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BLOCKAGE 2.5 User's Manual

Prepared by
D. V. Rao, W. Bernahl, J. Brideau, C. Shaffer, F. Souto

Science and Engineering Associates, Inc.

Software Edge, Inc.

Prepared for
U.S. Nuclear Regulatory Commission

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Prepared by
D. V. Rao, W. Bernahl*, J. Brideau, C. Shaffer, F. Souto

Science and Engineering Associates, Inc.
P. O. Box 3722
Albuquerque, NM 87190

*Software Edge, Inc.
1485 Chippewa Pathway
Riverwoods, IL 60015

M. L. Marshall, Jr., NRC Project Manager

Prepared for
Division of Engineering Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
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Abstract

The BLOCKAGE 2.5 code described in this User's Manual was developed by the United States Nuclear Regulatory Commission (NRC) as a tool to evaluate licensee compliance with NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling Water Reactors". As such, BLOCKAGE 2.5 provides a generalized framework into which a user can input plant-specific and insulation-specific data for performing analyses in accordance with Regulatory Guide 1.82, Rev. 2. This user's manual describes the capabilities of BLOCKAGE 2.5 along with a description of the graphics user's interface provided for data entry. Each input/output dialog is described in detail along with special considerations related to developing and executing BLOCKAGE. Also, several sample problems are provided such that user can easily modify them to suit a particular plant of interest. The models used in BLOCKAGE 2.5 and their validation are presented in the accompanying NUREG/CR-6371.

The BLOCKAGE models were designed to be parametric in nature, allowing the user flexibility to examine the impact of several modeling assumptions and to conduct sensitivity analyses. As a result, BLOCKAGE 2.5 results are known to be very sensitive to the user provided input. It is therefore strongly recommended that users become thoroughly familiar with BLOCKAGE models and their limitations as described in NUREG/CR-6224.

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List of Acronyms

ECCS	Emergency Core Cooling System
GUI	Graphical User Interface
LLOCA	Large LOCA
LOCA	Loss of Coolant Accident
MLOCA	Medium LOCA
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
BWRs	Boiling Water Reactors
RMI	Reflective Metallic Insulation
SLOCA	Small LOCA

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Several individuals made significant contributions towards development of BLOCKAGE 2.5. In particular, this study considerably benefited from technical and management support of Mr. Michael Marshall (RES), who was the NRC Task Manager for this effort. He provided critical technical direction, actively participated in the model development and implementation, and performed in-depth testing of BLOCKAGE 2.5. As always, Mr. Aleck Serkiz (RES) provided significant technical insights and review of the models and their results.

At SEA, Ms. Gwen Vergera led the effort of report peer review and its production. Ms. Rose Flores was responsible for the typing and layout of the final document. Finally, we would like to acknowledge contribution of Mr. R. Walsh and Ms. N. Ruiz, formerly of SEA, in developing earlier versions of BLOCKAGE.

1.0 Introduction

BLOCKAGE 2.5 (BLOCKAGE) is a versatile tool for independent evaluation of the design of suction strainers for emergency core cooling system (ECCS) pumps in boiling water reactors (BWRs). The code was developed by Science and Engineering Associates, Inc. (SEA) and Software Edge, Inc. for the Nuclear Regulatory Commission (NRC) to provide PC-based analysis software to evaluate licensee compliance with NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling Water Reactors." This User's Manual is intended to provide a user of the code the necessary background and instruction to effectively use BLOCKAGE to evaluate the potential for ECCS strainer blockage and loss of net positive suction head (NPSH) in a boiling water reactor.

The BLOCKAGE 2.5 version was accomplished in a series of steps. The background leading to the present version of the code is briefly discussed in the following section. An overview of online help available is described in Section 1.2. The organization of the manual is presented in Section 1.3. The computer hardware and software requirements are presented in Section 1.4. Finally, the procedures to install BLOCKAGE are outlined in Section 1.5.

1.1 Background

In 1993, the NRC initiated an evaluation of the potential of LOCA generated debris to block BWR suction strainers and prevent the ECCS from performing its long-term cooling function [NRC, NUREG/CR-6224]. The NRC had previously investigated the problem of sump screen blockage for pressurized water reactors, and sponsored the development of the computer codes PRA and TABLE to aid in that analysis [NRC, NUREG/CR-3394]. The determination of the probability of unacceptable sump blockage was based on the probability of occurrence of an initiating event and the probability of sump blockage occurring as a result of that event.

A new, PC-based computer code named BLOCKAGE was developed to predict whether or not accumulation of debris on the suction strainers following a LOCA would lead to loss of ECCS pump NPSH in a BWR. BLOCKAGE 1.0 was developed in FORTRAN and was validated by reproducing the NUREG/CR-3394 results [Brideau, 1993]. BLOCKAGE 2.0 was developed to reproduce the functions of BLOCKAGE 1.0, while accomodating input for a representative BWR, and calculated the frequency, per Rx-yr, of a sequence involving a LOCA followed by inadequate NPSH in the recirculation cooling system due to insulation debris generated by the LOCA. In addition, BLOCKAGE 2.0 provided for input of destruction and transport fractions for each destruction region and weld locations, respectively.

Two weaknesses of the preliminary BLOCKAGE model were that the model: 1) did not consider the effect of particulates, such as iron oxide sludge, and 2) did not give credit for sedimentation of the debris while in the suppression pool. These two issues were addressed through the development of a transient suppression pool model. This model was incorporated into BLOCKAGE and validated. This new version of the code underwent further testing and refinements, and evolved into the BLOCKAGE 2.4 version that was used in the NUREG/CR-6224 analysis.

In November 1994, the NRC Office of Nuclear Reactor Regulation issued a user need letter requesting the BLOCKAGE 2.4 computer code be modified to be more "user friendly" so that the NRC staff could use the code to independently verify plant-specific analyses. This letter initiated the effort to develop a graphic user interface (GUI) and provide the user more options for strainer blockage analysis. BLOCKAGE 2.5 is the result of incorporating these enhancements.

1.2 Overview of Online Help

BLOCKAGE provides extensive online help to guide the user in working with BLOCKAGE. During installation, the BLOCKAGE installation program allows the user to install the full BLOCKAGE User's Manual, including illustrations. Within the BLOCKAGE application program, BLOCKAGE has a **Help** menu which provides hypertext access to the BLOCKAGE User's Manual along with a section based search capability. Finally, the main BLOCKAGE input dialog boxes each contain a Help button that provides detailed information on the input parameters in each dialog box.

1.3 Organization of the User's Manual

The BLOCKAGE 2.5 User's Manual is organized into sections beginning with an overview of running the code followed by more specific information on

calculational strategy, input, special considerations for setting up an input model, and output. The appendices to the manual contain sample problems and a guide to executing BLOCKAGE from DOS. A summary of each section is provided below.

2.0 Getting Started. The mechanics of using BLOCKAGE are described in this section. An overview of BLOCKAGE execution is followed by a step-by-step description of using BLOCKAGE including the following:

(1) BLOCKAGE Windows
(2) Managing Models
(3) Using the Control Panel
(4) Entering Parameters
(5) Running BLOCKAGE
(6) Viewing Results
(7) Printing
(8) Menu Commands

This section also discusses how to access the online help function and addresses spreadsheet compatibility and output files.

BLOCKAGE allows the user several options for modeling ECCS strainer blockage due to LOCA-generated debris, including creating new input data sets, adapting existing models to new scenarios or plants, or modeling detailed LOCA pipe break locations and target pipes. Also, BLOCKAGE allows the organization of the results for detailed pipe break locations according to their break frequency for the purposes of probabilistic calculations. This section discusses these options to aid the user in deciding which calculational approach best suits the specific analysis at hand.

3.0 Input Description. This section describes the input data to BLOCKAGE in the context of dialog box requirements. The inputs for target-generated volumes and user-specified volumes are treated separately. Break and target data, break frequencies, plant-specific ECCS data, head loss correlations, event scenarios, and output options are also treated in this section.

4.0 Special Considerations. Additional guidance is provided in this section for specifying the size of the calculational time steps, the time-dependent input, the modeling of ECCS, the temperature dependent NPSH margins, modeling the headloss, the criteria for ECCS failure, and termination of calculations.

5.0 Output Guide. This section describes the output results generated by BLOCKAGE corresponding to each window. The contents of the various reports generated are also summarized.

6.0 References. A list of references is provided for the user.

Appendix A: Sample Problems. Two demonstration problems illustrating the use and capabilities of BLOCKAGE are presented. The first problem demonstrates the Target Generated Volumes option for the generation of the insulation of debris; the second problem demonstrates the User Specified Volumes option. These sample problems focus on the most common types of LOCA generated debris expected in BWRs, including fibrous debris, particulate and metallic insulation materials, paint chips, concrete dust, and suppression pool sludge.

Appendix B: Executing BLOCKAGE from DOS. Some users may prefer to execute BLOCKAGE directly from DOS rather than through the user interface. Appendix B contains instructions for DOS execution and complete specifications for file structure and variables.

1.4 Computer Hardware and Software Requirements

BLOCKAGE runs on standard IBM-PC compatible computers. BLOCKAGE requires the following minimum configuration:

- 80386-based PC with at least 4 Mb of RAM memory
- Hard disk with at least 6 Mb free
- Windows™ supported color video card and associated monitor capable of displaying at least 16 colors at a resolution of 640x480 pixels
- Mouse or other pointing device
- 1.4 MB 3.5 inch or 1.2 MB 5.25 inch floppy drive
- Microsoft Windows™ version 3.1 or Windows95™

1.5 Using BLOCKAGE

To install BLOCKAGE, perform these steps:

(1) Run Windows™ 3.1 or Windows 95™.

(2) Place the installation disk (disk 1) in the appropriate floppy drive. This section assumes that the disk is inserted in drive a.

(3) For Windows™ 3.1:
(a) From the Program Manager, select **Run** from the **File** menu.
(b) Enter "a:\setup" in the Command Line text box and click OK.

For Windows 95™:
(a) From the Task Bar, click **Start** and then select **Run** from the menu.
(b) Enter "a:\setup" in the Open text box and click OK.

From this point, the setup program proceeds automatically. Setup will ask the user to select the BLOCKAGE components to install and allow the user to specify the directory to install BLOCKAGE into. Setup prompts the user to insert additional program disks as required. Setup completes installation by adding the BLOCKAGE icon to the BLOCKAGE Program Group and giving the user the option viewing the "README.TXT" file.

2.0 Getting Started

2.1 Overview of BLOCKAGE Execution

BLOCKAGE consists of two parts, as illustrated in Figure 2.1-1:

(1) User Interface The portion of BLOCKAGE that allows the user to open models, edit parameters, and view results is called the user interface. The user interface is a Windows™ program that is designed to make it easier to build and review BLOCKAGE data.

(2) Calculation Engine Once a model is ready to calculate, the user interface starts a DOS program to perform the calculation. This program is called the calculation engine. While the calculation engine is running, the user interface displays a message box informing the user that a calculation is being performed. When the calculation is complete, the user interface removes the message box and allows the user to view the calculation results. The user never needs to interact directly with the calculation engine.

Specifying a BLOCKAGE model requires the user to enter many parameters. These parameters are stored in a file called a BLOCKAGE model file with the extension ".BLK". To open or save a model, BLOCKAGE reads or writes a BLOCKAGE model file. To modify BLOCKAGE models, BLOCKAGE provides input parameter dialog boxes that allow the user to review and modify the input parameters.

When the user is ready to run a calculation, BLOCKAGE automatically converts the parameters in the BLOCKAGE model file into two files, WELD.DAT and INPUT.DAT, which are read by the calculation engine. The calculation engine produces up to seven output result files as shown in Figure 2.1-1. These files contain reports, data for plotting, and error messages. The user never needs to deal with these

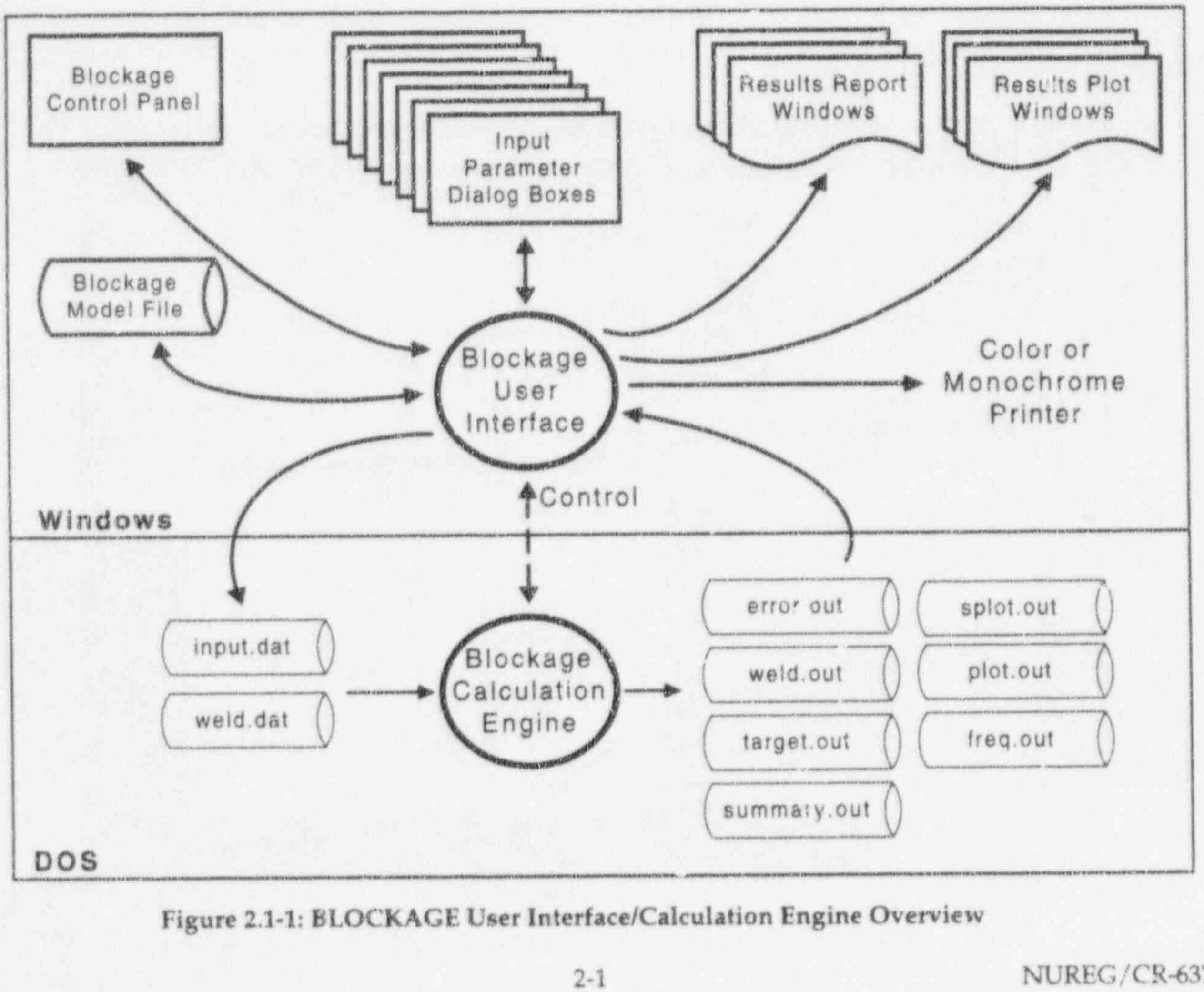

Figure 2.1-1: BLOCKAGE User Interface/Calculation Engine Overview

files directly; all access to the results is through the user interface.

To view calculation results, BLOCKAGE provides commands to display report windows and commands to build and display time-based plots.

2.2 Using BLOCKAGE

2.2.1 BLOCKAGE Windows

BLOCKAGE provides information in windows that can be resized, moved, maximized, and minimized to icon form. The user can work with many different windows at the same time in their open form or as icons. The remainder of this section provides an overview of the different BLOCKAGE windows. Subsequent sections discuss using these windows in more detail.

2.2.1.1 Main Window

A typical BLOCKAGE main window is shown in Figure 2.2.1.1-1.

The main window consists of the following elements:

- Caption Bar The caption bar appears at the top of the window and displays the name of the current BLOCKAGE model file.
- Menu Bar The menu bar, immediately below the caption bar, displays the drop-down menus for BLOCKAGE. Commands are provided permitting the user to open and save models, view and modify model parameters, run the calculation engine, view results, and arrange windows. A **Help** menu provides on-line information about BLOCKAGE. Menu commands are described in Section 2.2.8.
- Status Bar BLOCKAGE displays a status bar at the bottom of the main window. Normally, the status bar contains the word "Ready". When the user is traversing the menu, BLOCKAGE displays a short description of the currently selected menu item in the status bar. When the user has a plot results window selected, the status bar displays the (X,Y) coordinates of the cursor as an aid to examining interesting plot regions.

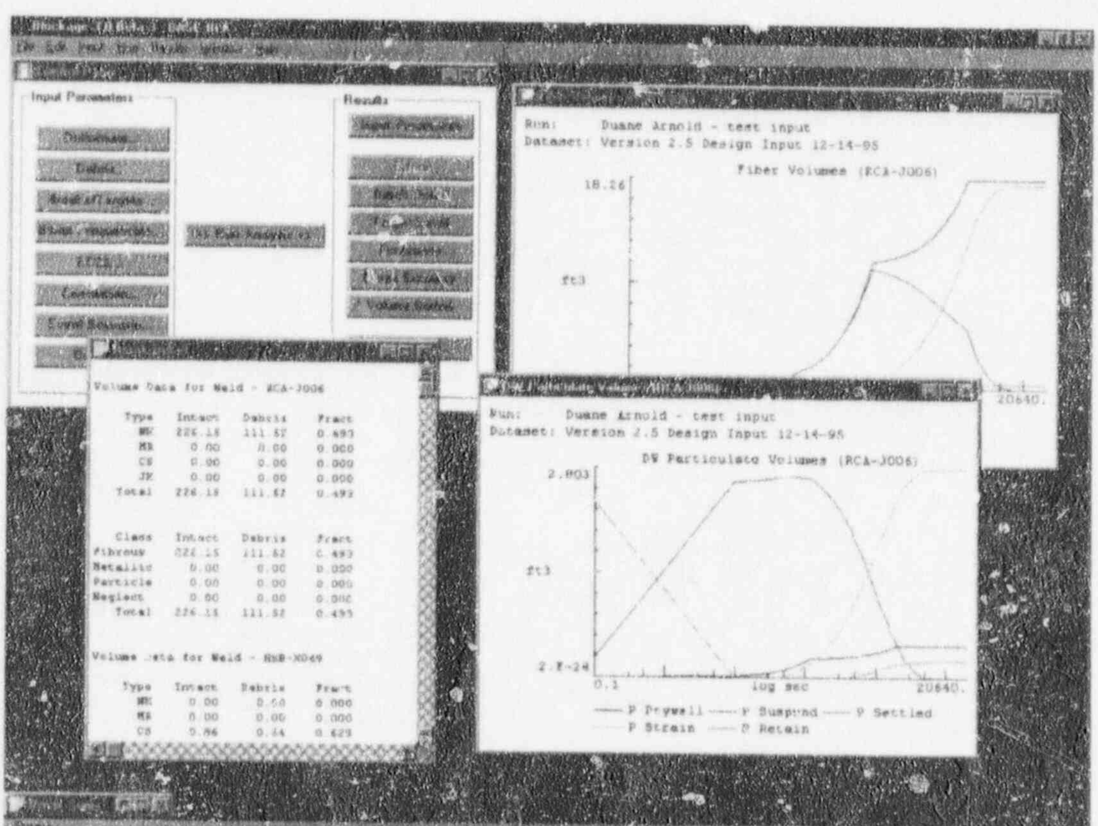

Figure 2.2.1.1-1: BLOCKAGE Main Window

- Main Window Workspace The main window workspace displays four types of child windows:

  (1) Control Panel Window
  (2) Input Parameter Dialog Windows
  (3) Report Results Windows
  (4) Results Windows

Each of the above window types is described in more detail below.

2.2.1.2 Control Panel Window

The control panel is shown at the upper left of Figure 2.2.1.1-1. It is through the control panel that the user edits input parameters, runs the calculation engine, and views results. The panel consists of three rows of buttons, one for editing input parameters, one for running the calculation engine, and one for viewing results. If a function is not available, the corresponding button is drawn with gray text to show that it is disabled.

2.2.1.3 Input Parameter Dialog Boxes

BLOCKAGE displays Windows™ dialog boxes to allow the user to view and edit BLOCKAGE input parameters. A variety of standard Windows™ controls are used to manage the data in the dialogs including: edit fields, radio buttons, check boxes, list boxes, and drop down lists. Once an input parameter dialog window is open, the user must finish working with the window and close it before opening other windows.

2.2.1.4 Results Windows

BLOCKAGE uses two types of results windows to display model data:

(1) Report Results Windows BLOCKAGE displays tabular results in report windows. If a report is too wide or long to completely fit in a report window, BLOCKAGE provides scroll bars to allow the user to view the entire report. A report results window is shown in Figure 2.2.1.1-1 on the lower left.

(2) Plot Results Windows BLOCKAGE displays graphical data using plot windows. All BLOCKAGE graphs have time along the X axis and the variables of interest along the Y axis. BLOCKAGE scales the graph in a plot window so that the entire plot is visible. Two plot results windows are shown in Figure 2.2.1.1-1.

2.2.2 Managing Models

The **File** menu provides commands to manage BLOCKAGE models. When BLOCKAGE is started, no model data is active. To begin working with BLOCKAGE, the user must create a new model or open an existing model. The **File** menu contains commands to allow the user to create a new model, open a stored model, save the current model, and exit BLOCKAGE.

2.2.2.1 Creating a New Model

To begin a new model, the user selects the **New** command from the **File** menu and indicates whether BLOCKAGE should derive insulation volumes from the break database or directly from user input. BLOCKAGE then loads an initial set of model parameters and displays the control panel. This initial set of parameters represents a simple, generic BLOCKAGE model for the user to use as a starting point. This model is complete and could, if the user desired, be processed by the calculation engine.

2.2.2.2 Opening an Existing Model

To open an existing model, the user can choose the **Open** command on the **File** menu. BLOCKAGE displays a dialog box allowing the user to specify the directory and file from which to read the model. Blockage model files contain the file name extension ".BLK" by default. If the user has not saved the current model and chooses the **Open** or **New** command, BLOCKAGE gives the user the option of saving the current model before proceeding. During installation, setup installs four demonstration model files.

2.2.2.3 Saving a Model

To save the current Blockage model, the user selects the **Save** command from the **File** menu. If the model was opened from a file or the model has been saved previously, BLOCKAGE saves the model using the current file name. If the model has not been saved previously, BLOCKAGE displays a dialog box which allows the user to specify the directory and file name for the model. BLOCKAGE adds a default extension of ".BLK" to the file name.

The user can create a copy of the current model under a new file name by choosing the **Save As** command from the **File** menu. BLOCKAGE displays a dialog box allowing the user to specify the directory and file name for the model. Once the user has entered the **Save As** command, future **Save** commands will save to the new file name.

2.2.3 Using the Control Panel

When the user opens a BLOCKAGE model file, BLOCKAGE displays the control panel window. A typical control panel window is shown in Figure 2.2.3-1. The control panel consists of buttons, arranged in associated groups, that allow the user to edit parameters, run the calculation engine, and view results. On the left side of the window are buttons that permit the user to view and edit the associated input parameters. Clicking on one of these input parameter buttons brings up a dialog box allowing the user to view and edit the specified input parameters. In the center of the window is a button, labeled **Run Analysis**, that runs the calculation engine with the current input parameters. On the right are buttons to view and generate output results. The **Input Parameter** button displays a report results window detailing the current input parameters. The set of six buttons below the **Input Parameter** button are used to display the indicated reports after the calculation engine has run.

If the calculation engine does not produce a report of a certain type, the related button is disabled. In Figure 2.2.3-1, the Error, Target Detail, and Frequency buttons are not available. Finally, at the bottom of results group is the **Time Based** button. This button displays the Time Based Results dialog box allowing the user to generate custom reports and plots for time based variables.

The control panel window corresponds directly with a model file. Closing the window closes the model. Similarly, closing the model closes the window. Only one control panel window is allowed at a time.

All of the buttons on the control panel have a corresponding menu command. This permits users who prefer to use the menu to do so.

2.2.4 Entering Parameters

Creating a BLOCKAGE model requires specifying a great many parameters. BLOCKAGE provides input forms to enter these parameters using Windows™ dialog boxes. BLOCKAGE organizes the input parameters as depicted in Table 2.2.4-1.

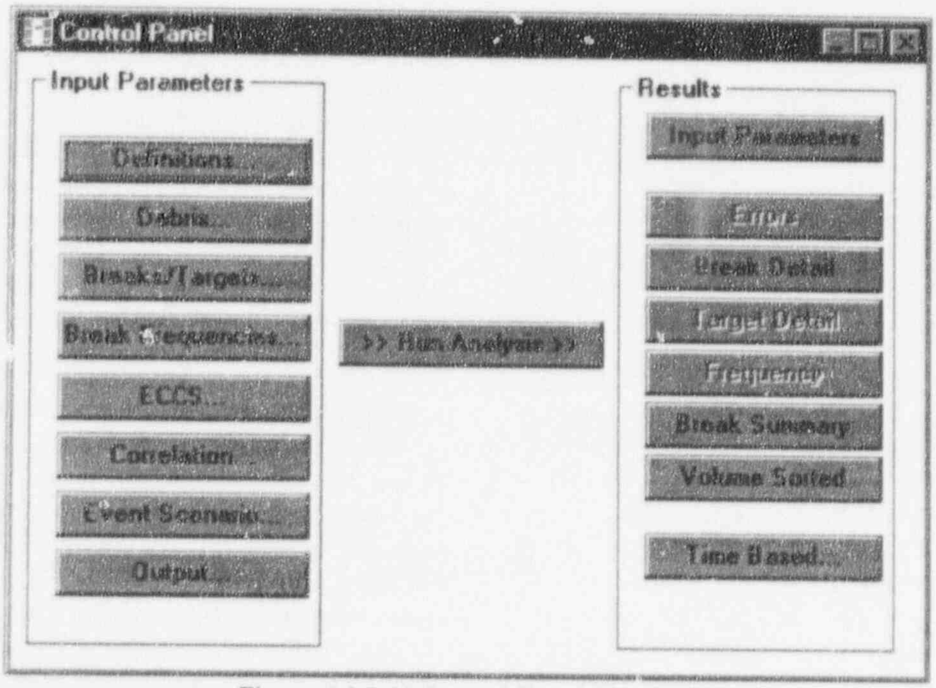

Figure 2.2.3-1: Control Panel Window

Table 2.2.4-1. BLOCKAGE Input Parameters

Dialogue Box Name	Description
Definitions	Overall plant and BLOCKAGE model configuration parameters (e.g., permissible break diameters, weld types, break locations)
Debris	Physical debris related attributes
Break/Targets	Breaks and their associated targets
Break Frequencies	Break frequency parameters
ECCS	Suppression pool parameters
Correlation	BLOCKAGE correlation selection and parameters
Event Scenario	Time-dependent BLOCKAGE function specifications
Output	BLOCKAGE output format parameters

The dialog boxes are activated by either choosing the name of the dialog from the **Input** menu or clicking on the name in the input parameters section of the control panel. Figure 2.2.4-1 shows a typical dialog box, the ECCS parameter dialog box.

The input parameter dialog boxes consist of standard Windows™ controls including edit fields, list boxes, drop down lists, check boxes and radio buttons. All controls operate in the standard Windows™ fashion. The user can access dialog box controls using either the keyboard or the mouse. Most dialog boxes have three buttons along the bottom: **OK**, **Cancel**, and **Help**. Choosing **OK** saves changes and exits the dialog. Choosing **Cancel** discards any changes and exits the dialog. Choosing **Help** displays a help window with text specific to the dialog. Only the more complex dialog boxes have a **Help** button.

2.2.4.1 Dialog Box/Control Availability

Not all dialog boxes or controls are available at all times. For example, if the user has decided to skip the probabilistic part of the analysis, the parameters in the Break Frequencies dialog box are no longer needed. In this case, Blockage disables the **Break Frequencies** button on the Blockage control panel, and the **Break Frequencies** command in the menu, so that the user can not select them. The text on a disabled button or menu command appears in a light shade of gray to indicate that it is disabled. Input parameter dialog fields are handled similarly.

2.2.4.2 Numeric Values

The input parameter dialog boxes have edit fields for both integer and real numbers. Integers must be entered without commas or decimal points (e.g., "1" or "3124"). Real numbers may either be entered in standard notation or scientific notation (e.g., "12.345" or "1.2345E1"). In either case, BLOCKAGE supports six significant digits in the mantissa and two in the ordinate. Both mantissa and ordinate may be assigned.

2.2.4.3 Parameter Validation

When the user selects the **OK** button in a dialog box, BLOCKAGE checks the input parameters in the dialog box for validity. If errors are detected, BLOCKAGE displays a message, positions the input focus to the offending field, and requires the user to correct the problem before saving any changes and exiting the dialog box.

2.2.4.4 List Box Controls

Some dialog boxes contain so much information that it can not all be displayed in a single dialog box. To handle this case, list boxes are used in the dialog box. A list box has the potential to have many more entries that can appear on the screen by using vertical scroll bars to move over the entries. To edit the values in a list box, the user double clicks on the entry in the list to edit. BLOCKAGE will display a child dialog box on top of the original dialog box with fields specific to the selected entry. The standard dialog box rules apply to using child dialogs. Figure 2.2.4.4-1 shows the child dialog box that would be displayed if the

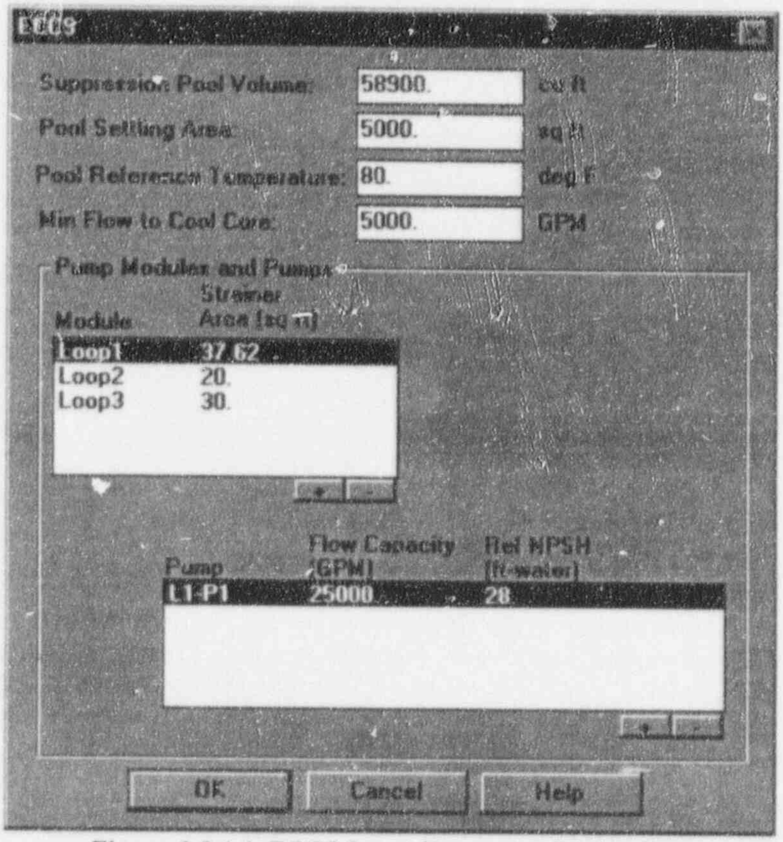

Figure 2.2.4-1: ECCS Input Parameter Dialog Box

user double-clicked on the Loop1 entry in the Pump Module section in the ECCS dialog shown in Figure 2.2.4-1.

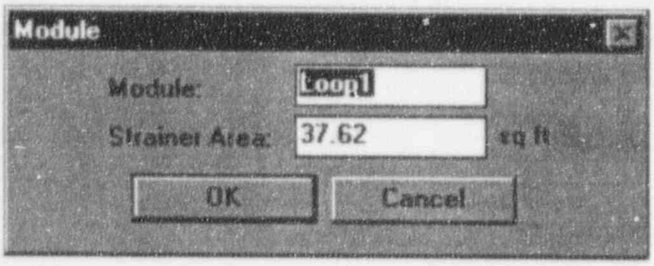

Figure 2.2.4.4-1: ECCS Module Child Dialog Box

Many input parameter list boxes support a variable number of entries. To insert a new entry, the user selects the entry *after* the desired position of the new entry, and clicks the '+' button located at the lower right edge of the list box. BLOCKAGE will display a child dialog box so that the user can enter the new values. To add an entry at the end of the list, the user can select the blank line after the last entry and click the '+' button. The user can delete an entry by selecting the entry to delete and clicking the '-' button located at the lower right edge of the list box.

2.2.4.5 Event Scenario Dialog Box

Most dialog boxes are fairly straightforward and easy to understand. However, one dialog box bears some additional explanation. The Event Scenario dialog box, illustrated in Figure 2.2.4.5-1 is the most sophisticated dialog box in BLOCKAGE. This dialog box is used to enter the time dependent functions for time step size, pump flow multiplier, pool temperature, drywell transport rate, resuspension factor, and turbulence factor.

The top part of the dialog box is fairly standard. On the left are fields for the end of calculation time, the break size defining the distinction between a medium LOCA and a large LOCA, and the integration check limit. On the right is a list box containing the interpolation option for each variable. To edit these values, the user can double click on them, as with any BLOCKAGE list box entry.

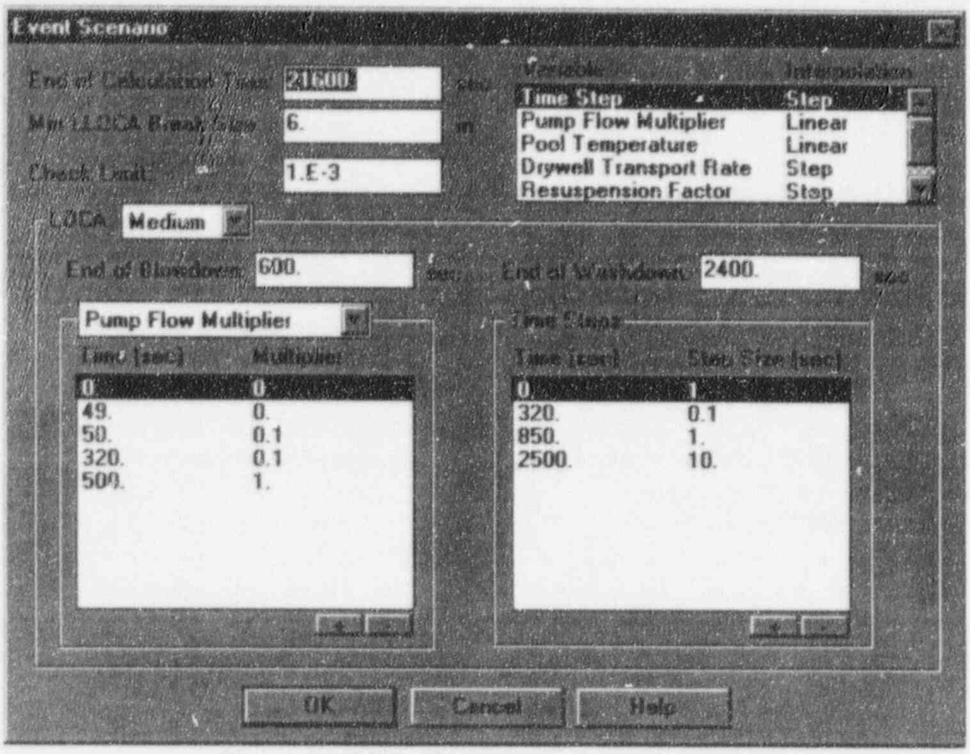

Figure 2.2.4.5-1: Event Scenario Dialog Box

Below the top section is a group box labeled LOCA followed by a drop down list containing either the word Medium or Large. If the list is set to Large, all of the variables in the group box refer to a large LOCA. If set to Medium, all of the values refer to a medium LOCA. This space saving technique allows one dialog box to handle setting the values for both a large LOCA and a medium LOCA.

