variable or RELAP5 table number.

A19.2.6 Cards 40CC0301 through 40CC0399, Simulator Dimensions

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) Fuel pellet radius (m). The range is 0.00385 m $\leq x \leq 0.00685$ m.

W2(R) Inner cladding radius (m). The range is $W1 < x < W3$ and 0.003935 m $\leq x \leq$ 0.00634 m.

W3(R) Outer cladding radius (m). The range is and 0.00457 m $\leq x \leq 0.00715$ m.

W4(I) Axial node number.

A19.2.7 Card 40CC0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 volume located above simulator rod.

W2(I) RELAP5 volume located below simulator rod.

A19.2.8 Cards 40CC0401 through 40CC0499, Hydraulic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 volume number. One volume number for each axial node, starting with Node 1.

A19.2.9 Cards 40CC0501 through 40CC0599, Radial Mesh Spacing

This card is required for NEW problems and cannot currently be input for RESTART problems. The information may be entered in either Format 1 or 2, but not both.

Format 1

Specify the number of intervals to be used across each material. The code will divide the radial distance across each material into the number of equally spaced mesh intervals specified. The number of radial nodes will be n+1, which is the total number of intervals plus one.

W1(I) Number of equally spaced intervals across the fuel.

W2(I) Number of intervals across gap. One interval is recommended.

W3(I) Number of equally spaced nodes across the cladding.

W4(I) Axial node number.

Format 2

Specify the radial position of each radial node for each axial node. In this format, the user must be careful to input the same number of radial nodes for each axial node, although the position of the radial nodes may be changed for each axial node.

W1(R) Radius to radial node 1 (m, ft). Enter pellet center radius of 0.0.

WN(R) Radius to radial node N (m, ft.). Enter radial node N. Radial nodes must be placed at least at the material interfaces (i.e., fuel pellet radius, and cladding inner radius). Radial nodes must be entered in ascending order and end with the last node placed on the cladding outer surface.

WN+1(I) Axial node.

A19.2.10 Cards 40CC0601 through 40CC0699, Initial Temperatures

These cards use both axial and radial self-expansion. They are required for NEW problems and cannot currently be input for RESTART problems.

W1... (R) Initial temperature at radial node 1 (K). The range is $300 \text{ K} \leq x \leq 3{,}123 \text{ K}$.

A19.2.11 Card 40CC1100, Power Multiplier

This card is optional for NEW and RESTART problems, and specifies the fraction of total core power which is generated in this component. The approach to specify power is as follows. First, a total core time-dependent power is specified (Section A18.1.9). Then a component power multiplier (this card) is used to determine the fraction of core power deposited in this fraction. The power in a single simulator can then be determined by dividing the component power by the number of simulators represented by this component. The linear heat generation rate at an individual axial node is determined by multiplying the rod power by an axial power profile factor (Section A19.2.12 & Section A19.2.13) and dividing by the axial node length. The power density at a specific radial node can then be determined by multiplying the local linear heat generation rate by the radial power factor (Section A19.2.14) and dividing by the cross-sectional area associated with that radial node.

W1(R) Fraction. This is the fraction of the core power in this component. The range for this power multiplier is $0.0 \leq x \leq 1.0$, and the default is 0.0.

A19.2.12 Card 40CC13P0, Axial Power Profile Time

In the card number, "P" is axial power profile number (start with Number 1). This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) End time for which this axial power profile applies (s).

A19.2.13 Cards 40CC13P1 through 40CC13P9, Axial Power Profile Data

Card numbering is specified similarly to the previous card, with "P" in the card number indicating the axial power profile number. This information is required for each profile and must be specified for each axial node of the component. This input specifies the fraction of rod power which is deposited at the axial node. The axial power fraction will be normalized over the length of the component.

W1... (R) Axial power factor at axial nodes. The range is $0.1 \leq x \leq 1.4$, and the default is 1.0.

A19.2.14 Cards 40CC1401 through 40CC1499, Radial Power Profile

This card is required for NEW problems and cannot currently be input for RESTART problems. The radial power factor is used to determine the power density at each radial node, based upon the local heat generation rate.

W1(R) Radial power factor.

W2(I) Radial node at which W1(R) applies. The last radial node that is input must align with the outer radius of the fuel pellet. The range is $x \leq 20$, and the default power factor is 1.0.

A19.2.15 Card 40CC9000, Volume of External Volumes

This card is optional for NEW problems and cannot currently be input for RESTART problems. This card specifies the volume of external volumes which may be attached to the void volume of electrical heater rods.

W1... (R) Volume of external volumes (m^3, ft^3). Up to 10 external volumes may be specified.

A19.2.16 Cards 40CC9001 through 40CC9099, Temperature History of External Volumes

This card is optional for NEW problems and cannot currently be input for RESTART problems. This card is used to specify the temperature history of external volumes which were specified in Section A19.2.15. The format of the card is to specify one point in the time-dependent temperature history of each volume.

W1(R) Time (s).

W2... (R) Temperature of external volume. Word 2 is repeated for each external volume specified by card 40CC9000. A maximum of 10 time points may be specified.

A19.3 PWR Control Rod Component

A19.3.1 Card 40CC0000, PWR Component Identification

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) Component name.

W2(A) Component type -- control.

A19.3.2 Card 40CC0100, Number of Rods

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) Number of rods. The range is $1 \leq x$.

W2(R) Control rod pitch (m). If a fuel rod component is entered, the control rod pitch should be equal to the pitch of the fuel rod, if it is in the same bundle.

A19.3.3 Card 40CC0300, Materials

This card is optional for NEW problems and cannot currently be input for RESTART problems. The materials identified by default are control rod absorber material (Ag-In-Cd for PWR's, B_4C for BWR's), stainless steel, and zircaloy. If as little as one material is specified, all default materials are ignored. If this card is not entered, then three materials are assumed. Material 1 is assumed to be Ag-In-Cd for PWR's, B_4C for BWR's, material 2 is assumed to be stainless steel, material 3 is assumed to be zircaloy. Other materials may be specified by using the material indices specified in Table 7. This card is intended to specify materials for non-standard control rod configurations.

W1(I) Absorber material index. Material index for control rod absorber.

W2(I) Sheath material index. Material index for control rod sheath.

WN(I) Guide tube material index. Material index for guide tube.

A19.3.4 Card 40CC0301 through 40CC0399, Geometry

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) Outer radius of control rod absorber (m, ft). The range is $0.0 < x < W2$.

W2(R) Outer radius of stainless steel sheath (m). The range is $W1 < x \leq W3$.

W3(R) Inner radius of zircaloy guide tube (m). The range is $W2 \leq x < W4$.

W4(R) Outer radius of zircaloy guide tube (m).

W5(I) Axial node for sequential expansion.

A19.3.5 Card 40CC0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 control volume located above control rod.

W2(I) RELAP5 control volume located below control rod.

A19.3.6 Cards 40CC0401 through 40CC0499, Hydraulic Volumes

This card specifies the RELAP5 hydrodynamic control volume which provides the boundary conditions for the control rod. A hydrodynamic volume must be specified for each axial node of the component. The style of this card, i.e., specifying a hydrodynamic volume number and an increment, has been chosen to match the style used by RELAP5 to specify heat structure left and right boundary conditions. This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 volume number.

W2(I) Increment.

W3(I) Axial node. Sequential expansion applies.

A19.3.7 Cards 40CC0501 through 40CC0599, Radial Mesh Spacing

This card is required for NEW problems and cannot currently be input for RESTART problems. This card may be entered in either Format 1 or 2, but you may not mix formats. A minimum of five radial nodes are required. Up to 20 radial nodes may be used. Nodes must be entered in consecutive order beginning with the first node at r = 0. Other required radial nodes must be placed at the outer radius of absorber material, the outer radius of stainless steel sheath, and the inner and outer radius of the zircaloy guide tube.

Format 1:

W1(I) Number of equally spaced intervals across the absorber material.

W2(I) Number of equally spaced intervals across the stainless steel sheath.

W3(I) Number of equally spaced nodes across the zircaloy guide tube.

W4(I) Axial node number for sequential expansion.

Format 2:

W1(R) Radial mesh spacing (m). Radial dimension of Node 1.

WN(R) Radial mesh spacing (m). Radial dimension of Node N.

WN+1(I) Axial node number.

Sequential expansion applies to this input.

A19.3.8 Cards 40CC0601 through 40CC0699, Initial Temperatures

This card is required for control rod components and may not be changed on RESTART calculations.

W1(R) Temperature (K, ^{o}F). Initial temperature at Radial Node 1. The range is 300 K $\leq$ x $\leq$ 3,123 K.

WN(R) Temperature N (K, ^{o}F). Enter an initial temperature for each radial node to radial node n, which is the last radial node. The range is 300 K $\leq$ x $\leq$ 3,123 K.

WN+1(I) Axial node. Input temperature at each radial node.

A19.3.9 Card 4ccc0700, Internal Gas Pressure

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) INTERNAL GAS PRESSURE (Pa)

A19.3.10 Card 4ccc0800, Mass of Silver

This card is not currently used. It is intended to be used for aerosol transport and deposition.This feature is not in the current versions of the code.

W1(R) TOTAL MASS OF TIN IN ALL RODS OF THIS COMPONENT (kg)

W2(R) TOTAL MASS OF SILVER IN ALL RODS OF THIS COMPONENT (kg)

A19.4 BWR Control Rods

A19.4.1 Card 40CC0000, Component Identification

W1(A) Component name. Descriptive of role in system.

W2(A) Component type -- bwr.

A19.4.2 Card 40CC0100, Number of Rods

W1(I) Number of rods in component.

A19.4.3 Cards 40CC0301 through 40CC0399, Geometry

W1(R) Outer radii for B_4C absorber. The range is 0.0 m < x < W2.

W2(R) Stainless steel cladding outer radii. The range is W1 < x < 0.00935 m.

W3(I) Axial number for sequential expansion.

A19.4.4 Card 40CC0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and may not be changed for RESTART problems.

W1(I) RELAP5 volume located above BWR rod.

W2(I) RELAP5 volume located below BWR rod.

A19.4.5 Cards 40CC0401 through 40CC0499, Hydraulic Volumes

This card is required for NEW problems and may not be changed for RESTART problems.

W1(I) RELAP5 volume number.

W2(I) Increment.

W3(I) Axial node. Sequential expansion applies.

A19.4.6 Cards 40CC0601 through 40CC0699, Initial Temperatures

This card is required for NEW problems and may not be changed for RESTART problems.

W1(R) B_4C absorber initial temperature (K, ^oF). The range is 300 K ≤ x ≤ 1723 K.

W2(R) Stainless steel cladding initial temperature (K, ^oF). The range is 300 K ≤ x ≤ 1723 K.

W3(I) Axial Node.

A19.5 BWR Control Blade/Channel Box Component

These cards contain physical dimensions, hydraulic information, initial conditions, and radial spreading information for each BWR blade/channel box component.

A19.5.1 Card 4CCC0000, Component Name and Type

This card is required for NEW problems and cannot currently be changed for RESTART problems.

W1(A) Component name. This is a descriptive name selected by the user. On most computers, there is an eight-character limit.

W2(A) Component type. Specify the keyword "bladebox."

A19.5.2 Card 4CCC0100, Number of Individual Structures

This card is required for NEW problems and cannot currently be changed for RESTART problems.

W1(I) Number of individual BWR blade/box structures in this component. An individual blade/ box structure consists of half of a control blade divided along the centerline of the row of absorber tubes (other half is symmetric) with length equal to Word 1 on Card 4CCC0300 and a channel box with length equal to the sum of Words 1 and 2 on Card 4CCC0300. The total mass represented by this component is equal to the mass of an individual blade/box structure multiplied by the value on this card. The range is 1 ≤ x.

A19.5.3 Card 4CCC0200, Radial Dimensions

This card is required for NEW problems and cannot currently be changed for RESTART problems.

W1(I) Number of absorber tubes in a control blade wing. This variable is used only to specify the relative proportions of a control blade wing. The length (wetted perimeter) of a control blade is specified in Word 1 on Card 4CCC0300. The range is 1 ≤ x.

W2(R) Inside diameter of stainless steel absorber tube (m, ft). The range is 0.0 ≤ x ≤ 0.0070 m.

W3(R) Thickness of stainless steel absorber tube wall (m, ft). The range is 0.0 ≤ x ≤ 0.0013 m.

W4(R) Thickness of gap between absorber tube and control blade sheath (m, ft). Specify a thickness of 0.0 to eliminate the additional thermal resistance associated with this gap. The range is 0.0 ≤ x ≤ 0.0003 m.

W5(R) Thickness of stainless steel control blade sheath (m, ft). The range is 0.0 ≤ x ≤ 0.0030 m.

W6(R) Distance between control blade and channel box (m, ft). The range is 0.0 ≤ x ≤ 0.0100 m.

W7(R) Thickness of zircaloy channel box wall (m, ft). The range is 0.0 ≤ x ≤ 0.0050 m.

