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DRAFT

Individual Plant Examination Database

User's Guide

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ABSTRACT

The Individual Plant Examination (IPE) database stores structured information about plant designs, core damage frequency (CDF) and containment performance obtained from the IPEs which licensees of nuclear power plants conducted in response to U.S. Nuclear Regulatory Commission Generic Letter 88-20. The IPE database records the presence or absence of hardware in each design, characterizes its functional dependencies, and relates these features to the CDF and containment performance. The IPE database supports detailed inquiries into these characteristics for a specific plant or class of plants. In particular, the IPE database is designed to answer questions that enable interested parties to compare the CDF and containment performance of boiling- and pressurized- water reactors (BWRs and PWRs) as a function of their design features, on the basis of information found in the IPE submittals.

It should be noted that the information in the IPE database has not been verified or validated. The database contains only information taken from the original IPEs submitted by the licensees and does not contain any changes to this information made because of updates to the licensees' IPEs.

To query the IPE database, two programs have been developed. The first is a self-contained, user friendly, menu-driven program written in Microsoft's Visual Basic language. This program answers the "basic queries" most often asked about the IPE submittals, through a process of sorting records within the IPE database. Queries of this type can be improvised on the spot. Other "advanced queries" that call for calculations, linking of data files, and ranking or sorting on the basis of calculation can be performed using the programming language within such personal computer data management applications as dBASE, Access, or Paradox. This IPE database user's guide provides guidance for formulating basic and advanced queries. The guidance for advanced queries is given in terms of Microsoft Access 2.0.

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1. INTRODUCTION

The Individual Plant Examination (IPE) database stores structured information about plant designs, core damage frequency (CDF) and containment performance. It records the presence or absence of hardware in each design, characterizes its functional dependencies, and relates these features to the CDF and containment performance. The IPE database supports detailed inquiries into these characteristics for a specific plant or class of plants. In particular, the IPE database is designed to answer questions that enable interested parties to compare the CDF and containment performance of boiling- and pressurized- water reactors (BWRs and PWRs) as a function of their design features, on the basis of information found in the IPE submittals.

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The IPE database reflects the contents of the IPE submittals as prescribed in NUREG-1335, "Individual Plant Examination: Submittal Guidance." The key information called for in NUREG-1335 are the plant-specific dependency table, dominant accident sequences, and release categories. To some extent, the level of detail presented in these areas varies among different submittals because NUREG-1335 provides the licensees substantial latitude in the presentation of required information. The present release of the IPE database reflects the level of detail that can reasonably be expected to be found in the majority of submittals.

Experience has shown that risk comparisons among plants can be driven by differences in plant design as well as differences in how analysts have taken credit for possible alternative means of core cooling. As a result, comparisons among plants can be misleading unless analytical differences are properly accounted for. Accordingly, another essential element of the IPE database (in addition to the dependency table, dominant accident sequences, and release categories mentioned above), is information about the success paths and design features for which each submittal has taken credit.

The backbone of the IPE database is a list of BWR and PWR systems that establish a consistent basis for accurate description or tabulation of the following characteristic:

- the design of any BWR or PWR
- plant-specific dominant accident sequences
- the success paths (its mission success criteria) assumed in the IPE submittals

The IPE database comprises 15 different database files, each of which stores a different type of information. In addition, four data files were generated to provide high level (summary) information regarding the IPE front-end and back-end analyses. Table 1.1 lists these files and identifies the types of information they contain. Figure 1.1 shows the relationships between major elements of the IPE database. Several of these elements contain field names in their file(s) corresponding to elements of the basic system list (i.e., system names: A, B, C, ...etc.). This correspondence is the essential linkage that relates accident sequences to functional dependencies. This is why the system list is referred to as the "backbone" of the IPE database.

Table 1.1 List of data files

Database table	Data entry	Data file name
General	General plant information	GENERAL
Level 1	BWR frontline systems	FRONTLIN
	PWR frontline systems	FRONTLIN
	BWR support systems	SUPPORT
	PWR support systems	SUPPORT
	BWR dependency table	B-DEPEND
	PWR dependency table	DEPENTAB
	BWR core damage prevention strategies	B-STRAT
	PWR core damage prevention strategies	STRATEGY
	BWR mission success paths	B-MISSUC
	PWR mission success paths	MISSUC
	BWR accident sequence table	B-ACCSEQ
	PWR accident sequence table	ACCIDSEQ
Level 2	LWR C-matrix	C-MATRIX
	LWR plant damage states	PDS
	LWR source terms	STERMS
	Level 2 analysis parameters	REL-CLAS
High level (Summary)	LWR conditional containment failure probabilities	CONT-FM
	PWR initiators CDF	FREQ2
	BWR initiators CDF	FREQBWR2
	Level 1 summary (sequences CDF)	SEQCDF

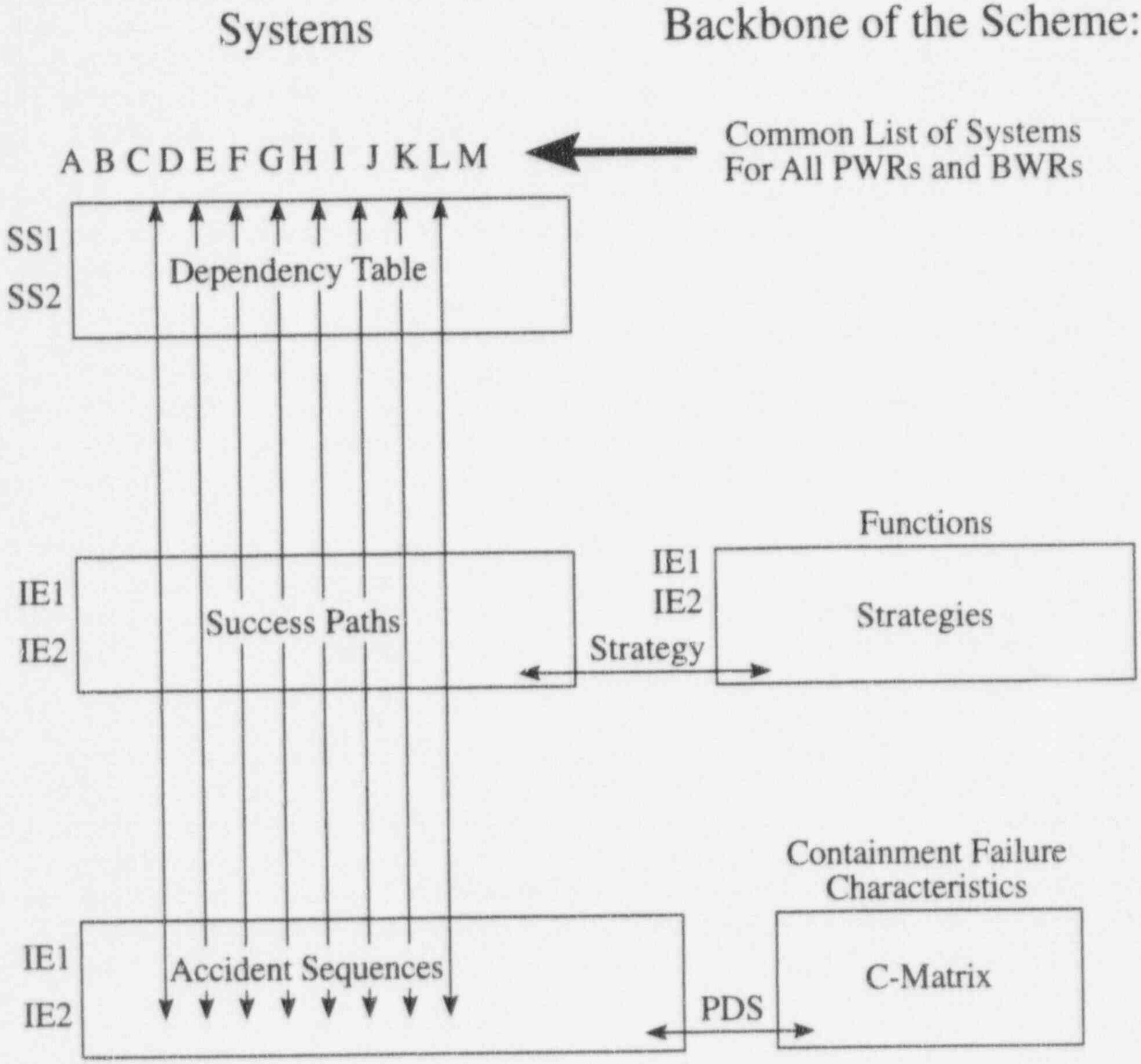


Figure 1.1 Structure of the IPE database

For purposes of illustration, consider the emergency feedwater (EFW) system (the safety-grade system supplying makeup to the secondary side) in a PWR. For each PWR plant, the dependency table database file (DEPENTAB) shows what other systems (SS1, SS2, etc.) support the EFW system. The mission success database file (MISSUC) shows what role (if any) this system plays in each of the success paths, and the dominant accident sequence database file (ADDIDSEQ) shows whether the EFW system fails in any given dominant accident sequence. The database file containing information on the dependence of BWR systems (B-DEPEND) is structured in a manner similar to that used in DEPENTAB. Finally, the frontline systems database file (FRONTLIN) shows how many trains of the EFW system each plant has and what this system is called at any given plant. The database stores similar information about every important BWR and PWR system.

The relationship between accident sequences and release categories is established through the "plant damage state" field, which is common to the accident sequence database (ADDIDSEQ or B-ACCSEQ) file and the containment matrix database file (C-MATRIX). NUREG-1335 did not prescribe scheme for plant damage state definitions, and none is presupposed there. If a given IPE submittal defines plant damage states, that scheme is used in the database. The presumption is that the IPE submittal partitions the frequency of all individual accident sequences over a set of release categories. If this is true, the IPE database can accommodate the variety found in the IPE submittals. However, this user's guide assumes that the definitions of release categories used in the IPE submittals reasonably correspond with the release category options used in the database. This scheme allows linkage of release categories to particular combinations of system failures, dependencies, mission success criteria, and so forth.

This user's guide provides detailed descriptions and illustrations of the operations used to extract information from the IPE database. Aside from these introductory comments and two appendices, this user's guide comprises of database tutorial sessions with a number of examples and instructions regarding database installation and queries. The appendices to this user's guide provide additional in-depth information about the IPE database. Appendix A presents a detailed description of the structure and major elements of the IPE database. Appendix B describes the conventions used in the IPE database to represent various modeling choices made in the IPE submittals.

2. BASIC QUERIES

The questions most often asked about the IPE database constitute "basic queries" that can be answered using a menu-driven program developed to provide a user-friendly interface for exploring the IPE database. Written in the Microsoft Visual Basic programming language, this program runs under the Microsoft Windows operating system. The major components of the program include two IPE database files (IPE.MDB and FREQ.MDB) and the executable Visual Basic program (IPE.EXE). Instructions for installing the menu-driven program are provided in the diskette labeled "SETUP." When installation is complete, an icon appears for the menu-driven program.

2.1 Start-up

To initiate the menu-driven program, users simply click on the related icon and select "**Query the Database**" button in the "**Welcome**" window. A main menu window as shown in Figure 2.1 will appear.

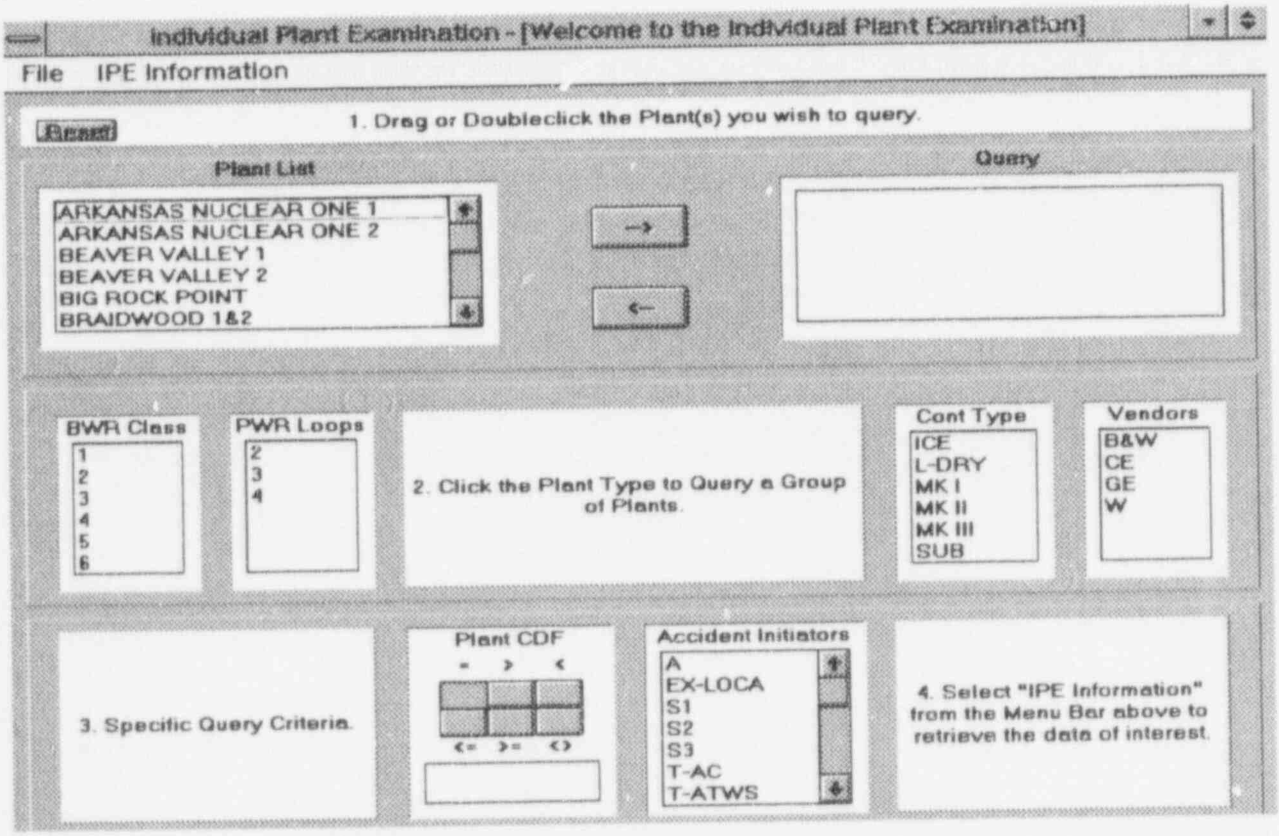


Figure 2.1 First selection screen, "Welcome to the IPE Database"

This window shown in Figure 2.1 presents the main menu for searching the database, and provides options that allow users to specify a plant or group of plants as the target(s) of the database search. Users can select plant individually by name (using the top left-hand plant name list box) simply by double-clicking the desired plant name in the **Plant List** box (in the upper left portion of the window) or by dragging the plant name from the **Plant List** box to the **Query** box (on the right side of the window). After selection, the name of the selected plant is removed from the **Plant List** box and appears in the **Query** box. Users can select multiple plants by repeating the selection procedure. Users can also "de-select" a plant by double-clicking the plant names in the **Query** box or dragging the plant names from the **Query** box back to the **Plant List** box.

As an alternative, users can search the IPE database for information related to plants that share selected characteristics, such as the type of reactor (BWR or PWR), nuclear steam supply system (NSSS) vendor, or containment type (using the box in the middle of the window). For example, users can restrict the selection and display of data to plants that have CDFs with a specified value, or to a particular accident initiator. (Table A.1.7 of Appendix A describes the notations used in the IPE database for the various accident initiators.)

The screen illustrated in Figure 2.2 shows the selection of PWR plants with Westinghouse 4-loop design. This screen restricts the search and display of IPE data to plants that satisfy the above conditions. To select or de-select ***all*** items under a given category, users simply click on the heading (**BWR Class** or **PWR Loops**) using the left mouse button. A "**Reset**" button (in the upper left corner of the window) enables users to clear the screen for making new selections.

The menu items shown at the top of the screen for this program comprise the menu for "**IPE Information**." Users may select the desired item after selecting the target plants and other conditions. Figure 2.2 shows the submenu items for this top menu. They are described in more detail in the following sections.

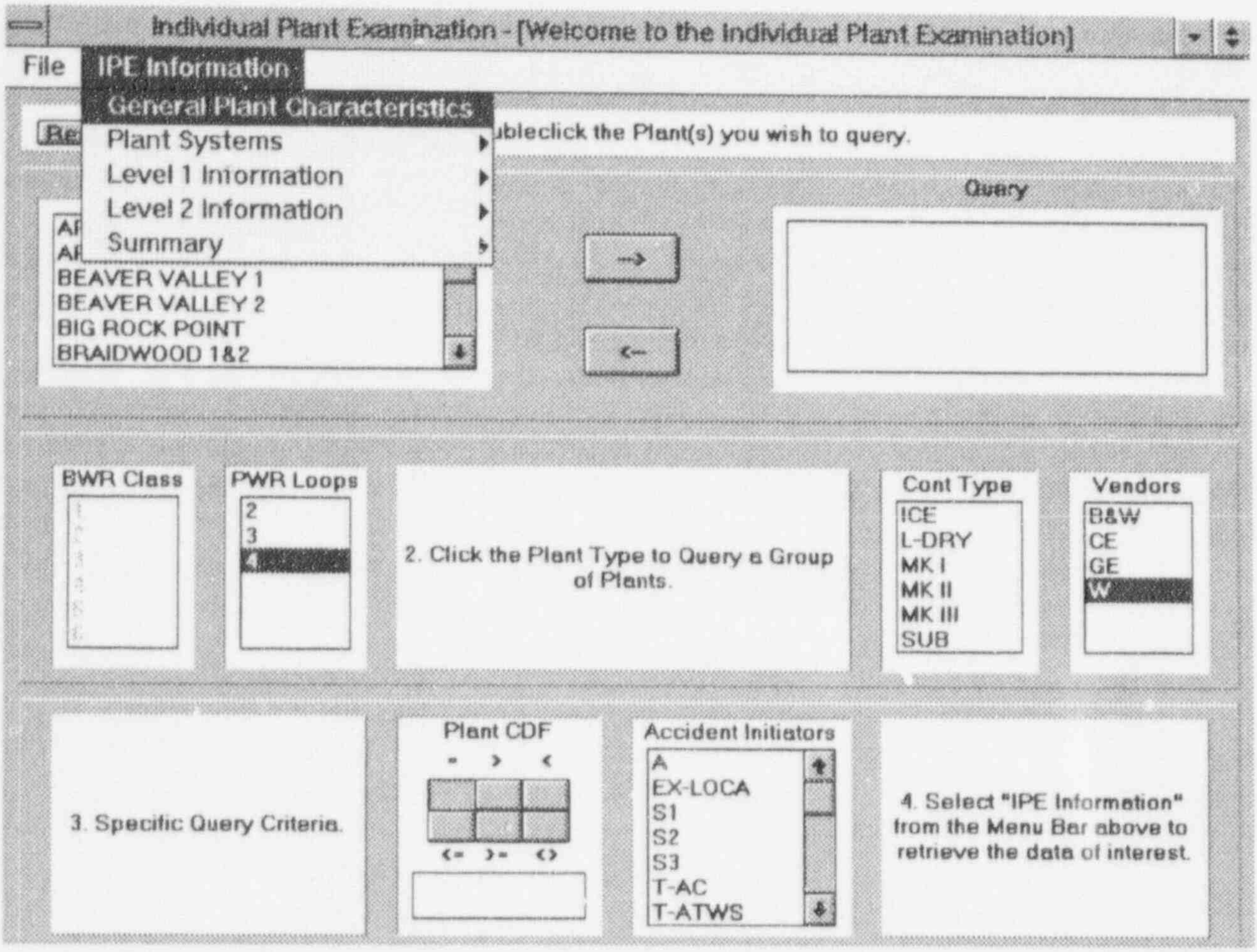
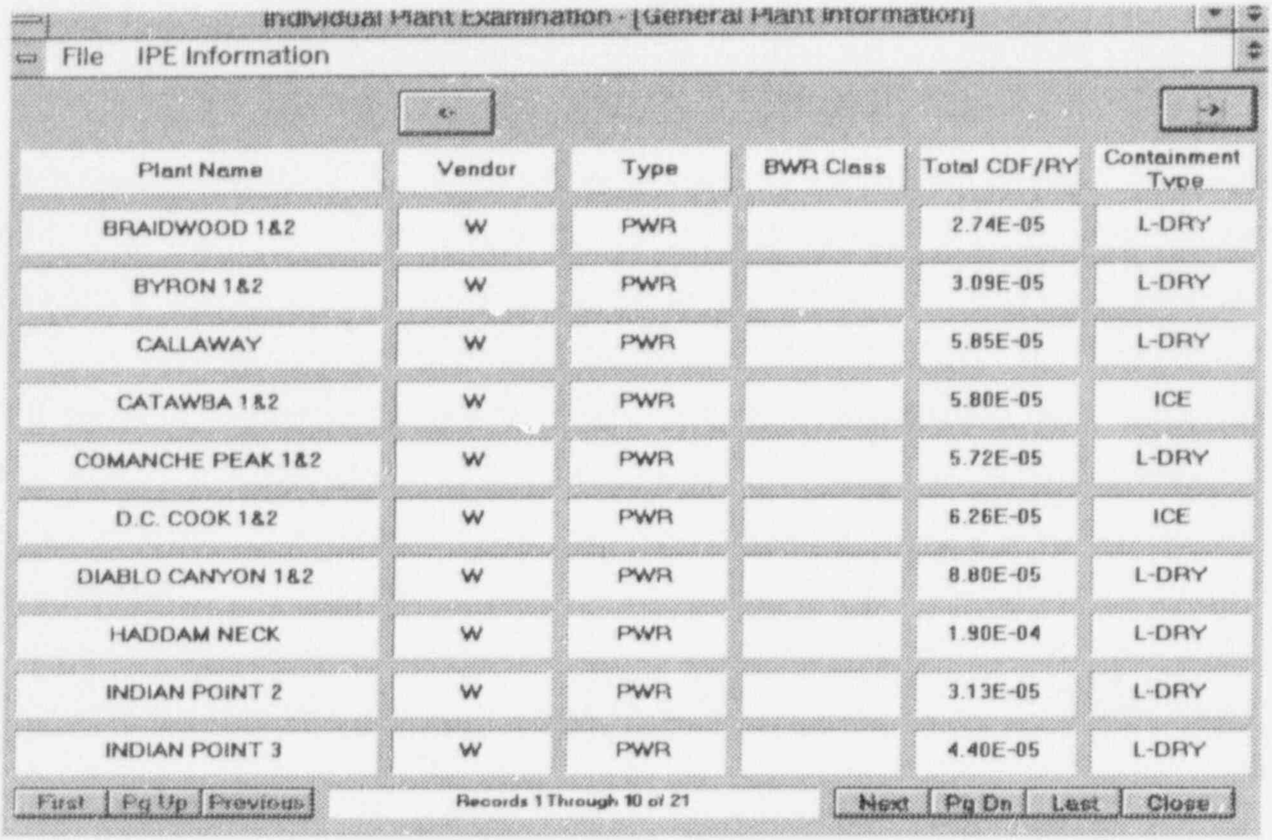


Figure 2.2 Selection of top menu items

2.2 General Plant Characteristics

Figure 2.2 shows a representative query targeting the general plant characteristics of four-loop PWRs manufactured by Westinghouse. As shown, the "**4**" and "**W**" are highlighted in the **PWR List** box and the **Vendor List** box, respectively. After the user selects "**General Plant Characteristics**" from the "**IPE Information**" menu item (by clicking the left mouse button), the program displays the answer to this query on the screen (as shown in Figure 2.3) using data exclusively related to four-loop Westinghouse plants. Specifically, the program displays data regarding **"General Plant Characteristics,"** as recorded in the General Plant Information database table (GENERAL) discussed in Section A.1.1 of Appendix A. By clicking the left mouse button on the arrows at the top of the screen, users can scroll the data horizontally to the left or right: the buttons at the bottom of the screen enable users to scroll the data vertically (up and down). Clicking any of the column headings causes the program to sort the data by the contents of the database field represented by the heading. For example, clicking "**Total CDF/RY**" causes the program to display in ascending order by CDF.



Plant Name	Vendor	Type	BWR Class	Total CDF/RY	Containment Type
BRAIDWOOD 1&2	W	PWR		2.74E-05	L-DRY
BYRON 1&2	W	PWR		3.09E-05	L-DRY
CALLAWAY	W	PWR		5.85E-05	L-DRY
CATAWBA 1&2	W	PWR		5.80E-05	ICE
COMANCHE PEAK 1&2	W	PWR		5.72E-05	L-DRY
D.C. COOK 1&2	W	PWR		6.26E-05	ICE
DIABLO CANYON 1&2	W	PWR		8.80E-05	L-DRY
HADDAM NECK	W	PWR		1.90E-04	L-DRY
INDIAN POINT 2	W	PWR		3.13E-05	L-DRY
INDIAN POINT 3	W	PWR		4.40E-05	L-DRY

Figure 2.3 Display screen for general plant information

2.3 Plant Systems

Figure 2.4 shows the plant systems selection screen for a representative query targeting four-loop Westinghouse PWRs with large-dry containments. After the user selects "**Front Line System**" from the "**Plant Systems**" menu item, the program displays another screen that enables the user to select the specific frontline systems to be addressed in the query. (Appendix A identifies the systems represented by the acronyms shown in this screen.) The program can also display descriptions of the selected systems when users point to an acronym and press the right mouse button. Users select the desired systems by "checking" the boxes to the left of the system acronym, and have the option to select multiple systems for display. Clicking the "**OK**" button after completing selection causes the program to display information regarding the selected systems for the designated plants. Clicking the "**OK**" button without selecting any specific system causes the program to display information regarding *all* frontline systems of the selected plants.

In the selection screens depicted in Figures 2.4 and 2.5, the user has limited the query to information regarding accumulators (ACC) and high pressure injection (HPI) systems for four-loop Westinghouse PWRs with large-dry containments. Figure 2.6 shows the query results, for which the program displays in alphabetical order by selected systems (obtained by clicking the heading of the "**System**" column on the screen). Specifically, Figure 2.6 shows that a total of 30 records satisfies the selection criteria, and Records 1 through 11 are displayed on this screen. The display screen shows the plant name, system acronym, number of trains of the system, other functions performed using of major components of the system, and additional notes. For example, the "**HPR**" under "**Other Function**" for the second record in the screen shows that for Braidwood, the HPI and the high pressure recirculation (HPR) systems share a major component (i.e., the pump). The presence of an additional note for a system is indicated by the "*" under "**Notes**" on the display screen. The note and additional information regarding the selected system can be displayed by double clicking the plant name of the selected system record. For example, double-clicking HADDAM NECK of the first record on the screen will open another screen showing additional information regarding the ACC system at Haddam Neck, including the note related to the system. Similar to the system selection screen (Figure 2.5), the program can display descriptive information for a system when users point to the system (e.g., ACC) and press the right mouse button.

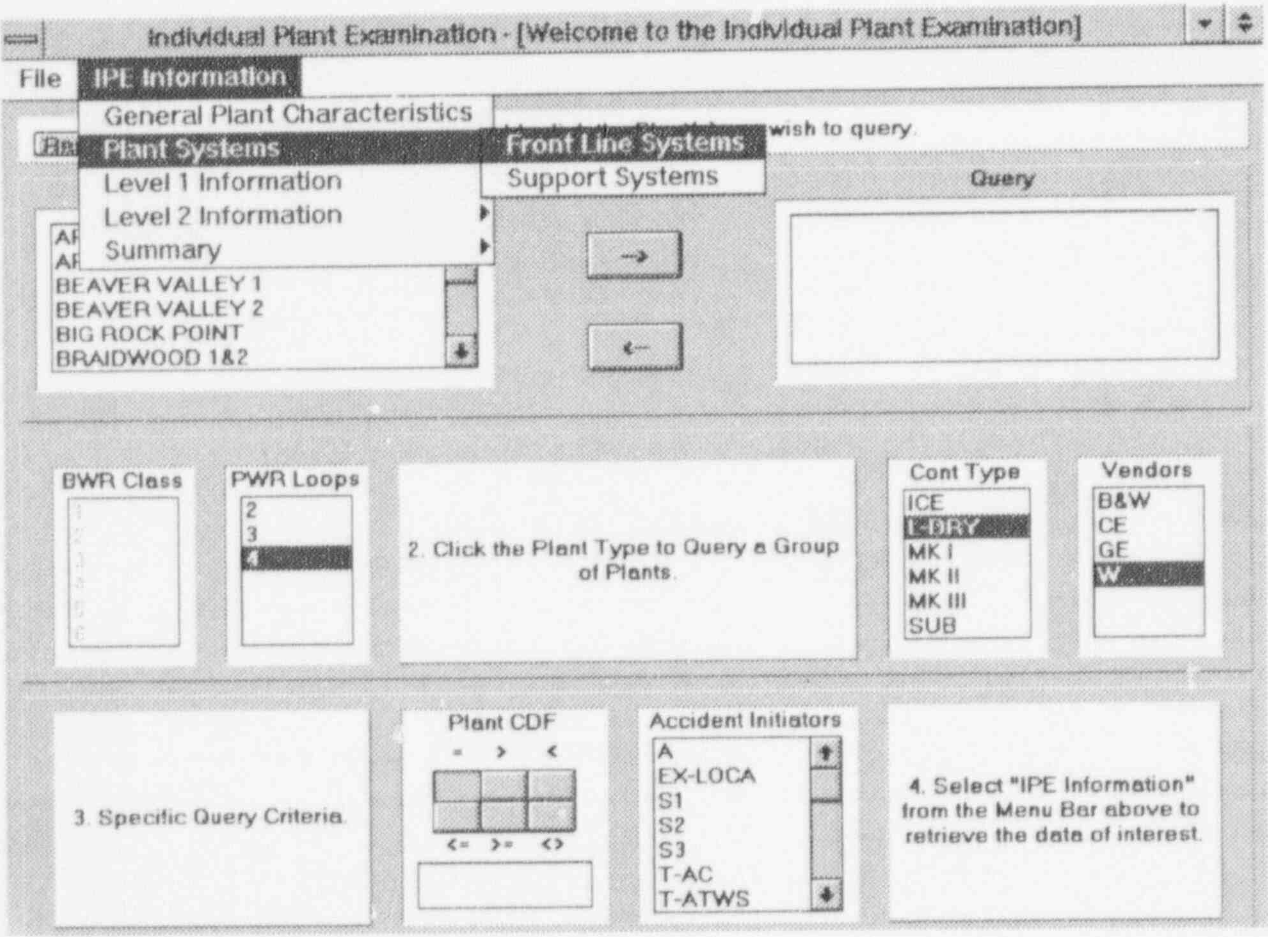


Figure 2.4 Menu items for plant systems

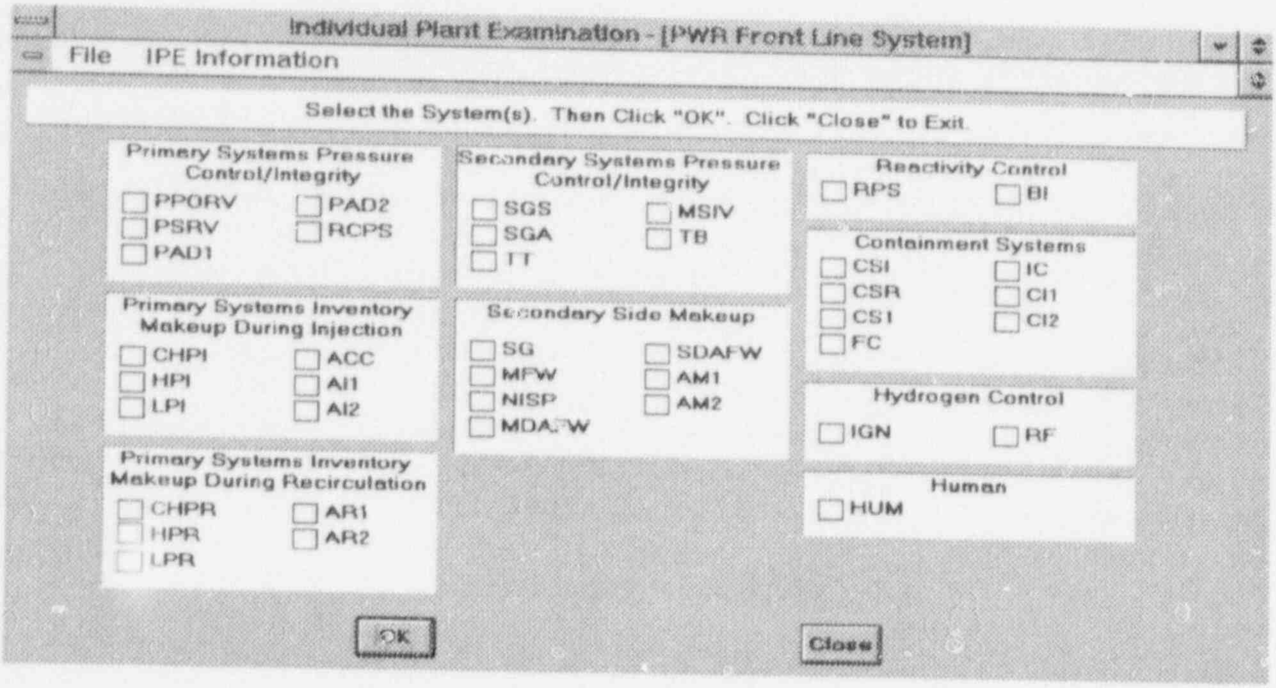
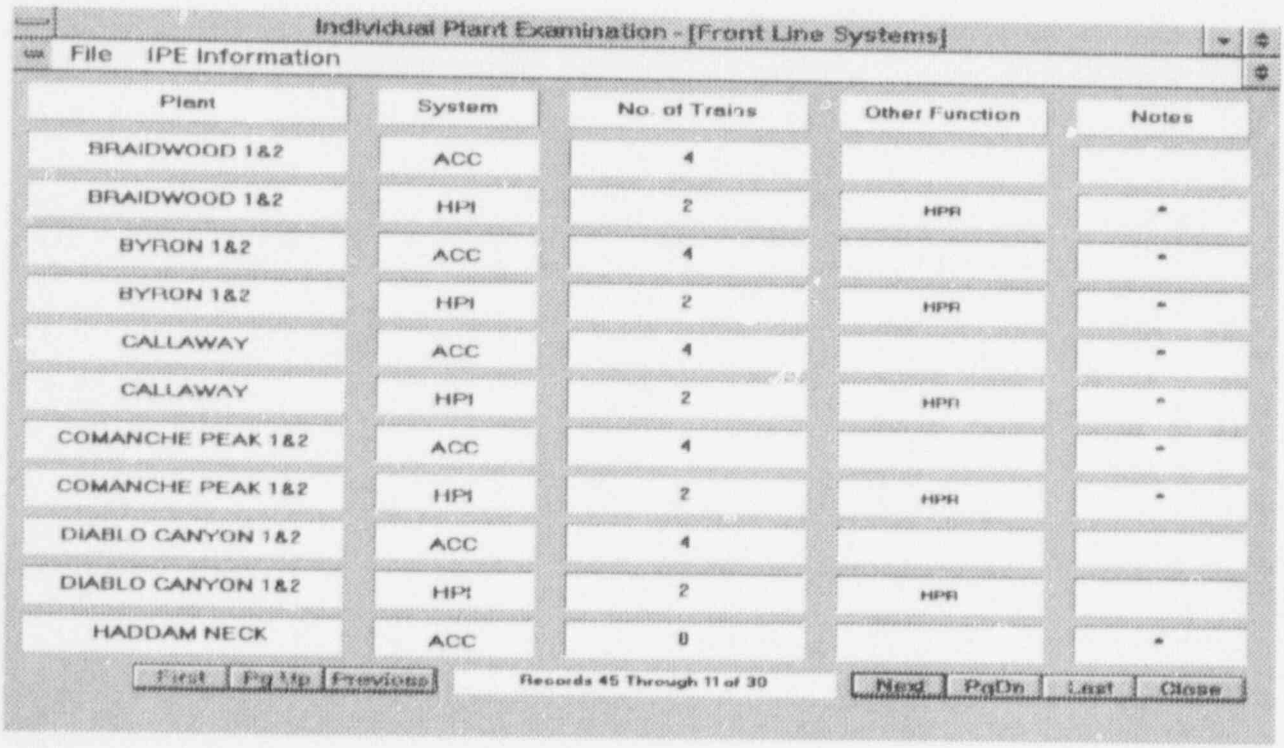


Figure 2.5 Selection of frontline systems for display



Plant	System	No. of Trains	Other Function	Notes
BRAIDWOOD 1&2	ACC	4		
BRAIDWOOD 1&2	HPI	2	HPR	*
BYRON 1&2	ACC	4		*
BYRON 1&2	HPI	2	HPR	*
CALLAWAY	ACC	4		*
CALLAWAY	HPI	2	HPR	*
COMANCHE PEAK 1&2	ACC	4		*
COMANCHE PEAK 1&2	HPI	2	HPR	*
DIABLO CANYON 1&2	ACC	4		
DIABLO CANYON 1&2	HPI	2	HPR	
HADDAM NECK	ACC	0		*

Figure 2.6 Display of frontline systems

The procedures for selecting and displaying information regarding support systems are similar to those used for frontline systems. Appendix A provides more detailed information about the data stored in the IPE database.

2.4 Level 1 Information

Figure 2.7 shows the menu items that users can select to limit the display of Level 1 information. These menu items include System Dependencies, Core Damage Prevention Strategies, Mission Success Paths, and Accident Sequences, as discussed in the following sections. Appendix A discusses database tables used to store data related to these items.

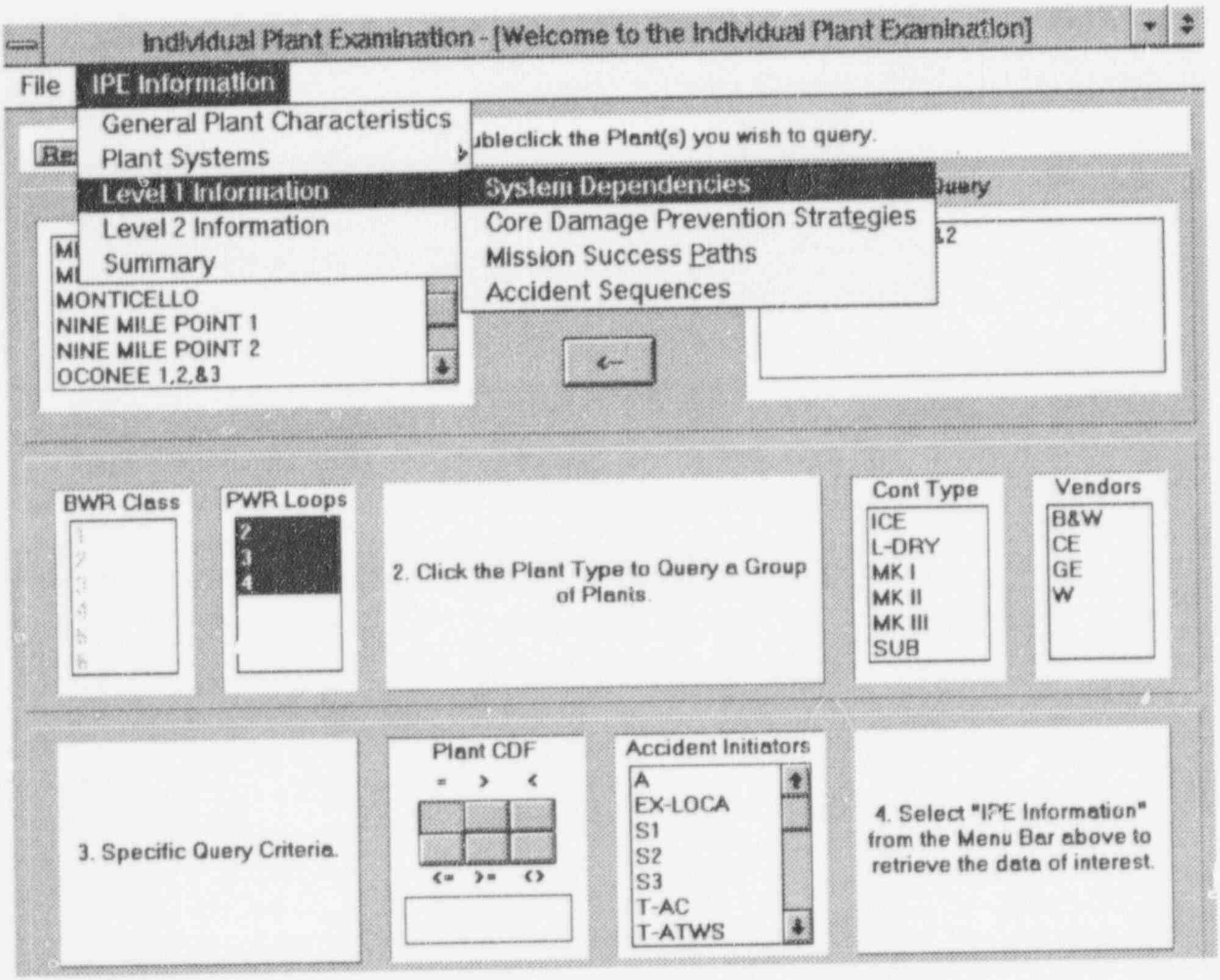


Figure 2.7 Main menu for selection of system dependencies

2.4.1 System Dependencies

The "**Welcome to the IPE Database**" screen enables users to limit a query to information regarding specific system dependencies. In the following example, the query is limited to dependencies specific to North Anna 1&2. After the user selects "**System Dependencies**" (as shown in Figure 2.7), the program displays another screen (Figure 2.8) to enable the user to select the desired dependent systems, the independent systems required to support operation of the dependent systems, and the types of dependencies between the dependent and independent systems. (The systems listed in the "**Systems**" box are the dependent systems while those in the "**Supporting Systems**" box are the independent systems.) The dependencies can be any of the types in the "**Dependency Type**" box. (Appendix A describes the various systems and dependency types.) Users can also cause the program to display descriptions of the system acronyms on the screen by pointing to the desired system acronyms and pressing the right mouse button.