Within the LOCA group, there are two entries at the top for specifying the end of blowdown time and end of washdown time for the LOCA. Below and to the right is a group box labeled Time Steps that contains a list for specifying the time step sizes to be used in the calculation.

To the left of the Time Steps group is a group labeled with a drop down list. In the figure, the list is showing the selection Pump Flow Multiplier. This drop down list can be set to any of the event scenario variables except Time Step. When set, the list box within the group changes to contain the values for the indicated variable. At the same time, the title above the list box is updated to use the proper units. Entries in the list box can be edited as with any other BLOCKAGE list box.

Although all of the drop down lists and associated list boxes may seem somewhat complicated, once the user understands their operation, he/she can quickly view or specify the event scenario profiles for 12 different functions (two LOCAs x (5 general variables + 1 time step variable)).

2.2.5 Running BLOCKAGE

After specifying the input parameters, the user runs the BLOCKAGE calculation engine by either clicking on the **Run Analysis** button on the control panel or selecting the **Analysis** command from the **Run** menu. In response, BLOCKAGE builds the necessary input files, checks to make sure that enough disk space exists for the output files, and executes the BLOCKAGE calculation code. During processing, BLOCKAGE displays a small window indicating that the calculation is ongoing and a larger window showing the actual calculation execution. When the calculation is complete, the window showing the calculation execution will display the files that have been produced. After reviewing this output to make sure that no errors were generated, the user must close this window by clicking on the close box or selecting **Close** from the system menu. If errors were encountered, BLOCKAGE displays a message.

To cancel a calculation before it is complete, the user can close the window showing the calculation execution by either double clicking on the close box or selecting **Close** from the system menu. Windows™ will warn the user that Windows™ can not shut the process down automatically and, if the user proceeds with closing the Window, unsaved information may be lost. If the user proceeds, BLOCKAGE will remove the window indicating that a calculation is being performed. At this point, the contents of the results files could be missing or incomplete. However, BLOCKAGE will allow the user to view and work with the files that were created.

If an error is encountered during the calculation, BLOCKAGE will warn the user that errors were encountered and suggest that the user check the error report. The error report is available by selecting the **Errors** button on the control panel or choosing the **Errors** command in the **Results** menu. In most cases, if errors were encountered, the other results files will not be created.

2.2.6 Viewing Results

After the calculation code has run, BLOCKAGE allows the user to view the analysis results in windows on the screen. BLOCKAGE can display both text based reports and graphical plots. If a text report exceeds the size of a window, the user can scroll the window horizontally and vertically. BLOCKAGE automatically scales plots to the size of their windows.

Until BLOCKAGE has been run the first time for a model file, there are no results to display. In this situation, BLOCKAGE disables the buttons and menus controlling these results windows to indicate this. The one exception is the input parameters report which is always available. After a calculation is complete, BLOCKAGE automatically updates the buttons and menus for the results to indicate which are available.

2.2.6.1 General Reports

The calculation engine produces the reports listed in Table 2.2.6.1-1. To view a report, the user can click on the name of the report from in the results group on the control panel or select the name of the report from the **Results** menu. If the report is already open, selecting the report again restores the window and brings it to the foreground. The user closes a report by either clicking on the close box for the window or choosing the **Close** command from the system menu.

2.2.6.2 Time-Based Plots and Reports

The BLOCKAGE calculation code produces a large file, named PLOT.OUT, which contains the values for more than 83 variables at each time step during the analysis. The format of PLOT.OUT was designed to be imported into spreadsheets. The extreme width of PLOT.OUT makes it difficult to view directly and the large number of time steps makes trends difficult to discern.

Table 2.2.6.1-1. Calculation Engine Reports

Name of Report	Description
Input Parameters	All input parameters for the model
Errors	Errors, if any, encountered during the calculation
Break Detail	Detailed break reports for selected breaks
Target Detail	Break/target details for selected breaks
Frequency	Break and strainer blockage summary
Break Summary	Break report summary by break
Volume Sorted	Summary report sorted by volume transported

BLOCKAGE allows the user to view subsets of this time-based data and to plot up to six variables on a common axis against time. To open a new window with a time-based report or plot, the user chooses the **Time Based** button from the Results section of the control panel or selects the **Time Based** command from the **Results** menu. BLOCKAGE then displays a dialog box, where the user can specify the result window contents he/she desires (see Figure 2.2.6.2-1).

BLOCKAGE provides controls to select the following:

(1) Break ID The break identifier of the break data to display. The user selects one break from a list of all breaks available.

(2) Title The title to appear at the top of the plot or report.

(3) Format The user must select whether to view the output in report or plot format.

(4) Variables The user selects the variables to be included in the output from a list of the more than 83 available variables. A list of variables that may be selected is given below. The user may select up to ten variables for a report and up to six variables for a plot. All plot variables will share the same Y axis and therefore must be of the same units.

(5) Scale For plots, the user can select the initial scaling to use. Scaling is described below.

(6) Predefined BLOCKAGE stores nine predefined plots which specify values for all of the controls listed above, except Break ID. To view one of the predefined plots, the user selects the plot from the drop-down list labeled Predefined. BLOCKAGE will then update all of the controls to reflect the settings associated with the plot The user may also select a predefined format as a starting point and then modify the controls.

In addition to the controls described above, BLOCKAGE provides two additional fields:

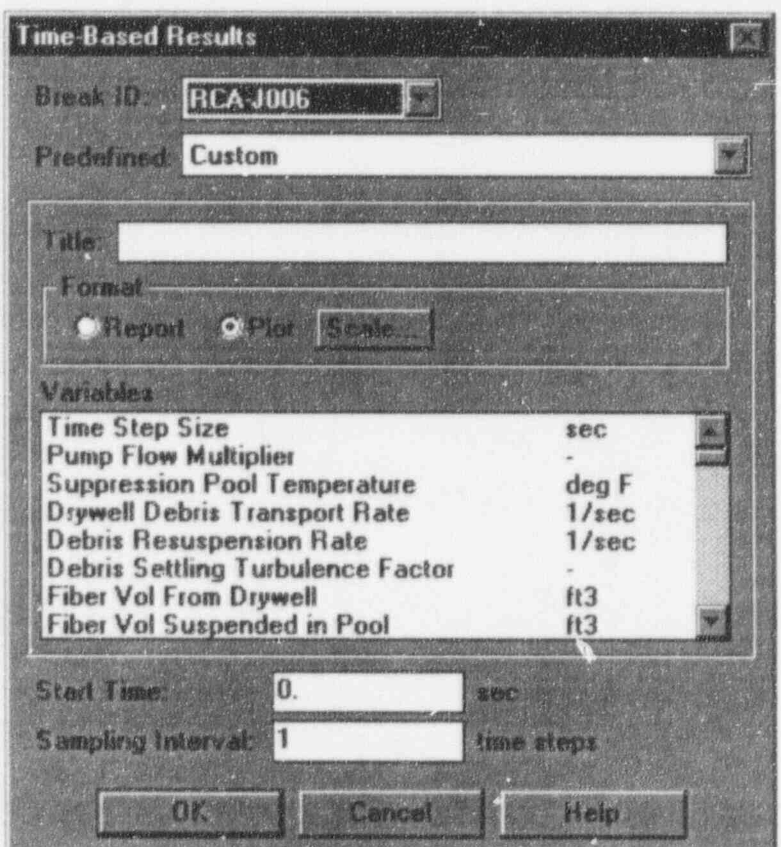

Figure 2.2.6.2-1: Time-Based Results Dialog Box

(1) Start Time By default, all plots and reports start at time 0. The user may wish to restrict his results to only points after a certain time. To do this, the user enters the start time in the Start Time field.

(2) Sampling Interval By default, BLOCKAGE uses every time point generated by the calculation. For calculations with a great many points, this may be more points that the user would like to use or more than BLOCKAGE can plot. In this instance, the user can set the Sampling Interval field to a value other than one - two would select every other point, three would select every third, and so forth.

Variables

A list of the available time-based variables, their legend abbreviations, and their units is shown in Table 2.2.6.2-1.

Plot Format

Figure 2.2.6.2-2 shows a typical BLOCKAGE plot. The plots generated by BLOCKAGE are intended for quick, exploratory data analysis -- not for presentation quality output. BLOCKAGE plots have the following characteristics:

- A title appearing at the top of the plot
- A Y-axis labeled in units of the variable(s) of interest with value labels
- An X-axis labeled in units of time with value labels
- Each variable displayed as a line connecting all data points, having an automatically assigned, distinct, color and line pattern
- A legend, below the X-axis, indicating the color and line pattern associated with each variable

The plot format may change based on the size of the window. In particular, for very small Windows, BLOCKAGE drops the title, legend, and axis labels.

Scaling

Plot scaling may either be automatic or manual for the X and Y axes independently. When the user selects automatic scaling, BLOCKAGE chooses appropriate limits automatically. For manual scaling, the user must specify a start value and a stop value. The user can also specify whether each axis should be plotted in a linear or logarithmic fashion. This linear/logarithmic selection is available for both

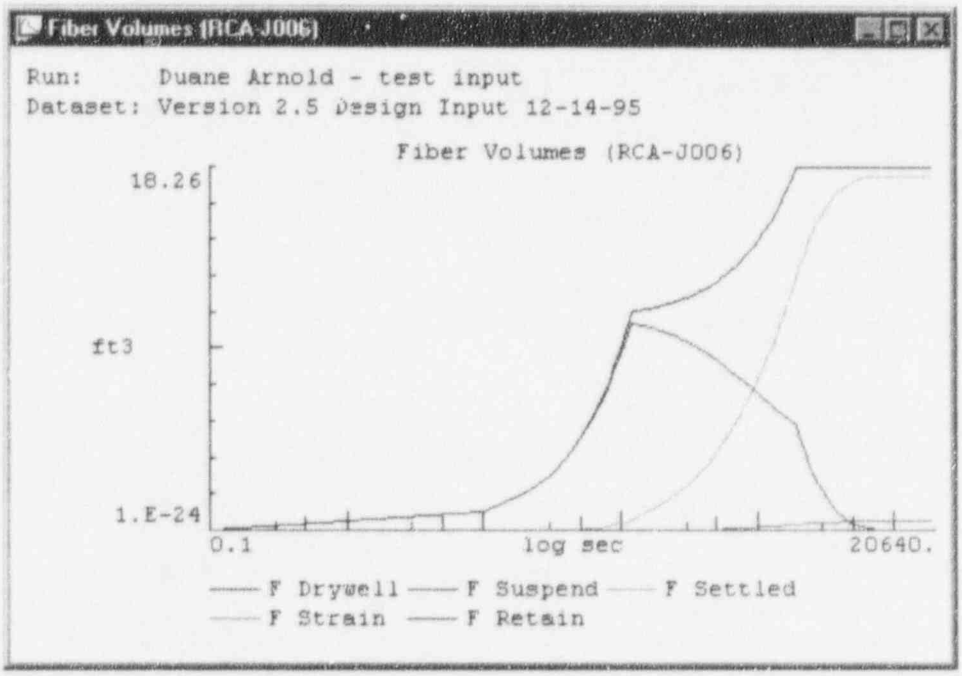

Figure 2.2.6.2-2. Typical Results

Table 2.2.6.2-1. Time-Based Variables, Their Legend Abbreviations, and Their Units

Variable	Plot Legend	Units
Time Dependent Input		
Time Step Size	Time Step	sec
Pump Flow Multiplier	Flow Mult	-
Pool Temp	Pool Temp	deg F
Drywell Debris Transport	DW Rate	1/sec
Debris Resuspension Rate	Rsus Rate	1/sec
Debris Settling Turbulence Factor	Turb Fact	-
Fibrous Debris Volumes		
Total Fiber Volume Transported from Drywell	F Drywell	ft^3
Fiber Volume Suspended in Suppression Pool	F Suspend	ft^3
Fiber Volume Settled on Wetwell Floor	F Settled	ft^3
Fiber Volume Deposited on All Strainers	F Strain	ft^3
Fiber Volume Retained by Primary System	F Retain	ft^3
Particulate Debris Volumes		
Total Particulate Volume Transported from Drywell	P Drywell	ft^3
Particulate Volume Suspended in Suppression Pool	P Suspend	ft^3
Particulate Volume Settled on Wetwell Floor	P Settled	ft^3
Particulate Volume Deposited on All Strainers	P Strain	ft^3
Particulate Volume Retained by Primary System	P Retain	ft^3
Metallic Debris Volumes	M Drywell	ft^3
Total Metallic Volume Transported from Drywell	M Suspend	ft^3
Metallic Volume Suspended in Suppression Pool	M Settled	ft^3
Metallic Volume Settled on Wetwell Floor	M Strain	ft^3
Metallic Volume Deposited on All Strainers	M Retain	ft^3
Metallic Volume Retained by Primary System		
ECCS Performance Data		
Total ECCS Flow	Tot Flow	GPM
Change in NPSH Margin from Reference NPSH	del-NPSH	ft-water
Clean Strainer NPSH Margin for First Pump	cNPSH-1	ft-water
Clean Strainer NPSH Margin for Second Pump	cNPSH-2	ft-water
Clean Strainer NPSH Margin for Third Pump	cNPSH-3	ft-water
Clean Strainer NPSH Margin for Fourth Pump	cNPSH-4	ft-water
Clean Strainer NPSH Margin for Fifth Pump	cNPSH-5	ft-water
Clean Strainer NPSH Margin for Sixth Pump	cNPSH-6	ft-water
Fouled Strainer NPSH Margin for First Pump	fNPSH-1	ft-water
Fouled Strainer NPSH Margin for Second Pump	fNPSH-2	ft-water
Fouled Strainer NPSH Margin for Third Pump	fNPSH-3	ft-water
Fouled Strainer NPSH Margin for Fourth Pump	fNPSH-4	ft-water
Fouled Strainer NPSH Margin for Fifth Pump	fNPSH-5	ft-water
Fouled Strainer NPSH Margin for Sixth Pump	fNPSH-6	ft-water
Strainer BLOCKAGE Data - Pumping Module No. 1		
Approach Velocity to Strainer	Str1 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str1 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str1 Athk	inch
Metallic to Fiber Mass Ratio	Str1 M/F	-
Particulate to Fiber Mass Ratio	Str1 P/F	-
Head Loss	Str1 Hlos	ft-water

Table 2.2.6.2-1. Time-Based Variables, Their Legend Abbreviations, and Their Units-Continued

Variable	Plot Legend	Units
Strainer BLOCKAGE Data - Pumping Module No. 2		
Approach Velocity to Strainer	Str2 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str2 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str2 Athk	inch
Metallic to Fiber Mass Ratio	Str2 M/F	-
Particulate to Fiber Mass Ratio	Str2 P/F	-
Head Loss	Str2 Hlos	ft-water
Strainer BLOCKAGE Data - Pumping Module No. 3		
Approach Velocity to Strainer	Str3 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str3 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str3 Athk	inch
Metallic to Fiber Mass Ratio	Str3 M/F	-
Particulate to Fiber Mass Ratio	Str3 P/F	-
Head Loss	Str3 Hlos	ft-water
Strainer BLOCKAGE Data - Pumping Module No. 4		
Approach Velocity to Strainer	Str4 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str4 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str4 Athk	inch
Metallic to Fiber Mass Ratio	Str4 M/F	-
Particulate to Fiber Mass Ratio	Str4 P/F	-
Head Loss	Str4 Hlos	ft-water
Strainer BLOCKAGE Data - Pumping Module No. 5		
Approach Velocity to Strainer	Str5 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str5 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str5 Athk	inch
Metallic to Fiber Mass Ratio	Str5 M/F	-
Particulate to Fiber Mass Ratio	Str5 P/F	-
Head Loss	Str5 Hlos	ft-water
Strainer BLOCKAGE Data - Pumping Module No. 6		
Approach Velocity to Strainer	Str6 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str6 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str6 Athk	inch
Metallic to Fiber Mass Ratio	Str6 M/F	-
Particulate to Fiber Mass Ratio	Str6 P/F	-
Head Loss	Str6 Hlos	ft-water
Strainer BLOCKAGE Data - Pumping Module No. 7		
Approach Velocity to Strainer	Str7 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str7 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str7 Athk	inch
Metallic to Fiber Mass Ratio	Str7 M/F	-
Particulate to Fiber Mass Ratio	Str7 P/F	-
Head Loss	Str7 Hlos	ft-water
Strainer BLOCKAGE Data - Pumping Module No. 8		
Approach Velocity to Strainer	Str8 Vel	ft/sec
Theoretical Fiber Cake Thickness (not Compressed)	Str8 Tthk	inch
Actual Cake Thickness (Compressed Fiber)	Str8 Athk	inch
Metallic to Fiber Mass Ratio	Str8 M/F	-
Particulate to Fiber Mass Ratio	Str8 P/F	-
Head Loss	Str8 Hlos	ft-water

automatically and manually scaled axes. Values less than 1E-12 can not be plotted on a logarithmic axis. If the user requests that values less than 1E-12 be plotted, BLOCKAGE will display a warning message and plot the data, as requested, but skip any data points with values less than 1E-12 for the axis in question.

To modify the scale settings before generating a plot, the user selects the **Scale** button in the Time-Based Results dialog box. BLOCKAGE will then display a dialog box allowing the user to set the scale parameters. Once a plot results window has been created, the user can modify the scaling by selecting the plot window and then choosing the **Scale** command in the **Edit** menu. Alternatively, the user can double click on the plot window. In either case, BLOCKAGE will display the Scale dialog.

Cursor Usage During Plot Viewing

As the user moves the cursor over the plot area of a selected plot, BLOCKAGE displays the (X,Y) coordinates of the cursor in the status bar. This allows the user to easily determine variable values at interesting locations.

2.2.7 Printing

BLOCKAGE supports printing results reports and plots to any Windows™ supported printer. Printer commands are available through the **File** menu. The **Printer Setup** command allows the user to select the printer to use and set printer attributes, such as page orientation. The **Print** command prints the report or plot that is currently active.

BLOCKAGE plots are in color. If a printer is color capable, the plot output will be drawn in color. If the printer is a monochrome printer, BLOCKAGE draws all variables in black and the variables can only be identified by their line patterns.

2.2.8 Menu Commands

The menu bar and pull-down menus of the main window provide the command interface for all of the BLOCKAGE windows. This section briefly describes each of the BLOCKAGE commands.

2.2.8.1 File Menu

The **File** menu provides commands to handle BLOCKAGE model files, print results windows, in addition to configuring the printer, and exiting BLOCKAGE.

File New

The **New** command is used to create a new BLOCKAGE model. When selected, this command prompts the user to save the current model, if required, and then asks the user to select whether to create a new Break Database or User Volume based model.

File Open

The **Open** command is used to create a new BLOCKAGE model. When selected, the **Open** command displays a dialog and allows the user to enter the directory and the file name of the model to open. By default, the selected file type is "BLOCKAGE Model File (*.BLK)". The user may also select "Combined DAT File (*.CDT)" file type which is used to open special test files containing the BLOCKAGE data in an ASCII format. Most users will not need to use CDT files. Details on CDT file format is provided in Appendix B.

File Close

The **Close** command closes the active BLOCKAGE model.

File Save

The **Save** command saves the BLOCKAGE model in the current model file. If there is no current file, a dialog box is displayed to allow the user to specify the directory and file name for the model.

File Save As

The **Save As** command saves the model under a new file name. When this command is selected, a dialog box is displayed allowing the user to enter the directory and file name of the model. After saving to a file with the **Save As** command, the file becomes the current file.

File Print

The **Print** command prints the active results window. If the printer supports color, plots are printed using colored lines to represent the data. If the printer does not support color, plots are printed using patterned lines to represent the data.

File Printer Setup

The **Printer Setup** command sets up the printer for printing. Using this command, the user can specify the printer to use and configure printer parameters such as the page orientation.

File <recent files>

This command opens the BLOCKAGE model in the indicated file. BLOCKAGE keeps track of the last four files opened, and displays them in the menu to make reopening these files faster.

File Exit

The **Exit** command terminates the BLOCKAGE application and returns to Windows™. If the current model has not been saved, BLOCKAGE give the user the option of saving the model before exiting.

2.2.8.2 Edit Menu

The **Edit** menu provides commands to modify the display of the current results view.

Edit Scale

The **Scale** command displays a dialog box allowing the user to change the scale settings for the selected plot. The user can choose between automatic and manual scaling, set scale minimum and maximum values, and select linear or log scaling.

2.2.8.3 Input Menu

The **Input** menu provides commands allowing the user to display and edit BLOCKAGE model parameters.

Input Definitions

The **Definitions** command displays a dialog box allowing the user to edit overall plant and BLOCKAGE model configuration parameters.

Input Debris

The **Debris** command displays a dialog box allowing the user to edit debris attributes.

Input Breaks/Targets

The **Breaks/Targets** command displays a dialog box allowing the user to edit breaks and their associated targets.

Input Break Frequencies

The **Break Frequencies** command displays a dialog box allowing the user to edit break frequency parameters. This command is only available for Break Database models and not for User Volume models.

Input ECCS

The **ECCS** command displays a dialog box allowing the user to edit suppression pool parameters.

Input Correlation

The **Correlation** command displays a dialog box allowing the user to edit correlation parameters.

Input Event Scenarios

The **Event Scenarios** command displays a dialog box allowing the user to edit time-dependent variable specifications.

Input Output

The **Output** command displays a dialog box allowing the user to edit output format parameters.

2.2.8.4 Run Menu

The **Run** menu provides commands to control the BLOCKAGE calculation engine.

Run Analysis

The **Analysis** command begins the execution of the BLOCKAGE calculation engine. While the engine is running, a message box is displayed to alert the user that the calculation is underway. When the calculation is completed, the message box is removed and the user may view the results.

2.2.8.5 Results Menu

The **Results** menu provides commands allowing the user to display and generate results windows. The **Input Parameter** command is always available. The other commands are only available after the calculation engine has run. Not all reports are available for every calculation.

Results Input Parameters

The **Input Parameters** command opens a results view displaying the input parameter report.

Results Errors

The **Errors** command opens a results view displaying the error report. The error report is only available if errors are encountered during the calculation. If errors are encountered, BLOCKAGE alerts the user with a dialog box and then enables the **Error** command and **Error** button on the control panel.

Results Break Detail

The **Break Detail** command opens a results view displaying the detailed break report for the breaks selected in the Output dialog box.

Results Target Detail

The **Target Detail** command opens a results view displaying the detailed break/target report for the breaks selected in the Output dialog box.

Results Frequency

The **Results Frequency** command opens a results view displaying the break and strainer blockage summary report.

Results Break Summary

The **Break Summary** command opens a results view displaying the break summary report by break.

Results Volume Sorted

The **Volume Sorted** command opens a results view displaying the summary report sorted by volume transported.

Results Time-Based

The **Time-Based** command displays a dialog box command allowing the user to generate a time-based result report or plot.

Results Save Results

The **Save Results** command allows the user to save the current report results window to a file. When this command is selected, a dialog box is displayed allowing the user to enter the directory and file name to save the results to. This command is not available for plots.

2.2.8.6 Window Menu

The **Window** menu provides commands to manage the child windows.

Window Cascade

Arranges the child windows in an overlapping, cascading fashion so that the caption bars of the child windows are visible.

Window Tile

Arranges the child windows in a non-overlapping fashion which completely fills the workspace of the main window.

Window Arrange Icons

Arranges all of the minimized child windows.

Window <named windows>

Restores the indicated window and makes it the active window.

2.2.8.7 Help Menu

BLOCKAGE help is provided using the standard Windows™ help system. When help is displayed, a help window is created with help navigation commands available in the menu and navigation buttons immediately below. The main body of the window contains the help text itself. For more information on using help, see the Windows™ User's Guide.

Help Contents

The **Contents** command displays a table of contents for all help topics. The user can request help on a topic by clicking on the indicated topic with the mouse.

Help Search

The **Help** command allows the user to search for a help topic using a user supplied keyword.

Help About BLOCKAGE

The **About BLOCKAGE** command displays a dialog box containing program information, version number and copyright.

2.3 Online Help

BLOCKAGE provides the user access to online help. Help is available using the standard menu items for help or through the **Help** buttons in each main input parameter dialog.

General Help

The general help provides access to the BLOCKAGE User's Manual. Diagrams are not available in the online help.

Dialog Box Help
When viewing an input parameter dialog box, the user may choose the **Help** button to receive help on the function of the dialog box and the particular controls and fields in the dialog box.

2.4 Spreadsheet Compatibility and Output Files

BLOCKAGE does not provide specific support for formatting data into spreadsheet compatible formats. However, the PLOT.OUT file generated by the calculation engine and the time-based results files do have a format that a user could import into a spreadsheet using the text import capabilities of spreadsheets or presentation graphics applications.

2.5 Calculational Strategy

BLOCKAGE allows several options to model ECCS strainer BLOCKAGE due to LOCA generated debris, including creating totally new input data sets, adapting existing models to other scenarios or plants, or modeling detailed LOCA pipe break locations and target pipes. In addition, BLOCKAGE allows the organization of the results for detailed pipe break locations according to their break frequency, thus allowing ECCS strainer blockage probabilistic calculations. The following sections describe these options in more detail.

2.6 Starting New versus Modifying Existing Input

To begin working with BLOCKAGE, the user must create a new input model or open an existing one. By selecting a new input model, BLOCKAGE will load an initial set of parameters that represents a generic model to use as a starting point. In particular, this initial set of parameters include typical data for NUKON™ fibrous debris and suppression pool sludge. In addition, typical data is included for the time dependency for both a medium and a large LOCA scenarios. This information is based on experimental data, for the case of debris characteristics, or well accepted data as in the case of the LOCA event scenario [NRC, NUREG/CR-6224] and, therefore, is considered to be applicable to most plants with NUKON™ insulation. The user, however, has to provide the specific information for the weld breaks and targets, in the case of Target Generated volumes, or the initial debris volumes, in the case of the User Specified Volumes. The user also has to provide the ECCS and suppression pool data. This information is always plant specific, and is loaded as part of the initial parameter set only to illustrate how to provide the plant specific data required by BLOCKAGE.

Alternatively, the user may choose to begin working with BLOCKAGE by modifying an existing file, such as the sample problems included in the distribution package, or any model previously created. In the case of the sample problems, the input data include some characteristics typical of mineral wool and reflective metallic insulation debris, in addition to NUKON™ fibrous debris and suppression pool sludge. Again, the ECCS and suppression pool data, as well as the breaks and targets or initial debris volumes information, are always plant specific and must be provided by the user; this can be done by modifying the existing values.

2.7 Target versus User Specified Volumes

The first important decision to make in using BLOCKAGE involves the method used to specify the quantities of insulation materials, in terms of volumes, generated during a LOCA in a BWR. BLOCKAGE allows two options for this specification: Target Generated Volumes and User Specified Volumes. In the Target Generated Volumes option, the code calculates the volume of each type of insulation debris as a function of the broken weld and the insulated lengths of the target pipes within the destruction region surrounding the break. In the User Specified Volumes option, the user specifies directly the volume of each type of insulation generated by the postulated break.

The Target Generated Volumes option allows the detailed representation of all the welds considered for LOCA break analysis, and all the insulated pipes considered to be targets of the LOCA jets. In addition, this option allows the specification of the break frequency for each weld for use in probabilistic analysis. To calculate these volumes for each weld break, BLOCKAGE requires the specification, for each target pipe, of the type of insulation, the associated as-fabricated thickness, and the lengths of insulated pipe within each of the three zones of destruction considered in the analysis.

In the User Specified Volumes option, the user directly provides the volumes of each type of insulation debris susceptible to be transported from the drywell to the wetwell for each break. When this option is used, no information with respect to destruction regions, destruction fractions or insulated pipes is required, simplifying the input data collection for BLOCKAGE. In this case, however, the user is responsible for estimating the amount of insulation debris generated by each break. By using this option, BLOCKAGE will not produce probabilistic reports. Consequently this option does not require the specification of the weld break frequencies, thus further simplifying the data collection effort with respect to the Target Generated Volumes.

2.8 Probabilistic versus Non-Probabilistic

When the Target Generated Volumes option is selected, BLOCKAGE allows probabilistic analyses, i.e., the code can generate results based on weld break frequencies or ECCS failure frequencies due to strainer blockage. The probabilistic results include the distribution of weld breaks frequencies according to their pipe diameter, location in the drywell and broken piping system. In addition, these results include the distribution of weld breaks, and their corresponding frequencies, leading to ECCS strainer blockage. These results may be useful, for example, in determining the contribution to the core damage frequency due to ECCS strainer blockage with LOCA generated debris in Probabilistic Risk Assessment applications. However, it is considered, that this option is of interest mainly when a large quantity of weld breaks (i.e., more than 20 weld break locations) is analyzed.

In the case of the User Specified Volumes option, or when the Skip Probabilistic Analysis dialog is selected in the case of the Target Generated Volumes option, BLOCKAGE will not produce results based on weld break frequencies. In this case, the main advantage for the user is that the weld break frequency input data is not required, simplifying the data collection effort. Notice, however, that the probabilistic calculations do not impact significantly the computational time in a BLOCKAGE analysis.

3.0 Input Description

When the user opens a BLOCKAGE model file (New or Old), BLOCKAGE displays the control panel window shown in Figure 2.2.3-1. The control panel consists of several buttons arranged in three groups: Input parameters, Run Analysis and Results. The input parameters consist of eight buttons: **Definitions, Debris, Breaks/Targets, Break Frequencies, ECCS, Correlation, Event Scenario, and Output**. Each of these buttons is associated with one or more dialog boxes by which the user can input the BLOCKAGE model parameters. The following sections describe the input fields in each of the dialog boxes. Note that data contained in the dialog boxes when they are opened for the first time is the default data provided to help the user and should be modified accordingly to suit the particular application of interest.

3.1 Definitions

The input fields in the **Definitions** dialog box allow the user to define overall BLOCKAGE model configuration parameters, such as permissible break diameters, permissible weld types, and permissible break locations. Figure 3.1-1 and 3.1-2 show these dialog boxes corresponding to two modeling options: 1) Target Generated Volumes and 2) User Specified Volumes. The differences between these figures can be attributed to the fact that under the User Specified Volumes option BLOCKAGE does not perform debris generation calculations or probabilistic analyses which would require user input related to destruction regions, weld types and systems identifiers.

Table 3.1-1 provides a description of each input field associated with these dialogs and their description. A brief version of these descriptions can be found in the on-line help menu by depressing the **Help** button in the dialog box.

3.2 Debris

The physical attributes of the insulation and other debris generated and/or transported following a LOCA are entered in the code through the associated dialog boxes. Figure 3.2-1 shows the main dialog box associated with the **Debris** button in the control panel. By default, this dialog box consists of information used in NUREG/CR-6224 study for three types of debris: NUKON, Paint and Sludge. To add or remove debris types, the user should depress the '+' or '-' buttons, respectively, by double-clicking on the entry. Also, the attributes of an existing debris type can be accessed and modified by 'double clicking'. In both cases, a child window shown in Figure 3.2-2 will be displayed.