W8(R) Distance between channel box and first row of fuel rods (m, ft). The range is 0.0 ≤ 0.0080 m.

A19.5.4 Card 4CCC0300, Blade/Box Lengths and View Factors

This card is required for NEW problems and cannot currently be changed for RESTART problems.

W1(R) Length (wetted perimeter) of control blade and channel box segment number 1 (m, ft). The range is 0.0 m ≤ x.

W2(R) Length (wetted perimeter) of channel box segment 2 (m, ft). This is the portion of the channel box not adjacent to a control blade. The range is 0.0 m ≤ x.

W3(R) Geometric view factor from channel box segment 1 to control blade. This factor is based on the area of channel box segment 1. The range is 0.0 ≤ x ≤ 1.0.

W4(R) Geometric view factor from channel box segment 2 to control blade. This factor is based on the area of channel box segment 2. The range is 0.0 ≤ x ≤ 1.0.

A19.5.5 Card 4CCC0400, Upper and Lower Volume Numbers

This card is required for NEW problems and cannot currently be changed for RESTART problems

W1(I) Volume number of hydraulic volume just above the fuel bundle volumes specified in Word 1 on Cards 4CCC0401 through 4CCC0499.

W2(I) Volume number of hydraulic volume just below the fuel bundle volumes specified in Word 1 on Cards 4CCC0401 through 4CCC0499.

A19.5.6 Cards 4CCC0401 through 4CCC0499, Volume Connections

These cards are required for NEW problems and cannot currently be changed for RESTART problems. A modified sequential expansion format is used where Words 1 and 2 are incremented by Word 3.

W1(I) Volume number of hydraulic volume connected to fuel bundle side of channel box axial node. This is the first volume number used in the sequential expansion. Each subsequent volume number is generated by adding the increment specified in Word 3.

W2(I) Volume number of hydraulic volume connected to control blade axial node and interstitial side of channel box axial node. This is the first volume number used in the sequential expansion. Each subsequent volume number is generated by adding the increment specified in Word 3.

W3(I) Volume number increment. This increment may be positive, negative, or zero.

W4(I) Axial node number used for the sequential expansion. The node numbers specified on these cards must be in ascending, but not necessarily consecutive, order. The range is $1 \leq x \leq N$, where N is the number of axial nodes specified on Card 400001000

A19.5.7 Card 4CCC0500, Initial Oxide Thicknesses

This card is optional for NEW problems and cannot currently be changed for RESTART problems.

W1(R) Initial thickness of ZrO_2 layer on fuel bundle side of channel box (m, ft). The thicknesses for the two channel box segments and all axial nodes are identical. The default is 0.0 m and the range is 0.0 m $\leq x \leq$ 0.5*W7 on Card 4CCC0200.

W2(R) Initial thickness of ZrO_2 layer on interstitial side of channel box (m, ft). The thicknesses for the two channel box segments and all axial nodes are identical. The default is 0.0 m and the range is 0.0 m $\leq x \leq$ 0.5*W7 on Card 4CCC0200.

W3(R) Initial thickness of stainless steel oxide layer on control blade surfaces (m, ft). The thicknesses for all axial nodes are identical. The default is 0.0 m and the range is 0.0 m $\leq x \leq$ MIN (W3 on Card 4CCC0200, 0.5*W5 on Card 4CCC0200).

A19.5.8 Cards 4CCC0601 through 4CCC0699, Initial Temperatures

This card is required for NEW problems and cannot currently be changed for RESTART problems. A sequential expansion format is used.

W1(R) Initial temperature of control blade (K, ^oF). The temperatures of the three control blade radial nodes are identical at each axial node. The range is $300 \leq x \leq 1,505$ K.

W2(R) Initial temperature of channel box (K, ^oF). The temperatures of the two channel box segments are identical at each axial node. The range is $300 \leq x \leq 1,523$ K.

W3(I) Axial node number used for the sequential expansion. The node numbers specified on these cards must be in ascending, but not necessarily consecutive, order. The range is $1 < x < N$, where N is the number of axial nodes specified on Card 40000100.

A19.5.9 Cards 4CCC0701 through 4CCC0799, Segment 1 Radial Spreading

These cards are optional for NEW problems and cannot currently be changed for RESTART problems. Specify one card for each component that can receive molten material from channel box segment 1. Omit this card if there are no components that can receive molten material from channel box segment 1.

W1(I) Component number of fuel rod or electrically-heated simulator rod component that can receive molten material from channel box segment 1.

W2(R) Mass fraction of molten material from channel box segment 1 received by component specified in Word 1. The range for individual mass fractions is 1.0e-6

≤ x ≤ 1.0. The sum of all mass fractions on Cards 4CCC0701 through 4CCC0799 must be unity.

A19.5.10 Cards 4CCC0801 through 4CCC0899, Segment 2 Radial Spreading

These cards are optional for NEW problems and cannot currently be changed for RESTART problems. Specify one card for each component that can receive molten material from channel box segment 2. Omit this card if there are no components that can receive molten material from channel box segment 2.

W1(I) Component number of fuel rod or electrically-heated simulator rod component that can receive molten material from channel box segment 2.

W2(R) Mass fraction of molten material from channel box segment 2 received by component specified in Word 1. The range for individual mass fractions is 1.0e-6 ≤ x ≤ 1.0. The sum of all mass fractions on Cards 4CCC0801 through 4CCC0899 must be unity.

A19.6 Shroud Component

A19.6.1 Card 40CC0000, Component Name

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(A) Component name.

W2(A) Keyword - shroud.

A19.6.2 Card 40CC0100, Number of Shroud Configurations

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) Number of shrouds.

A19.6.3 Card 40CC0200, Shroud Geometry

This card is required for NEW problems and cannot currently be input for RESTART problems. Words 1 and 2 are required, Words 3 and 4 are optional.

W1(R) Perimeter of inner shroud surface (m, ft). Required input.

W2(R) Shroud flow area thickness (m, ft). Required input. Suggested value: 3.5×10^{-3} m.

W3(I) Molten pool interaction flag; optional flag to determine whether or not shroud interfaces with molten pool. If “0” is entered then no interaction is modeled, if “1” is entered, then interaction is modeled. Default is to model shroud interaction with molten pool. W4(R) Threshold thickness (m, ft). Threshold thickness of liquefied structural material for breakup of crust of solidified molten pool material at periphery of core. If maximum possible rate of melting of structure at periphery of core due to interaction with molten pool is to be modeled, this word should be 0.0, if minimum, this word should be 1.0.

A19.6.4 Card 40CC0300, Indices of Materials

This card is required for NEW problems and cannot currently be input for RESTART problems. A shroud component must have at least three materials (even if all three have the same index), and a maximum number defined by the parameter 'ndmatr' in common block 'scddat'. As transmitted by the INEL the maximum number of materials is ten.

W1... (I) Material index. Material layers beginning with outer layer (radial node 1 is at outer edge of outer layer). Indices from Table 7. The default materials are Zr, ZrO_2, and Zr.

A19.6.5 Cards 40CC0301 through 40CC0399, Material Layer Radial Coordinates

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1... (R) Coordinate of outer surface of each material layer (m). Assuming the outer surface of shroud has coordinate of "0.0", enter the remaining coordinates in consecutive order. Each material interface must fall on a mesh point.

A19.6.6 Card 40CC0400, Upper and Lower Hydrodynamic Volumes

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 control volume just above the shroud.

W2(I) RELAP5 control volume just below the shroud.

A19.6.7 Cards 40CC0401 through 40CC0499, Volume Number of Hydrodynamic Volumes

This card defines the RELAP5 control volume which provides the boundary conditions for the component. There are usually two control volumes defined for each axial node. However, for the shroud component only, there is the capability to specify a heat flux boundary condition on the outside of the shroud. This is done by specifying zero (0) for the outer hydrodynamic volume and then including Card 40CC8000. Refer to Cards 40CC8N01 through 40CC8N99, Heat Flux Boundary Condition Specifications for further information. This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) RELAP5 control volume number that is in contact with the inner surface of the shroud. This inner surface overlays the maximum radial node number for the shroud.

W2(I) RELAP5 control volume number that is in contact with the outer surface of the shroud. This outer surface overlays radial node number 1. Enter "zero" if adiabatic boundary at the outer surface of shroud (outer surface is at radial node 1).

W3(I) Increment.

W4(I) Axial node number.

A19.6.8 Cards 40CC0501 through 40CC0599, Radial Mesh Spacing

This card specifies the location of radial mesh points across the component. A heat conduction solution is performed at each radial mesh point. Error trapping includes checks to ensure that the first radial mesh point is located at 0.0, that the mesh points are in consecutive order, and that there is a mesh point at each material interface. For the first axial node only, all radial nodes must be on one card number, even if it is necessary to use continuation cards. This card is required for NEW problems and cannot currently be input for RESTART problems.

W1... (R) Input “0.0”.

WN(R) Distance from outer surface of shroud to radial node N (m).

WN+1(I) Axial node number.

A19.6.9 Cards 40CC0601 through 40CC0699, Initial Temperature

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) Initial temperature at radial node 1(K).

WN(R) Initial temperature at radial node N (K).

WN+1(I) Axial node number. The range is $300 \text{ K} \leq x \leq 2{,}033 \text{ K}$[1]

A19.6.10 Card 40CC0800, Embedded Flow Channel Geometry

This card allows the user to model embedded hydrodynamic flow channels within the SHROUD component. This card is optional for NEW problems, and cannot currently be input for RESTART problems.

W1(I) Number of the interval between radial nodes that contains embedded hydrodynamic flow channels, where internal number 1 is between radial nodes 1 and 2.

A19.6.11 Card 40CC0801 through 40CC0899, Embedded Flow Channel Hydrodynamics

If Card 40CC0800 is entered then this card is required. If not, then this card is not used.

W1(I) Hydrodynamic volume, linked to embedded flow channel at the lowest axial node.

W2(I) Increment. Number to be added to W1 to form hydrodynamic volumes for each volume above W1.

A19.6.12 Card 40CC1100, Power Multiplier

This card is optional for NEW and RESTART problems, and specifies the fraction of total core power which is generated in this component. The approach to specify power is as follows. First, a total core time-dependent power is specified (Section A18.1.9). Then a component power multiplier (this card) is used to determine the fraction of core power deposited in this fraction. The power in a single shroud can then be determined by dividing the component power by the number of shrouds represented by this component. The linear heat generation rate at an individual axial node is determined by multiplying the shroud power by an axial power profile factor (Section A19.6.13 & Section A19.6.14) and dividing by the axial node length. The power

1. Upper limit based on the melting point of zircaloy

density at a specific radial node can then be determined by multiplying the local linear heat generation rate by the radial power factor (Section A19.6.15) and dividing by the cross-sectional area associated with that radial node.

W1(R) Fraction. This is the fraction of the core power in this component. The range for this power multiplier is $0.0 \leq x \leq 1.0$, and the default is 0.0.

A19.6.13 Card 40CC13P0, Axial Power Profile Time

In the card number, “P” is axial power profile number (start with Number 1). This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(R) End time for which this axial power profile applies (s).

A19.6.14 Cards 40CC13P1 through 40CC13P9, Axial Power Profile Data

Card numbering is specified similarly to the previous card, with “P” in the card number indicating the axial power profile number. This information is required for each profile and must be specified for each axial node of the component. This input specifies the fraction of rod power which is deposited at the axial node. The axial power fraction will be normalized over the length of the component.

W1... (R) Axial power factor at axial nodes. The range is $0.1 \leq x \leq 1.4$, and the default is 1.0.

A19.6.15 Cards 40CC1401 through 40CC1499, Radial Power Profile

This card is required for NEW problems and cannot currently be input for RESTART problems. The radial power factor is used to determine the power density at each radial node, based upon the local heat generation rate.

W1(R) Radial power factor.

W2(I) Radial node at which W1(R) applies. The last radial node that is input must align with the outer radius of the fuel pellet. The range is $x \leq 20$, and the default power factor is 1.0.

A19.6.16 Card 40CC5000, Shroud Insulation and Failure

This card is required for NEW problems and cannot currently be input for RESTART problems.

W1(I) Index of material that has its insulation quality degraded after shroud fails. This index must be one of the indexes on Card 40CC0300.

W2(R) Time at which shroud fails. After the time of shroud failure, both sides of the metallic Zr liner on the inside surface of the shroud are calculated to oxidize. In addition, a multiplier is applied to thermal conductivity of the shroud insulation.

W3(R) Multiplier on thermal conductivity for failed shroud.

A19.6.17 Cards 40CC8N01 through 40CC8N99, Heat Flux Boundary Condition

These cards are used to specify a table of heat flux as a function of time, to be applied on the outer surface of the shroud, and are read if, and only if, the hydrodynamic volume used for the outer surface boundary condition is specified as zero (0). The ‘100s’ digit, shown as ‘N’ in the card number is used to determine the heat flux profile number for n-th time point, in that the first profile should be entered on Cards 40CC8101 through 40CC8199, and the second on 40CC8201 through 40CC8299, and so forth. There are two possible formats for this card. In the first, a time is entered as Word 1, and a heat flux is entered as Word 2, with no additional input. In this format the specified heat flux will be applied to all axial nodes of the component. In the second format, a time is entered as Word 1, and a series of heat fluxes are entered as Words 2 through N, where N is the number of axial nodes plus 1. In this format, Word 2 specifies the heat flux to be applied at Node 1, Word 3 specifies that at Node 2, and so forth. This card is required for NEW problems, and cannot currently be input for RESTART problems.