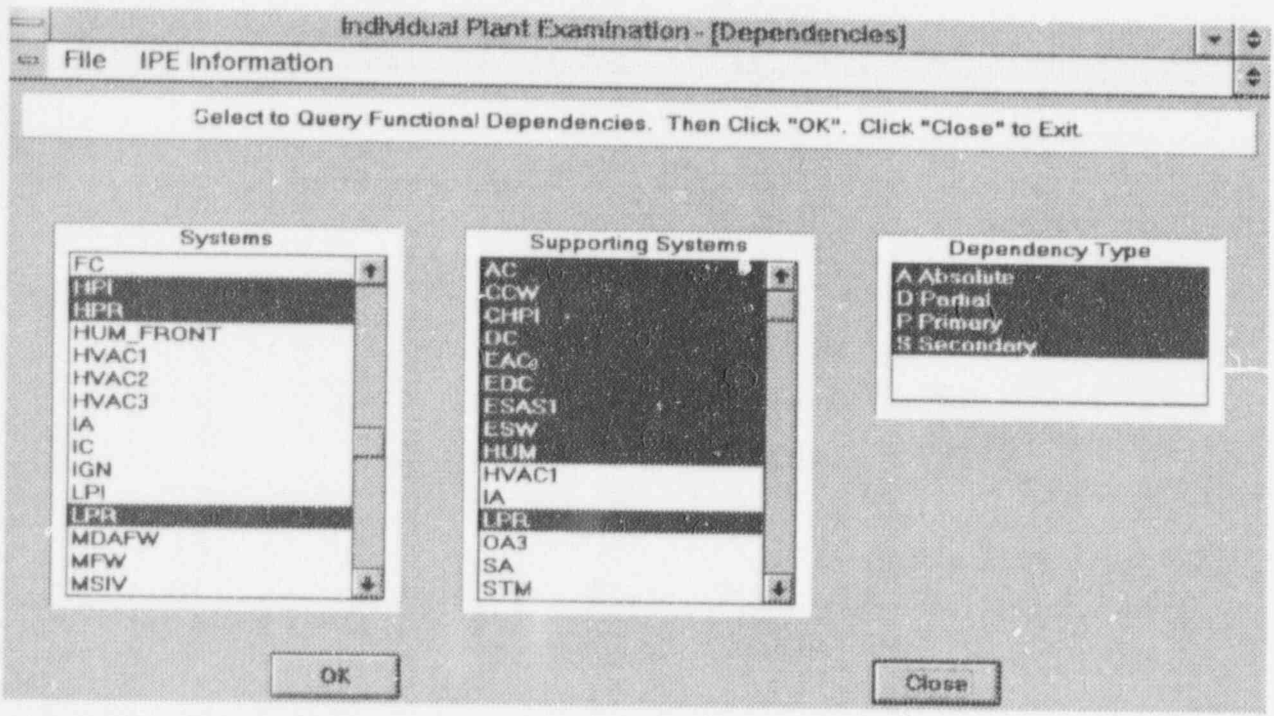
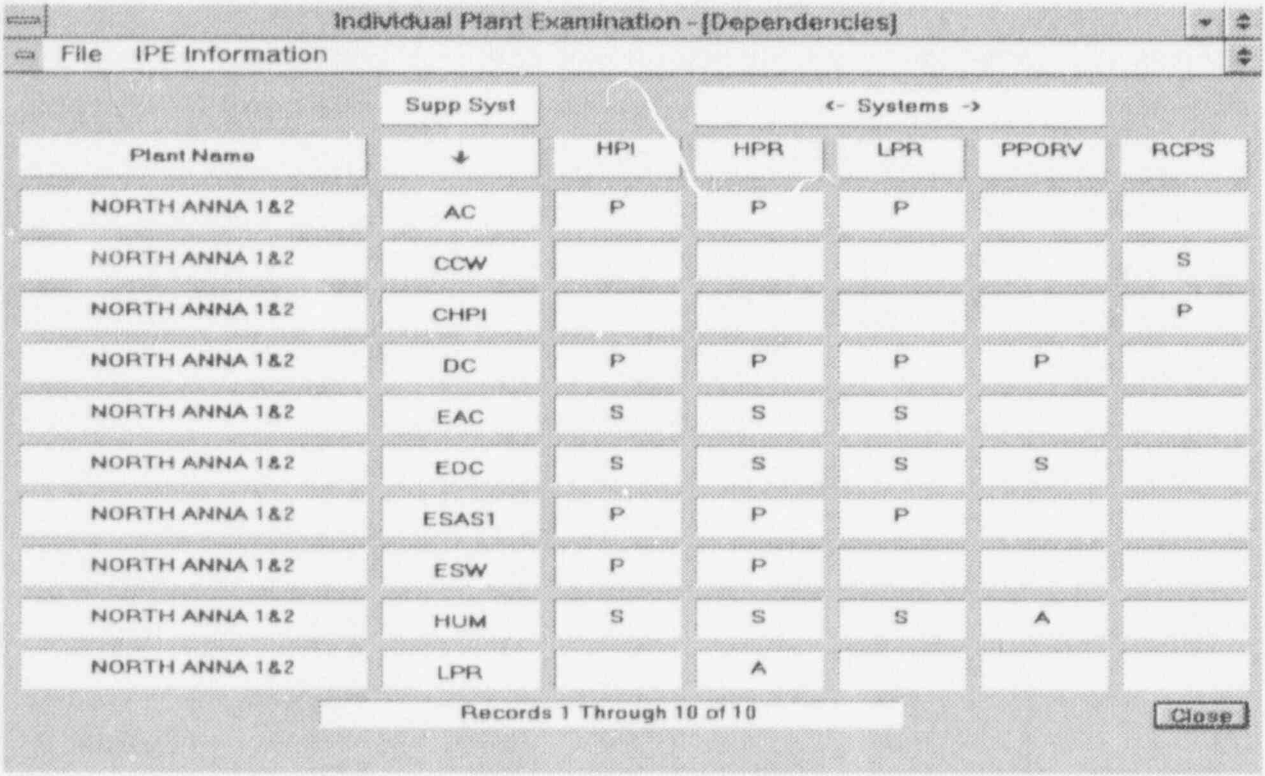


Figure 2.8 Selection of system dependencies for display

Figure 2.8 shows the systems and dependency types selected for data display in this example. Figure 2.9 shows the results of these selections. Specifically, Figure 2.9 shows that the HPI system has a "**Primary**" dependence on vital AC buses and a "**Secondary**" dependence on emergency diesel generators (EAC), indicating that the emergency diesel generators support the HPI system. Figure 2.9 also shows that HPR has an "**Absolute**" dependence on low pressure injection - recirculation (LP) indicating that HPR takes suction from LP and will not work if LP fails. The dependence of reactor coolant pump seals (RCPS) on both component cooling water

(CCW) and the charging system (CHPI) indicates that a seal LOCA would develop only if both the CCW and the CHPI fail. The "**P**" and "**S**" dependencies of HPR on signals from the engineering safety system (ESAS1) and operator actions (HUM) indicate that HPR will automatically be initiated on ESAS1 signals and can also be initiated by operator action. In some other plants, HPR operation requires operator action (e.g., to switch the system from the injection mode to the recirculation mode); in such instances, the program would display an "**A**" dependence of HPR on HUM.


Individual Plant Examination - [Dependencies]

File IPE Information

Plant Name	Supp Syst	HPI	HPR	LPR	PPORV	RCPS
NORTH ANNA 1&2	AC	P	P	P		
NORTH ANNA 1&2	CCW					S
NORTH ANNA 1&2	CHPI					P
NORTH ANNA 1&2	DC	P	P	P	P	
NORTH ANNA 1&2	EAC	S	S	S		
NORTH ANNA 1&2	EDC	S	S	S	S	
NORTH ANNA 1&2	ESAS1	P	P	P		
NORTH ANNA 1&2	ESW	P	P			
NORTH ANNA 1&2	HUM	S	S	S	A	
NORTH ANNA 1&2	LPR		A			

<- Systems ->

Records 1 Through 10 of 10

Close

Figure 2.9 Display of system dependencies

2.4.2 Core Damage Prevention Strategies

A core damage prevention strategy (CDPS) shows what combination(s) of safety functions may be needed to prevent core damage, given a particular challenge (i.e., an accident initiator.) Each unique combination of functions is termed a CDPS for that challenge, and any particular challenge may be addressed by one or more strategies. Figure 2.10 shows the screen used for CDPS selection regarding a given plant or group of plants. This screen is the same as that used for "**System Dependencies**," but for "**CDPS**," the screen is also used to select the challenges (i.e., accident initiators) as a basis for limiting data display. The screen presented in Figure 2.10 shows the selection of the "**A**" (i.e., large LOCA) initiator. This causes the program to display the CDPSs for a large loss-of-coolant accident (LOCA). The program will display the CDPSs for all selected accident initiators if the user selects more than one initiator. Similarly, the program will display the CDPS of all accident initiators stored in the database if the user does not select any accident initiators in this screen.

The accident initiators whose CDPSs are developed in the IPE database table depend on the accident event trees, and the accident initiators considered in the IPE submittals. Notably, the CDPSs may not be developed for all transient initiators in the IPE database when they are similar and the IPE submittals use a single accident event tree for all of them. Some IPE submittals use a single accident event tree developed for all transient events (including events initiated by the loss of both frontline and support systems). Therefore, the CDPSs in the database table are for representative transient initiators. For example, a single event tree is used to represent either a turbine trip (T-TT) or a reactor trip (T-RX).

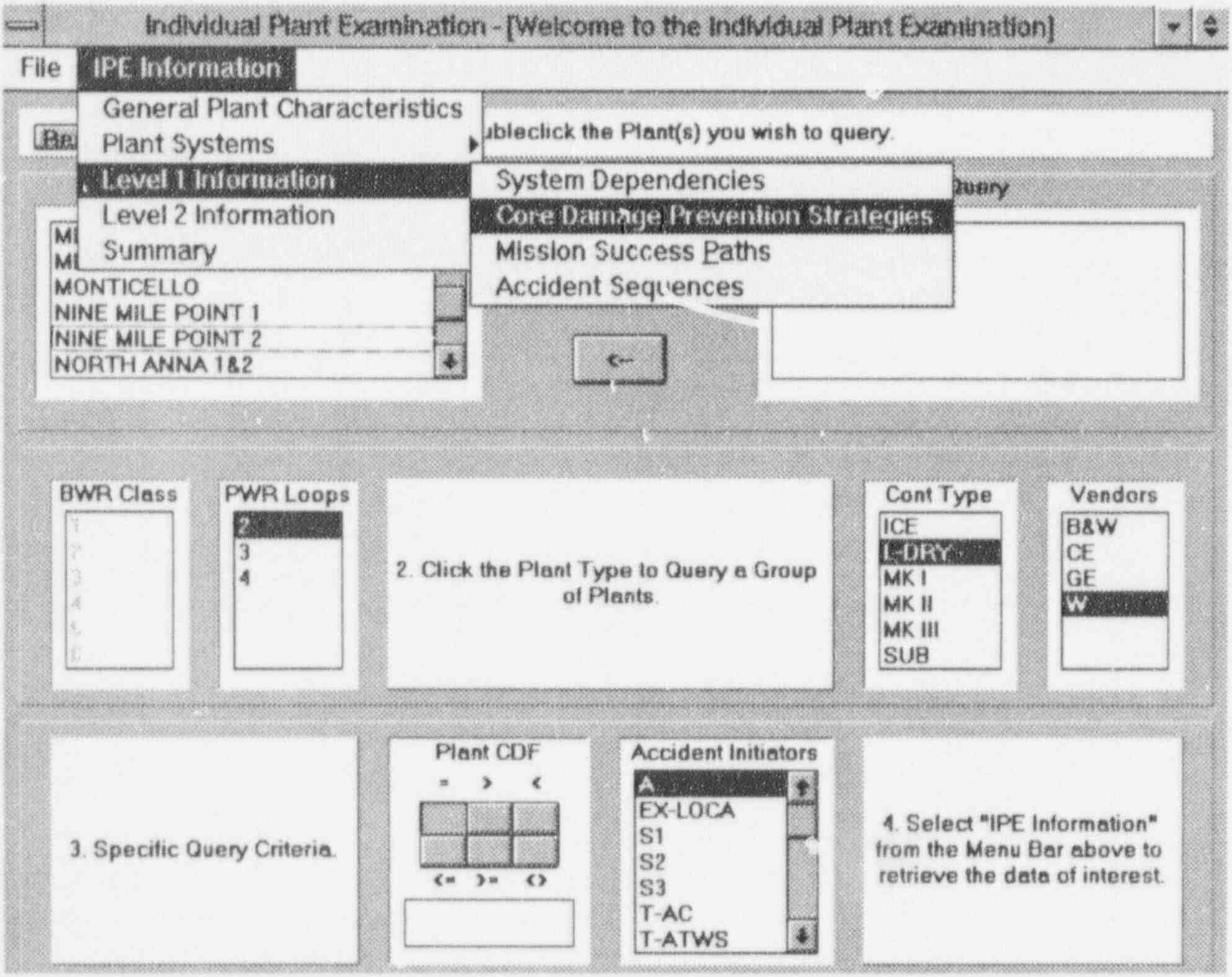


Figure 2.10 Selection screen of core damage prevention strategies

In addition to CDPSs, the process used to select accident initiators on the "Welcome to the IPE Database" screen (Figure 2.10) is also used for the menu items related to mission success paths, accident sequences, as well as initiating event summary data. Appendix A describes the accident initiators presented in the **Accident Initiators** box. However, some accident initiators that can be selected in the "**Accident Initiators**" box require special discussion. For example, EX-LOCA represents excessive LOCA or reactor rupture. Core damage is assured for this initiator and, therefore, no CDPSs are available for this initiator. CDPSs are also not available for an anticipated transient without scram (ATWS) or station blackout (SBO). These are not used as accident initiators, but are used to limit the selection of initiating event summary data displayed (as discussed in Section 2.6.3). If provided in the IPE submittals, the CDPSs for ATWS may be retrieved from the database by selecting T-ATWS in the "**Accident Initiators**" box. SBO is not treated in the IPE database as an accident initiator. However, if developed in the IPE submittals, the SOB-related CDPSs may be retrieved from the database by selecting T-LOOP in the "**Accident Initiators**" box (for loss of offsite power) with SBO denoted in the "**Notes**" field of the database table.

After the user selects the "**Core Damage Prevention Strategies**" item from the menu (Figure 2.10), the program displays the CDPS selection screen (Figure 2.11). The screen shows the safety functions that are involved in the CDPSs. Descriptions of the safety functions are provided in Appendix A. User can also view a brief description of the safety function on the screen by pointing to the specific safety function and pressing the right mouse button. If the user selects one or more of safety functions, the program will display those CDPSs that involve any of the selected safety functions (through an OR operation of the selected items). By contrast, the program will display all CDPSs if the user does not select any individual item.

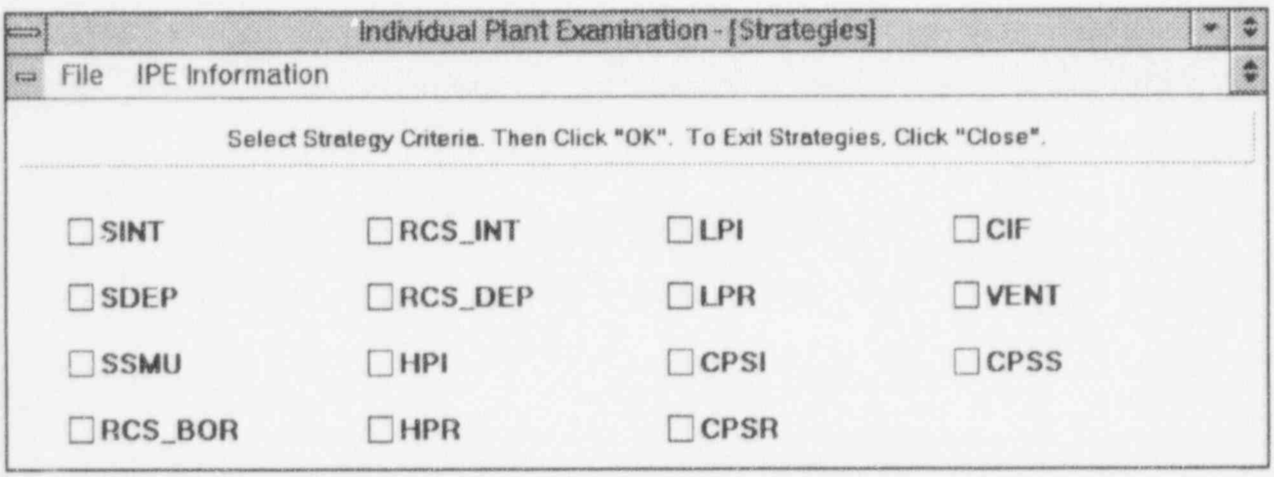


Figure 2.11 Selection screen for core damage prevention strategies

The screen depicted in Figure 2.12 displays the results of the selection indicated in Figure 2.10. Since we selected the "**A**" initiator (large LOCA) for two-loop Westinghouse plants with large-dry containments and did not select any item on the CDPS selection screen (Figure 2.11), the program displays all CDPSs for large LOCA for the selected plants (Figure 2.12). Figure 2.12 shows two CDPSs for Ginna and one CDPS for the other selected plants. Both of the CDPSs for Ginna require low pressure injection (LPI), low pressure recirculation (LP), and containment pressure suppression - recirculation (CPSR), but one of the two strategies (i.e., Strategy 1) requires an additional containment pressure suppression - injection (CPSI) safety function. This indicates that, in addition to core injection, Ginna also requires containment heat removal (CHR) by CPSR to prevent core damage in a large LOCA-initiated event.

The systems required to achieve the safety functions for the CDPSs are identified in the Mission Success Path (MSP) table. A review of the MSPs for Ginna (discussed in the next section) reveals that while Strategy 1 achieves CHR by containment spray injection (CPSI) with late recirculation (CPSR), Strategy 2 achieves CHR through the use of containment fan coolers (CPSR) running continuously from accident inceptions. Figure 2.12 also shows that while Ginna and Prairie Island require CHR to prevent core damage associated with a large LOCA, Kewaunee and Point Beach do not require this capability.

To obtain detailed information (e.g., the notes as denoted by a "*" in the **Notes** field on the screen) for the CDPSs, users simply double-click the plant name of the specific CDPS in the "**Plant**" column of the screen.

Individual Plant Examination - [Strategies]

File IPE Information

Plant	Initiator	Strategy	Functions Used	Notes
GINNA	A	1	LPI, LPR, CPSI, CPSR	*
GINNA	A	2	LPI, LPR, CPSR	*
KEWAUNEE	A	1	LPI, LPR	
POINT BEACH 1&2	A	1	LPI, LPR	
PRAIRIE ISLAND 1&2	A	1	LPI, LPR, CPSR	

Figure 2.12 Display of core damage prevention strategies

2.4.3 Mission Success Paths

The MSP database table shows what success paths the IPE assumed in its reported results. The MSPs relate to the CDPSs discussed in the previous section in that they show the plant systems that can be used to achieve the CDPS. There may be many MSPs associated with a given CDPS because different plant systems can be used to achieve the same safety function. For example, PWRs can achieve secondary heat removal (SSMU in Figure 2.11) through the use of either the motor-driven auxiliary feed water (MDAFW) system, the steam-driven AFW (SDAFW), or, in some cases, the pumps used for normal feedwater supply.

To select the plants and accident initiators for data display, users employ the same screen used for CDPS selection (i.e., Figure 2.10). After the user selects the Mission Success Paths menu item, the program displays the related selection screen for Mission Success Paths (Figure 2.13). This screen and its associated menu for system selection are the same as for selection of frontline systems (Figure 2.5). On the MSP selection screen, the program displays only MSPs that involve all of the selected systems (through an "AND" operation). Conversely, the program displays all MSPs if the user does not select any system on the screen.

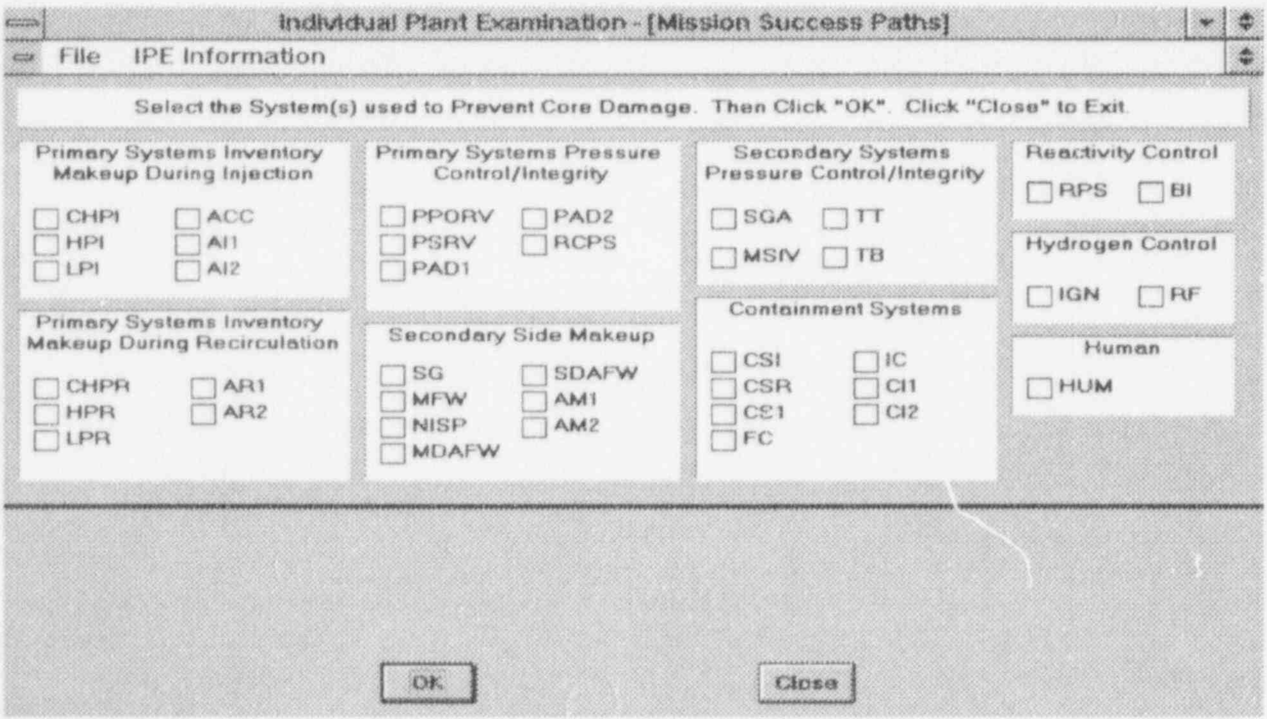


Figure 2.13 Selection screen for mission success paths

Figure 2.14 shows the results of the selection illustrated in Figure 2.13. Since no items are selected in Figure 2.13, the program displays all MSPs for the selected initiator (i.e., the A initiator) for the selected plants (two-loop Westinghouse PWRs). Figure 2.12 shows that Ginna has two CDPSs, and Figure 2.14 shows that there is one MSP for each of the two CDPSs. By contrast, Figure 2.14 shows two MSPs (with Success Paths 1 and 2) for the single CDPS for Prairie Island.

Next, the user can view a display of the systems required for the MSPs simply by double-clicking the plant name associated with the specific MSP. For example, double-clicking the plant name (i.e., Prairie Island 1&2) associated with Success Path 1 and Strategy 1 causes the program to display the systems required for this MSP. As shown in Figure 2.15, those systems include LPI, LPR and CSR (containment spray recirculation). Figure 2.15 also shows that one train (or one pump) of each of the above systems is required for success. These systems are required to satisfy the LPI, LP, and CPSR safety functions in Figure 2.12 for the CDPS (i.e., Strategy 1). In addition, Figure 2.15 indicates that LP and CSR operation requires operator intervention (denoted by the "**H**" suffix to the numbers used to indicate the required number of trains for the systems).

Individual Plant Examination - [Mission Success]

File IPE Information

Plant	Initiator	Strategy	Succ Path	
GINNA	A	1	1	
GINNA	A	2	1	
KEWAUNEE	A	1	1	
POINT BEACH 1&2	A	1	1	
PRAIRIE ISLAND 1&2	A	1	1	
PRAIRIE ISLAND 1&2	A	1	2	

Figure 2.14 Display of mission success paths

In addition to the "**H**" suffix, another suffix that is frequently used in the IPE database is the "**S**" suffix. This suffix indicates that a given system is required to support another system that performs a safety function to prevent core damage. For example, HPR is required to prevent core damage for some accident. However, the availability of the HPR safety function requires the operation of both the HPR and LPR systems. This is because the HPR pumps take suction from the LPR system discharge and their availability, therefore, relies on operation of the LPR system. The requirement of the LPR system for such cases is denoted by an "**S**" suffix. Appendix A describes the various systems and the associated number designators (including the suffix). In addition, users can obtain a display of brief descriptions on the screen by pointing to the item and pressing the right mouse button.

Figure 2.15 shows the system requirement for MSP 1. A display of the system requirement for MSP 2 for the same CDPS (i.e., Strategy 1 for Prairie Island) shows that the CPSR safety function can also be achieved through operation of two of the containment fan coolers. As shown in Figure 2.15, the success of the LPI function for Prairie Island does not require the accumulators (ACCs). Display of the MSPs for other plants (e.g., Kewaunee) shows that, in addition to one LPI pump, at least one accumulator is required for successful low-pressure injection.

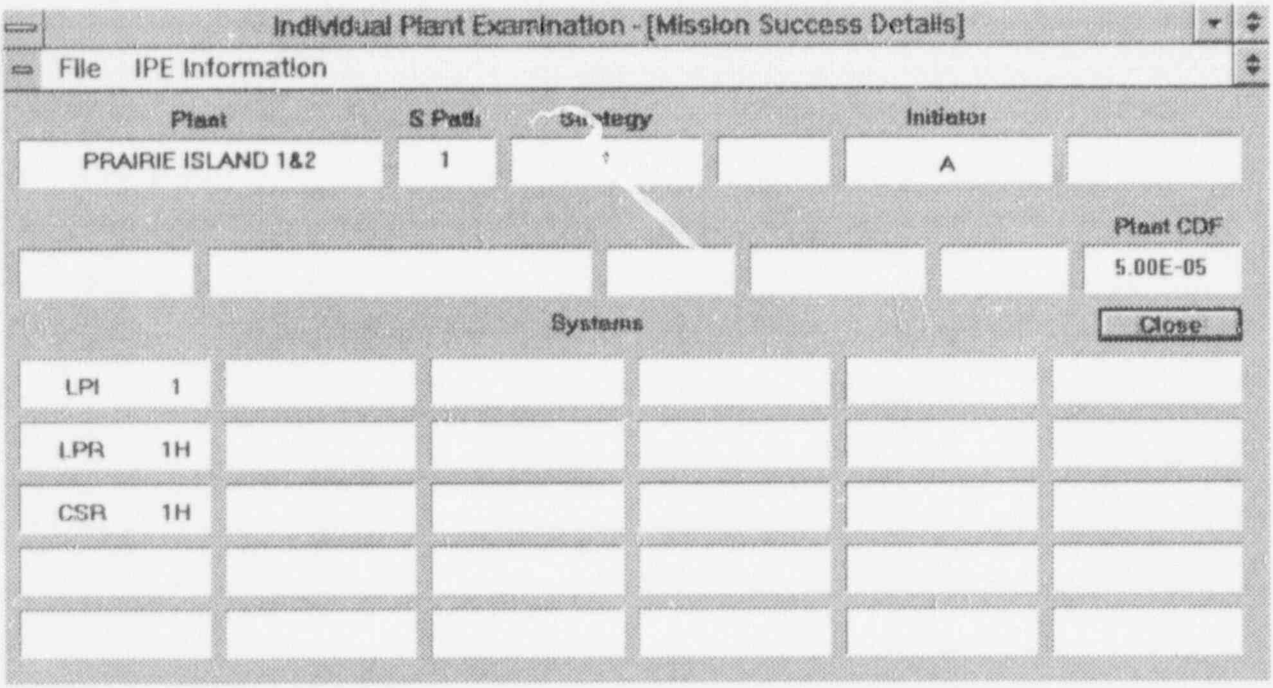


Figure 2.15 Detailed display of mission success paths (system requirements)

2.4.4. Accident Sequences

The database table for accident sequences (B-ACCSEQ and ACCIDSEQ) stores dominant accident sequences derived from the IPE submittals. The object is to record which systems failures in the sequence lead to core damage, what functional failures go along with these failures, and with what frequency of the sequence occurs. The database tables record the PDSs for the accident sequences, if available in the submittals. These PDSs can then be used to determine the containment failure profile for the accident sequence (as obtained from the Level 2 analyses of the IPE submittals).

To select the plants and accident initiators for accident sequences, users employ the screen used for core damage prevention strategies (Figure 2.10). After the user selects the **Accident Sequences** menu item, the program displays the selection screen for accident sequences (Figure 2.16). The top part of this screen, which is similar to that of the MSP selection screen (Figure 2.13), allows users to select systems that may fail in the sequences. The bottom part of the screen shows the selection of the support systems, attributes, and causes for which accident sequences should be displayed. Once the user makes the desired selection, the program displays only those sequences that satisfy the properties selected in these boxes. For example, if the user selects SBO (station blackout) in the **Attributes** box, the program displays only those sequences involving SBO in the attributes field of the database table.

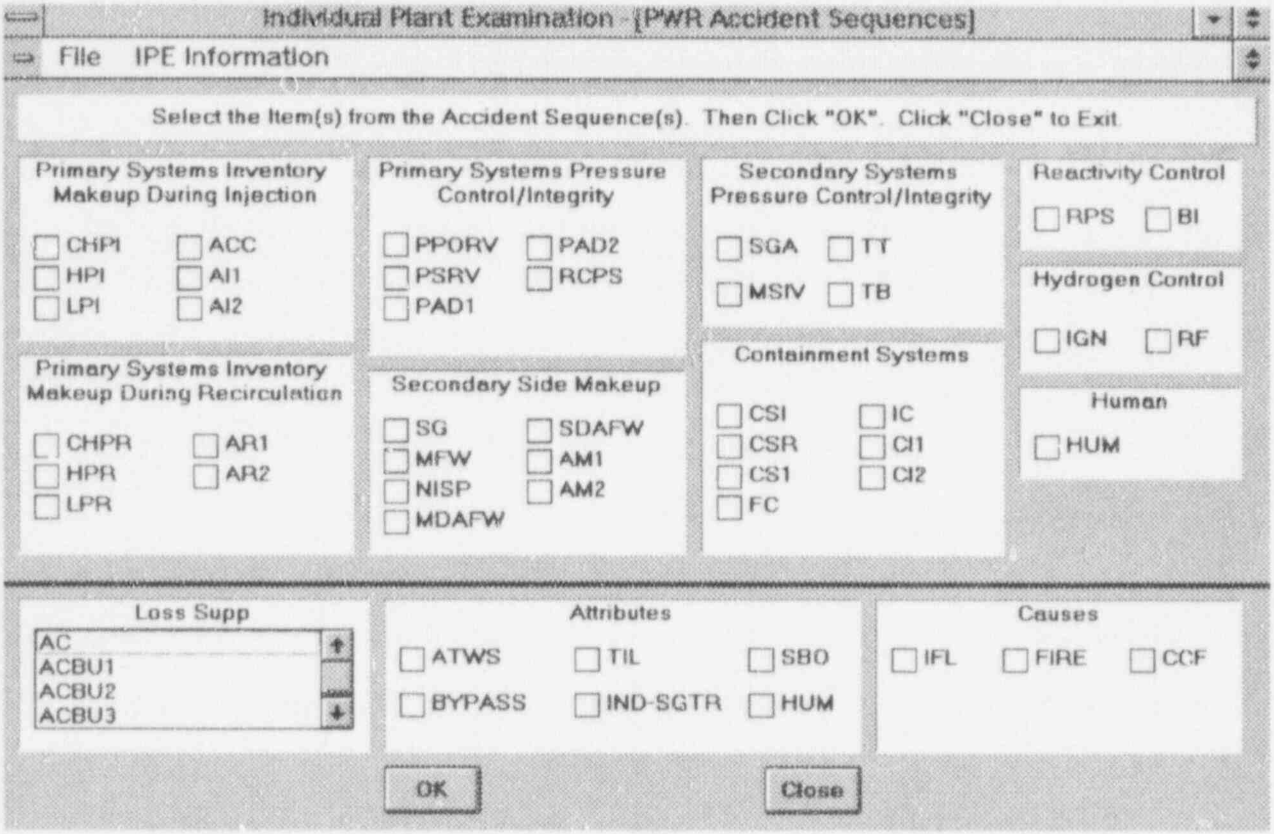
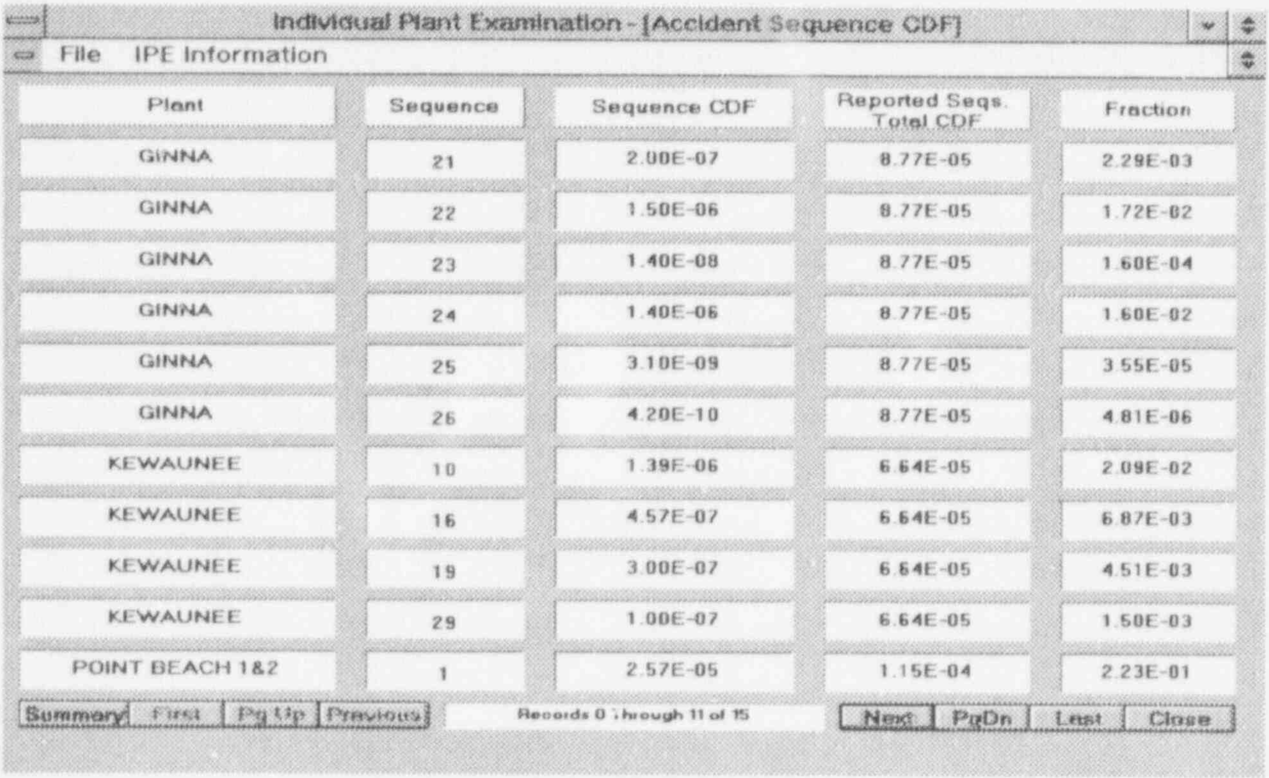


Figure 2.16 Selection screen for accident sequences

It should be noted that licensees have considerable freedom in how they report accident sequences in the IPE submittals. Furthermore, the IPE submittals present only a limited number of sequences. The SBO sequences displayed by the above selection are those that are presented in the submittals as involving SBO, and they may not include all sequences identified in the IPE analyses. As a result, the total CDF associated with the SBO sequences for a plant may be less than that shown in the summary results for the plant (which will be discussed later). The difference between the total CDF of the sequences recorded in the IPE database and the total plant CDF derived from all sequences identified in the IPE analyses is represented in the IPE database by a record (in the accident sequence table) with a "REMAINDER" initiator.

Figure 2.17 shows the results of the selection illustrated in Figure 2.16. Since no items are selected in the example shown in Figure 2.16, the program displays all "**A**" (or large LOCA) sequences for the selected plants. For each plant, the parameters displayed include the plant name, sequence numbers, sequence frequencies (**Sequence CDF** on the screen), total frequencies of the selected sequences (**Reported Sequences Total CDF**), and the fractions of the sequence frequencies to the total frequency (the ratios of **Sequence CDF** to **Reported Sequences Total CDF**).



Plant	Sequence	Sequence CDF	Reported Seqs. Total CDF	Fraction
GINNA	21	2.00E-07	8.77E-05	2.29E-03
GINNA	22	1.50E-06	8.77E-05	1.72E-02
GINNA	23	1.40E-08	8.77E-05	1.60E-04
GINNA	24	1.40E-06	8.77E-05	1.60E-02
GINNA	25	3.10E-09	8.77E-05	3.55E-05
GINNA	26	4.20E-10	8.77E-05	4.81E-06
KEWAUNEE	10	1.39E-06	6.64E-05	2.09E-02
KEWAUNEE	16	4.57E-07	6.64E-05	6.87E-03
KEWAUNEE	19	3.00E-07	6.64E-05	4.51E-03
KEWAUNEE	29	1.00E-07	6.64E-05	1.50E-03
POINT BEACH 1&2	1	2.57E-05	1.15E-04	2.23E-01

Figure 2.17 Display of accident sequences

Users can obtain a display of more detailed information about the sequences simply by pointing to the plant name associated with the sequence and pressing the right mouse button. Figure 2.18 shows the detailed information for Sequence 10 of Kewaunee. As shown in this figure, core damage occurs because of the loss of LPR and HUM. The "*" next to HUM indicates operator error, and the "**C**" next to LPR indicates that the loss of LPR results from the failure of other systems (an operator error in this case). The data in the "**Notes**" field describe the failure by stating, "**operator fails to establish low pressure recirculation**." The screen also shows that the sequence does not involve failure from any support system or from any cause, e.g., internal flooding (IFL), or common cause failure (CCF). HUM appears in the "**Attribute**" box to indicate that the sequence involves human error. Besides HUM, the sequence does not involve any other attribute included in the **Attributes** box of the selection screen (e.g., SBO, ATWS, etc.). Appendix A describes the systems and the associated code next to the systems (e.g., **C**). In addition, users can view a display of brief descriptions on the screen simply by pointing to the item and pressing the right mouse button. The detailed information for other sequences shown in Figure 2.17 can be displayed without returning to Figure 2.17 by clicking on the "**First**," "**Next**," or "**Last**" buttons on the bottom of the screen shown in Figure 2.18.

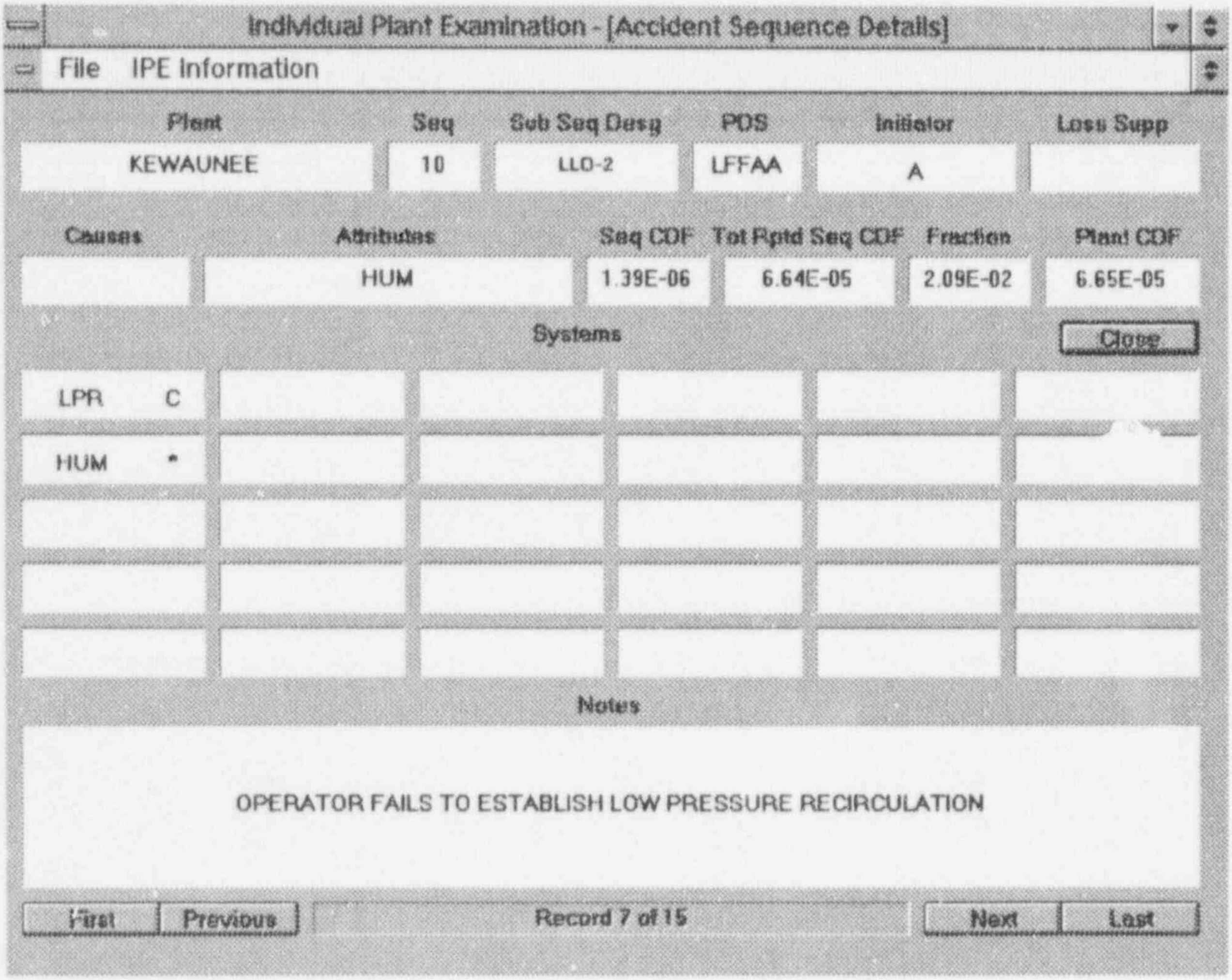


Figure 2.18 Detailed display of accident sequences

Users can also view a display of summary results for the selected sequences by clicking the **Summary** key on the screen shown in Figure 2.17. Figure 2.19 shows the summary results, which include the total CDFs reported in the IPE submittals for the plants, total CDFs of the selected sequences (in this case, the large LOCA sequences), and the fractions of the total CDFs of the selected sequences to the total plant CDFs. Figure 2.19 shows that the total CDF of large LOCA sequences is 3.57% of the total plant CDF for Ginna. Users can sort the display by plant name, as well as by CDF or fraction value, simply by clicking the column heading for these items.