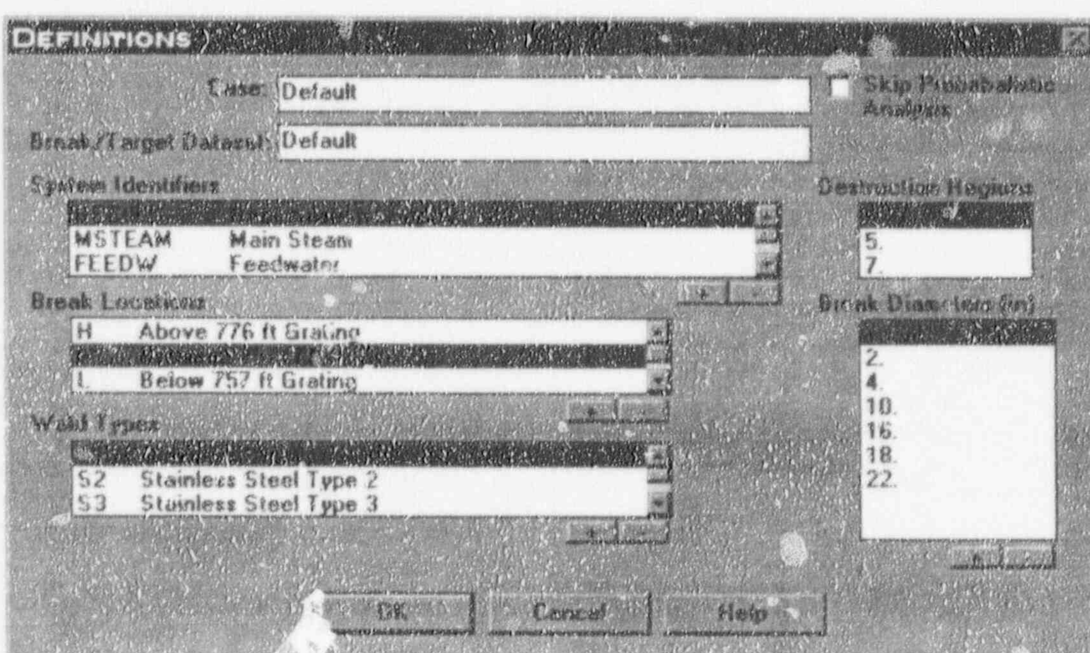

Figure 3.1-1: Dialog Box for Definitions Corresponding to Target Generated Volumes Option

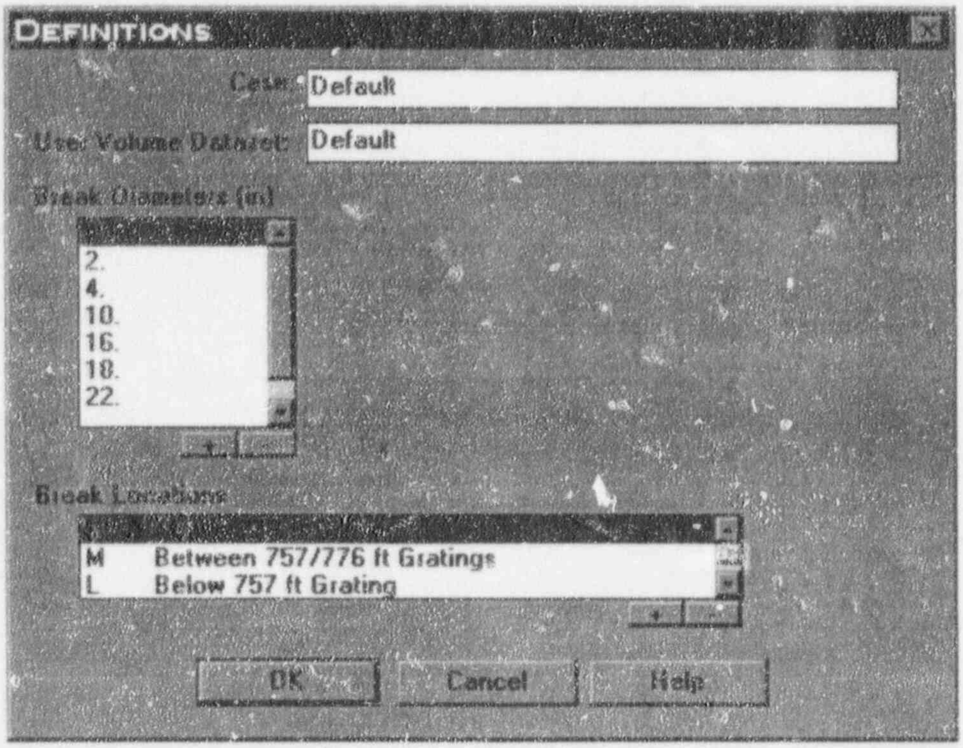

Figure 3.1-2. Dialog Box for Definitions Corresponding to User Specified Volumes Option

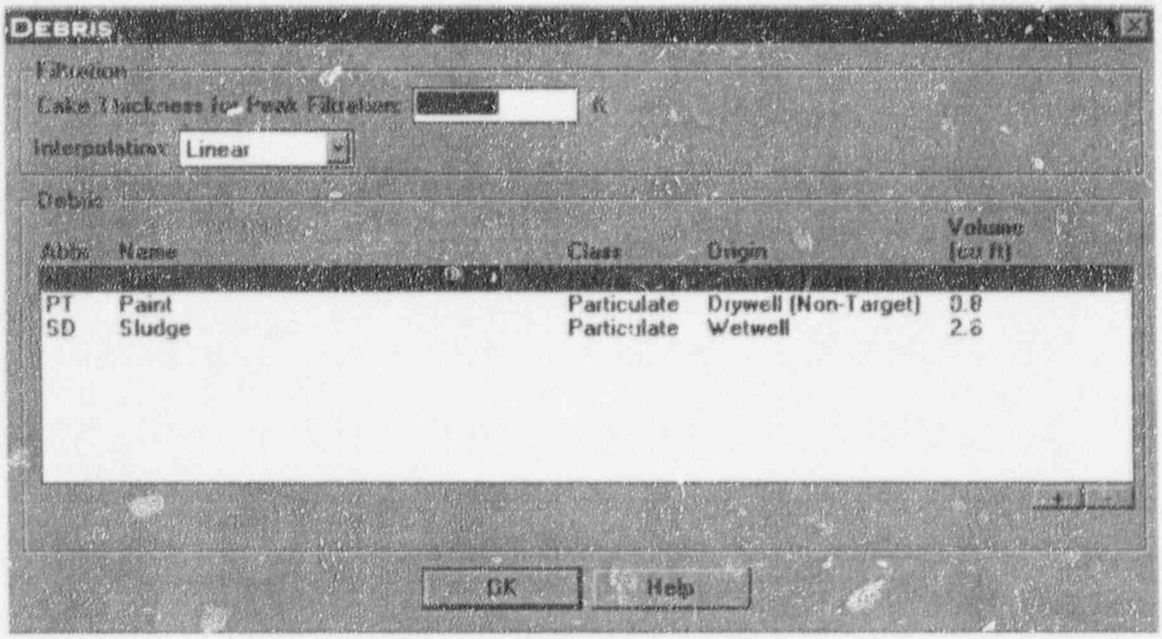

Figure 3.2-1. Debris Dialog Box

Table 3.1-1: Input Fields and Their Descriptions for Definitions Dialog Box
(Bold input fields are required only for Target Generated Volume option)

Input Field	Input Description
Case	A name by which an analysis and the associated print outs can be identified by.
Break/Target Data Sets	A BLOCKAGE Case can be run with several different Break/Target data sets without having to recreate the entire input model. A particular run can be identified by the Break/Target Data Set used in it.
System Identifiers	Permissible abbreviated names for piping systems in which breaks are located and/or which are insulated targets. The code uses these identifiers for the following purposes: • To provides pipe break/BLOCKAGE frequency estimates grouped by these system identifiers • To diagnose if all of the targets/breaks are legitimate primary systems defined in this dialog box.
Break Locations	BLOCKAGE allows the user to bin the breaks in to a maximum of five (5) 'Break Location' categories; each of which is associated with a set of drywell transport factors (see Section x.x of NUREG/CR-6224). This input field allows the user to define the permissible 'break location' identifiers and their descriptions. The code uses these input entries for the following purposes: • To assign a set of drywell transport fraction for each break location • To provide pipe break/BLOCKAGE frequency estimates grouped by the break location identifiers
Skip Probabilistic Analysis	Provides the user an option to select if probabilistic analyses are to be conducted or not. See Section 4.0 for further details on important considerations for selecting this option.
Weld Types	The weld break frequency depends on the type of weld (e.g., carbon steel-304ss, etc.). The user can use this input field to define permissible weld types and the descriptions associated with them. *This is essential if probabilistic analyses are required and recommended from the calculations tractability point-of-view.*
Break Diameters	The weld break frequency depends also on the pipe O.D.. The user can input a set of permissible break diameters. The code uses them to sort the pipe break frequency and BLOCKAGE frequency by these diameter classifications. *This is essential if probabilistic analyses are required and recommended from the calculations tractability point-of-view.*
Destruction Regions	These are the zones used in selecting the pipes as targets for insulation debris generation. These regions are specified as the ratio of the region boundary distance from the pipe weld break divided by the diameter of the broken pipe (L/D). These regions are used only in determining the weld break and target data, but are not used in the BLOCKAGE calculations. The code simply reads in the values as a remainder to the user of the region selection inherent in the development of the Break/Targets data set. Notice that, by doing this, the BLOCKAGE models for debris generation do not assume a particular shape for the zone of destruction [NRC, NUREG/CR-6224], but have enough flexibility to allow the user to determine a particular shape (such as spherical or 90° back-to-back cones) by selecting the segments of insulated pipes affected by the break jet.

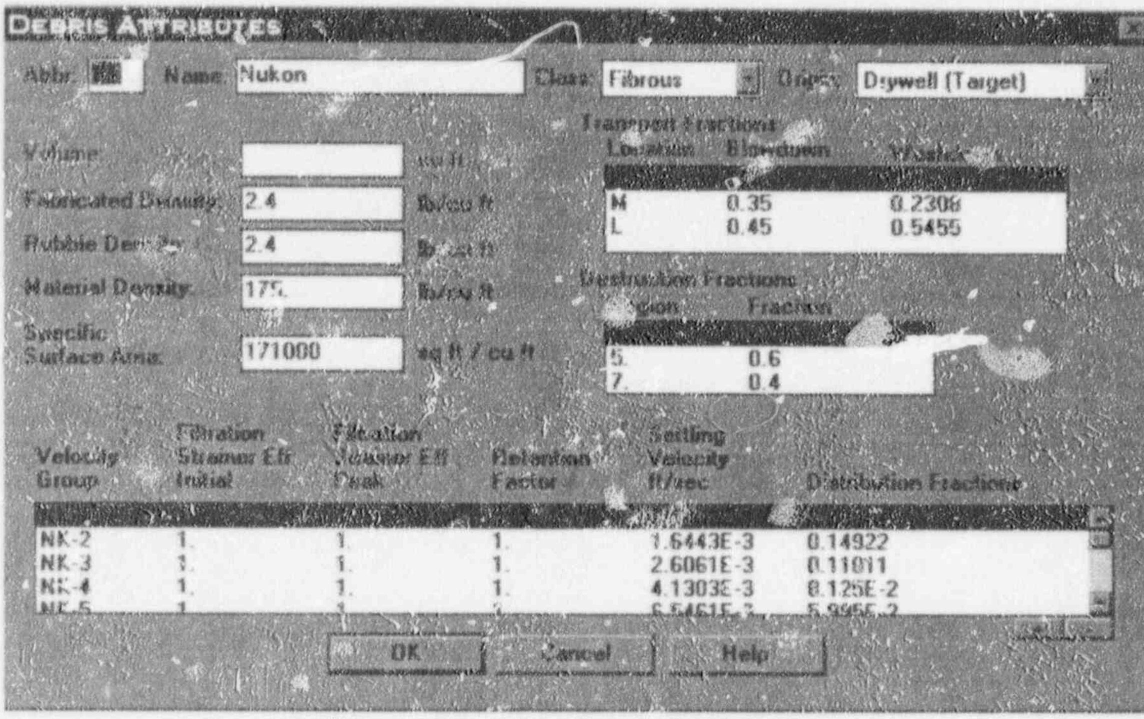

Figure 3.2-2. Debris Type Child Dialog Box

As shown in Figures 3.2-1 and 3.2-2, these dialog boxes allow the input of all information required by BLOCKAGE with respect to debris characteristics, and are divided into the following categories: name, class, origin, physical characteristics, destruction and transport fractions, filtration characteristics, and settling velocities. These categories are described in more detail in the following paragraphs.

Cake Thickness for Peak Filtration and Interpolation Option. The filtration efficiency is defined as the fraction of the debris approaching the strainer that is retained and contained in the debris bed, and is a function of the debris characteristics, such as material, size distribution and shape, as well as the bed thickness and flow approach velocity. The filtration model implemented in BLOCKAGE is developed to handle the variation of the filtration efficiency with the bed thickness and with debris type and size distribution. This filtration model assumes that the filtration efficiency varies with the bed thickness, which in turn is a function of time, from an initial value corresponding to no bed thickness, to a peak value when the bed thickness corresponds to the bed thickness specified in the **Cake Thickness for Peak Filtration** dialog box. The variation of the filtration efficiency with the bed thickness is specified as a step, linear or exponential function in the **Interpolation** dialog box.

Debris Names and Abbreviations. In these dialog boxes the names of the debris materials and their corresponding two-character abbreviations are provided. Although the **Name** dialog box allows for more than 6 characters, notice that in the Break Detail output report a maximum of 6 characters are printed for the name of each debris material.

Class. These data specify whether the debris is a fibrous, metallic or particulate type of material. By selecting the ignore option, the transport of a particular type of material is tracked, but its contribution to the head loss across the strainer is neglected.

Origin. These data specify where the debris originates. If the debris is generated in the drywell by direct LOCA jet impingement on insulated target pipes, the user has to select the **Drywell (Target)** option. If the debris is generated by the impingement of the LOCA jet on structures other than insulated pipes, such as the debris composed of paint chips or concrete dust, the user has to select the **Drywell (Non-target)** option. If the debris materials are initially present in the wetwell, such as the sediments

typically found on the floor of the suppression pools, commonly referred to as sludge, the user has to select the **Wetwell** option.

Volume These data define the quantity, in terms of as-fabricated volume, of each type of debris generated in the Drywell (Non-Target) or the Wetwell.

Fabricated Density This density, also called the as-manufactured density, is the effective density of the material, including its porosity, i.e., its void fraction. For the case of NUKON™ fiberglass insulation blankets, the as-fabricated density is 2.4 lbm/ft^3 (38 kg/m^3) for a porosity of 0.986.

Material Density This is simply the solid density of the material, i.e., assuming no porosity; for NUKON™, for example, the material density of fiberglass is 175 lbm/ft^3 (2800 kg/m^3).

Note that the as fabricated density, c_o, is given by:

$$c_o = (1 - \epsilon)\, \rho_m \qquad (3\text{-}1)$$

where, ϵ is the porosity and ρ_m is the solid material density.

Rubble Density Once the debris reaches the strainer at the suction of the ECCS pump, the pressure drop or head loss produced by the debris accumulation on the surface of the strainer will compress the debris bed, therefore increasing the density of the debris materials on the strainer. The rubble density is the maximum density of the debris material produced by head loss compression of the debris bed on the strainer. For example, for the iron oxide particles composing most of the suppression pool sludge, the rubble density is estimated to be 65 lbm/ft^3 (1041 kg/m^3) [NRC, NUREG/CR-6224].

Specific Surface Area This is the total surface area of the debris particle divided by its volume. For fibers of diameter d_f, much less than their length, such as NUKON™ insulation debris, the specific surface area, S_v, is given by $4/d_f$. For spherical particles [illegible]meter d_p, such as the sludge particles, S_v is given [illegible]$_p$. Finally, for sheets of thickness t much less than the other dimensions, as in the case of reflective metallic insulation (RMI) sheets, S_v is given by 2/t.

Transport Fractions The transport of debris from the drywell to the wetwell consists of two components: (a) transport during blowdown by recirculating steam flow, and (b) transport due to washdown of the debris remaining in the drywell structures by the cascading break flow, the condensate flow, or the containment spray flow. BLOCKAGE allows the specification of the transport fractions, for each debris type and break location in this dialog box. For non-target drywell debris, BLOCKAGE does not consider the dependency of the transport fraction on the break location.

Destruction Fractions Each of the three destruction regions previously discussed in Section 3.1 is characterized by a destruction fraction, i.e., the fraction of insulation volume within the region that is destroyed into transportable form. BLOCKAGE allows the user to specify these destruction fractions in this dialog box.

Velocity Group Data The settling velocity of a debris particle and their filtration properties depend not only on the class of material, for example NUKON™ fiberglass versus iron oxide, but also on the size distribution and shapes. BLOCKAGE allows the specification of the settling velocities, as well as the filtration and system retention characteristics for each debris material, in terms of "Settling Groups" [NRC, NUREG/CR-6224]. Using settling groups, the total amount of each class of debris can be divided into up to 20 settling velocity bins; the data to be provided in these groups is described in the following paragraphs.

Velocity Group Name Name associated with each settling velocity group for each type of debris.

Initial and Peak Filtration Efficiencies Only a fraction of the debris reaching the strainer will be trapped or filtered by the strainer to form a debris bed on the strainer surface. The initial value for the filtration efficiency, when there is no bed thickness, is specified for each class of debris in the **Filtration Strainer Eff(iciency) Initial** dialog box. The maximum value for the filtration efficiency, corresponding to the bed thickness for peak filtration, is specified for each class of debris in the **Filtration Strainer Eff(iciency) Peak** dialog box.

There are very limited experimental measurements for the filtration efficiencies of the materials and conditions of interest here. However, the NRC sponsored some experiments as part of the NUREG/CR-6224 for the particular case of NUKON™ fibers and

iron oxide particles simulating suppression pool sludge [NRC, NUREG/CR-6367].

Retention Factor The debris passing through the bed on the strainer will be carried by the ECCS flow to the reactor vessel and associated piping and, eventually, may return to the suppression pool. Blockage allows the specification of a Retention Factor to account for the debris not returning back to the suppression pool. One minus this factor is returned immediately to the pool. BLOCKAGE considers that the retention factor depends on the debris type and settling velocity group.

Settling Velocity The size distribution of the debris particles in the wetwell is handled by BLOCKAGE in terms of the terminal settling velocity. The data in this dialog box correspond to the settling velocities characterizing each settling group.

Distribution Fraction This data is the fraction of debris having the settling velocity representative of each settling group. This fractions must sum to one for each debris type.

In the case of the NUREG/CR-6224 study, for example, the mass-based settling velocity cumulative distribution function was experimentally measured for NUKON™ shreds and simulated suppression pool sludge [NRC, NUREG/CR-6368]. Subsequently, this information was used to create the corresponding Settling Groups.

3.3 Breaks/Targets

The Breaks/Targets dialog boxes allow the user to input data related to breaks and their associated targets. The structure of these dialog boxes and the associated input fields depends on the user choice related to mode of debris volume input, i.e., **Target Generated Volumes** vs. **User Specified Volumes**.

3.3.1 Target Generated Volumes

The insulation damage produced by a LOCA jet depends upon several factors including, in addition to the thermal-hydraulic conditions in the broken pipe, the break size diameter, the distance from the break to the pipes in which the insulation is located, and the type of insulation. Figures 3.3-1 and 3.3-2 show the dialog boxes available to input this data. As evident from these figures, these dialog boxes provide the user a very flexible means by which the target information can be input.

The following paragraphs describe the required information for the welds susceptible to break and the pipe insulation considered to be targets within each destruction region.

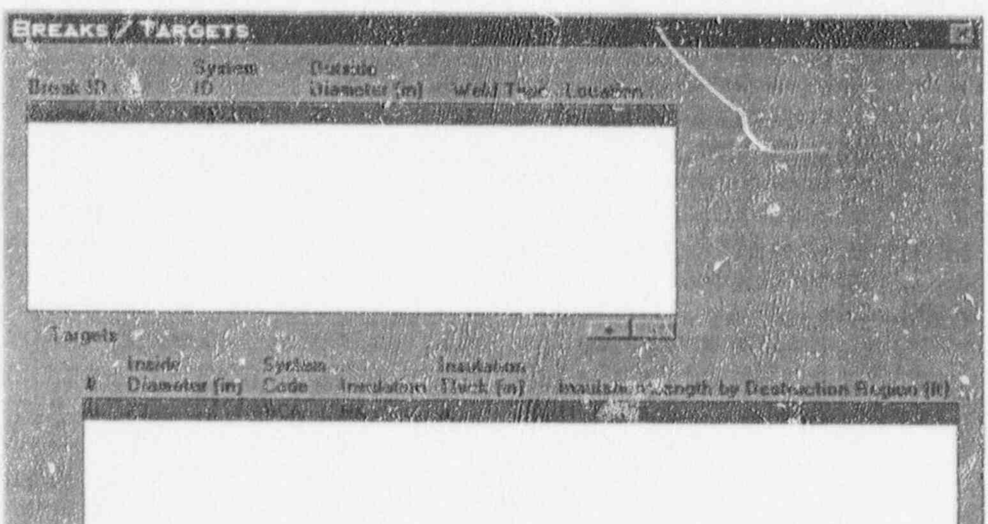

Figure 3.3-1. Breaks/Targets Dialog Box Corresponding to Target Generated Volumes Option

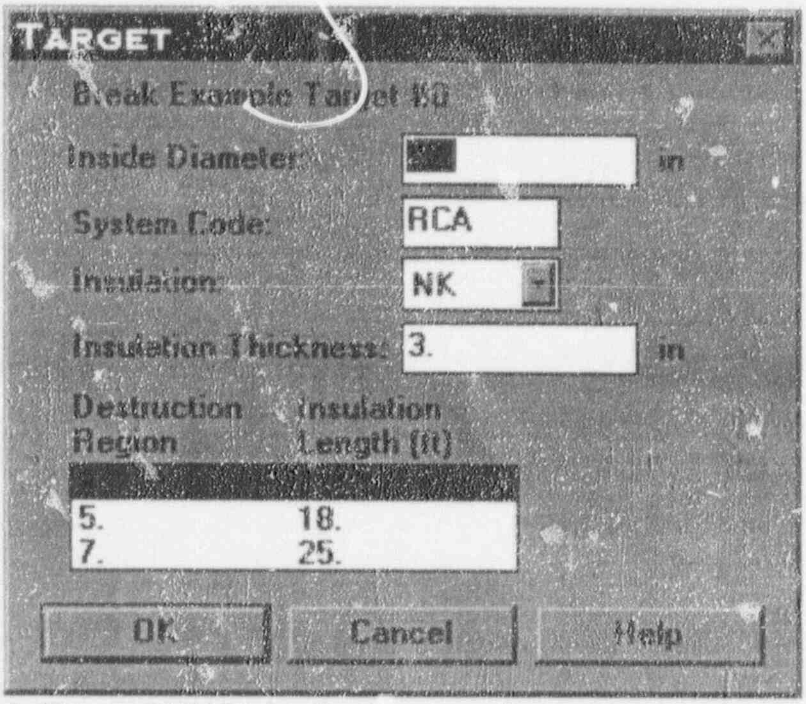

Figure 3.3-2. Breaks/Targets Child Dialog Box Corresponding to Target Generated Volumes Option

Break ID Name of the break. For example, it can be the identifier of the specific weld for break analysis.

System ID Selection of the identifier of the system in which the break occurs already specified in the **Definitions** window.

Outside Diameter Selection of the pipe diameter associated with this break or weld already specified in the **Definitions** window.

Weld Type Selection of the type of weld already specified in the **Definitions** window.

Location Selection of the location region in the drywell window for this break or weld already specified in the **Definitions** window.

Targets: Child Window (Figure 3.3-2)

> The target pipe insulations are specified by providing the following characteristics of every insulated pipe identified for analysis within the destruction region. Notice that the first target is usually associated with the insulation surrounding the pipe which has the break or weld for analysis, although this is not a requirement.

Inside Diameter This is the inner diameter of the target pipe insulation.

System Code Identifies the piping system associated with the target. Notice, however, that this information is only printed in the Target Detail output report but it is not used in the code calculations.

Insulation Selection of the type of insulation material corresponding to the target pipe already specified in the **Definitions** window.

Insulation Thickness This is the thickness of the as-fabricated insulation in the target.

Insulation Length by Destruction Region Length of the target pipe within each of the three L/D destruction regions. The lengths are measured from zero to each the L/D boundaries and, therefore, the second length must be larger than or equal to the first length and the third length must be larger than or equal to the second length.

3.3.2 User Specified Volumes

This option allows the user to specify directly the volumes of each type of insulation destroyed by every analyzed break. When this option is used, no information with respect to regions and fractions for destruction is required, simplifying the input data for BLOCKAGE. In this case the user is responsible for estimating the amount of insulation generated by each break and entering the data through the associated dialog boxes shown in Figures 3.3-3 and 3.3-4. Also, note that when using this option, BLOCKAGE will not produce probabilistic reports.

<u>Break ID</u> Name of the break. For example, it can be the identifier of the specific weld for break analysis.

<u>Outside Diameter</u> Selection of the pipe diameter associated with this break or weld already specified in the **Definitions** window.

<u>Location</u> Selection of the location region in the drywell for this break or weld already specified in the **Definitions** window.

<u>Debris Type</u> Selection of the type of the debris material, already specified in the **Debris** window, generated by the break.

<u>Volume</u> Amount of debris, in terms of its volume, generated by the considered break in the drywell, and available for transport to the wetwell.

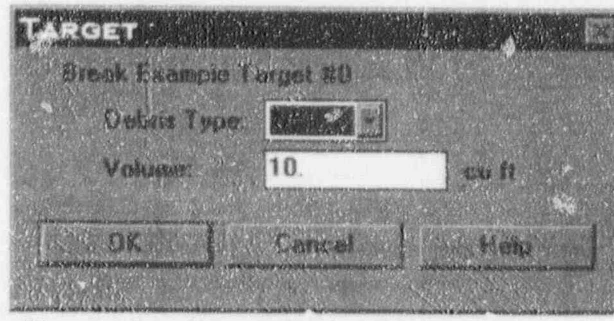

Figure 3.3-4. Targets Dialog Box Corresponding to User Specified Volumes Option

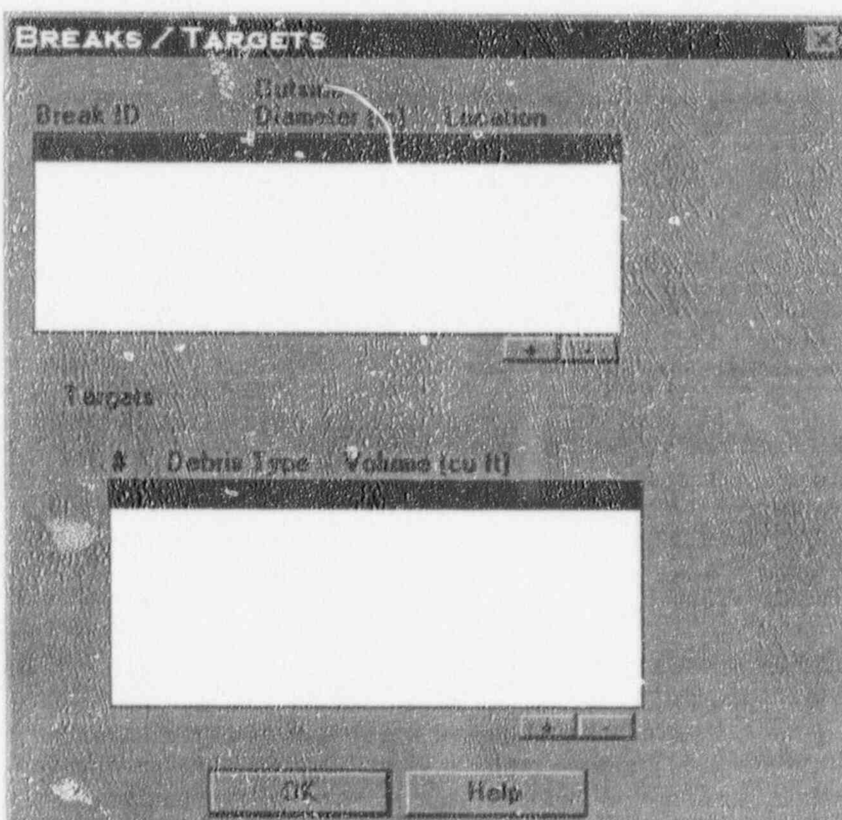

Figure 3.3-3. Breaks/Targets Dialog Box Corresponding to User Specified Volumes Option

3.4 Break Frequencies

When the **Target Generated Volumes** option is used, BLOCKAGE allows the generation of probabilistic output reports. These reports may be used to estimate the ECCS strainer BLOCKAGE frequency for a postulated LOCA. These reports are based on the pipe break frequencies which, in turn, depend on the outside diameter of the pipe and the weld type. When **the User Specified Volumes** option is used, or when the user checks the **Skip Probabilistic Analysis** dialog box in the **Definitions** window, the **Break Frequencies** window will not be activated and BLOCKAGE will not generate probabilistic output reports. The **Break Frequencies** dialog boxes are shown in Figures 3.4-1 and 3.4-2

Smallest Diameter The pipe diameters, already specified in the **Definitions** window, are classified into size groups as required by the methods used to calculate weld break frequencies. This variable specifies the smallest diameter in each class. The largest diameter in each class is then the smallest diameter of the class above it.

Label These labels are used in the probability output reports where plant wide BLOCKAGE results are correlated by pipe diameter class.

Break Frequency Estimated break frequency for each diameter class and weld type already defined. The Appendix A of the NUREG/CR-6224 report [NRC, NUREG/CR-6224] provides useful information to assign these frequencies.

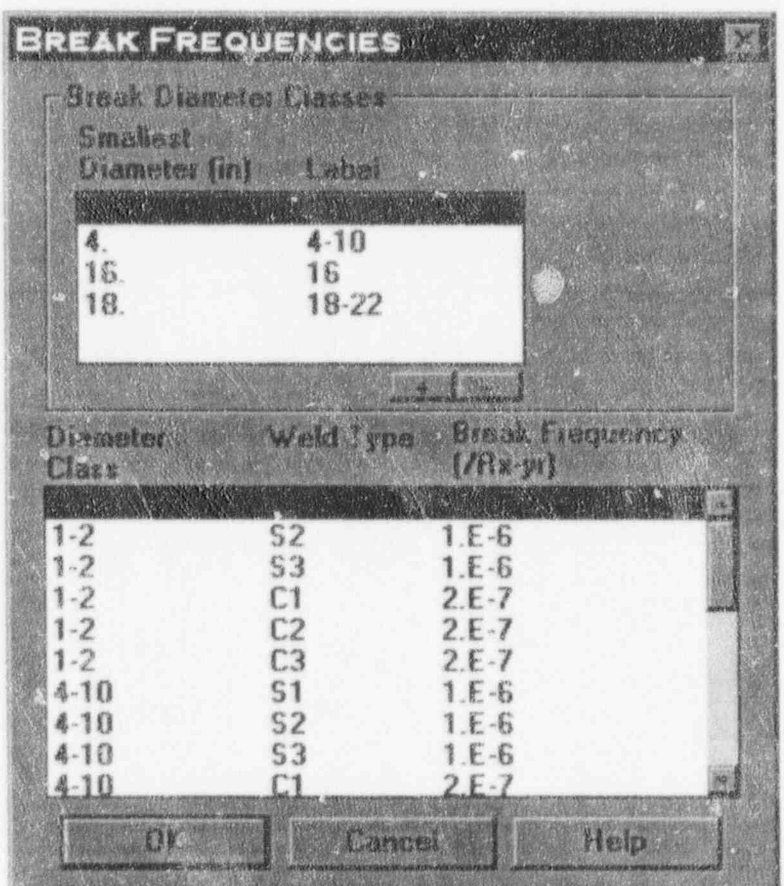

Figure 3.4-1. Break Frequencies Dialog Box

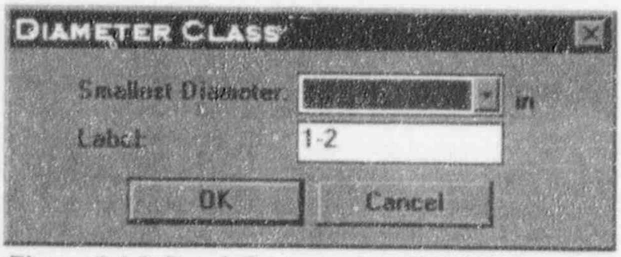

Figure 3.4-2. Break Frequencies Child Dialog Box

3.5 ECCS

BLOCKAGE assumes that an ECCS consists of several modules such that each module can have one to four ECCS pumps taking suction from a common header equipped with one strainer. In reality, more than one strainer may be connected to a module. In such a case, the user can sum the areas of each individual strainer to arrive at the total strainer area for that module. NUREG/CR-6367 provides further details on the ECCS model used in BLOCKAGE. Figures 3.5-1, 3.5-2 and 3.5-3 show the dialog boxes used in BLOCKAGE to input ECCS Data.

The input fields used to enter the data are described below:

Main ECCS Dialog (Figure 3.5-1)

Suppression Pool Volume This is the wetwell water volume of the specific plant for analysis.

Pool Settling Area This is the surface area available in the wetwell for debris settling.

Pool Reference Temperature The NPSH margin for a pump depends on the water temperature. The BLOCKAGE model for the NPSH as a function of time requires, in addition to the time behavior of the wetwell water temperature, a reference NPSH for each analyzed pump, i.e., the NPSH at a given reference temperature. This reference temperature is provided in this dialog box. Notice that all NPSH values must be specified at this same reference temperature.

Min Flow to Cool Core This value is used to determine the condition of strainer blockage (ECCS failure) for probabilistic results. When the total ECCS flow decreases below this user specified minimum, ECCS failure is reported in the output calculations. The user can optionally terminate the BLOCKAGE calculations when the ECCS fails according to the condition specified by this value.

Module Child Dialog Box (Figure 3.5-2)

Pump Modules
All the ECCS and RHR pumps taking suction from the suppression pool can be modeled by BLOCKAGE. This modeling includes the possibility of having multiple pumps attached to a common strainer, for example, each independent division in some LPCI systems. While each pump will have a separate NPSH margin and flow capacity in this case, the same time behavior will be assumed for each pump, i.e., all the analyzed pumps will start and reach the operation flow at the same time. BLOCKAGE assumes that each pump will provide the specified flow until the strainer BLOCKAGE head losses exceed its NPSH margin, causing the pump to fail and its flow to cease. The failure of a pump attached to a common strainer depends on the NPSH, which is specific to that pump, and is assumed to be independent of the operation of the other pumps. The head losses associated to the common strainer, however, will reflect the total flow of those pumps still operating and attached to it. Multiple strainers attached to a common header are not modeled explicitly by BLOCKAGE, but they tend to behave as a single strainer. Therefore, they can be modeled as a single equivalent strainer with the total surface area of all the strainers and the flow of all the pumps attached to the common header passing through the single equivalent strainer.

Module Name of the train of pumps attached to a common strainer.

Strainer Area Total surface area of the common strainer.

Pump Child Dialog Box (Figure 3.5-3)

Pump Name of each pump in the module.

Flow Capacity Pump flow when the pump is operating at 100% capacity. Pump may be operated at less or greater than 100% by specifying the pump flow multiplier.

Reference NPSH This is the NPSH of each pump that corresponds to the user specified pool reference temperature, and is used in the BLOCKAGE models to calculate the NPSH margin as a function of the suppression pool temperature.

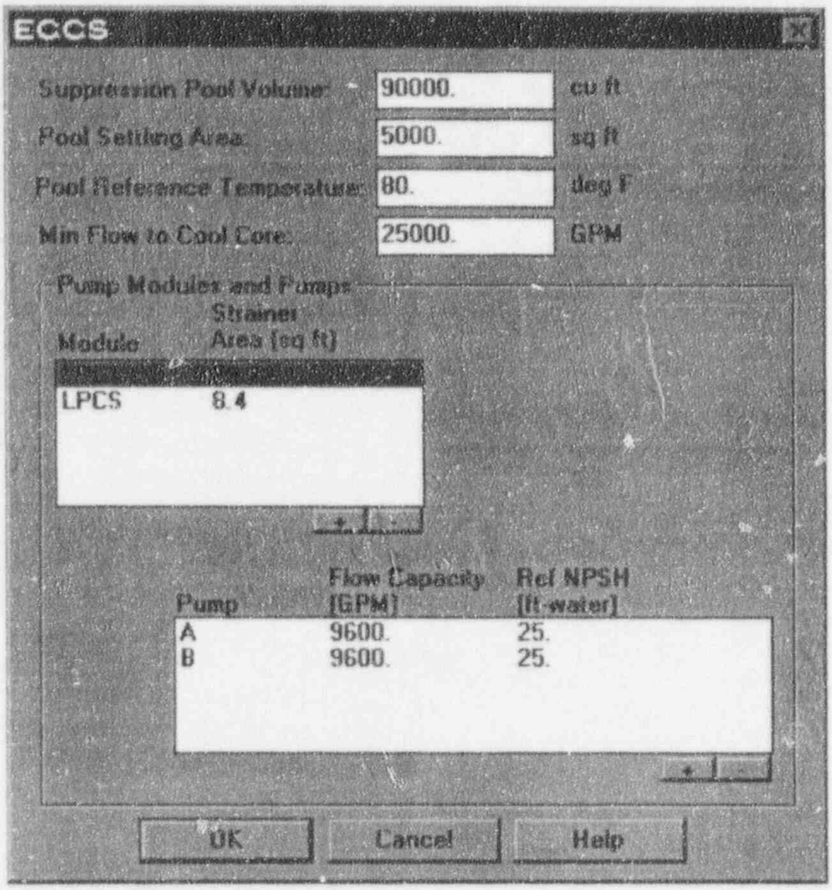

Figure 3.5-1. ECCS Dialog Box

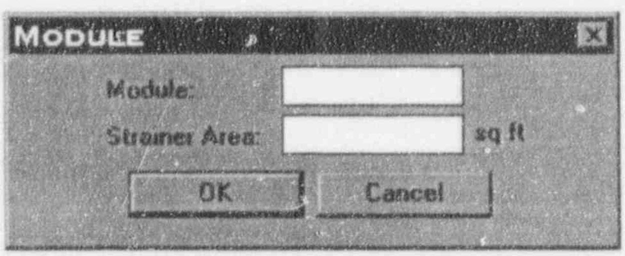

Figure 3.5-2. ECCS Module Child Dialog Box

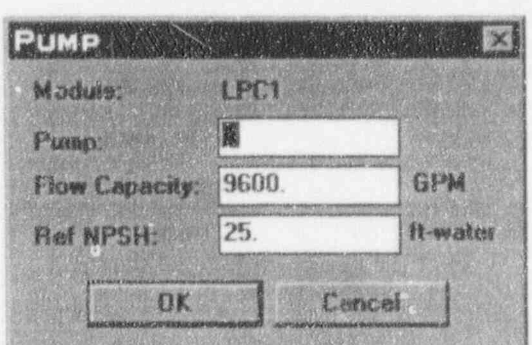

Figure 3.5-3. ECCS Pump Child Dialog Box

3.6 Correlation

The main objective of BLOCKAGE is to predict the pressure drop, or head loss, across the strainer due to debris accumulation as a function of time. BLOCKAGE incorporates four options to estimate the head loss across the strainer. The four options incorporate semi-theoretical and empirical models and user defined correlations. The associated dialog boxes shown in Figures 3.6-1, 3.6-2, and 3.6-3 can be used by the user to input the related information. The following paragraphs describe these alternative head loss correlations and the information required in detail.