W1(R) Time (s).

W2(R) Heat flux (W/m^2, Btu/s-ft^2).

A19.7 ATR Fuel Element

A19.7.1 Card 40CC0000, Fuel Element Component

This card is required for NEW problems and may not currently be changed on restart.

W1(A) Component name.

W2(A) Keyword - atr.

A19.7.2 Card 40CC0100, Number and Perimeter of Fuel Element

This card is required for NEW problems and may not currently be changed on RESTART.

W1(A) Number of fuel elements.

W2(R) Average fuel element perimeter (m).

A19.7.3 Card 40CC0400, Upper and Lower Hydraulic Volumes

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) RELAP5 volume above the fuel element.

W2(I) RELAP5 volume below the fuel element.

A19.7.4 Cards 40CC0401 through 40CC0450, Inner Hydraulic Volumes

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) RELAP5 volume numbers connected to the inner surface.

A19.7.5 Cards 40CC0451 through 40CC0499, Outer Hydraulic Volumes

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) RELAP5 volume numbers connected to the outer surface.

A19.7.6 Cards 40CC0501 through 40CC0599, Radial Mesh Spacing

This card is required for NEW problems and may not currently be changed on RESTART

W1(R) Radial node spacing (m). Starting from the outer surface. Uses axial self-expansion.

A19.7.7 Cards 40CC0601 through 40CC0699, Initial Temperature Distribution

This card is required for NEW problems and may not currently be changed on RESTART.

W1(R) Initial temperature (K). For each radial node at present axial node. Uses axial and radial self-expansion. The range is 300 K $\leq x \leq$ 913 K[1].

A19.7.8 Cards 40CC0801 through 40CC0899, Material Types

This card is required for NEW problems and may not currently be changed on RESTART.

W1(I) Material index. The first and last index numbers must be 15 or 16. Also, the number of material indexes specified must equal the number of material layers specified on the next card. Must be constant with axial nodes, the numbers are used for consistency.

A19.7.9 Cards 40CC0901 through 40CC0999, Material Layer Spacing

W1(R) Material layer spacing (m). Starting from outer layer. Must be constant with axial nodes, the numbers are used for consistency.

A19.7.10 Card 40CC1100, Power Multiplier

This card is optional for NEW and RESTART problems. If not specified the component power is set to zero. One and only one word may be entered when power is specified with either a general table or control variable, and three words are required when the power is specified by reactor kinetics. See Section A12

W1(R) Fraction. If power is specified with 'table' or 'cntlvar', this is the fraction of the core power in this component. If power is specified with 'kinetics' this is the fraction of the fission power in component 'CC'.

W2(R) If 'kinetics', fraction of fission product decay power in component 'CC'.

W3(R) If 'kinetics', fraction of actinide decay power in component 'CC'.The range for all fractions are $0.0 \leq x \leq 1.0$

A19.7.11 Card 40CC13P0, Axial Power Profile Time

P axial power profile number. Start with Number 1. This card is required for NEW problems and may not currently be input for RESTART problems.

W1(R) End time (s).

A19.7.12 Cards 40CC13P1 through 40CC13P9, Axial Power Profile Data

This card is required for NEW problems and may not currently be changed on RESTART. This information is required for each profile.

W1... (R) Axial power factor at axial nodes. P axial power profile number. The range is $0.1 \leq x \leq 1.4$.

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1. Based on the melting point of aluminum

A19.7.13 Cards 40CC1401 through 40CC1499, Radial Power Profile

This card is required for NEW problem and may not currently be input for RESTART problems.

W1(R) Radial power factor.

W2(I) Radial node at pellet surface. The last radial node that is input must align with the outer radius of the fuel pellet. The range is $x \leq 20$.

A19.7.14 Card 40CC1500, Shutdown Time and Fuel Density

This card is optional for NEW problems and may not currently be input for RESTART problems.

W1(R) Time of shutdown (s). This card is required. Default is 1.0e8.

W2(R) Fraction of fuel theoretical density. This card is required. The range is $0.94 \leq x \leq 0.96$. Default is 0.95.

W3(R) ^{239}U production per fission. This word is required only if the power for this component is computed using the decay option.

W4(R) ^{235}U enrichment. This word is required only if the power for this component is computed using the decay option. If the power data option on Card 1000 is 'decay,' then you must input either the 15XX Cards, or the 1600, 17XX, and 18XX Card series.

A19.7.15 Cards 40CC1601 through 40CC1699, Previous Power History

This card is optional for NEW problems and may not currently be input for RESTART problems. A prior power history can be defined for the decay heat calculation and is required to initialize the fission product inventory (PARAGRASS). The power is assumed to be a series of plateaus, with no interpolation. The last power density in this table is the transient power density until the problem time exceeds the shutdown time. Time in this table is referenced to the start of the operation of the reactor and not to the start of the transient analysis.

W1(R) Power history (W/m^3). The range is 40.67×10^6 W/m^3 $\leq x \leq$ 279.3×10^6 W/m^3.

W2(R) Time (s).

A19.7.16 Cards 40CC2101 through 40CC2199, Fission Product Masses

This card is required.

W1(R) Initial mass of fission product NN (kg).

W2(I) Axial node for sequential expansion.

A20. UPPER PLENUM STRUCTURE MODEL

This section describes the input cards that are required when using the upper plenum structure (UPS) model. Each UPS input card begins with a card number of the general form 48SSTTNN, where SS represents the user-specified upper plenum structure number, TT represents the card type, and NN represents the card count. Word numbers (W1, W2, etc.) are utilized in the following discussion to promote better understanding of the input requirements, but they are not part of the input data. UPS input values are specified on six cards (or card sets) that contain information about nodalization, physical dimensions, initial conditions, and hydraulic boundary conditions for each different upper plenum structure. As many as ten upper plenum structures can be used in an input deck; although this limit can be increased by changing the value of parameter NMUPD and recompiling RELAP5-SCDAP. The UPS input data can be specified in SI or British units. The “Input Units” parameter (Word 1) on RELAP5 Card 102 designates the system of units for the input cards. To assist the user, the input variables are compared with a range of typical values. If a range violation is encountered, either a warning message or an error message will be printed in the output file. A warning message allows the calculation to proceed, but an error message causes the calculation to terminate after the completion of input processing. The range for a particular input variable is identified in this section in the following format:

A20.1 Card 48SS0000, Axial Levels

This card is required for NEW problems and cannot currently be changed for RESTART problems.

W1(I) Total number of axial levels. The range is $1 \leq x \leq 15$. The upper limit of 15 axial levels can be increased by changing the value of parameter NMUPAX and recompiling SCDAP/ RELAP5.

A20.2 Cards 48SS0101 through 48SS0199, Mesh Data

These cards are required for NEW problems and cannot currently be changed for RESTART problems. For each axial level NN, there must be one Card 48SS01NN.

W1(R) Initial lengths of nodes along conduction path (m, ft). For each axial level, specify one word for each conduction node. The number of words on a card defines the total number of conduction nodes at that axial level. The first word is the initial length of the left (or bottom) node, and the last word is the initial length of the right (or top) node. The range for the total number of conduction nodes at an axial level is $1 \leq x \leq 6$. The range of the initial lengths of nodes is $\underline{1.0e\text{-}6\ m} \leq x$. The upper limit of 6 conduction nodes at an axial level can be increased by changing the value of parameter NMUPCN and recompiling RELAP5-SCDAP.

A20.3 Cards 48SS0201 through 48SS0299,Surface and Relocation Data

These cards are required for NEW problems and cannot currently be changed for RESTART problems. A sequential expansion format is used.

W1(R) Heat transfer surface area (m^2, ft^2). The surface areas of the left (or bottom) and right (or top) nodes at an axial level are identical. The range is $\underline{0.0\ m^2} < x$.

W2(I) Flag indicating surface orientation. Specify 0 for a vertical orientation or 1 or 2 for a horizontal orientation. If a horizontal structure is located at an axial level directly below a vertical structure, then a flag of 1 indicates that the horizontal surface blocks downward relocation from only the right surface, and a flag of 2 indicates that the horizontal surface blocks downward relocation from both the left and right surfaces. The range is x = 0, 1, or 2.

W3(R) Height along vertical relocation path (m, ft). The heights of the left and right nodes at an axial level are identical. For a horizontal surface, this height must be specified, but is not used. The range is 1.0e-6 m ≤ x.

W4(I) Axial level used for sequential expansion. The axial levels specified on these cards must be in ascending, but not necessarily consecutive order. The range is 1 ≤ x ≤ N, where N is the total number of axial levels specified on Card 48SS0000.

A20.4 Card 48XX0300, Initial Oxide Thicknesses

This card is optional for NEW problems and cannot currently be changed for RESTART problems.

W1(R) Initial thickness of left (or bottom) oxide layer (m, ft). The thicknesses for all axial levels are identical. The default is 0.0 m and the range is 0.0 m ≤ x ≤ N where N is the initial length (or half of the initial length when there is only one node at an axial level) of the smallest right (or top) node specified on Cards 48SS0101 through 48SS0199.

W2(R) Initial thickness of right (or top) oxide layer (m, ft). The thicknesses for all axial levels are identical. The default is 0.0 m and the range is 0.0 m ≤ x ≤ N where N is the initial length (or half of the initial length when there is only one node at an axial level) of the smallest left (or bottom) node specified on Cards 48SS0101 through 48SS0199.

A20.5 Cards 48SS0401 through 48SS0499, Initial Temperatures

These cards are required for NEW problems and cannot currently be changed for RESTART problems. For each axial level nn, there must be one Card 48SS04NN.

W1.. (R) Initial temperatures of nodes (K, ^{o}F). For each axial level, specify one word for each conduction node defined on Cards 48SS0101 through 48SS0199. The first word on a card is the initial temperature of the left (or bottom) node, and the last word is the initial temperature of the right (or top) node. The range is 300 K ≤ x ≤ N where N is the melting temperature of the metal.

A20.6 Cards 48SS501 through 48SS599, Hydraulic Boundary Conditions

These cards are required for NEW problems, and cannot currently be changed for RESTART problems. A modified sequential expansion format is used where Words 1 and 2 are incremented by Word 3.

W1(I) Volume number of hydraulic volume adjacent to left (or bottom) node. This is the first volume number used in the sequential expansion. Each subsequent volume number is generated by adding the increment specified in Word 3.

W2(I) Volume number of hydraulic volume adjacent to right (or top) node. This is the first volume number used in the sequential expansion. Each subsequent volume number is generated by adding the increment specified in Word 3.

W3(I) Volume number increment. This increment may be positive, negative, or zero.

W4(I) Axial level used for sequential expansion. The axial levels specified on these cards must be in ascending, but not necessarily consecutive order. The range is $1 \leq x \leq N$, where N is the total number of axial levels specified on Card 48SS0000.

A21. RADIATION HEAT TRANSFER

RELAP5-SCDAP has the capability of modeling radiation heat transfer between a group of core components, as described in Volume 1. Each group, called an enclosure, typically consists of a separate hydrodynamic flow channel, and a group of isolated components which exchange heat through radiation. If the SCDAP components are modeling a reactor core, then a radiation enclosure is normally defined for a rod bundle in each stack of RELAP5 control volumes that represent the fluid flowing through the reactor core.

A21.1 Radiation Enclosure Number

The radiation heat transfer input is detected by the presence of the two digits ‘49’ at the beginning of the card. The next two digits, specified as ‘NN’ in the following input description, denote the radiation enclosure number.

A21.1.1 Card 49NN0000, Enclosure Components

This card is required for NEW problems and cannot currently be input for RESTART problems. The presence of this card triggers radiation heat transfer input processing for the next enclosure.

W1(A) Keyword ‘bundle’.

A21.2 User Specified View Factor and Path Length

Either the 1000 or 2000 series cards are needed, but not both. The 1000 series allows the user to specify radiation view factors and path lengths on input, while the 2000 series causes the view factors and path lengths to be automatically generated. The 1000 series cards must be used if the enclosure includes a BWR blade/box component.

A21.2.1 Card 49NN1000, Number of Components in Enclosure

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1.. (I) List of component numbers in the enclosure.

The last component number on this card, if it is a shroud component, is assumed to enclose the radiation heat transfer; this implies that all previous components listed, that are shrouds, will have their outer surfaces exposed to this enclosure, and the last component listed will have it’s inner surface exposed to this enclosure.

A21.2.2 Cards 49NN1001 through 49NN1099, View Factors

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1.. (R) View factors.