Individual Plant Examination - [Plant CDF Summary]

File IPE Information

Plant	Total Plant CDF	Total Selected Sequences CDF	Fraction
GINNA	8.74E-05	3.12E-06	3.57E-02
KEWAUNEE	6.65E-05	2.25E-06	3.38E-02
POINT BEACH 1&2	1.15E-04	2.64E-05	2.30E-01
PRAIRIE ISLAND 1&2	5.00E-05	3.72E-06	7.44E-02

Figure 2.19 Display of summary information for selected sequences

As another example, Figure 2.20 shows the detailed display of one of the SBO seal LOCA sequences for Prairie Island. These sequences are selected by checking RCPS in the **PWR Systems** box and **SBO** in the **Attributes** box on the selection screen (Figure 2.16). Since the selection is not limited to the A sequences, the selection of "**A**" in the **Accident Initiators** box in Figure 2.10 is removed.

Figure 2.20 shows that SBO Sequence 19 is initiated by a loss of offsite power (T-LOOP). Although many support systems are lost as a result of the loss of all AC power, the program displays only important support systems in the **Loss Supp** box. "EAC" in this box indicates the loss of all diesel generators, and "EDC" shows the loss of all plant batteries. The attributes shown in the **Attributes** box include SBO, TIL, and HUM. SBO indicates an SBO sequence, TIL indicates the occurrence of a transient-induced LOCA (a reactor coolant pump seal LOCA in this case), and HUM indicates some human error (in this case, the operator fails to restore power).

As shown in Figure 2.20, the CDF for this sequence is 2.3E-7, the fraction of the frequency of this sequence to the total frequency of the all reported sequences is 4.6E-3, and the total CDF for the plant is 5.0E-5. The systems shown in the **Systems** box are the important systems that, if lost, would contribute significantly to core damage for this sequence. Among the listed systems, RCPS indicates the development of a seal LOCA. The "**C**" next to RCPS indicates that the seal LOCA results from the loss of other systems (in this case, the cooling systems for the RCP seals). The cooling systems required to prevent a seal LOCA can be identified in the system dependency table discussed in Section 2.2.4. Users can compare the list of important systems that, if loss, could cause core damage (as those displayed in Figure 2.20) with those required for mission success.

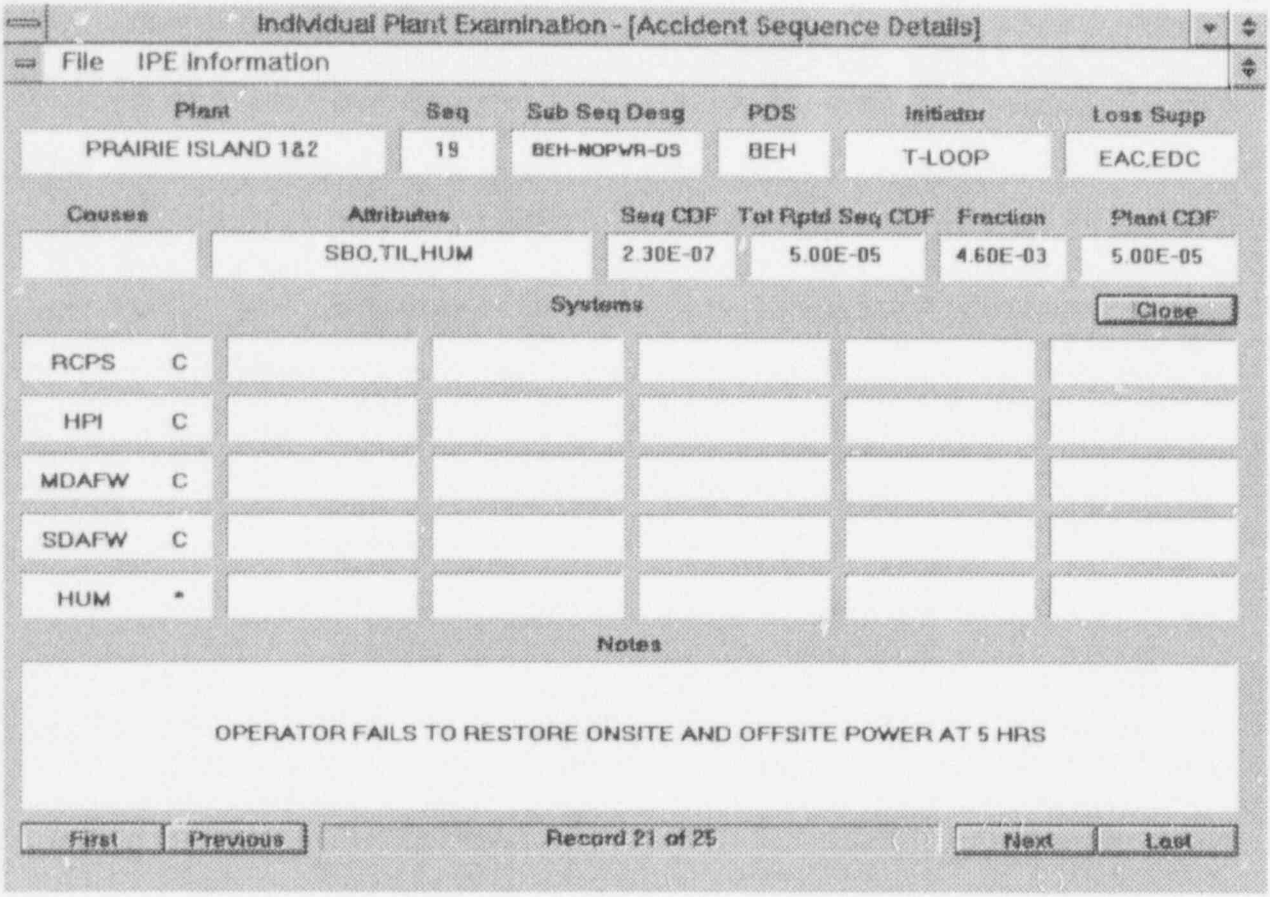


Figure 2.20 Detailed display of accident sequences (seal LOCA in SBO sequences)

2.5 Level 2 Information

Figure 2.21 shows the menu items for Level 2 Information. The four available items are: **Plant Damage States, Release Class, Containment Performance (C-Matrix), and Source Terms**.

The Level 2 portion of the IPE database is linked to the Level 1 portion through the plant damage states (PDS). In the Level 2 analyses, the plant damage states are divided into several possible fission product release paths or containment failure modes (Release Classes). Each failure mode is associated with a quantity of fission products released to the environment (source terms). The distributions of each PDS to the release classes are provided in the C-Matrix. The database is structured to capture the various elements of the Level 2 portion of an IPE. Each element of the Level 2 IPE is allocated a separate database table, and four database tables (corresponding to the items available in the menu system) are currently used in the IPE database as indicated above.

The following sections discuss procedures for using the menu system to examine the contents of these database tables. In addition, Appendix A discusses database tables associated with the various menu items.

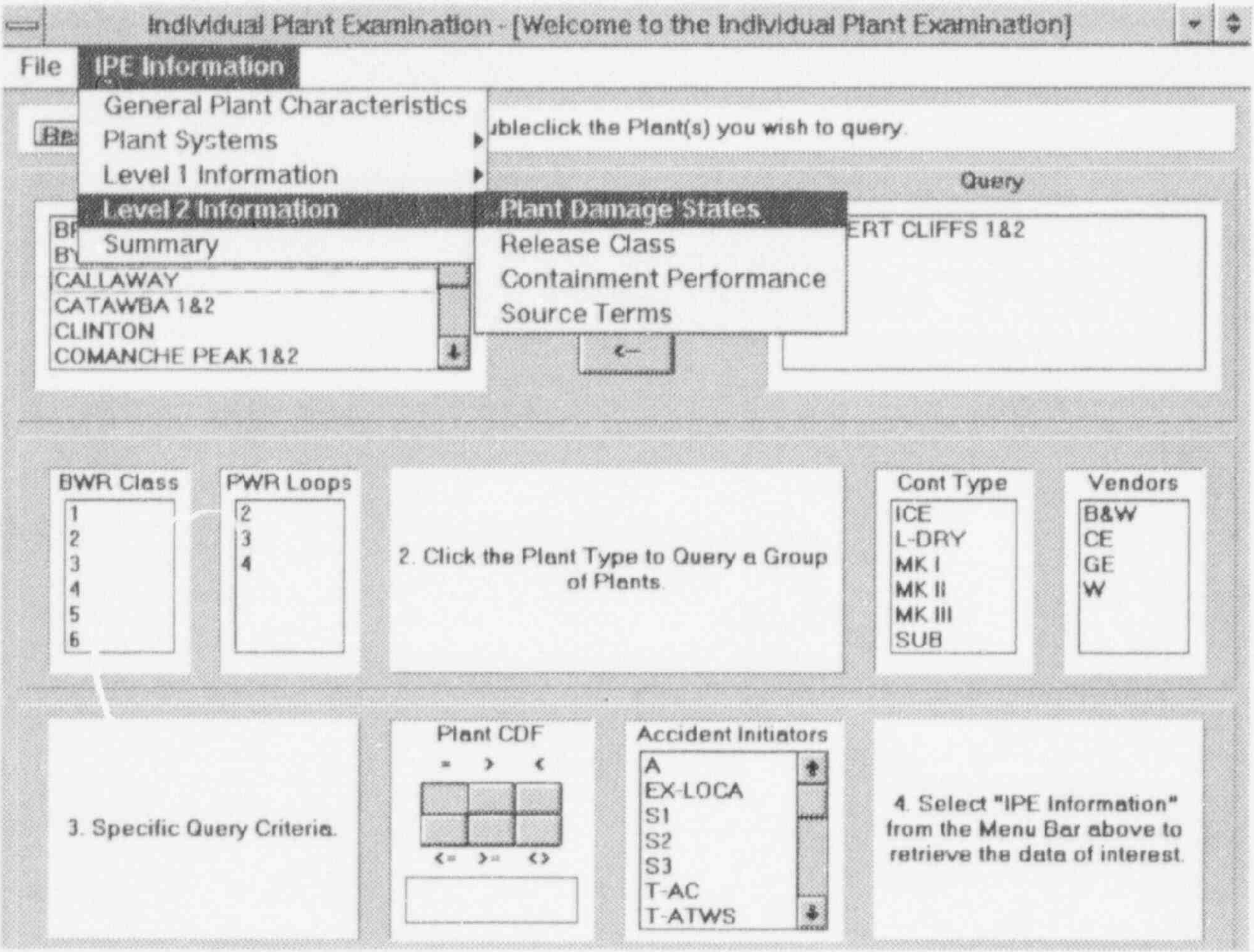


Figure 2.21 Menu items for Level 2 information

2.5.1 Plant Damage States

The PDS database table is structured to capture the information used by the IPE analyst to define the various plant damage states. To query the PDS, users can select the "**Plant Damage States**"menu item on the selection screen shown in Figure 2.21 (where Calvert Cliff is selected). After the user makes the selection, the program displays another selection screen for PDSs as shown in Figure 2.22. This figure shows the parameters that are commonly used in the IPE submittals to define PDSs, along with possible values for these parameters. It should be noted that the PDS definitions vary among IPE submittals and some IPE submittals do not provide all the parameter values shown in Figure 2.22. In general, however, almost all IPE submittals provide the first two parameters, reactor coolant system (RCS) pressure and containment conditions.

Figure 2.22 only shows the values of the first three boxes; however, the user can click the headings of the other boxes to see the values available for each box. For example, in Figure 2.22

if the user has elected to display the contents of the **PDS** box, as a result, the program will display the PDS designators used in the Calvert Cliffs IPE, and these designators are available for selection. Since the IPE submittals use a flexible PDS designation scheme, the designators used in an IPE submittal can be any values.

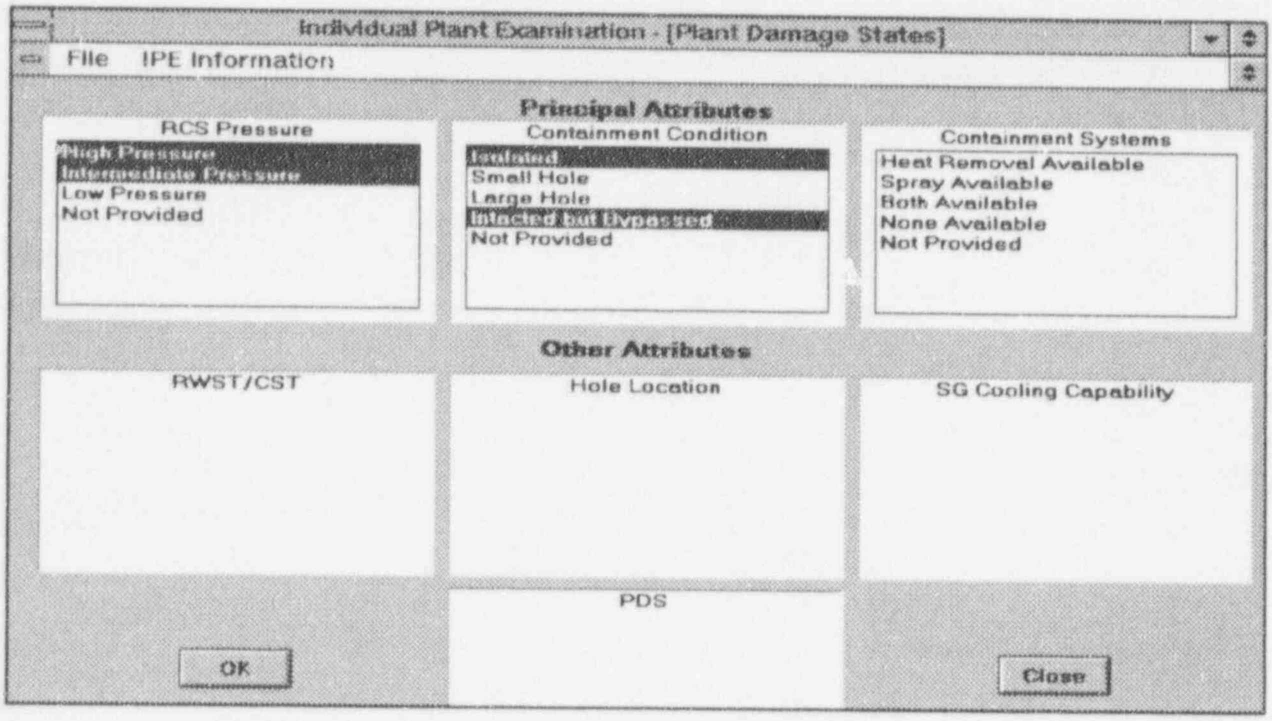
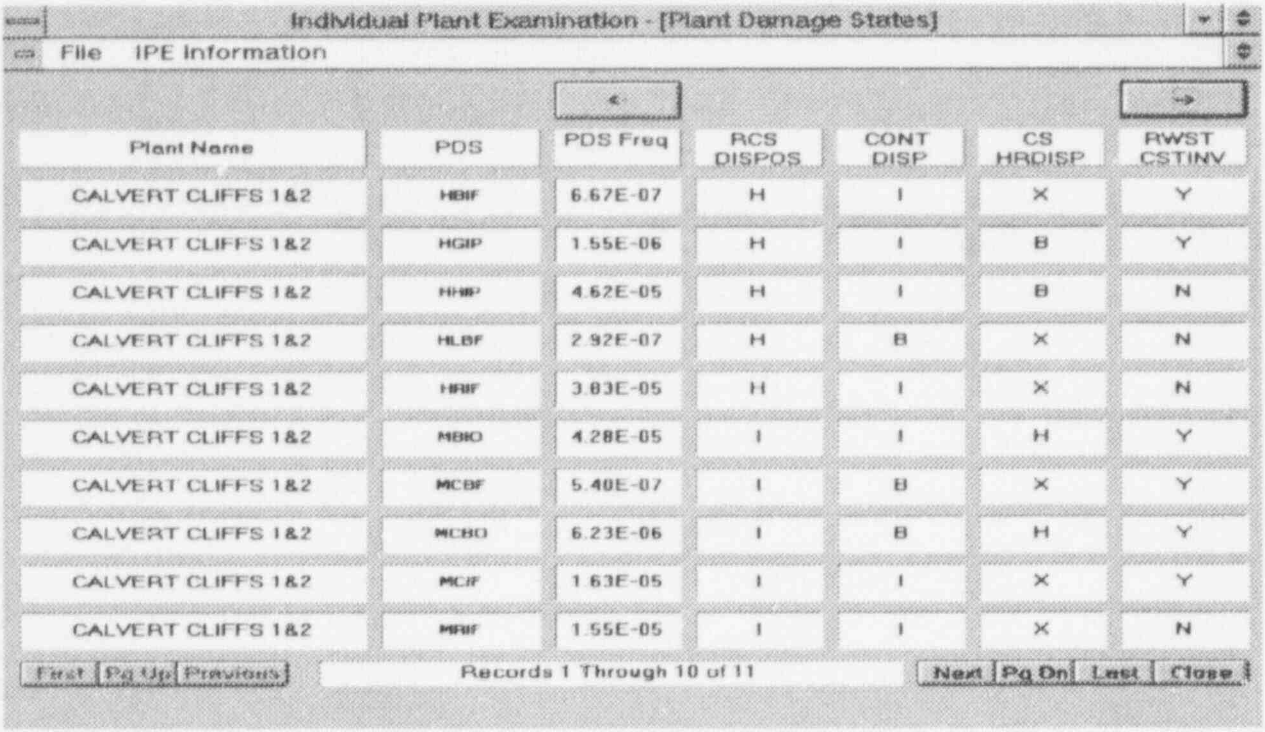


Figure 2.22 Selection of PDSs for display

Figure 2.23 illustrates the results of the selection shown in Figure 2-22. (As in other selection screens, all PDSs are selected if no items are selected on the selection screen). Since "**High Pressure**" and "**Intermediate Pressure**" were selected in the **RCS Pressure** box and "**Isolated**" and "**Intacted but Bypassed**" were selected in the **Containment Condition** box, the program displays only the PDSs that satisfy these conditions. That is, the PDSs displayed include those with High *or* Intermediate RCS Pressure (an "OR" operation for items selected in the same box) *and* with the containment either Isolated *or* Bypassed (an "AND" operation for items selected in different boxes). Figure 2.23 shows the PDSs that satisfy the above conditions. The values displayed for a PDS in Figure 2.23 include the frequency and other parameter values of interest for the PDS.

The summation of the frequencies of all selected PDSs provides important information. For example, if the user selects only high-pressure PDSs, the summation of the frequencies of all selected PDSs shows the total frequency of high-pressure sequences obtained in the IPE analysis. Summary information of this type is not available in the menu system, but can be obtained through the use of "Advance Queries" as described in Section 3.



Individual Plant Examination - [Plant Damage States]

File IPE Information

Plant Name	PDS	PDS Freq	RCS DISPOS	CONT DISP	CS HRDISP	RWST CSTINV
CALVERT CLIFFS 1&2	HBIF	6.67E-07	H	I	X	Y
CALVERT CLIFFS 1&2	HGIP	1.55E-06	H	I	B	Y
CALVERT CLIFFS 1&2	HHIP	4.62E-05	H	I	B	N
CALVERT CLIFFS 1&2	HLBF	2.92E-07	H	B	X	N
CALVERT CLIFFS 1&2	HRIF	3.83E-05	H	I	X	N
CALVERT CLIFFS 1&2	MBIO	4.28E-05	I	I	H	Y
CALVERT CLIFFS 1&2	MCBF	5.40E-07	I	B	X	Y
CALVERT CLIFFS 1&2	MCBO	6.23E-06	I	B	H	Y
CALVERT CLIFFS 1&2	MCIF	1.63E-05	I	I	X	Y
CALVERT CLIFFS 1&2	MRIF	1.55E-05	I	I	X	N

First | Pg Up | Previous | Records 1 Through 10 of 11 | Next | Pg Dn | Last | Close

Figure 2.23 Display of selected PDSs

2.5.2 Release Classes

The database table for the definition of release classes (REL-CLAS) stores information about containment failure modes and other Level 2 analysis parameters that are important to fission product releases (i.e., the source terms). This database table is linked to the rest of the IPE database through the release category designators.

After the user selects the "**Release Class**" menu item on the selection screen shown in Figure 2.21 (where Calvert Cliffs is selected), the program displays the selection screen for Release Classes as shown in Figure 2.24. This figure shows the parameters that are commonly used in the IPE submittals for RC definition, as well as the possible values for these parameters.

Similar to the definition of PDSs, the definition of RCs varies among IPE submittals and some submittals do not provide all of the values shown in Figure 2.24. Among the parameters (or boxes) shown in Figure 2.24, "Failure Time" and "Failure Size" are provided in most IPE submittals. Although some IPE submittals do not provide detailed information regarding the causes of containment, most IPE submittals include at least some of the parameter values listed in the **Failure Cause** box. Of the remaining parameters, the RCS pressure used to define the **Reactor Vessel Breach Mode** is the RCS pressure at vessel breach. This is different from that used in the PDS definition (at core damage). RCS depressurization between these two time frames can be achieved through operator action or by creep rupture of the RCS.

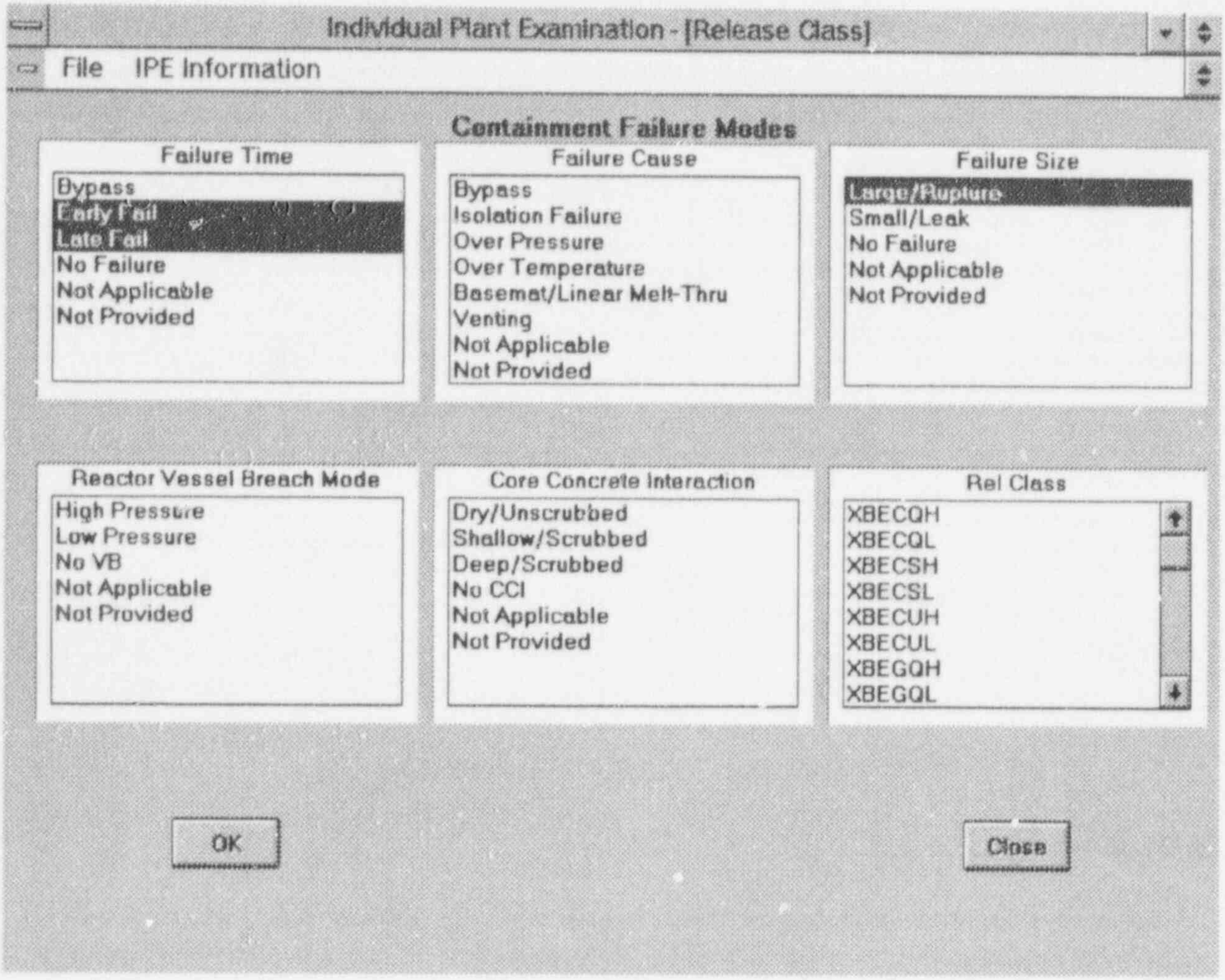
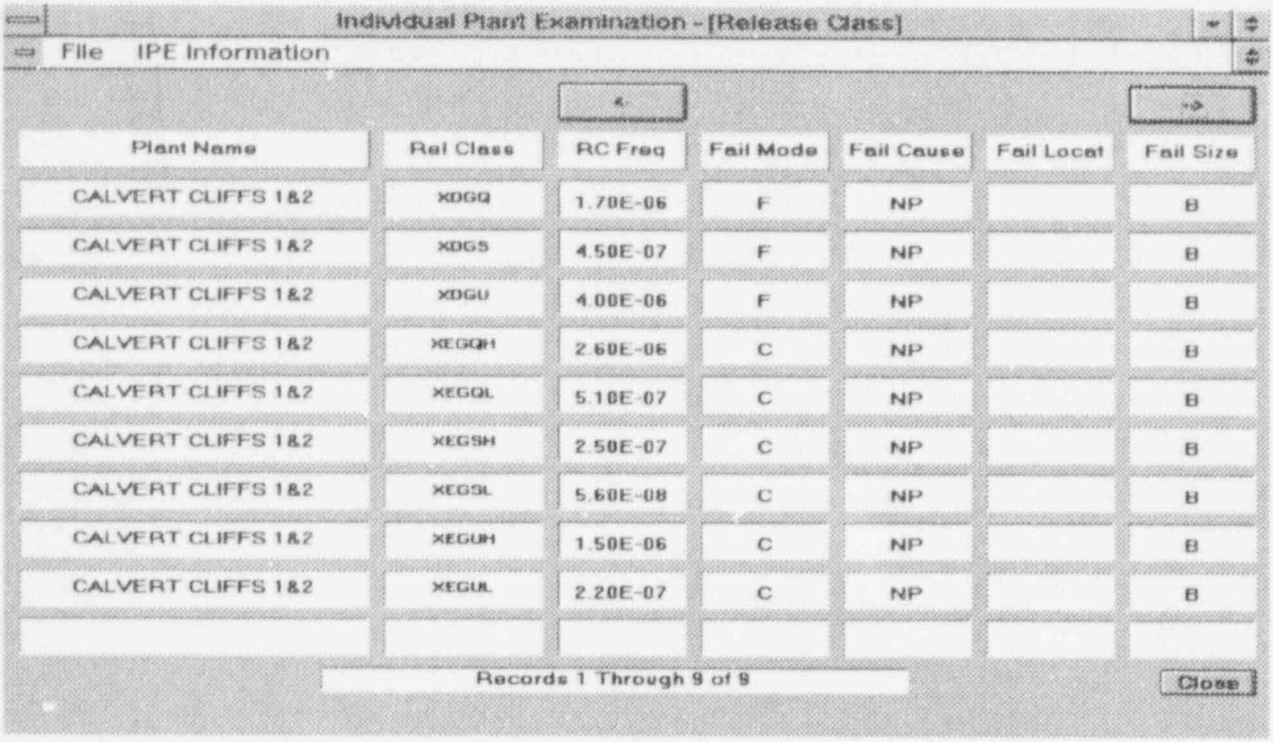


Figure 2.24 Selection of release classes

The RC designators presented in the **Rel Class** box of Figure 2.24 are those available for the selected IPE submittals. The IPE submittals use a flexible RC designation scheme that will essentially admit any format used in the IPE submittals.

Figure 2.25 displays the RCs selected by Figure 2.24. The RCs displayed in Figure 2.25 are those with either "Early" *or* "Late Failure" *and* with a large failure size. Figure 2.25 shows the frequencies of the RCs and the associated parameter values. The user can also view the meanings of the parameter values (e.g., F for Fail Mode) on the screen by pointing to the desired parameter value and pressing the right mouse button.



Individual Plant Examination - [Release Class]

File IPE Information

Plant Name	Rel Class	RC Freq	Fail Mode	Fail Cause	Fail Locat	Fail Size
CALVERT CLIFFS 1&2	XDGQ	1.70E-06	F	NP		B
CALVERT CLIFFS 1&2	XDGS	4.50E-07	F	NP		B
CALVERT CLIFFS 1&2	XDGU	4.00E-06	F	NP		B
CALVERT CLIFFS 1&2	XEGQH	2.60E-06	C	NP		B
CALVERT CLIFFS 1&2	XEGQL	5.10E-07	C	NP		B
CALVERT CLIFFS 1&2	XEGSH	2.50E-07	C	NP		B
CALVERT CLIFFS 1&2	XEGSL	5.60E-08	C	NP		B
CALVERT CLIFFS 1&2	XEGUH	1.50E-06	C	NP		B
CALVERT CLIFFS 1&2	XEGUL	2.20E-07	C	NP		B

Records 1 Through 9 of 9

Close

Figure 2.25 Display of selected release classes

2.5.3 Containment Performance -- The C-Matrix

The data stored in the database table for containment performance (C-MATRIX) relate the plant damage states to various release classes (or failure modes). As discussed above, the IPE submittals use flexible PDS and release class designation schemes. However, since some structure had to be imposed on the various failure modes to be included in the containment matrix, six "super" release classes or failure modes are currently used in the C-Matrix database table.

Each record in this database table contains a plant name, PDS designator, PDS frequency, and split fractions that allocate the indicated PDS over the various possibilities including bypass, early failure, late failure, basemat melt-through, vessel breach without containment failure, and no vessel breach. Because the entries are split fractions, they should sum to unity within a given PDS. In addition, each split fraction is allocated a release category designator. This designator connects the containment performance database table (C-Matrix) to the source term database table (STERMS).

After the user selects the "**Containment Performance**" menu item on the selection screen shown in Figure 2.21 (where Calvert Cliffs is selected), the program displays the selection screen for containment performance. This screen (shown in Figure 2.26) can be used to select for display of the PDSs that satisfy a particular condition.

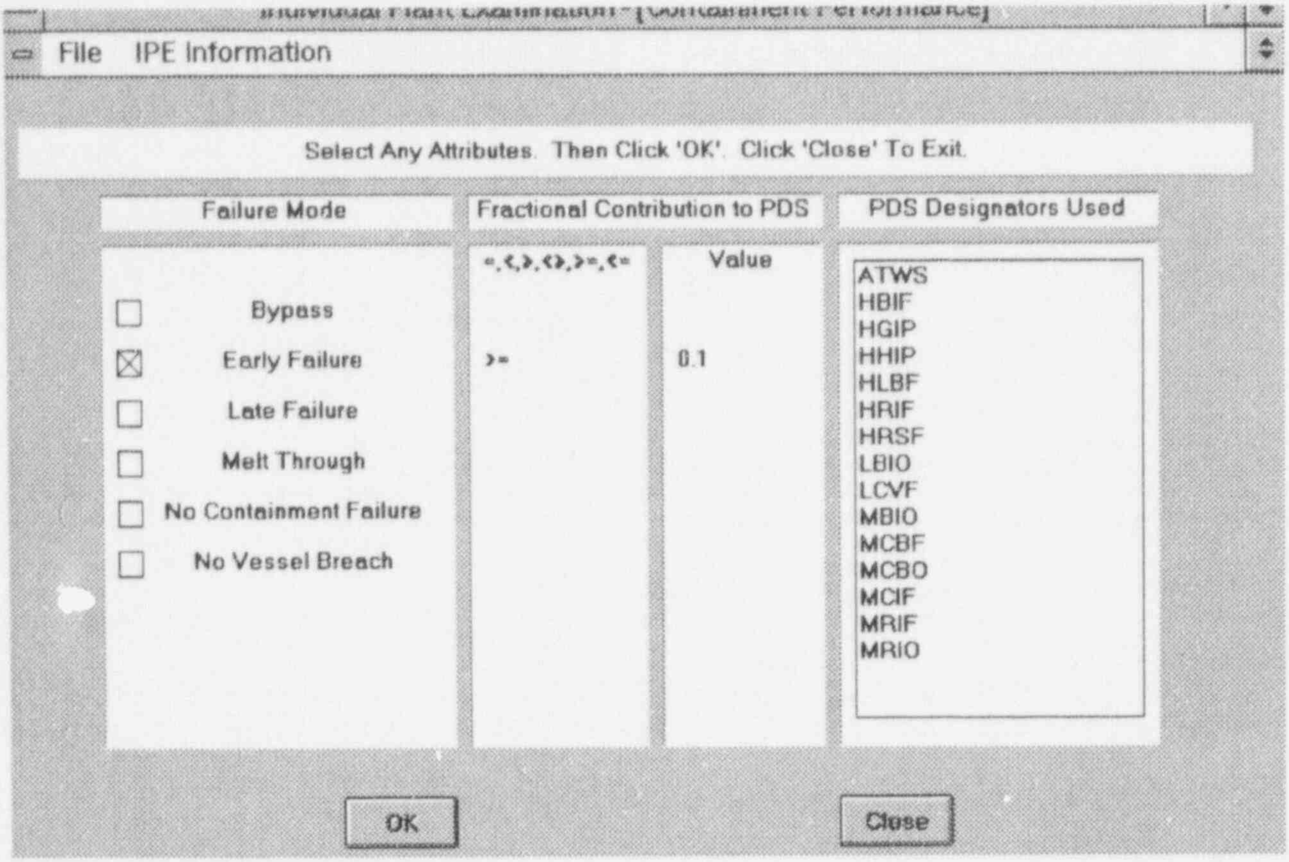
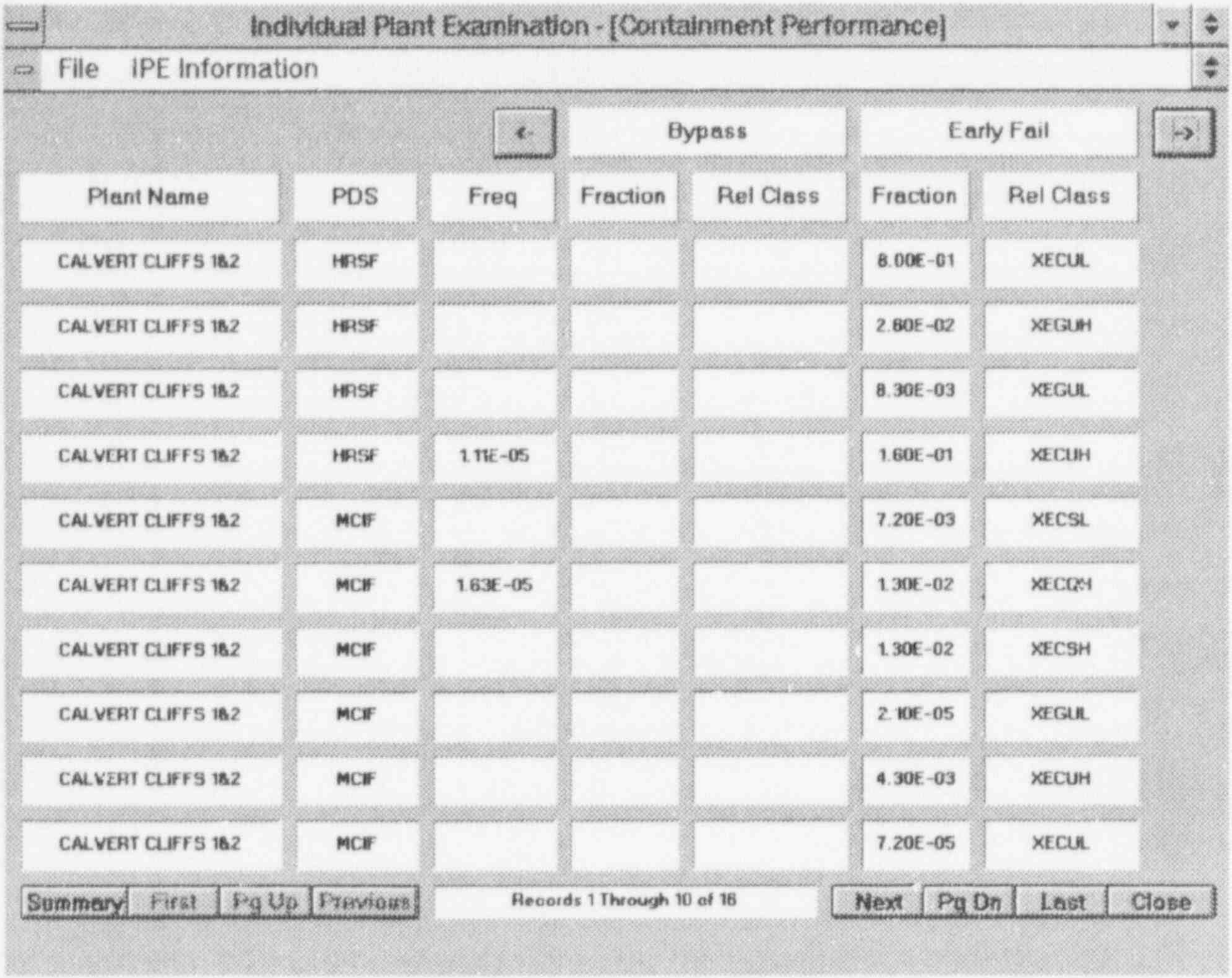


Figure 2.26 Selection of PDSs for containment performance

As shown in Figure 2.26, these selections reflect the conditional probabilities of the PDSs to the six super RCs discussed previously. For example, the selections on the screen shown in Figure 2.26 include all PDSs that have an early failure conditional probability greater than or equal to 0.1. Displaying the C-Matrix for these selected PDSs, Figure 2.27 shows two PDSs (HRSF and MCIF) that satisfy the selection criteria.

As shown in the Figure 2.27, the accident progression of PDS HRSF leads to four different early failure release classes (XECUL, XEGUH, XEGUL, and XECUH). The user can view the characteristics of these release classes displayed in the Release Class screen (e.g., Figure 2.25) as well as the source terms of these release classes displayed in the Source Term screen (see Section 2.5.4 of this report).

In addition, users can view the conditional probabilities of other release classes in other failure modes for PDS HRSF by scrolling the screen to the right by clicking the right arrow at the upper right corner of the screen. As previously mentioned, the summation of the contributions to all release classes for a PDS should be unity. As shown in Figure 2.27, the PDS frequency for a PDS is provided for only one of the records associated with the PDS, although it applies to all records associated with the PDS (four for PDS HRSF).



			Bypass		Early Fail	
Plant Name	PDS	Freq	Fraction	Rel Class	Fraction	Rel Class
CALVERT CLIFFS 1&2	HRSF				8.00E-01	XECUL
CALVERT CLIFFS 1&2	HRSF				2.60E-02	XEGUH
CALVERT CLIFFS 1&2	HRSF				8.30E-03	XEGUL
CALVERT CLIFFS 1&2	HRSF	1.11E-05			1.60E-01	XECUH
CALVERT CLIFFS 1&2	MCIF				7.20E-03	XECSL
CALVERT CLIFFS 1&2	MCIF	1.63E-05			1.30E-02	XECQM
CALVERT CLIFFS 1&2	MCIF				1.30E-02	XECSH
CALVERT CLIFFS 1&2	MCIF				2.10E-05	XEGUL
CALVERT CLIFFS 1&2	MCIF				4.30E-03	XECUH
CALVERT CLIFFS 1&2	MCIF				7.20E-05	XECUL

Figure 2.27 Display of the containment performance for selected PDSs

The program also displays summary information (Figure 2.28), if the user clicks the **Summary** button on the screen shown in Figure 2.27. The summary information includes the fractional distributions of the selected PDSs to the six super RCs. As shown in Figure 2.28, the conditional probability for early failure is 0.131 for both PDS HRSF and MCIF, each of which satisfies the selection criteria presented in the selection screen (Figure 2.26). Scrolling the screen to the right reveals that, in addition to the 13% for early failure, the conditional probability for late failure is 0.875 for these two PDSs.

As previously discussed, PDSs provide a link between the Level 1 and Level 2 analysis results. Through the use of PDSs, the release profiles for individual accident sequences or groups of accident sequences can then be determined. The display of such information requires the linking of the Level 1 and Level 2 data and can be obtained through the use of the technique described in Section 3 of this report, Advanced Queries.