1) NUREG/CR-6224. The NUREG/CR-6224 head loss correlation [NRC, NUREG/CR-6224], is a semi-theoretical model developed to estimate the head loss due to combination of fibrous and particulate materials. By assigning the proper values for the specific characteristics of each debris material in the **Debris Attributes** window described in Section 3.2, this correlation has enough flexibility to handle a variety of fibrous and particulate materials, such as fiberglass, mineral wool and iron oxide particles [NRC, NEA/CSNI/R(95)11], and its predictions have been validated for NUKON™ fibrous debris and simulated suppression pool sludge [Rao and Souto, 1996].

   K Term. In addition to fibrous and particulate materials, BLOCKAGE allows the possibility of considering parametrically the influence of RMI debris by setting the K Term to a number greater than zero in this dialog; if no credit is going to be given to RMI debris in the head loss calculation, the user may specify this K term equal to zero or, alternatively, may reclassify this type of debris from Metallic to Ignore in the **Debris Attributes** window.

2) BWROG 1994. The BWROG 1994 head loss correlation is a empirical correlation developed by the BWR Owners' Group for NUKON™ fibers combined with iron oxide corrosion products [BWROG, 1994]. The same parametric correlation for RMI debris implemented in the NUREG/CR-6224 correlation is incorporated in the BWROG 1994 correlation and, therefore, the user may model the contribution of RMI by setting the K parameter to a number greater than zero in the **K Term** dialog.

3) Generic 1. In addition to these semi-theoretical and empirical relations, BLOCKAGE allows the specification of two generic correlations defined by the user. The Generic 1 correlation is given by:

$$H = A_1 (\Delta L_o)^{B1} (C_1 + D_1\eta)^{E1} U^{F1} + A_2(\Delta L_o)^{B2} (C_2 + D_2\eta)^{E2} U^{F2} \quad (3\text{-}2)$$

where,

H is the head loss (ft-water),
L_o is the theoretical debris bed thickness (i.e., the as-fabricated volume of debris divided by the strainer surface area) (ft),
η is the ratio of particulate mass to fiber mass,
U is the strainer flow approach velocity (ft/sec),
and A_1, B_1, C_1, D_1, E_1, F_1, A_2, B_2, C_2, D_2, E_2, and F_2 are the user defined constants.

BLOCKAGE allows the specification of these user defined constants in the corresponding dialog boxes (see Figure 3.6-3). The same parametric correlation for metallic debris is applied to the Generic 1 correlation, and the user may model the contribution of this class of debris by setting the K parameter to a number greater than zero. Manipulation of these 12 constants provides enough flexibility in BLOCKAGE to generate many other correlations. For example, the NUREG-0897, Rev. 1, provided the following equation for predicting head loss for mineral wool as

$$H = 123\, U^{1.51}(\Delta t_o)^{1.36}$$

This equation can be simulated using BLOCKAGE by assigning the following values to the selcted code as follows:

$A_1 = 123$	$A_2 = 0.0$
$B_1 = 1.36$	$B_2 = 1.0$
$C_1 = 1.0$	$C_2 = 0.0$
$D_1 = 0.0$	$D_2 = 0.0$
$E_1 = 1.0$	$E_2 = 1.0$
$F_1 = 1.51$	$F_2 = 1.0$

4) Generic 2. The Generic 2 correlation is similar to the first Generic 1 correlation, but replaces the theoretical debris bed thickness ΔL_o by the mass of debris per unit area (lbm/ft^2) of the strainer. The same user defined constants may be specified.

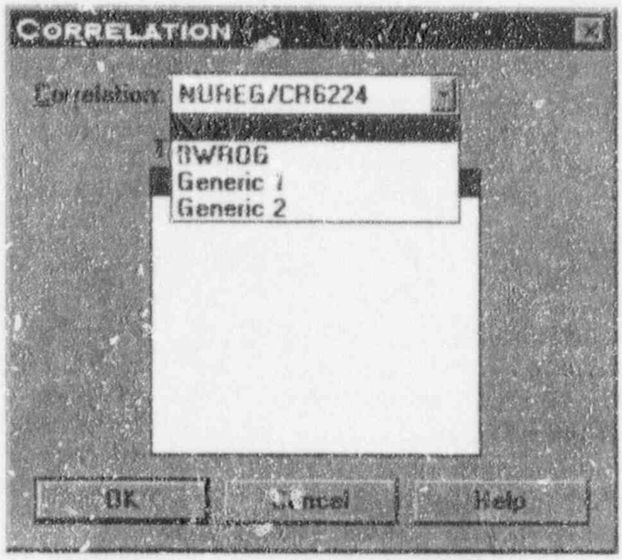

Figure 3.6-1. Correlations Dialog Box for NUREG/CR-6224 Correlation

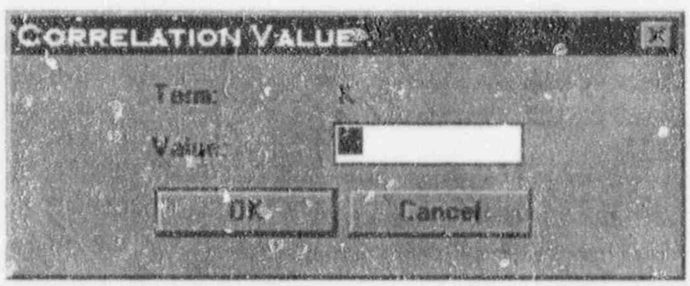

Figure 3.6-2. Correlations Correlation Value Child Dialog Box

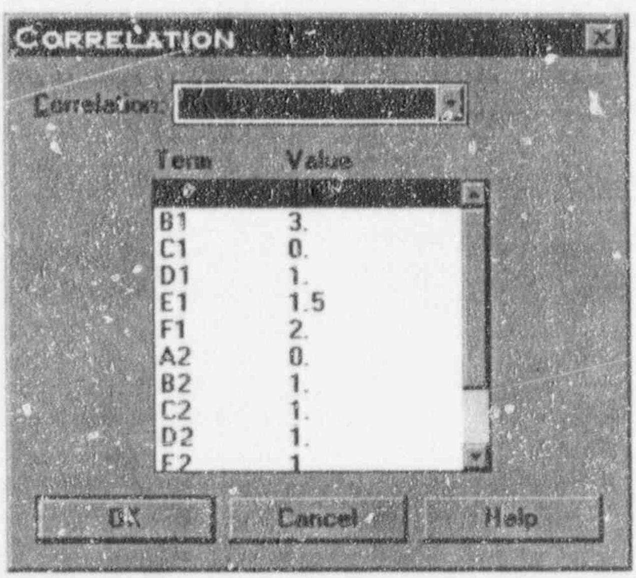

Figure 3.6-3. Correlations Dialog Box for Generic 1 Correlation

4) Generic 2 The Generic 2 correlation is similar to the first Generic 1 correlation, but replaces the theoretical debris bed thickness ΔL_o by the mass of debris per unit area (lbm/ft^2) of the strainer. The same user defined constants may be specified.

3.7 Event Scenarios

The time dependency associated with all the phenomena for analysis, i.e., the debris generation during a LOCA, their transport from the drywell to the wetwell, the deposition of debris on the surface strainer and the subsequent head loss, is modeled by BLOCKAGE in the **Event Scenario** window. This dialog box is shown and described in Section 3.2.4.5. The following paragraphs provide further explanation of the input fields used in these dialog boxes:

End of Calculation Time Determines the default termination option for the BLOCKAGE calculations.

Min LLOCA Break Size Minimum diameter of a pipe to be considered as a large LOCA in case of break. All pipes with diameters less than this value are treated as medium LOCA. This value is inputted in this dialog box, and it is used to distinguish the different time-dependent behavior associated with the break size in a LOCA; in addition, this value is used to classify the break as either a large or medium LOCA in the output reports.[1]

LOCA This dialog box allows the user to specify the different time-dependent behavior associated with a medium and a large LOCA. Notice that the time-dependent behavior for both sizes of LOCA must be specified in the input.

Check Limit This parameter is a quality assurance check limit for flagging incomplete drywell transport to the wetwell. A message is written to the error message report and the calculation is aborted if the drywell transport rate does not integrate to 1.0 plus or minus this value for both the blowdown and washdown transport periods.

End of Blowdown and End of Washdown These are the times which demark the end of the blowdown and washdown periods, and are used to distinguish the different transport characteristics associated with these phases. The user has to specify these values for both a medium and a large LOCA. Notice that BLOCKAGE requires that the end of the washdown occurs after the end of blowdown.

Pump Flow Multiplier With this feature, BLOCKAGE models the elapsed time between ECCS initiation and the actual coolant injection into the reactor core. This situation is of particular interest in the case of the low pressure systems, which actually inject water into the core when the pressure in the reactor vessel is reduced below a certain value. Notice also that the a flow larger than the flow capacity specified in the **Flow Capacity** dialog in the ECCS window can also be simulated by BLOCKAGE.

The time dependency of the ECCS flow is modeled in BLOCKAGE first by selecting the desired mode of **Interpolation**, step, linear or exponential, for the **Pump Flow Multiplier** variable; next, the user has to specify the desired fraction (unitless) of the nominal pump flow, both for a large and a medium LOCA, as a function of time using the child dialog box shown in Figure 3.7-1.

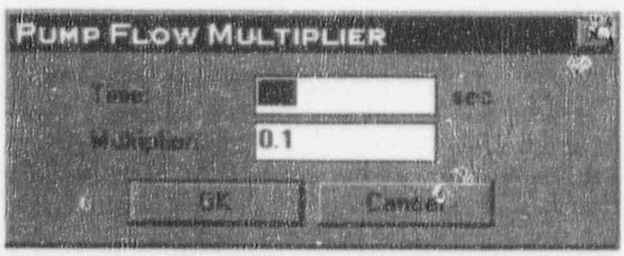

Figure 3.7-1. Pump Flow Multiplier Child Dialog Box

Pool Temperature As previously indicated, BLOCKAGE models the dependency of the head loss and the NPSH on the wetwell water temperature. During a LOCA, the temperature of the water in the suppression pool will vary with time, and BLOCKAGE allows the specification of this variation in the **Event Scenario** window. First, the user selects the mode of **Interpolation** (whether step, linear or exponential) for the **Pool Temperature** variable, and then assigns the desired values (°F) in the corresponding **Time-Temperature** dialog. These values are in general different for a medium and a large LOCA.

Drywell Transport Rate The time dependency of the transport fraction is modeled in BLOCKAGE by

[1]The BLOCKAGE calculational methodology does not address small LOCA, primarily because accident progression following SLOCA is expected to be substantially different from that of LLOCA or MLOCA.

specifying, for a medium and a large LOCA break, the desired option for **Interpolation**: step, linear, or exponential for the **Drywell Transport Rate** variable. Next, the user has to specify the Drywell Transport Rate (unitless) as a function of time in the corresponding **Time-Rate** dialog boxes in the **Event Scenario** window, making sure that the integrated transport fraction is within 1 plus or minus the **Check Limit** provided by the user in the corresponding dialog box. Inaccurate drywell transport is most likely caused by either the incorrect input of the time-dependent drywell transport rates or by excessively large time steps. This is further discussed in Section 4.2.

Resuspension Factor The resuspension factor is the rate of resuspension of debris deposited onto the suppression pool floor, i.e., the fraction of the deposited debris resuspended per second, and once resuspended, the debris is available for transport to the ECCS strainers. To model resuspension, the user has to select the desired mode of **Interpolation**: step, linear, or exponential, for the **Resuspension Factor**; then, the user has to specify, in the corresponding input table, the desired factors $(sec)^{-1}$ for each time during the blowdown as well as the washdown phases for both a medium and a large LOCA.

Turbulence Factor The turbulence factor is applied to the suppression pool debris settling term that predicts the terminal settling rate for a quiescent pool to account for the level of turbulence in the pool, i.e., the fraction by which the terminal settling velocity of the debris particles is reduced due to turbulence within the pool. A value of one implies that the pool is completely quiescent and a factor of zero implies that the pool is so turbulent that debris is unable to settle. To model turbulence in the wetwell, the user has to select first the desired mode of **Interpolation**: step, linear, or exponential, for the **Turbulence Factor** variable; then, the user has to specify, in the corresponding input table, the desired factors (unitless) for each time during the blowdown as well as the washdown phases for both a medium and a large LOCA.

Time Steps BLOCKAGE allows the user to control the time step size used to advance the calculation solution through time. This is done by selecting first the mode of **Interpolation**, step, linear or exponential, and then by specifying the desired time step sizes (sec) in the corresponding **Time-Step Size** dialog boxes. The user should attempt to keep these time steps relatively small through rapid transient periods to increase calculation accuracy, but then increase them through the relatively slower periods to speed the calculation. Further guidance on selecting time step sizes is provided in Section 4.1.

3.8 Output Options

The **Output** window in BLOCKAGE allows the user to select the results for up to 20 postulated breaks, and to control the level of detail in the results printed in the output. The dialog box used for data input is shown in Figure 3.8-1. Note that the output files may overwhelm the computer memory, if the output options are not properly selected. As a result, the user is cautioned to pay close attention to the description of various options provided below.

Selected Breaks First the user has to select, out of the break data set specified in the **Breaks/Targets** window, the desired breaks for detailed analysis in the output results. This is done in the **Selected Breaks** dialog box; for the non-selected breaks, only the summary of the results and the probabilistic analysis are printed out.

Include Detailed Information Most of the BLOCKAGE results for the selected breaks are printed out in the **Break Detail Report**, including: the amount of each type of debris generated and transported to the wetwell for each break considered for analysis; the flow and head loss information for each pump as a function of time; and, the time-dependent specific distribution of debris in the drywell, in the wetwell water, on the wetwell floor, on the strainers, or retained in the reactor cooling system. However, the amount of printed information, can be very large. Therefore, BLOCKAGE allows several options to control the size of this Break Detail Report. By checking the **Include Detailed Information** dialog box, the specific information for each settling velocity group for each debris class is printed in the output results.

Output Frequency This value controls the interval at which the results are printed. By specifying a relatively small time interval for printing the results, i.e., less than 10,000 s, the output file may be very large and, in some cases, may exceed the available disk space.

Output Interval This value controls the frequency at which these results are plotted, i.e., an interval of one plot one point every time step, an interval of two plots data points every other time step and so on.

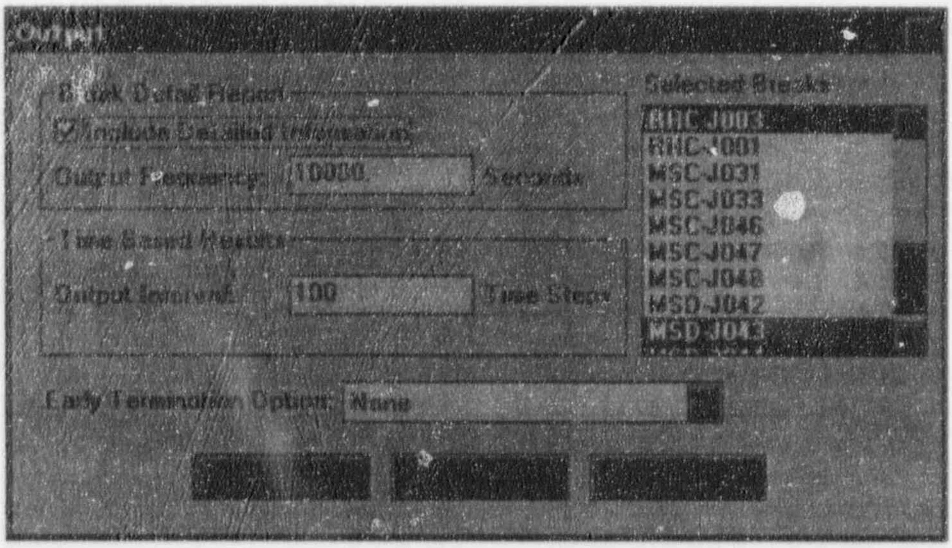

Figure 3.8-1. Output Dialog Box

<u>Early Termination Option</u> BLOCKAGE allows the following calculation termination alternatives in this dialog box:

- End of calculation at the first pump loss-of-NPSH margin.
- End of calculation when the first strainer is totally blocked.
- End of calculation when all the strainers are totally blocked.
- End of calculation when the ECCS flow is less than the user specified minimum.
- No early termination, i.e., end of calculation at the user specified time.

Notice that the calculation will not be allowed to run longer than the user input end time if another user selected termination option has not terminated the calculation.

4.0 Special Considerations

The user may need additional guidance for certain aspects of setting up a BLOCKAGE input model. Additional guidance is provided in this section for: 1) understanding the time-dependent input scheme, 2) specifying the size of the calculational time steps, 3) specifying input parameters that govern the transport of debris from the drywell to the wetwell, 4) modeling the ECCS pumping systems and strainers, and 5) terminating the calculation.

4.1 Time-Dependent Input

The BLOCKAGE code requires the input of several parameters that vary as the calculation progresses with time. These parameters are:

- the time step size
- the pump flow rate multiplier
- the suppression pool temperature
- the drywell transport rate
- the suppression pool resuspension factor
- and the suppression pool settling turbulence factor.

The user must specify these parameters as time-dependent input tables with up to 100 entry pairs. This data is entered into the code using the **Event Scenario** window where the user selects one of these six parameters and then proceeds to enter the data table, one pair at a time. Note that the GUI will automatically arrange the entries so that the time entries are in sequential order.

As the calculation progresses through time, BLOCKAGE accesses these tables and looks up a value to use during its current time step. When the current time step is between time entries in one of the time data tables, an interpolation procedure determines the current value from the entry pairs located before and after the current time. Three interpolation schemes were implemented into BLOCKAGE to provide the user with a great deal of flexibility in constructing an input table. These interpolation options are stepwise, linear, and exponential interpolation.

Stepwise Interpolation The stepwise interpolation option holds the value of the time-dependent variable constant at the value of the preceding entry until the next table entry is encountered, thus the resulting time-dependent plot will look like stair steps. This is the scheme typically used by codes to specify time step sizes.

Linear Interpolation The linear interpolation scheme performs a linear interpolation between the entry pairs before and after the current calculational time resulting in a straight line connection between all the points of a plot showing the time-dependent table. This option can be used to fairly accurately input an actual data curve by specifying a large number of data entries into the table.

Exponential Interpolation The exponential interpolation scheme is similar to the linear scheme except that the interpolation involves the linear interpolation between the natural logarithms of the input parameter. Although this option is not widely used, there are times when it is applicable. In debris BLOCKAGE calculations, the exponential has been effectively used to simulate an exponential decay in the pool turbulence levels following the very turbulent primary system depressurization into the wetwell. Note that the exponential option requires that all parameter data entries be non-zero (the time entry can be zero) because the natural logarithm of zero does not exist mathematically and both the GUI and BLOCKAGE test for these non-allowed zero entries to prevent an illegal entry.

It is recommended that the user begin each time-dependent table with an entry corresponding to zero time and it is required that the time step size table start at zero. The other parameter input tables can be started with a non-zero time as the first entry and the GUI will perform an interpolation from the first two data pairs to obtain a value for time zero. When a calculation proceeds beyond the last entry in a data table, the code simply uses the last entry in the table until the calculation terminates. Note that BLOCKAGE does not perform an interpolation beyond the last table entry.

The user is encouraged to review the plots of the time-dependent input that are available after the calculation is completed to ensure that the time-dependent data actually used by BLOCKAGE agree with the user's intent. These plots are found in the **Time-Based Results** window.

4.2 Time Step Control

The BLOCKAGE input model requires that the user specify the time step sizes for advancing the numerical solution for debris transport through time. This is accomplished in the **Event Scenario** window of the GUI where the user can specify the time step

size and the corresponding time at which the time step applies. The time steps must be specified for both large and medium LOCA scenarios.

The size of the time step between the time entries is determined by the interpolation option chosen by the user. The time step used most often during the NUREG/CR-6224 study for interpolation was the step option which means that a particular time step remains in force until it is changed by another time/time-step entry. The linear interpolation option can be used to linearly interpolate between the entries in the table, while the exponential interpolation option performs an exponential interpolation between the table entries. Thus the user can specify time step schemes by simply applying a single time step for the entire calculation or the user can implement much more complex time-dependent functions.

Selecting the time step size is in general a trade-off between the run speed and the accuracy of the calculation, i.e., the smaller the size of the time step, the greater the accuracy of the calculation but the more time required to complete the calculation. There are of course limits to how small or how large a time step can be. Reducing the time steps below a certain limit does not continue to produce greater accuracy due to the accuracy limits of the computer or the compiler, i.e., the number of significant digits of accuracy being used. At the other extreme, time steps sizes that are too large can simple bypass potentially important aspects in the modeled processes. Furthermore, large time steps can cause the time-dependent drywell debris transport rates to not integrate to one (discussed in the next section). One valid approach to maintaining calculational accuracy while simultaneously increasing the run speed is to specify finer time steps during earlier highly transient portions of a calculation but then use larger time steps later in the calculation when the debris transport becomes less transient.

A time step sensitivity study was done as part of the coding verification effort and this study is documented in Section 4.3.2.4 of the Reference Manual. The results of the study indicate that a time step size of 1 second is more than adequate for most aspects of blockage calculations. Past blockage analytical studies have used 10 seconds for the later portion of the calculation, after about 2500 seconds, where the debris transport is not very transient or strainer blockage has already occurred. Some previous studies have used a small time step of 0.1 seconds through the period of strainer blockage in order to better capture the predicted time for pump loss-of-NPSH margin, i.e., at one numerical time the pump has not lost NPSH margin but at the next numerical time it has lost NPSH margin, therefore, the smaller the time interval, the more closely the user will know the predicted loss-of-NPSH margin time. The time steps table shown in the sample problems represent reasonable time step models to use as a starting point.

The user should be aware of a BLOCKAGE code capability where the code exactly matches each event time that is specified for any of the time-dependent input variables. For example, the drywell transport rate normally changes at the end of the blowdown period prior to entering the washdown period (note the user is forced to enter the time corresponding to the end of blowdown). If the user specifies a time step that passes over this end of blowdown time, the code will automatically calculate a time step that causes the code to exactly match the end of blowdown time and then the code executes this time step once only, prior to proceeding with the user specified time step sizes. The code also matches the calculation termination time.

4.3 Drywell Debris Transport

The drywell debris transport models in BLOCKAGE depend upon the location where the debris is generated, whether the debris is transported by primary system depressurization flows (blowdown period) or by condensate, recirculation, or spray flows (washdown period) following the depressurization period, and the timing of debris transport. The user controls the rate and quantity of debris transported from the drywell to the wetwell by specifying overall transport fractions and a time-dependent debris transport rate. The debris transport fractions are considered an attribute of the debris type, i.e., separate transport fractions must be specified for each type of debris.

4.3.1 Location Dependent Transport

The BLOCKAGE code allows the user to group weld breaks into location regions (1 to 5 regions allowed) so that the user can then specify different debris transport fractions for each of these locations. In the NUREG/CR-6224 study, the drywell of the Mark I Reference Plant was subdivided in three vertically oriented locations which were separated by the platform gratings in the drywell. The study assumed

that more debris would be transported to the wetwell if the weld break and subsequently the debris generation were closer to the downcomer vent entrances. Therefore, the transport fractions were incrementally reduced for breaks in sequentially higher locations. The location regions do not, however, need to be vertically oriented. The regions for example could be specified to match various compartments, rooms, barriers, etc., that may exist in a particular design.

The user specifies the location regions by identifying and naming the regions in the **Definitions** window and then associating each weld break with one of the locations in the **Breaks/Targets** window. The transport fractions are entered for each location in the **Debris Attributes** window. Note that the transport of non-target debris originating in the drywell is not location dependent.

4.3.2 Blowdown and Washdown Period Transport

The time-dependent transport of debris from the drywell to the wetwell was modeled during two discrete time intervals referred to as the blowdown period and the washdown period. Debris transport during the blowdown period would be driven by the primary system depressurization flows. During the washdown period, the debris transport was driven by the recirculation flows from the break, the containment spray flows if active, and the drainage of steam condensate from the structures. A separate transport fraction is specified by the user for each of these two periods for each of the location regions.

The transport fraction for the blowdown period, T_b, is defined as the total fraction of a particular type of debris that will be transported to the wetwell during the blowdown period. The transport fraction for the washdown period, T_w, is defined as the fraction of the debris remaining at the end of the blowdown period (i.e., one minus the blowdown fraction) that is transported to the wetwell during the washdown period. The total debris transported to the wetwell over both the blowdown and the washdown periods, T_{tot}, is then:

$$T_{tot} = T_b + T_w (1 - T_b) \tag{4-1}$$

The acceptable values for both the blowdown and the washdown transport fractions range from zero to one and the resulting total transport fractions also range from zero to one. If the blowdown transport fraction is specified as one then no debris would remain in the drywell for transport during the washdown period.

4.3.3 Time-Dependent Transport

The BLOCKAGE input model requires the user to specify a time-dependent rate for debris transport from the drywell to the wetwell. This is accomplished in the **Event Scenario** window where the user can specify the transport rate in terms of the fraction of available debris per second as a function of time. The user also specifies when the blowdown and the washdown periods end. Note that the transport rate must be specified separately for both large and medium LOCA scenarios.

The total debris transport to the wetwell is dependent upon the type of debris and is specified using the transport fractions in the **Debris Attributes** window. The quantity of debris generated times the appropriate transport fraction determines the quantity of debris to be transported to the suppression pool but the timing of this transport is determined by the time-dependent debris transport rates which are LOCA scenario dependent. Thus, the total debris to be transported times the transport rate times the current time step size determines the quantity of debris actually transported to the pool during the current numerical time interval. This is illustrated in the following equation which is separately applied to each type of debris.

$$\Delta V_{trans} = G(t,loca)\ T_{frac}(period)\, V_{debris}\ \Delta t \tag{4-2}$$

where

V_{trans}	=	volume of debris transported during a given time step for a particular debris type (ft^3)
$G(t,loca)$	=	time and LOCA scenario dependent transport rates (fraction/second)
$T_{frac}(t)$	=	total transport fractions for either the blowdown or the washdown period (unitless)
V_{debris}	=	total drywell debris volume of particular debris type (ft3)
Δt	=	current time step size (second).

The period dependent transport fraction, T_{frac}, is shown by the following equation.

$$T(t)_{frac} = \begin{bmatrix} T_b & if & t \le t_b \\ T_w(1-T_b) & if & t_b < t \le t_w \\ 0 & if & t > t_w \end{bmatrix} \qquad (4\text{-}3)$$

where

t_b = the blowdown period end time
t_w = the washdown period end time.

In order to get the correct total debris transport to the suppression pool, the time-dependent transport rates must integrate to one over the blowdown period and again over the washdown period. Furthermore, the rates must integrate to one using the exact time steps selected by the user. To ensure that these integrals equal one, the BLOCKAGE code integrates the rates during the input process using the input time steps. Likewise, BLOCKAGE stops the calculation with an error message if the integrals do not equal one within a user specified acceptable error limit called the check limit, **cklim**. The check limit is a number ranging from zero to one. The function of the check limit is illustrated by the following equation,

$$1 - cklim \;<\; \int_{0,\, t_b}^{t_b,\, t_w} G(t,loca)\, dt \;<\; 1 + cklim \qquad (4\text{-}4)$$

where the debris transport rate integration is actually performed four times during the input processing for each calculation, i.e., over the blowdown period from zero to t_b, again over the washdown period from t_b to t_w, and for both medium and large LOCA scenarios. The conditions required to satisfy the above equation must be met for all four integrations before a calculation is allowed to proceed. The user, therefore, must specify a time dependent transport rate, blowdown and washdown end times, and calculational time steps that fulfill these requirements.

If the user specifies a large check limit then the calculation of the debris transport could become inaccurate. But if the number were too small, it may become difficult to satisfy the integrations. A check limit of 0.001 has been found satisfactory for the time steps and the transport rates used in the sample problems included with the code. The completeness of the transport can be verified following a calculation by looking at the "Transport Completion" column for each weld break in **Break Summary** report and in the **Break Detail** report for the breaks selected for detailed output. Note that the transport completion number reported in the detailed report is a function of time so the user must look at an edit at the end of the calculation to determine final transport completion. If the calculation is terminated prior to the end of washdown, the transport completion will not necessarily be complete.

The calculations performed for NUREG/CR-6224 and the sample problems included in this users manual assume that the time-dependent transport rate is a constant value, i.e., the debris transport rate was uniform throughout the blowdown period and again throughout the washdown period. The input rate in this case is actually one divided by the appropriate time period in seconds. While it is recognized that the transport rate is not likely to occur at a constant rate, a more realistic model has currently not been validated. Therefore, should a user develop a transport rate model that varies with time, such as correlating debris transport with the primary system depressurization rate, it is anticipated that the integration of the transport rate could be somewhat problematic for the user.

Normally once a new transport rate model is developed, it will be reused over and over again so that any difficulty encountered with developing a new model will be relatively minimal. The user should consider the following concepts when developing a new transport rate model.

- The user should consider integrating the function describing the transport rate with other software before implementing the function into the BLOCKAGE code. This step would help to ensure that the function itself is capable of integrating to one.

- The transport rate curve can be better approximated by specifying more data points (up to 100 points) in the time-dependent input and the user should carefully consider the

optional method for interpolating between those points (i.e., step, linear, or exponential).

- As with any numerical integration of a mathematical function, the accuracy of the integration is a function of the size of the time steps.

- The user can relax the required accuracy of the integration by increasing the check limit, but the user must determine the acceptable accuracy for their particular application.

4.4 Modeling of ECCS

The ECCS models included in the BLOCKAGE code allow the user to implement multiple pumping systems that in turn may have multiple pumps attached to a common header. The available NPSH margin for each pump is determined separately based on the time-dependent temperature of the suppression pool and head loss associated with debris deposited onto the strainer of that pumping system. The strainer head losses due to deposited debris are predicted for fibrous and particulate debris beds and for deposits of metallic debris. A particular pump is assumed lost when its available NPSH margin goes to zero and when a pump is lost the flow through its strainer is reduced accordingly. The ability of the ECCS to perform its mission of cooling the reactor core is assumed to fail once the total ECCS flow rate drops below a user specified minimum flow rate.

4.4.1 Multiple Pump and Multiple Strainer Concept

The ECCS pump and header model in BLOCKAGE allows the user to tailor the strainer BLOCKAGE calculation to the plant specific ECCS pumping systems. As many as eight independent pumping systems can be modeled in a single calculation. A single pumping system consists of multiple pumps (or a single pump) attached to a common header that draws water from a single strainer. The strainer areas of each of the multiple strainers attached to a common header are combined and the flow through the equivalent strainer is the combined flow of each of the operating pumps attached to the common header. As many as four pumps can be attached to the common header. The ECCS pump and header model is illustrated schematically in Figure 4.4.1-1.

Each pump attached to a common header is modeled with a separate flow capacity and a separate NPSH margin but all pumps use a common time-dependent flow multiplier. Each pump provides ECCS flow to the reactor until strainer blockage head losses exceed its available margin of NPSH causing the pump to fail and its flow to cease. Pump performance modeled, pump brake power, pump head, pump efficiency was not modeled as a function of pump flow rate. The calculation of the strainer blockage head losses is based on the total flow of those pumps still operating on the common header, but the loss of NPSH margin for each pump is determined independently of the other pumps.

The user defines the structure of the ECCS in the **ECCS** window. Each pumping module is specified with a unique name and a strainer area, then the pumps associated with that module are listed with a unique pump name and the flow capacity and the reference NPSH for that pump.

4.4.2 NPSH Margins

The NPSH margins are used by BLOCKAGE to determine if and when a pump is lost and no longer provides coolant to the reactor core. The NPSH margin is the pressure at the pump inlet minus the vapor pressure of the water at the pool temperature corrected to the elevation of the pump. In the BLOCKAGE code, a pump is assumed tripped and removed from further use when the NPSH margin is reduced to zero either due to an increase in the pool temperature or to head loss from debris deposited onto the pump strainer. In BLOCKAGE, the NPSH margin is tracked based on both a clean strainer configuration (i.e., no debris deposits) and a fouled strainer configuration. These two margins are referred to as the Clean and Fouled NPSH margins in the output reports., and are defined below.

<u>Clean Strainer NPSH Margin</u> The clean strainer NPSH margin is the margin calculated without including a head loss due to debris blockage on the strainer. This margin changes only with the change in the suppression pool temperature.

<u>Fouled Strainer NPSH Margin</u> The fouled strainer NPSH margin is the margin calculated considering the head loss due to debris blockage on the strainer, i.e., it is equivalent to the Clean Strainer NPSH margin less the predicted debris blockage head loss.