This input should be considered a square matrix of view factors, where, for example, the third word of the second row is the view factor from the third component specified on Card 49NN1000 to the second component specified on Card 49NN1000.

A21.2.3 Cards 49NN1101 through 49NN1199, Path Length

This card is optional for NEW problems and cannot currently be input for RESTART problems.

W1.. (R) Radiation path lengths.

Just as in Card 49NN1001, this input should be considered a square matrix of radiation path lengths, where, for example, the third word of the second row is the path length from the third component specified on Card 49NN1000 to the second component specified on Card 49NN1000.

A21.3 Generated View Factor and Path Length

A21.3.1 Card 49NN2000, Pitch of Rods

W1(R) Pitch (m). Pitch of rods in enclosure.

W2(I) Component number of shroud enclosing this enclosure. This word is optional, and if missing no shroud is modeled.

A21.3.2 Cards 49NN2001 through 49NN2099, Enclosure Description

W1.. (I) Matrix of integers identifying the component in each slot of the enclosure. The maximum size of the array is ndcomp x ndcomp, where ndcomp is a parameter defined at compilation which defines the number of components permitted by RELAP5-SCDAP. If the code remains as transmitted, this parameter is defined to be 20.

A22. COUPLE Control Cards

These cards are input whenever a COUPLE calculation is begun. These cards can be entered on either NEW or RESTART problems. Every COUPLE calculation must begin with a 50000000 card. Cards 5M001000 through 5M0030000 may be entered for each COUPLE mesh 'M'.

A22.1 Card 50000000 COUPLE Identification

This card is required, whenever a COUPLE mesh is to be input.

W1(A) Keyword. 'couple'

W2(A) Input format. Enter the keyword 'old' for old-style (formatted) input, or 'new' for unformatted, RELAP5 card number style input.

A22.2 Card 50004000 Ex-Vessel Heat Transfer

This card is optional, and may be entered on either NEW or RESTART problems. If entered this card is used to control ex-vessel heat transfer correlations.

W1(I) Containment volume. This volume is the number of a hydrodynamic volume representing the containment. Any COUPLE node which has this volume specified as the hydrodynamic volume for convective heat transfer will use the ex-vessel heat transfer correlations.

W2(R) Heat transfer coefficient. The heat transfer coefficient to use for vapor phase heat transfer, when the node is modeled as being uncovered.

W3(I) Correlation flag. Integer flag describing which set of boiling correlations to use. Two sets of correlations are currently available. Set 1 (W3 = 1) is a set of correlations for heat transfer to subcooled fluid. Set 2 (W3 = 2) is a set of correlations for heat transfer to saturated fluid. Note that whichever set of correlations are used, the sink temperature will be either the saturation temperature for the pressure in the volume identified in Word 1, or 10 K below that.

W4(I) Containment level variable. (General table if negative, control variable if positive.) The parameter which specifies the containment liquid level.

A22.3 Card 5M010000 through 5M01003N, Debris Bed Control

This section describes COUPLE control cards which are specific to each COUPLE mesh. Each card number begins with two digits, '5' and 'M'. As described in the previous section, the '5' denotes that COUPLE input is being presented, and the 'M' represents the COUPLE mesh number. One of these cards can be read for each COUPLE mesh "M", where "M" is between 1 and the allowed maximum number of meshes. The maximum allowed number of meshes is defined by parameter 'maxcpm' in common block 'cpmdat'. The maximum number of allowed meshes in the unmodified transmittal is 5.

W1(I) COUPLE flag and input indicator.

0 = Used on a restart run to turn off the COUPLE model for mesh "M".

-1 = Used on a restart run to replace some of the values on this card for mesh

"M".

1 = Read COUPLE input for mesh "M".

This option can be used on RESTART to add or change a COUPLE mesh, unless debris is received from core components and core slumping into the mesh has already started.

W2(I) Number of the RELAP5 volumes to receive COUPLE debris. On a restart run, this word may not be changed, but a 0 may be entered as input.

W3(I) Debris source indicator for COUPLE mesh "M":

-1 = No slumping. Debris material is already present at the start of the application.

0 = Debris received from core components (default).

1 = User-defined slumping.

2 = Depends on components above mesh (non LWRs).

3 = Corium hydro model (not yet available).

Only 1 mesh may be designated as receiving debris from RELAP5-SCDAP core components.

W4(I) Flag for breakup of COUPLE debris:

0 = Debris may be broken up (default).

1 = Debris is never broken up.

W5(I) Maximum number of RELAP5-SCDAP hydraulic time steps to use per COUPLE time steps. Default = 200.

W6(R) Maximum COUPLE time step. Default = 10.0 seconds. If Word 5 is 1, this input is not used.

A22.4 Card 5M011000 through 5M11104N, Debris Bed Model Control

For each new COUPLE mesh "M" for which a Card 5M001000 was entered with Word 3 equal to 2 or 3, this card is needed to specify 1 to 6 connected SCDAP components. On restart, this card is read if, and only if, Word 1 on Card 5M001000 is 1.

W1(I) Number of first SCDAP component connected to COUPLE mesh "M".

WN(I) Number of n-th SCDAP component connected to COUPLE mesh "M", if any.

A22.5 Card 5M012000 through 5M0111M0, Power

This card is used for each new COUPLE mesh "M" for which a Card 5M001000 is entered with Word 3 equal to 2. It is optional on both NEW and RESTART problems.

W1(I) Power source indicator.

0 = Constant power from slumping material at time of slumping (default).

1 = Power is determined by RELAP5 reactor kinetics power in the associated SCDAP components.

2 = Power is determined by power other than RELAP5 reactor kinetics power in the associated SCDAP components.

If Word 1 is 0, then none of the following values on this card are used.

W2(R) Multiplier for fission power in the COUPLE mesh if the associated SCDAP components obtain their power from RELAP5 reactor kinetics. Default = 1.0.

W3(R) Multiplier for fission product decay power in the COUPLE mesh. Used only if the associated SCDAP components obtain their power from RELAP5 reactor kinetics. The default = 1.0.

W4(R) Multiplier for actinide decay power in the COUPLE mesh. Used only if the associated SCDAP components obtain their power from RELAP5 reactor kinetics. The default = 1.0.

A22.6 Cards 5M013001 through 5M003009, Fission Product Decay

These cards are used only for each new COUPLE mesh “M” for which a Card 5M003000 with Word 1 equal to 2. These cards are optional on both NEW and RESTART problems. The default = 0.0.

The fission product species, in this order are: I, CsI, CsOH, Te, HI, HTe, Cd, Ag, UO_2, Sn, Fe, Ru, Ba, Sb, Cs*, I*, Zn, Xe, and Kr.

W1(R) Fraction of fission product decay heat from first species.

W19(R) Fraction of fission product decay heat from 19th species.

These fractions are used only if the SCDAP components associated with this COUPLE mesh obtain their power from RELAP5 reactor kinetics. For those species to be tracked in the COUPLE mesh, the fractions are used to account for fission product decay power decreases from fission product loss. A zero fraction value for a given species will mean no power decrease from any loss of that species. Since not all species need be tracked in the COUPLE mesh, the sum of these fractions does not need to be 1, but it should probably not exceed 1.

Currently when material relocates to a lower axial node in a SCDAP component with power, the power calculated at each axial node is not exactly correct, unless the axial power profile is flat. The same is true then for the power slumped out of such a SCDAP component into a COUPLE mesh. All or none of the powered SCDAP components listed on Card 5M002000 must obtain their power from RELAP5 reactor kinetics.

A23. COUPLE MESH GENERATION (New Format)

A23.1 Mesh Limit

A23.1.1 Card 5M014000, Mesh Limits

W1(I) Maximum value of I in couple mesh. This is the maximum number of nodes in the horizontal direction.

W2(I) Maximum value of J in couple mesh. This is the maximum number of nodes in the vertical direction.

W3(I) Number of material blocks. This is the number of different material regions specified on the Material Block Assignment Card(s).

W4(I) Geometric code.

0 = r-, z-axisymmetric.

1 = x-, y-plane body.

W5R) Multiplier. This multiplier operates on dimensions input on the 200 Line Segment Cards and elsewhere in the input. The multiplier allows the couple input to use inches as the unit for length even though the calculations use meters for length. (This word) x (value of input number) = dimension.

A23.1.2 Cards 5M020001 through 5M029999, Line Segment Cards

Any reasonable combination of internal and external line segments that represent circular arcs, straight lines, or points in the r-, z- or x-, y-plane can be used to generate a finite element mesh. The line segments are defined by the location of the end points. Circular line segments are defined by one intermediate point, or the center, in addition to the end points. The line segment cards can be input in any order. Any given (i, j) pair can be input only once.

The elements that may be filled by relocated material must be quadrilateral and not triangular in shape. Two of the sides must be perpendicular to the direction in which material is transported into the element.

W1(I) Line segment type parameter.

0 = Point (input only 1st i, j, r, z).

1 = Straight line (input only 1st and 2nd set of i, j, r, z as end point of line).

3 = Circular arc with second point as midpoint (input 1st and 3rd sets of i, j, r, z as end

points of arc and 2nd set as midpoint on arc).

4 = Circular arc with third point as center of radius of curvature (input 1st and 2nd sets of i, j, r, z as end points of arc and 3rd set of r, z as coordinates of center of radius of curvature).

W2(I) I-coordinate of 1st point.

W3(I) J-coordinate of 1st point.

W4(R) R-coordinate of 1st point.

W5(R) Z-coordinate of 1st point.

W6(I) I-coordinate of 2nd point.

W7(I) J-coordinate of 2nd point.

W8(R) R-coordinate of 2nd point.

W9(R) Z-coordinate of 2nd point.

W10(I) I-coordinate of 3rd point.

W11(I) J-coordinate of 3rd point.

W12(R) R-coordinate of 3rd point.

W13(R) Z-coordinate of 3rd point.

Straight or curved lines segments in the r-, z-plane must correspond to either a straight line (i- or j-constant along line) or a stepped diagonal segment [ABS(vI) = ABS(vJ)] in that i-, j-plane. Note on a stepped diagonal segment that i is incremented first and then j. Repeat the Line Segment Cards until the finite element mesh has been completely defined by the specification of line segments. In general, a finite-element mesh can be completely defined by inputting a Line Segment Card for each segment of the surface of the mesh. For modeling gap resistances, input two consecutive values of i or j that have identical coordinates.

A23.2 COUPLE Material Input

A23.2.1 Cards 5M040001 through 5M040099, Material Assignment

W1(I) Material identification number. The COUPLE model considers up to 15 different materials.The materials and their identification numbers are listed in Table 9.

Table 9: COUPLE Material Indices

Material	ID. No.
Relocated debris	1
Stainless steel	2
Inconel	3
Carbon steel	4
Coolant	5
Null material	6
MHTGR graphite	7
MHTGR fuel compact	8
MHTGR target	9
MHTGR smeared (homogenized)	10

Table 9: COUPLE Material Indices

Material	ID. No.
User specified materials	11-15

For user-specified materials, the user supplies constant property values by entering the values on the Material Properties and Material Data Cards. For user-specified materials, the code will not model phase change.

Each element defined to have relocated debris is considered to contain coolant until the coolant has been displaced by relocated debris that has slumped into the element. The exception to this is the "no slumping" case (Word 3 = -1 on COUPLE Card 5M001000), in which Material 1 is already present at the start of the problem. If on the Fission Products Card(s) the gap heat transfer is not specified for nodes that are part of null element, then no heat transfer will occur across the null element. Null elements are used to differentiate between two regions with different heat generation rates and to model heat transfer between two materials with a possible gap between them.

W2(I) Minimum I.

W3(I) Maximum I.

W4(I) Minimum J.

W5(I) Maximum J.

W6(R) Porosity of materials in elements. If material type is 1 and element is at start of analysis, input 1.

W7(I) Material flag. For materials other than material type 1 (relocated material), always input the integer 0. For material Type 1, indicate as follows whether relocated material is in the mesh at the start of the analysis.materials.

0 = No material in region.

2 = Material in region.

These flags are not used for the case of no fluid flow in the debris.

W8(I) Indicator for debris.

0 = None.

1 = Partially full.

2 = Full.

W9(I) Particle diameter.

A23.2.2 Card 5M050000, Emissivity

W1(R) Emissivity. Emissivity for internal radiation in material with ID No. 1. The standard value is 0.8.

A23.2.3 Cards 5M050001 through 5M050099, Material Properties

These data are used as default values in case built-in procedures (derivative method in COUPLE) fail to meet specified criteria. If data are not available, low-temperature default data given in Table 10 should be input. These default values are required.

Table 10: Default Material Values

Material ID	Material	Density (kg/m^3)	Specific Heat Capacity (J/kg·K)	Thermal Conductivity (J/m·s·K)
2	Stainless steel	7894.	300.	13.0
3	Inconel	8000.	427	11.0
4	Carbon steel	8000.	489	42.0
7	MHTGR graphite	1730.	2000	30.0
8	MHTGR fuel compact	1900.	1200	10.5
9	MHTGR target	1560.	1200	7.0
10	MHTGR smeared	1730.	2000	30.0

W1(I) Material identification number. If material identification number greater than 11 is input, then properties are defined as input on this card (density) and on the Material Data Card, but materials properties do not change with temperature.