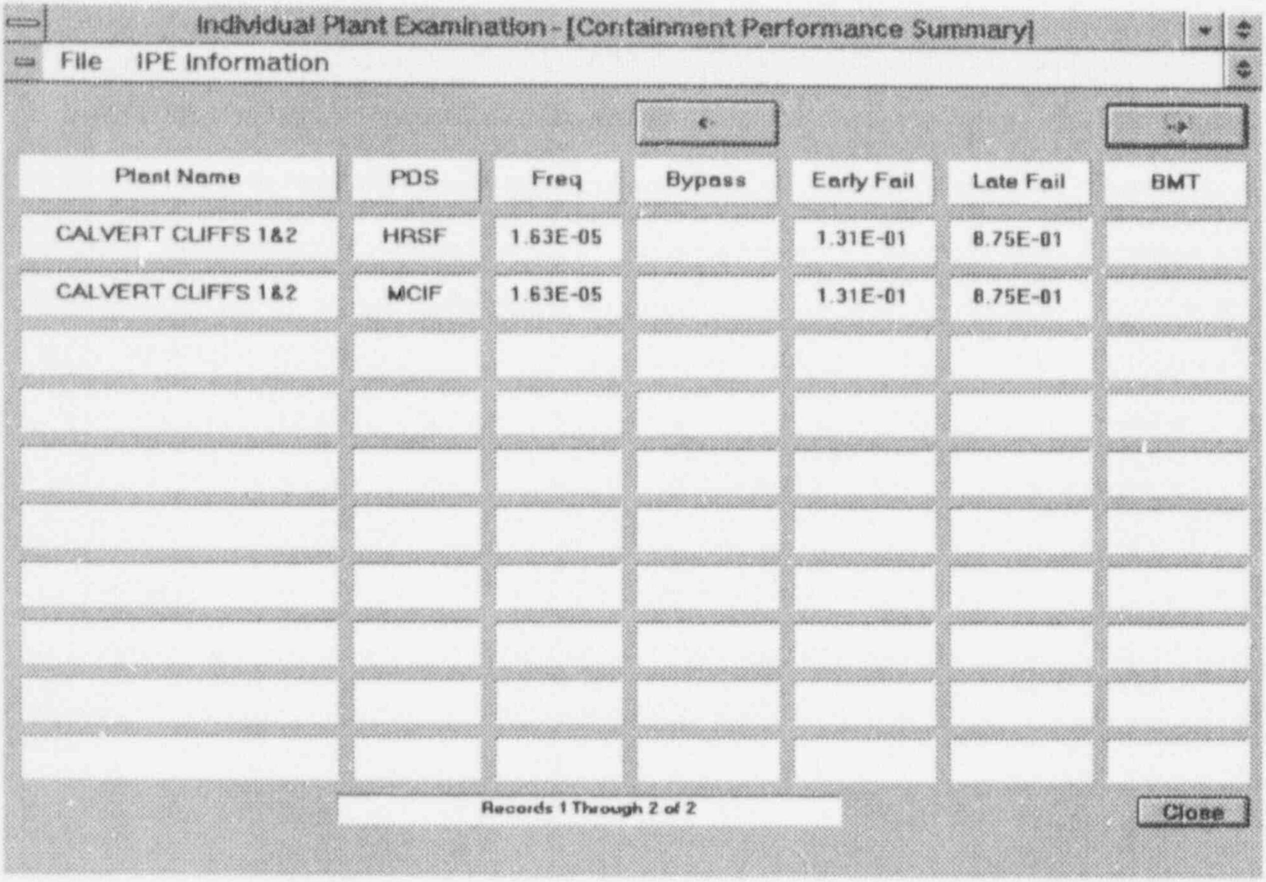


Figure 2.28 Display of summary for containment performance

2.5.4 Source Terms

The database table for source terms (STERMS) relates the release category designators identified in the IPE database table for release classes (REL-CLAS) to the quantity of fission products released to the environment. Each record in the file contains a plant name, the release class designator, and the fractional release (to the environment) of up to nine different fission product groups.

After the user selects the "**Source Terms**" menu item on the selection screen shown in Figure 2.21 (where Calvert Cliffs is selected), the program displays the selection screen for source terms. This screen (shown in Figure 2.29) can be used to select for display the RCs that satisfies a particular condition. As shown in the figure, the selections reflect the release fractions of selected radionuclide groups. In the example shown in Figure 2.29, the selected conditions require display of the release classes that have release fractions for both Iodine *and* Cesium greater than or equal to 0.15. Figure 2.30 shows the results of the selection, including the release class designators and release fractions for the nine radionuclide groups. Through the release class designators, the characteristics of the release classes (e.g., early failure, bypass, etc.) and frequencies can then be identified.

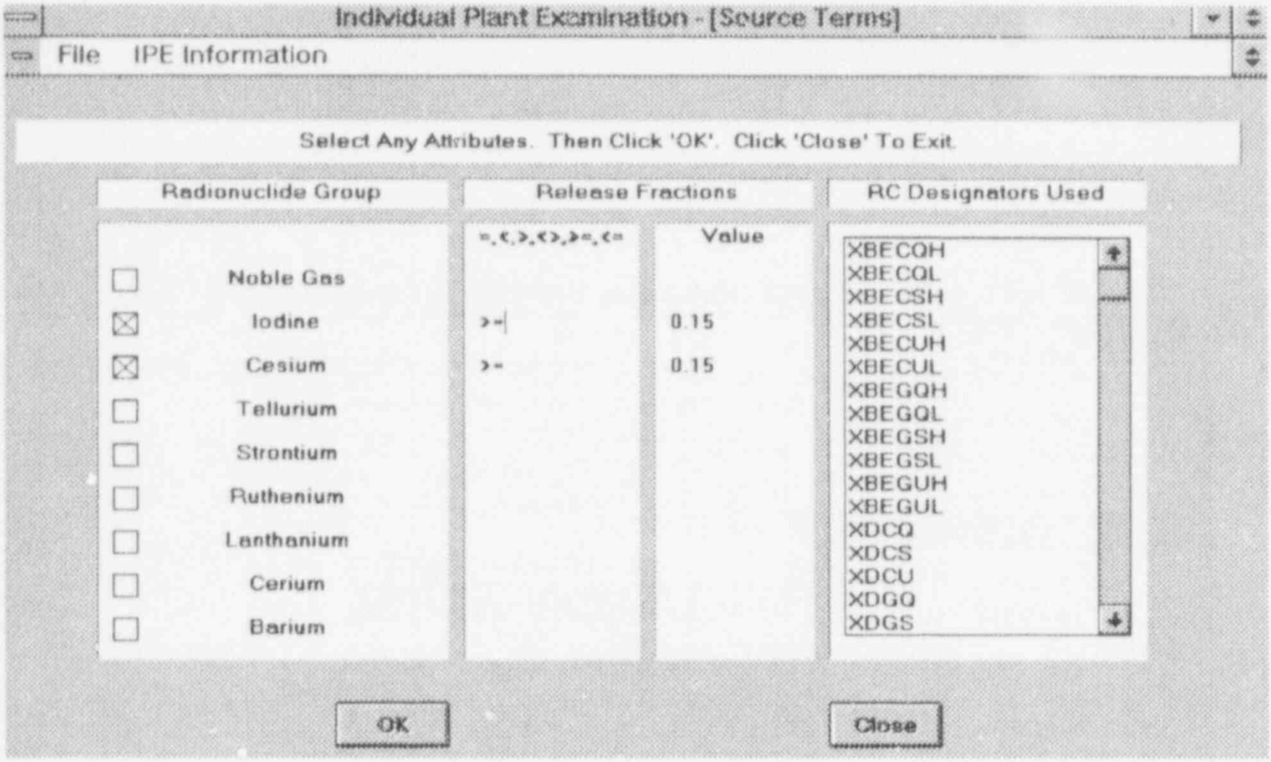


Figure 2.29 Selection of release classes for source term display

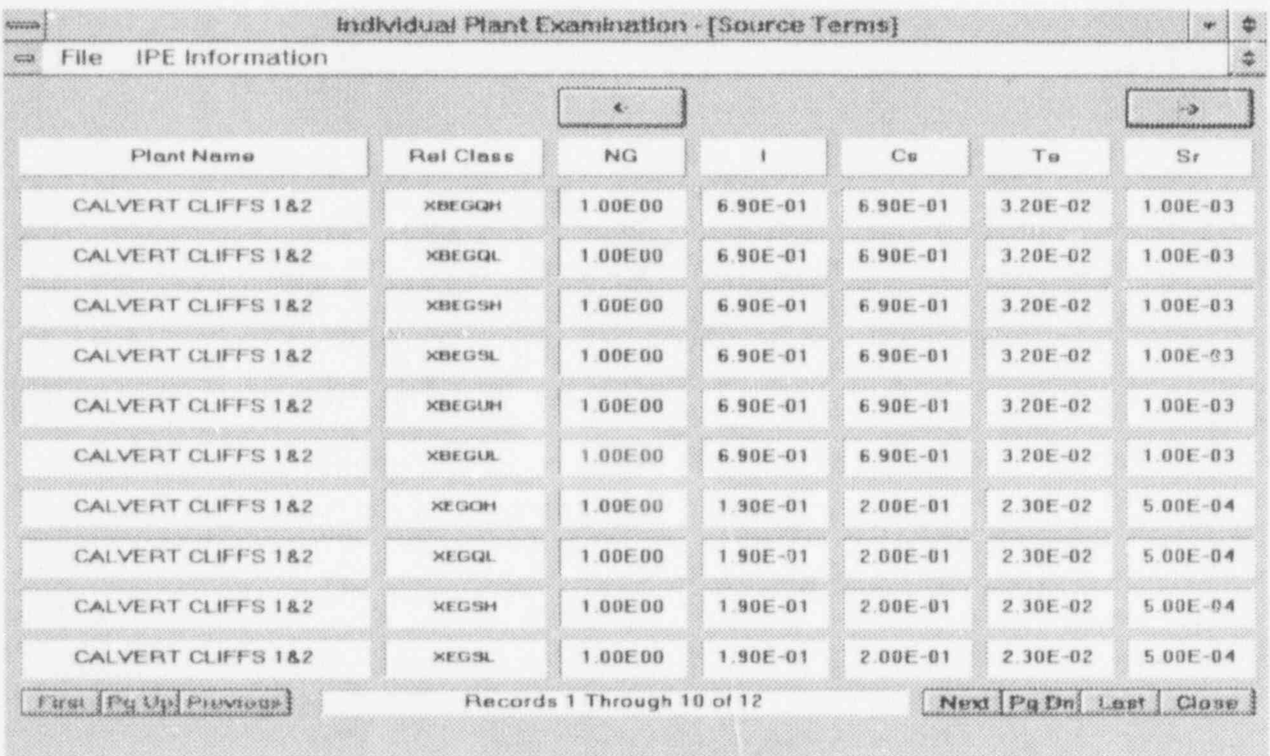


Figure 2.30 Display of the source terms for selected release classes

2.6 Summary Information

Figure 2.31 shows the menu items for Summary Information, which include **Initiators CDF, Containment Failure Probability,** and **Sequences CDF**. These items are discussed in the following sections.

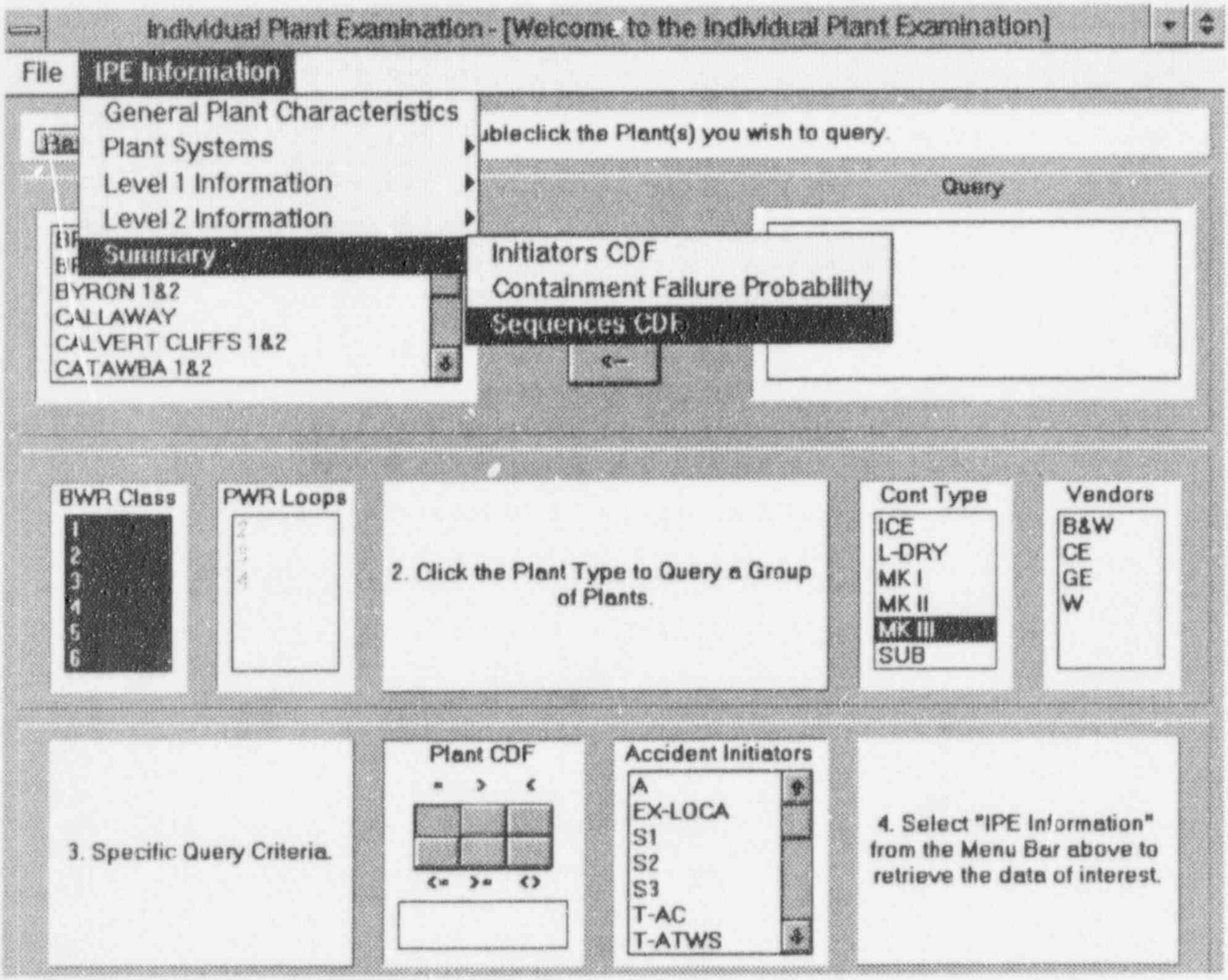


Figure 2.31 Menu items for summary information

2.6.1 Level 1 Summary - Sequences CDF

The Level 1 Summary database table is structured to capture information obtained in the Level 1 analysis of the IPE submittals. The data stored in this table include the frequencies and the fractions to total plant CDF for the following accident classes:

- station blackout (SBO)

- anticipated transients without scram (ATWS)
- transients
- LOCA
- steam generator tube rupture (SGTR)
- interfacing system LOCA (ISLOCA)
- internal flooding (IFL)

It should be noted that the Level 1 summary database table includes updated information provided by the revised Salem 1&2 and Watts Bar IPE submittals while the other database tables have not been updated accordingly. Therefore, the Level 1 summary database table should be used for these two particular plants.

Figure 2.32 shows the data displayed for the selection of BWR Mark III plants shown in Figure 2.31, including the frequencies of the various accident classes. Users can also sort the displayed data (in descending order of numerical values) by clicking the heading of a given field. The data displayed in Figure 2.33 are sorted by the frequency of the SBO accident class.

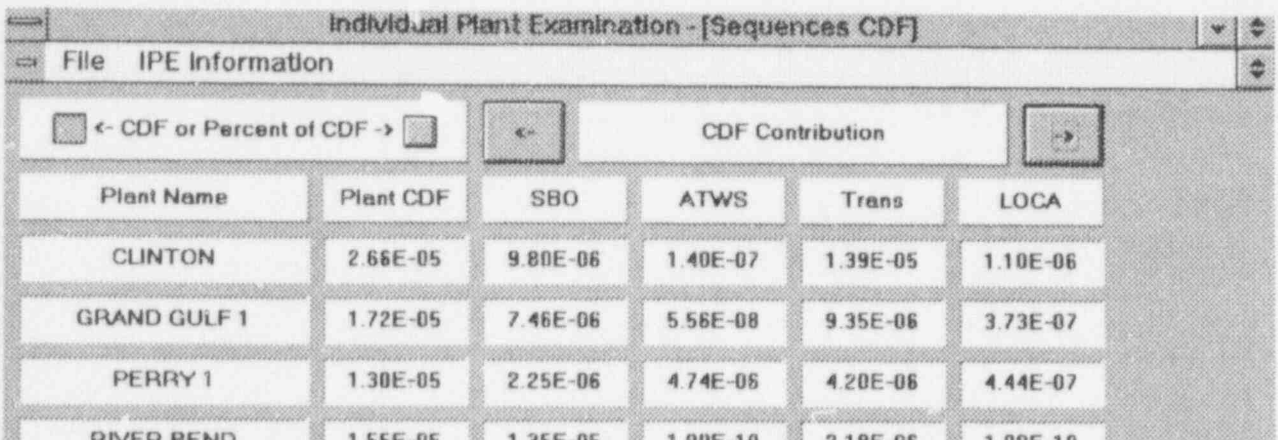


Figure 2.32 Display of accident sequences CDF summary (in frequency)

The buttons provided in the upper left corner of the screen enable users to display either the frequencies or the fractions to the total plant CDF of the accident classes. Figure 2.33 shows the display of fractions (or percent of CDF contribution), sorted by plant CDF.

Individual Plant Examination - [Sequences CDF]

File   IPE Information

<- CDF or Percent of CDF ->   <-   CDF Contribution   ->

Plant Name	Plant CDF	SBO	ATWS	Trans	LOCA
CLINTON	2.66E-05	3.68E-01	5.26E-03	5.23E-01	4.14E-02
GRAND GULF 1	1.72E-05	4.34E-01	0.00E00	5.44E-01	2.17E-02
PERRY 1	1.30E-05	1.73E-01	3.65E-01	3.23E-01	3.42E-02
RIVER BEND	1.55E-05	8.71E-01	6.45E-06	1.41E-01	6.45E-06

Figure 2.33 Display of accident sequences CDF summary (in fraction)

2.6.2 Level 2 Summary -- Containment Failure Probability

The Level 2 summary database table is structured to capture information obtained in the Level 2 analyses of the IPE submittals. The data stored in this database table include the frequencies and fractions to total plant CDF for the following containment failure modes (or release classes):

- containment bypass
- containment isolation failure
- early failure
- late failure
- no failure

Figure 2.34 shows the data displayed for the Level 2 summary (using the same selection screen used for Level 1 summary shown in Figure 2.31), including the frequencies of the various containment failure modes. As with the Level 1 summary, users can sort the data by clicking the heading of a given field. The data displayed in Figure 2.34 are sorted by plant CDF. Figure 2.35 illustrates the display of the fractions, with the sorted by the fractions of early containment failure.

Individual Plant Examination - [Containment Failure Probability]

File IPE Information

<- Conditional Failure Probability or Containment Failure Frequency ->

Containment Failure Frequency

Plant Name	Plant CDF	Bypass	Isol Fail	Early CF	Late CF	No CF
CLINTON	2.60E-05	0.00E00	6.97E-07	1.30E-07	4.84E-07	2.47E-05
GRAND GULF 1	1.72E-05	0.00E00	0.00E00	8.05E-06	5.66E-06	3.51E-06
PERRY 1	1.32E-05	0.00E00	3.96E-09	3.14E-06	4.76E-06	5.30E-06
RIVER BEND	1.55E-05	0.00E00	4.12E-07	3.96E-06	2.14E-06	8.98E-06

Figure 2.34 Display of containment failure summary (in frequency)

Individual Plant Examination - [Containment Failure Probability]

File IPE Information

<- Conditional Failure Probability or Containment Failure Frequency ->

Conditional Failure Probability

Plant Name	Plant CDF	Bypass	Isol Fail	Early CF	Late CF	No CF
CLINTON	2.60E-05	0.00E00	2.68E-02	5.00E-03	1.86E-02	9.51E-01
GRAND GULF 1	1.72E-05	0.00E00	0.00E00	4.68E-01	3.29E-01	2.04E-01
PERRY 1	1.32E-05	0.00E00	3.00E-04	2.38E-01	3.61E-01	4.02E-01
RIVER BEND	1.55E-05	0.00E00	2.66E-02	2.56E-01	1.38E-01	5.80E-01

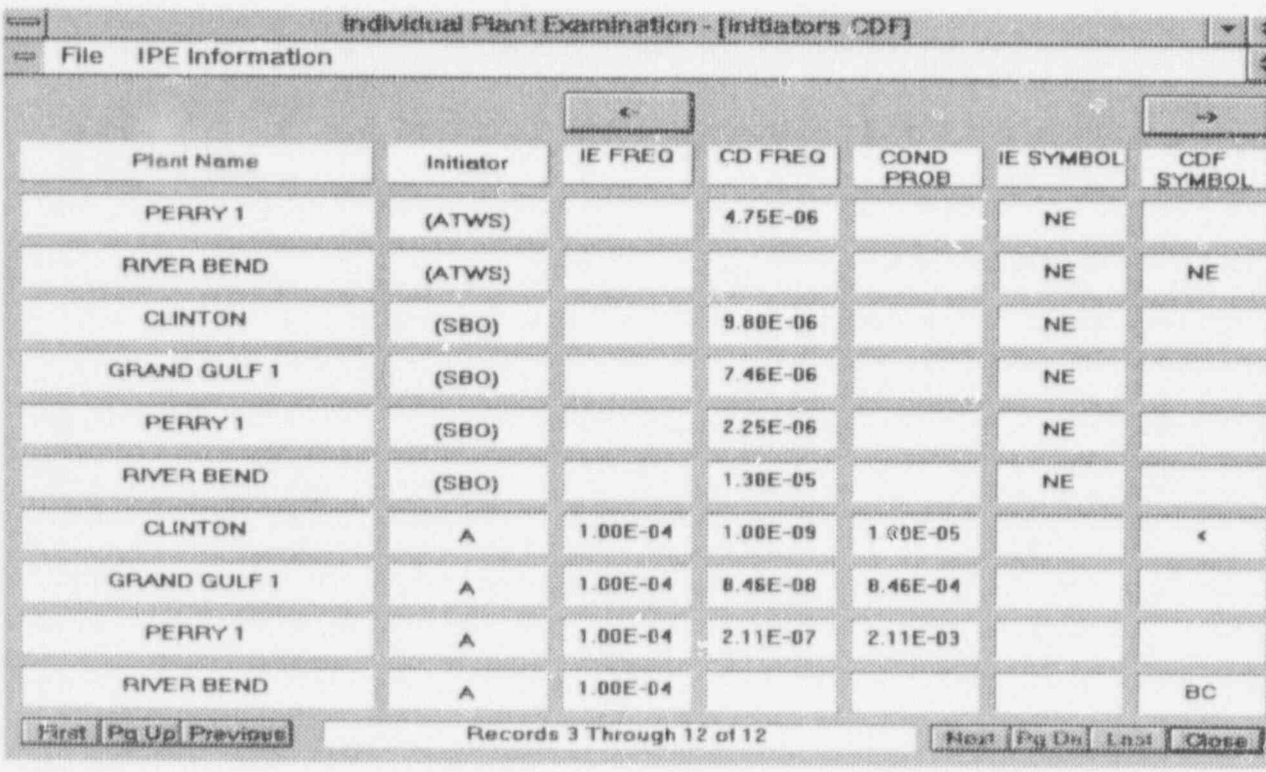
Figure 2-35 Display of containment failure summary (in fraction)

2.6.3 Initiating Event Summary - Initiators CDF

The Initiating Event Summary database table is structured to capture information derived from the initiating event analysis in the IPE submittals. Specifically, the data stored in this table include the initiating event frequencies used in the IPE analysis, as well as the CDFs derived for these initiating events in the IPE analysis.

To select the initiating event summary display, users employ the selection screen shown in Figure

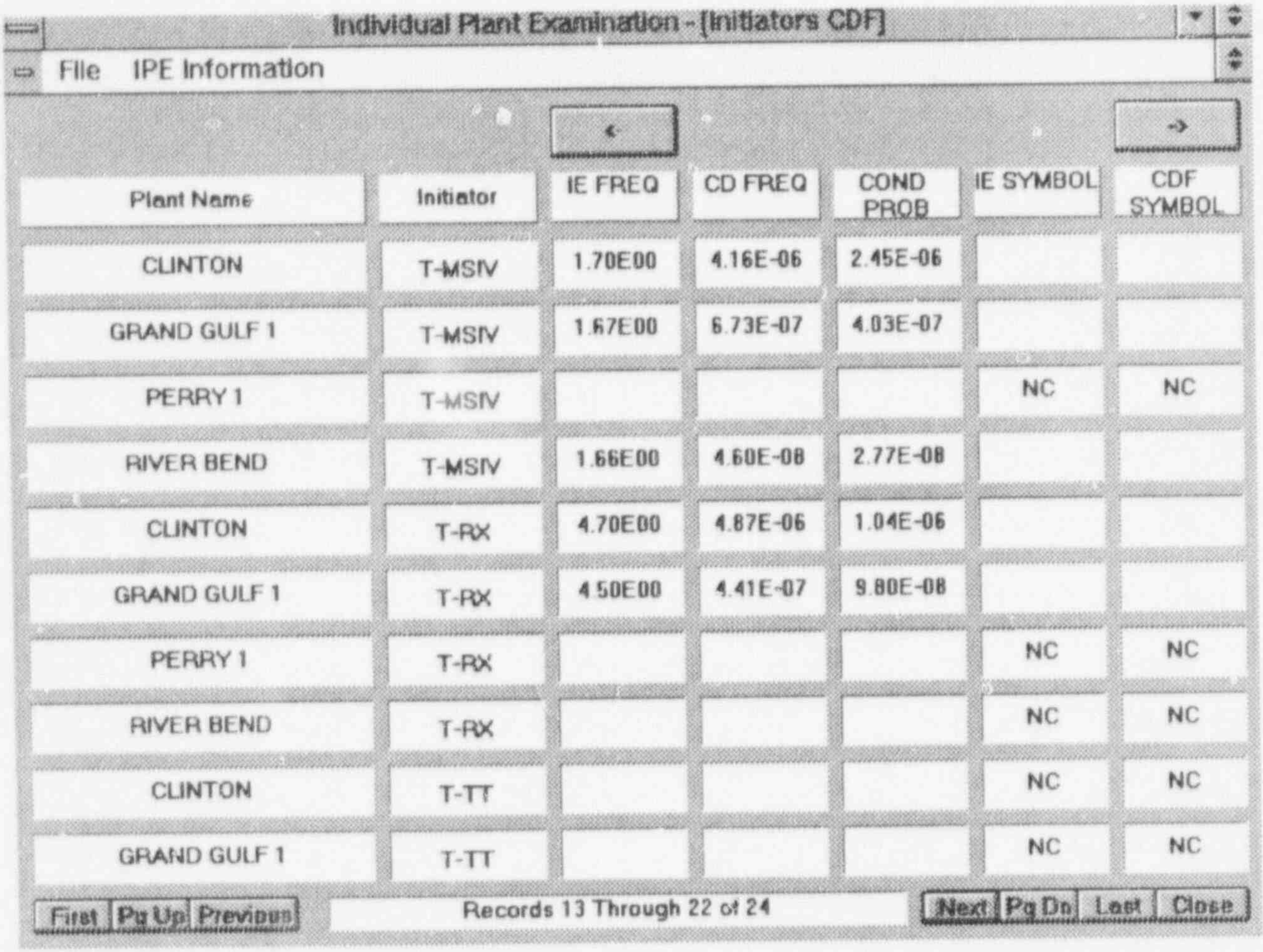
2.31. However, contrary to the selection shown in Figure 2.31 in which the user did not select any accident initiators, a user interested in the Initiating Event Summary would select some accident initiators shown in the **Accident Initiators** box in Figure 2.31. Figure 2.35 shows Records 3 through 12 of 44 selected records, sorted by initiator. It should be noted that "**(ATWS)**" and "**(SBO)**" in the **Initiator** field are not initiators; therefore, the IPE submittal does not provide initiating event frequencies (**IE FREQ**) for these parameters. This is indicated by the NE value (i.e., not explicitly given in the submittal) in the **IE SYMBOL** field. These parameters are provided here to show the frequencies of the accident sequences that involve ATWS or SBO. Figure 2.36 also shows the IE frequencies and CDFs for large LOCA (i.e., **A**). The "less than" sign (<) in the **CDF SYMBOL** for Clinton indicates that the CDF of large LOCA is less than the value presented in the CD FREQ field for this initiator (i.e., 1E-9). The value BC in the CDF SYMBOL field for River Bend indicates that the CDF for this initiator is below the cutoff value used for that particular plant.



Plant Name	Initiator	IE FREQ	CD FREQ	COND PROB	IE SYMBOL	CDF SYMBOL
PERRY 1	(ATWS)		4.75E-06		NE	
RIVER BEND	(ATWS)				NE	NE
CLINTON	(SBO)		9.80E-06		NE	
GRAND GULF 1	(SBO)		7.46E-06		NE	
PERRY 1	(SBO)		2.25E-06		NE	
RIVER BEND	(SBO)		1.30E-05		NE	
CLINTON	A	1.00E-04	1.00E-09	1.00E-05		<
GRAND GULF 1	A	1.00E-04	8.46E-08	8.46E-04		
PERRY 1	A	1.00E-04	2.11E-07	2.11E-03		
RIVER BEND	A	1.00E-04				BC

Figure 2.36 Display of initiator frequencies and CDFs for the initiators

Figure 2.37 shows the last part of the selected records. The NC value in the **IE SYMBOL** and **CDF SYMBOL** fields indicates that the IPE submittals do not consider those initiators. Although Figure 2.37 indicates that Clinton and the Grand Gulf IPE submittals did not consider turbine trip events, such events may be considered in the IPE submittals as part of reactor trip events (T-RX).



Plant Name	Initiator	IE FREQ	CD FREQ	COND PROB	IE SYMBOL	CDF SYMBOL
CLINTON	T-MSIV	1.70E00	4.16E-06	2.45E-06		
GRAND GULF 1	T-MSIV	1.67E00	6.73E-07	4.03E-07		
PERRY 1	T-MSIV				NC	NC
RIVER BEND	T-MSIV	1.66E00	4.60E-08	2.77E-08		
CLINTON	T-RX	4.70E00	4.87E-06	1.04E-06		
GRAND GULF 1	T-RX	4.50E00	4.41E-07	9.80E-08		
PERRY 1	T-RX				NC	NC
RIVER BEND	T-RX				NC	NC
CLINTON	T-TT				NC	NC
GRAND GULF 1	T-TT				NC	NC

Figure 2.37 Display of initiator frequencies and CDFs for the initiators (cont.)

As another example, Figure 2.38 display the data for Davis-Besse. Since no accident initiators are selected in the selection screen (Figure 2.31), the program displays all data in this database table for Davis-Besse. As shown in Figure 2.38, the values in the **Initiator** field of this database table include a few "**Groups**" because some IPE submittals provide initiating event frequencies and/or CDF not for the individual initiators, but for groups of initiating events. In such cases, the CDF for the individual initiating event is denoted by a blank, and an entry (i.e., 1, 2, 3, etc.) under the Grouping Designator (**GROUP DES**) field indicates that the corresponding initiating event was grouped with other initiating events. The group is denoted by an initiating event called Group x (x = 1, 2, 3, etc.), and the corresponding CDF for the group (and sometimes the initiating frequency for the group) is indicated.

For Davis-Besse, the IPE submittal provided the initiating event frequencies for the individual initiators, but provided the CDFs for groups rather than individual initiators. As shown in Figure 2.38, Group 2 includes, among other initiators, T-AC (as indicated by the number 2 in the **GROUP DES** field). Users can scroll down to see more Group 2 initiators, where available. As shown in the figure, the IE frequency is provided for T-AC, but the CDF is not provided for this initiator. The C in the IE SYMBOL field for Group 2 indicates that the IE frequency for this group can be calculated from the IE frequencies for the individual initiators in this group.

Individual Plant Examination - [Initiators CDF]

File IPE Information

Plant Name	Initiator	IE FREQ	CD FREQ	COND PROB	IE SYMBOL	CDF SYMBOL
DAVIS-BESSE	GROUP 2		6.10E-07		C	
DAVIS-BESSE	GROUP 3		7.20E-06		C	
DAVIS-BESSE	GROUP 4		1.40E-05		C	
DAVIS-BESSE	S1	3.00E-04	2.06E-06	6.87E-03		
DAVIS-BESSE	S2	3.60E-03	2.10E-06	5.83E-04		
DAVIS-BESSE	S3				NC	NC
DAVIS-BESSE	T-AC	3.57E-01				
DAVIS-BESSE	T-ATWS		3.54E-07		NP	
DAVIS-BESSE	T-CCW	3.41E-01	0.00E00	0.00E00		
DAVIS-BESSE	T-CPE				NC	NC

First | Pg Up | Previous — Records 5 Through 14 of 36 — Next | Pg Dn | Last | Close

Figure 2.38 Display of initiator frequencies and CDFs for the initiators (cont.)

3. ADVANCED QUERIES

3.1 Introduction

Advanced queries enable users to explore the IPE database using more complex questions that may involve linking Level 1 and Level 2 data, as well as calculations to derive specific information. However, such queries require application of data management software, such as Microsoft Access, dBASE, or Paradox. In particular, such advanced queries involve the use of aggregation functions, ("TOTALS" for instance) to derive summary information. It should be noted that advanced queries could yield incorrect answers if a user fails to design the query in the correct way. Therefore, users should first be familiar with at least one of the data management software in order to obtain correct answers to the advanced queries. It is beyond the scope of this user's guide to provide instruction regarding proper use of these applications. However, the following sections present samples queries that cover a broad range of interest regarding the IPE database. These sample queries should serve as a model to help users create valid queries specific to their own interests.

3.2 Getting Started

This section discusses basic steps to guide users in loading the required files to their computers and starting to query the database. This discussion reflects the use of Microsoft Access 2.0 to perform the requisite steps as follows:

(1) Install and open the database: First, instal the database. Instructions for installing the IPE database are provided on the diskette labeled "SETUP." Installation and use of the database follow the standard procedures associated with the Windows operating system; instructions for these procedures can be found in the user's guide for the Windows operating system. When the installation is complete, an icon appears for the IPE database. Users simply click the related icon to open the IPE database and the application software that is Microsoft Access 2.0. The IPE database files will appear as the title in the IPE database window and all objects will be available.

(2) Query the database: With the IPE database open, click on the "**Query**" icon, then click on "**New**." At the "**New Query**" window, click on "**New Query**" button. After the user clicked the "**New Query**" button, the program presented a "**Select Query**" window along with an "**Add Table**" dialogs box. At the "**Add Table**" dialog box, select the tables one-by-one and click on "**Adding**" to add the table(s) appropriate for the query designed by the user.

The remainder of this section presents a variety of examples to demonstrate the techniques used in preparing advanced queries of the IPE database. As previously noted, these examples cover a wide scope of interests in the database.

3.3 Example 1: RCS Pressures for Selected Initiators

This example illustrates a query design to find the CDFs for the initiators with various RCS pressures. It also shows how to create an IPE database table for use in examining the RCS pressures for selected initiators of selected plants. The steps used to design this query are as follows:

(1) Following Step 2 in Section 3.2 above, double-click to "**Add**" the **ACCIDSEQ, GENERAL,** and **PDS** tables as shown in Figure 3.1.

(2) Join the tables by connecting the common **PLANTNAME** and **PDS** fields.

(3) Bring **PLANTNAME**, **INITIATOR**, **RCS_DISPOS**, and **CDF** fields to the QBE (Query By Example) grid. Define the **RCS_DISPOS** field as "RCS_Pres" and **CDF** as "CDF."

(4) Click on the **Totals button** (∑) to add a row entitled **Total** to the QBE grid with "**Group By"** on this row for each field in the grid. However, this query is designed to calculate the CDF totals for a specific initiator; consequently, replace the aggregate function "**Group By**" with the "**Sum"** for the CDF field. This completes the query design.

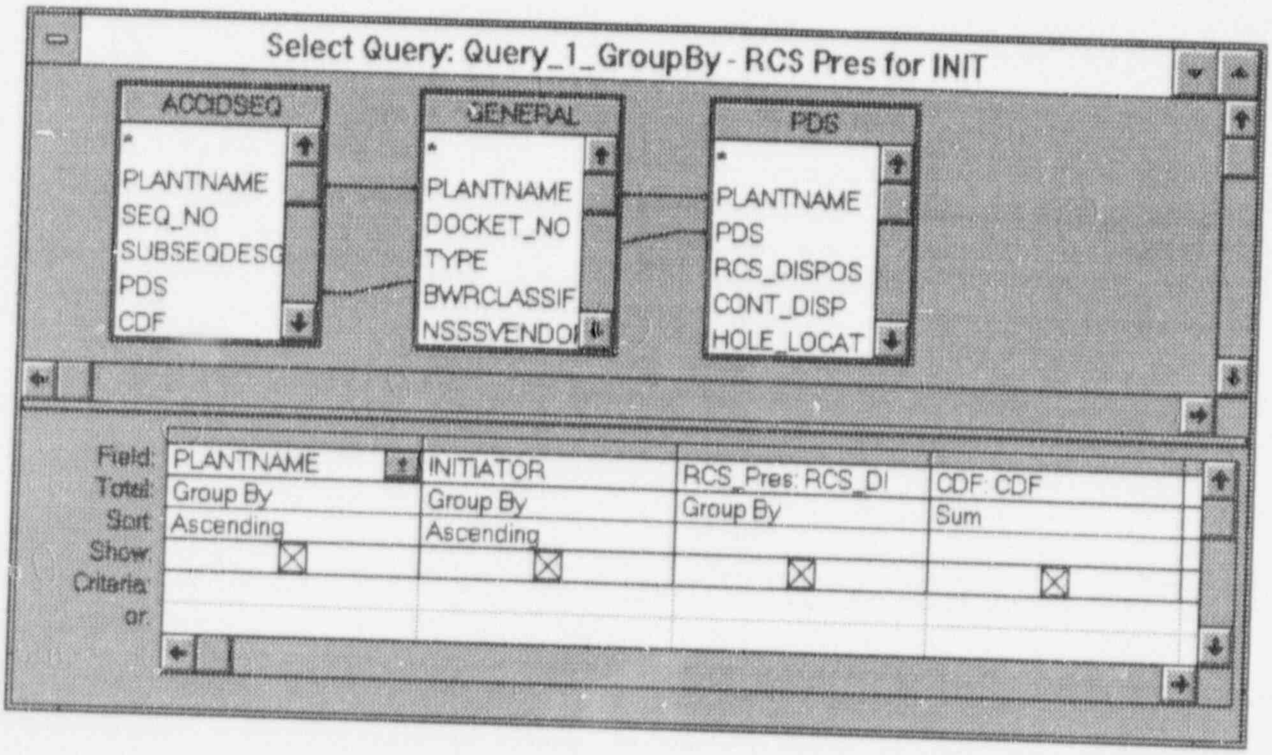
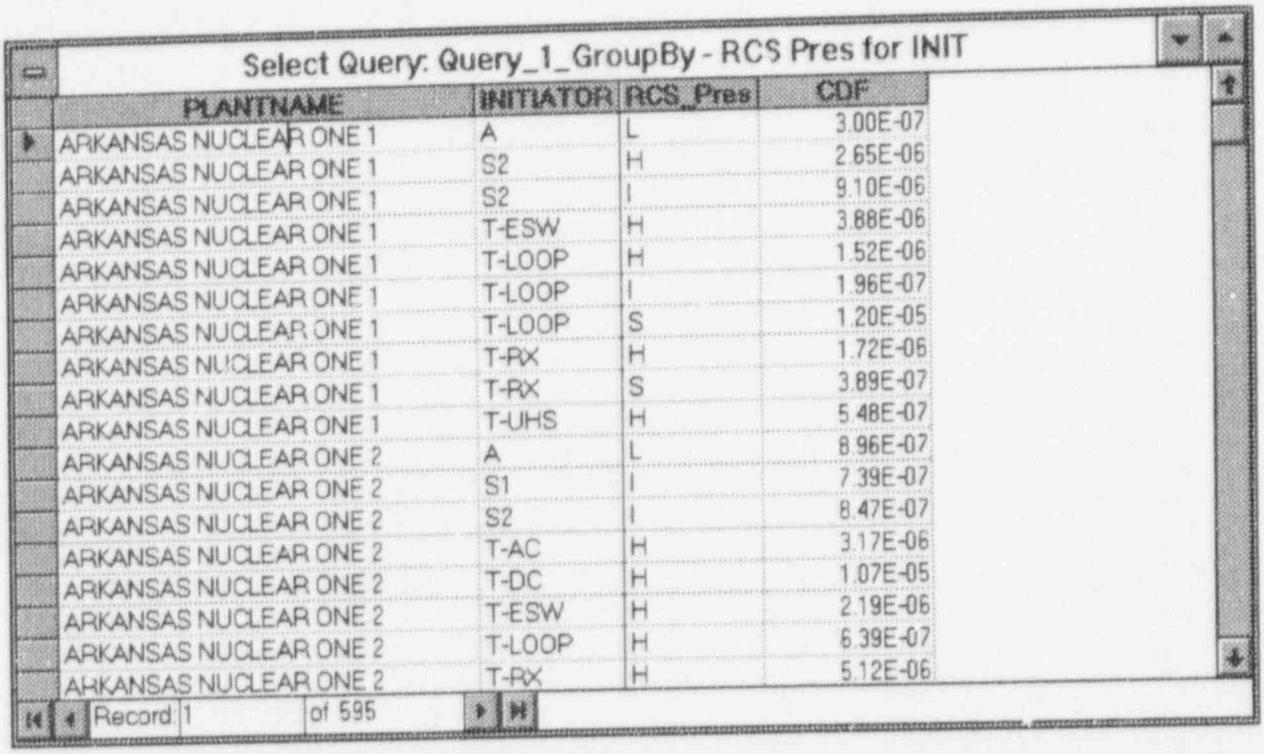


Figure 3.1 Query design window for RCS pressures for selected initiators

(5) Click on the **Data sheet** button to view the answers to the query as shown in Figure 3.2. This figure shows that, for Arkansas Nuclear One 1, the RCS pressure is low for all large LOCA sequences (i.e., "**A**" sequences). For small LOCA sequences (S2), the CDF for high RCS pressure is 2.65E-6, and the CDF for intermediate RCS pressure is 9.1E-6.