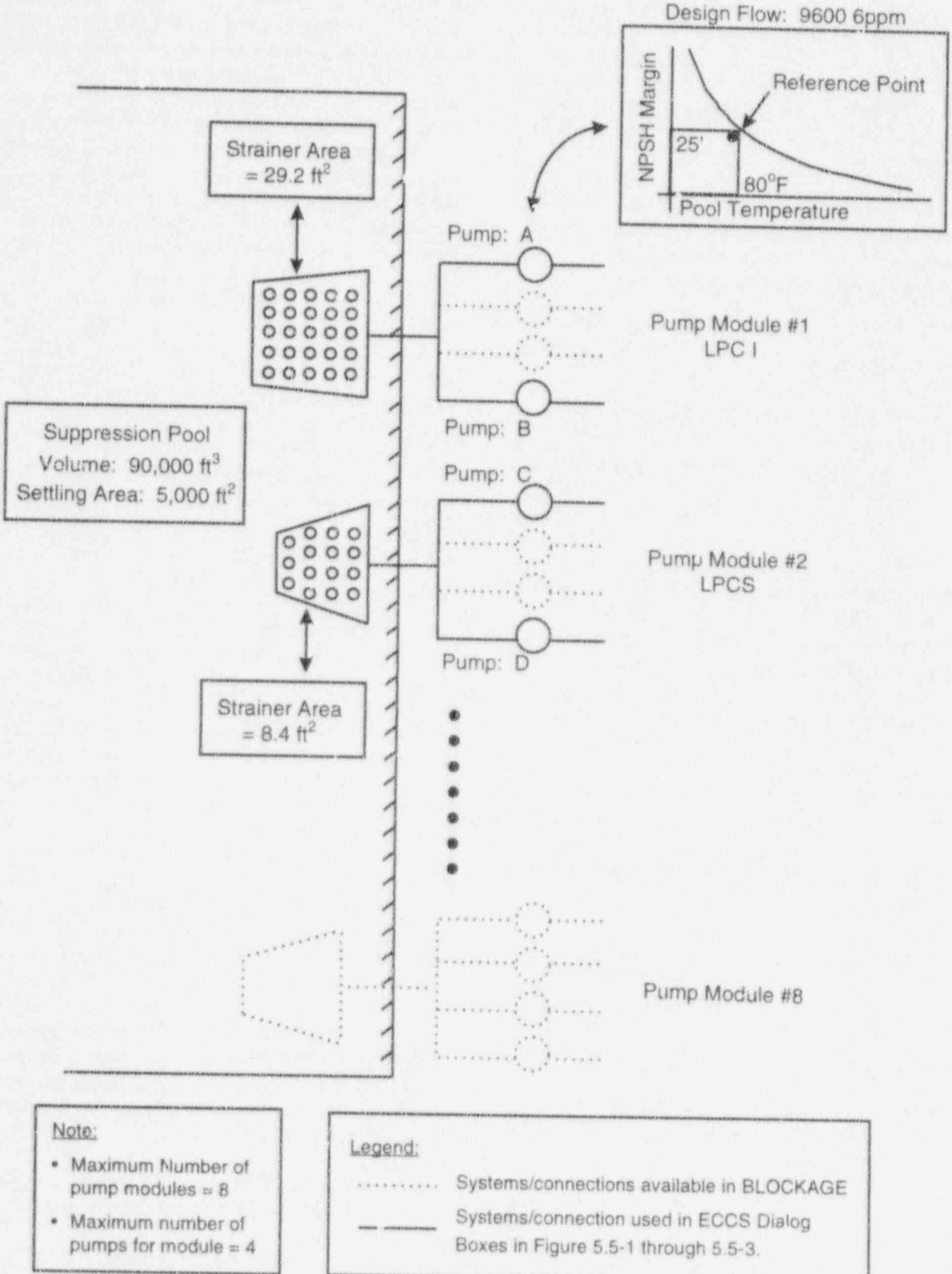

Figure 4.4.1-1. ECCS Pump and Header Model

The equations used to calculate the Clean and Fouled NPSH margins are:

$$cNPSH(t) = NPSH_o - \left[\frac{P_a - P_{vo}}{\gamma_{wo}} - \frac{P_a - P_v(T_w(t))}{\gamma\ (T_w(t))} \right] \qquad (4\text{-}5)$$

and

$$fNPSH(t) = cNPSH(t) - \Delta H_{Loss}(t)$$

where

cNPSH(t)	=	the time and temperature dependent NPSH margin for a clean strainer
fNPSH(t)	=	the time and temperature-dependent NPSH margin for a fouled strainer
$NPSH_o$	=	the clean strainer pump NPSH margin at the reference temperature,
$\Delta H_{loss}(t)$	=	the time dependent strainer head loss due to debris blockage
P_a	=	the standard atmospheric pressure (14.7 psia)
P_{vo}	=	the water vapor pressure at the reference temperature
$P_v(T_w(t))$	=	the temperature dependent water vapor pressure
γ_{wo}	=	the specific weight of water at the reference temperature
$\gamma(T_w(t))$	=	the temperature dependent specific weight of water.

The user specifies the reference temperature and the clean strainer NPSH at the reference temperature for each pump in the **ECCS** window. The time dependent suppression pool temperature is specified in the **Event Scenario** window.

4.4.3 Strainer Head Losses

Strainer head loss is calculated by BLOCKAGE using one of the four head loss correlations implemented into the code. The user must select the most appropriate correlation and then specify the required constants in the **Correlation** window. These head loss correlations are discussed in Section 3 of this report and in the associated Reference Manual. The NUREG/CR-6224 correlation is recommended for predicting head loss associated with a particulate and fiber debris bed. However, the user can implement other correlations using one of the two generic correlation forms, i.e., Generic 1 or Generic 2. Examples of this process are included in this report.

These correlations were coded to predict head loss associated with 'Fibrous', 'Particulate', 'Metallic', or 'Ignore' debris. Each type of debris is classified in the **Debris Attributes** window by the user. Predicting the head loss associated with fibrous and particulate debris was the focus of BLOCKAGE but metallic insulation debris could also be present in the strainer debris bed. Since an appropriate metallic debris head loss correlation was not available for implementation into this version of BLOCKAGE, a single metallic head loss term was added to each of the four correlations (the term applied to each correlation was identical) that allows the user some capability, albeit mediocre, of predicting strainer head loss associated with metallic insulation debris. When using the metallic head loss, the user should understand that the any interactions between the fibrous and particulate debris bed and the metallic debris bed are not simulated. This metallic head loss term has a leading coefficient, K, that the user must specify. If the metallic head loss term is used, the user will have to somehow benchmark the metallic term against experimental data, i.e., no guidance is available at this time for inclusion into this report.

The use of the Ignore debris classification allows the user to track a particular debris type without that debris impacting the head loss prediction, i.e., the head loss correlations simply ignore a debris type with this classification. The initial purpose of this classification was to maintain the capability of reproducing the NUREG/CR-6224 study results with this version of the code, but this capability has possible uses in other studies. For example, a user could examine the importance of a particulate debris type by changing the classification of that debris type to Ignore debris classification and running the calculation a second time and then comparing the results.

The head loss correlations were developed considering one type of fiber and one type of particulate debris on the strainer at a time. Thus, when multiple debris types of the same classification

are deposited onto the same strainer, these debris types are combined into a mixture with the appropriate properties associate with that mixture. For example, consider two types of fibrous debris that have distinctly different densities, specific surface areas, and rates of deposition onto a strainer. The effective properties for that mixture of fibers depends upon their respective density and specific surface areas and the time dependent composition of the mixture. This is true of multiple types of particulate or metallic debris, as well. The mixture properties are then used in the head loss predictions. The equations for calculating the mixture properties are available in the associated Reference Manual and the time dependent properties are printed in the **Break Details** reports when detailed information is requested in the **Output** window.

4.4.4 Specifying Criteria for ECCS Failure

A probabilities report includes ECCS failure probabilities (referred to as ECCS blockage frequencies in the output probabilities report) as well as pipe weld break frequencies. In studies performed with BLOCKAGE code versions prior to version 2.5 (such as the NUREG/CR-6224 study), the ECCS failure was simply the determination of strainer blockage since the code only modeled one pump and one strainer. Since BLOCKAGE allows the user to model multiple pumps on multiple pumping system headers (up to 32 individual pumps and 8 independent strainer are possible), the criteria for ECCS failure became a function of the total flow supplied to the reactor core. Since the minimum ECCS flow required to cool the core is now a user supplied value specified in the **ECCS** window, it is important that the user understand how this value is used by the code to determine whether or not ECCS has failed. Further, the user can control this value to tailor the probabilities report. Also, one of the termination options allows the user to terminate the calculation whenever ECCS failure is predicted.

The total ECCS flow rate supplied to the reactor core is:

$$Q_{ECCS}(t) = \sum_{k=1}^{N_{str}} \sum_{n=1}^{N_{pk}} \delta_{kn} \; M(t,loca) \; Q_{kn} \qquad (4\text{-}6)$$

where:

QECCS(t)	=	the time-dependent ECCS flow to the reactor core
δ_{kn}	=	indicates whether or not pump n on header k is active (1=active and 0=not)
M(t,loca)	=	the time and scenario dependent flow multiplier
Q_{kn}	=	the full volumetric flow capacity of pump n on common header k
N_{str}	=	the number of common headers or strainers
N_{pk}	=	the number of pumps attached to common header k.

The time-dependent flow multiplier which is provided in a tabular form by the user is generally intended to model the pump startup where the multiplier is initially zero and then increases to one when the pump has reached full speed. The shape of the flow multiplier curve between zero and one should represent the startup performance of the pump. The user is required to specify two pump flow multiplier curves, i.e., one curve for LLOCA weld break scenarios and one for MLOCA scenarios. The user may specify a pump flow multiplier curve that either does not reach a value of one to represent a degraded performance for the pumps or a curve that exceeds a value of one representing pumps that are driven beyond their normal rated flow capacity.

The ECCS failure criteria can be specified as the loss-of-NPSH margin of any pump by setting the user input minimum ECCS flow rate to a value below the total capacity of all of the pumps but higher than the total flow any combination of pumps where only one pump is lost. Thus, when loss-of-NPSH margin is predicted for any single pump, the predicted flow to the reactor core drops below the specified minimum value and ECCS failure is signaled. A more realistic criteria would be to use a minimum flow required to cool the core that was determined by a core cooling code. Depending upon the arrangement of pumps and headers, multiple losses-of-NPSH margin may be required to actually fail to cool the reactor core. (It should be noted that when a single pump fails on a multiple pump header arrangement, the strainer blockage head loss existing at the time of the loss drops because the flow through the strainer is reduced.) These two schemes will likely result in different ECCS failure probabilities.

Basically the ECCS is assumed to fail when the total ECCS flow falls below a user specified minimum flow

criteria once the ECCS flow has been established. The definition for the ECCS failure criterion that was coded into BLOCKAGE is:

$$\sum_{k=1}^{N_{str}} \sum_{n=1}^{N_{pk}} \delta_{kn} Q_{kn} < Q_{min} \qquad (4\text{-}7)$$

where:

Q_{min} = the user specified minimum ECCS flow required cool the core.

Although BLOCKAGE allows the user to specify time-dependent flow multipliers greater than one, or less than one, implying that the pumps can be run at greater than, or less than, 100% capacity, the ECCS failure criteria was not programmed to look for this possibility. If a probability report is to be generated, it is highly recommended that the user specify the pumps to run at 100% following a reasonably brief start up period.

If ECCS failure occurs after the pumps have reached full 100% capacity, then the failure is signaled when the total flow drops below the minimum required flow. However, in more extreme conditions, it is possible for the code to predict ECCS failure before full capacity is reached. Under these conditions, the code will determine if enough capacity exists with the remaining operating pumps to meet the minimum core cooling requirement once the pumps are running at full capacity. If the remaining total full capacity flow is sufficient to cool the core once the pumps reach full capacity, ECCS will not be considered as failed. Therefore, it is assumed that the pumps will obtain full capacity in a reasonable short period of time, i.e., the core will not be damaged due to insufficient flow during this brief period immediately following the pipe break.

The output reports specify event times when the first pump lost its NPSH margin and when the overall ECCS was predicted to fail to cool the core. If the user were to specify only one pump in the total ECCS system, then these two event times would be identical. However, if multiple pumps are specified, then the loss of a single pump does not necessarily signal the failure of the ECCS because the remaining pumps may supply adequate flow. This, of course, entirely depends upon how the user sets up the problem. The user can specify a minimum ECCS flow rate high enough that all pumps are required to supply the minimum flow rate, therefore the loss of a single pump also signals the failure of the ECCS.

As discussed in Section 5, the user can terminate a calculation prior to reaching the specified end time if the user is only interested in the results up to a certain event time such a the failure of the ECCS. This capability could save the user computational time and is user-driven. This user selected option is located in the **Output** window. Note that the early termination option does not affect the calculation in any other way, specifically it does not affect the determination of loss of NPSH margin or the failure of ECCS. There is only one definition of failure of the ECCS and that failure is defined by the ECCS failure criterion equation.

4.5 Calculation Termination

Normally the time transient portion of each calculation is terminated for each particular weld when the calculational time reaches the user specified termination time specified in the **Event Scenario** window. Several options, specified in the **Output** window, are also available for terminating the calculation prior to this time based upon pump loss-of-NPSH events, however, under no circumstances will a calculation exceed the user specified termination time. The early termination options are:

- termination when the first pump has lost NPSH margin,
- termination when all pumps on any single strainer have lost NPSH margin,
- termination when all pumps in the calculation have lost NPSH margin,
- termination when ECCS is predicted to fail to cool the reactor core.

The early termination options can be used by the user to reduce calculational time. For example, the user may need to input a relatively large termination time is order to ensure a complete calculation but not be interested in the results after ECCS was predicted to fail. This can be accomplished by selecting the early termination option where the calculation stops after the ECCS has failed. The probability report will not be affected for this case. It is the user's responsibility to select the termination option that applies to the calculation of interest, if in doubt, do not use an early termination option.

5.0 Output Guide

The following sections describe the output results generated by BLOCKAGE in the corresponding windows. Detailed information about the meaning of the output variables and the specific models in BLOCKAGE is presented in the NUREG/CR-6224 [NRC, NUREG/CR-6224] and in the Reference Manual [NRC, NUREG/CR-6371].

5.1 Input Parameters

The detailed input data specified by the user is presented as part of the output results in this window. This report reproduces exactly the input parameters, described in detail in Section 5.0, provided by the user in the corresponding dialog boxes in the Input Parameters window to model the specific case for analysis. Among other applications, the information in this report can be used to check that the actual input data to BLOCKAGE corresponds to the desired case for analysis. In addition, this report may be helpful in documenting the values and assumptions used in the calculations. Since this report contains the description of the abbreviations used in the particular case for analysis, it may be also useful in following the results presented in the other output reports. Notice, however, that the system identifiers in this report correspond to those specified by the user, and may not necessarily correspond to the sequential integer numbers assigned by BLOCKAGE to identify the systems in the frequencies output report.

5.2 Error Messages

BLOCKAGE has two levels of input data verification to check for the type and range of the input variables. The first level verifies the proposed values directly in the input dialog boxes and, if no errors are detected at this level, BLOCKAGE initiates the calculations by checking the proper specification of the input data by conducting a second level of verification. An example of this first level of input data verification is when the specified distribution fraction for the settling velocity groups does not add to $1.0 \pm 1 \times 10^{-5}$. In this case, the following message is prompted: "Distribution fractions must sum 1.0 +/- 1e05". If no errors are detected, BLOCKAGE executes and no messages in the **Errors** report are presented.

If no errors are detected by BLOCKAGE during the first level of verification but an error is detected during the second level of verification, BLOCKAGE generates the corresponding error message in the **Errors** report. In most cases, the error message gives some information to solve the problem. An example of the second level of input verification is when an exponential mode of interpolation for the filtration efficiency is selected and the initial efficiency for a particular debris settling velocity group is set equal to zero. In this case, BLOCKAGE generates the following message in the **Errors** report:

```
POOLIN: Error in initial filtration efficiency
POOLIN: for debris type 4
POOLIN: and velocity group 1
POOLIN: requires 0. < EFILT = > 1. if an
POOLIN: exponential interpolation option selected
```

Another example of particular interest is when the drywell transport rate specified in the corresponding Time-Rate table in the Event Scenario does not integrate to 1 plus or minus the value assigned for the check limit, a situation described in Section 4.3. In this case, the following message is generated in the **Errors** report:

```
POOLIN: Error in MLOCA drywell transport rates
POOLIN: for washdown transport period
POOLIN: Integral is 0.086114E+01
POOLIN: Require Integral = 1. + or - cklim
```

In addition to error messages, BLOCKAGE generates warning messages in the **Errors** report, i.e., potential input data problems that do not stop the calculations. An example of this situation is when a drywell transport rate different from zero is specified after the end of washdown, in which case the following message is generated in the **Errors** report:

```
POOLIN: Warning: MLOCA Drywell Transport
POOLIN: Rates > 0 after end of washdown not used
```

5.3 Break Details

The Break Detail report contains the detailed ECCS strainer blockage information at specific times for each break selected for analysis. In particular, this report includes the following time dependent information:

- Generation of each type of debris in the drywell, their transport to the wetwell, and the quantity of the debris initially present in the wetwell.

- ECCS flow rate, pool water temperature, specific pump flow rate, pump NPSH data (see

Section 4.4 for definitions of NPSH margins), and pump status.

- Strainer data, i.e., fiber, metallic, and particulate debris volumes, cake thickness, mass ratios, and head loss for each strainer.
- Detailed debris distribution data, i.e., volumes for each type of debris in the drywell, suspended in the pool, settled on the wetwell floor, deposited on the strainer, and retained by the primary system.
- The volumes reported in the case in which the user does not select the **Include Detailed Information** output option are the sums of all the settling velocity groups for each debris class, but do not contain information regarding the velocity group distributions. If this output option is selected, the settling velocity group distributions are saved for each type of debris at each location.

5.4 Target Details

The target output report reflects the break and target input and contains the calculated insulation volumes for each target for each weld break. The weld data includes the weld identifier, the system in which it is located, the pipe diameter, and the type and location of the weld. The target data includes the diameter of the pipe, the reference for the piping system, the type of insulation, i.e., fibrous (F), particulate (P) or metallic (M), the pipe lengths within each destruction region, and the corresponding volumes of intact insulation and generated debris.

5.5 Frequency Report

This report contains the weld break results organized according to their frequencies. The report is activated only when the Target Generated Option is used without checking the Skip Probabilistic Analysis dialog. In particular, this report includes the number of weld breaks of each diameter and diameter class, together with their corresponding break and ECCS strainer blockage frequencies, arranged by their location in the drywell. It also includes the information about the weld breaks of each diameter and diameter class, and their corresponding break frequencies and ECCS strainer blockage frequencies, arranged by the piping systems in which they are located.

5.6 Summary Report

This report contains summary results for the entire calculation. In particular, it includes the weld identifier, the diameter of the broken pipe, the piping system and drywell location of the weld and the break frequency for each weld. In addition, this report includes the volumes of each type of debris in the wetwell, as well as the final ECCS flow, time of the first pump loss of NPSH margin and time of ECCS failure for each weld break.

5.7 Volume Sorted Summary Report

This report contains selected results, collated by fiber volume and LOCA size, such as volume of fibers transported to the wetwell, the final ECCS flow rate, the time of first pump loss of NPSH margin and the ECCS failure time, for each weld break sorted by the size of the LOCA break, i.e., medium versus large LOCA. These results can be used to make a plot of ECCS failure time vs. Fiber volume.

5.8 Time Based Plots and Reports

This output generates quick-look plots and reports of the BLOCKAGE time-dependent results variables of the weld breaks selected for detailed analysis. The contents of this output panel is discussed in the following sections.

<u>Break ID</u> This specifies the weld break, out of the welds selected for detailed calculation, for which the specific plots or reports are desired.

<u>Predefined</u> This dialog allows the selection of individual output variables or, by the **Custom** option, the selection of all the output variables grouped in the same general category, i.e.,

- Fiber Volumes
- DW Particulate Volumes
- Metal Particulate Volumes
- Strainer Approach Velocities
- Strainer Theoretical Cake Thickness
- Strainer Actual Cake Thickness
- Strainer Metal to Fiber Ratio
- Strainer Particulate to Fiber Ratio
- Strainer Head Loss
- Clean Strainer NPSH Margin
- Fouler Strainer NPSH Margin.

Title This is the user specified name appearing in the specific plot or report.

Format Here the user can select a **Report**, i.e., the table of the specific variable versus time, which can be exported to other graphics programs, or a **Plot**, in which case the corresponding graphical results are generated automatically. To save the **Report**, go to the **Results** menu and select **Save Results**.

Scale In the case of the Plot option, the user may select between a linear or a logarithmic scale for both the X variable, i.e., time, and the Y variable, i.e., the output variable of interest. The user may further select between an **Automatic** or a **Manual** specification of the range of the X and Y variables.

Variables The following list presents the BLOCKAGE results available for output plots or reports:

1) **Time Dependent Input**
- Time Step Size
- Pump Flow Multiplier
- Suppression Pool Temperature
- Drywell Debris Transport
- Debris Resuspension Rate
- Debris Settling Turbulence Factor

2) **Fibrous Debris Volumes**
- Total Fiber Volume Transported from Drywell
- Fiber Volume Suspended in Suppression Pool
- Fiber Volume Settled on Wetwell Floor
- Fiber Volume Deposited on All Strainers
- Fiber Volume Retained by Primary System

3) **Particulate Debris Volumes**
- Total Particulate Volume Transported from Drywell
- Particulate Volume Suspended in Suppression Pool
- Particulate Volume Settled on Wetwell Floor
- Particulate Volume Deposited on All Strainers
- Particulate Volume Retained by Primary System

4) **Metallic Debris Volumes**
- Total Metallic Transported from Drywell
- Metallic Volume Suspended in Suppression Pool
- Metallic Volume Settled on Wetwell Floor
- Metallic Volume Deposited on All Strainers
- Metallic Volume Retained by Primary System

5) **ECCS Performance**
- Total ECCS Flow
- Change in NPSH from Reference NPSH, i.e., the NPSH at the actual suppression pool temperature minus the NPSH at the reference temperature.
- Clean Strainer NPSH Margin for First Six Pumps
- Fouled Strainer NPSH Margin for First Six Pumps
- Approach Velocity Strainer
- Theoretical Fiber Cake Thickness (Not Compressed)
- Actual Cake Thickness (Compressed Fiber)
- Metallic to Fiber Mass Ratio
- Particulate to Fiber Mass Ratio
- Head Loss

Start Time Here the user may specify the initial time for the output plots or reports of the specific variables.

Sampling Interval Here the user can specify the sampling interval, in terms of time steps, for the points in the plots or reports of the specific variables.

6.0 References

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Appendix A

Sample Problems

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This section presents two demonstration problems illustrating the use and the capabilities of the Blockage computer code. The first problem shows the Target Generated Volumes option for the generation of insulation debris, whereas the second problem shows the corresponding User Specified Volumes option. These demonstration problems focus on the most common types of debris expected in typical Boiling Water Reactors (BWR) during LOCA conditions, including fibrous as well as particulate and metallic insulation materials, paint chips, concrete dust, and suppression pool sludge. The proposed ECCS's pump and header arrangement includes redundant trains or divisions for the low pressure injection and core spray systems in a hypothetical plant. The NUREG/CR-6224 head loss correlation and filtration efficiency models are the best options currently available and, therefore, are proposed in these demonstration problems.

Although the intention was to use realistic values whenever possible, the proposed problems do not represent the specific conditions of any particular BWR. Furthermore, most of these values were based on very limited experimental or analytical data and, consequently, considerable caution must be exercised when using them for other purposes than testing the calculation options in Blockage.

A.1 Sample Problem No. 1: Target Generated Volumes

In the Target Generated Option, Blockage calculates the amount of insulation debris generated and susceptible to be transported to the wetwell for each considered break. The following paragraphs describe the plant related information required by this option in Blockage. The detailed input data is presented in Table A.1.

A.1.1 Insulati Material Types

In general, this demonstration problem assumes that the main pipes in the recirculation system are insulated with NUKON™, whereas the manifold raisers, the high pressure core injection and the residual heat removal lines are supposed to be insulated with calcium silicate insulation. The main steam lines are assumed to be insulated with reflective metallic insulation (stainless steel RMI). Finally, the feedwater system pipes are assumed to be in ulated with mineral wool.

A.1.2 Weld Information

With respect to the weld breaks, the demonstration problem includes a total of 23 welds, 12 of which represent large break LOCAs, i.e., welds in pipes of diameters greater than 6 inches, and 11 represent medium break LOCAs. Out of the 12 large LOCA weld breaks, 5 are located in a high region in the drywell, 6 in a middle region, and 1 in the lower region. For the medium LOCA weld breaks, 9 are located in the lower region of the drywell and 2 in the middle region; no medium LOCA breaks are analyzed in the high region of this drywell.

The demonstration problem analyzes 7 welds in the recirculation system, 11 breaks in the main steam system, 1 weld in the feedwater system, 2 welds in the steam line of the high pressure core injection system, and 2 welds in the residual heat removal system.

Thirteen of the 23 welds considered in this demonstration problem are of type C1, i.e., joining pipes of carbon steel CS 106, 7 are of type S1, i.e., joining pipes of stainless steel SS 304, 2 are of type C3, i.e., joining pipes of carbon steel CS 333, and 1 is of type S2, i.e., joining a pipe of stainless steel SS 316 with a pipe of stainless steel SS 304. The break frequencies associated to each type of weld are as follows:

2×10^{-7} per reactor-year for C1 and C3 weld types, regardless of pipe diameter,
2×10^{-7} per reactor-year for weld types S1 and S2 in pipes of diameters greater than 18",
2×10^{-6} per reactor-year for weld types S1 and S2 in pipes of diameters from 12 to 16",
1×10^{-6} per reactor-year for weld types S1 and S2 in pipes of diameters less than 10".

A.1.3 Debris Characteristics

Blockage essentially considers three general classes of debris: fibrous, metallic and particulate materials. The demonstration problem includes two types of fibrous debris, namely, NUKON™ and mineral wool, one type of metallic debris, i.e., RMI, and four types of particulate matter debris, i.e., calcium silicate, paint chips, concrete dust, and suppression pool sludge.

A.1.3.1 Fibrous Debris

<u>NUKON™</u>

For NUKON™ debris, the demonstration problem considers the same values used in the NUREG/CR-

6224 study, i.e., a material density of 175 lbm/ft^3, an as-fabricated and rubble densities of 2.4 lbm/ft^3, and a specific surface area of 1.71×10^5 ft^{-1}.

The zone of influence for debris generation in the demonstration problem is divided into three regions defined by radii of 3D, 5D, and 7D (where D is the diameter of the broken pipe), with corresponding destruction factors of 0.75, 0.60 and 0.40.

The transport factors for NUKON™ debris during blowdown are assumed to be 0.15, 0.35 and 0.45 for the high, middle and lower elevations in the drywell, respectively. For the washdown, the assumed transport factors are 0.10, 0.15 and 0.30 for the high, middle and low elevations respectively; the corresponding total transport factors are thus: 0.24, 0.45 and 0.62 for high, middle and low elevations in the drywell.

The following twelve settling velocity groups for NUKON™ fibrous debris were used in this demonstration problem:

Fraction of Total Debris by Mass

Fraction by Mass	Settling Velocity (ft/s)
0.43067	6.5306×10^{-3} ft/s
0.14922	1.6443×10^{-3} ft/s,
0.11011	2.6061×10^{-3} ft/s,
8.125×10^{-2}	4.1303×10^{-3} ft/s,
5.995×10^{-2}	6.5461×10^{-3} ft/s,
4.424×10^{-2}	1.0375×10^{-2} ft/s,
3.265×10^{-2}	1.6443×10^{-2} ft/s,
2.409×10^{-2}	2.6061×10^{-2} ft/s,
1.778×10^{-2}	4.1303×10^{-2} ft/s,
1.312×10^{-2}	6.5461×10^{-2} ft/s,
9.68×10^{-3}	0.13075 ft/s,
2.725×10^{-2}	0.24606 ft/s.

Mineral Wool

For mineral wool debris, the demonstration problem assumes a material density of 180 lbm/ft^3, an as-fabricated density of 6 lbm/ft^3, and a rubble density of 12 lbm/ft^3. The specific surface area is assumed to be 121,900 ft^{-1}.

This demonstration problem assumes arbitrarily destruction factors of 0.8, 0.7 and 0.5 for regions bounded by radii 3D, 5D and 7D, respectively. The same transport factors proposed for NUKON™ are assumed for mineral wool.

In the absence of better data, this demonstration problem includes a single settling velocity group, with a settling velocity equal to the median settling velocity for NUKON™ debris, i.e., 3.28×10^{-3} ft/s (1 mm/s).

A.1.3.2 Metallic Debris

For stainless steel RMI debris, the demonstration problem assumes a material density of 491 lbm/ft^3, an as-fabricated density of 25 lbm/ft^3, a rubble density of 100 lbm/ft^3, and a specific surface area of 2400 ft^{-1}.

For RMI, this problem assumes arbitrarily destruction factors of 0.5, 0.3 and 0.1 for regions bounded by radii 3D, 5D and 7D, respectively. With respect to the transport during blowdown, transport factors of 0.05, 0.15 and 0.25 are assumed for high, middle and low elevations respectively; the corresponding transport factors during washdown are assumed to be 0.05, 0.1 and 0.2 for high, middle and low elevations in the drywell, respectively.

For metallic debris, independent of the size, the settling velocity is assumed to be 0.39 ft/s (120 mm/s).

A.1.3.3 Particulate Debris

Calcium Silicate

For calcium silicate debris, this demonstration problem assumes a material density of 150 lbm/ft^3, an as-fabricated density of 120 lbm/ft^3, a rubble density of 65 lbm/ft^3, and a specific surface area of 60,000 ft^{-1}.

In the absence of better data, this demonstration problem assumes destruction factors of 0.8, 0.6 and 0.4 for regions bounded by radii 3D, 5D and 7D, respectively. In this case, the transport factors during blowdown are assumed to be 0.25, 0.35 and 0.45 for high, middle and low elevations respectively, whereas the transport factors during washdown are assumed to be 0.15, 0.3 and 0.6 for high, middle and low elevations in the drywell, respectively.

For calcium silicate particles, this demonstration problem assumes a single group with a characteristic settling velocity of 8.5×10^{-4} ft/s.

Paint Chips

For paint chips, the same values in the NUREG/CR-6224 study are proposed for this demonstration problem, i.e., a material density of 142 lbm/ft^3, equal to its as-fabricated density, and a rubble density of 65

lbm/ft³. The specific surface area is arbitrarily assumed to be 1.71×10^5 ft^{-1}.

In this case, a volume of 0.7 ft³ is assumed to be generated during the LOCA, and transport factors of 0.75 and 1.0 are proposed during blowdown and washdown, respectively, independent of the break location. A single group with a characteristic settling velocity of 0.2 ft/s is assumed in this demonstration problem.

Concrete Dust

For concrete dust particles, and following the assumptions in the NUREG/CR-6224 study, 156 lbm/ft³ is used for both the material and the as-fabricated densities, whereas a rubble density of 65 lbm/ft³ is proposed. The specific surface area in this case is assumed to be 1.71×10^5 ft^{-1}.

A volume of 1 ft³ is supposed to be generated during any LOCA, and the same transport factors as in the case of paint chips are assumed. A single group with a characteristic settling velocity of 0.4 ft/s is postulated in this demonstration problem.

Suppression Pool Sludge

The material density of the iron oxide particles composing the suppression pool sludge, which is the same as the as fabricated density in this case, is 324 lbm/ft³; and the rubble density is 65 lbm/ft³. A specific surface area of 1.71×10^5 ft^{-1} is assumed for the sludge particles.

A volume of 2.4 ft³ of sludge is considered to be already present in the suppression pool, and the following settling velocity groups [NUREG/CR-6224, 1995] are included in this demonstration problem:

Fraction by Mass	Settling Velocity (ft/s)
0.20897	6.5306×10^{-4} ft/s,
4.658×10^{-2}	1.6443×10^{-3} ft/s,
5.477×10^{-2}	2.6061×10^{-3} ft/s,
6.325×10^{-2}	4.1303×10^{-3} ft/s,
7.145×10^{-2}	6.5461×10^{-3} ft/s,
7.848×10^{-2}	1.0375×10^{-2} ft/s,
8.322×10^{-2}	1.6443×10^{-2} ft/s,
8.442×10^{-2}	2.6061×10^{-2} ft/s,
8.101×10^{-2}	4.1303×10^{-2} ft/s,
7.249×10^{-2}	6.5461×10^{-2} ft/s,
5.943×10^{-2}	0.13075 ft/s,
9.593×10^{-2}	0.24606 ft/s.

A.1.4 ECCS Characteristics

This demonstration problem considers two types of low pressure core cooling systems, namely, core injection and core spray, taking suction from a suppression pool with a volume capacity of 58,900 ft³ and a reference temperature of 80°F. For the hypothetical situation analyzed in this problem, it is assumed that a flow of 5000 gpm is sufficient to mitigate the accident. In addition, it is assumed that the low pressure core injection system has two redundant trains, each with one strainer and two pumps, and that the low pressure core spray also has two redundant trains, each with one strainer and one pump.

A.1.4.1 Low Pressure Core Injection System

The core injection system considered in this demonstration problem has two identical trains, each taking suction from a strainer with a surface area of 14.6 ft², and two pumps with a flow capacity of 4800 gpm each. To test Blockage modeling of different NPSH, in this case it is arbitrarily assumed that one pump in each train has a NPSH of 14 ft of water, whereas a NPSH of 24 ft of water was postulated for the other pump in each train.

A.1.4.2 Low Pressure Core Spray System

The core spray system in this demonstration problem has two trains, each taking suction from a dedicated 4.21 ft² strainer. In this case, however, it is arbitrarily assumed that one of the trains has a pump with a flow capacity of 3020 gpm and a NPSH 32 ft of water, while the other train is postulated to have a pump of 3100 gpm in flow capacity and a NPSH of 17 ft of water.

A.2 Sample Problem No. 2: User Specified Volumes

The objective of this demonstration problem is to illustrate the use of Blockage, in the case in which the user provides the volumes of each type of debris to be used for each break considered in the calculations. The same insulation materials and debris characteristics proposed in the "Target Generated Volumes Demonstration Problem" will be used in this case. The proposed ECCS's pump and header arrangement will consider, in addition to the low pressure core injection and spray systems, a high pressure core injection system. Again, the user is cautioned that the proposed problem does not

represent the specific conditions of any particular BWR.

A.2.1 Insulation Debris Volumes

This demonstration problem includes 10 breaks, two of which are representative of medium LOCAs, one in the high and the other in the low elevations considered in the drywell, while the remaining eight represent large LOCAs. Out of the 8 LOCAs, 3 are located in the high elevation in the drywell, 4 in the middle elevation, and one the low elevation. Both NUKON™ and mineral wool were included as fibrous insulation materials, as well as calcium silicate and stainless steel as particulate and reflective metallic insulation materials, respectively.

A.2.2 ECCS Characteristics

As in the case of the target generated volumes, this demonstration problem includes two types of low pressure core cooling systems, namely, core injection and core spray, but considers also a high pressure core injection system, all of them taking suction from a pressure suppression pool with volume capacity of 58,900 ft^3 and at a reference temperature of 80° F. Again, it is assumed that a flow of 5000 gpm to the core is sufficient to mitigate the accident.

The same characteristics considered for the low pressure systems in the "Target Generated Volumes Demonstration Problem" are used in this case. For the high pressure core injection system, it is arbitrarily assumed that a single train with one strainer with 14.6 ft^2 of surface area, and one pump with a flow capacity of 4800 gpm and a NPSH of 24 ft of water.

A.3 Output Results

The purpose of this section is to provide some examples of the Blockage results for these sample problems. The first example illustrates the Blockage capabilities in generating results for use in probabilistic analyses, whereas the second example shows Blockage results for head loss across the strainer and its NPSH effects on the pump B of the postulated LPCS system.