W2(R) Density of material, (kg/m^3). If null material (an element used to model gap resistance), then leave these columns blank.

W3(R) Horizontal thermal conductivity, k_r (J/m-s-K). Input 0.0 for null material.

W4(R) Axial thermal conductivity, k_z (J/m-s-K). Input 0.0 for null material.

W5(R) Specific heat capacity, C_P (J/kg-K). Input 0.0 for null material.

W6(R) Fast neutron fluence (n/cm^2)

W7(R) Cross-section area of graphite (m^2). Only required if Word 1 = 7 or 10.

W8(R) Cross-section area of fuel compact (m^2) Only required if Word 1 = 10.

W9(R) Cross-section area of target (m^2) Only required if Word 1 = 10.

W10(R) Cross-section area of helium coolant channels (m^2) Only required if Word 1 = 10.

A23.2.4 Card 5M060000, Control Card

W1(R) Relaxation parameter in numerical solution. Recommended value is 0.5.

W2(R) Convergence parameter in numerical solution. Recommended value is 1.0. If gap elements (elements with null material) are being modeled, then the computer run time can be very sensitive to this input value. To avoid excessive run time, it may be necessary to define the convergence parameter to be greater than 1.0, perhaps as large as 5.0.

W3(R) Inner radius of lower head of vessel. Use the same units as the coordinates on the Line Segment Card. If a spherical lower head is not being modeled, input 0.0.

A23.2.5 Cards 5M060001 through 5M060099, Initial Mesh Temperature

W1(R) Initial temperature of mesh (K).

A23.3 COUPLE Geometry

A23.3.1 Card 5M070000, Lower Head Description

W1(R) Outer radius of region in finite element mesh that can fill with slumping material. Use the same units as the coordinates on the Line Segment Card. If a spherically shaped lower head is being modeled, input 0.0. If a cylindrically shaped lower head is being modeled or plane coordinates are being used, then this input is used. If plane coordinates are being used, this input specifies the inner radius of pipe being modeled in plane geometry.

W2(R) Thickness of lower head of vessel or elevation of top surface of structural material supporting debris. Use the same units as the coordinates on the Line Segment Card. If a spherical lower head is not being modeled, then input the distance from the bottom of the finite element mesh to the surface that supports the slumping material.

W3(I) Spherical lower head modeling flag.

0 = Spherical lower head of vessel is not being modeled.

1 = Spherical lower head of vessel is being modeled.

W4(I) Maximum number of iterations. Recommended value is 10.

W5(R) Inner radius of region that can fill in with slumping material. Use the same units as for the Line Segment Card. Omit for the case of spherical lower head. Omit this input for the RELAP5-SCDAP/MOD2 version of the code. For the case of plane geometry, input 1.0

W6(R) Depth (thickness) of plane. Use the same units as for the Line Segment Card. Omit this input for axisymmetric geometry.

A23.3.2 Cards 5M070001 through 5M070099, User-Defined Layer

If these cards are used, the order in which elements receive slumped debris is defined by the user. The user can divide the elements into layers, which will fill sequentially as the debris slumps. Within each layer the debris is assumed to self-level across all elements in that layer.

The user defines the layers of elements by adding cards immediately after this one; one card for each layer. The code limits the inputs to 25 elements per layer for up to 25 layers. The last card in the list should contain a single 0 to indicate the end of the list. Each card that defines a layer must conform to the format as defined below.

W1(I) Number of elements in this layer.

W2..(I) The element numbers in this layer. Five spaces for each element, continued on the next card if necessary.

The last card in the list must contain a single 0.

A23.4 COUPLE Boundary Conditions

A23.4.1 Card 5M080000, Number of Materials

W1.. (I) Number of materials for which internal heat generation is not possible. If relocated debris is being considered, input the number that is one less than the input in Columns 1 through 5 of the Material Data Information Card. Otherwise, input the same number.

A23.4.2 Cards 5M080001 through 5M080099, Power Densities

These cards may be used to define power density in the mesh, if and only if the debris source (Word 3 on Card 5M010000) is set to "no slumping".

W1(I) I of first node in group.

W2(I) J of first node in group.

W3(I) I of last node in group.

W4(I) J of last node in group.

W5(R) Multiplier for table specified on next card. If zero, constant power density.

W6(I) Number of RELAP5 general table of power density.

A23.4.3 Cards 5M090001 through 5M090099, Mass Fractions

These cards are optional for the "no slumping" COUPLE case (Word 3 = -1 on the COUPLE Card 5M001000) and are not allowed otherwise. Each pair of cards defines the mass fractions for the constituents in a consecutive group of COUPLE elements with Material 1. These fractions are converted to atomic fractions and stored as such.

W1(I) Number of the first element in the group.

W2(I) Number of the last element in the group.

W3(R) Mass fraction of zircaloy.

W4(R) Mass fraction of metallic uranium.

W5(R) Mass fraction of stainless steel.

W6(R) Mass fraction of silver.

W7(R) Mass fraction of boron carbide.

W8(R) Mass fraction of uranium dioxide.

W9(R) Mass fraction of oxidized zircaloy.

W10(R) Mass fraction of aluminum.

W11(R) Mass fraction of lithium.

W12(R) Mass fraction of cadmium.

W13(R) Mass fraction of soil.

This input overrides the SCDAP values for the elements specified.

A23.4.4 Cards 5M100001 through 5M100099, Fission Products

These cards are optional for the "no slumping" COUPLE case (Word 3 = -1 on the COUPLE Card 5M001000) and are not allowed otherwise. They cannot change the fission product species selected on the SCDAP Fission Products Input Card, but the cards can be used to override the masses for selected elements. Each set of these cards (which may consist of 1, 2, or 3 cards, depending on the number of fission products selected in the SCDAP input) redefines the initial fission product masses for a group of elements with Material 1. The values in a set must be in the same order as those in the SCDAP input.

W1(I) Number of the first element in the group.

W2(I) Number of the last element in the group.

W3.. (R) Density of the fission products. Input in the same order as done in the SCDAP cards. Species selected in the SCDAP fission product input cannot be changed, but the initial masses can be overridden.

The remaining fission products are specified on this card and on a second (and third) card as needed.

A23.4.5 Card 5M110000, Number of Nodes with Convection

W1(I) Number of nodes in finite element mesh at which convection heat transfer can occur. Nodes specified twice on the Fission Product Card(s) count as two nodes for this input. Nodes that are part of finite elements that receive relocated material should be defined as nodes at which convection heat transfer occurs. Otherwise, convective heat transfer will not be modeled at the surface of the relocated material. Nodes at both surfaces of gap modeled as null material must be defined.

A23.4.6 Cards 5M110001 through 5M10099, Convective and Radiative Heat Transfer

All convective boundary data should be input for a line of points (that is, i2 equal i1, j2 not equal j1 or i2 not equal i1, j2 equal j1) with the nodal coordinates increasing from the first to the second node. The program will automatically assign values at nodal points intermediate to the first and second defined nodal points. Each line must contain a minimum of two points. Nodes that are on a surface and not listed on the fission product card are treated as being part of an adiabatic surface. The code then calculates convective heat transfer normal to the lines defined by the points.

W1(I) I coordinate of 1st node.

W2(I) J coordinate of 1st node.

W3(I) I coordinate of 2nd node

W4(I) J coordinate of 2nd node.

W5(R) Gap heat transfer coefficient. For case of materials in both sides of the gap being solid state, otherwise, leave blank.

W6(I) Number of RELAP5-SCDAP volumes that interface these nodes. Input the full nine-digit number.

A24. FORMATTED COUPLE INPUT (Old Format)

The old style COUPLE input data consist of a series of ordered input blocks or input data sections. Those data blocks that do not apply to a particular job may be omitted without affecting other sections of input. Each data block consists of an initial block header card, several data cards, and a block terminator blank card. No units are built into the program, and the user must be careful to be consistent throughout. The input is not free-form and must be properly positioned within the specified columns (spaces) of 80- character records (cards). Integer and exponential types of input data must be right-hand justified. The required type of input data is indicated by A for alphanumeric, I for integer, and R for real. The columns for each piece of input data are specified by the two numbers to the left of the definition of the piece of input data. The type of input data is indicated by the character in parentheses to the right of the column specifier.

Note that a RELAP deck terminator card should be input prior to COUPLE cards with the old style input. If it is desired to use the new style couple input, see Section A30.

A24.1 Title Block

A24.1.1 Header for Title Block

1-5(A) Block header. Since only the first four characters (columns 1 through 4) are actually checked on each block header card for each section, the rest may be used as a comment card.

Always input the following word: title.

A24.1.2 Title Card

1-80(A) First title card.

A24.1.3 Title Card

1-80(A) Second title card. This is a good place to list the unit set employed.

A24.1.4 Block Terminator

Block terminator (blank card).

A24.2 Mesh Generation Block

COUPLE Mesh Generation Overview

The COUPLE model advances transient heat conduction and associated heat transfer in two dimensional structures using a combination of triangular and quadrilateral finite elements. Allowed geometries are x-y plane or r-z axisymmetric. (The COUPLE model is so named because much of it is derived from the standalone COUPLE program developed at INEL.) The COUPLE model is quite general and it can be applied to multiple situations where two dimensional modeling is important in much the same manner as multiple RELAP5 heat structures can be applied. The primary application of the COUPLE model is the computation of the thermal behavior of the lower part of the primary pressure vessel and the molten material or debris that may have fallen to this region from the core region.

The finite element mesh must be defined by input data. A very general mesh could be allowed but that would require considerable input. So instead, a automatic mesh generation procedure which allows simpler input with some loss of generality is used.

Two related meshes, the simple mesh and the transformed mesh, are considered in automatic mesh generation. The simple mesh is a two dimensional mesh of J_M rows of nodes, with I_M nodes in each row, and with the $J_M \cdot I_M$ nodes arranged in a square pitch. The nodes are connected with I_M vertical lines and J_M horizontal lines. The $(I_M-1)\cdot(J_M-1)$ squares formed by the vertical and horizontal lines in the simple mesh will become the quadrilateral finite elements in the transformed mesh. The nodes (I_n) are numbered consecutively starting at the lower left with node 1, progressing horizontally to the right, and vertically to the top.The finite elements (I_e) are numbered similarly starting with the finite element at the lower left. The nodes can also still be identified by their I, J coordinates. Thus finite element I_e is formed by the horizontal and vertical lines connecting nodes I_e, I_e+1, I_e+IM, and I_e+IM+1, or in coordinate notation, (I, J), (I+1,J), (I,J+1), and (I+1,J+1) assuming that I and J are the coordinates of I_e. The coordinate notation is used primarily in input specifications and the node numbers (I_n) and finite element numbers (I) are used in printed output. The quantities, I_M and J_M, defining the simple mesh are user input.

The simple mesh must be transformed into the finite element mesh needed to represent the actual geometry of the application. For the typical application to the lower portion of the pressure vessel, the actual geometry would be a r-z axisymmetric mesh imposed on a cross section of the pressure vessel. Starting with the node at the centerline at the bottom of the pressure vessel, the outside perimeter of the mesh would proceed along the curved part of the lower plenum to the start of the cylindrical section, vertically up the cylindrical section to a point matching the top of the enclosed hydrodynamic volume, horizontally to the centerline, and finally downward to the starting point. The finite element mesh would include space occupied by the hydrodynamic volume since the hydrodynamic volume may be filled with core material dropping from the core region. The finite mesh may represent pressure vessel features such as having an outer section of carbon steel with an inner lining of stainless steel. The transformed mesh most likely does not have the square pitch of the simple mesh, and instead of only vertical and horizontal straight lines connecting nodes, the connecting lines can be straight lines (no longer necessarily vertical or horizontal) or circular arcs positioned as needed to connect the nodes. But the node connections remain the same. That is, the four nodes forming the square in the simple square mesh are the same nodes forming the quadrilateral finite element in the transformed mesh. An important feature of this is that the relationship of the nodes to the finite elements is set automatically and this information need not be entered in the input data.

If all the nodes in the simple mesh are preserved in the transformed mesh, only quadrilateral finite elements are generated. (A "triangularly" shaped quadrilateral finite element can be generated in that the angle of the lines meeting at a node can be 180 deg.) Through a feature called, stepped diagonal elements, the number of nodes can vary in a regular fashion and finite elements resulting from this feature can be triangular.

In the input descriptions that follow, the Mesh Generator Control Card includes input to define the simple mesh, that is the number of vertical nodes, I_M, and the number of horizontal nodes, J_M. The Mesh Point Positioning Data is used to transform the positions of the I, J nodes in the simple mesh to their position in the transformed mesh. Not every node needs to be explicitly positioned by this input. Nodes not explicitly positioned are automatically positioned by one of two processes. The input provides for point or line type input. The point input explicitly positions a single mesh point. The line type input explicitly positions the end points of the line segment. Using either the point or the line type, each mesh point is explicitly positioned by associating its I, J mesh point with its x-y or r-z position in the transformed mesh.