(6) In the query design window, click "**Query**" and then select "**Make Table.**" Name the database table as "**Table-Q1-RCS Pres for INT**," run the query to generate a database table.



Select Query: Query_1_GroupBy - RCS Pres for INIT

PLANTNAME	INITIATOR	RCS_Pres	CDF
ARKANSAS NUCLEAR ONE 1	A	L	3.00E-07
ARKANSAS NUCLEAR ONE 1	S2	H	2.65E-06
ARKANSAS NUCLEAR ONE 1	S2	I	9.10E-06
ARKANSAS NUCLEAR ONE 1	T-ESW	H	3.88E-06
ARKANSAS NUCLEAR ONE 1	T-LOOP	H	1.52E-06
ARKANSAS NUCLEAR ONE 1	T-LOOP	I	1.96E-07
ARKANSAS NUCLEAR ONE 1	T-LOOP	S	1.20E-05
ARKANSAS NUCLEAR ONE 1	T-RX	H	1.72E-06
ARKANSAS NUCLEAR ONE 1	T-RX	S	3.89E-07
ARKANSAS NUCLEAR ONE 1	T-UHS	H	5.48E-07
ARKANSAS NUCLEAR ONE 2	A	L	8.96E-07
ARKANSAS NUCLEAR ONE 2	S1	I	7.39E-07
ARKANSAS NUCLEAR ONE 2	S2	I	8.47E-07
ARKANSAS NUCLEAR ONE 2	T-AC	H	3.17E-06
ARKANSAS NUCLEAR ONE 2	T-DC	H	1.07E-05
ARKANSAS NUCLEAR ONE 2	T-ESW	H	2.19E-06
ARKANSAS NUCLEAR ONE 2	T-LOOP	H	6.39E-07
ARKANSAS NUCLEAR ONE 2	T-RX	H	5.12E-06

Record: 1 of 595

Figure 3.2 Display of RCS pressures for selected initiators

3.4 Example 2: RCS Pressures for Small LOCA

This example illustrates how to design a query to determine the fraction of the S2 sequences at high and low RCS pressures, respectively. It also demonstrates how to use **Crosstab** to present the data in a more readable form, so that you can easily make comparisons.

(1) Perform Step 2 of Section 3.2 and "**Add**" the table, **"Table -Q1-RCS Pres for INT"** to the QBE window as shown in Figure 3.3.

(2) Bring all of the table's fields to the QBE (Query By Example) grid.

(3) From the Query menu, choose **Crosstab.** The **Total** and **Crosstab** rows appear in the

QBE grid.

(4) "**Group By**" appears in the **Total** cell for each field in the QBE grid. However, this query is designed to calculate the CDF totals for a specific initiator, consequently, replace the aggregate function "**Group By**" with the "**Sum**" for the CDF field. In addition, to search the data for a specific initiator (S2), place an aggregation function "**Where**" and a search criteria **"S2"** in the **INITIATOR** field.

(5) Click the **Crosstab** cell for the field name you want to use as the row heading, click the arrow, and then select **Row Heading** for **PLANTNAME** and **Column Heading** for **RCS Pres**.

(6) Click on the **Data sheet** button to view the answers to the query, as shown in Figure 3.4. This figure displays the CDFs for the various RCS pressures for a selected initiator (small LOCA, S2, for this case).

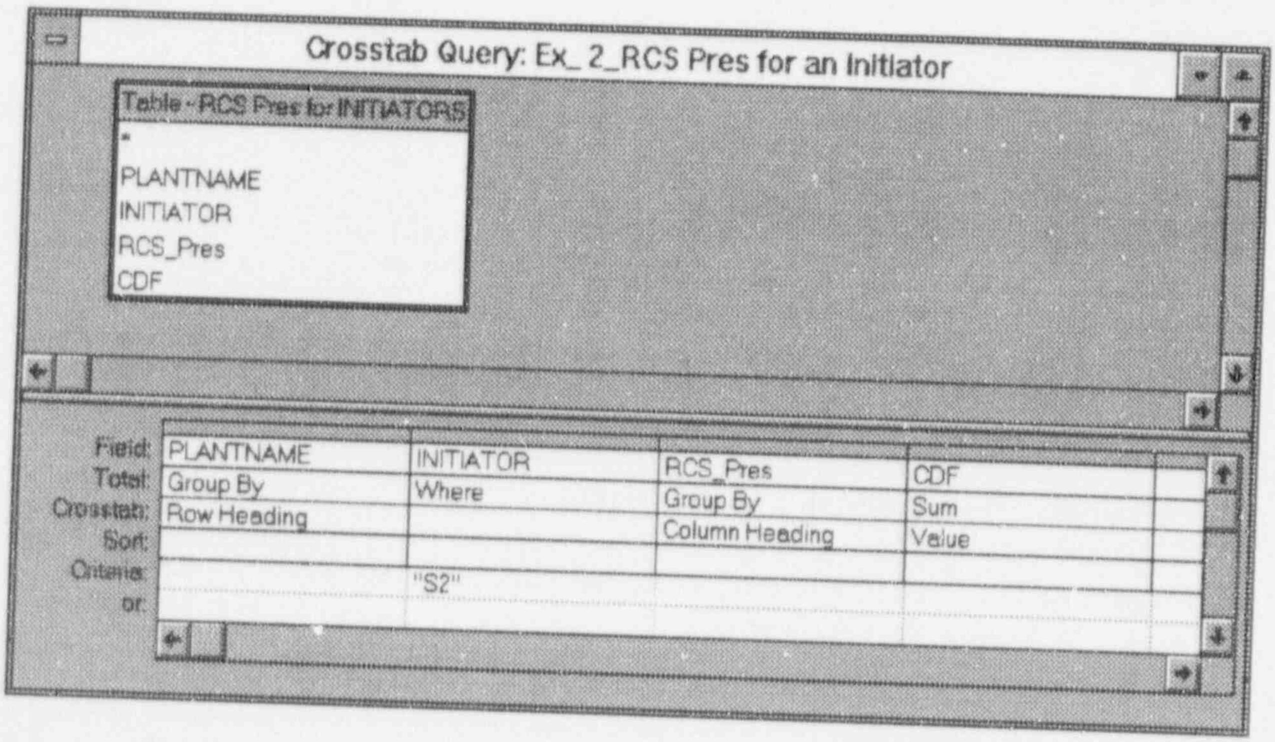


Figure 3.3 Query design window for RCS pressures for a small LOCA

Crosstab Query: Ex2 - RCS Pres for an initiator

PLANTNAME	H	I	L	NP
ARKANSAS NUCLEAR ONE 1	2.65E-06	9.10E-06		
ARKANSAS NUCLEAR ONE 2		8.47E-07		
BEAVER VALLEY 1	9.63E-06	2.23E-06		
BEAVER VALLEY 2	1.78E-05			
BRAIDWOOD 1&2	2.52E-07			1.87E-07
BYRON 1&2	5.76E-08		1.68E-07	3.06E-07
CALLAWAY		1.94E-06		
CALVERT CLIFFS 1&2		4.71E-06		
CATAWBA 1&2		5.05E-06		
COMANCHE PEAK 1&2		1.70E-06		9.94E-08
CRYSTAL RIVER 3		7.01E-06		
D.C. COOK 1&2		2.96E-05		
FARLEY 1&2	5.08E-06		1.00E-05	
FORT CALHOUN 1		7.83E-07		
GINNA		4.93E-06		4.40E-08
HADDAM NECK	1.24E-05			
INDIAN POINT 2	5.42E-06			
INDIAN POINT 3				5.09E-07

Record: 3 of 40

Figure 3.4 Display of RCS pressures for a small LOCA

3.5 Example 3: Steam Generator Tube Rupture Transients

This query demonstrates the use of the IPE database to search the initiator frequencies and CDFs for a selected initiator(s) (T-SGTR, in this case). It also shows the conditional core damage probabilities (CCDP) for the initiator derived using a calculation technique provided by Access. Although this query designed to reflect the FREQ2 data file for PWRs, which contains information regarding initiating event (IE) frequencies and the associated CDFs, a similar query can be constructed for BWRs using the FREQBWR2 data file.

The steps to create this query are as follows:

(1) Perform Step 2 of Section 3.2 and "**Add**" the **GENERAL** and **FREQ2** tables to the QBE window, as shown in Figure 3.5.

(2) Join the tables by connecting the common **PLANTNAME** field.

(3) Bring the **PLANTNAME, INITIATOR, IE_FREQ,** and **CD_FREQ** fields to the QBE (Query By Example) grid. Define the **IE_FREQ** field as Initiator_Frequency and **CD_FREQ** as CD_Freqency.

(4) To calculate the CCDPs for T-SGTR, type **Conditional_Prob:[CD_FREQ]/[IE_FREQ]**

in the **Field** row.

(5) To select the data for T-SGTR only, enter **T-SGTR** in the **Criteria** row of the **INITIATOR** field.

The Query design window is shown in Figure 3.5, and the answers to this query are shown in Figure 3.6. It should be noted that the results for T-SGTR show a reasonable range of IE frequencies, while the CCDPs for T-SGTR have a wide range among the different IPE submittals. One can also examine the variations of IEs and CCDPs for selected plants or a group of plants through the use of the **GENERAL** table. For instance, if you are interested in CE plants only, bring in the **NSSSVENDOF** field from the **GENERAL** table. Enter **CE** in the **Criteria** row of the **NSSSVENDOF** field to specify the search.

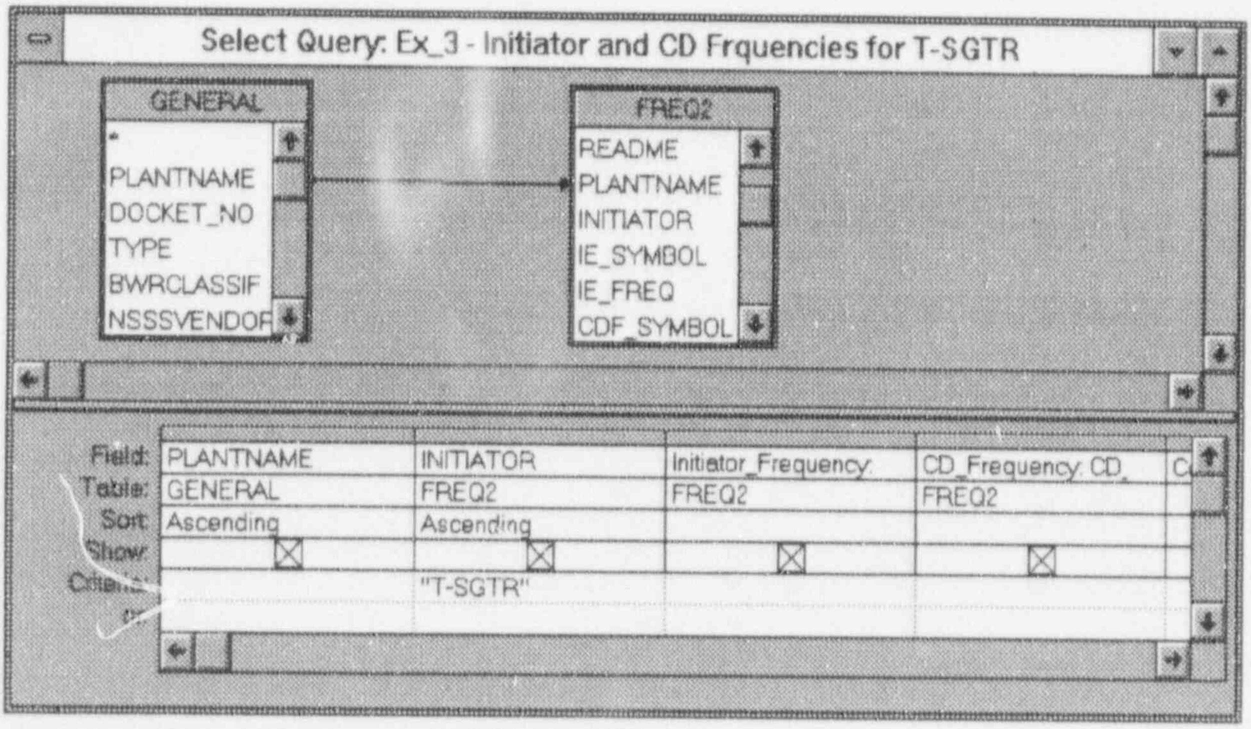


Figure 3.5 Query design window for initiator frequencies and CDF for T-SGTR

Select Query: Ex_3 - Initiator and CD Frquencies for T-SGTR

PLANTNAME	INITIATOR	Initiator_Frequency	CD_Frequency	Conditional_Prob
ARKANSAS NUCLEAR ONE 1	T-SGTR	9.77E-03	2.08E-07	2.13E-05
ARKANSAS NUCLEAR ONE 2	T-SGTR	9.77E-03	9.54E-08	9.76E-06
BEAVER VALLEY 1	T-SGTR	1.32E-02	7.28E-06	5.51E-04
BEAVER VALLEY 2	T-SGTR	2.05E-02	7.10E-06	3.47E-04
BRAIDWOOD 1&2	T-SGTR	1.10E-02	2.75E-08	2.50E-06
BYRON 1&2	T-SGTR	1.10E-02	3.51E-08	3.19E-06
CALLAWAY	T-SGTR	1.20E-02	8.48E-07	7.07E-05
CALVERT CLIFFS 1&2	T-SGTR	3.79E-03	4.49E-06	1.18E-03
CATAWBA 1&2	T-SGTR	9.00E-03	1.00E-10	1.11E-08
COMANCHE PEAK 1&2	T-SGTR	2.84E-02	3.54E-06	1.25E-04
CRYSTAL RIVER 3	T-SGTR	1.70E-02	6.89E-07	4.06E-05
D.C. COOK 1&2	T-SGTR	7.20E-03	7.07E-06	9.82E-04
DAVIS-BESSE	T-SGTR	9.00E-03	4.60E-07	5.11E-05
DIABLO CANYON 1&2	T-SGTR	1.40E-02	1.80E-06	1.29E-04
FARLEY 1&2	T-SGTR	1.00E-02	2.66E-07	2.66E-05
FORT CALHOUN 1	T-SGTR	9.27E-03	7.62E-07	8.22E-05
GINNA	T-SGTR	1.20E-02	2.69E-05	2.24E-03
H.B. ROBINSON 2	T-SGTR	1.00E-02	5.73E-06	5.73E-04

Record: 5 of 49

Figure 3.6 Display of initiator frequencies and CDF for T-SGTR

3.6 Example 4: CCDPs for T-LOOP and Station Blackout

This query demonstrates how to extract similar data related to T-LOOP and station blackout (SBO). As shown in the following discussion, this query involves creation of a table containing only the SBO data and then using this table to obtain IE frequencies and CDFs for SBO.

The steps to create this query are as follows:

(1) Create a database table for SBO events. "**Add**" the **FREQ2** table to the QBE window as shown in Figure 3.7. Bring the **PLANTNAME, INITIATOR, IE_FREQ,** and **CD_FREQ** fields to the QBE grid. Define the **IE_FREQ** field as SBO_IE_FREQ and **CD_FREQ** as SBO_CDF. To select the data for SBO, enter **(SBO)** in the **Criteria** row of the **INITIATOR** field. From the Query menu, choose **Make Table,** and a Query Properties window appears. Name the table as **"Table-SBO IE Freq & CDF**."

(2) Click the "**Run**" in Query menu to generate the **"Table-SBO IE Freq & CDF**" as displayed in Figure 3.8.

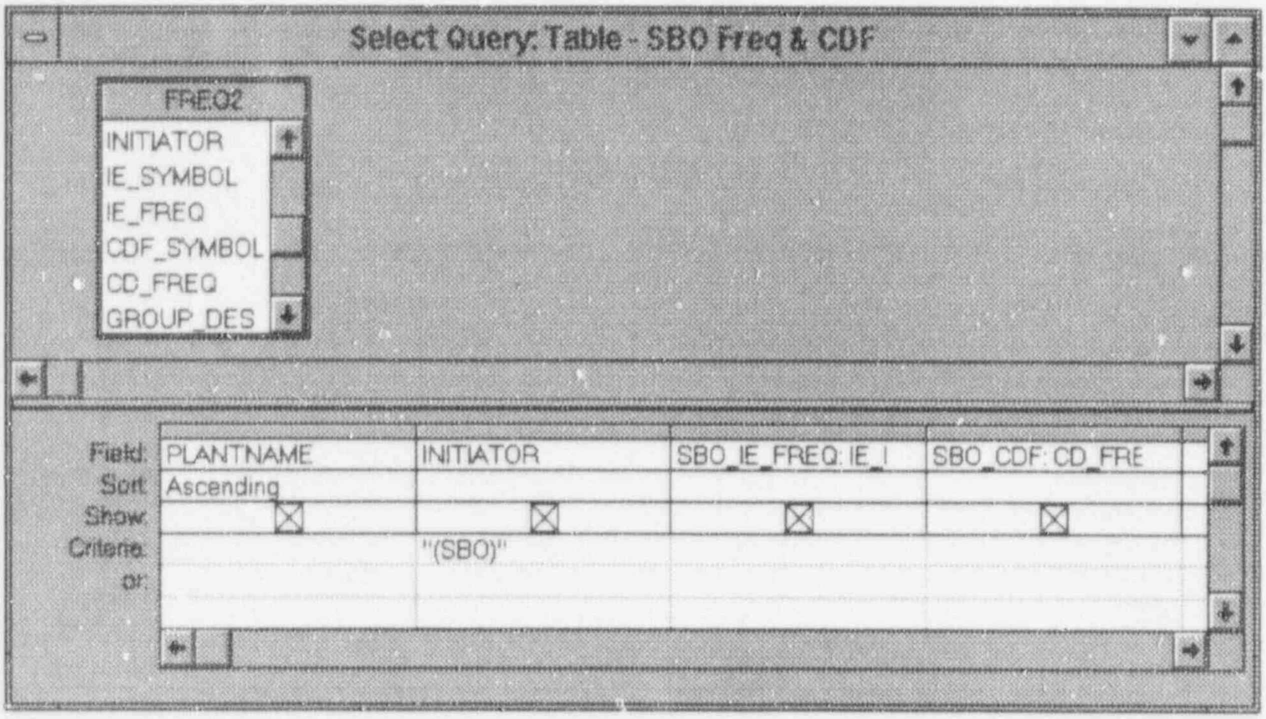
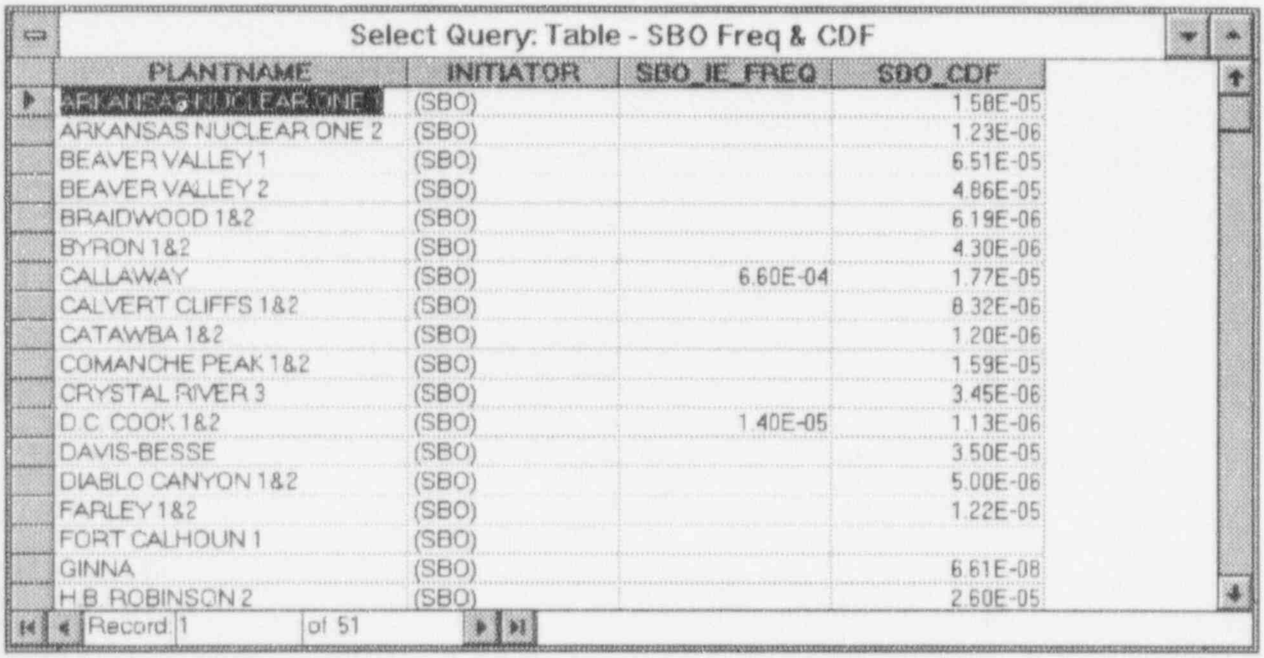


Figure 3.7 Query design window for making database table "SBO Freq & CDF"



PLANTNAME	INITIATOR	SBO_IE_FREQ	SBO_CDF
ARKANSAS NUCLEAR ONE 1	(SBO)		1.58E-05
ARKANSAS NUCLEAR ONE 2	(SBO)		1.23E-06
BEAVER VALLEY 1	(SBO)		6.51E-05
BEAVER VALLEY 2	(SBO)		4.86E-05
BRAIDWOOD 1&2	(SBO)		6.19E-06
BYRON 1&2	(SBO)		4.30E-06
CALLAWAY	(SBO)	6.60E-04	1.77E-05
CALVERT CLIFFS 1&2	(SBO)		8.32E-06
CATAWBA 1&2	(SBO)		1.20E-06
COMANCHE PEAK 1&2	(SBO)		1.59E-05
CRYSTAL RIVER 3	(SBO)		3.45E-06
D.C. COOK 1&2	(SBO)	1.40E-05	1.13E-06
DAVIS-BESSE	(SBO)		3.50E-05
DIABLO CANYON 1&2	(SBO)		5.00E-06
FARLEY 1&2	(SBO)		1.22E-05
FORT CALHOUN 1	(SBO)		
GINNA	(SBO)		6.61E-08
H.B. ROBINSON 2	(SBO)		2.60E-05

Figure 3.8 Display of database table "SBO Freq & CDF"

(3) The steps used to query the SBO data are very similar to those discussed in Example 3 above. The query design window is shown in Figure 3.9, and results of this query are shown in Figure 3.10. In that figure, the **IE_FREQ** field shows the variation in the IPE submittals among the T-LOOP initiator frequencies for the selected plants. The **CDF_Fraction** shows the CCDPs for T-LOOP given a LOOP event. Similarly, **SBO_IE_Fraction** shows the conditional probability of SBO given a LOOP event, and **SBO_CDF_Fraction** shows the conditional probability of core damage due to SBO given a LOOP event.

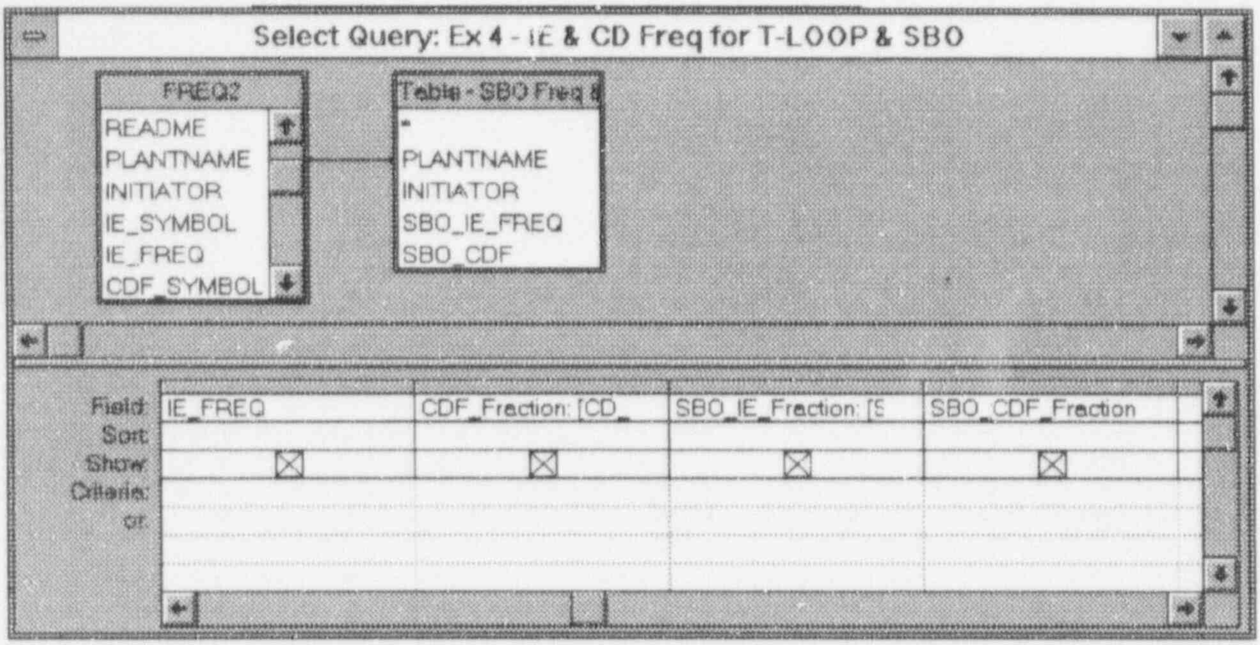


Figure 3.9 Query design window for IE and CDF for T-LOOP and SBO

As shown in Figure 3.10, for Beaver Valley 1 and 2, the CDF for SBO is greater than for T-LOOP. This indicates that some SBO sequences are not initiated by T-LOOP (which is also the case for most other IPE submittals). The Davis-Besse and Ginna IPE submittals do not separately report the CDF for T-LOOP. Instead, T-LOOP is included with other IEs (as part of Group 1 in the FREQ2 database table). Similarly, the Fort Calhoun and Millstone 2 submittals do not separately report the CDF for SBO. For more information, see the SBO-related notes for the database record in FREQ2.

Select Query: Ex 4 - IE & CD Freq for T-LOOP & SBO

PLANTNAME	IE_FREQ	CDF_Fraction	SBO_IE_Fraction	SBO_CDF_Fraction
ARKANSAS NUCLEAR ONE 1	3.58E-02	4.64E-04		4.41E-04
ARKANSAS NUCLEAR ONE 2	5.84E-02	2.95E-05		2.11E-05
BEAVER VALLEY 1	6.64E-02	7.70E-04		9.80E-04
BEAVER VALLEY 2	7.44E-02	3.82E-04		6.53E-04
BRAIDWOOD 1&2	4.54E-02	5.31E-04		1.36E-04
BYRON 1&2	4.43E-02	5.78E-04		9.70E-05
CALLAWAY	4.60E-02	3.87E-04	1.43E-02	3.85E-04
CALVERT CLIFFS 1&2	1.36E-01	2.67E-04		6.12E-05
CATAWBA 1&2	3.50E-02	3.43E-05		3.43E-05
COMANCHE PEAK 1&2	3.50E-02	4.54E-04		4.54E-04
CRYSTAL RIVER 3	4.35E-01	7.58E-06		7.93E-06
D.C. COOK 1&2	4.00E-02	3.26E-05	3.50E-04	2.82E-05
DAVIS-BESSE	3.50E-02	0.00E+00		1.00E-03
DIABLO CANYON 1&2	9.10E-02	3.96E-04		5.49E-05
FARLEY 1&2	4.70E-02	4.18E-04		2.60E-04
FORT CALHOUN 1	2.17E-01	2.88E-05		
GINNA	3.50E-03			1.89E-05
H.B. ROBINSON 2	6.10E-02	9.39E-04		4.26E-04

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Figure 3.10 Display of frequencies & CDF for T-LOOP and SBO

3.7 Example 5: Availability of HHSI and IHSI Pumps

This query shows the availability of the high head safety injection (HHSI) system and the intermediate head safety injection (IHSI) system pumps for the selected plants. The HHSI system uses the chemical and volume control system (CVCS) centrifugal charging pumps for injection. The shutoff head of these pumps is above the primary safety valve set pressure, but the capacity is usually low. The IHSI pumps are designed specifically for safety injection(SI). Their shutoff heads are below the set pressure, and their capacities are higher than those of the CVCS pumps. Some plants use CVCS pumps for injection and do not have SI pumps, while others rely on the SI pumps for injection because their CVCS pumps do not have sufficient capacity. Some plants have both HHSI and IHSI pumps.

As shown in the following discussion, this query involves creation of a table containing only the HHSI data, and then using this table to obtain information regarding the availability of HHSI and HHSI system pumps for the selected plants.

The steps to create this query are as follows:

(1) Create a database table for HHSI. Perform Step 2 of Section 3.2 and "**Add**" the **FRONTLIN** and **GENERAL** tables to the QBE window, as shown in Figure 3.11. Join the tables by connecting the **PLANTNAME** field. Bring **PLANTNAME, SYSTEM,**

NOMENCLAT, NO_TRANS, SEMI_OR_S, OTHER_FUNC, CROSSTIE, and **NOTES** fields to the QBE grid. To select the HHSI data, enter "**CHPI**" in the **Criteria** row of the **SYSTEM** field, and "**HHSI**" in the **NOTES** field. From the Query menu, choose **Make Table,** and a Query Properties window appears. Name the table as "**Table - PWR HHSI**."

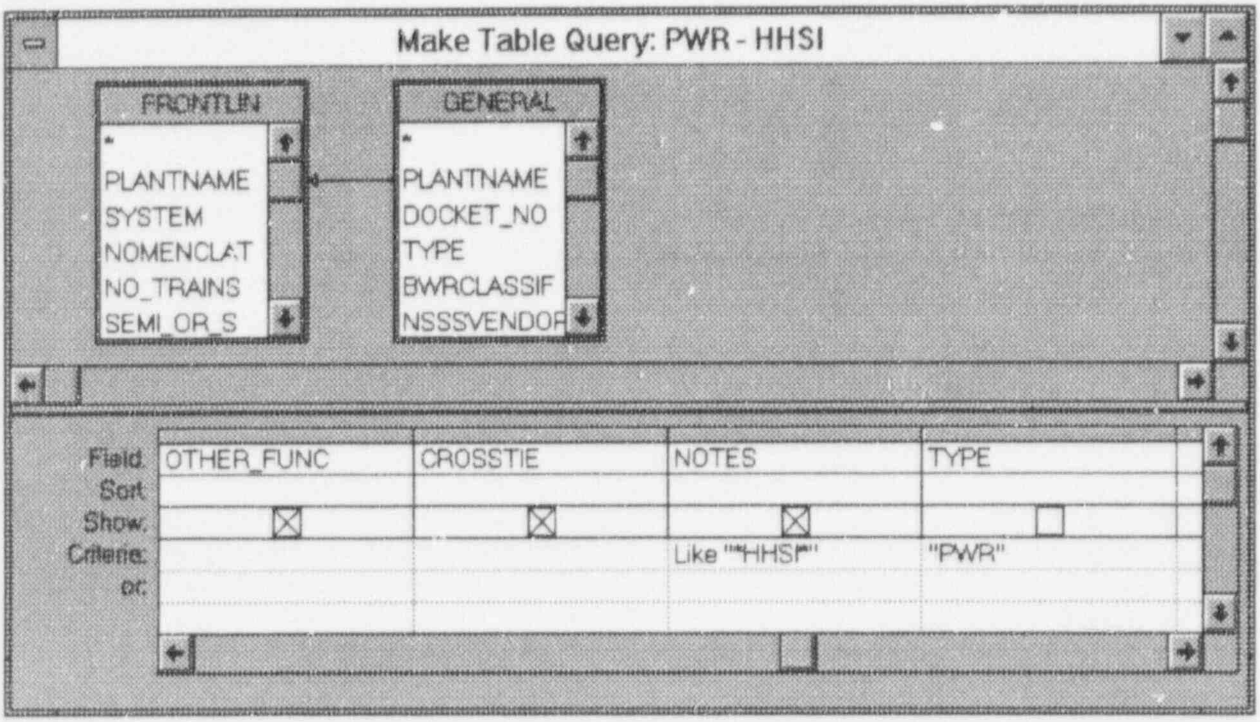


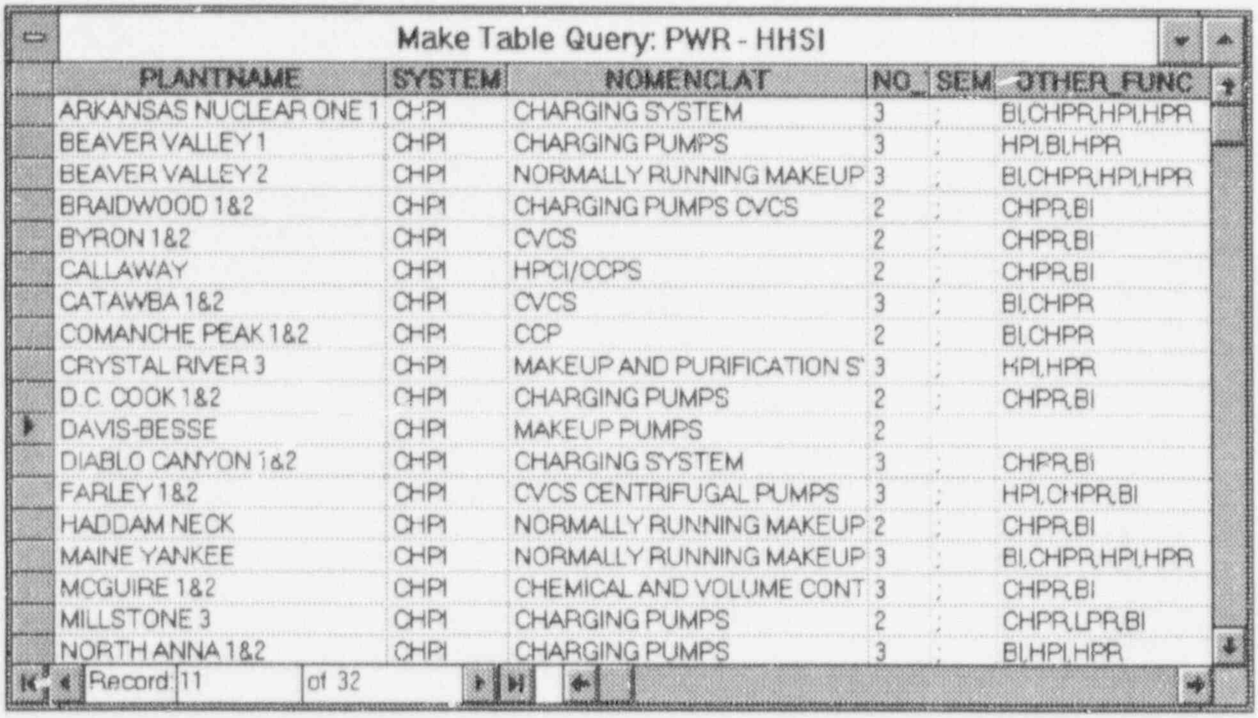
Figure 3.11 Query design window for making database table "PWR HHSI"

(2) The steps used to query the IHSI data are very similar to those discussed above.

The query design window for making the database table, "**Table - PWR HHSI**," is shown in Figure 3.11, and the results of this query, shown in Figure 3.12, identify the plants that use the CVCS pumps for HHSI.

Although the pump shutoff heads are above the primary safety valve set pressure, RCS depressurization using the primary pressure-operated relief valves (PORVs) may still be required for feed-and-bleed in some IPE submittals because of the low pump capacities at high RCS pressures. RCS depressurization is not required for some IPE submittals. The requirement of a depressurization for feed-and-bleed using HHSI pumps can be identified by the data presented in the mission success paths database table.

The query design window for HHSI system is shown in Figure 3.13, and the results of this query are shown in Figure 3.14. It shows that North Anna has three HHSI pumps. The plants that do not have entries for NO_TRANS field are those whose CVCS pumps do not have sufficient capacity to be used for safety injection. These include, among others, ANO2, Calvert Cliff, etc. To query the database regarding IHSI, follow steps similar to those discussed above for HHSI.



PLANTNAME	SYSTEM	NOMENCLAT	NO_	SEM	OTHER_FUNC
ARKANSAS NUCLEAR ONE 1	CHPI	CHARGING SYSTEM	3	;	BI,CHPR,HPI,HPR
BEAVER VALLEY 1	CHPI	CHARGING PUMPS	3	;	HPI,BI,HPR
BEAVER VALLEY 2	CHPI	NORMALLY RUNNING MAKEUP	3	;	BI,CHPR,HPI,HPR
BRAIDWOOD 1&2	CHPI	CHARGING PUMPS CVCS	2	;	CHPR,BI
BYRON 1&2	CHPI	CVCS	2	;	CHPR,BI
CALLAWAY	CHPI	HPCI/CCPS	2	;	CHPR,BI
CATAWBA 1&2	CHPI	CVCS	3	;	BI,CHPR
COMANCHE PEAK 1&2	CHPI	CCP	2	;	BI,CHPR
CRYSTAL RIVER 3	CHPI	MAKEUP AND PURIFICATION S'	3	;	HPI,HPR
D.C. COOK 1&2	CHPI	CHARGING PUMPS	2	;	CHPR,BI
DAVIS-BESSE	CHPI	MAKEUP PUMPS	2		
DIABLO CANYON 1&2	CHPI	CHARGING SYSTEM	3	;	CHPR,BI
FARLEY 1&2	CHPI	CVCS CENTRIFUGAL PUMPS	3	;	HPI,CHPR,BI
HADDAM NECK	CHPI	NORMALLY RUNNING MAKEUP	2	;	CHPR,BI
MAINE YANKEE	CHPI	NORMALLY RUNNING MAKEUP	3	;	BI,CHPR,HPI,HPR
MCGUIRE 1&2	CHPI	CHEMICAL AND VOLUME CONT	3	;	CHPR,BI
MILLSTONE 3	CHPI	CHARGING PUMPS	2	;	CHPR,LPR,BI
NORTH ANNA 1&2	CHPI	CHARGING PUMPS	3	;	BI,HPI,HPR

Figure 3.12 Display of the CVCS pumps for HHSI

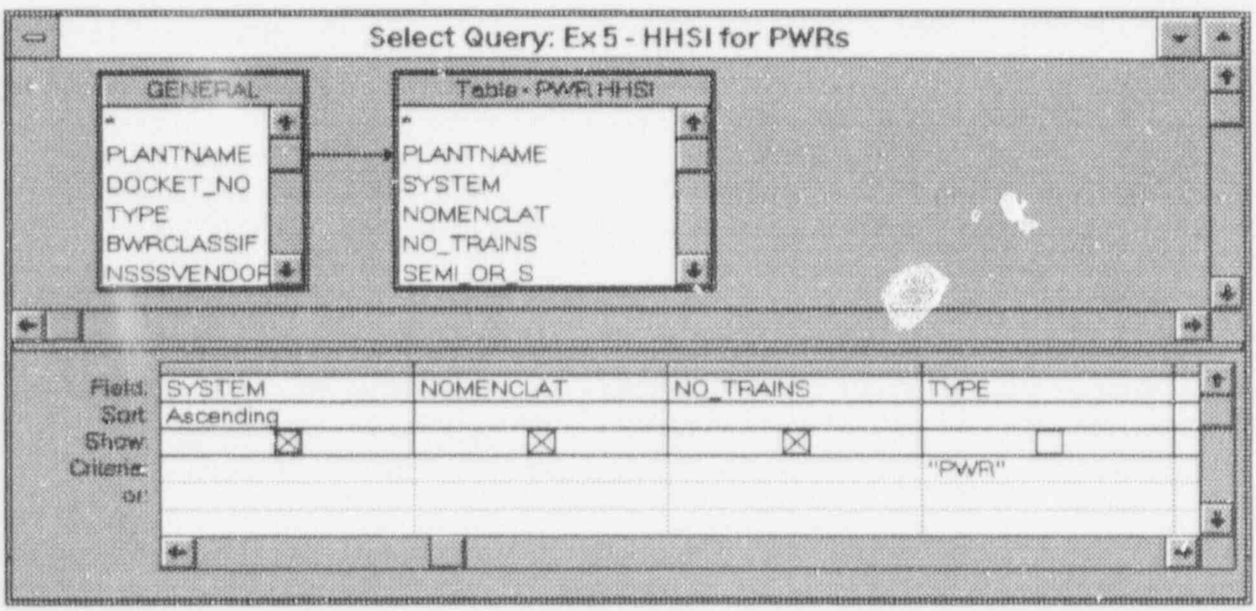


Figure 3.13 Query design window for HHSI for PWRs

Select Query: Ex 5 - HHSI for PWRs

PLANTNAME	SYSTEM	NOMENCLAT	NO_TRAINS
ARKANSAS NUCLEAR ONE 1	CHPI	CHARGING SYSTEM	3
ARKANSAS NUCLEAR ONE 2			
BEAVER VALLEY 1	CHPI	CHARGING PUMPS	3
BEAVER VALLEY 2	CHPI	NORMALLY RUNNING MAKEUP (INJECTION)	3
BRAIDWOOD 1&2	CHPI	CHARGING PUMPS CVCS	2
BYRON 1&2	CHPI	CVCS	2
CALLAWAY	CHPI	HPCI/CCPS	2
CALVERT CLIFFS 1&2			
CATAWBA 1&2	CHPI	CVCS	3
COMANCHE PEAK 1&2	CHPI	CCP	2
CRYSTAL RIVER 3	CHPI	MAKEUP AND PURIFICATION SYSTEM (MU)	3
D.C. COOK 1&2	CHPI	CHARGING PUMPS	2
DAVIS-BESSE	CHPI	MAKEUP PUMPS	2
DIABLO CANYON 1&2	CHPI	CHARGING SYSTEM	3
FARLEY 1&2	CHPI	CVCS CENTRIFUGAL PUMPS	3
FORT CALHOUN 1			
GINNA			
H.B. ROBINSON 2			

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Figure 3.14 Display HHSI for PWRs

3.8 Example 6: Transients-Induced LOCA Profiles

This query shows the CDFs for transient-induced LOCA (TIL) events and their various modes, which are categorized as seal LOCAs, stuck-open relief valves (SORVs), and RCS failures. This query requires database tables generated by using ACCIDSEQ file for the various TIL modes.