ECCS Strainer Blockage Frequencies

Table A.2 is a summary of the Blockage calculations for Sample Problem No. 1. For each of the 23 welds considered in this problem, this summary contains the weld identifier; the diameter of the broken pipe, used to classify the break as either a medium or large LOCA; the identifier of the system in which the weld is located; the break frequency; the volumes of each type of debris in the suppression pool; the final ECCS flow; the time at which the first cavitation occurred, and the time at which the ECCS failed. As indicated in Table A.2, the frequency for the total of 23 weld breaks is 7×10^{-6} ; out of these 23 weld breaks, 14 lead to a core flow less than 5000 gpm, which was the condition specified in this sample problem for ECCS failure. Tables A.3 and A.4 present frequencies for loss of ECCS due to debris blockage arranged by weld break location in the drywell and by the piping system in which the weld break is located, respectively. As indicated in these tables, there is a total ECCS strainer blockage frequency of 5.2×10^{-6} per reactor-year, which suggests that a fraction of about 0.74 of the total weld break frequency will lead to ECCS failure in this hypothetical plant. Table A.3 also shows that breaks in the lower region of the drywell contribute to this total ECCS strainer blockage frequency with a frequency of 2.2×10^{-6} per reactor-year. As indicated in Table A.4, the ECCS strainer blockage frequency is dominated by breaks in the recirculation system piping (System No. 1). From these tables, it is also possible to conclude that, in this hypothetical plant, the ECCS strainer blockage frequency is dominated by large LOCA breaks, i.e., breaks in pipes of diameter greater than 6 inches. Further information about the probabilistic results is included in the Frequency Report generated by Blockage.

ECCS Pump Head Loss and NPSH Effects Due to Strainer Blockage

This example illustrates some of the Blockage capabilities in analyzing the head loss across the strainer and its effect on the NPSH of the low pressure core spray pump CS-B in Loop 4 for the specific case of the large LOCA break identified as VOLUME-6 in Sample Problem No. 2. This pump is assumed to have a reference NPSH of 32 ft of water at 80°F and its NPSH is lost in about 115 sec, as indicated in the summary at the end of the **Break Detail** output report for this break. According to the models in Blockage, loss-of-NPSH occurs when the head loss across the strainer exceeds the NPSH margin of the pump, defined as the NPSH available minus the NPSH required by the pump. It may be of interest, however, to analyze in detail the time behavior of the head loss across the strainer, and compare it with the NPSH evolution. The following procedure shows how the Blockage calculations can be used for this particular analysis.

The CS-B pump in Loop 4 corresponds to pump no. 6 in the Blockage output; the associated strainer is strainer no. 4 in the output. To examine the head loss and NPSH evaluation for this pump, the user has to choose the **Pump 6: Clean Strainer NPSH Margin** (i.e., the variation of the NPSH just as a function of the pool temperature), the **Pump 6: Foul Strainer NPSH Margin** (i.e., the clean NPSH minus the head loss accross the strainer), and the **Strainer 4: Head Loss** in the **Time Based** output variables. Figure A.1 presents these variables as a function of time. As indicated in this figure, loss of pump CS-B NPSH occurs when the head loss across the strainer no. 4 is equal to the clean NPSH, i.e., at about 115 sec.

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1

```
==============================================================================
DEFINITIONS
==============================================================================

Run    : Version 2.5 Input No. 1
Dataset: Sample Problem Input 1

Don't Skip Probabalistic Analysis

Break
Diameters
------------
0.75
1.
2.
3.
4.
6.
10.
12.
16.
18.
20.
22.

Destruction
Regions
------------
3.
5.
7.

System Identifiers
   Abbr    Description
   ------  --------------------------
   0       Recirculation Loop
   1       Main Steam
   2       Feedwater
   3       HPCI Steam Line
   4       RHR Injection Lines
```

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Weld Types

Abbr	Description
S1	S1
S2	S2
S3	S3
C1	C1
C2	C2
C3	C3

Break Locations

Abbr	Description
H	Above 776 ft Grating
M	Between 757/776 Gratings
L	Below 757 ft Grating

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

==
DEBRIS
==

Cake Thickness for Peak Filtration: 2.08E-2 ft
Interpolation: Linear

Abbreviation: NK
Name : Nukon
Class : Fibrous
Origin: : Drywell (Target)

Volume cu ft	Fabricated Density lb/cu ft	Rubble Density lb/cu ft	Material Density lb/cu ft	Specific Surf Area sq ft/cu ft
n.a.	2.4	2.4	175.	171000

Transport Fractions

Location	Blowdown	Washdown
H	0.15	0.1
M	0.35	0.15
L	0.45	0.3

Destruction Fractions

Region	Fraction
3.	0.75
5.	0.6
7.	0.4

Velocity Group	Filtration Strainer Eff Initial	Filtration Strainer Eff Peak	Retention Factor	Settling Velocity ft/sec	Distribution Fraction
NK-01	1.	1.	1.	6.5306E-4	0.43067
NK-02	1.	1.	1.	1.6443E-3	0.14922
NK-03	1.	1.	1.	2.6061E-3	0.11011
NK-04	1.	1.	1.	4.1303E-3	8.125E-2
NK-05	1.	1.	1.	6.5461E-3	5.995E-2
NK-06	1.	1.	1.	1.0375E-2	4.424E-2
NK-07	1.	1.	1.	1.6443E-2	3.265E-2
NK-08	1.	1.	1.	2.6061E-2	2.409E-2
NK-09	1.	1.	1.	4.1303E-2	1.778E-2
NK-10	1.	1.	1.	6.5461E-2	1.312E-2
NK-11	1.	1.	1.	0.13075	9.68E-3
NK-12	1.	1.	1.	0.24606	2.725E-2

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

```
--------------------------------------------
Abbreviation: MW
Name        : Mineral Wool
Class       : Fibrous
Origin:     : Drywell (Target)

             Fabricated   Rubble       Material     Specific
Volume       Density      Density      Density      Surf Area
cu ft        lb/cu ft     lb/cu ft     lb/cu ft     sq ft/cu ft
------------ ------------ ------------ ------------ ------------
n.a.         6.           12.          180.         121900

Transport Fractions
   Location     Blowdown     Washdown
   ------------ ------------ ------------
   H            0.15         0.1
   M            0.35         0.15
   L            0.45         0.3

Destruction Fractions
   Region       Fraction
   ------------ ------------
   3.           0.8
   5.           0.7
   7.           0.5

         Filtration   Filtration                Settling
Velocity Strainer Eff Strainer Eff Retention    Velocity     Distribution
Group    Initial      Peak         Factor       ft/sec       Fraction
-------- ------------ ------------ ------------ ------------ ------------
MW-01    1.           1.           1.           3.28E-3      1.
--------------------------------------------
Abbreviation: MR
Name        : RMI
Class       : Metallic
Origin:     : Drywell (Target)

             Fabricated   Rubble       Material     Specific
Volume       Density      Density      Density      Surf Area
cu ft        lb/cu ft     lb/cu ft     lb/cu ft     sq ft/cu ft
------------ ------------ ------------ ------------ ------------
n.a.         25.          100.         491.         2400.
```

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Transport Fractions

Location	Blowdown	Washdown
H	5.E-2	5.E-2
M	0.15	0.1
L	0.25	0.2

Destruction Fractions

Region	Fraction
3.	0.5
5.	0.3
7.	0.1

Velocity Group	Filtration Strainer Eff Initial	Filtration Strainer Eff Peak	Retention Factor	Settling Velocity ft/sec	Distribution Fraction
MR-01	1.	1.	1.	0.39	1.

Abbreviation: CS
Name : Cal-Sil
Class : Particulate
Origin: : Drywell (Target)

Volume cu ft	Fabricated Density lb/cu ft	Rubble Density lb/cu ft	Material Density lb/cu ft	Specific Surf Area sq ft/cu ft
n.a.	120.	65.	150.	60000.

Transport Fractions

Location	Blowdown	Washdown
H	0.25	0.15
M	0.35	0.3
L	0.45	0.6

Destruction Fractions

Region	Fraction
3.	0.8
5.	0.6
7.	0.4

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Velocity Group	Filtration Strainer Eff Initial	Filtration Strainer Eff Peak	Retention Factor	Settling Velocity ft/sec	Distribution Fraction
CS-01	0.	0.5	0.5	8.5E-4	1.

Abbreviation: PT
Name : Paint
Class : Particulate
Origin: : Drywell (Non-Target)

Volume cu ft	Fabricated Density lb/cu ft	Rubble Density lb/cu ft	Material Density lb/cu ft	Specific Surf Area sq ft/cu ft
0.7	142.	65.	142.	171000

Transport Fractions

Location	Blowdown	Washdown
All	0.75	1.

Velocity Group	Filtration Strainer Eff Initial	Filtration Strainer Eff Peak	Retention Factor	Settling Velocity ft/sec	Distribution Fraction
PT-01	0.	0.5	0.5	0.2	1.

Abbreviation: CC
Name : Conc
Class : Particulate
Origin: : Drywell (Non-Target)

Volume cu ft	Fabricated Density lb/cu ft	Rubble Density lb/cu ft	Material Density lb/cu ft	Specific Surf Area sq ft/cu ft
1.1	156.	65.	156.	171000

Transport Fractions

Location	Blowdown	Washdown
All	0.75	1.

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Velocity Group	Filtration Strainer Eff Initial	Filtration Strainer Eff Peak	Retention Factor	Settling Velocity ft/sec	Distribution Fraction
Conc-1	0.	0.5	0.5	0.4	1.

Abbreviation: SD
Name : Sludge
Class : Particulate
Origin: : Wetwell

Volume cu ft	Fabricated Density lb/cu ft	Rubble Density lb/cu ft	Material Density lb/cu ft	Specific Surf Area sq ft/cu ft
2.6	324.	65.	324.	171000

Velocity Group	Filtration Strainer Eff Initial	Filtration Strainer Eff Peak	Retention Factor	Settling Velocity ft/sec	Distribution Fraction
wwp-01	0.	0.5	0.5	6.5306E-4	0.20897
wwp-02	0.	0.5	0.5	1.6443E-3	4.658E-2
wwp-03	0.	0.5	0.5	2.6061E-3	5.477E-2
wwp-04	0.	0.5	0.5	4.1303E-3	6.325E-2
wwp-05	0.	0.5	0.5	6.5461E-3	7.145E-2
wwp-06	0.	0.5	0.5	1.0375E-2	7.848E-2
wwp-07	0.	0.5	0.5	1.6443E-2	8.322E-2
wwp-08	0.	0.5	0.5	2.6061E-2	8.442E-2
wwp-09	0.	0.5	0.5	4.1303E-2	8.101E-2
wwp-10	0.	0.5	0.5	6.5461E-2	7.249E-2
wwp-11	0.	0.5	0.5	0.10375	5.943E-2
wwp-12	0.	0.5	0.5	0.24606	9.593E-2

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

BREAKS/TARGETS

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
PSA-J006	3	10.	C1	H	0	10.	PSA	CS	2.5	5.,8.54,9.58
					1	20.	MSB	MR	3.	4.06,7.81,16.9
					2	10.	FWB	MW	3.	0.,0.,7.89

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
PSA-J001	3	10.	C1	H	0	10.	PSA	CS	2.5	4.,5.75,7.44
					1	20.	MSB	MR	3.	4.93,12.92,12.92
					2	10.	FWB	MW	2.5	0.,0.,2.2

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RCA-J003	0	22.	S1	H	0	22.	RCA	NK	3.	7.33,11.,14.67
					1	20.	MSD	MR	3.	0.,7.4,15.76
					2	20.	MSC	MR	3.	0.,0.,3.7
					3	20.	MSB	MR	3.	0.,0.,3.7
					4	20.	MSA	MR	3.	0.,4.9,15.76
					5	10.	FWD	MW	2.5	0.,0.,11.3
					6	10.	FWA	MW	2.5	0.,0.,11.3
					7	10.	RRH	CS	2.5	0.,7.5,12.6
					8	10.	RRA	CS	2.5	0.,7.5,12.6

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RCA-J006	0	22.	S1	H	0	22.	RCA	NK	3.	11.,18.33,25.67
					1	10.	RRA	CS	2.5	0.,0.,13.
					2	10.	RRH	CS	2.5	0.,0.,13.
					3	16.	RMA	NK	3.	0.,0.,5.5
					4	16.	RMB	NK	3.	0.,0.,5.5
					5	20.	MSA	MR	3.	5.5,11.7,20.3
					6	20.	MSD	MR	3.	5.5,11.7,20.3
					7	20.	MSB	MR	3.	0.,4.71,17.13
					8	20.	MSC	MR	3.	0.,4.71,17.13
					9	10.	FWA	MW	2.5	0.,0.,5.5
					10	10.	FWD	MW	2.5	0.,0.,5.5
					11	10.	FWB	MW	2.5	0.,0.,3.7

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
MSB-J021	1	6.	C1	M	0	20.	MSA	MR	3.	2.88,4.93,6.95
					1	20.	MSB	MR	3.	2.93,4.96,6.97
					2	10.	FWB	MW	2.5	0.,0.,1.33
					3	10.	PSA	CS	2.5	0.,1.38,2.81

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RCA-J038	0	22.	S1	L	0	22.	RCA	NK	3.	11.,18.33,25.67
					1	20.	RHC	CS	3.	0.,4.,5.5
					2	16.	RMA	NK	3.	0.,0.,18.33
					3	10.	RRF	CS	3.	0.,0.,1.83
					4	10.	RRG	CS	3.	0.,0.,1.83

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RCA-J008	0	22.	S1	M	0	22.	RCA	NK	3.	11.,18.33,25.67
					1	16.	RMA	NK	3.	0.,0.,2.
					2	16.	RMB	NK	3.	0.,0.,3.
					3	20.	MSA	MR	3.	4.15,11.1,18.3
					4	20.	MSD	MR	3.	4.15,11.1,18.3
					5	20.	MSB	MR	3.	4.15,11.1,18.3
					6	20.	MSC	MR	3.	4.15,11.1,18.3
					7	16.	FWA	MW	2.5	0.,6.1,11.8
					8	16.	FWB	MW	2.5	0.,6.1,11.8

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RRG-J007	0	10.	S1	M	0	10.	RRG	CS	2.5	2.5,4.2,5.83
					1	16.	RMA	CS	3.	5.,6.7,8.34
					2	22.	RCA	NK	3.	0.,3.,5.27
					3	20.	RHD	CS	3.	0.,0.,4.
					4	20.	MSD	MR	3.	0.,3.62,8.12

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RCA-J027	0	4.	S2	L	0	4.	RCA	NK	3.	1.,1.67,2.33
					1	22.	RCA	NK	3.	2.,3.5,4.75
					2	4.	RBA	NK	3.	1.,1.7,2.33

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RCB-J028	0	1.	S1	L	0	1.	RCB	NK	2.	0.25,0.42,0.58
					1	22.	RCB	NK	3.	1.5,1.5,1.5

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
MSC-J031	1	1.	C1	M	0	1.	MSC	MR	2.	0.25,0.42,0.58
					1	20.	MSC	MR	3.	2.29,2.29,2.29
MSC-J033	1	1.	C1	M	0	1.	MSC	MR	2.	0.25,0.42,0.58
					1	20.	MSC	MR	3.	1.88,1.88,1.88
MSC-J046	1	2.	C1	L	0	2.	MSC	CS	2.5	0.5,0.83,1.17
MSC-J047	1	2.	C1	L	0	2.	MSC	CS	2.5	1.,1.67,2.33
MSC-J048	1	2.	C1	L	0	2.	MSC	CS	2.5	1.,1.67,2.33
MSD-J042	1	2.	C1	L	0	2.	MSD	CS	2.5	0.5,0.88,1.17
MSD-J043	1	2.	C1	L	0	2.	MSD	CS	2.5	1.,1.67,2.33
MSD-J044	1	2.	C1	L	0	2.	MSD	CS	2.5	1.,1.67,2.33

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
MSA-J014	1	20.	C1	H	0	20.	MSA	MR	3.	5.,8.33,11.67
					1	20.	MSB	MR	3.	6.11,14.67,28.04
					2	10.	FWA	MW	2.5	0.,4.82,11.93
					3	10	RRB	CS	2.5	9.11,11.97,17.21
					4	10.	RRA	CS	2.5	0.,0.,12.33
					5	10.	RRC	CS	2.5	0.,0.,9.42
					6	16.	RMB	NK	3.	1.85,13.46,24.8
					7	10.	FWB	MW	2.5	0.,8.07,18.21
					8	22.	RCB	NK	3.	0.,2.6,6.93
					9	20.	RHC	CS	3.	0.,3.92,12.29

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
MSB-J050	1	2.	C1	L	0	2.	MSB	CS	2.5	1.,1.67,2.33

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
FWA-J033	2	16.	C3	M	0	16.	FWA	MW	2.5	8.,13.33,18.67
					1	20.	MSB	MR	3.	0.,14.74,23.6
					2	20.	MSA	MR	3.	0.,7.77,16.81
					3	10.	PSA	CS	2.5	0.,3.83,6.73
					4	10.	FWB	MW	2.5	0.,0.,1.79
					5	22.	RCA	NK	3.	0.,0.,5.24

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RHC-J003	4	20.	C3	M	0	20.	RHC	CS	3.	5.,11.5,32.93
					1	22.	RCA	NK	3.	8.41,12.88,16.35
					2	16.	RMA	NK	3.	7.3,15.2,22.31
					3	10.	RRF	NK	2.5	0.,2.61,6.68
					4	10.	RRG	NK	2.5	0.,2.61,6.68
					5	20.	MSC	MR	3.	0.,5.71,14.07
					6	20.	MSD	MR	3.	0.,2.31,7.19
					7	10.	FWC	MW	2.5	0.,0.,10.

Break ID	System ID	Diameter in	Weld Type	Loc	#	Diameter inch	Sys Code	Ins Type	Ins Thick in	Ins Length by Destruction Region ft
RHC-J001	4	20.	S1	M	0	20.	RHC	CS	2.5	5.,8.33,34.09
					1	22.	RCA	NK	3.	9.68,13.24,16.6
					2	16.	RMA	NK	3.	8.74,15.94,22.82
					3	10.	RRF	NK	2.5	0.,3.42,7.19
					4	10.	RRG	NK	2.5	0.,3.42,7.19
					5	20.	MSC	MR	3.	0.,2.76,13.7
					6	20.	MSD	MR	3.	0.,2.23,7.18

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

```
==========================================================================================
BREAK FREQUENCIES
==========================================================================================

Break Diameter Classes
   Smallest
   Diameter
   in            Label
   ------------ --------
   0.75          .75-2
   4.            4-10
   12.           12-16
   18.           18-+

                               Break
                               Frequency
Diameter   Weld Type   /Rx-yr
---------  ---------   ------------
.75-2      S1          1.E-6
.75-2      S2          1.E-6
.75-2      S3          1.E-6
.75-2      C1          2.E-7
.75-2      C2          2.E-7
.75-2      C3          2.E-7
4-10       S1          1.E-6
4-10       S2          1.E-6
4-10       S3          1.E-6
4-10       C1          2.E-7
4-10       C2          2.E-7
4-10       C3          2.E-7
12-16      S1          2.E-6
12-16      S2          2.E-6
12-16      S3          2.E-6
12-16      C1          2.E-7
12-16      C2          2.E-7
12-16      C3          2.E-7
18-+       S1          2.E-7
18-+       S2          2.E-7
18-+       S3          2.E-7
18-+       C1          2.E-7
18-+       C2          2.E-7
18-+       C3          2.E-7
```

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

ECCS

Suppression Pool Volume:	58900.	cu ft
Pool Settling Area:	5000.	sq ft
Pool Reference Temperature:	80.	deg F
Min Flow to Cool Core:	5000.	GPM

Module Name	Strainer Area sq ft	Pump Name	Flow Capacity GPM	Ref NPSH ft-water
Loop1	14.6	LPCI-A	4800.	14.
		LPCI-C	4800.	24.
Loop2	14.6	LPCI-B	4800.	14.
		LPCI-D	4800.	24.
Loop3	4.21	CS-A	3100.	17.
Loop4	4.21	CS-B	3020.	32.

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

```
==========================================================================================
CORRELATION
==========================================================================================

Correlation: NUREG/CR6224

Term Value
---- ------------
K    1.
```

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

```
==========================================================================================
EVENT SCENARIO - GENERAL
==========================================================================================

Variable                  Interpolation
------------------------  -------------
Time Step                 Step
Pump Flow Multiplier      Linear
Pool Temperature          Linear
Drywell Transport Rate    Step
Resuspension Factor       Step
Turbulence Factor         Exponential

End of Calculation Time:  21600.      sec
Min LLOCA Break Size:     6.          in
Check Limit:              1.E-3       in
```

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

```
================================================================================
EVENT SCENARIO - MEDIUM LOCA
================================================================================

End of Blowdown: 600.          sec
End of Washdown: 2400.         sec
```

Time sec	Time Step sec
0.	1.
49.	1.
50.	1.
320.	0.1
500.	0.1
600.	0.1
720.	0.1
850.	1.
2400.	1.
2500.	10.

Time sec	Pump Flow Multiplier
0.	0.
49.	0.
50.	0.1
320.	0.1
500.	1.
600.	1.
720.	1.
850.	1.
2400.	1.
2500.	1.

Time sec	Pool Temperature def F
0.	80.
49.	95.
50.	95.
320.	150.
500.	170.
600.	170.
720.	160.
850.	150.
2400.	100.
2500.	195.

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Time sec	Drywell Transport Rate
0.	1.66667E-3
49.	1.66667E-3
50.	1.66667E-3
320.	1.66667E-3
500.	1.66667E-3
600.	5.5556E-4
720.	5.5556E-4
850.	5.5556E-4
2400.	0.
2500.	0.

Time sec	Resuspension Factor
0.	1.
49.	1.
50.	1.
320.	1.
500.	1.
600.	0.
720.	0.
850.	0.
2400.	0.
2500.	0.

Time sec	Turbulence Factor
0.	1.E-4
49.	1.E-4
50.	1.E-4
320.	1.E-4
500.	1.E-4
600.	1.E-4
720.	0.5
850.	0.5
2400.	0.5
2500.	0.5

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

```
==========================================================================================
EVENT SCENARIO - LARGE LOCA
==========================================================================================

End of Blowdown: 120.          sec
End of Washdown: 1920.         sec

Time            Time Step
sec             sec
------------    ------------------------
0.              0.1
4.              0.1
5.              0.1
49.             0.1
50.             0.1
100.            0.1
120.            0.1
420.            1.
1920.           1.
2500.           10.

Time            Pump Flow Multiplier
sec
------------    ------------------------
0.              0.
4.              0.
5.              0.1
49.             0.1
50.             1.
100.            1.
120.            1.
420.            1.
1920.           1.
2500.           1.

Time            Pool Temperature
sec             def F
------------    ------------------------
0.              80.
4.              81.
5.              81.
49.             100.
50.             130.
100.            180.
120.            180.
420.            170.
1920.           150.
2500.           120.
```

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

Time sec	Drywell Transport Rate
0.	8.33333E-3
4.	8.33333E-3
5.	8.33333E-3
49.	8.33333E-3
50.	8.33333E-3
100.	8.33333E-3
120.	5.5556E-4
430.	5.5556E-4
1920.	0.
2500.	0.

Time sec	Resuspension Factor
0.	1.
4.	1.
5.	1.
49.	1.
50.	1.
100.	1.
120.	0.
420.	0.
1920.	0.
2500.	0.

Time sec	Turbulence Factor
0.	1.E-4
4.	1.E-4
5.	1.E-4
49.	1.E-4
50.	1.E-4
100.	1.E-4
120.	1.E-4
420.	0.5
1920.	0.5
2500.	0.5

Table A.1. Example of a Blockage Detailed Input Data: Sample Problem No. 1 - Continued

```
==========================================================================================
OUTPUT
==========================================================================================

Include Detailed Information in Break Detail Report
Break Detail Report Output Frequency: 10000. sec

Time-based Output Interval: 100 time steps
Early Termination: None

Selected
Breaks
---------
PSA-J006
RCA-J003
RCA-J006
MSB-J021
FWA-J033
RHC-J003
MSD-J043
MSD-J044
```

Table A.2. Summary of Blockage Calculations for Sample Problem No. 1

```
Run:     Version 2.5 Input No. 1                    (SP1.BLK       )
Plant:   Sample Problem Input 1
Version: BLOCKAGE 2.5y
```

No.	Weld ID	Dia (in)	Sys	Loc	Break Freq (1/Rx-yr)	WW Pool Debris Volumes Fiber (ft3)	Metal (ft3)	Part. (ft3)	Ignore (ft3)	Final Flow (GPM)	1st Loss of NPSH (sec)	ECCS Failed (sec)	Trans. Complt
1	PSA-J006	10.0	4	H	2.00E-07	0.79	0.60	6.02	0.00	0.	94.0	1185.0	1.000
2	PSA-J001	10.0	4	H	2.00E-07	0.18	0.71	5.62	0.00	0.	95.1	5260.0	1.000
3	RCA-J003	22.0	1	H	2.00E-07	5.34	0.93	7.63	0.00	0.	86.6	215.8	1.000
4	RCA-J006	22.0	1	H	2.00E-07	11.98	2.39	6.97	0.00	0.	80.0	154.6	1.000
5	MSB-J021	6.0	2	M	2.00E-07	0.20	1.60	4.92	0.00	0.	95.0	5080.0	1.000
6	RCA-J038	22.0	1	L	2.00E-07	21.29	0.00	8.89	0.00	0.	72.4	115.3	1.000
7	RCA-J008	22.0	1	M	2.00E-07	18.95	6.91	4.40	0.00	0.	73.8	125.4	1.000
8	RRG-J007	10.0	1	M	1.00E-06	1.98	0.54	10.92	0.00	0.	90.2	277.6	1.000
9	RCA-J027	4.0	1	L	1.00E-06	3.72	0.00	4.40	0.00	0.	441.8	605.5	1.000
10	RCB-J028	1.0	1	L	1.00E-06	1.16	0.00	4.40	0.00	0.	472.7	961.0	1.000
11	MSA-J014	20.0	2	H	2.00E-07	8.10	1.58	12.40	0.00	0.	82.4	165.3	1.000
12	MSB-J050	2.0	2	L	2.00E-07	0.00	0.00	4.68	0.00	25320.	NONE	NO	1.000
13	FWA-J033	16.0	3	M	2.00E-07	7.59	3.02	5.68	0.00	0.	82.9	189.5	1.000
14	RHC-J003	20.0	5	M	2.00E-07	18.34	1.32	17.91	0.00	0.	71.3	109.5	1.000
15	RHC-J001	20.0	5	M	2.00E-07	17.62	1.09	15.30	0.00	0.	72.2	112.1	1.000
16	MSC-J031	1.0	2	M	2.00E-07	0.00	0.41	4.40	0.00	12620.	2480.0	NO	1.000
17	MSC-J033	1.0	2	M	2.00E-07	0.00	0.34	4.40	0.00	12620.	2480.0	NO	1.000
18	MSC-J046	2.0	2	L	2.00E-07	0.00	0.00	4.54	0.00	25320.	NONE	NO	1.000
19	MSC-J047	2.0	2	L	2.00E-07	0.00	0.00	4.68	0.00	25320.	NONE	NO	1.000
20	MSC-J048	2.0	2	L	2.00E-07	0.00	0.00	4.68	0.00	25320.	NONE	NO	1.000
21	MSD-J042	2.0	2	L	2.00E-07	0.00	0.00	4.54	0.00	25320.	NONE	NO	1.000
22	MSD-J043	2.0	2	L	2.00E-07	0.00	0.00	4.68	0.00	25320.	NONE	NO	1.000
23	MSD-J044	2.0	2	L	2.00E-07	0.00	0.00	4.68	0.00	25320.	NONE	NO	1.000

Table A.3. Frequencies for Loss of ECCS Arranged by Weld Location

ECCS BLOCKAGE FREQUENCIES PLANT: Sample Problem Input 1

DIAMETER	TOTAL	LOCATION: H	M	L
0.8	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.0	1.00E-06	0.00E+00	0.00E+00	1.00E-06
2.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.0	1.00E-06	0.00E+00	0.00E+00	1.00E-06
6.0	2.00E-07	0.00E+00	2.00E-07	0.00E+00
10.0	1.40E-06	4.00E-07	1.00E-06	0.00E+00
12.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16.0	2.00E-07	0.00E+00	2.00E-07	0.00E+00
18.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20.0	6.00E-07	2.00E-07	4.00E-07	0.00E+00
22.0	8.00E-07	4.00E-07	2.00E-07	2.00E-07
TOTAL	5.20E-06	1.00E-06	2.00E-06	2.20E-06

Table A.4. Frequencies for Loss of ECCS Arranged by System Location

ECCS BLOCKAGE FREQUENCIES PLANT: Sample Problem Input 1

DIAMETER	TOTAL	SYSTEM NUMBER: 1	2	3	4	5
0.8	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.0	1.00E-06	1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.0	1.00E-06	1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.0	2.00E-07	0.00E+00	2.00E-07	0.00E+00	0.00E+00	0.00E+00
10.0	1.40E-06	1.00E-06	0.00E+00	0.00E+00	4.00E-07	0.00E+00
12.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16.0	2.00E-07	0.00E+00	0.00E+00	2.00E-07	0.00E+00	0.00E+00
18.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20.0	6.00E-07	0.00E+00	2.00E-07	0.00E+00	0.00E+00	4.00E-07
22.0	8.00E-07	8.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL	5.20E-06	3.80E-06	4.00E-07	2.00E-07	4.00E-07	4.00E-07

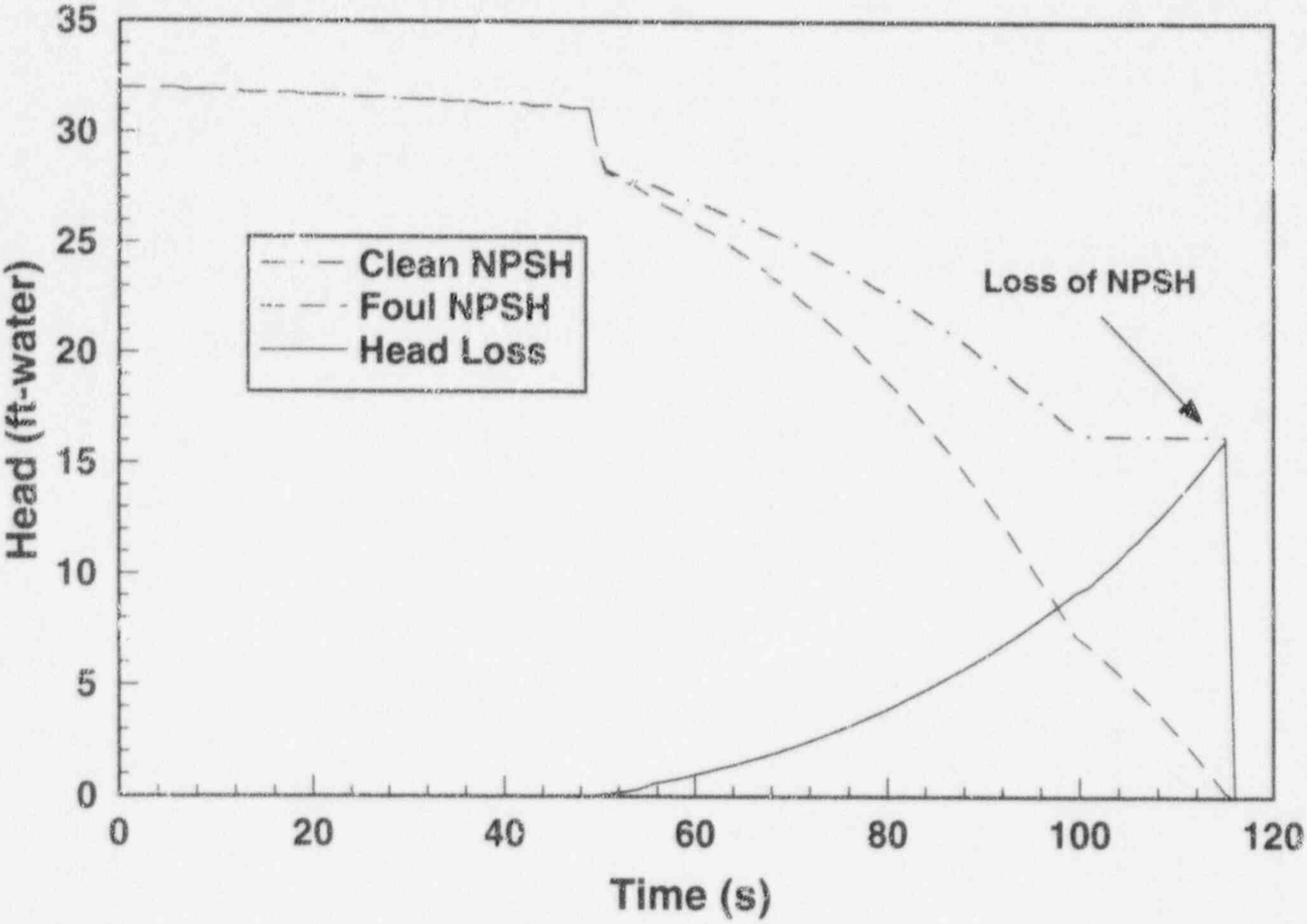

Figure A.1. Pump SC-B Head Loss Behavior

Appendix B

Executing BLOCKAGE from DOS

Table of Contents

List of Tables

B.1 Introduction

This appendix provides the information needed to prepare input files and run the BLOCKAGE code at the DOS level. The BLOCKAGE code was originally developed as a stand alone code to be executed from a DOS prompt or DOS window. A GUI was developed to make the code more user friendly, but for certain applications, the user may find it advantageous to run the BLOCKAGE code from the DOS prompt. For example, a series of sensitivity study calculations can be executed using DOS BATCH files and the BLOCKAGE code sensitivity study option more proficiently than running the calculations one at a time with the GUI (see Section B.5).

B.2 Executing BLOCKAGE from the DOS Prompt

The installation of the BLOCKAGE code package places the code executable, BLKAGE.EXE, in a directory included in the computer PATH. Once the user has created the two required input files, INPUT.DAT and WELD.DAT, and placed these files in a directory or a subdirectory of the user's choice, the BLOCKAGE code can executed by typing "blkage" followed by a "return". The output files will appear in this same directory.

B.3 Preparing DOS Input Files

User input is arranged in a free-format and read into the code using list-directed READ statements. The following rules apply:

- Data must be entered for each of the required input parameters on a line-by-line basis as indicated in the user input descriptions in Section B.5
- Data entries may start in the first column
- Multiple numbers must be separated by either commas or spaces,
- Character data input must not contain spaces or it must be enclosed in single quotes
- Comments are allowed beyond the data, i.e., once the code has read in the data required for a particular line, it then ignores the remainder
- Blank lines may be left in the input file to separate sections of input

CAUTION: The user should be careful to ensure that the lines of input data correspond to the required record types. While the BLOCKAGE code input processor does check input values for validity, it does not have the ability to determine if a line of data is missing or duplicated. If a line of data is missing, the next line after the missing line will be read by the wrong READ statement, thus causing a mismatch between the input data and the code variables. If this happens, the calculation will almost certainly abort. However, the resulting error message will likely not indicate the true nature of the problem and some detective work by the user will be required to determine the root cause of the problem.

B.4 Additional Code Options Available to DOS Users

Two options are available to the DOS user that were not extended to the GUI users. One option allows the user to print single line output files that can be appended for a series of calculations to form a spreadsheet showing the output sensitivity for the particular variable selected by the user. Since this option was developed for use with DOS BATCH files, it is not applicable for use with the GUI. The second option provides an alternate method of calculating the break frequencies referred to as the Plant Method. This Plant Method was not extended to the GUI user because its use was expected to be very limited. The Weld Method that is available to the GUI user is the recommended method for the BLOCKAGE code user. But the Plant Method was maintained for potential special cases that may arise.