The line type has a further subdivision in that it can indicate whether the line connecting the end points is a straight line segment or a circular arc. The circular arc has yet another subdivision. One defines a circular arc by explicitly defining the two end points and also explicitly positioning a third point between the two end points. In the other form of defining circular arcs, the two end points are explicitly positioned and the center of the radius of curvature is given.

In the line type input, variations in the values of I and J are restricted to values that correspond to a coordinate oriented line along either a horizontal or vertical mesh line, or a stepped diagonal. Variations outside these two allowed variations are input errors.

The coordinate oriented line input requires that either the I or the J of the two end points have the same value and the other coordinate of the two end points be different. If the absolute value of the difference is greater than one, the additional mesh points are positioned on the straight line or arc connecting the two end points. These additional points are automatically positioned on the line using interpolation between the end points. This coordinate oriented line input and the point input do not remove nodes from the transformed mesh and do not generate any triangular finite elements. If only coordinate oriented and point input are used, all the finite elements would be quadrilateral elements.

The stepped diagonal input requires that the absolute value of the differences of the I and J coordinates be identical. Use of this feature eliminates some I, J nodes from the transformed mesh. Triangular finite elements will be located adjacent to the missing nodes. For one example of an application of this feature, consider that the cross section of the problem is a parallelogram, broad at the bottom and narrow at the top. With the quadrilateral mesh, the number of nodes used at each end of the parallelogram are identical, but the size of the nodes will be much different because of the difference in the problem dimensions between the bottom and top. Through the use of the stepped diagonal feature, fewer nodes can be used at to top of the mesh, thus allowing a more consistent mesh size over the entire problem.

After processing the Mesh Positioning Data, some nodes may still not be positioned. These nodes are then positioned by the second automatic process which positions the nodes to minimize truncation error.

The transformed mesh can be dramatically different from the simple mesh. But this transformation cannot change the nodes that define a square element in the simple mesh from those that define its corresponding finite element in the transformed mesh. Likewise, the lines in the simple mesh separating one finite element from another separate the same finite elements in the transformed mesh.

To use the automatic mesh generation, all nodes on external boundaries and all nodes on internal material interfaces should either be defined explicitly or be automatically defined by interpolation. Some other nodes may be similarly positioned to place nodes in areas of particular interest. The remaining nodes can be positioned by the second automatic technique.

As part of input processing, the location of all automatically positioned nodes are printed; nodes not included in this edit were positioned explicitly. The extent of the COUPLE mesh generation to detect input violations and the adequacy of diagnostic messages is not known.

Further constraints on the COUPLE mesh are imposed when the model is applied to the lower plenum. As debris or molten material is dropped from the core regions to the lower plenum, the material is assumed to be spread uniformly in the horizontal plane. To simplify the coding, only quadrilateral finite elements may be used in the region of the mesh receiving relocated material, and the top and bottom lines forming those finite elements must be horizontal. This requires that all nodes forming those finite elements be positioned explicitly or by interpolation.

The Graphical User Interface (GUI) contains a display of the COUPLE noding. This display is an accurate presentation of the nodes and finite elements of the transformed mesh. To activate the GUI, include -n gui or -n guii on the command line used to execute the code. Depressing the right mouse button and clicking on "Display windows' --> "Couple Noding" displays the noding diagram. Depressing the right mouse button on "Display values" and then "ijnode", "nnode", or "enode" adds to the display the i-j noding numbers, the node numbers, or the finite element numbers respectively. Entering one of the other "Display values" (such as "tmpcou" for node temperatures) places those quantities on the display. As the transient advances in time, the values on the display are updated. The background color will change from dark blue to red as the temperature increases.

This input is considered difficult and referring to sample input and a resulting noding diagram can be helpful. The scvp2 problem, typically distributed with the code, includes a COUPLE model of the lower plenum and can be used with the GUI as described above.

A24.2.1 Header for Mesh Generation Block

1-8(A) Header for mesh generation block. Always input the following word: automesh.

A24.2.2 Mesh Generator Control Card

1-5(I) Maximum value of I in mesh. This is the maximum number of nodes in the horizontal direction.

6-10(I) Maximum value of J in mesh. This is the maximum number of nodes in the vertical direction.

11-15(I) Number of material blocks to be assigned. This is the number of different material regions specified on the material block assignment Card(s).

16-20(I) Geometric code.

0 = r-, z-axisymmetric.

1 = x-, y-plane body.

21-30(R) Multiplier. This multiplier operates on dimensions that are input on the line segment card(s) and elsewhere in the input. The multiplier allows the COUPLE input to use inches as the unit for length even though the calculations use meters as the unit for length. (This word) x (value of input number) = (dimension in m).

A24.2.3 Mesh Point Positioning Data

Each card can enter one of four types of mesh positioning data. The type of positioning is entered in the field using columns 67-71. Based on the type, other fields are used or left blank. A point type explicitly positions a single point. A straight line segment explicitly positions its end points and an arc explicitly positions the end points of the arc. The definition of the curvature of the arc requires an additional point, either an intermediate point on the arc or the center of radius of curvature of the arc. The intermediate point on the arc is also explicitly positioned. If the absolute differences in the changes of either the I or J coordinate is greater than one, the intermediate points are automatically positioned by interpolation. Not all nodes need be positioned explicitly or by interpolation. If the absolute differences in the changes of both I and J are identical, nodes are removed from the transformed mesh and triangular finite elements are used where the nodes are removed. The mesh point positioning data can be input in any order.

The elements that may be filled by relocated material must be quadrilateral and not triangular in shape. Two of the sides must be perpendicular to the direction in which material is transported into the element.

1-3(I) I-coordinate of 1st point.

4-6(I) J-coordinate of 1st point.

4-14(R) R-coordinate of 1st point.

15-22(R) Z-coordinate of 1st point.

If the line segment type (columns 67 to 71) is 0, then omit the input in columns 23 through 66.

23-25(I) I-coordinate of 2nd point.

26-28(I) J-coordinate of 2nd point.

29-36(R) R-coordinate of 2nd point.

37-44(R) Z-coordinate of 2nd point.

If the line segment type (columns 67 to 71) is 1, then omit the input in columns 45 through 66.

45-47(I) I-coordinate of 3rd point.

48-50(I) J-coordinate of 3rd point.

51-58(R) R-coordinate of 3rd point.

59-66(R) Z-coordinate of 3rd point.

67-71(I) Line segment type of parameter.

0 = Point (input only 1st i, j, r, z).

1 = Straight line (input only 1st and 2nd sets of i, j, r, z as end points of line).

3 = Circular arc with midpoint of arc specified (input 1st and 3rd sets of i, j, r, z as end points of arc and 2nd set as midpoint on arc).

4 = Circular arc with center of radius of curvature specified (input 1st and 2nd sets of i, j, r, z as end points of arc and 3rd set of r, z as coordinates of center of radius of curvature).

Straight or curved lines segments in the r-z plane must correspond to either a vertical or horizontal line (i- or j-constant along line) in the simple mesh or a stepped diagonal segment [abs(I)=abs(J)] in that simple mesh. Note on a stepped diagonal segment that i is incremented first and then j.

Repeat the above card until the sufficient nodes have been positioned explicitly or by interpolation such that the second automatic positioning can complete the positioning. The mesh can be completely positioned explicitly or by interpolation by inputting a line type input for each segment of the either the horizontal or the vertical lines of the simple mesh.

For modeling gap resistances, input two consecutive values of i or j that have identical coordinates.

A24.2.4 Mesh Generation Block Terminator

Block terminator (blank card).

A24.3 Material Identifier Block

A24.3.1 Material Block Assignment

A card is needed for each block specified. Each card assigns a material definition number to a block of elements defined by the i, j coordinates.

1-5(I) Material identification number. The COUPLE model considers up to 15 different materials. The materials and their identification numbers are listed in Table 11

Table 11: COUPLE material indices

Material	ID No.
Relocated Debris	1
Stainless Steel	2
Inconel	3
Carbon Steel	4
Coolant	5
Null Material	6
MHTGR graphite	7
MHTGR fuel compact	8
MHTGR target	9
MHTGR smeared (homogenized)	10
User-specified materials	11-15

For user-specified materials, the user supplies constant property values by entering the values on the Material Properties and Material Data Cards. For user-specified materials, the code will not model phase change.

Each element defined to have relocated debris is considered to contain coolant until the coolant has been displaced by relocated debris that has slumped into the element. The exception to this is the “no slumping” case (Word 3 = -1 on COUPLE Card 5M010000), in which material 1 is already present at the start of the problem. If on, the fission products card(s) gap heat transfer is not specified for nodes that are part of a null element, then no heat transfer will occur across the null element. Null elements are used to differentiate between two regions with different heat generation rates and to model heat transfer between two materials with a possible gap between them.

6-10(I) Minimum i.

11-15(I) Maximum i.

16-20(I) Minimum j.

21-25(I) Maximum j.

26-35(R) Always input 0.0.

35-45(R) Porosity of material in these elements. If material type is 1 and the element is at the start of analysis, input 1.

46-50(I) Always input the integer 0.

51-55(I) Always input the integer 0.

56-65(R) Particle diameter

A24.3.2 Material Identifier Block Terminator

Block teminator (blank card)

A24.4 Material Block

A24.4.1 Material Block Assignment

A card is needed for each block specified. Each card assigns a material definition number to a block of elements defined by the i, j coordinates.

1-8(A) Block header. Always input the following word: material.

A24.4.2 Material Data Information

1-5(I) Number of different materials to be defined. Materials that do not exist in the finite element mesh can be defined. In the current version of COUPLE input, if Material 5 is to be used, Materials 1, 2, 3, and 4 need also to be defined.

A24.4.3 Emissivity

1-10(R) Emissivity. Emissivity for internal radiation in material with ID No. 1. The standard value is 0.8.

A24.4.4 Material Properties

1-5(I) Material identification number. If material identification number greater than 11 is input, then properties are defined as input on this card (density) and on the Material Data Card, but materials properties do not change with temperature.

11-20(R) Density of material (kg/m^3). If null material (an element used to model gap resistance), then leave these columns blank.

21-52(A) Material title information. For example, if stainless steel material, input “stainless steel."

A24.4.5 Material Data

These data are used as default values in case built-in procedures (derivative method in COUPLE) fail to meet specified criteria. If data are not available, low-temperature default data given in the following table format should be input. These default values are required. If the input columns are left blank, the code does not automatically set the input variable to the default value. See Card 103, Restart-Plot Input File Control Card on page 13,.

1-10(R) Horizontal thermal conductivity, k_r (J/m-s-K). Input 0.0 for null material.

11-20(R) Axial thermal conductivity, k_z (J/m-s-K). Input 0.0 for null material.

21-30(R) Specific heat capacity, c_p (J/kg-K). Input 0.0 for null material.

31-80 Blank. Unless material = 7, then input next word.

31-40(R) Fast neutron fluence (n/cm^2).

Repeat the two previous cards until each type of material in the mesh has been defined.

If material = 10, then insert the next card.

A24.4.6 MHTGR Material Data

1-10(R) Cross-sectional area of graphite (m^2).

11-20(R) Cross-sectional area of fuel compact (m^2).

21-30(R) Cross-sectional area of target (m^2).

31-40(R) Cross-sectional area of helium coolant channels (m^2).

41-50(R) Fast neutron fluence (n/cm^2).

The cross-sectional areas are in the plane perpendicular to longitudinal axis of the reactor core.

A24.4.7 A23.4.7 Material Block Terminator

Block terminator (blank card).

A24.5 Time Step Data

A24.5.1 Time Step Data Block Header

1-4(A) Time step data block header. Always input the following word: step.

A24.5.2 Temperature Control Card

31-40(R) Initial temperature of finite element mesh (K).

41-50(R) Relaxation parameter in numerical solution. Recommended value is 0.5.

51-60(R) Convergence parameter in numerical solution. Recommended value is 1.0. If gap elements (elements with null material) are being modeled, then the computer run time can be very sensitive to this input value. To avoid excessive run time, it may be necessary to define the convergence parameter to be greater than 1.0, perhaps as large as 5.0.

61-70(R) Inner radius of lower head of vessel. Use the same units as the coordinates on the Line Segment Card. If a spherical lower head is not being modeled, input 0.0.

A24.5.3 Description of Lower Head of Vessel

1-10(R) Outer radius of region in finite element mesh that can fill with slumping material. Use the same units as the coordinates on the Line Segment Card. If a spherically shaped lower head is being modeled, input 0.0. If a cylindrically shaped lower head is being modeled or plane coordinates are being used, then this input is used. If plane coordinates are being used, this input specifies the inner radius of pipe being modeled in plane geometry.

11-20(R) Thickness of lower head of vessel or elevation of top surface of structural material supporting debris. Use the same units as the coordinates on the Line Segment Card. If a spherical lower head is not being modeled, then input the distance from the bottom of the finite element mesh to the surface that supports the slumping material.