The steps to create this query are as follows:

(1) Create database tables.

(a) The first database table to be created is designed to find the CDFs for TIL events, using the query design window shown in Figure 3.15. This figure shows that the **ACCIDSEQ** table is "**ADD**"ed to the QBE window. Bring the **PLANTNAME, CDF,** and **ATTRIBUTES** fields to the QBE grid, and name the **CDF** field as **CDF_Total_TIL**. To calculate the sum of the CDFs for TIL events, select the aggregate function "**Sum**" for the CDF field. To select the data for TIL events, enter **"Like *TIL"** in the **ATTRIBUTES** field. From the Query menu, choose **Make Table,** and a Query Properties window appears. Name the table as "**Table - Total TIL CDF**." Figure 3.16 displays the data contained in this table.

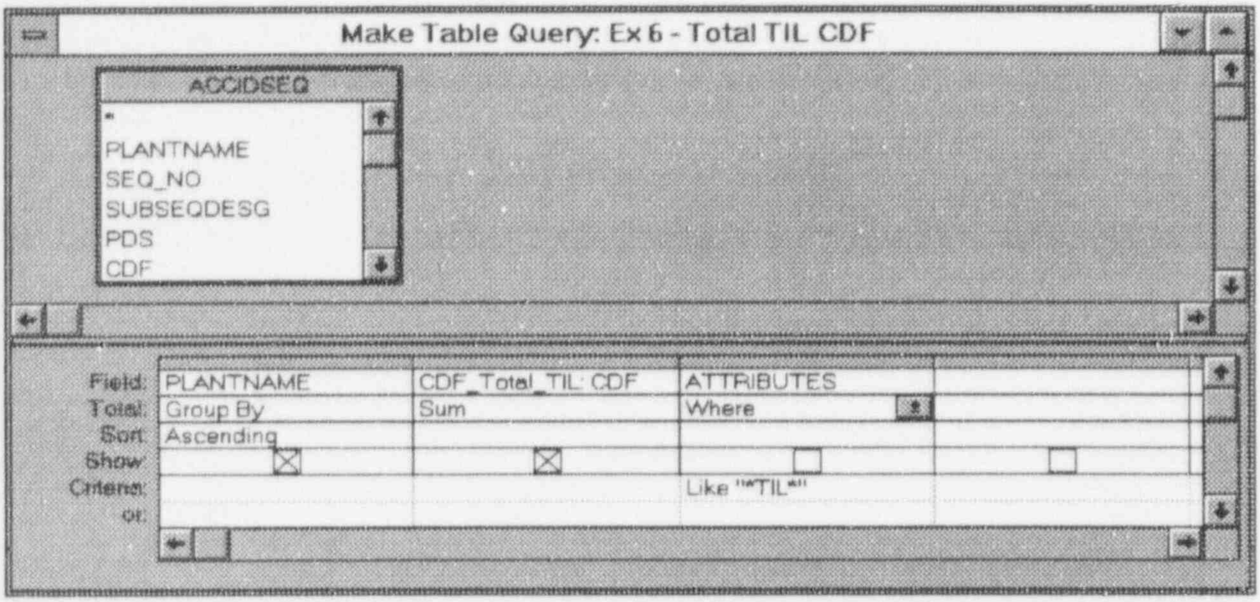


Figure 3.15 Query design window for making database table "Total TIL CDF"

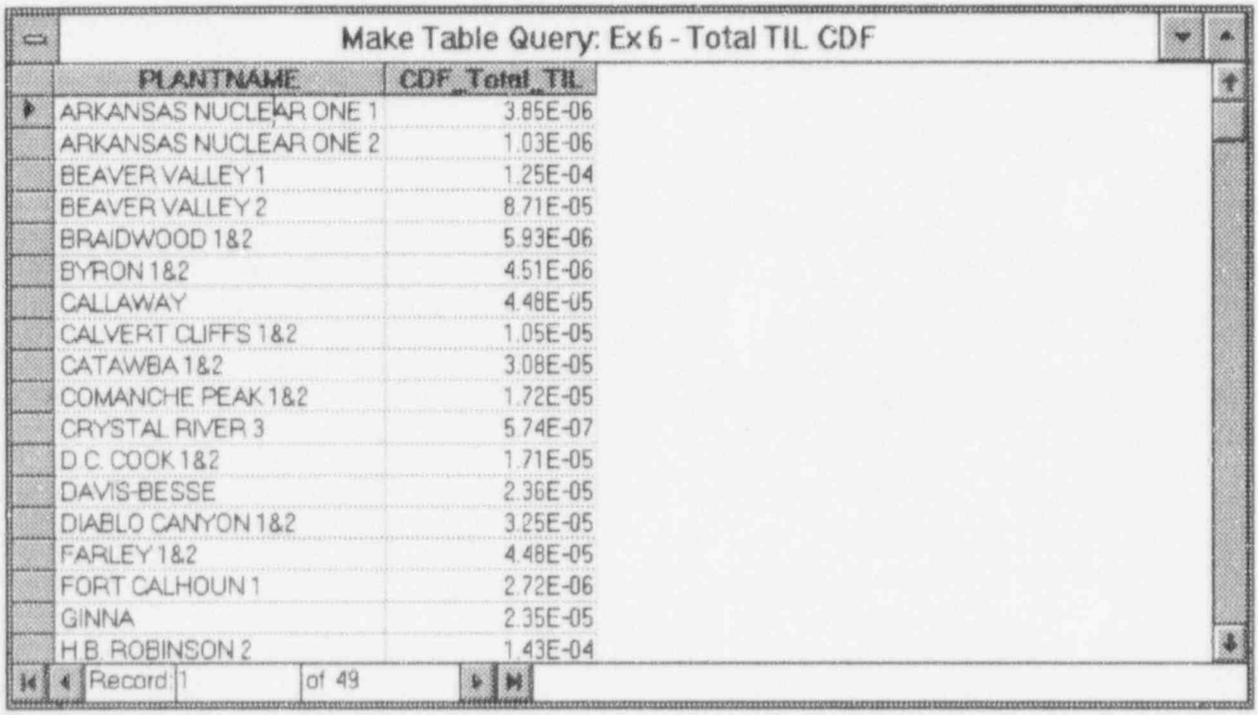


Figure 3.16 Display of database table "Total TIL CDF"

(b) The next three IPE database tables to be generated are **Table - TIL w/Seal LOCA**, **Table - TIL w/SORV**, and **Table - TIL w/RCS Fail**. The steps for generating these two tables are very similar to those used to generate the table for total TIL CDFs. The query design windows for these three tables are shown in Figures 3.17, 3.18, and 3.19.

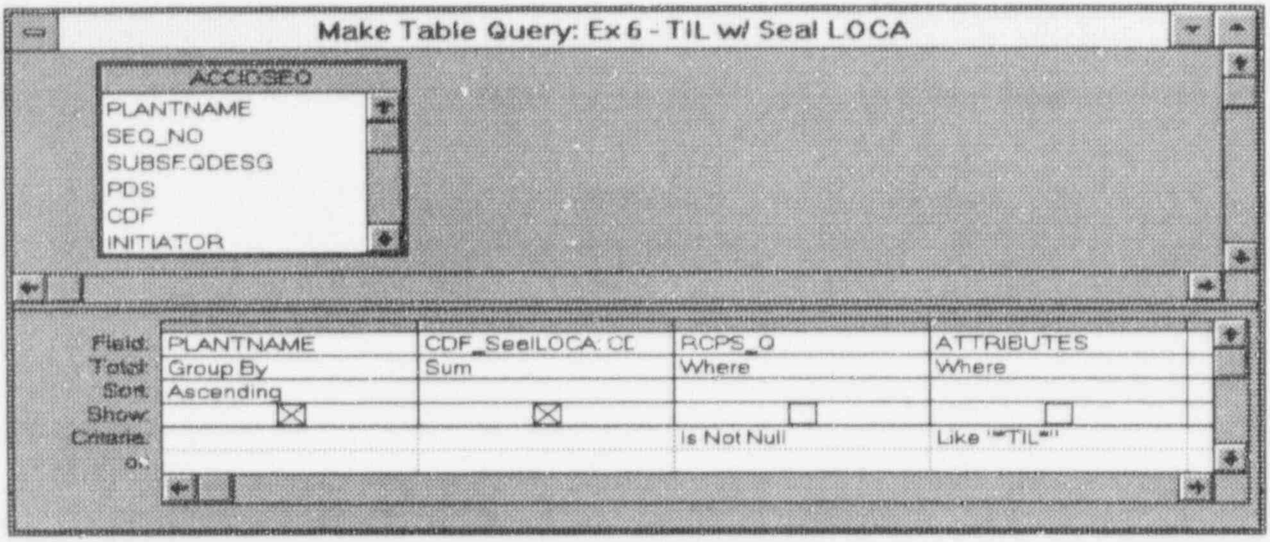


Figure 3.17 Query design window for making database table "TIL w/Seal LOCA"

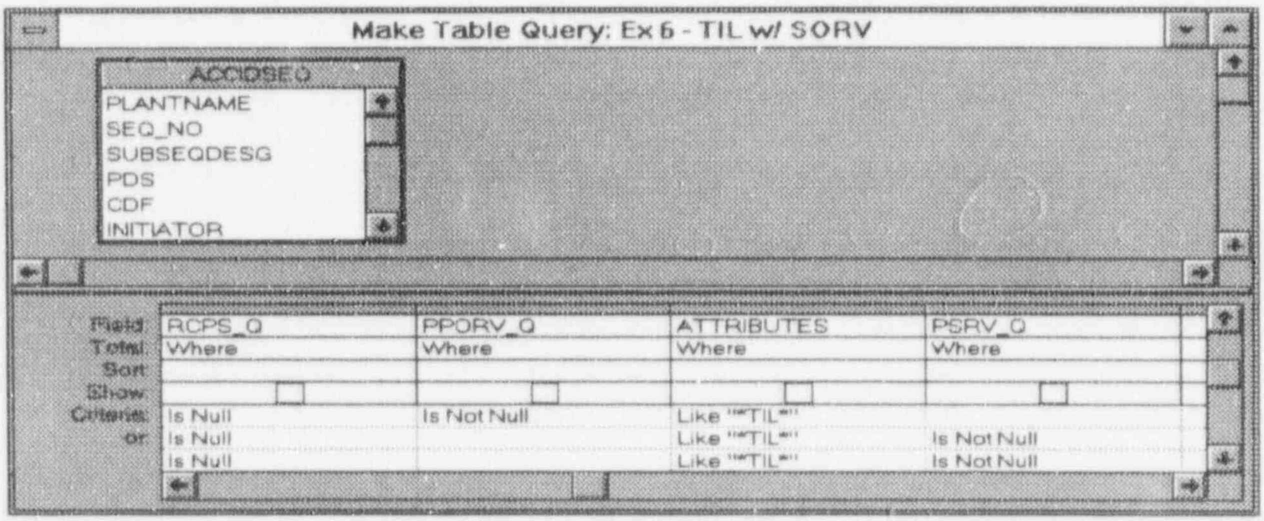


Figure 3.18 Query design window for making database table "TIL w/SORV"

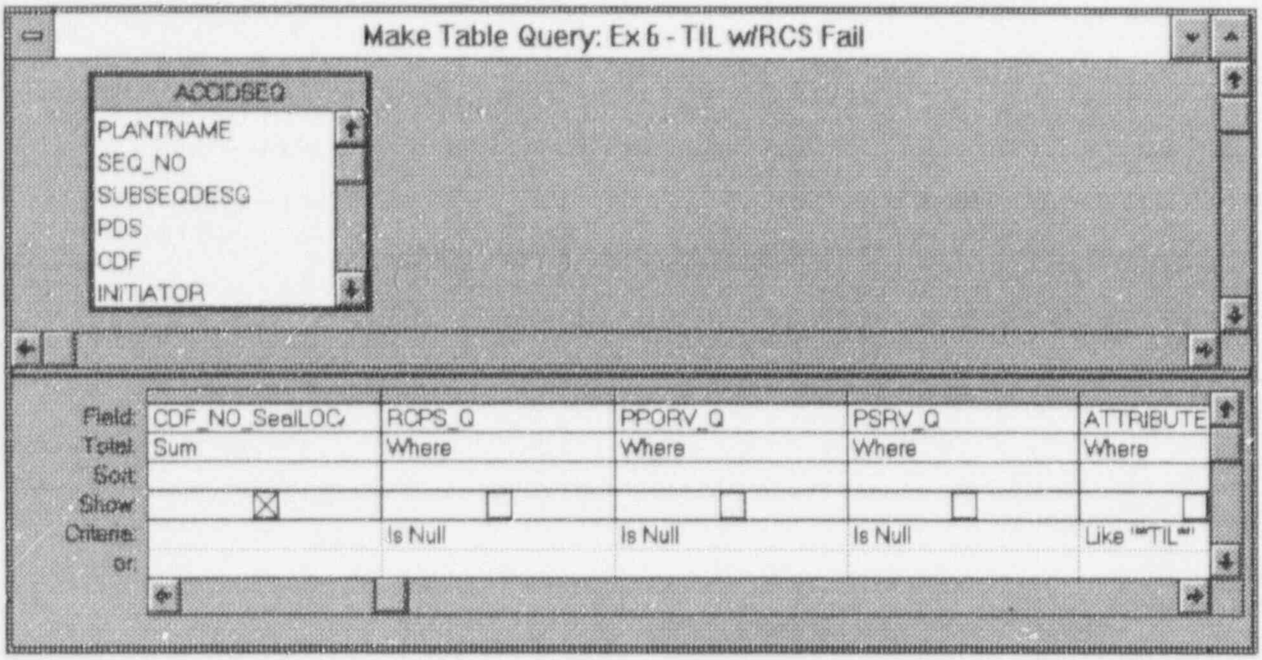


Figure 3.19 Query design window for making database table "TIL w/RCS Fail"

(2) Design the query to derive the CDFs for various TIL modes using the following steps:

(a) "**Add**" the **GENERAL**, **Table - Total TIL CDF**, **Table - TIL w/Seal LOCA**, **Table - TIL w/SORV,**" and **Table - TIL w/RCS Fail** tables to the QBE window as shown in Figure 3.20.

(b) Join the tables by connecting the common **PLANTNAME** field.

(c) Bring the **PLANTNAME**, **CDF_Seal_LOCA**, **CDF_SORV**, and **CDF_NO_SealLOCA_or_SORV** fields to the QBE grid.

(d) Name **CDF_Seal_LOCA** as "**Seal LOCA CDF**," **CDF_SORV** as "SORV CCDF", and **CDF_NO_SealLOCA_or_SORV** as "RCS Fail CDF."

Figure 3.21 depicts the results of this query. As indicated, seal LOCA events are generally the most significant contributor to TILs for PWR plants.

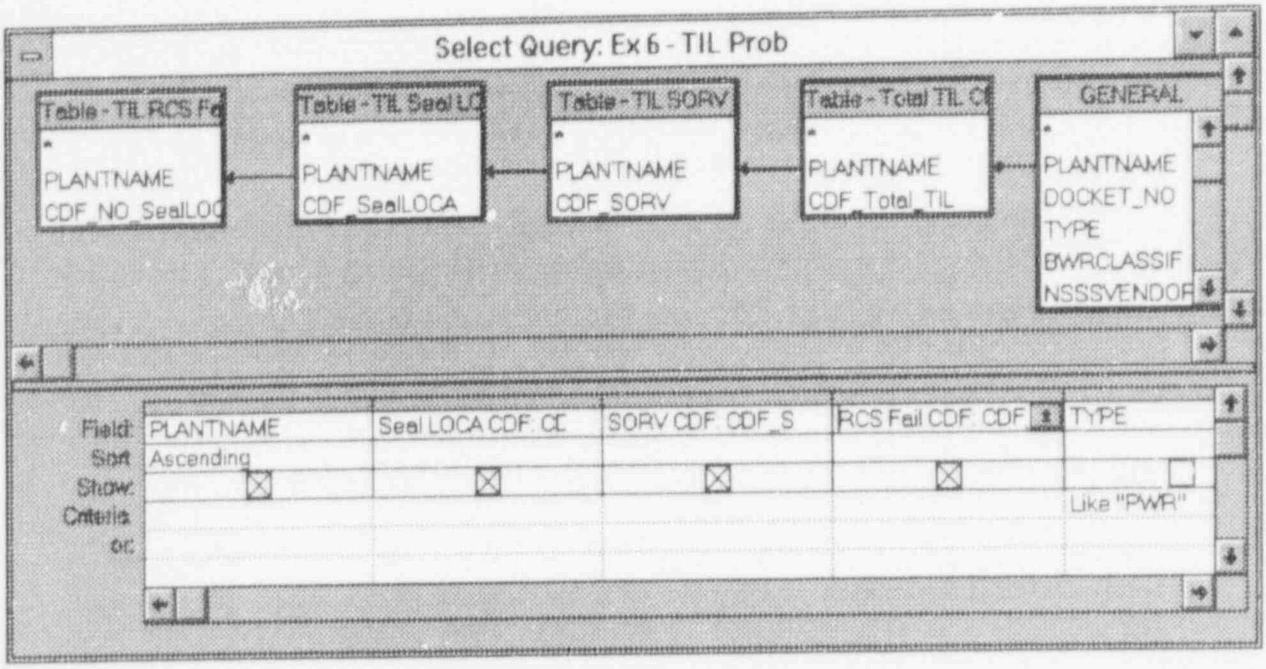
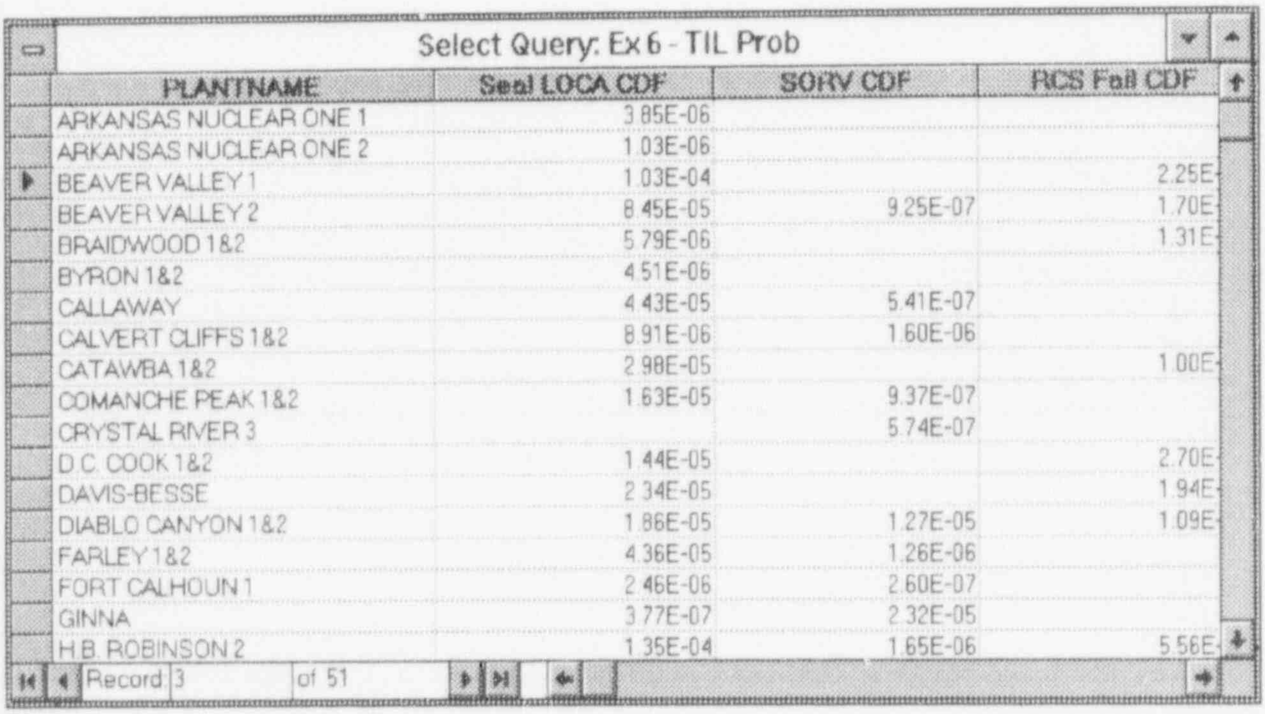


Figure 3.20 Query design window for various modes of TIL CDF


Select Query: Ex 6 - TIL Prob

PLANTNAME	Seal LOCA CDF	SORV CDF	RCS Fail CDF
ARKANSAS NUCLEAR ONE 1	3.85E-06		
ARKANSAS NUCLEAR ONE 2	1.03E-06		
BEAVER VALLEY 1	1.03E-04		2.25E
BEAVER VALLEY 2	8.45E-05	9.25E-07	1.70E
BRAIDWOOD 1&2	5.79E-06		1.31E
BYRON 1&2	4.51E-06		
CALLAWAY	4.43E-05	5.41E-07	
CALVERT CLIFFS 1&2	8.91E-06	1.60E-06	
CATAWBA 1&2	2.98E-05		1.00E
COMANCHE PEAK 1&2	1.63E-05	9.37E-07	
CRYSTAL RIVER 3		5.74E-07	
D.C. COOK 1&2	1.44E-05		2.70E
DAVIS-BESSE	2.34E-05		1.94E
DIABLO CANYON 1&2	1.86E-05	1.27E-05	1.09E
FARLEY 1&2	4.36E-05	1.26E-06	
FORT CALHOUN 1	2.46E-06	2.60E-07	
GINNA	3.77E-07	2.32E-05	
H.B. ROBINSON 2	1.35E-04	1.65E-06	5.56E

Record: 3 of 51

Figure 3.21 Display of CDFs for various TIL modes

3.9 Example 7: Significant Releases

This query is designed to determine the significance of release of certain fission products for selected plants. Specifically, this query derives the CDFs and fractions of the CDFs to total plant CDF for release classes with release fractions of I or Cs greater than 0.1.

The steps for the query design are as follows:

(1) "**Add**" the **GENERAL**, **REL-CLA** and **STERMS** tables to the QBE window, as shown in Figure 3.22.

(2) Join the tables by connecting the common **PLANTNAME** field, and join the **REL_CLASS** field between the tables of **REL-CLA** and **STERMS**.

(3) Bring the fields **PLANTNAME**, **RC_FREQ, TOTAL_CDF, TYPE, GR2_I**, and **GR3_CS** to the QBE grid.

(4) To calculate the fraction of the CDFs to total plant CDFs for I and Cs, enter a field as: **Fraction:Sum([RC_FREQ])/Max([TOTAL_CDF])**.

(5) In the **Total** row , select "**Max** "for **TOTAL_CDF**, "**Expression**" for **Fraction**, and "**Where**" for **TYPE, GR2_I**, and **GR3_CS**.

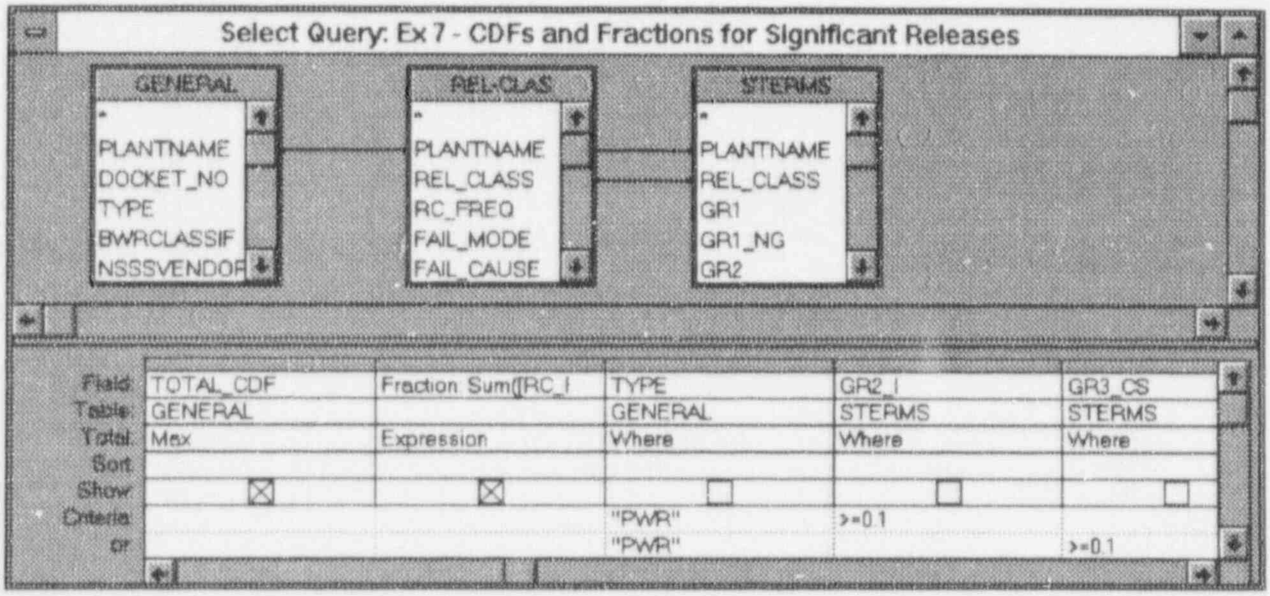


Figure 3.22 Query design window for significant release

(6) To select the data for PWR plants and for release classes with release fractions of I or Cs

greater than 0.1, enter **(PWR)** in the **Criteria** row of the **TYPE** field, and the enter "**>=0.1**" as the value for **GR2_I**, and **GR3_CS** fields.

Figure 3.23 shows the CDFs (SumOfRC_FREQ), total plant CDFs (MaxOfTOTAL_CDF), and the fractions of the CDFs to total plant CDFs (Fraction). For plants that lack values for CDFs and fractions (e.g., BV2 and McGuire, etc.), the lack of information is attributed to the fact that the IPE submittals do not specify the frequencies for the release classes.

Select Query: Ex 7 - CDFs and Fractions for Significant Releases

PLANTNAME	SumOfRC_FREQ	MaxOfTOTAL_CDF	Fraction
ARKANSAS NUCLEAR ONE 1	1.54E-06	4.67E-05	3.29%
ARKANSAS NUCLEAR ONE 2	1.17E-06	3.40E-05	3.45%
BEAVER VALLEY 1	2.45E-06	2.14E-04	1.15%
BEAVER VALLEY 2		1.92E-04	
CALLAWAY	4.48E-07	5.85E-05	0.77%
CALVERT CLIFFS 1&2	1.71E-05	2.40E-04	7.13%
CATAWBA 1&2	6.98E-08	5.80E-05	0.12%
COMANCHE PEAK 1&2	3.71E-06	5.72E-05	6.49%
D.C. COOK 1&2	2.09E-06	6.26E-05	3.35%
DAVIS-BESSE	6.69E-06	6.60E-05	10.13%
DIABLO CANYON 1&2	2.33E-06	8.80E-05	2.65%
FARLEY 1&2	4.53E-07	1.30E-04	0.35%
FORT CALHOUN 1	1.25E-06	1.36E-05	9.20%
GINNA	2.08E-05	8.74E-05	23.77%
H.B. ROBINSON 2	5.70E-07	3.20E-04	0.18%
HADDAM NECK	9.00E-06	1.90E-04	4.74%
INDIAN POINT 2	1.99E-06	3.13E-05	6.36%
INDIAN POINT 3	[illegible]	[illegible]	[illegible]

Record: 1 of 47

Figure 3.23 Display of database table of significant release

3.10 Example 8: CDFs at Various RCS Pressures

This query examines data from the IPE submittals to determine the CDFs for accident sequences at various RCS pressures. The steps to create this query are as follows:

(1) Perform the following steps to create a data table for PDS frequencies:

   (a) "**Add**" the **C-MATRIX** table to the QBE window, as shown in Figure 3.24. Bring the **PLANTNAME**, **PDS**, **FREQ**, **BYPASS**, and **EARLY_FAIL** fields to the QBE (Query By Example) grid.

   (b) Define the **FREQ** field as "Frequency", **BYPASS** as "Bypass", and **EARLY_FAIL** as "EF."

(c) In the "**Total**" cell for each field in the QBE grid, select the "**Group By**" aggregate function for the **PLANTNAME** and **PDS** fields, and select the "**Sum"** for the **FREQ, BYPASS,** and **EARLY_FAIL** fields.

(d) From the "Query" menu, choose **Make Table,** and a "Query Properties" window appears. Name the table as "**Table-PDS Frequency**."

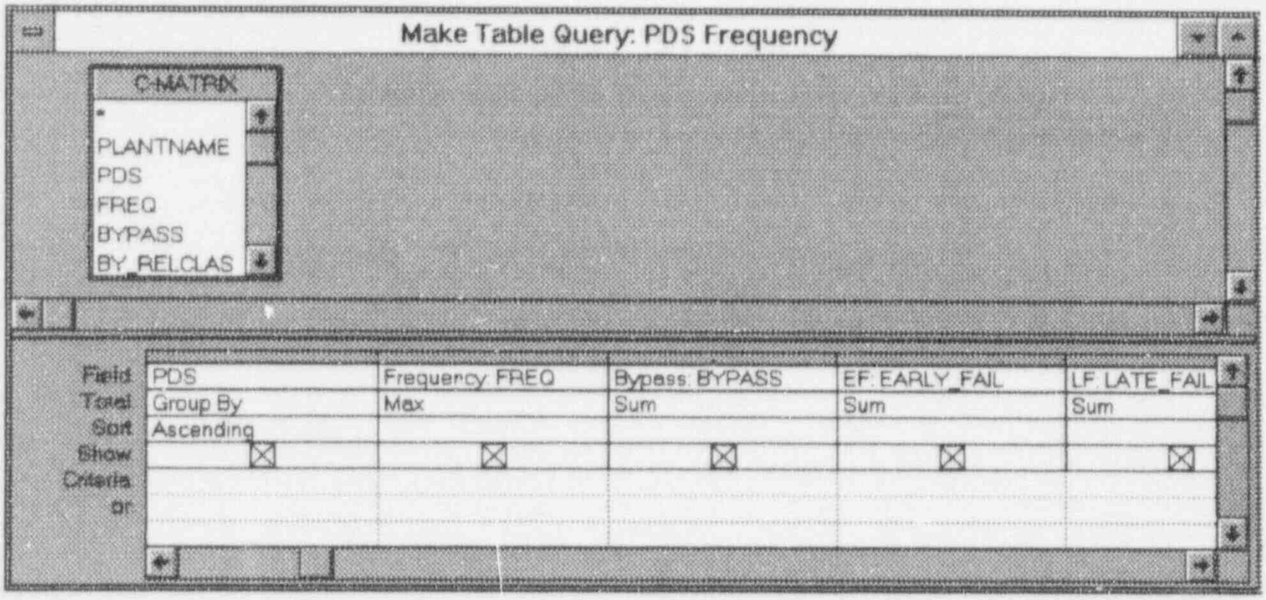


Figure 3.24 Query design window for making database table "PDS Frequency"

(2) Perform the following steps to design the query as shown in Figure 3.25:

(1) "**Add**" the **PDS** and **Table-PDS Frequency** tables to the QBE window.

(2) Join the tables by connecting the common **PLANTNAME** and **PDS** fields.

(3) Bring the **PLANTNAME**, **RCS_DISPOS,** and **Frequency** fields to the QBE grid.

(4) In the "**Total**" cell for each field in the QBE grid, select the "**Group By**" aggregate function for the **PLANTNAME** and **RCS_DISPOS** fields, and select "**Sum"** for the **Frequency** field.

(5) To generate a more readable table, choose the **Crosstab** from the Query menu and select **"Row Heading** for **PLANTNAME** and **"Column Heading"** for **RCS_DISPOS.**

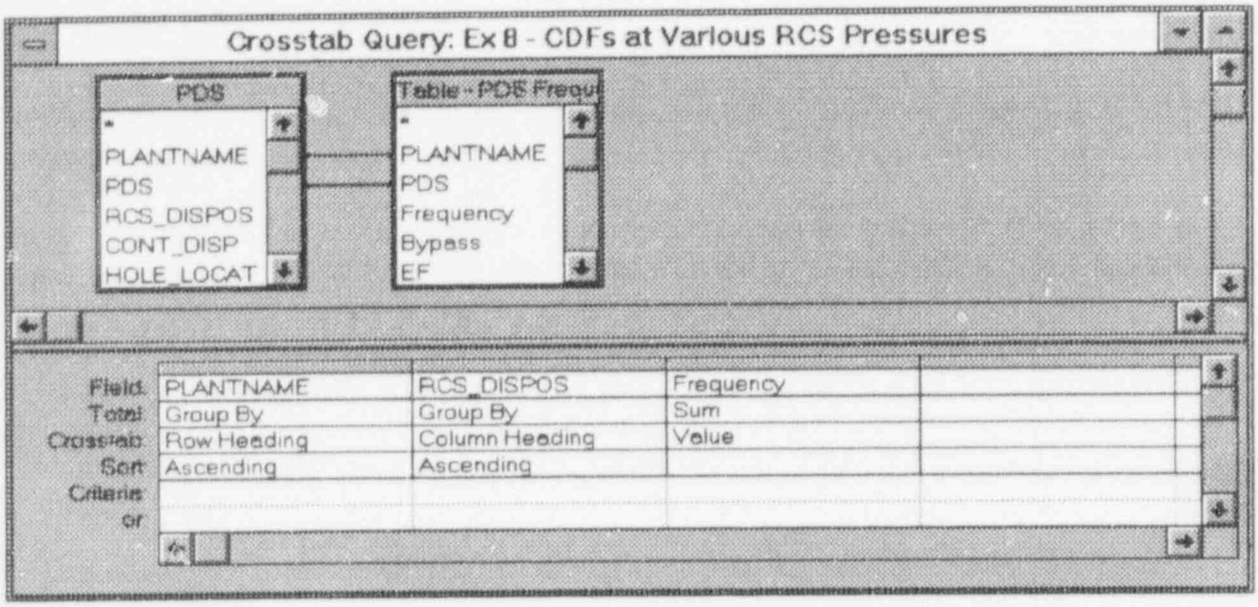
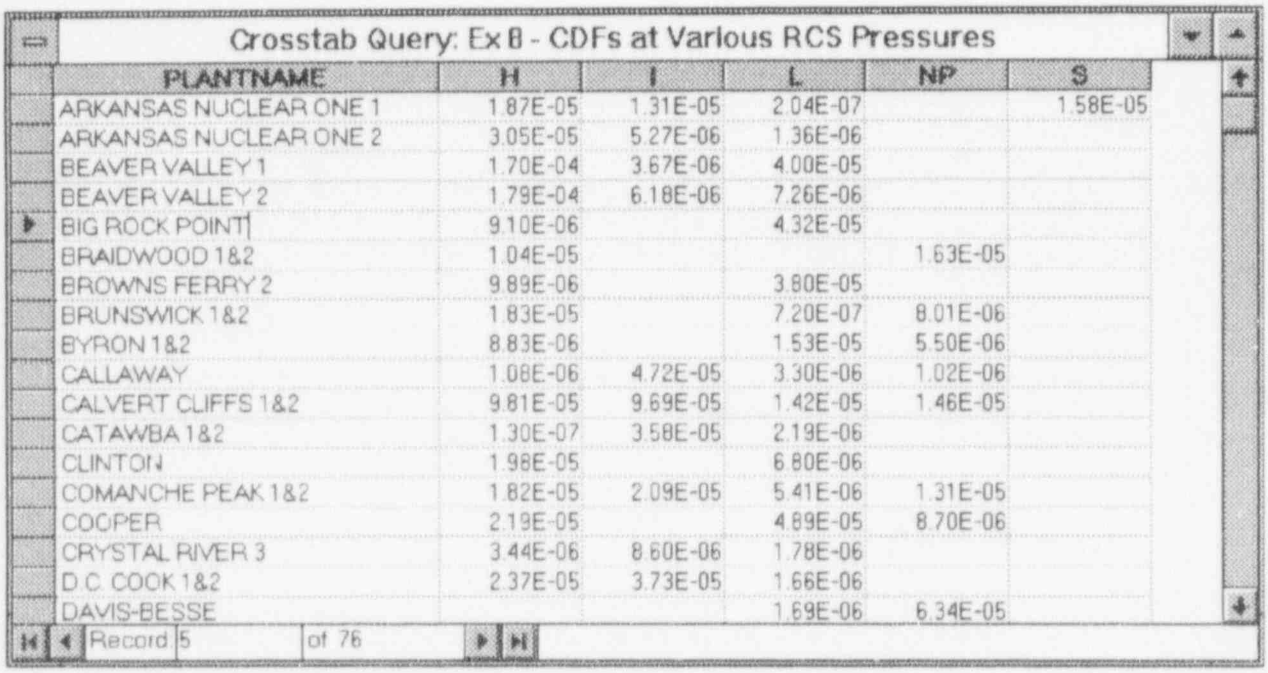


Figure 3.25 Query design window for CDFs at various RCS pressures

Figure 3.26 depicts the output of this query, showing CDFs at various RCS pressures for selected plants. It should be noted that "**H**" stands for "High pressure," "**I**" for "Intermediate," "**L**" for "Low," "**NP**" for "Not Provided," and "**S**" for "RCS-induced failure before lower head failure." See Appendix A for details.



Crosstab Query: Ex 8 - CDFs at Various RCS Pressures

PLANTNAME	H	I	L	NP	S
ARKANSAS NUCLEAR ONE 1	1.87E-05	1.31E-05	2.04E-07		1.58E-05
ARKANSAS NUCLEAR ONE 2	3.05E-05	5.27E-06	1.36E-06		
BEAVER VALLEY 1	1.70E-04	3.67E-06	4.00E-05		
BEAVER VALLEY 2	1.79E-04	6.18E-06	7.26E-06		
BIG ROCK POINT	9.10E-06		4.32E-05		
BRAIDWOOD 1&2	1.04E-05			1.63E-05	
BROWNS FERRY 2	9.89E-06		3.80E-05		
BRUNSWICK 1&2	1.83E-05		7.20E-07	8.01E-06	
BYRON 1&2	8.83E-06		1.53E-05	5.50E-06	
CALLAWAY	1.08E-06	4.72E-05	3.30E-06	1.02E-06	
CALVERT CLIFFS 1&2	9.81E-05	9.69E-05	1.42E-05	1.46E-05	
CATAWBA 1&2	1.30E-07	3.58E-05	2.19E-06		
CLINTON	1.98E-05		6.80E-06		
COMANCHE PEAK 1&2	1.82E-05	2.09E-05	5.41E-06	1.31E-05	
COOPER	2.19E-05		4.89E-05	8.70E-06	
CRYSTAL RIVER 3	3.44E-06	8.60E-06	1.78E-06		
D.C. COOK 1&2	2.37E-05	3.73E-05	1.66E-06		
DAVIS-BESSE			1.69E-06	6.34E-05	

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Figure 3.26 Display of CDFs of various RCS pressures

3.11 Example 9: Frequencies of Containment Failure Modes for Selected Initiators

This query determines the frequencies of various containment failure modes (CFMs) for selected initiators. Table A-2.2 of Appendix A summarizes the categories of CFMs in the IPE submittals.

This query design involves the use of the **Table-PDS Frequency** database table created in Example 8 (above). The steps to this query are as follows:

(1) Perform the following steps to create a database table for CFMs associated with accident sequences, as shown in Figure 3.27:

(a) "**Add**" the **ACCIDSEQ** and **Table-PDS Frequency** tables to the QBE window.

(b) Join the tables by connecting the common **PLANTNAME** and **PDS** fields.

(c) Bring the **PLANTNAME**, **SEQ_NO, INITIATOR, CDF, PDS, Bypass, EF, LF, BMT, NCF, NVB,** and **ATTRIBUTES** fields to the QBE grid.