B.4.1 Procedure for Conducting Parameter Sensitivity Studies

Parameter sensitivity calculations have been found to provide useful insights to strainer blockage studies. A procedure was developed and used to produce the single parameters sensitivities studies published in Appendix C of NUREG/CR-6224. For the NUREG/CR-6224 study, 13 input parameters were varied one-at-a-time through a range plausible values and the results for 15 output variables were then plotted versus the input variable. Since over 300 individual BLOCKAGE calculations were required to complete this study, the BLOCKAGE code was modified to facilitate the process.

The parameter sensitivity option added to the code simply writes the values of the sensitivity study output variables to single line output files for the first two welds selected for output using input variable

IDWELD, i.e., one output file for each of the two welds. The output file names are PWELD1.OUT and PWELD2.OUT. The option is activated with the input parameter ISENS on Record Type 4. The input parameter PSENS on Record Type 5 specifies the value of the variable varied for this particular calculation. PSENS is merely echoed to the sensitivity output files and does not affect the calculation in any way. The single line output files for a single parameter sensitivity study were then appended to form a spreadsheet for importing into other software.

The specific steps for running one simple parameter sensitivity study are:

- Create the INPUT.DAT and WELD.DAT input files for the base case.
- Determine the input parameter to be varied.
- Activate the sensitivity study option in INPUT.DAT (ISENS=1) and place the base value in PSENS.
- Create a base directory to contain the study and execute the base calculation.
- Write a DOS BATCH command file which creates subdirectories for each change case and copies the input files into each of these subdirectories. Run the BATCH file.
- Manually transfer to each of these subdirectories and alter the input variable being changed at both PSENS and it normal input location.
- Write a BATCH command file which transfers into each subdirectory and executes the BLOCKAGE code. Run the BATCH file.
- Write a BATCH command file which appends the PWELD1.OUT files from all the subdirectories and from the base case into a single file. Make sure that the files are appended in the proper order. Repeat for PWELD2.OUT. The first column of the spreadsheet will contain the value of the input variable that was varied.
- Import the spreadsheet into software capable of manipulating and plotting its data.

The output variables available for study are fixed within the code. These variables are listed in Table B.4.1-1.

Table B.4.1-1: Output Variables Avaliable for Study Fixed Within the Code

Variable Description	Units	Time Saved
Global		
1. Value of Input Variable	Varies	Beginning
2. Total ECCS Blockage Frequency	1/Rx-yr	End
3. Minimum Pump Flow	GPM	End
4. Time of First Loss-of-NPSH Margin	Seconds	End
5. Time of ECCS Failure	Seconds	End
6. Drywell Transport Completion	-	End
Applied to First Strainer		
7. Deposited Fiber Volume*	ft^3	First Loss-of-NPSH Margin or End
8. Deposited Metal Volume*	ft^3	First Loss-of-NPSH Margin or End
9. Deposited Particulate Volume*	ft^3	First Loss-of-NPSH Margin or End
10. Metal to Fiber Mass Ratio	-	First Loss-of-NPSH Margin or End
11. Particulate to Fiber Mass Ratio	-	First Loss-of-NPSH Margin or End
12. Theoretical Fiber Cake Thickness (Uncompressed)	inch	First Loss-of-NPSH Margin or End
13. Actual Fiber Cake Thickness (Compressed)	inch	First Loss-of-NPSH Margin or End
14. Thickness of Metallic Debris	inch	First Loss-of-NPSH Margin or End
15. Minimum Fouled NPSH Margin	ft-water	End
16. Maximum Head Loss	ft-water	End

* Volumes Based on Fabricated Densities

B.4.2 Plant Method Break Frequency Model

The weld break frequencies are used by BLOCKAGE to generate the probability reports when requested by the user. The Plant Method for calculating the weld break frequencies requires the user to specify the break frequencies by diameter class, i.e., the total break frequency for all of the pipe welds with pipe diameters that fit within a particular diameter class. Then the break frequencies for an individual pipe weld break is determined using weighting factors that are specified by the diameter class and the weld type. Whereas, the Weld Method simply specifies the break frequencies by the diameter class and the weld type. The governing equation for the Plant Method is presented in the Reference Manual for the interested user.

B.5 Accessing Output Files

The BLOCKAGE code output files for the DOS user are in the form of ASCII text files that can be read with most available editors or imported into spreadsheet software. BLOCKAGE creates the same output files when executed from a DOS prompt as when executed with the GUI. The names of the DOS output files are listed in Table B.5-1 correlated with the GUI window that reads these files when the GUI is employed.

Note that the GUI window that echoes out the "Input Parameters" is a GUI function and there is not a BLOCKAGE output file corresponding to this function. These output files are described in Section 5.

B.6 Importing DOS Input File to Graphical User Interface

The user running BLOCKAGE from a DOS prompt may need to transport an input model to the GUI. The GUI user creates an input model with the GUI by entering the data into its various windows and saves the input model in a file, designated as a *.BLK file name (* indicates name of user file). The DOS prompt user creates an input model by entering data into ASCII input files, designated as *.DAT files, which are read by the BLOCKAGE code. The GUI reads *.BLK files and the BLOCKAGE code reads *.DAT files. The user can transport a GUI *.BLK input model down to a DOS prompt input model by simply unning the GUI since the GUI writes the *.DAT files before executing the BLOCKAGE code. The GUI does not delete these files when the calculation is finished.

A crude method was developed that the allows the user to import a DOS prompt input model into the GUI without typing all of the input into its various windows. This method is not particularly user friendly, i.e., it will not necessarily warn the user that a mistake is about to be made. If a mistake is made, the import process simply does not work.

Table B.5-1: DOS Output Files Correlated with GUI Windows

GUI Window	DOS Output File	Information
Input Parameters	None	This window contains input parameters echoed to output.
Errors	ERROR.OUT	This output file contains error and warning messages, if any, from the BLOCKAGE code.
Break Detail	WELD.OUT	This output file contains detailed information for selected weld breaks printed for times when an event such as loss-of-NPSH margin occurs and at a user specified print frequency.
Target Detail	TARGET.OUT	This output file reflects the weld and target input and contains the calculated insulation volumes for each target for each weld.
Frequency	FREQ.OUT	This output file contains the probabilistic results.
Break Summary	SUMMARY.OUT	This output file contains summary results for the entire calculation.
Volume Sorted	SPLOT.OUT	This output file contains selected summary results that are sorted by LOCA size and the volume of fibrous debris.
Time Based	PLOT.OUT	This output file contains the time dependent results in spreadsheet form.
None	PWELD1.OUT PWELD2.OUT	These output files contains the single line output results when the parameter sensitivity analysis option is selected.

However,the following procedure, shown in Table B.6-1, does work and if it is followed exactly, the user can readily convert the *.DAT files to a *.BLK file that the GUI can read and execute. This procedure creates an intermediate file designated as a *.CDT file that is readable by the GUI import capability.

B.7 User Input Descriptions for BLOCKAGE Version 2.5

Each BLOCKAGE calculation requires two input data files, i.e., INPUT.DAT and WELD.DAT described in Section B.7.1 and B.7.2, respectively. Calculational run data is generally located in INPUT.DAT while the plant data base is in WELD.DAT. Example input files are presented in Section B.7.3.

B.7.1 Run Input Data File INPUT.DAT

The INPUT.DAT file contains run identification and control information, probabilistic information, insulation destruction and transport information, emergency core cooling system information, debris attributes information, screen blockage correlation input, and time-dependent input.

Table B.6-1: Procedure for Converting a DOS Prompt Input Model to GUI Input Model

Step No.	Procedure
	Prepare DOS Prompt Files
1	Ensure that sensitivity option, ISENS in INPUT.DAT, is equal to zero and PSENS is not present in the file because the GUI does not support this option.
2	Ensure that the break frequency model is set to the Weld Method (W) because the GUI does not support the optional Plant Method (P).
3	If volumes are computed from break/target data base (ivolm=0), then ensure that the list of permissible weld diameters, PWDS(I) in WELD.DAT, includes each of the smallest diameters allowed in the diameter classes, WDCTBL(I) in INPUT.DAT. This condition is required by the GUI input processing.
4	Ensure that there are no comments on input lines beyond the data fields. These comments are allowed in the DOS execution but not by the GUI.
5	Set the number of lines for page breaks, IPAGE in INPUT.DAT, to 53 to produce identical file layouts for TARGET.OUT and SUMMARY.OUT files produced with DOS and with GUI, i.e., the GUI automatically sets IPAGE to 70.
	Create *.CDT GUI Import File
6	Append WELD.DAT to INPUT.DAT and rename the file *.CDT. (Note: spaces are allowed between lines.)
7	Edit the *. CDT file by placing "**CDT <number of weld locations> <number of weld types>**" at the beginning of the file (first line of input). *[Example: CDT 3 6].* If using the User Specified Volume option (ivolm=1), then use 1 for the number of weld types.
8	Edit the *.CDT file by placing "**ENDOFBREAKS<return>**" at the end of the file (last line). Do not forget the **return**.
	Importing *.CDT into GUI
9	Activate GUI, select **open** in the file menu, type in the *.CDT file under file name, then click OK.
10	After opening the *.CDT file, open the **Output** window and select the breaks for output. The break selection information was not carried over from the INPUT.DAT file and therefore must be reentered.
11	Save the import input model as a *.BLK file by opening **Save As** under the file menu.
12	The problem can now be executed with the **Run Analysis** command.

B.7.1.1 Run Identification and Control Input

Record Type: 1 *Number:* 1 *Required:* Always			*List of Variables:* **runid** *Description:* Run title. *Example:* Base Case Input (June 5, 1995)	
Variable	*Type*	*Units*	*Limitations*	*Description*
runid	character A40	-	up to 40 characters	Printed in output headers.

Record Type: 2 *Number:* 1 *Required:* Always			*List of Variables:* **compid** *Description:* User interface file identifier. *Example:* TWELVE-CHARS	
Variable	*Type*	*Units*	*Limitations*	*Description*
compid	character A12	-	up to 12 characters	This identifier is used by user interface to identify computer file names. The BLOCKAGE code merely repeats it in the output files headers. The identifier must be specified even if the user interface is not used.

Record Type: 3 *Number:* 1 *Required:* Always			*List of Variables:* **iprob, ivolm, iterm** *Description:* Model selection variables for probabilistic results and volume input method *Example:* 1 0 5	
Variable	*Type*	*Units*	*Limitations*	*Description*
iprob	integer	-	either 0, 1	Controls whether or not probabilistic calculations/reports are performed. =0; no, do not preform calculations or create probabilistic reports. =1; yes, preform calculations and create probabilistic reports. *Probabilistic reports are not done when user inputs volumes (ivolm=1).*
ivolm	integer	-	either 0, 1	Selects method for determining insulation debris volumes. =0; volumes are computed from target data base. =1; volumes are inputed by user. *If ivolm set to 1, then iprob must equal 0 (coding resets iprob internally).*

Record Type: 3 *Number:* 1 *Required:* Always			*List of Variables:* **iprob, ivolm, iterm** *Description:* Model selection variables for probabilistic results and volume input method *Example:* 1 0 5	
Variable	***Type***	***Units***	***Limitations***	***Description***
iterm	integer	-	1 to 5	Selects Option for Terminating Calculation =1; termination at first pump loss-of-NPSH margin. =2; termination at first strainer totally blocked. =3; termination at all strainers totally blocked. =4; termination at ECCS flow less than user specified minimum flow. =5; termination at user input end time. *The calculation will not exceed the user input end time under any condition.*

Record Type: 4 *Number:* 1 *Required:* Always			*List of Variables:* **ipage, iplot, isens, iweld, iprint, pfreq** *Description:* Variables control output format and level of information. *Example:* 46 2 1 1 1 100.	
Variable	***Type***	***Units***	***Limitations***	***Description***
ipage	integer	-	ipage≥ 10	A page break is inserted every ipage lines in output files TARGET.OUT and SUMMARY.OUT.
iplot	integer	-	iplot≥ 0	Time-dependent data is saved every iplot time cycle with first cycle always automatically saved except for iplot=0 where no data is saved.
isens	integer	-	either 0, 1	Controls whether or not data is written to sensitivity output files PWELD1.OUT and PWELD2.OUT. =0; Data not printed. =1; Data printed.
iweld	integer	-	1 to 20	Controls number of welds selected for printing time-dependent results to PLOT.OUT and for printing data to TARGET.OUT and WELD.OUT if iprint=0. Welds selected are specified by IDWELD(iweld).
iprint	integer	-	either 0, 1	Controls whether or not detailed data is written to output file WELD.OUT. =0; data not written to WELD.OUT. =1; data is written to WELD.OUT. *Saving this data could significantly increase the size of the WELD.OUT file.*

Record Type: 4 *Number:* 1 *Required:* Always			*List of Variables:* **ipage, iplot, isens, iweld, iprint, pfreq** *Description:* Variables control output format and level of information. *Example:* 46 2 1 1 1 100.	
Variable	*Type*	*Units*	*Limitations*	*Description*
pfreq	real	seconds	pfreq ≥ 1, ≤ 1.e6	Controls the frequency at which data is printed to the WELD.OUT file. *Caution: A relatively small print interval can create a rather large output file.*

Record Type: 5 *Number:* 1 *Required:* If isens = 1			*List of Variables:* **psens** *Description:* Value of parameter varied in sensitivity study. *Example:* 58900.	
Variable	*Type*	*Units*	*Limitations*	*Description*
psens	real	same as parameter	psens ≥ 0, ≤ 10^7	The value of psens is printed as the first variable in sensitivity output files, PWELD1.OUT and PWELD2.OUT to facilitate the subsequent analysis of the sensitivity results. It is not used in any calculations.

Record Type: 6 *Number:* iweld *Required:* Always			*List of Variables:* **idweld(i)** *Description:* Identification of welds selected for output. *Example:* RCA-J006	
Variable	*Type*	*Units*	*Limitations*	*Description*
idweld(i)	character A8	-	must match a weld identifier in weldid	The time-dependent results of these weld breaks will be saved in PLOT.OUT and BLOCKAGE results will be saved in WELD.OUT. One value of idweld per card. *Names are case specific.*

B.7.1.2 Probabilistic Input

Record Type: 7 *Number:* 1 *Required:* If iprob=1 and ivolm=0			*List of Variables:* **break** *Description:* Break frequency calculation method *Example:* W	
Variable	*Type*	*Units*	*Limitations*	*Description*
break	character A1	-	either P, W	Selects method for calculating weld break frequency for each weld. P = Plant Method W= Weld Method

Record Type: 8 *Number:* 1 *Required:* If iprob=1 and ivolm=0			*List of Variables:* **ndc** *Description:* Number of diameter classes *Example:* 4	
Variable	***Type***	***Units***	***Limitations***	***Description***
ndc	integer	-	1 to 4	Specifies the number of diameter classes used in calculating the weld break frequencies.

Record Type: 9 *Number:* 1 *Required:* If iprob=1 and ivolm=0			*List of Variables:* **wdctbl(i), i=1, ndc** *Description:* Smallest pipe diameter for pipes in diameter class i. *Example:* 0.75, 4.0, 12.0, 18.0	
Variable	***Type***	***Units***	***Limitations***	***Description***
wdctbl(i)	real	inch	wdctbl ≥ 0, ≤ 100	The pipe diameters are classified into size groups as required by the methods used to calculate weld break frequencies. This variable specifies the smallest diameter in each class. The largest diameter in each class is then the smallest diameter of the class above it. The smallest diameter of the first class must be less than smallest pipe diameter in the weld database. The largest diameter class has no upper diameter limit.

Record Type: 10 *Number:* 1 *Required:* If iprob=1 and ivolm=0			*List of Variables:* **wdclbl(i), i=1, ndc** *Description:* Label associated with pipe diameter class i *Example:* '.75-4' '4-12' '12-18' '18-+'	
Variable	***Type***	***Units***	***Limitations***	***Description***
wdclbl(i)	character A5	-	Each Label Must be Distinctly Different	These labels are used in the probability reports where plant wide blockage results are correlated by pipe diameter class.

Record Type: 11 *Number:* 1 Required: If iprob=1, ivolm=0 , and break=P			*List of Variables:* **wdcffr(i), i=1, ndc** *Description:* Diameter Class Break Frequency *Example:* 1.5e-5 8.4e-5 1.8e-5 2.3e-5	
Variable	***Type***	***Units***	***Limitations***	***Description***
wdcffr(i)	real	1/Rx-yr	wdcffr ≥ 0, ≤ 1	Diameter class break frequency used by the Plant Method to calculate pipe break frequencies.

Record Type: 12 *Number:* npwt *Required:* If iprob=1 and ivolm=0			*List of Variables:* **wwffwf(i, j), i=1, ndc** *Description:* Weld weighing factors (P) or weld frequencies (W) *Example*: 0.4 0.3 0.2 0.1 (P) 1.e-6 1.e-6 2.e-6 2.e-7 (W)	
Variable	*Type*	*Units*	*Limitations*	*Description*
wwffwf (i, j)	real	- (if P) or 1/Rx-yr (if W)	wwffwf ≥ 0	If Plant Method is used to calculate break frequencies (P), then wwffwf (i, j) is a weld weighing factor for a weld in pipe diameter class i and weld type j. If Weld Method is used to calculate break frequencies (W), then wwffwf (i, j) is the weld break frequency for a weld in pipe diameter class i and weld type j. *One record of this record type must exist for each permissible weld type*

B.7.1.3 Debris Attributes Input

Record Type: 13 *Number:* 1 *Required:* Always			*List of Variables:* **ntypes, ntg, ndw, nww** *Description:* Specifies the number of debris types by debris origination. *Example:* 6 3 2 1	
Variable	*Type*	*Units*	*Limitations*	*Description*
ntypes	integer	-	ntypes≥ 1, ≤ 20 and ntypes = ntg + ndw + nww	Total number of debris types.
ntg	integer	-	ntg≥ 1, ≤ 20 and ntg = npim	Number of debris types originating in the drywell from target destruction.
ndw	integer	-	ndw≥ 0,≤ 20	Number of debris types originating in the drywell but not from target destruction.
nww	integer	-	nww≥ 0,≤ 20	Number of debris types originating within the wetwell.

Record Type: 14 *Number:* 1 *Required:* Always			*List of Variables:* **debris(i), i=1, ntypes** *Description:* Debris type identifiers. *Example:* NK MR CS PT CC SD	
Variable	*Type*	*Units*	*Limitations*	*Description*
debris(i)	character A2	-	up to 2 characters	Unique identifier for each debris type. The identifiers for the debris generated from target destruction must be listed first and they must agree with the insulation material identifiers (variable pims) in input file WELD.DAT. The identifiers must also be in the same order.

Record Type: 15 *Number:* 1 *Required:* Always			*List of Variables:* **ifilt, tfilt** *Description:* Specifies debris class numbers and strainer filtration model. *Example:* 2 0.0208	
Variable	*Type*	*Units*	*Limitations*	*Description*
ifilt	integer	-	1, 2, or 3	Interpolation option for strainer filtration efficient model. Option applies to all debris classes (1 = step, 2 = linear, and 3 = exponential).
tfilt	real	ft	tfilt≥ 0, ≤ 3.	Cake thickness corresponding to peak filtration efficiency.

Record types 16 through 21 must be repeated for each debris type input for a total of ntypes. In addition, these debris attributes must be entered in the same order that they are inputed on record type number 14. The data for each debris type must be inputed as a unit before moving on to the next debris type, i.e., one record type 16, one 17, one 18, one 19, one 20, and ngroup (1) record 21 for debris type 1, then repeat until ntypes of debris are entered. The index i indicates the debris type number.

Record Type: 16 *Number:* ntypes *Required:* Always			*List of Variables:* **dname(i), debris(i), dclass(i), dloc(i), ngroup(i), volume(i)** *Description:* Specifies debris identification, type, classification, origination, and volume. *Example:* NUKON NK F TG 12 0.	
Variable	*Type*	*Units*	*Limitations*	*Description*
dname(i)	character A6	-	up to 6 characters	Name associated with debris type. Each name must be unique.
debris(i)	character A2	-	up to 2 characters	Unique identifier for each debris type. These identifiers must agree with the identifiers specified on record type 14. The identifiers must also be in the same order.

Record Type: 16
Number: ntypes
Required: Always

List of Variables: **dname(i), debris(i), dclass(i), dloc(i), ngroup(i), volume(i)**
Description: Specifies debris identification, type, classification, origination, and volume.
Example: NUKON NK F TG 12 0.

Variable	*Type*	*Units*	*Limitations*	*Description*
dclass(i)	character A1	-	1 character only	Debris classification flag which specifies how debris is treated by the head loss correlation, i.e., as fibrous, metallic, particulate, or neglected. = F; treat debris as fibrous. = M; treat debris as metallic. = P; treat debris as particulate. = N; to neglect the debris in the head loss calculation. *For debris originating from targets, these flags must agree with the flags specified in the WELD.DAT input file using the input variable fibflg.*
dloc(i)	character A2	-	up to 2 characters	Specifies debris origination. = TG; debris originated from target destruction in the drywell. = DW; debris originates within drywell but not from target destruction. = WW; debris originates within wetwell.
ngroup(i)	integer	-	ngroup≥ 1, ≤ 20	Number of settling velocity groups for this debris type.
volume(i)	real	ft^3	volume≥ 0, ≤ 250.	Volume of debris for this debris type, if the debris origination is DW or WW. If the debris origination is TG, this variable will be ignored. For DW originated debris, transport fractions will be applied to this volume to determine amount of debris entering the drywell.

Record Type: 17
Number: ntypes
Required: Always

List of Variables: **dfab(i), drub(i), dmat(i), ssa(i)**
Description: Specifies debris densities and specific surface areas.
Example: 2.4 2.4 175.0 1.71e+05

Variable	*Type*	*Units*	*Limitations*	*Description*
dfab(i)	real	lbm/ft^3	dfab≥ 0.5, ≤ 1250	For target generated debris, fabricated density is the as-manufactured density of the insulation on the pipe. This density together with the target inner diameter, thickness, and length are used to estimate the nominal volume of the debris generated. For example, the fabricated density of an RMI metallic foil cassette is the mass of the cassette divided by the volume of the assembly.

Record Type: 17 *Number:* ntypes *Required:* Always			*List of Variables:* **dfab(i), drub(i), dmat(i), ssa(i)** *Description:* Specifies debris densities and specific surface areas. *Example:* 2.4 2.4 175.0 1.71e+05	
Variable	***Type***	***Units***	***Limitations***	***Description***
drub(i)	real	lbm/ft^3	drub ≥ 0.5, ≤ 1250	The rubble density is the packing density of this debris type on the strainer surface and is used to determine cake thicknesses.
dmat(i)	real	lbm/ft^3	dmat ≥ .5, ≤ 1250.	The material density is the density of the solid debris. For fibrous debris, the material density is the density of an individual fiber. For particulate debris, it is the density of an individual particle and for metallic debris, it is the density of the metal.
ssa(i)	real	ft^2/ft^3	ssa ≥ 10., ≤ 1.e+07	The specific surface area is the total surface area for this type of debris divided by its total volume.

Record Type: 18 *Number:* ntg *Required:* If dloc(i)= TG and ivolm=0			*List of Variables:* **dfract(i,j), j=1, 3** *Description:* Insulation destruction fractions. *Example:* 0.75 0.60 0.40	
Variable	***Type***	***Units***	***Limitations***	***Description***
dfract(i,j)	real	-	dfract ≥ 0, ≤ 1	These destruction factors are used to calculate the volume of target insulation destroyed when the user specifies that the debris volume for this debris type is computed from the target base data.

Record Type: 19 *Number:* ntg + ndw *Required:* if ntg or ndw > 0			*List of Variables:* **tfract(i,j), j=1, npwl for TG; j=1 for DW** *Description:* Drywell debris blowdown transport fractions. *Example:* 00.15 0.35 0.45	
Variable	***Type***	***Units***	***Limitations***	***Description***
tfract(i,j)	real	-	tfract ≥ 0, ≤ 1	Fractions of debris transported from the drywell to the suppression pool by blowdown flows. For target generated debris (TG), the transport fractions apply to the target weld location as specified by the variable pwls in WELD.DAT. There are npwl of these locations. For non-target drywell debris (DW), only one value is inputed for this debris type. For debris originally located in the wetwell, the record type does not apply and should not be inputed.

Record Type: 20 *Number:* ntg + ndw *Required:* If ntg or ndw > 0			*List of Variables:* **tlate(i,j), j=1, npwl for TG; j=1 for DW** *Description:* Drywell debris washdown transport fractions. *Example:* 0.1176 0.2308 0.5455	
Variable	***Type***	***Units***	***Limitations***	***Description***
tlate(i,j)	real	-	tlate ≥ 0, ≤ 1	Fractions of debris transported from the drywell to the suppression pool by washdown flows. For target generated debris (TG), the transport fractions apply to the target weld location as specified by the variable pwls in WELD.DAT. There are npwl of these locations. For non-target drywell debris (DW), only one value is inputed for this debris type. For debris originally located in the wetwell, the record type does not apply and should not be inputed.

Record Type: 21 *Number:* ngroup(i) *Required:* Always			*List of Variables:* **vname(i,j), efilt(i,j,1), efilt(i,j,2), eheld(i,j), vterm(i,j), fdist(i,j)** *Description:* Attributes specified for each settling velocity group j of each debris type i. *Example:* 'NK-01' 1.0 1.0 1.0 6.53306e-04 0.43067	
Variable	***Type***	***Units***	***Limitations***	***Description***
vname(i,j)	character A6	-	up to 6 characters	Name associated with settling velocity group j of debris type i. Each name must be unique within each debris type.
efilt(i,j,1)	real	-	efilt(i,j,1)≥ 0, ≤ 1	Initial (bare strainer) strainer filtration efficiency for velocity group j. *If exponential interpolation is used (ifilt=3), then efficiencies must be > 0.*
efilt(i,j,2)	real		efilt(2,j,2)≥ 0, ≤ 1	Peak strainer filtration efficiency for velocity group j. *If exponential interpolation is used (ifilt=3), then efficiencies must be > 0.*
eheld(i,j)	real	-	eheld(i,j)≥ 0, ≤ 1	Fraction of debris passing through strainer which is not returned to the suppression pool for velocity group j.
vterm(i,j)	real	ft/sec	vterm(i,j)≥ 0, ≤ 10	Debris suppression pool settling velocity for velocity group j.
fdist(i,j)	real	-	fdist(i,j)≥ 0, ≤ 1 and $\sum$fdist(i,j)=1.0 $\pm 10^{-5}$ for each i	Debris settling velocity distribution for debris of velocity group j. This distribution must sum to one for each debris type i. If this sum is not within $1.\pm 10^{-5}$, the code will write a message to the error message file and abort the calculation.

B.7.1.4 Emergency Core Cooling System Input

Record Type: 22 *Number:* 1 *Required:* Always			*List of Variables:* **apool, vpool** *Description:* Suppression pool parameters. *Example:* 5000. 58900.	
Variable	*Type*	*Units*	*Limitations*	*Description*
apool	real	ft^2	vpool/apool > 0.001, < 100.	Suppression pool area based on the model assumption that the cross-sectional area of the pool is constant with elevation. The limitation is based on the height of water in the pool.
vpool	real	ft^3	vpool > 10., < 1.e6	Total volume of water in suppression pool.

Record Type: 23 *Number:* 1 *Required:* Always			*List of Variables:* **nmods, eccmin, to** *Description:* ECCS data. *Example:* 3 5000. 80.	
Variable	*Type*	*Units*	*Limitations*	*Description*
nmods	integer	-	nmods≥ 1, ≤ 8	Number of individual pumping modules, i.e., independent ECCS recirculation loops.
eccmin	real	GPM	eccmin≥ 0, ≤ 100000.	User specified minimum ECCS flow rate required to cool the reactor core. This value is used to determine the condition of strainer blockage (ECCS failure) for the probabilistic results and may optionally be used to terminate the calculation. *ECC failure will not be tested until total pump flow exceeds this value, i.e., pump capacity times flow multiplier.*
tref	real	°F	tref≥ 40., ≤ 200.	Suppression pool reference temperature used to specify the NPSH for each pump. All NPSH values must be specified at this same reference temperature.

Record types 24 and 25 must be repeated for each pump module input for a total of nmods. The data for each pumping module must be inputed as a unit before moving on to the next module, i.e., one record type 24 and npumps (1) record type 25 for pumping module 1, then repeat until nmods of pumping modules are entered. The index i indicates the pumping module number.

Record Type: 24 *Number:* nmods *Required:* Always			*List of Variables:* **mname(i), npumps(i), area(i)** *Description:* Pumping module data. *Example:* Loop1 2 20.	
Variable	*Type*	*Units*	*Limitations*	*Description*
mname(i)	character A6	-	up to 6 characters	Name associated with pumping module i. Each module name must be unique.
npumps(i)	integer	-	npumps ≥ 1, ≤ 4	Number of pumps pumping from the common header in pumping module i.
area(i)	real	ft^2	area > 0, < 1000.	Total surface area of ECCS strainers for pumping module i.

Record Type: 25 *Number:* npumps(i) *Required:* Always			*List of Variables:* **pname(i,j), pflow(i,j), npsho(i,j)** *Description:* Pump data. *Example:* L1-P1 25000. 28.	
Variable	*Type*	*Units*	*Limitations*	*Description*
pname(i,j)	character A6	-	up to 6 characters	Name associated with pump j of pumping module i. Each pump name must be unique within each module.
pflow(i,j)	real	GPM	pflow> 0, < 100000.	Flow capacity for pump j of pumping module i.
npsho(i,j)	real	ft-water	npsho > 0, < 250.	Reference Net Pump Suction Head (NPSH) Margin Available to ECCS for pump j of pumping module i. This margin must correspond to the reference temperature T_{ref} specified on record type 23.

B.7.1.5 Strainer BLOCKAGE Correlation Input

Record Type: 26 *Number:* 1 *Required:* Always			*List of Variables:* **iblk, ncoef, hsens** *Description:* Selection blockage correlation and correlation constants. *Example:* 3 13 1.0	
Variable	*Type*	*Units*	*Limitations*	*Description*
iblk	integer	-	iblk ≥ 1, ≤ 3	This variable selects the blockage correlation to be used in predicting strainer head losses throughout the entire calculation. It is the user's responsibility to select the most appropriate correlation for his calculation. The correlation options are: = 1; NUREG/CR-6224 compressible fiber correlation (requires 1 input constant). = 2; BWROG correlation (requires 1 input constant). = 3; First generic user defined correlation

Record Type: 26 Number: 1 Required: Always			List of Variables: iblk, ncoef, hsens Description: Selection blockage correlation and correlation constants. Example: 3 13 1.0	
Variable	*Type*	*Units*	*Limitations*	*Description*
ncoef	integer	-	ncoef≥ 0, ≤ 13	User defined input constants for the selected blockage correlation. The number of constants must agree with the blockage correlation selected. The constant for the SEA and BWROG correlations and the last constant for the generic correlation is the coefficient for the additive head loss term.
hsens	real	-	hsens≥ 0.1,≤ 1	Sensitivity coefficient applied directly to each head loss correlation as a leading coefficient which multiplies the entire equation. The purpose of this coefficient is to allow the user to directly test the sensitivity of the BLOCKAGE results to the accuracy of the correlation selected. A coefficient of 1.0 leaves the correlation unaltered.

Record Type: 27 Number: 1 Required: Always			List of Variables: cblk(i), i=1, ncoef Description: Blockage correlation constants. Example: 12. 3.0 0.0 1.0 1.5 2.0 0.0 1.0 1.0 1.0 1.0 1.0 0.1	
Variable	*Type*	*Units*	*Limitations*	*Description*
cblk(i)	real	-	cblk≥ 0., ≤ 1.e+11	Blockage correlation constants. When using the user defined correlation, the user must select constants which do not cause an illegal mathematics operation to be attempted, such as raising zero to the zero power.

B.7.1.6 Time Control Input

Record Type: 28 Number: 1 Required: Always			List of Variables: dlloca, tend, cklim Description: Miscellaneous Time-Dependency Related Data. Example: 6.0 21600. 0.001	
Variable	*Type*	*Units*	*Limitations*	*Description*
dlloca	real	inch	dlloca≥ 1., < 100.	Minimum pipe diameter for a weld break to be treated as a LLOCA. All pipes with diameters smaller than dlloca are treated as MLOCAs.
tend	real	seconds	tend> 0.	Calculation end time.

Record Type: 28 *Number:* 1 *Required:* Always			*List of Variables:* **dlloca, tend, cklim** *Description:* Miscellaneous Time-Dependency Related Data. *Example:* 6.0 21600. 0.001	
Variable	*Type*	*Units*	*Limitations*	*Description*
cklim	real	-	cklim≥ 0., ≤ 1.	This parameter is a QA check limit for flagging incomplete drywell transport to the wetwell. A message is written to the error message file and the calculation is aborted if the time dependent drywell transport rate does not integrate to 1.0 ± cklim. The time-dependent drywell transport rates must integrate to 1.0 over both the blowdown and the washdown periods. Inaccurate drywell transport is most likely caused by either the incorrect input of the time-dependent drywell transport rates or by excessively large time steps.

Record Type: 29 *Number:* 1 *Required:* Always			*List of Variables:* **interp(i), i=1, 6** *Description:* Interpolation options for time-dependent input. *Example:* 1 2 2 1 1 3	
Variable	*Type*	*Units*	*Limitations*	*Description*
interp(i)	integer	-	either 1, 2, or 3	This variable specifies the interpolation method applied to each of the six time-dependent input parameters (time step size, flow multiplier, suppression pool temperature, drywell transport rate, resuspension factor, and settling turbulence factor; for i=1 to 6, respectively). 1 = input treated as a step function, 2 = linear interpolation between points, 3 = exponential interpolation between points. *If the exponential interpolation option is selected, then all entries for that variable must be greater than zero. Note: Data is not extrapolated beyond the last time entry in timtbl, i.e., at times greater than the last time entry. The last values are used for the remainder of the calculation.*

B.7.1.7 LLOCA Time Dependent Input

Record Type: 30 *Number:* 1 *Required:* Always			*List of Variables:* **numdt(1), tblowdn(1), twashdn(1)** *Description:* LLOCA timing data. *Example:* 10 120. 1920.	
Variable	*Type*	*Units*	*Limitations*	*Description*
numdt(1)	integer	-	numdt(1) > 0., ≤ 100	Number of input time entries for LLOCA time dependent input.
tblowdn(1)	real	seconds	tblowdn(1)> 0	End time for the blowdown period for a LLOCA weld break. The blowdown period corresponds to the depressurization of the primary system.
twashdn(1)	real	seconds	twashdn(1) > tblowdn(1)	End time for the washdown period for a LLOCA weld break. The washdown period corresponds to containment spray washdown of debris following system depressurization.