21-25(I) Spherical lower head modeling flag.

0 = Spherical lower head of vessel is not being modeled.

1 = Spherical lower head of vessel is being modeled.

26-30(I) Maximum number of iterations. Recommended value is 10.

31-40(R) Inner radius of region that can fill in with slumping material. Use the same units as for the Line Segment Card. Omit for the case of spherical lower head. For the case of plane geometry, input 1.0.

41-50(R) Depth (thickness) of plane. Use the same units as for the Line Segment Card. Omit this input for axisymmetric geometry.

51-55(I) Transient configuration of debris slumping flag.

0 = Debris slumping is self-leveling throughout the COUPLE mesh.

1 = Configuration of slumped debris is defined by the user.

If this flag is set, the order in which elements receive slumped debris is defined by the user. The user can divide the elements into layers, which will fill sequentially as the debris slumps. Within each layer the debris is assumed to self-level across all elements in that layer. The user defines the layers of elements by adding cards immediately after this one; one card for each layer. The code limits the inputs to 25 elements per layer for up to 25 layers. The last card in the list should contain a single 0 to indicate the end of the list.

Each card that defines a layer must conform to the format as defined below.

A24.5.4 User-Defined Layer of the COUPLE Mesh

1-4(I) Number of elements in this layer.

5-10(I) The element number in this layer. Five spaces for each element, continued on the next card if necessary. The last card in the list must contain a single 0.

A24.5.5 Block Terminator

Block terminator (blank card).

A24.6 Internal Heat Generation Block

A24.6.1 Internal Heat Generation Block Header

1-10(A) Block header. Always input the following word: generation. The generation block is required input.

A24.6.2 Number of Materials Without Internal Generation

1-5(I) Number of materials for which internal generation is not possible. If relocated debris is being considered, input the number that is one less than the input in Columns 1 through 5 of the Material Data Information Card. Otherwise, input the same number.

6-10(I) NAF. The number of pairs of lines of mass fractions input.

11-15(I) NFP. The number of lines of fission products input.

A24.6.3 Power Densities

These cards are optional for the "no slumping" COUPLE case (Word 3 = -1 on the Couple Card 5M0010000), and are not allowed otherwise. Each card defines a power density for a specified group of consecutive nodes. This input can be used for selected nodes to override the power density option set for all COUPLE Material 1 by SCDAP.

1-5(I) I1I of first node in the group.

6-10(I) J1J of first node in the group.

11-15(I) I2I of last node in the group.

16-20(I) J2J of last node in the group.

21-30(R) X204 Multiplier of power density from Table N402. If N402 = 0, then X204 = constant power density (W/m^3).

31-35(I) N402 Number of RELAP5 general tables of power density (W/m^3).

A24.6.4 Block Terminator

Blank card.

A24.7 Material Without Internal Generation

A24.7.1 Material Numbers Without Internal Generation

1-5(I) First material number.

6-10(I) Second material number.

Continue in Columns 11-15, 16-20, etc., until all materials defined in the Material Properties Card have been identified. Null material must be defined as material with no internal heat generation.

A24.7.2 Mass Fractions

These cards are optional for the “no slumping” COUPLE case (Word 3 = -1 on the COUPLE Card 5M001000) and are not allowed otherwise. Each pair of cards defines the mass fractions for the constituents in a consecutive group of COUPLE elements with Material 1. These fractions are converted to atomic fractions and stored as such.

<u>Card 1:</u>

1-5(I)	NEL1. Number of first element in the group.
6-10(I)	NEL2. Number of last element in the group.
11-20(R)	Mass fraction of zircaloy.
21-30(R)	Mass fraction of metallic uranium.
31-40(R)	Mass fraction of stainless steel.
41-50(R)	Mass fraction of silver.
51-60(R)	Mass fraction of boron carbide.
61-70(R)	Mass fraction of uranium dioxide.
71-80(R)	Mass fraction of oxidized zircaloy.

<u>Card 2</u>:

1-10(R)	Mass fraction of aluminum.
11-20(R)	Mass fraction of lithium.
21-30(R)	Mass fraction of cadmium.
31-40(R)	Mass fraction of soil.

This input overrides the SCDAP values for the elements specified.

A24.7.3 Fission Products

These cards are optional for the “no slumping” COUPLE case (Word 3 = -1 on the COUPLE Card 5M001000) and are not allowed otherwise. They cannot change the fission product species selected on the SCDAP Fission Products Input Card, but the cards can be used to override the masses for selected elements. Each set of these cards (which may consist of 1, 2, or 3 cards, depending on the number of fission products selected in the SCDAP input) redefines the initial fission product masses for a group of elements with Material 1. The values in a set must be in the same order as those in the SCDAP input.

1-5(I)	NEL1 Number of first element in the group.
6-10(I)	NEL2 Number of last element in the group.
11-20(R)	First in the list of specified fission product (kg/m^3).
21-30(R)	Second in the list of specified fission product (kg/m^3).

The remaining fission products are specified in 10-column fields on this card and on a second (and third) card as needed.

A24.7.4 Block Terminator

Block terminator (blank card).

A24.8 Convection Data Block

A24.8.1 Convection Data Block Header

1-11(A) Block header. Always input the following word: convectsets.

A24.8.2 Number of Nodes with Convection

1-5(I) Number of nodes in finite element mesh at which convection heat transfer can occur. Nodes specified twice on the cards described in Section A1.6 count as two nodes for this input. Nodes that are part of finite elements that receive relocated material should be defined as nodes at which convection heat transfer occurs. Otherwise, convective heat transfer will not be modeled at the surface of the relocated material. Nodes at both surfaces of gap modeled as null material must be defined. Must be ≤ 2000.

6-10(I) Input the integer 1.

A24.8.3 Boundary Conditions for Elements That Fill With Slumping Debris

1-10(R) Always input 1000.0.

11-20(R) Always input 500.0.

A24.8.4 Identification of Surfaces With Convective and Radiative Heat Transfer

All convective boundary data should be input for a line of points (that is, i2 equal i1, j2 not equal j1 or i2 not equal i1, j2 equal j1) with the nodal coordinates increasing from the first to the second node. The program will automatically assign values at nodal points intermediate to the first and second defined nodal points. Each line must contain a minimum of two points. Nodes that are on a surface and not listed on the these cards are treated as being part of an adiabatic surface.

1-5(I) I coordinate of 1st node.

6-10(I) J coordinate of 1st node.

11-15(I) I coordinate of 2nd node.

16-20(I) J coordinate of 2nd node.

21-30(R) If these convective nodes are not modeling heat transfer across the gap, leave these columns blank. Otherwise, input gap heat transfer coefficient for case of materials in both sides of the gap being solid state.

55-60(I) If these convective nodes are not modeling heat transfer across the gap, leave these columns blank. Otherwise, input -1.

These cards are repeated as many times as necessary to define all the convection boundary data.

A24.8.5 Number of Interfacing RELAP5-SCDAP Volumes

Omit this card if -1 is input in columns 55-60 on the previous card.

1-10(I) Volume number of hydrodynamic volumes that interfaces these nodes. Input the full nine-digit number.

A24.8.6 Block Terminator

Block terminator (blank card).

A24.9 Initial Temperature

A24.9.1 Initial Temperature Block Header

1-8(A) Block header. Always input the following word: tempsets.

A24.9.2 Number of Temperature Nodes

5-10(I) Number of nodes in mesh at locations that may be filled with slumping debris. Always input the integer 0.

16-20(I) Always input the integer 0.

21-30(R) Always input 0.0.

A24.9.3 Block Terminator

Block terminator (blank card).

A24.10 Plot Control

A24.10.1 Plot Control Header

1-5(A) Block header. Always input the following word: plots.

A24.10.2 Plot Control Card

1-5(I) Always input the integer 1.

6-10(I) Always input the integer 0.

11-15(I) Always input the integer 2.

A24.10.3 Plot Control Block Terminator

Block terminator (blank card).

A24.11 Solution Control

A24.11.1 Solution Control Header

1-6(A) Block header. Always input the following word: couple.

A24.11.2 Solution Control Block Terminator

Block terminator (blank card).

A24.11.3 Problem Termination Card

1-11(A) Problem termination card. Always input the following words: end of data.

A25. USER DEFINED CORE SLUMPING

These cards enable the code user to specify a series of one or more user-defined slumpings of core material into a COUPLE mesh. At least one COUPLE mesh, and one RELAP5-SCDAP core component must be specified. The user should note that the card number provides a significant amount of information to the code. The first digit is always '5' to identify it as COUPLE input. The second digit is 'M', the mesh number into which the slump enters. The third and fourth digits are '20' to identify this input as pertaining to user-defined slumping.

A25.0.1 Card 5M200000, Definition

The first card specifies a RELAP5-SCDAP general table which is used as a multiplier on the debris power. The specification of the table number may not be changed on restart, although the table itself may be changed. The same table is applied to all slumps.

W1(I) Table number. Table to define the power decay of the slumps.

A25.0.2 Card 5M20S100, Duration

This card specifies the duration and power of each period of slumping. The card number uses the integer 'M' to specify the mesh into which material is slumped, and the integer 'S' to specify the slump number in chronological order, maximum of 25 slumps may be defines.

W1(R) Time at which core slumping begins (s). W1 (S-th slumping) > W2 (S - 1th slump).

W2(R) Time at which core slumping ends (s).

W3(R) Power multiplier.

The total power in the slump (W) is defined by this factor multiplied by the value from the general table specified on Card 5M200000. The power added to the mesh for each time step is then (W3)*(table number from previous card) * (time step)/(W2 - W1), where W1, W2, and W3 are Words 1, 2, and 3, respectively, from this card.

A25.0.3 Card 5M20S200, Characteristics

W1(R) Temperature of slumped material (K).

W2(R) Radius of particles of slumped material (m).

W3(R) Porosity of slumped materials.

A25.0.4 Cards 5M20S301 through 5M20S399, Mass

W1(R) Mass of zircaloy that slumped during period (kg).

W2(R) Mass of metallic uranium (kg).

W3(R) Mass of stainless steel (kg).

W4(R) Mass of silver (kg).

W5(R) Mass of boron carbide (kg).

W6(R) Mass of uranium dioxide (kg).

W7(R) Mass of oxidized zircaloy (kg).

W8(R) Mass of aluminum (kg).

W9(R) Mass of lithium (kg).

W10((R) Mass of cadmium (kg).

A25.0.5 Cards 5M20S401 through 5M20S499, Fission Product Species

W1.. (R) Mass of specie (kg). Mass of fission products to track.

Input in the following order: I, CsI, CsOH, Te, HI, HTe, Cd, Ag, UO_2, Sn, Fe, Ru, Ba, Sb, Cs*, I*, Zn, Xe, Kr.

A26. CARDS 1001 THROUGH 1999, STRIP REQUEST DATA

These cards are required only in STRIP-type problems. One or more cards are entered, each containing one variable request. Card numbers need not be consecutive. Variables are ordered on the STRIPF file in the order of increasing card numbers. 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.

A27. CARDS 1001 THROUGH 1999, COMPARE DUMP FILES CONTROL DATA

These cards are required only in CMPCOMS problems. One or more cards are entered, each containing one request to compare dump blocks on the files specified with the -A and -B options on the command line. Card numbers need not be consecutive.

W1(I) Dump file number from file specified on -A command line option.

W2(I) Dump file number from file specified on -B command line option.

The values in Words 1 and 2 on a succeeding card must be greater than the values on the preceding card. The values in Words 1 and 2 are the advancement number when the dump block was written. This information is written as a line in the printed output of the run writing the dump file. The form of the line is, "---Dmpcom no. nnn written, block no. mmm on unit u---," where nnn is the advancement count number, mmm is the count of the number of blocks written, and u is A or B indicating the file specified by the -A or -B option.

A28. UNCERTAINTY ANALYSIS INPUT REQUIREMENTS

A complete uncertainty analysis requires execution of three related phases, the setup phase, a simulation phase consisting of several runs, and the post processing phase.

Because of the large number of files involved in the uncertainty analysis, specific suffixes on file names are required. Also to eliminate modification of the input file used during the simulation runs command line option is used to indicate the uncertainty phase and the run number during the simulation phase runs.

The setup phase generates the uncertainty weight information needed for each run and the post processing phase. The setup phase generates the total number of simulation runs needed based on either a user specified quantity, a value determined from the Wilks' formula with a provision for sparse. The setup information is written on disk files, one for each simulation run, and another one for the post processing. The setup phase requires the standard input file that will also be used in each simulation run and information to determine the number of runs using information entered on card 29000000. Cards 290XXXXX allow the user to modify the generation of weight for correlations that are built into the code. Cards 291XXXXX allow the user to specify weights for user supplied input data. The command line for executing the setup phase is

relap5o.exe -i mylbreak.is -uncrun setup

The file name, "mylbreak" in the example above, has to be the same name in all phases. Same name is used for the input, output, restart plot and weight files. The command line will specify the file name as the input file but the other file names will be generated internally and are not entered on the command line. The suffix "is" is the required suffix for the input file. The output file will be mylbreak.os, the restart plot file will be mylbreak.rs, and the weight files will be mylbreakNNNN.w. The number of weight files, N_w, will be equal the number of uncertainty runs entered or determined during this phase and NNNN will range from 0001 through N_w.