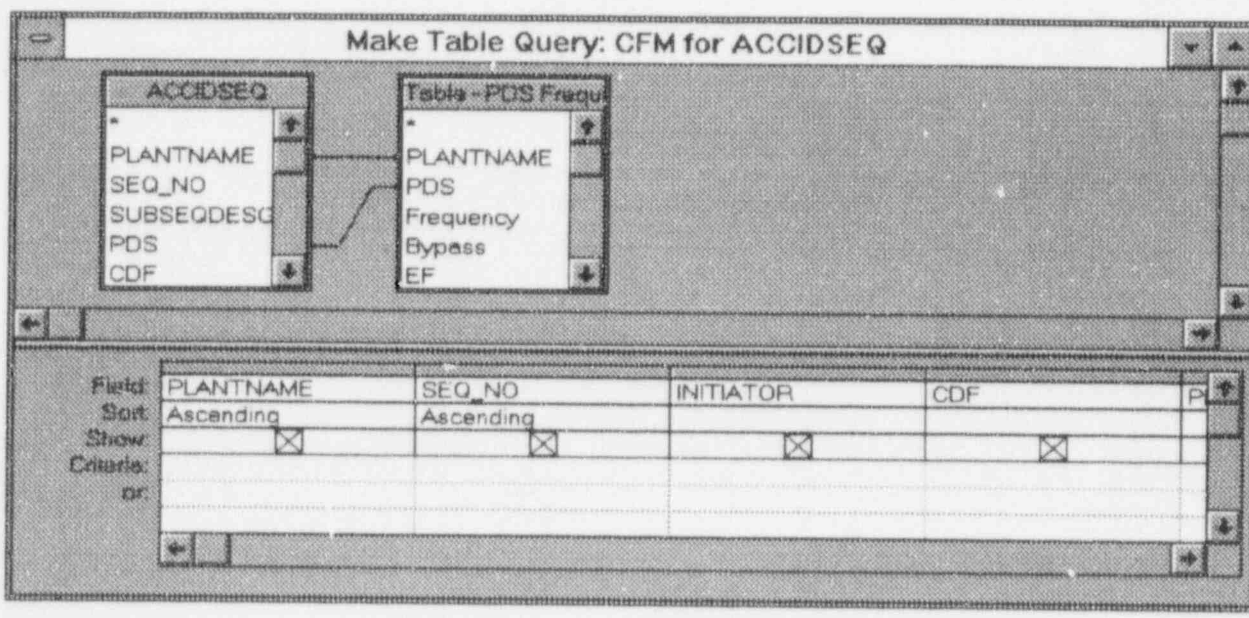
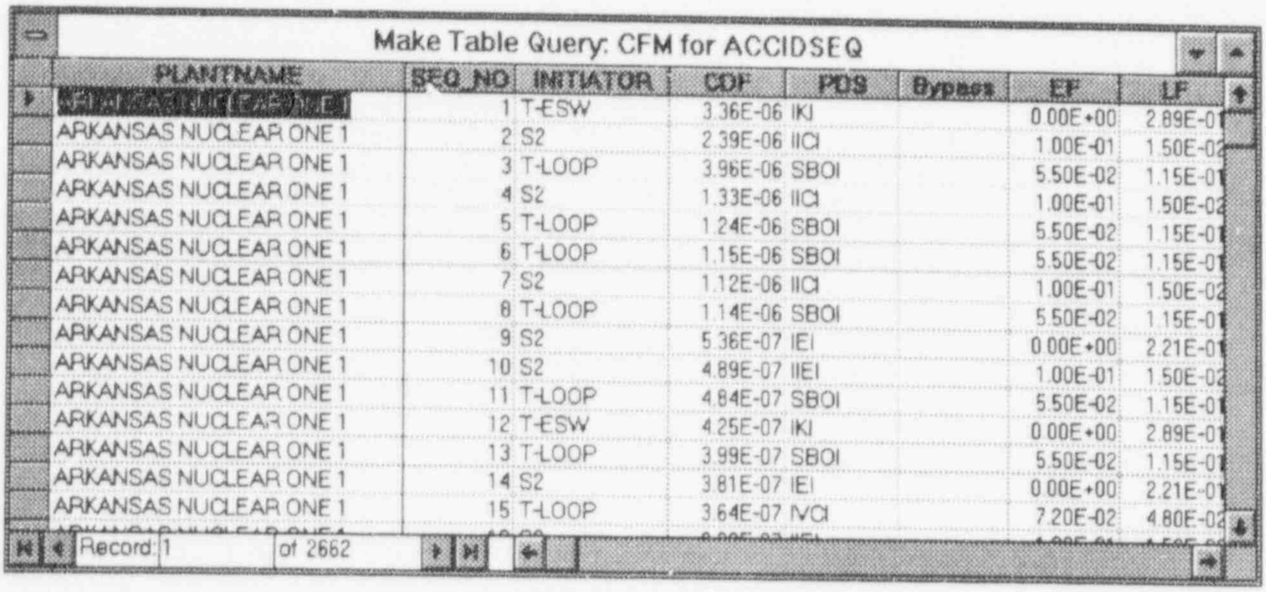


Figure 3.27 Query design window for making database table "CFM for ACCIDSEQ"

(4) From the Query menu, choose **Make Table,** and a Query Properties window appears. Name the table as "**Table-CFM for Accident**." Figure 3.28 depicts of this database table.



Make Table Query: CFM for ACCIDSEQ

PLANTNAME	SEQ_NO	INITIATOR	CDF	PDS	Bypass	EF	LF
ARKANSAS NUCLEAR ONE 1	1	T-ESW	3.36E-06	IKI		0.00E+00	2.89E-01
ARKANSAS NUCLEAR ONE 1	2	S2	2.39E-06	IICI		1.00E-01	1.50E-02
ARKANSAS NUCLEAR ONE 1	3	T-LOOP	3.96E-06	SBOI		5.50E-02	1.15E-01
ARKANSAS NUCLEAR ONE 1	4	S2	1.33E-06	IICI		1.00E-01	1.50E-02
ARKANSAS NUCLEAR ONE 1	5	T-LOOP	1.24E-06	SBOI		5.50E-02	1.15E-01
ARKANSAS NUCLEAR ONE 1	6	T-LOOP	1.15E-06	SBOI		5.50E-02	1.15E-01
ARKANSAS NUCLEAR ONE 1	7	S2	1.12E-06	IICI		1.00E-01	1.50E-02
ARKANSAS NUCLEAR ONE 1	8	T-LOOP	1.14E-06	SBOI		5.50E-02	1.15E-01
ARKANSAS NUCLEAR ONE 1	9	S2	5.36E-07	IEI		0.00E+00	2.21E-01
ARKANSAS NUCLEAR ONE 1	10	S2	4.89E-07	IIEI		1.00E-01	1.50E-02
ARKANSAS NUCLEAR ONE 1	11	T-LOOP	4.84E-07	SBOI		5.50E-02	1.15E-01
ARKANSAS NUCLEAR ONE 1	12	T-ESW	4.25E-07	IKI		0.00E+00	2.89E-01
ARKANSAS NUCLEAR ONE 1	13	T-LOOP	3.99E-07	SBOI		5.50E-02	1.15E-01
ARKANSAS NUCLEAR ONE 1	14	S2	3.81E-07	IEI		0.00E+00	2.21E-01
ARKANSAS NUCLEAR ONE 1	15	T-LOOP	3.64E-07	IVCI		7.20E-02	4.80E-02

Record: 1 of 2662

Figure 3.28 Display of database table "CFM for ACCIDSEQ"

2. Perform the following steps to design the query for CFM for accident initiators, as shown in Figure 3.29:

   (a) "**Add**" the **Table -CFM Frequency** table to the QBE window.

   (b) Bring the **PLANTNAME, SEQ_NO, INITIATOR, CDF, Bypass, EF, LF, BMT, NCF,** and **NVB** fields to the QBE grid.

   (c) Define **CDF** as "Frequency", **SUM([CDF]*[Bypass])** as "Bp_Freq," **SUM([CDF]*[EF])** as "EF_Freq," **SUM([CDF]*[LF])** as "LF_Freq," **SUM([CDF]*[BMT])** as "BMT_Freq," **SUM([CDF]*[NCF])** as "NCF_Freq", and **SUM([CDF]*[NVB])** as "NCF_Freq."

   (d) In the "**Total**" cell for each field in the QBE grid, select the "**Group By**" aggregate function for the **PLANTNAME** and **INITIATOR** fields, and select "**Sum"** as the **Expression** for all other fields.

Figure 3.30 depicts the output of this query, showing the fiequencies of various CFMs resulting from accident initiators reported in the IPE submittals. To determine the various CFMs for one or more selected initiator(s), enter the specific initiator(s) in the **Criteria** row of the QBE window and run the query to generate the database table.

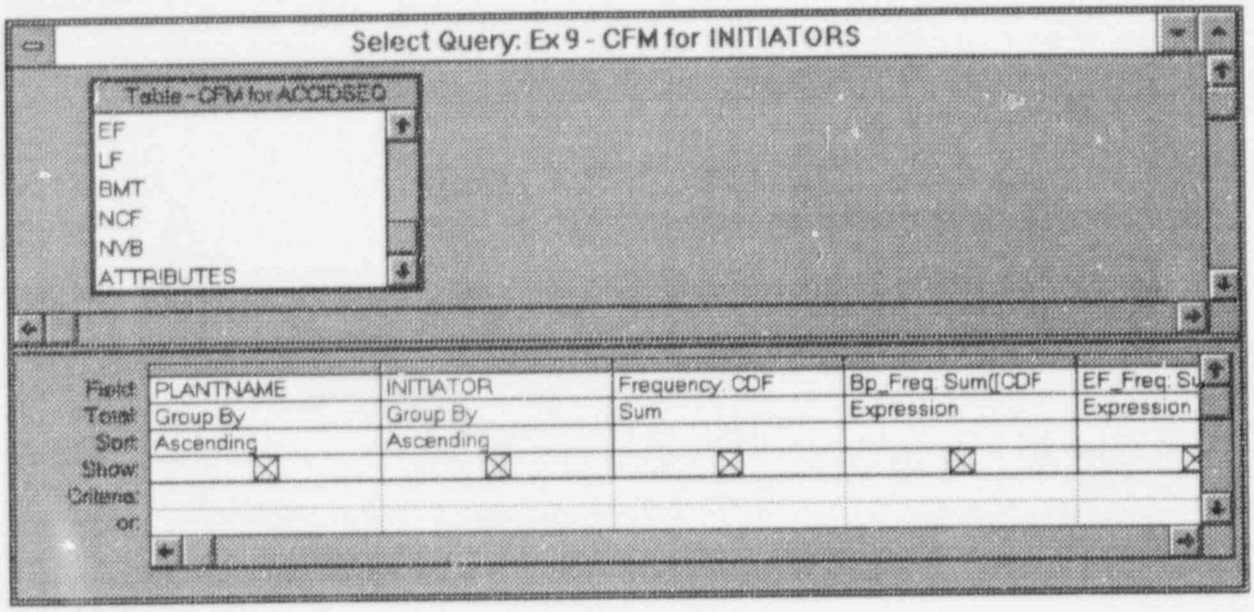
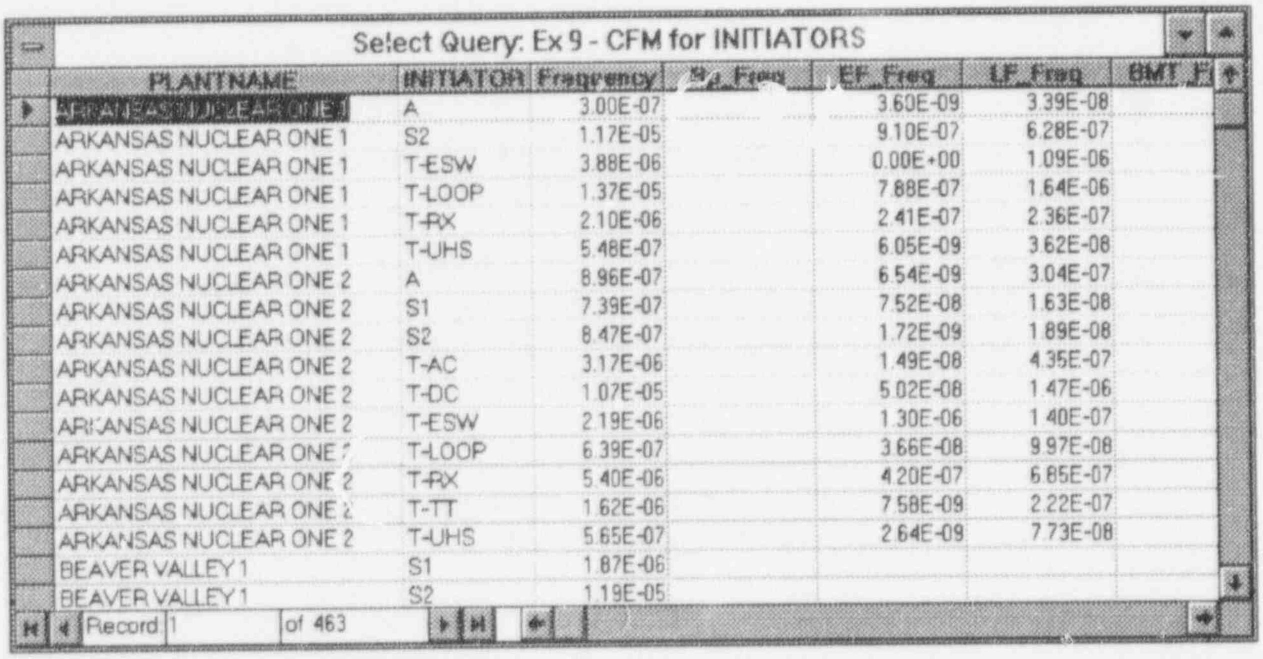


Figure 3.29 Query design window of containment failure modes for accident initiators


Select Query: Ex 9 - CFM for INITIATORS

PLANTNAME	INITIATOR	Frequency	Bp_Freq	EF_Freq	LF_Freq	BMT_F
ARKANSAS NUCLEAR ONE 1	A	3.00E-07		3.60E-09	3.39E-08	
ARKANSAS NUCLEAR ONE 1	S2	1.17E-05		9.10E-07	6.28E-07	
ARKANSAS NUCLEAR ONE 1	T-ESW	3.88E-06		0.00E+00	1.09E-06	
ARKANSAS NUCLEAR ONE 1	T-LOOP	1.37E-05		7.88E-07	1.64E-06	
ARKANSAS NUCLEAR ONE 1	T-RX	2.10E-06		2.41E-07	2.36E-07	
ARKANSAS NUCLEAR ONE 1	T-UHS	5.48E-07		6.05E-09	3.62E-08	
ARKANSAS NUCLEAR ONE 2	A	8.96E-07		6.54E-09	3.04E-07	
ARKANSAS NUCLEAR ONE 2	S1	7.39E-07		7.52E-08	1.63E-08	
ARKANSAS NUCLEAR ONE 2	S2	8.47E-07		1.72E-09	1.89E-08	
ARKANSAS NUCLEAR ONE 2	T-AC	3.17E-06		1.49E-08	4.35E-07	
ARKANSAS NUCLEAR ONE 2	T-DC	1.07E-05		5.02E-08	1.47E-06	
ARKANSAS NUCLEAR ONE 2	T-ESW	2.19E-06		1.30E-06	1.40E-07	
ARKANSAS NUCLEAR ONE 2	T-LOOP	6.39E-07		3.66E-08	9.97E-08	
ARKANSAS NUCLEAR ONE 2	T-RX	5.40E-06		4.20E-07	6.85E-07	
ARKANSAS NUCLEAR ONE 2	T-TT	1.62E-06		7.58E-09	2.22E-07	
ARKANSAS NUCLEAR ONE 2	T-UHS	5.65E-07		2.64E-09	7.73E-08	
BEAVER VALLEY 1	S1	1.87E-06				
BEAVER VALLEY 1	S2	1.19E-05				

Record: 1 of 463

Figure 3.30 Display of containment failure modes for accident initiators

3.12 Example 10: Mission Success Paths for Selected Success Criteria

This query presents an example in which the mission success paths database tables (B-MISSUC and MISSUC) are used to extract information of interest from the IPE database. This query yields information regarding plants that do not depend on accumulators to prevent core damage in a large LOCA event. Similar queries can be constructed to identify the IPE submittals in which core damage can be avoided without LPI for large LOCAs, the IPE submittals in which secondary cooling (SSMU) is required to prevent core damage for transient events (in most IPE submittals, core damage can be prevented by feed-and-bleed if SSMU is not available), or IPE submittals in which refill of the refueling water storage tank (RWST) is credited for preventing core damage in transients such as SGTR and LOCA events.

This example uses MISSUC for PWR plants. Similar queries can be constructed for BWR plants using the B-MISSUC database table.

Perform the following steps to design the query, as shown in Figure 3.31.

(1) "**Add**" the **GENERAL** and **MISSUC** tables to the QBE window.

(2) Join the tables by connecting the common **PLANTNAME** field.

(3) Bring **PLANTNAME, INITIATOR**, **ACC_M,** and **TYPE** fields to the QBE grid.

(4) To select only the data regarding large LOCA events for plants that do not depending on accumulators to prevent core damage, enter "**A**" in the **Criteria** row of the **INITIATOR** field and "**Is Null**" in the **ACC_M** field. To further restrict the search for PWR plants only, enter "**PWR**" in the **TYPE** field.

Figure 3.32 shows the results of the query, listing the plants that do not require accumulators to prevent core damage as a result of large LOCA events. This list can then be compared with the data presented in the frontline system table (FRONTLIN) to determine the number of accumulators available for these plants. This comparison reveals that none of these plants are equipped with accumulators.

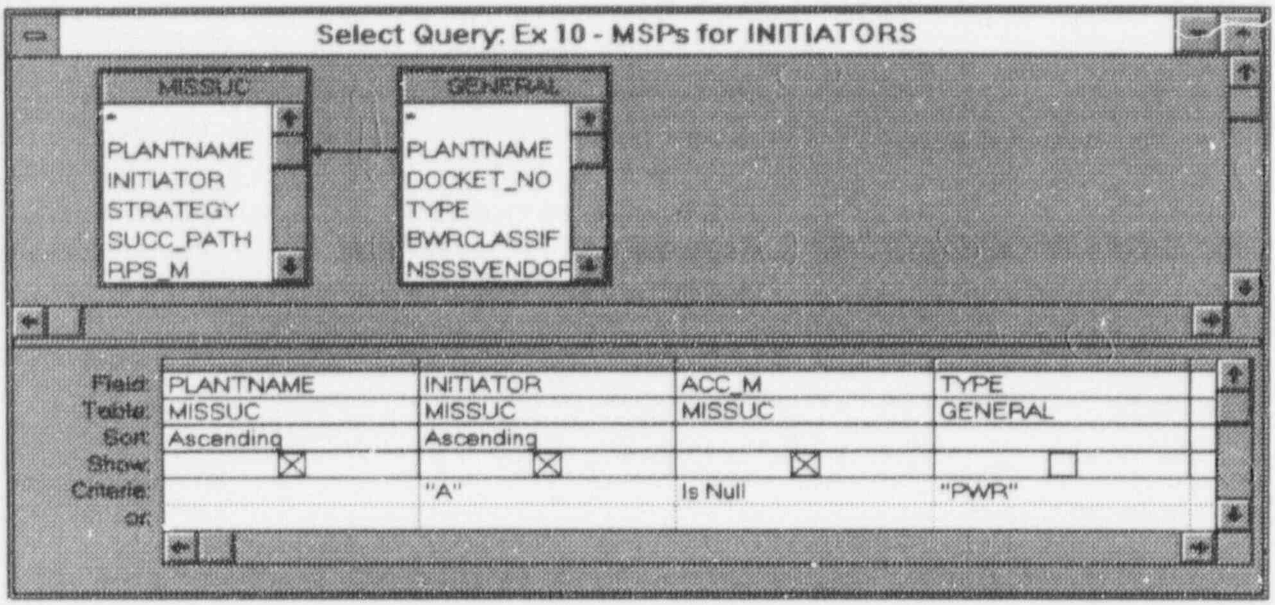


Figure 3.31   Query design window for MSPs for accident initiators

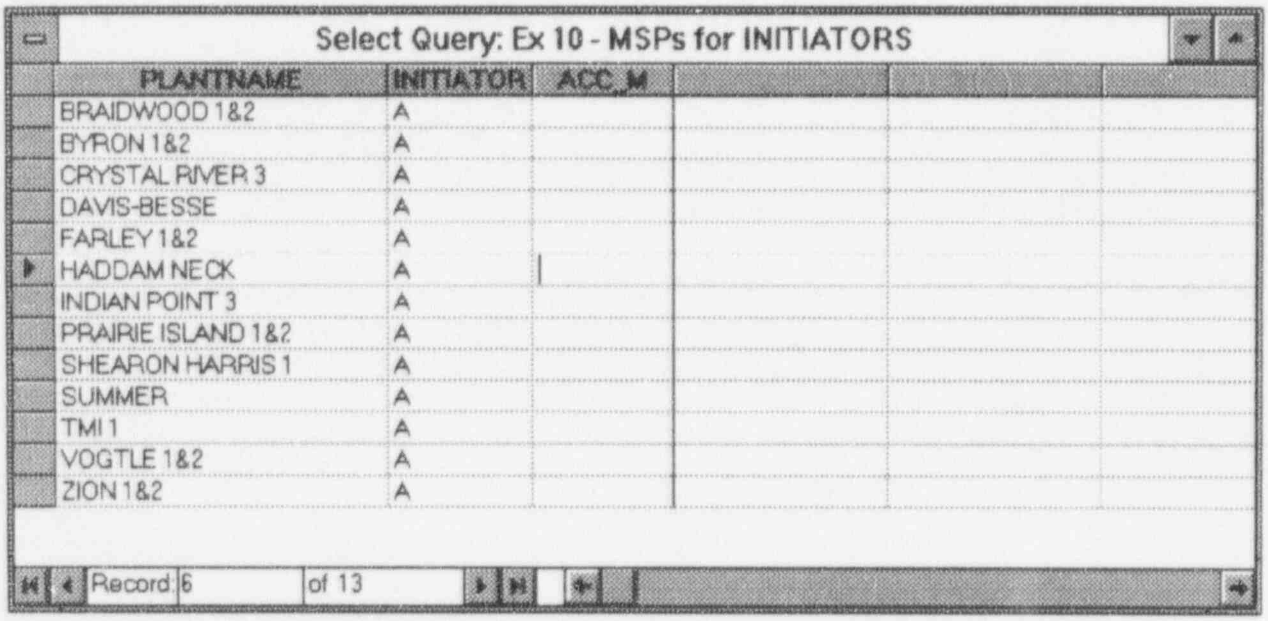


Figure 3.32   Display of mission success paths for a selected accident initiator

APPENDIX A

STRUCTURE AND MAJOR ELEMENTS OF THE IPE DATABASE

A.1 Major Elements of the Level 1 IPE Database

The first 11 data files listed in Table 1.1 are used to capture the Level 1 information contained in the IPE submittals. Specifically, these data files contain General Plant Information, Front-Line Systems, Support Systems, Dependency Tables, Core Damage Prevention Strategies, Mission Success Paths, and the Accident Sequence tables for both boiling- and pressuized-water reactors (BWRs and PWRs). This section presents additional detail about the types of information contained in each of these database files.

A.1.1 General Plant Information

General plant information is entered into a file named GENERAL. Specifically, this information includes plant name, plant type, nuclear steam supply system (NSSS) vendor, number of loops, plant output, containment type, number of units, and total core damage frequency (CDF). In addition, for multi-unit sites, the GENERAL file indicates whether support systems are shared, whether crosstie capability exists, and whether the units share a common control room. This information enables the IPE database user to sort or query across a subset of the entire database (by plant type, containment type, and/or NSSS vendor, for example).

A.1.2 Front-Line and Support Systems

Information on front-line and support systems is entered into two database files named FRONTLIN and SUPPORT, respectively. Each of these files includes information from the IPE submittals for both BWRs and PWRs.

Development of a list of key systems for both BWRs and PWRs is a crucial first step in constructing the IPE database files. The FRONTLIN and SUPPORT files relate the generic key systems list (frontline and support) to plant specific nomenclature and information on the number of trains and any credit taken for cross-tie from another unit. The records in these files, therefore, contain the fields for the plant name, key systems list, plant-specific nomenclature, number of trains (four fields), and notes/source. These fields are described in the following subsections.

A.1.2.1 Plant Name

The first field is the name of the plant.

A.1.2.2 Key Systems List

The second field contains the key systems list for the given plant. The key systems list has been described as the backbone of the IPE database, because defining this list goes a long way toward defining the structure of the entire data base. Dependencies, mission success criteria, and accident sequence descriptions are all keyed to this list. However, the formulation of this list is not unique. As experience gained for review of the IPE submittals, it becomes necessary to modify the definition of this list in order to improve the usefulness of the database and to make compromises.

The following basic sets of PWR functions were defined and used to organize the frontline systems list. These are: reactivity control, primary integrity, primary inventory-injection, primary inventory-recirculation, secondary integrity, secondary inventory, containment. In Table A.1.1 key system have been listed under each of these functions.

Table A.1.1 List of Key Frontline Systems for PWRs

Function	System
Reactivity Control	Reactor Protection System (RPS)
	Borated Injection (BI)
Primary Systems Pressure Control/Integrity	Pressurizer PORVs (PPORV)
	Pressurizer SRVs (PSRV)
	Alternate Depressurization 1 (PAD1)
	Alternate Depressurization 2 (PAD2)
	RCP Seals (RCPS)
Primary Systems Inventory Makeup During Injection	Normally Running Makeup (Injection) (CHPI)
	High Head Safety Injection (HPI)
	Low Pressure Injection (LPI)
	Accumulators (ACC)
	Alternate Injection 1 (AI1)
	Alternate Injection 2 (AI2)
Primary Systems Inventory Makeup During Recirculation	Normally Running Makeup (CHPR)
	High Head Safety Injection (HPR)
	Low Pressure Injection (LP)
	Alternate Recirculation 1 (AR1)
	Alternate Recirculation 2 (AR2)

Table A.1.1 List of Key Frontline Systems for PWRs

Function	System
Secondary Systems Pressure Control/Integrity	SG Safety Valves (SGS)
	SG Safety Valves (SGS)
	SG Atm Dump Valves (SGA)
	Turbine Trip (Stop) Valve (TT)
	Main Steam Isolation Valve (MSIV)
	Turbine Bypass Valves (TB)
Secondary Side Makeup	Steam Generators (SG)
	Main Feedwater Pumps (MFW)
	Non-1E Startup Pumps (NIP)
	Motor-Driven Auxiliary Feedwater Pumps (MDAFW)
	Steam-Driven Auxiliary Feedwater Pumps (SDAFW)
	Alternate Makeup 1 (AM1)
	Alternate Makeup 2 (AM2)
Containment Systems: Pressure Control	Containment Spray Injection (CSI)
	Containment Spray Recirculation (CSR)
	Containment Spray 1 (CS1)
	Fan Coolers (FC)
	Ice Condenser (IC)
	Containment Isolation 1 (CI1)
	Containment Isolation 2 (CI2)
Containment Systems: Hydrogen Control	Ignitors (IGN)
	Recirculating Fans (RF)
Human	Operator Action (HUM)

Table A.1.2 List of Key Support Systems for PWRs

Function	System
Steam	Motive Steam (STM)
AC Power (Motive)	Emergency Diesel Generators (EAC)
	Vital AC Buses (AC)
	Other Onsite Backup 1 (ACBU1)
	Other Onsite Backup 2 (ACBU2)
	Other Onsite Backup 3 (ACBU3)
DC Power	Battery-Backed DC Buses (EDC)
	DC Buses (DC)
AC Power (Control)	Vital Instrument AC (VAC)
Auxiliary Cooling: Open Cycle	Essential Service Water (ESW) Systems
	Alternate Service Water 2 (SW2) Systems
	Alternate Service Water 3 (SW3) Systems
	Alternate Service Water 4 (SW4) Systems
Auxiliary Cooling: Closed Cycle	Component Cooling Water (CCW) Systems
	Auxiliary Cooling 2 (AUXC2) Systems
	Auxiliary Cooling 3 (AUXC3) Systems
	Auxiliary Cooling 4 (AUXC4) Systems
Essential Safeguards Actuation	Engineered Safety Actuation System 1 (ESAS1)
	Engineered Safety Actuation System 2 (ESAS2)

Table A.1.2 List of Key Support Systems for PWRs

Function	System
Compressed Air	Instrument Air (IA)
	Station Air (SA)
	Alternate Air System 2 (OA3)
	Alternate Air System 3 (OA3)
	Alternate Air System 4 (OA4)
	Bottled Nitrogen (IA Backup) (NIT)
Environmental Control	Heating, Ventilation, & Air-conditioning 1 (HVAC1)
	Heating, Ventilation, & Air-conditioning 2 (HVAC2)
	Heating, Ventilation, & Air-conditioning 3 (HVAC3)

In a similar manner, a basic set of BWR functions has been used to organize the frontline systems list: reactivity control, pressure boundary integrity, high pressure injection, low pressure injection, and containment systems. Tables A.1.1.3 and A.1.1.4 list key systems under each of these functions.

The key systems lists for both PWRs and BWRs include "dummy" systems to accommodate plants that take credit for unique systems that do not directly correlate with a strict categorization of functions. It is unlikely that any individual BWR or PWR will have all of the systems that appear on the respective key systems list, but essentially any system playing a significant role will correspond to one of the actual or "dummy" system entries. Thus, the list serves as a vehicle for comparing the design features of various plants, enables the IPE database users to "check off" systems associated with each plant.

Table A.1.3 List of Key Frontline Systems for BWRs

Function	System
Reactivity Control	Reactor Protection System (RPS)
	Alternate Rod Insertion (ARI)
	Standby Liquid Control (SLC)
	Control Rod Drive System (CRDS)
	Recirculation Pumps (RECIRC)
Pressure Boundary Integrity	Safety Relief Valves (SRVS)
	Automatic Depressurization System (ADS)
	Main Steam Isolation Valves (MSIV)
	Alternate Depressurization System (ADEP)
	Turbine Bypass Valves (TBV)
High Pressure Injection	High Pressure Coolant Injection (Spray) (HPCI/HPCS)
	Reactor Core Isolation Cooling (RCIC)
	Reactor Water Cleanup System (RWCU)
	Main Feedwater (MFW)
	High Pressure 1 (BP1)
	High Pressure 2 (BP2)
Low Pressure Injection	Low Pressure Coolant Injection (LPCI)
	Core Spray (CS)
	Condensate Transfer System (CTS)
	Low Pressure 1 (LPl)
	Low Pressure 2 (LP2)
	Low Pressure 3 (LP3)
	Low Pressure 4 (LP4)

Table A.1.3 List of Key Frontline Systems for BWRs

Function	System
Containment Systems	Condenser Available (CONDA)
	Suppression Pool Cooling (SPC)
	Drywell Sprays (DWS)
	Drywell Coolers (DWC)
	Alternate Suppression Pool Cooling (ASPC)
	Isolation Condenser System (ICS)
	Containment Isolation 1 (CI1)
	Containment Isolation 2 (CI2)
	Venting System (VENT)
	Drywell Ignitors (DWIGN)
	Wetwell Ignitors (WWIGN)
Human	Operator Action (HUM)

Table A.1.4 List Key Support Systems for BWRs

Function	System
Motive Steam	Steam (STM)
AC Power (Motive)	Emergency Diesel Generators (EAC)
	Vital AC Buses (AC)
	Other Onsite Backup 1 (ACBU1)
	Other Onsite Backup 2 (ACBU2)
	Other Onsite Backup 3 (ACBU3)
DC Power	Battery-Backed DC Buses (EDC)
	DC Buses (DC)
AC Power (Control)	Vital Instrument AC (VAC)

Table A.1.4 List Key Support Systems for BWRs

Function	System
Open Cycle Cooling	Normal Service Water (NSW)
	Emergency Service Water (ESW)
	Alternate Service Water 2 (SW2)
	Alternate Service Water 3 (SW3)
	Alternate Service Water 4 (SW4)
Closed Cycle Cooling	Reactor Building Closed Loop Cooling Water (RBCLCW)
	Auxiliary Cooling 2 (AUXC2)
	Turbine Building Closed Loop Cooling Water (TBCLCW)
	Auxiliary Cooling - 4 (AUXC4)
Engineered Safeguards Actuation	Engineered Safety Actuation System 1 (ESAS1)
	Engineered Safety Actuation System 2 (ESAS2)
Compressed Air	Instrument Air (IA)
	Station Air (SA)
	Alternate Air System 3 (OA3)
	Alternate Air System 4 (OA4)
	Bottled Nitrogen (IA Backup) (NIT)
Environmental Control	Heating, Ventilation, & Air-conditioning 1 (HVAC1)
	Heating, Ventilation, & Air-conditioning 2 (HVAC2)
	Heating, Ventilation, & Air-conditioning 3 (HVAC3)

A.1.2.3 Plant-Specific Nomenclature

The third field stores the plant specific nomenclature used in the IPE submittal corresponding to the equivalent system in the key systems list.

A.1.2.4 Number of Trains

For a fluid system, "train" simply means a pump and the associated flowpaths (regardless of whether a single pump suffices to fulfill a particular requirement). Each record uses four fields to store information on the number of trains a particular system has, but also whether these pumps are identified with more than one system, and whether a given system can be supplemented by cross-tying to another unit.

For example, consider low-pressure injection (LPI) and suppression pool cooling (SPC) in a BWR, which may involve the same pumps both, but the flowpaths differ, as do the consequences of failure for each of the two functions. The database reflects the number of pumps used in both LPI and SPC. In addition, to signal that the pumps identified in the LPI field are also part of a different system (SPC), the database provides two adjacent fields, including one containing a semicolon to signal that this hardware is multipurpose, and another to identify the other systems. Thus, a semicolon in the "signaling" field means that this hardware is actually part of another system on the list.

A.1.3 Dependency Tables

The dependency tables for BWRs and PWRs (B-DEPEND and DEPENTAB, respectively) show the direct functional dependencies of each frontline and support system (i.e., what other systems any given system depends on). Information that can be entered into the files is given in Table A.1.5. Each dependency table can be depicted as a matrix, with headings across the top containing acronyms for the various systems from the key systems lists (Tables A.1.1 thru A.1.4) and labels going down the left-hand side containing acronyms for the related support systems. A system that performs a frontline function and also supports another frontline system will appear as a label on the left-hand side (as a support), as well as a heading across the top (as a frontline system). The entry at the intersection of each rod and column in each matrix tells about the degree of functional dependence between the two indicated systems, using one of the codes shown in Table A.1.5.

In this conceptual matrix, every **row** corresponds to a **record** in the B-DEPEND and DEPENTAB database files. Thus, many records are necessary in order to describe the functional dependencies for any given plant, and the necessary number of records is not known in advance. A printout of all records with a given "plant name" entry constitutes a dependency table for that plant.

Table A.1.5 Valid entries for B-DEPEND and DEPENTAB fields

Field	Entry	Description
System acronym	Acronym	The entry is the acronym of a frontline system or a support system.
Frontline or support system (enter one of the entries)	A	Absolute (Failure of system 2 causes failure of system 1.)
	P	Primary (Failure of system 2 causes failure of system 1 unless backup is brought into play.)
	S	Secondary (System 2 is a backup to some primary support of system 1.)
	D	Partial (Failure of system 2 increases the probability of failure of system 1. Typically, failure of system 2 *and* some other system will fail system 1.)
	Blank	

A.1.4 Core Damage Prevention Strategies

The core damage prevention strategy files for BWRs and PWRs (B-STRAT and STRATEGY, respectively) shows the combinations of safety functions are needed to prevent core damage in the event of a particular challenge (i.e., an accident initiator). Each unique combination of functions is termed a core damage prevention strategy for the given challenge, and any particular challenge may be addressed by one or more strategies. The list of PWR and BWR safety functions considered for the strategies is given in Table A.1.6.

Each B-STRAT and STRATEGY contains fields identifying the plant name, the challenge, the strategy number, the safety functions used in the particular strategy, and relevant notes for each strategy. The challenge refers to the accident initiator. Section A.1.5 discusses the valid entries for this challenge field. The safety functions used in the particular strategy are identified by and asterisks (*) under one or more of the safety functions shown in Table A.1.6.

Various combinations of systems may be available to accomplish the safety functions for a particular strategy. These system combinations are discussed under mission success paths in the next section.

Table A.1.6 Functions used in the core damage prevention strategies

Function	Descriptions
SINT	Secondary integrity (PWR only)
SDEP	Secondary depressurization (PWR only)
SSMU	Secondary side makeup (PWR only)
RCS-BOR	RCS boration
RCS-INT	RCS integrity
RCS-DEP	RCS depressurization
HPI	RCS high-pressure injection
HPR	RCS high-pressure recirculation
LPI	RCS low-pressure injection
LP	RCS low-pressure recirculation (including decay heat removal)
CPSI	Containment pressure suppression injection (PWR only)
CPSR	Containment pressure suppression recirculation (PWR only)
CPSS	Containment pressure suppression systems (BWR only)
CIF	Containment isolation
VENT	Containment venting (manual or passive)

A.1.5 Mission Success Paths

The files reflect the mission success paths assumed in the results reported in the IPE submittals for BWRs and PWRs (B-MISSUC and MISSUC, respectively). Mission success path record in these files relates a specific complement of equipment to a particular type accident initiator (or challenge) and a particular safety function. If a safety analysis takes credit for more than one way to remove heat, for example, its results cannot be understood without an unambiguous statement of exactly how decay heat can be removed. Table A.1.7 identifies the information that can be entered into the B-MISSUC and MISSUC files

Each mission success path (distinct way of carrying out a given strategy) receives its own record. Consequently, the mission success path files display all of the distinct combinations of key systems that can be used to accomplish the functions required for a particular strategy. For example, depressurization and low pressure injection are called for following a transient with failure of high-pressure systems, but several low-pressure systems may be capable of injecting enough water to cool the core. This situation would, therefore, be represented by several mission success path records.

Table A.1.7 Valid entries for B-MISSUC and MISSUC fields

Field	Entry	Description
Challenge	S1	Medium LOCA
	S2	Small LOCA
	S3	Small-small LOCA
	A	Large LOCA (including beyond ECCS capability)
	V-(xx)	Interfacing systems LOCA, (xx) can be a system acronym where break is located
	T-LOOP	Transient - loss of offsite power
	T-RX	Transient - reactor trip
	T-TT	Transient - turbine trip
	T-ATWS	Anticipated transient without scram
	T-UHS	Transient - loss of ultimate heat sink (includes loss of condenser vacuum or condensate, etc.)
	T-RCP	Transient - reactor coolant pump trip (PWR only)
	T-RECIRC	Transient - recirculation pump trip (BWR only)
	T-LNMU	Transient - loss of normal RCS makeup (includes loss of seal injection)
	T-LMFW	Transient - loss of main feedwater
	T-EXFW	Transient - excessive feedwater addition
	T-SLBOC	Transient - steam line break outside containment
	T-SLBIC	Transient - steam line break inside containment
	T-SGTR	Transient - steam generator tube rupture (PWR only)
	T-SORV/ IORV	Transient - stuck-open or intermittent relief valve

Table A.1.7 Valid entries for B-MISSUC and MISSUC fields

Field	Entry	Description
Challenge (cont.)	T-SSI	Transient - spurious safety injection
	T-Other	Transient - other (transient would be characterized by loss support or failed function fields)
	T-Acronym	Transient initiated by loss of the support system or other plant system/function called out by the acronym designated for that frontline or support system. Note: Either a frontline or support system acronym must be used for this initiator.
Strategy		The entries are numbered sequentially.
Success Path		The entries are numbered sequentially.
Frontline System	The entry is a numeral and may be followed by one of the following:	
	H	Human action required.
	T	Must be throttled/controlled.
	I	Manual isolation
	S	Supports other equipment
	V	Operator controlled venting (BWR only)

A.1.6 Accident Sequences

The accident sequences database tables for BWRs and PWRs (B-ACCSEQ and ACCIDSEQ, respectively) store information about the dominant accident sequences reported in each IPE submittal. The objective is to record which systems failures in the sequence led to core damage, what functional failures were associated with those failures, and how frequently the sequence occurred.

Licensees have considerable freedom in how they report this information. The present structure of B-ACCSEQ and ACCIDSEQ is a compromise between simplicity and "search ability." The fields in these files include a plant name, the sequence designator used in the submittal, plant damage state, core damage frequency, initiator, lost supports, failed functions, causes, "attributes," the key systems list, and related comments. Table A.1.8 identifies the valid entries for each of these fields, and the subsequent sections provide additional detail.

A.1.6.1 Plant Name

Since all sequences appear in one of two files (for BWRs or PWRs), they must be associated with the specific plant name.

A.1.6.2 Sequence Designator

This field stores the sequence designator used in the IPE submittals. The purpose of this field is traceability or the ability to associate every record in the file with a specific result reported in the submittal.

A.1.6.3 Plant Damage State

This field stores the plant damage state designator used in the IPE submittals. The purpose of this field is to link accident sequences with phenomenology, as represented in the containment performance matrix (discussed in Section A.2).

It is possible for a submittal to define plant damage states more specifically than it defines the resulting accident sequence outcomes. As a result, there may be more plant damage states than there are sequences. If a submittal assigns multiple plant damage states to a single sequence, the sequences should be desegregated for entry into the database, wherever possible.

A.1.6.4 Core Damage Frequency

This field stores the core damage frequency (events per reactor year).

A.1.6.5 Initiator

This field stores the accident sequence initiator. This information may be implicit in the sequence designator, but this will not be standard across plants; that is submittals do not use a universal scheme for designating initiators or sequences. For the purpose of consistency and ease of reporting, however, B-ACCSEQ and ACCIDSEQ use the set of initiators designated Table A.1.8. (Note that support system initiators receive special designation.)

A.1.6.6 Lost Supports

If the accident sequence involved total loss of one or more support systems (such as emergency ac or service water), this field identifies the lost support function(s), including but not limited to, sequences initiated by loss of a support function.

A.1.6.7 Failed Functions

Every accident sequence involves failure of at least one safety function as identified in this field.

A.1.6.8 Causes

This field records whether a particular physical cause contributed to the particular accident sequence.

A.1.6.9 Attributes

Many potential uses of the IPE database involve totaling results for such *ad hoc* categories of sequences as "blackout." For such *ad hoc* categories, B-ACCSEQ and ACCIDSEQ use the catchall "Attributes" field. This field contains a list of key attributes (separated by commas), such as station blackout represented by "SBO," and ATWS by "ATWS."

A.1.6.10 Key Systems List

These fields record which systems failure led to core damage in each sequence. As previously discussed, the same key systems list is used in discussing dependencies, mission success criteria, and accident sequences. The present convention is to show only those frontline systems that failed in order to bring about core damage. In an accident sequence record, an asterisk (*) under a system means that it failed in that sequence; a "C" means that it failed consequentially, as a result of failure of another system (e.g., a support system).

The type of failure reflected in the operator field of the accident sequence files is either failure to perform an action required in a primary success path, or failure to implement an alternative success path. Recovery of failed equipment is beyond the scope of this field.

A.1.6.11 Notes

This field is used to record any additional information not captured in the previous fields, which is considered important for understanding the sequence.