Record Type: 31 *Number:* numdt(1) *Required:* Always			*List of Variables:* **timtbl(1,j), dttbl(1,j), qflow(1,j), temp(1,j),g(1,j), resk(1,j), turbk(1,j)** *Description:* LLOCA time-dependent input. *Example:* 0.0 0.1 0.0 80. 0.008333 1.0 0.0001	
Variable	*Type*	*Units*	*Limitations*	*Description*
timtbl(1,j)	real	seconds	timtbl(1,1)=0., table must include tblowdn(1) and twashdn(1)	Time entry for LLOCA event time table. Each time entry must be larger than the preceding time entry. Furthermore, the event time matching logic which ensures that a time step is executed at both the end of blowdown and the end of washdown times requires that the table include these two time values.
dttbl(1,j)	real	seconds	dttbl(1,j)> 0.	LLOCA size of the time steps used to advance the calculational solution through time. The user should attempt to keep these time steps relatively small through rapid transient periods to increase calculational accuracy but then increase them though the relatively slower periods to speed up the calculation.
qflow(1,j)	real	-	qflow(1,j)≥ 0.	LLOCA pump flow multiplier. This parameter is used to simulate partial pump flow such as when the pump is spinning up to full capacity. Larger or smaller than rated capacity can also be simulated but the multiplier was generally intended to go from 0 to 1 for 100% capacity. *If exponential interpolation is used (iterp(2)=3), then the flow multiplier must be > 0.*
temp(1,j)	real	°F	temp(1,j) ≥ 40., ≤ 212.	Time dependent suppression pool temperature for LLOCA.

Record Type: 31 *Number.* numdt(1) *Required:* Always			*List of Variables:* **timtbl(1,j), dttbl(1,j), qflow(1,j), temp(1,j),g(1,j), resk(1,j), turbk(1,j)** *Description:* LLOCA time-dependent input. *Example:* 0.0 0.1 0.0 80. 0.008333 1.0 0.0001	
Variable	*Type*	*Units*	*Limitations*	*Description*
g(1,j)	real	fract/sec	g(1,j) ≥ 0	LLOCA drywell transport rate. This parameter controls the time-dependency of the transfer of fibrous debris from the drywell to the wetwell. To ensure that the correct volume is transferred during both the blowdown and the washdown periods, the integral of the drywell transport rate must equal e when integrated over the blowdown period and again when integrated over the washdown period within n error limit of ± cklim. *If exponential interpolation is used (iterp(4)=3), then the drywell transport rate must be > 0.*
resk(1,j)	real	sec^{-1}	resk(1,j)≥ 0., ≤ 1.	LLOCA suppression pool resuspension factor. *If exponential interpolation is used (iterp(5)=3), then the resuspension factor must be > 0.*
turbk(1,j)	real	-	turbk(1,j)≥ 0., ≤ 1.	LLOCA suppression pool settling turbulence factor. *If exponential interpolation is used (iterp(6)=3), then the settling turbulence factor must be > 0.*

B.7.1.8 MLOCA Time Dependent Input

Record Type: 32 *Number:* 1 *Required:* Always			*List of Variables:* **numdt(2), tblowdn(2), twashdn(2)** *Description:* MLOCA timing data. *Example:* 10 600. 2400.	
Variable	*Type*	*Units*	*Limitations*	*Description*
numdt(2)	integer	-	numdt(2) > 0., ≤ 100	Number of input time entries for MLOCA time dependent input.
tblowdn(2)	real	seconds	tblowdn(2)> 0	End time for the blowdown period for a MLOCA weld break. The blowdown period corresponds to the depressurization of the primary system.
twashdn(2)	real	seconds	twashdn(2) > tblowdn(2)	End time for the washdown period for a MLOCA weld break. The washdown period corresponds to containment spray washdown of debris following system depressurization.

Record Type: 33 *Number:* numdt(2) *Required:* Always			*List of Variables:* **timtbl(2,j), dttbl(2,j), qflow(2,j), temp(2,j), g(2,j), resk(2,j), turbk(2,j)** *Description:* MLOCA time-dependent input. *Example:* 0.0 1.0 0.0 80. 0.001667 1.0 0.0001	
Variable	*Type*	*Units*	*Limitations*	*Description*
timtbl(2,j)	real	seconds	timtbl(2,1)=0., table must include tblowdn(2) and twashdn(2)	Time entry for MLOCA event time table. Each time entry must be larger than the preceding time entry. Furthermore, the event time matching logic which ensures that a time step is executed at both the end of blowdown and the end of washdown times requires that the table include these two time values.
dttbl(2,j)	real	seconds	dttbl(2,j)> 0.	MLOCA size of the time steps used to advance the calculational solution through time. The user should attempt to keep these time steps relatively small through rapid transient periods to increase calculational accuracy but then increase them though the relatively slower periods to speed the calculation.
qflow(2,j)	real	-	qflow(2,j)≥ 0.	MLOCA pump flow multiplier. This parameter is used to simulate partial pump flow such as when the pump is spinning up to full capacity. Larger or smaller than rated capacity can also be simulated but the multiplier was generally intended to go from 0 to 1 for 100% capacity. *If exponential interpolation is used (iterp(2)=3), then the flow multiplier must be > 0.*
temp(2,j)	real	°F	temp(2,j)≥ 40., ≤ 212.	Time dependent suppression pool temperature for MLOCA.
g(2,j)	real	fract/sec	g(2,j) ≥ 0	MLOCA drywell transport rate. This parameter controls the time-dependency of the transfer of fibrous debris from the drywell to the wetwell. To ensure that the correct volume is transferred during both the blowdown and the washdown periods, the integral of the drywell transport rate must equal one when integrated over the blowdown period and again when integrated over the washdown period within n error limit of ± cklim. *If exponential interpolation is used (iterp(4)=3), then the drywell transport rate must be > 0.*
resk(2,j)	real	sec^{-1}	resk(2,j)≥ 0., ≤ 1.	MLOCA suppression pool resuspension factor. *If exponential interpolation is used (iterp(5)=3), then the resuspension factor must be > 0.*

Record Type: 33 *Number:* numdt(2) *Required:* Always			*List of Variables:* **timtbl(2,j), dttbl(2,j), qflow(2,j), temp(2,j), g(2,j), resk(2,j), turbk(2,j)** *Description:* MLOCA time-dependent input. *Example:* 0.0 1.0 0.0 80. 0.001667 1.0 0.0001	
Variable	*Type*	*Units*	*Limitations*	*Description*
turbk(2,j)	real	-	turbk(2,j)≥ 0., ≤ 1.	MLOCA suppression pool settling turbulence factor. *If exponential interpolation is used (iterp(6)=3), then the settling turbulence factor must be > 0.*

B.7.2 Plant Data Base File WELD.DAT

B.7.2.1 Plant Data Set Identification

Record Type: 1 *Number:* 1 *Required:* Always			*List of Variables:* **probid** *Description:* Plant data set name. *Example:* Reference Plant	
Variable	*Type*	*Units*	*Limitations*	*Description*
probid	character A40	-	up to 40 characters	Name identifies the plant or weld data set for this calculation. This name printed in output headers.

B.7.2.2 Plant Pipe Diameters

Record Type: 2 *Number:* 1 *Required:* If ivolm = 0			*List of Variables:* **npwd** *Description:* Number of pipe diameter sizes allowed in plant data set. *Example:* 10	
Variable	*Type*	*Units*	*Limitations*	*Description*
npwd	integer	-	npwd≥ 1, ≤ 30	Number of pipe diameter sizes allowed in plant data set.

Record Type: 3 *Number:* npwd/5 (rounded upward) *Required:* If ivolm = 0			*List of Variables:* **pwds(i), i=1, npwd** *Description:* Plant pipe diameters of postulated weld breaks. *Example:* 10. 16. 18. 20. 22.	
Variable	*Type*	*Units*	*Limitations*	*Description*
pwds(i)	real	inch	pwds(j) >0., < 100.	Plant pipe outside diameters of postulated weld breaks. Five diameters are entered per record until npwd diameters are entered. Last record may contain less than 5 diameters. Furthermore, the pipe diameters must be entered in order of increasing diameter. These pipe diameters are used in writing the probabilistic reports and check against the data set pipe diameters as a quality assurance

B.7.2.3 Piping Systems

Record Type: 4 *Number:* 1 *Required:* If ivolm = 0			*List of Variables:* **nsys** *Description:* Number of systems *Example:* 5	
Variable	*Type*	*Units*	*Limitations*	*Description*
nsys	integer	-	nsys ≥ 1, ≤ 10	Number of systems in plant data set.

Record Type: 5 *Number:* nsys *Required:* If ivolm = 0			*List of Variables:* **systbl(j), j=1, nsys** *Description:* System Description *Example:* 'Recirculation Loop'	
Variable	*Type*	*Units*	*Limitations*	*Description*
systbl(j)	character A26	-	up to 26 characters	These system descriptions are entered one per record and are printed in the probabilistic reports to identify a system number with a particular system.

B.7.2.4 Weld Break Locations

Record Type: 6 *Number:* 1 *Required:* Always			*List of Variables:* **npwl** *Description:* Number of weld break location regions. *Example:* 3	
Variable	*Type*	*Units*	*Limitations*	*Description*
npwl	integer	-	npwd ≥ 1, ≤ 5	Number of weld break location regions.

Record Type: 7 *Number:* 1 *Required:* Always			*List of Variables:* **pwls(i), i=1, npwl** *Description:* Weld break location region identifier. *Example:* 'H' 'M' 'L'	
Variable	*Type*	*Units*	*Limitations*	*Description*
pwls(i)	character A2	-	up to 2 characters	Weld break location region identifiers. Each identifier must be distinctly different from the others.

Record Type: 8 *Number:* npwl *Required:* Always			*List of Variables:* **lcdesc(i), j=1, npwl** *Description:* Weld break location region description. *Example:* 'Above 776 ft Grating'	
Variable	*Type*	*Units*	*Limitations*	*Description*
lcdesc(i)	character A50	-	up to 50 characters	Weld break location region description. These descriptions are printed in the probabilistic reports.

B.7.2.5 Weld Types

Record Type: 9 *Number:* 1 *Required:* If ivolm = 0			*List of Variables:* **npwt** *Description:* Number of weld types in plant data set. *Example:* 6	
Variable	*Type*	*Units*	*Limitations*	*Description*
npwt	integer	-	npwt≥ 1, ≤ 20	Number of weld types in plant data set.

Record Type: 10 *Number:* 1 *Required:* If ivolm = 0			*List of Variables:* **pwts(i), i=1, npwt** *Description:* Weld type identifier. *Example:* S1,S2,S3,C1,C3,C4	
Variable	*Type*	*Units*	*Limitations*	*Description*
pwts(i)	character A2	-	up to 2 characters	Weld type identifier. Each identifier must be distinctly different from the others.

B.7.2.6 Insulation Materials

Record Type: 11 *Number:* 1 *Required:* Always			*List of Variables:* **npim** *Description:* Number of insulation materials in plant data set. *Example:* 4	
Variable	*Type*	*Units*	*Limitations*	*Description*
npim	integer	-	npim≥ 1, ≤ 10	Number of insulation materials in plant data set.

Record Type: 12 *Number:* 1 *Required:* Always			*List of Variables:* **pims(i), i=1, npim** *Description:* Insulation material identifier. *Example:* 'NK' 'MR' 'CS' 'NN'	
Variable	*Type*	*Units*	*Limitations*	*Description*
pims(i)	character A2	-	up to 2 characters	Insulation material identifier. Each identifier must be distinctly different from the others.

Record Type: 13 *Number:* 1 *Required:* Always			*List of Variables:* **fibflg(i), i=1, npim** *Description:* Insulation material type. *Example:* 'F' 'N' 'N' 'N'	
Variable	*Type*	*Units*	*Limitations*	*Description*
fibflg(i)	character A1	-	1 character only	Insulation material type. Each type must be an 'F', 'M', 'P', or 'N,' where F implies fibrous material, M implies metallic material, P implies particulate material, and N implies that material will be neglected by the head loss correlations.

B.7.2.7 Weld and Target Data Set

Record Type: 14 *Number:* 1 *Required:* ivolm = 0			*List of Variables:* **ld(k), k= 1, 3** *Description:* Data set destruction regions. *Example:* 3. 5. 7.	
Variable	*Type*	*Units*	*Limitations*	*Description*
ld(k)	real	-	ld(k) > 0, < 20	Destruction regions used in creating the weld and target data set. These regions are specified as the ratio of the region boundary distance from the pipe weld break divided by the diameter of the broken pipe (L/D). These regions were used in developing the associated weld and target data but are not used by the BLOCKAGE code in any way. The code simply reads in the values as a reminder to the user of the region selections inherent in the development of the data set.

Record Type: 15 *Number:* 1 to 800 *Required:* If ivolm = 0			*List of Variables:* weldid(j), sysid(j), wdiam(j), wtype(j), wloc(j), ntgts(j), tgtno(j,1), tgtdia(j,1), tgtsys(j,1), tgttyp(j,1), tgtthk(j,1), tgtlen(j,1,k), k=1,3 *Description:* Specifies data for a weld and its first target. *Example:* RCA-J003 1 22.0 S1 H 9 1 22.0 RCA NK 3.00 7.33 11.00 14.67	
Variable	*Type*	*Units*	*Limitations*	*Description*
weldid(j)	character A8	-	up to 8 characters	Unique weld identifier. Each identifier must be distinctly different from the others.
sysid(j)	integer	-	sysid(j)≥ 1, ≤ nsys	Specifies plant system associated with this weld.
wdiam(j)	real	inch	wdiam(j) >0., < 100.	Outside pipe diameter associated with this weld. This diameter must match one of the diameters specified in pwds(i), i=1, npwd.

Record Type: 15 *Number:* 1 to 800 *Required:* If ivolm = 0			*List of Variables:* weldid(j), sysid(j), wdiam(j), wtype(j), wloc(j), ntgts(j), tgtno(j,1), tgtdia(j,1), tgtsys(j,1), tgttyp(j,1), tgtthk(j,1), tgtlen(j,1,k), k=1,3 *Description:* Specifies data for a weld and its first target. *Example:* RCA-J003 1 22.0 S1 H 9 1 22.0 RCA NK 3.00 7.33 11.00 14.67	
wtype(j)	character A2	-	up to 2 characters	Specifies type of weld. This weld type identifier must match one of the identifiers specified in pwts(i), i=1, npwt.
wloc(j)	character A2	-	up to 2 characters	Specifies weld break location region for this weld. This region identifier must match one of the identifiers specified in pwls(i), i=1, npwl.
ntgts(j)	integer	-	ntgts(j)≥ 1, ≤ 40	Number of targets for this welds.
tgtno(j,1)	integer	-	tgtno(j,1)= 1	First target associated with this weld. The first target is always number one. The first target is normally associated with the insulation surrounding the pipe which has this weld; however, this is not a requirement.
tgtdia(j,1)	real	inch	tgtdia(j,1) >0., < 200	Inside diameter of first target.
tgtsys(j,1)	character A3	-	up to 3 characters	Target reference information. This information is printed in the TARGET.OUT file but is not used by the code. The user could use this variable to indicate a piping system associated with the target or possibly a design drawing.
tgttyp(j,1)	character A2	-	up to 2 characters	Type of insulation material for this target. This identifier must match one of the identifiers specified in pims(i), i=1, npim.
tgtthk(j,1)	real	inch	tgtthk(j,1) >0., < 100.	The thickness of insulation for the first target.
tgtlen(j,1,k)	real	ft	tgtlen(j,1,k)≥ 0., ≤ 100.	Target length for each of the three L/D destruction regions. The lengths are measured from zero to each of the L/D boundaries as specified in ld(k), k= 1, 3. The incremental length for the second region is tgtlen(j,1,2) minus tgtlen(j,1,1) and for the third region, it is tgtlen(j,1,3) minus tgtlen(j,1,2). Therefore, the second length must be larger than or equal to the first length and third length must be larger than or equal to the second length.

Record Type: 16 *Number:* ntgts(j) *Required:* If ivolm = 0 and ntgts(j) > 1			*List of Variables:* **tgtno(j,n), tgtdia(j,n), tgtsys(j,n), tgttyp(j,n), tgtthk(j,n), tgtlen(j,n,k), k=1,3** *Description:* Specifies data for additional targets associated with preceding weld. *Example:* 2 10.0 RRA NK 2.50 0.00 7.50 12.60	
Variable	***Type***	***Units***	***Limitations***	***Description***
tgtno(j,n)	integer	-	tgtno(j,n)≥ 2, ≤ ntgts(j)	Additional targets associated with preceding weld.
tgtdia(j,n)	real	inch	tgtdia(j,n) >0., < 200	Inside diameter of this target.
tgtsys(j,n)	character A3	-	up to 3 characters	Target reference information. This information is printed in the TARGET.OUT file but is not used by the code. The user could use this variable to indicate a piping system associated with the target or possibly a design drawing.
tgttyp(j,n)	character A2	-	up to 2 characters	Type of insulation material for this target. This identifier must match one of the identifiers specified in pims(i), i=1, npim.
tgtthk(j,n)	real	inch	tgtthk(j,n) >0., < 100.	The thickness of insulation for this target.
tgtlen(j,n,k)	real	ft	tgtlen(j,n,k) ≥ 0., ≤ 100.	Target length for each of the three L/D destruction regions. The lengths are measured from zero to each of the L/D boundaries as specified in ld(k), k= 1, 3. The incremental length for the second region is tgtlen(j,n,2) minus tgtlen(j,n,1) and for the third region, it is tgtlen(j,n,3) minus tgtlen(j,n,2). Therefore, the second length must be larger than or equal to the first length and third length must be larger than or equal t the second length.

B.7.2.8 Weld and User Volume Input

Record Type: 17 *Number:* 1 to 10 *Required:* If ivolm = 1			*List of Variables:* **weldid(j), wloc(j), wdiam(j), ntgts(j), tgtno(j,1), tgttyp(j,1), vuser(j,1)** *Description:* Specifies data for first user input volume for a particular weld break calculation. *Example:* VOLUME-1 H 1.0 4 1 NK 5.	
Variable	***Type***	***Units***	***Limitations***	***Description***
weldid(j)	character A8	-	up to 8 characters	Unique user input volume identifier for each weld break calculation. Each identifier must be distinctly different from the others.

Record Type: 17 *Number:* 1 to 10 *Required:* If ivolm = 1			*List of Variables:* **weldid(j), wloc(j), wdiam(j), ntgts(j), tgtno(j,1), tgttyp(j,1), vuser(j,1)** *Description:* Specifies data for first user input volume for a particular weld break calculation. *Example:* VOLUME-1 H 1.0 4 1 NK 5.	
Variable	***Type***	***Units***	***Limitations***	***Description***
wloc(j)	character A2	-	up to 2 characters	Specifies weld break location region for this weld. This region identifier must match one of the identifiers specified in pwls(i), i=1, npwl.
wdiam(j)	real	inch	wdiam(j) >0., < 100.	Outside pipe diameter associated with this weld. This diameter must match one of the diameters specified in pwds(i), i=1, npwd.
ntgts(j)	integer	-	ntgts(j)≥ 1, ≤ 40	Number of user input volumes per weld break. Similar to the number of targets per weld specified in record type 15.
tgtno(j,1)	integer	-	tgtno(j,1)= 1	First user volume for this weld break calculation. This number must be one.
tgttyp(j,1)	character A2	-	up to 2 characters	Specifies type of weld. This weld type identifier must match one of the identifiers specified in pwts(i), i=1, npim.
vuser(j,1)	real	ft^3	vuser(j,1) > 0, < 250.	Volume of location dependent target insulation debris in drywell available for transport to wetwell.

Record Type: 18 *Number:* 1 to ntgts(j) *Required:* If ivolm = 1 and ntgts(j) > 1			*List of Variables:* **tgtno(j,n), tgttyp(j,1), vuser(j,n)** *Description:* Specifies data for additional user input volumes. *Example:* 2 NK 0.01	
Variable	***Type***	***Units***	***Limitations***	***Description***
tgtno(j,n)	integer	-	tgtno(j,n)≥ 2, ≤ ntgts(j)	Additional volumes for weld break calculation specified in preceding record type 17.
tgttyp(j,n)	character A2	-	up to 2 characters	Specifies type of weld. This weld type identifier must match one of the identifiers specified in pwts(i), i=1, npim.
vuser(j,n)	real	ft^3	vuser(j) > 0, < 250.	Volume of location dependent target insulation debris in drywell available for transport to wetwell.

B.7.3 Sample Input for Version 2.5

Sample input is presented to further clarify the DOS level input process. The input values in this sample input files are shown in regular print, their corresponding computer variables in *italic* print and comments in **bold** print. If all of the italic and bold lines of print were removed, the remaining data would represent valid input files for

Version 2.5. These input files, however, are only intended to illustrate the input capability and input organization of the new models and the values are not necessarily realistic.

B.7.3.1 Sample INPUT.DAT

Calculation Control Input

```
runid
Version 2.5 Test Input 6-6-96
compid
TWELVE-CHARS
iprob      ivolm      iterm
1          0          5
ipage      iplot      isens      iweld      iprint     pfreq
46         100        1          2          1          100.
psens
58900.
idweld(i=1, iweld)
MIXTURE
MIXTURE2
```

Probabilistic Input

```
break
W
ndc
4
wdctbl(i=1, ndc)
0.75       4.0        12.0       18.0
wdclbl(i=1, ndc)
'.75-2'    '4-10'     '12-16'    '18-+'
wwffwf(i=1,ndc ,j=1, npwt)
1.e-6      1.e-6      2.e-6      2.e-7
1.e-6      1.e-6      2.e-6      2.e-7
1.e-6      1.e-6      2.e-6      2.e-7
2.e-7      2.e-7      2.e-7      2.e-7
2.e-7      2.e-7      2.e-7      2.e-7
2.e-7      2.e-7      2.e-7      2.e-7
```

Debris Attributes Input

```
ntypes     ntg        ndw        nww
6          3          2          1
debris(i=1, ntypes)
NK         MR         CS         PT         CC         SD
ifilt      rfilt
2          0.0208
```

Next Block of Records Must Be Repeated ntypes Times

```
dname(1)   debris(1)  dclass(1)  dloc(1)    ngroup(1)  volume(1)
NUKON      NK         F          TG         12         0.
dfab(1)  drub(1)  dmat(1)  ssa(1)
```

```
2.4        2.4        175.0      1.71e+05
dfract(1, j= 1, 3)
0.75       0.60       0.40
tfract(1, j=1, 3)
0.15       0.35       0.45
tlate(1, j=1, 3)
0.1176     0.2308     0.5455
vname(1, j)  efilt(1,j,k)  efilt(1,j,k)  eheld(1,j)  vterm(1,j)        fdist(1,j)
'NK-01'      1.0           1.0           1.0         6.5306e-04        0.43067
'NK-02'      1.0           1.0           1.0         1.6443e-03        0.14922
'NK-03'      1.0           1.0           1.0         2.6061e-03        0.11011
'NK-04'      1.0           1.0           1.0         4.1303e-03        0.08125
'NK-05'      1.0           1.0           1.0         6.5461e-03        0.05995
'NK-06'      1.0           1.0           1.0         1.0375e-02        0.04424
'NK-07'      1.0           1.0           1.0         1.6443e-02        0.03265
'NK-08'      1.0           1.0           1.0         2.6061e-02        0.02409
'NK-09'      1.0           1.0           1.0         4.1303e-02        0.01778
'NK-10'      1.0           1.0           1.0         6.5461e-02        0.01312
'NK-11'      1.0           1.0           1.0         1.0375e-01        0.00968
'NK-12'      1.0           1.0           1.0         2.4606e-01        0.02724

dname(2)     debris(2)     dclass(2)     dloc(2)     ngroup(2)   volume(2)
RMI          MR            M             TG          4           0.
dfab(2)   drub(2)   dmat(2)   ssa(2)
25.       100.      491.0     2400.
dfract(2, j= 1, 3)
0.50       0.30       0.10
tfract(2, j=1, 3)
0.05       0.15       0.25
tlate(2, j=1, 3)
0.05       0.10       0.20
vname(2, j)  efilt(2,j,k)  efilt(2,j,k)  eheld(2,j)  vterm(2,j)  fdist(2,j)
'MR-01'      1.0           1.0           1.0         1.0e-02     0.10
'MR-02'      1.0           1.0           1.0         5.0e-02     0.15
'MR-03'      1.0           1.0           1.0         1.0e-01     0.25
'MR-04'      1.0           1.0           1.0         5.0e-01     0.50

dname(3)     debris(3)     dclass(3)     dloc(3)     ngroup(3)   volume(3)
Cal-Sil      CS            P             TG          5           0.
dfab(3)      drub(3)       dmat(3)       ssa(3)
120.         65.           150.0         60000.
dfract(3, j= 1, 3)
0.80       0.60       0.40
tfract(3, j=1, 3)
0.25       0.35       0.45
tlate(3, j=1,3)
0.15       0.30       0.60
vname(3, j)  efilt(3,j,k)  efilt(3,j,k)  eheld(3,j)  vterm(3,j)  fdist(3,j)
'CS-01'      0.0           0.5           0.5         1.0e-02     0.10
'CS-02'      0.0           0.6           0.6         5.0e-02     0.15
'CS-03'      0.0           0.7           0.8         1.0e-01     0.25
'CS-04'      0.1           0.8           0.9         2.0e-01     0.30
'CS-05'      0.2           0.9           1.0         5.0e-01     0.20
```

dname(4)	*debris(4)*	*dclass(4)*	*dloc(4)*	*ngroup(4)*	*volume(4)*
Paint	PT	P	DW	3	0.8
dfab(4)	*drub(4)*	*dmat(4)*	*ssa(4)*		
142.	65.	142.0	20000.		
tfract(4, 1)					
0.75					
tlate(4, 1)					
1.00					
vname(4, j)	*efilt(4,j,k)*	*efilt(4,j,k)*	*eheld(4,j)*	*vterm(4,j)*	*fdist(4,j)*
'PT-01'	0.0	0.5	0.2	5.0e-02	0.15
'PT-02'	0.1	0.6	0.3	1.0e-01	0.35
'PT-03'	0.2	0.7	0.4	3.0e-01	0.50

dname(5)	*debris(5)*	*dclass(5)*	*dloc(5)*	*ngroup(5)*	*volume(5)*
Conc	CC	P	DW	1	1.1
dfab(5)	*drub(5)*	*dmat(5)*	*ssa(5)*		
157.	65.	157.0	1.2e+05		
tfract(5, 1)					
0.65					
tlate(5, 1)					
0.90					
vname(5, j)	*efilt(5,j,k)*	*efilt(5,j,k)*	*eheld(5,j)*	*vterm(5,j)*	*fdist(5,j)*
'Conc-1'	0.0	0.7	0.8	4.0e-01	1.00

dname(6)	*debris(6)*	*dclass(6)*	*dloc(6)*	*ngroup(6)*	*volume(6)*
Sludge	SD	P	WW	12	2.6
dfab(6)	*drub(6)*	*dmat(6)*	*ssa(6)*		
324.	65.	324.0	1.5e+05		
vname(6, j)	*efilt(6,j,k)*	*efilt(6,j,k)*	*eheld(6,j)*	*vterm(6,j)*	*fdist(6,j)*
'wwp-01'	0.0	0.5	0.5	6.5306e-04	0.20897
'wwp-02'	0.0	0.5	0.5	1.6443e-03	0.04658
'wwp-03'	0.0	0.5	0.5	2.6061e-03	0.05477
'wwp-04'	0.0	0.5	0.5	4.1303e-03	0.06325
'wwp-05'	0.0	0.5	0.5	6.5461e-03	0.07145
'wwp-06'	0.0	0.5	0.5	1.0375e-02	0.07848
'wwp-07'	0.0	0.5	0.5	1.6443e-02	0.08322
'wwp-08'	0.0	0.5	0.5	2.6061e-02	0.08442
'wwp-09'	0.0	0.5	0.5	4.1303e-02	0.08101
'wwp-10'	0.0	0.5	0.5	6.5461e-02	0.07249
'wwp-11'	0.0	0.5	0.5	1.0375e-01	0.05943
'wwp-12'	0.0	0.5	0.5	2.4606e-01	0.09593

ECCS Input

apool	*vpool*	
5000.	58900.	
nmod	*ECCmin*	*To*
3	5000.	80.

Next Block of Records Must Be Repeated nmod Times

mname(1)	*npumps(1)*	*area(1)*
Loop1	1	37.62
pname(1,j)	pflow(1,j)	npsho(1,j)

L1-P1	25000.	28.

mname(2)	*npumps(2)*	*area(2)* Loop2	2	20.
pname(2,j)	pflow(2,j)	npsho(2,j)		
L2-P1	25000.	28.		
L2-P2	6000.	30.		

mname(3)	*npumps(3)*	*area(3)*
Loop3	3	30.
pname(3,j)	pflow(3,j)	npsho(3,j)
L3-P1	25000.	28.
L3-P2	5000.	30.
L3-P3	1500.	32.

BLOCKAGE Correlation Input

iblk	*ncoef*	*hsens*						
3	13	1.0						
cblk(i=1,ncoef)								
12.	3.0	0.0	1.0	1.5	2.0	0.0	1.0	1.0
	1.0	1.0	1.0	0.1				

Time Control Input

dloca	*tend*	*cklim*			
6.0	21600.	0.001			
interp(i=1,6)					
1	2	2	1	1	3

LLOCA Time-Dependent Input

numdt(1)	*tblowdn(1)*	*twashdn(1)*				
10	120.0	1920.				
timtbl(1,j)	*dttbl(1,j)*	*qflow(1,j)*	*temp(1,j)*	*g(1,j)*	*resk(1,j)*	*turbk(1,j)*
0.0	0.1	0.0	80.	0.00833333	1.0	0.0001
4.0	0.1	0.0	81.	0.00833333	1.0	0.0001
5.0	0.1	0.1	81.	0.00833333	1.0	0.0001
49.0	0.1	0.1	100.	0.00833333	1.0	0.0001
50.0	0.1	1.0	130.	0.00833333	1.0	0.0001
100.0	0.1	1.0	180.	0.00833333	1.0	0.0001
120.0	0.1	1.0	180.	0.00055556	0.0	0.0001
420.0	1.0	1.0	170.	0.00055556	0.0	0.5
1920.0	1.0	1.0	150.	0.0	0.0	0.5
2500.0	10.0	1.0	120.	0.0	0.0	0.5

MLOCA Time-Dependent Input

numdt(2)	*tblowdn(2)*	*twashdn(2)*				
10	600.0	2400.				
timtbl(2,j)	*dttbl(2,j)*	*qflow(2,j)*	*temp(2,j)*	*g(1,j)*	*resk(2,j)*	*turbk(2,j)*
0.0	1.0	0.0	80.	0.00166667	1.0	0.0001
49.0	1.0	0.0	95	0.00166667	1.0	0.0001
50.0	1.0	0.1	95.	0.00166667	1.0	0.0001
320.0	0.1	0.1	150.	0.00166667	1.0	0.0001

500.0	0.1	1.0	170.	0.00166667	1.0	0.0001
600.0	0.1	1.0	170.	0.00055556	0.0	0.0001
720.0	0.1	1.0	160.	0.00055556	0.0	0.5
850.0	1.0	1.0	150.	0.00055556	0.0	0.5
2400.0	1.0	1.0	100.	0.0	0.0	0.5
2500.0	10.0	1.0	195.	0.0	0.0	0.5

B.7.3.2 Sample WELD.DAT

Plant Data Set Identification

probid
Version 2.5 Test Input 6-6-96

Plant Pipe Diameters

npwd
8
pwds(i=1, npwd)

1.0	2.0	3.0	4.0	6.0
10.	18.	22.		

Piping Systems

nsys
5
systbl(j=1, nsys)
'Recirculation Loop'
'Main Steam'
'Feedwater'
'HPCI Steam Line'
'RHR Injection Lines'

Weld Break Locations

npwl
3
pwls(i=1, npwl)
'H' 'M' 'L'
lcdesc(j=1, npwl)
'Above 776 ft Grating'
'Between 757/776 Gratings'
'Below 757 ft Grating'

Weld Types

npwt
6
pwts(i=1, npwt)
S1,S2,S3,C1,C2,C3

Insulation Materials

npim

3
pims(i=1, npim)
'NK' 'MR' 'CS'
fibflg(i=1, npim)
'F' 'M' 'P'

Weld and Target Data Set

ld(k=1, 3)
3. 5. 7.

weldid	*sysid*	*wdiam*	*wtype*	*wloc*	*ntgts*	*tgtno*	*tgtdia*	*tgtsys*	*tgttyp*	*tgtthk*	*tgtlen's*		
MIXTURE	1	22.0	S1	M	12	1	22.0	RCA	NK	3.00	11.00	18.33	25.67
						2	10.0	RRA	CS	2.50	0.00	0.00	13.00
						3	10.0	RRH	NK	2.50	0.00	0.00	13.00
						4	16.0	RMA	MR	3.00	0.00	0.00	5.50
						5	16.0	RMB	NK	3.00	0.00	0.00	5.50
						6	20.0	MSA	NK	3.00	5.50	11.70	20.30
						7	20.0	MSD	MR	3.00	5.50	11.70	20.30
						8	20.0	MSC	NK	3.00	0.00	4.71	17.13
						9	10.0	FWD	NK	2.50	0.00	0.00	5.50
						10	10.0	FWB	CS	2.50	0.00	0.00	3.70
						11	10.0	FWC	NK	2.50	0.00	0.00	3.70
						12	16.0	FWA	NK	2.50	0.00	0.00	13.63
weldid	*sysid*	*wdiam*	*wtype*	*wloc*	*ntgts*	*tgtno*	*tgtdia*	*tgtsys*	*tgttyp*	*tgtthk*	*tgtlen's*		
MIXTURE 2	1	22.0	S1	M	3	1	22.0	RCA	NK	3.00	11.00	18.33	25.67
						2	10.0	RRA	CS	2.50	0.00	0.00	13.00
						3	16.0	RMA	MR	3.00	0.00	0.00	5.50

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D. V. Rao, W. Bernahl*, J. Brideau, C. Shaffer, F. Souto

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10. SUPPLEMENTARY NOTES

M. L. Marshall, Jr., NRC Project Manager

11. ABSTRACT (200 words or less)

The BLOCKAGE 2.5 code described in this User's Manual was developed by the United States Nuclear Regulatory Commission (NRC) as a tool to evaluate licensee compliance with NRC Bulletin 96-03, "Potential Plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling Water Reactors". As such, BLOCKAGE 2.5 provides a generalized framework into which a user can input plant-specific and insulation-specific data for performing analyses in accordance with Regulatory Guide 1.82, Rev. 2. This user's manual describes the capabilities of BLOCKAGE 2.5 along with a description of the graphics user's interface provided for data entry. Each input/output dialog is described in detail along with special considerations related to developing and executing BLOCKAGE. Also, several sample problems are provided such that user can easily modify them to suit a particular plant of interest. The models used in BLOCKAGE 2.5 and their validation are presented in the accompanying NUREG/CR-6371.

The BLOCKAGE models were designed to be parametric in nature allowing the user flexibility to examine the impact of several modeling assumptions and to conduct sensitivity analyses. As a result, BLOCKAGE 2.5 results are known to be very sensitive to the user provided input. It is therefore strongly recommended that users become thoroughly familiar with BLOCKAGE models and their limitations as described in NUREG/CR-6224.

12. KEY WORDS/DESCRIPTORS (List word or phrases that will assist researchers in locating the report.)

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Loss of NPSH
Debris Generation
Debris Transport
Debris Interceptors
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