The simulation phase requires a base run in which the simulation is done as there were no uncertainty option available, and the set of uncertainty runs which have uncertainty input and source modifications. The simulation phase reads a file generated by the setup phase for each run and writes information to be used in the post processing in the plot records of the restart plot file. The input data used for the simulation phase should be the same for the base run and each simulation run and is also the same used during the setup run. The command line for executing the simulation phase is

relap5o.exe -i mylbreak.i -uncrun n

The suffix "i" is the required suffix for the input file. The number n is 0 for the base case and is the run number for the uncertainty runs, and this number written as four digits with leading zeros will be appended to the name of the output and restart plot files, mylbreaknnnn.o mylbreaknnnn.r. The weight file to be used in the uncertainty runs will be mylbreakNNNN.w.

The post processing phase reads the restart plot files written during the base and the uncertainty runs and generates the rank matrices (values sorted according its rank). The rank matrices are written to disk for each parameter for which bounds are to be obtained. These parameters are defined in cards 2080XXXX. It is the user responsibility to ensure that the desired parameters are placed on the restart plot files during the simulation runs. Cards 292XXXXX are required to indicate the simulation runs to be included in the post processing phase. The command line for executing the post processing phase is relap5o.exe -i mylbreak.ip -uncrun postpr

The post processing phase will generate a rank matrix file for each requested parameter. Each matrix is written to disk with the file name mylbreakMMMM.m, where MMMM ranges from 0001 to the number of requested parameters. A graph containing the time history of the base result, the upper and lower and the difference between the bounds will be generated for each requested parameter. The output file will be mylbreak.op.

Cards used for the setup, simulation, post-processing phases of the uncertainty analysis are described here.

A28.1 Card 29000000, Select Setup Run

This card is required for the setup run, which must precede any simulation run using RELAP5-SCDAP uncertainty mode. The entire input deck is required in a setup run.

W1(I) Number of uncertainty runs. If zero is entered Wilks' formula will be used to determine the number of uncertainty runs. If positive non zero is entered, the number will be the number of uncertainty runs.

The next three words are required either if W1 is zero or if the Wilks' formula is to be evaluated to allow the user to compare the number of uncertainty runs required by the Wilks' formula to the number entered by the user.

W2(R) Confidence level of the one-sided tolerance limits. Quantity must be greater than zero and less than one.

W3(R) Percentile of population below the one-sided tolerance limit.Quantity must be greater than zero and less than one.

W4(I) Order of Wilks' formula application.

The next three words are optional.

W5(I) Number of uncertainty runs to be added to the number computed by Wilks' formula. Quantity must be greater than or equal to zero.

W6(I) Minimum number of uncertainty runs.

W7(I) Maximum number of uncertainty runs. This word must be entered if W6 is entered.

A28.2 Cards 29000001 - 29001000, User Modification of Uncertainty Distribution Information Defined in Source Code

The next words define the probability distribution function associated to the source uncertainty coefficient entered in W1.

W1-W2(A) Alphanumeric definition of the source uncertainty coefficient. This must be entered as one alphanumeric entry of at least nine characters. Entry of at least nine characters is processed within the code as two alphanumeric words.

W3(A) Alphanumeric definition of the distribution type. Three types of distribution are allowed. If ND is entered, the normal distribution will be used for the random sampling process. If UD is entered, the uniform distribution will be used for the random sampling process. If TD, the trapezoidal distribution will be used for the random sampling process.

The next four words are the characteristic parameters defining the distribution type entered in W3.

W4(R) If definition entered in W3 is ND, the required quantity is the mean. If definition entered in W3 is UD, the required quantity is the minimum value. If definition entered in W3 is TD, the required quantity is the lower left limit.

W5(R) If definition entered in W3 is ND, the required quantity is the standard deviation. If definition entered in W3 is UD, the required quantity is the maximum value. If definition entered in W3 is TD, the required quantity is the upper left limit.

W6(R) If definition entered in W3 is TD, the required quantity is the upper right limit. In other cases enter 0.0.

W7(R) If definition entered in W3 is TD, the required quantity is the lower right limit. In other cases enter 0.0.

W8(R) Weight related number. If -1.0 is entered, a weight will be computed according to W3 - W7 entered information. If a positive non zero quantity is entered, it will be used as the weight for all uncertainty code runs.

A28.3 Cards 291DDWWX, Input Parameters Uncertainty Distribution Information

A28.3.1 Cards 291DD000, Distribution Type Information

These cards hold the distribution type data for a DD set.

W1(A) Alphanumeric definition of the distribution type. Three types of distribution are allowed. If ND is entered, the normal distribution will be used for the random sampling process. If UD is entered, the uniform distribution will be used for the random sampling process. If TD, the trapezoidal distribution will be used for the random sampling process.

The next four words are the characteristic parameters defining the distribution type entered in W1.

W2(R) If definition entered in W3 is ND, the required quantity is the mean. If definition entered in W3 is UD, the required quantity is the minimum value. If definition entered in W3 is TD, the required quantity is the lower left limit.

W3(R) If definition entered in W3 is ND, the required quantity is the standard deviation. If definition entered in W3 is UD, the required quantity is the maximum value. If definition entered in W3 is TD, the required quantity is the upper left limit.

W4(R) If definition entered in W3 is TD, the required quantity is the upper right limit. In other cases enter 0.0.

W5(R) If definition entered in W3 is TD, the required quantity is the lower right limit. In other cases enter 0.0.

A28.3.2 Cards 291DDWW0, Weight Information

This card indicates that a weight is to be computed or entered for the cards 291DDWWX that entered specific input quantities to have weights applied.

W1(R) Weight related number. If -1.0 is entered, a weight will be computed according to

W3 - W7 entered information. If a positive non zero quantity is entered, it will be used as the weight for all uncertainty code runs.

A28.3.3 Cards 291DDWWX, Input Quantity with Weight Modification

One or more input quantities to be modified as part of the uncertainty analysis are entered on this card using four quantities in each set. Each set may enter one or more quantities. One or more sets may be entered on each card. DD characters indicate a distribution type and its parameters. Each WW within a DD indicate weight to be using the DD distribution type. Finally X indicates input quantities to be modified using the WW weight within the DD distribution type.

Each input quantity to be modified must appear in the input deck.

W1(I) Card number containing quantity to be modified.

W2(I) Word number of the first quantity in the card to be modified.

W3(I) Word number of the last quantity in the card to be modified.

W4(I) Skip factor. This quantity must be entered even if its equal to one.

A28.4 Cards 29200000 - 29209999, Selection of Run Numbers for Post Processing

The post processing phase reads information from the setup phase, time history information from the base run and several uncertainty runs, and from that information, generates rank matrices and graphs of uncertainty bounds.

Information from the base case is always included in the post processing analysis. These cards select which of the runs are to be included in the post processing and allows the user to select all runs or to ignore simulation runs which are judged to be unsatisfactory.

One or more of these cards are required for the post processing phase of the uncertainty analysis. Card numbers need not be consecutive. Runs during the simulation phase are numbered from 0 up to the maximum established during the setup phase. The run corresponding to the base case is numbered 0 and uncertainty runs are numbered from 1 up to the maximum. Using one or two words sets, the number of either a single uncertainty run or the numbers of a set of consecutive uncertainty runs is selected. The words entered on these cards must be in increasing run number. A positive run number followed by a negative run number is a two words set and indicates a range of run numbers. A one word set is indicated by a positive number followed by a positive number.

W1(I) A run number or the first number of a two words set indicating a range of consecutive run numbers.

W2(I) A positive number indicating another single run number or a negative number indicating the second word of a range.

... Enter additional one or two words sets as needed.

For example entering 1, 3, -59 would indicate runs 1, 3, 4, 5, 6, ..., 59.

A28.5 Cards 20800000 - 20810000, Selection of Output Uncertainty Quantities

These cards 20800000 - 20810000 select which of the simulation results are to have rank matrices and bounds computed. The format of these cards which is used in the post processing phase of the uncertainty analysis is the same as the 20800000 - 20810000 cards described in

Section A1.6. The quantities selected on these cards indicate the quantities to be processed in the post processing phase. However the indicated selected quantities must be present in the plot records of the base run and each of the uncertainty runs. If any the selected data is missing in any of the runs the post processing phase will be terminated and no results generated. To ensure that the selected quantities are present the following procedure is strongly recommended. The selection of the range of 2080000 - 20810000 numbers should be towards the high end such as 20809000 - 20810000 to differentiate these cards which specify uncertainty quantities from the normal 208XXXXX cards use to select additional plot variables. The cards specifying the uncertainty quantities should be added to the input deck for each simulation runs. Inserting the 208XXXXX cards from the uncertainty runs is recommended even if the simulation deck already specifies the quantity in its 208XXXXX cards. The duplication does cause an input failure and does not lead in an increase of plot records.

A29. RELAP5-SCDAP OPERATING PROCEDURES

When operating on Unix or Windows systems, the RELAP5-SCDAP program can interpret a Unix-style command line. The command is written with all of the desired options. Each option is prefixed by a minus sign and must always be followed with a file name. The options may be specified in any order, but may not be repeated. If an option is not entered, the default is used. For operating systems other than Unix and Windows, the default file names must be used. See Table 12.

Table 12: Explanation of Command Line Options

Option	Default	Application
-i	indta	Input (formatted) file. This file must be available for all run types or else a diagnostic message will be written to the screen followed by immediate termination.
-o	outdta	Output (formatted with standard Fortran carriage print controls in column 1) file. This file must not exist at start of execution of a set of problems or else a diagnostic message will be written to the screen followed by immediate termination.
-r	rstplt	Restart-plot (unformatted) file. This file must not exist at start of execution of a NEW problem and must exist at start of execution of a RESTART problem. Problems opening or reading the restart-plot file will be noted as diagnostics in the printed output, but processing will complete to the end of input processing.
-s	stripf	For strip runs, contains the plot data selected from plot records on the restart-plot file (formatted or unformatted as selected by user). See Section A1.6. For IN-COND runs, contains initial conditions or a user selected time step (formatted).
-all	Base part, no suffix of file name	Base part of file names for input, output, restart-plot, and strip files. A common practice is to use a common base name for the input, output, restart-plot and strip files, and append the option as a suffix to the base name. An example is, -i myprob.i -o myprob.p -r myprob.r is myprob.s. Entering -all myprob is a shortcut to entering the four options and parameters in the example. If the -all option is used, none of the -i, -o, -r, or -s options may be entered.
-j	jbinfo	An optional (formatted) file, created by the user, which is copied to the output file at the beginning of a set of input.

Table 12: Explanation of Command Line Options

Option	Default	Application
-A	dumpfil 1	This (unformatted) file and the similar file selected by the -B option are used to dump common and dynamic blocks for debugging purposes. These files must not exist for the run that creates them and must exist for the CMPCOMS run. This capability currently does not include files switched to Fortran 90 coding.
-B	dumpfil 2	See -A above.
-w	tpfh2o	Light water thermodynamic property (unformatted) file. Must be available for NEW, RESTART, and PLOT runs that use H_2O.
-d	tphd2o	Heavy water thermodynamic property (unformatted) file. Must be available for NEW, RESTART, and PLOT runs that use D_2O.
-n	null	These are not file names and the allowed entries are gui or guii. Entry of gui activates a Graphical User Interface (GUI) during the transient portion of a NEW or RESTART run. Entry of guii activates the GUI during input processing and also during the transient processing.
-verbose	none	No parameter. If this option is entered, the version identification of the executable is displayed and the program then terminates without doing any processing of the input file.
-Q	none	When RELAP5-SCDAP starts executing, a window is created. This window presents the version number of the code being used, file usage, whether input processing was completed successfully and the progress of line advancements during a simulation. If plots have been requested, they are placed in subwindows. At the end of the simulation and any plot processing, the code pauses to allow interactive viewing and saving of plot files. To terminate processing of the problems, the user must interactively close the window. The -Q option, if entered automatically closes the window without user interaction. This is useful for multiple problems when an input file or for several executions of RELAP5-SCDAP within a batch file.

The command line capability eliminates the need to have all files needed for execution in the same directory or to copy/rename files to match the default names. For example, the command:

relap5.x -i myprob.i -o /usr/rjw/myprob.o -r /usr/rjw/myprob.r -w /u2/rjw/
tpfh2o (Unix)

relap5o -i myprob.i -o \rjw\temp\myprob.o -r \rjw\temp\myprob.r -w
\rjw\perm\tpfh2o (Windows)

takes the executable file and input file from the current directory, writes to a different directory for the output and restart-plot files, and uses a water property file from a yet another directory.