Table A.1.8 Valid entries for B-ACCSEQ and ACCIDSEQ fields

Field	Entry	Description
Initiator	S1	Medium LOCA
	S2	Small LOCA
	S3	Small-small LOCA
	A	Large LOCA (including beyond ECCS capability)
Initiator	V-(xx)	Interfacing Systems LOCA, (xx) can be a system acronym indicating where break is located

Table A.1.8 Valid entries for B-ACCSEQ and ACCIDSEQ fields

Field	Entry	Description
Initiator	T-LOOP	Transient - loss of offsite power
	T-RX	Transient - reactor trip
	T-TT	Transient - turbine trip
	T-ATWS	Anticipated transient without scram
	T-UHS	Transient - loss of ultimate heat sink (includes loss of condenser vacuum or condensate, etc.)
	T-RCP	Transient - reactor coolant pump trip (PWR only)
	T-RECIRC	Transient - recirculation pump trip (BWR only)
	T-LNMU	Transient - loss of normal RCS makeup (includes loss of seal injection)
	T-LMFW	Transient - loss of main feedwater
	T-EXFW	Transient - excessive feedwater addition
	T-SLBOC	Transient - steamline break outside containment
	T-SLBIC	Transient - steamline break inside containment
	T-SGTR	Transient - steam generator tube rupture (PWR only)
	T-SORV/ IORV	Transient - stuck-open or intermittent relief valve
	T-SSI	Transient - spurious safety injection
	T-Other	Transient - other (transient would be characterized by loss support or failed function fields)
	T-Acronym	Transient initiated by loss of the support system or other plant system/function called out by the acronym designated for that frontline or support system. (Note: Either a frontline or support system acronym *must* be used for this initiator.)
	Remainder	Sequence(s), if necessary, used to ensure that CDF of entered sequences totals 100%.

Table A.1.8 Valid entries for B-ACCSEQ and ACCIDSEQ fields

Field	Entry	Description
Lost Supports	Lost Supp.	The entry may be blank or (at most) the acronym of two support systems.
Failed Functions	The entry is a subset of at most three of the following:	
	SINT	Secondary integrity (PWR only)
	SDEP	Secondary depressurization (PWR only)
	SSMU	Secondary side makeup (PWR only)
	RCS-BOR	RCS boration
	RCS-INT	RCS integrity
	RCS-DEP	RCS depressurization
	HPI	RCS high-pressure injection
	HPR	RCS high-pressure recirculation
	LPI	RCS low-pressure injection
	LP	RCS low-pressure recirculation (including decay heat removal)
	CPSI	Containment pressure suppression injection (PWR only)
	CPSR	Containment pressure suppression recirculation (PWR only)
	CPSS	Containment pressure suppression systems (BWR only)
	CIF	Containment isolation containment isolation
	VENT	Containment venting (manual or passive)
	Note: Additional failed functions may be indicated in the Notes field.	
Causes	The entry may be blank or (at most) two of the following entries:	
	IFL	Internal flood
	FIRE	Fire
	CCF	Common cause failure
Attributes	The entry is at most three of the following entries:	

Table A.1.8 Valid entries for B-ACCSEQ and ACCIDSEQ fields

Field	Entry	Description
Attributes	ATWS	Anticipated transient without scram
	BYPASS	Bypass
	TIL	Transient-induced LOCA
	IND-SGTR	Induced steam generator tube rupture (PWR only)
	SBO	Station blackout
	HUM	Human action
Frontline Systems	The entry is one of the following:	
	*	The system failed in that sequence
	C	The system failed as a result of failure of another frontline system reflected with an asterisk (*) in the same record, or as a result of a support system failure. If the sequence involved equipment that failed as a result of human error, there *must* be a * in the HUM column.
	V	Failure of this system caused containment venting capability to be lost (BWR only).
	Blank	No dependency exists.

A.2 Major Elements of the Level 2 Ipe Database

The Level 1 portion of the IPE database is connected to the Level 2 portion through the plant damage states, which are divided into several possible fission product release paths or containment failure modes. Each failure mode is associated with a quantity of fission products released to the environment (source terms or release classes). The database is structured to capture the various elements of the Level 2 analyses reported in the IPE submittals. Each element of the Level 2 IPE analyses is allocated to one of four distinct database files as indicated in Table 1.1. Specifically, the four database files currently used are: LWR Plant Damage States (PDS), Containment Matrix (C-Matrix), LWR Source Terms (STERMS), and LWR Level 2 Analysis Parameters (REL-CLAS). The following sections discuss the structure of each of these data files.

A.2.1 Plant Damage States

The plant damage states reported in the IPE submittals are recorded in the PDS file of the IPE database. This file is structured to capture the information that the IPE analyst used to define the various plant damage states. Table A.2.1 identifies the valid entries for plant name, PDS identifies, RCS disposition, containment disposition, preexisting hole location, RWST/CST inventory, containment sprays and heat removal cooling capability. Additional detail appears in the following subsections.

A.2.1.1 Plant Name

The first field of each PDS record simply specifies the plant name.

A.2.1.2 PDS Identifier

The second field of each PDS record indicates the PDS identifier from the IPE submittals. The PDS designation scheme is flexible and accommodates virtually any format used in the IPE submittals.

A.2.1.3 RCS Disposition

The third field of each PDS record indicates the pressure (low, intermediate, or high) in the reactor vessel immediately before the core debris penetrated the lower vessel head. The pressure at the time of vessel failure has a significant influence on such ex-vessel phenomena as direct containment heating (DCH) and core debris coolability.

A.2.1.4 Containment Disposition

The fourth field of each PDS record provides information concerning the status of containment integrity at the start of the accident. The containment can be intact (isolated), have preexisting leakage (with small or large flow rates), or be bypassed (as in an interfacing systems LOCA).

A.2.1.5 Preexisting Hole Location

The fifth field of each PDS record applies only to BWRs and is intended to provide information on whether or not fission products passed through the suppression pool (and hence were subject to pool scrubbing) prior to release to the environment. A failure location in the drywell implies no pool scrubbing whereas a failure location in the wetwell implies pool scrubbing.

A.2.1.6 RWST/CST Inventory

The sixth field of each PDS record provides information concerning the amount of water injected into containment during a severe accident. For example, if the RWST inventory is injected into the containment of some PWRs, the reactor cavity would be flooded before the core debris penetrates the lower vessel head. A flooded cavity influences a number of ex-vessel phenomena such as DCH and debris bed coolability. Injection of the RWST inventory can also imply that coolant flow to the RCS failed in recirculation, which influences the time to core damage.

A.2.1.7 Containment Sprays and Heat Removal Disposition

The seventh field of each PDS record captures information concerning the operability of the containment systems. The field distinguishes between sprays and heat removal. Sprays can influence the airborne aerosol concentration, which in turn lowers the environmental source term. Heat removal is essential to limit the pressure increase in containment during a severe accident. Together, the effectiveness of containment sprays and heat removal can significantly influence containment performance during a severe accident.

A.2.1.8 Steam Generator Cooling Capability

The final field in each PDS record applies only to PWRs. Specifically, this field provides information concerning the availability of secondary side cooling, which influences the timing of core damage.

Table A.2.1 Valid entries for PDS fields

Field	Entry	Description
RCS Disposition	L	Low pressure < 200 psia
	I	Intermediate pressure 200 to 650 psia
	H	High pressure 650 to PSRV set point
	S	RCS-induced failure prior to lower head failure [valid for high pressure and PWR's only]
	NP	Not provided
Containment Disposition	I	Isolated
	S	Small preexisting hole < 3" diameter
	L	Large preexisting hole > 3" diameter
	B	Intact but bypassed
	NP	Not provided
Preexisting Hole Location (BWRs only)	D	In drywell
	W	In wetwell airspace

Table A.2.1 Valid entries for PDS fields

Field	Entry	Description
	X	Not applicable
	NP	Not provided
RWST/CST Inventory	Y	Injected to RCS/containment via ECCS
	N	Not injected
	NP	Not provided
Containment sprays and heat removal disposition	B	Both sprays & heat removal available
	S	Sprays only available
	H	Heat removal only available
	X	Neither available
	NP	Not provided
Steam generator cooling capability (PWRs only)	A	Secondary side flow cooling available
	X	Not available
	C	Secondary side cooling by condensation only
	NP	Not provided

A.2.2 Containment Matrix

Information on containment performance is captured in an IPE database file known as C-MATRIX. This matrix relates the plant damage states to various failure modes. The PDS designation scheme is flexible, but some structure has been imposed on the failure modes for inclusion in the containment performance matrix. Currently, the C-MATRIX includes six "super" release classes or failure modes, i.e., bypass, early failure, late failure, basemat melt-through, vessel breach without containment failure, and no vessel breach.

Each record in this file contains the plant name; a plant damage state designator; frequency; and split fractions that allocate the indicated plant damage state over the following possibilities, including bypass, early failure, late failure, basemat melt-through, vessel breach without containment failure, and no vessel breach. (Because the entries are split fractions, they should sum to unity within a given plant damage state.) In addition, each split fraction is allocated a release category designator. This designator connects the C-MATRIX file to the source term file (STERMS, refer to Section A.2.3). Each of the fields is described below.

A.2.2.1 Plant Name

The first field of each C-MATRIX record specifies plant name.

A.2.2.2 PDS Designator

The second field of each C-MATRIX record specifies the plant damage state designator from the IPE submittal.

A.2.2.3 Frequency

This field of each C-MATRIX record indicates the frequency of each PDS, as identified in the IPE submittals. If not specifically addressed in the IPE submittals, the PDS frequencies could also be derived by summing the frequencies of the accident sequences contributing to the PDS, as recorded in the accident sequence data files (B-ACCSEQ and ACCIDSEQ, refer to A.1.6). However, the PDS frequencies calculated from the accident sequence data files will, in most cases, not sum to the total PDS frequency since the IPE submittals report only dominant accident sequences.

A.2.2.4 Bypass

Split fractions associated with events that bypass the containment are entered into the fourth field of each C-MATRIX record, while the corresponding release class designators are entered into the fifth field. Events such as interfacing systems LOCAs and steam generator tube rupture (in which secondary side isolation fails) are typically included in these fields.

A.2.2.5 Early Failure

The sixth and seventh fields of each C-MATRIX record include split fraction associated with events that result in containment failure soon after the core debris penetrates the reactor vessel. Therefore "early" in this context is relative to the time-of-vessel failure, not the time of accident initiation. Early containment failure can be caused by such events as DCH, steam explosions, or hydrogen (H_{2}) combustion events.

A.2.2.6 Late Failure

The eighth and ninth fields of each C-MATRIX record include split fraction associated with events that result in containment failure several hours after reactor vessel failure. Late containment failure can result from gradual overpressurization caused by steam and noncondensible gas generation, H_2 combustion events, or thermal degradation of seals.

A.2.2.7 Basemat Melt-through

The tenth and eleventh fields of each C-MATRIX record include split fraction associated with events that result in the core debris penetrating the concrete basemat underneath the reactor vessel.

A.2.2.8 Vessel Breach without Containment Failure

The twelfth and thirteenth fields of each C-MATRIX record include split fraction associated with events that do not result in any loss of containment integrity. Under these circumstances, the source term is essentially design-basis leakage.

A.2.2.9 No Vessel Breach

The final two fields in each C-MATRIX record include split fraction associated with events in which coolant injection is restored and the core debris is retained within the reactor vessel. This category pertains to events similar to Three-Mile Island (TMI), which are expected to result in containment failure.

A.2.3 Source Terms

Information on source terms is entered into an IPE database file known as STERMS. This file relates the release category designators identified in the containment performance matrix (C-MATRIX, refer to Section A.2.2) to the quantity of fission products released to the environment.

Each record in the STERMS file contains the plant name, release class designator, and the fractional release (to the environment) of up to nine different fission product groups. Each of these fields is described below.

A.2.3.1 Plant Name

The first field of each STERMS record specifies plant name.

A.2.3.2 Release Class

The second field of each STERMS record contains the release class designator used in the IPE submittals. This designator should be identical to the corresponding value recorded in the containment performance matrix.

A.2.3.3 Fission Produce Groups

The release fractions (or source terms) of up to nine distinct fission product groups are entered into fields three through eleven each STERMS record. Nine different fission product groups have been incorporated into the file; however, not every IPE submittal will include source terms estimates for all of these groups. Therefore, the STERMS file will contain only those release fractions provided in the IPE submittals. (If data is not provided for a given fission product group, a zero will appear in the corresponding field.)

A.2.4 Level 2 Analysis Parameters or Source Term Characteristics

Information on containment failure modes and other Level 2 IPE analysis parameters is contained in an IPE database file known as REL-CLAS. This file is connected to the rest of the database through the release category designators. Consequently, this file provides information on how the source terms were calculated for each release category.

Each record in the file contains the plant name, release class, containment failure mode, containment failure cause, failure location (BWRs only), containment failure size, Zr oxidation (in-vessel), amount of core in core/concrete interactions (CCI), CCI disposition, vessel failure mode, suppression pool bypass (BWRs only), sprays available, credit taken for decontamination in reactor building (BWRs) or auxiliary building (PWRs), and relevant notes. Table A.2.2 summarizes the various entries for each of these fields, and additional detail appears in the subsections following the table.

Table A.2.2 Valid entries for REL-CLAS fields

Field	Entry	Description
Containment Failure Mode	A	Containment bypassed (not submerged)
	B	Containment bypassed (submerged)
	C	Containment failure before or without vessel failure
	D	Containment failure at vessel failure
	E	Late containment failure (vessel failure within six hours)
	F	Very late containment failure (vessel failure within 24 hours)
	G	No containment failure
	H	Manual venting of containment (before an ultimate yield)

Table A.2.2 Valid entries for REL-CLAS fields

Field	Entry	Description
Containment Failure Mode	NA	Not applicable
	NP	Information not provided
Containment Failure Cause	A	Steam and core exit gas pressurization
	B	A and H_2 burns
	C	A with DCH
	D	Basemat melt-through (for BWR Mark Is, this entry implies liner melt-through)
	I	Isolation failure
	T	Overtemperature failure
	V	Bypass
	NA	Not applicable
	NP	Information not provided
Failure location (BWRs only)	D	In drywell
	W	In wetwell
	B	Below wetwell waterline
	N	No failure
	NA	Not applicable
	NP	Information not provided
Containment failure size	A	Catastrophic failure
	B	Rupture (approx. 7 ft^2)
	C	Leak (approx. 0.1 ft^2)
	D	No failure

Table A.2.2 Valid entries for REL-CLAS fields

Field	Entry	Description
	E	Containment pressure induced isolation loss before containment failure or preexisting hole (flow area < .1 ft^2)
Containment failure size	F	Containment pressure induced isolation loss before containment failure or preexisting hole (flow area > .1 ft^2)
	V	Containment vented
	NA	Not applicable
	NP	Information not provided
Zr Oxidation (In Vessel)	L	Low oxidation (0 to 40%) available
	H	High oxidation (> 40%)
	NA	Not applicable
	NP	Information not provided
Amount of Core in CCI	L	Large amount (70% to 100%)
	M	Moderate amount (30% to 69%)
	S	Small amount (0 to 29%)
	N	None
	NA	Not applicable
	NP	Information not provided
CCI Disposition	A	Dry cavity
	B	Prompt, shallow water
	C	Delayed, deep water
	D	No CCI
	NA	Not applicable
	NP	Information not provided

Table A.2.2 Valid entries for REL-CLAS fields

Field	Entry	Description
Vessel Failure Mode	A	Pour (low-pressure)
	B	HPME (high-pressure melt ejection) gross head failure
	C	HPME ablating penetration
	D	No failure
	NA	Not applicable
	NP	Information not provided

A.2.4.1 Plant Name

The first field of each REL-CLAS record specifies the plant name.

A.2.4.2 Release Class

The second field of each REL-CLAS record contains the release class designator, which should correspond to the designator used in the source term file (STERMS, refer to Section A.2.3) and containment performance matrix (C-MATRIX, refer to Section A.2.2.)

A.2.4.3 Containment Failure Mode

The third field of each REL-CLAS record indicates how the containment failed (structural, bypassed, or vented) and when it failed (before vessel failure, at vessel failure, or after vessel failure).

A.2.4.4 Containment Failure Cause

The fourth field of each REL-CLAS record stores the cause of containment failure (steam and gas pressurization, H_2 combustion, DCH, or basement melt-through). Loss of containment isolation or bypass events can also be entered into this field.

A.2.4.5 Failure Location

The fifth field of each REL-CLAS records applies only to BWRs. This field identifies the containment failure location (in the drywell with no pool scrubbing, or in the wetwell with some pool scrubbing.)

A.2.4.6 Containment Failure Size

The sixth field of each REL-CLAS record indicates the size of the opening in containment and can also distinguish between structural failure, loss of isolation, and venting. The size of the containment opening (after failure or bypass occurs) can significantly influence the quantity of fission products released to the environment.

A.2.4.7 Zr Oxidation

The seventh field of each REL-CLAS record stores the amount of Zr oxidized in vessel for each release class. The amount of in-vessel Zr determines whether early H_2 combustion events occur. It also can influence the release of Te during core degradation.

A.2.4.8 Amount of Core in CCI

The eighth field of each REL-CLAS records indicates the quantity of core materials participating in core-concrete interactions. This is an important parameter in Level 2 analyses. If a large quantity of core materials participates, the potential exists for the core debris to remain hot (deeper pool), leading to extensive concrete erosion. If a small quantity of core materials participates, the core debris could cool (shallow pool), thereby limiting concrete erosion.

A.2.4.9 CCI Disposition

The ninth field of each REL-CLAS record stores information regarding the conditions in the cavity (dry or flooded) during CCI and whether the core debris is coolable (no CCI).

A.2.4.10 Vessel Failure Mode

The tenth field of each REL-CLAS record stores information on how the core debris penetrates the reactor vessel lower head. If the primary system is at low pressure, the release of core debris will be a gradual pour; however, if the primary system is at high pressure, rapid melt ejection could occur (through an ablating penetration or large failure of the bottom head). This field can also show the absence of bottom failure.

A.2.4.11 Suppression Pool Bypass

The eleventh field of each REL-CLAS record applies only to BWRs and is coupled to the fifth field (failure location). If all of the fission products bypass the suppression and are not subject to pool scrubbing, the environmental release could be high. This field records whether or not pool scrubbing occurs.

A.2.4.12 Sprays Available

The twelfth field of each REL-CLAS record indicates whether the sprays were available and turned on in a post core-melt environment. If so, the airborne fission product concentration will be significantly reduced. This, in turn, could reduce the quantity of fission products released to the environment. If the sprays were not available, the source term could be higher.

A.2.4.13 Credit Taken for Decontamination in the Reactor Building or Auxiliary Building

This final field of each REL-CLAS record simply indicates whether the source terms reported in the IPE submittals reflect retention of fission products in the reactor building or auxiliary building.

BWR ACRONYM LIST

Acronym	Meaning	Function
AC	Vital AC Buses	Electrical Power: AC Power (Motive)
ACBU1	Other Onsite Backup 1	Electrical Power: AC Power (Motive)
ACBU2	Other Onsite Backup 2	Electrical Power: AC Power (Motive)
ACBU3	Other Onsite Backup 3	Electrical Power: AC Power (Motive)
ADEP	Alternate Depressurization 1	Depressurization
ADS	Automatic Depressurization System	Depressurization
ARI	Alternate Rod Insertion	Reactivity Control
ASPC	Alternate Suppression Pool Cooling	Suppression Pool Cooling
AUXC2	Auxiliary Cooling 2	Closed Cycle Cooling
AUXC4	Auxiliary Cooling 4	Closed Cycle Cooling
CI1	Containment Isolation 1	Containment
CI2	Containment Isolation 2	Containment
CONDA	Condenser Available	Containment
CRDS	Control Rod Drive Pumps	High-Pressure Injection
CS	Core Spray	Low-Pressure Injection
CTS	Condensate Pumps	Low-Pressure Makeup
DC	DC Buses	Electrical Power: DC Power
DWC	Drywell Coolers	Containment Heat Removal
DWIGN	Drywell Ignitors	H_2 Control
DWS	Drywell Sprays	Containment Heat Removal
EAC	Emergency Diesel Generators (EDGs)	Electrical Power: AC Power (Motive)
EDC	Battery-backed DC Buses	Electrical Power: DC Power
ESAS1	Engineered Safety Actuation System 1	Essential Safeguards Actuation System
ESAS2	Engineered Safety Actuation System 2	Essential Safeguards Actuation System
ESW	Essential Service Water Pumps	Open Cycle Cooling
HP1	High-Pressure 1	High-Pressure Makeup
HP2	High-Pressure 2	High-Pressure Makeup
HPCS/HPCI	High-Pressure Coolant Injection (Spray)	High-Pressure Injection
HUM	Operator Action	Human
HVAC1	Heating, Ventilation, & Air Conditioning 1	Environmental Control
HVAC2	Heating, Ventilation, & Air Conditioning 2	Environmental Control

BWR ACRONYMS LIST (Cont.)

Acronym	Meaning	Function
HVAC3	Heating, Ventilation, & Air Conditioning 3	Environmental Control
IA	Instrument Air Compressors	Compressed Air
ICS	Isolation Condenser System	Containment Heat Removal
LP1	Low-Pressure 1	Low-Pressure Makeup
LP2	Low-Pressure 2	Low-Pressure Makeup
LPCI	Low-Pressure Coolant Injection	Low-Pressure Injection
MFW	Power Conversion System: Main Feedwater	High-Pressure Makeup
MSIV	Main Steam Isolation Valves	Pressure Boundary Integrity
NIT	Bottled Nitrogen (IA Backup)	Compressed Air
NSW	Normal Service Water Pumps	Open Cycle Cooling
OA3	Alternate Air System 3	Compressed Air
OA4	Alternate Air System 4	Compressed Air
RBCLCW	Reactor Building Closed Loop Cooling Water	Closed Cycle Cooling
RCIC	Reactor Core Isolation Cooling	High-Pressure Injection
RECIRC	Recirculation Pumps	Reactivity Control
RPS	Reactor Protection System	Reactivity Control
RWCU	Reactor Water Cleanup Pumps	High-Pressure Injection
SA	Station Air Compressors	Compressed Air
SLC	Standby Liquid Control	Reactivity Control
SPC	Suppression Pool Cooling	Suppression Pool Cooling
SRVS	Safety Relief Valves Steam	Pressure Boundary Integrity
STM	Steam	Steam
SW2	Alternate Service Water 2	Open Cycle Cooling
SW3	Alternate Service Water 3	Open Cycle Cooling
SW4	Alternate Service Water 4	Open Cycle Cooling
TBCLCW	Turbine Building Closed Loop Cooling Water	Closed Cycle Cooling
TBV	Turbine Bypass Valves	Closed Cycle Cooling
TDV	Torus Drywell Vent	Pressure Boundary Integrity (Relief)
VC	Vital Instrument AC	Electrical Power: AC Power (Control)
VENT	Venting System	Containment Venting System
WWIGN	Wetwell Ignitors	H_2 Control

PWR ACRONYM LIST

Acronym	Meaning	Function
AC	Vital AC Buses	Electrical Power: AC Power (Motive)
ACBUL	Other Onsite Backup 1	Electrical Power: AC Power (Motive)
ACBU2	Other Onsite Backup 2	Electrical Power: AC Power (Motive)
ACBU3	Other Onsite Backup 3	Electrical Power: AC Power (Motive)
ACC	Accumulators	Primary Systems Inventory Makeup (Passive)
AI1	Alternate Injection 1	Primary Systems Inventory Makeup During Injection
AI2	Alternate Injection 2	Primary Systems Inventory Makeup During Injection
AM1	Alternate Makeup 1	Secondary Side Makeup
AM2	Alternate Makeup 2	Secondary Side Makeup
AR1	Alternate Recirculation 1	Primary Systems Inventory Makeup During Recirculation
AR2	Alternate Recirculation 2	Primary Systems Inventory Makeup During Recirculation
AUXC2	Auxiliary Cooling 2	Auxiliary Cooling Systems: Closed Cycle
AUXC3	Auxiliary Cooling 3	Auxiliary Cooling Systems: Closed Cycle
AUXC4	Auxiliary Cooling 4	Auxiliary Cooling Systems: Closed Cycle
BI	Borated Injection	Reactivity Control
CCW	Component Cooling Water	Auxiliary Cooling Systems: Closed Cycle
CHPI	Normally Running Makeup (Injection)	Primary Systems Inventory Makeup During Injection
CHPR	Normally Running Makeup (During Recirculation)	Primary Systems Inventory Makeup During Recirculation
CI1	Containment Isolation 1	Containment Systems: Pressure Control
CI2	Containment Isolation 2	Containment Systems: Pressure Control
CSI	Containment Spray Injection	Containment Systems: Pressure Control
CSR	Containment Spray Recirculation	Containment Systems: Pressure Control
CS1	Containment Spray 1	Containment Systems: Pressure Control
DC	DC Buses	Electrical Power: DC Power
EAC	Emergency Diesel Generators (EDGs)	Electrical Power: AC Power (Motive)
EDC	Battery-backed DC Buses	Electrical Power: DC Power
ESAS1	Engineered Safety Actuation System 1	Essential Safeguards Actuation System
ESAS2	Engineered Safety Actuation System 2	Essential Safeguards Actuation System
ESW	Essential Service Water Pumps	Auxiliary Cooling Systems: Open Cycle
FC	Fan Coolers	Containment Systems: Pressure Control

PWR ACRONYMS LIST (Cont.)

Acronym	Meaning	Function
HPI	High Head Safety Injection	Primary Systems Inventory Makeup During Injection
HPR	High Head Safety Injection	Primary Systems Inventory Makeup During Recirculation
HUM	Operator Action	Human
HVAC1	Heating, Ventilation, & Air Conditioning 1	Environmental Control
HVAC2	Heating, Ventilation, & Air Conditioning 2	Environmental Control
HVAC3	Heating, Ventilation, & Air Conditioning 3	Environmental Control
IA	Instrument Air Compressors	Compressed Air
IC	Ice Condenser	Containment Systems: Pressure Control
IGN	Ignitors	Containment Systems: Hydrogen Control
LPI	Low Pressure Injection	Primary Systems Inventory Makeup During Injection
LPR	Low Pressure Injection	Primary Systems Inventory Makeup During Recirculation
MDAFW	Motor-Driven Auxiliary Feedwater Pumps	Secondary Side Makeup
MFW	Main Feedwater Pumps	Secondary Side Makeup
MSIV	Main Steam Isolation Valve	Secondary Systems Pressure Control/Integrity
NIPP	Non-1E Startup Pumps	Secondary Side Makeup
NIT	Bottled Nitrogen (IA Backup)	Compressed Air
OA3	Alternate Air System 3	Compressed Air
OA4	Alternate Air System 4	Compressed Air
PAD1	Alternate Depressurization 1	Primary Systems Pressure Control/Integrity
PAD2	Alternate Depressurization 2	Primary Systems Pressure Control/Integrity
PPORV	Pressurizer PORVs	Primary Systems Pressure Control/Integrity
PSRV	Pressurizer Safety Relief Valves	Primary Systems Pressure Control/Integrity
RCPS	Reactor Coolant Pump Seals	Primary Systems Pressure Control/Integrity
RF	Recirculating Fans	Containment Systems: Hydrogen Control
RHR	Residual Heat Removal	Decay Heat Removal

PWR ACRONYMS LIST (Cont.)

Acronym	Meaning	Function
RPS	Reactor Protection System	Reactivity Control
SA	Station Air Compressors	Compressed Air
SDAFW	Steam-Driven Auxiliary Feedwater Pumps	Secondary Side Makeup
SG	Steam Generators	Secondary Side Makeup
SGA	SG Atmospheric Dump Valves	Systems Control/Integrity
SGS	SG Safety Valves	Systems Control/Integrity
STM	Steam	Steam
SW2	Alternate Service Water 2	Auxiliary Cooling Systems: Open Cycle
SW3	Alternate Service Water 3	Auxiliary Cooling Systems: Open Cycle
SW4	Alternate Service Water 4	Auxiliary Cooling Systems: Open Cycle
TB	Turbine Bypass Valves	Secondary Systems Pressure Control/Integrity
TT	Turbine Trip (Stop) Valves	Secondary Systems Pressure Control/Integrity
VAC	Vital Instrument AC	Electrical Power: AC Power (Control)

APPENDIX B

CONVENTIONS USED IN THE IPE DATABASE

B.1 IPE Database Conventions and Query Conditions for PWR Frontline Systems and Their Dependencies on Other Frontline and Support Systems

B.1.1 Conventions Used for System Dependency

In general, the values entered into the database are derived from the dependency table (if any) provided as part of the IPE submittal. The system discussion section of the IPE submittal should also be reviewed because the relationships presented in the IPE dependency table may not be the same as those used in the IPE database (i.e., "A," "P," "S," "D," and " "), and, not all of the dependencies required in the database are available in the IPE dependency table. The data extraction process may involve interpretation of the information presented in the IPE submittals.

The IPE dependency table does not usually address the dependence of system functions on operator intervention. However, this dependency is included in the IPE database because plant operators in the control room can actuate many of the safety systems if automatic actuation fails. For example, plant operators in the main control room can actuate all ECCS systems if the actuation signal (e.g., the safety injection signal from ESAS or ESFAS) is not available. Since the ECCS (e.g., safety injection system) does not absolutely dependent on ESAS, an "A" dependency on ESAS is not appropriate. Consequently, the database reflects either a "D" (i.e., partial) dependency on ESAS1, or "P" and "S" dependencies on ESAS1 and HUM (i.e., operator actions), respectively. Although both representations are considered adequate, the latter is considered a better representation.

Similarly, some systems that can be used to prevent core damage require operator action to accomplish their safety functions. For example, on low RWST water level, operator action is required to initiate the transfer of ECCS pump suction from RWST to the containment sump for recirculation mode operation. Although pipe realignment is automatically established on low RWST water level in some cases, operator action is still required to start the recirculation mode operation. To reflect this requirement, the IPE database reflects an "A" dependency on HUM is assigned for recirculation mode operation of ECCS (HPR and LPR).

Operator action is also required for RCS depressurization using pressurizer PORVs (PPORVs), which is required for feed-and bleed cooling. The dependency of PPORVs on HUM is more complicated because, in some cases, the PPORVs also perform the function of RCS overpressure protection (with a pressure setpoint). Since RCS depressurization is a more important function for PPORVs in core damage prevention, the dependency of PPORV on HUM is more appropriately represented by a value of "A." However, the IPE database reflects a "D" dependency on ESAS1 and/or HUM if the PPORVs have setpoints and open automatically when the RCS pressure exceeds their set pressures, or if the injection pump has a shut-off head above the PORV set pressure and thus manual depressurization is, therefore, not required for feed-and bleed cooling.

Successful emergency boron injection (BI) requires operator actions and the IPE database therefore reflects an "A" dependency of BI on HUM. Specifically, operator action is required (for alignment and initiation) if injection of boric acid from the boron injection tank (BIT) to the RCS is required for reactivity control. However, operator action is not required if boron concentration in the RWST is sufficient for radioactivity control. In this case, the dependency of BI on HUM or ESAS1 is more appropriately represented by a value "D."

In addition to these safety systems, some non-safety systems can be used to prevent core damage, but the availability of these systems can be affected by an ESFAS signal. For example, the compressed air systems at some plants require cooling, and the cooling water to these systems may be isolated upon receiving an ESFAS signal. In such instance, operator action is required to reestablish the cooling system and the supply of compressed air to the air system. Since the compressed air remains available for some time after the compressed air supply is terminated (using the compressed air in the headers) and operator actions can be used to reestablish air supply, the IPE database shows a "D" dependency for this relationship.

Under certain accident conditions, plant operators can use an alternative method, which does not involve the use of any plant systems described in the IPE analyses or the database, to perform a function that is lost because of the loss of a plant system. For example, upon the loss of some HVAC systems, the operators can open the door of the room where HVAC is lost and thus preserve the service of the systems or equipment (e.g., pumps or electrical switchgear) in the room. Plant operators can also secure all but one pump in the pump room upon the loss of pump room cooling, thereby maintaining the service of the pump for the mission time. The IPE database reflects this type of dependency is represented by "P" and "S" dependencies on HVAC and HUM, respectively.

B.2 Frontline System Conventions and Query Conditions

B.2.1 Reactor Protection System

Some IPE submittals treat the reactor protection system (RPS) as though it consists of both the reactor trip system (RTS) and the engineered safety features actuation system (ESFAS). However, in the IPE database, RPS refers to RTS as the system that initiates a reactor trip when plant conditions reach specified safety system setpoints.

A solid-state protection system (SSPS) is usually used for both RTS and ESFAS. This SSPS monitors key sensed and calculated process and nuclear parameters. When those parameters exceed preset safe limits, the SSPS produces activation signals for reactor trip and engineered safety feature systems. The reactor trip system (RTS) trips the reactor on a reactor trip signal from either the SSPS or plant operators. (The trip action consists of rapid insertion of the control rods.)

The SSPS usually contains two redundant logic trains that are physically and electrically independent. The SSPS receives input from the instrumentation signal, field contacts, or main control room switches, and logically combines the input signals (typically from four independent channels) to generate output signals (using two-out-of-four and two-out-of-three logic) for system actuations. For the RPS, all instrument channels and circuits are designed using a fail-safe philosophy: A loss of signal or electric current places a channel in the equivalent of the tripped condition.

To provide a non-safety grade backup to the RPS, some plants use ATWS mitigation system actuating circuitry (AMSAC), which is automatically activated following an ATWS event to trip the reactor, trip the turbine/generator, and initiate auxiliary feedwater (AFW) flow. For plants with the AMSAC system, the signals that are sent to the RPS for reactor trip are also sent to the AMSAC for turbine trip and AFW actuation.

Despite the complexity of these dependencies, some IPE submittals only briefly discussed RPS in the ESFAS section. Since both the ESFAS and the RPS use the same SSPSs, the number of trains for the RPS should be the same as the number used for the ESFAS. The IPE database, therefor, indicates either the number of trains (usually 2) or the number of channels (usually 4) in the NO_TRAIN field of either B-DEPEND or DEPENTAB, as appropriate for BWR or PWR, respectively.

The RPS also requires either DC or VAC power for signal transmittal and processing. Although the system is usually fail safe (trip on loss of power), correct signal processing and transmittal requires electric power. The IPE database, therefore, reflects a dependency on electric power "P" and "S" dependencies on DC and EDC, respectively, or an "A" dependency on VAC.

The reactor is tripped upon receiving an appropriate ESFAS signal, or when manually tripped by the operators in the control room. The IPE database reflects "P" and "S" dependencies on ESAS1 and HUM, respectively.

B.2.2 Borated Water Injection System

Injection of borated water into the RCS for reactivity control is performed by the chemical and volume control system (CCS). The charging pumps of the CCS can take suction from the volume control tank (VAT), the RWST, or the boric acid tanks (BATs). VCT provides the RCS coolant makeup source under normal operating conditions, RWST provides the makeup source during the injection phase of ECCS operation (in response to an ESFAS signal), and the BATs provide highly concentrated borated water for emergency boration following an ATWS event. (It should be noted, however, that borated water from the BATs is not required if the boric acid concentration in the RWST is adequate for reactivity control.)

Operator action may be required to align the CVCS charging system to the BATs if borated water from the BATs is required for emergency boration. After proper alignment, borated coolant from the BATs can be supplied to the charging pumps via either the boric acid makeup (BAMU) pumps or through a gravity feed path. Since operator action is required, the IPE database assigns the BI function an "A" dependency on HUM.

In the IPE database, the BI system usually refers to the pumps that deliver the borated water from the BATs to the RCS (i.e., the charging pumps of the CVCS). Since these pumps are used for both CHPI and BI, a semicolon ";" is entered in the SEMI_OR_S field, and BI is entered in the OTHER_FUNC field for the CHPI system in the B-DEPEND or DEPENTAB database table.

For some plants, however, BI refers to the BAMU pumps. Since the CHPI pumps are required to deliver borated water to the RCS, the BI system (i.e., the BAMU pumps) will depend on the CHPI pumps to accomplish its function. The IPE database reflects this relationship with an "A" dependency of BI on CHPI. (San Onofre, Watts Bar, Kewaunee, Arkansas 2, Haddam Neck, Farley, BV1, Sequoyah, and Salem 2 use the boron injection tank)

The IPE database may also reflect a "D" dependency on HUM if operator action is not required for emergency boron injection. For example, in some IPE submittals where the RWST is assumed to have sufficient boron concentration for reactivity control, boron injection is achieved by the injection systems (e.g., CHPI or HPI), and the use of the coolant in the boron injection tank may not be required.

B.2.3 Pressurizer PORVs and Safety Valves

The pressurizer PORVs (PPORVs) and safety relief valves (PSRVs) are mounted on the pressurizer and used for RCS pressure control. The PSRVs are used for RCS overpressure protection and will lift mechanically on high RCS pressure. The PPORVs may also have setpoints and thus perform the same function as the PSRVs for RCS overpressure protection. In addition, plant operators can cause the PPORVs to open at lower pressures. Such manual operation reduces the challenge to the PSRVs and is used in performing the bleeding function of feed-and-bleed core cooling. Upstream of the PPORVs is a block valve, which is normally open and can be closed if there is a leakage through the PPORVs.

The control power for the PPORVs usually comes from either DC or VAC, and the motive power for valve operation depends on the air system (IA and NIT). The dependency of PPORVs on HUM is more complicated, however, when the PPORVs also perform the RCS overpressure protection function (with a pressure setpoint). Since the IPE submittals consider RCS depressurization to be a more important function for PPORVs in core damage prevention, the dependency of PPORVs on HUM is more appropriately represented by a value of "A." However, the IPE database also uses a "D" dependency on HUM and/or ESAS1 if the PPORVs have setpoints and thus open automatically when the RCS pressure exceeds the set pressures, or if the injection pump has a shutoff head above the PPORV set pressure (and thus manual depressurization is not required for feed-and bleed cooling).

B.2.4 Alternate RCS Depressurization Systems

The alternate RCS depressurization systems include the pressurizer sprays and valves other than the PPORVs. Usually, the PPORV reflected in the IPE database includes these systems because they perform the same RCS depressurization function as the PPORV. Although the use of these systems is preferred to the use of the PPORVs for RCS depressurization (because the use of PPORVs will cause coolant loss from the RCS), they may not be available when they are needed (because of their dependence on the recirculation pump and charging pump).

B.2.5 Reactor Coolant Pump Seals

The number (NO.) of RCPSs recorded in the IPE database is the number of reactor coolant pumps (RCPs) in the plant. The IPE database includes this value to address the seal LOCA issue. Specifically, plants usually require either seal injection (by the CHPI) or thermal barrier cooling (using CCW) to prevent an RCP seal LOCA. The IPE database reflects this requirement by assigning "P" and "S" dependencies (of RCPS) on CHPI and CCW, respectively, in the B-DEPEND or DEPENTAB database table. In some IPE submittals, however, seal LOCA is assumed not to occur (even with the loss of seal cooling) if the operator trips the RCP within a certain time after the loss of seal cooling. In such instance, the IPE database reflects a "D" dependency of RCPS on CCW. Since operator actions (to trip the RCP) are required to prevent a seal LOCA, a "P" and "S" dependencies on CCW and HUM, respectively.

B.2.6 Charging Pump System

The charging pumps of the CVCS can provide high-pressure injection for RCS coolant makeup in an accident. In the injection mode (CHPI), the charging pumps take suction from the RWST and discharge to the RCS. Usually, the charging pumps include two motor-driven centrifugal charging pumps (CCPs) and one positive-displacement charging pump (PDCP). Because of its low capacity, the PDCP may not be considered in the IPE as an effective RCS coolant injection source. The number of trains for CHPI presented in the IPE database is therefore the number of CCPs considered in the IPE submittals for RCS injection. (The IPE database also includes a note if a PDCP is available but is not considered in the IPE as a sufficient RCS injection source.) It should be noted, however, that some IPE submittals consider the PDCP to be an effective RCP seal injection source. In this case, AI1 (or AI2) can be assigned to represent PDCP. Since aligning the PDCP for seal injection (upon loss of the CCPs) requires operator action, the IPE database reflects an "A" dependency on HUM for the PDCP (i.e., AI1 or AI2 in the database).

Upon depletion of the RWST water, the suction source for RCS injection pumps is switched to the containment sump for recirculation mode operation. The charging pumps are not used in the recirculation mode of operation as described in some IPE submittals. For plants that use the charging pumps for recirculation mode operation (CHPR), the charging pumps usually take suction from the discharge of the low-pressure recirculation system (LPR). The IPE database reflects this condition by assigning an "A" dependency of CHPR on LPR in the B-DEPEND or

DEPENTAB database table. Since CHPI and CHPR use the same pumps, a semicolon (;) is entered in the SEMI_OR_S field, and "CHPR" is entered in the OTHER_FUNC field of the record pertaining to CHPI.

Control of the charging pumps usually requires DC or VAC ("P" and "S" dependencies on DC and EDC, respectively, or "A" dependency on VAC) and AC for motive power. Since the pumps are usually loaded on the emergency diesel generators, they have "P" and "S" dependencies on AC and EAC, respectively. The CHPI pumps may also require motor and/or lube oil cooling, which (in turn) require room cooling and/or cooling water from CCW or ESW. The IPE database assigns an "A" dependency if cooling is required, a "D" dependency if the failure is delayed, and no dependency if the pumps can survive the mission time without requiring cooling.

B.2.7 High-Pressure Safety Injection System

The high pressure injection (HPI) pumps are sized for small or medium LOCAs. Their basic purpose is to maintain RCS pressure at some value (lower than normal) while the plant comes to an orderly shutdown and depressurization. These pumps start automatically at about 1800 psi on receipt of the safety injection signal (considered in the IPE database as part of the ESFAS, or ESAS1) after the reactor has tripped. The HPI pumps have a shutoff head in the range of 1,400 to 1,800 psig and, therefore, are not capable of providing makeup at full RCS pressure. RCS makeup at high pressure is thus limited to the capacity of the charging pumps (about 150 gpm above system pressure). If the RCS pressure remains above the shutoff head of the HPI pumps, RCS depressurization is needed to allow the use of HPI pumps to provide RCS makeup. RCS depressurization can be accomplished either by secondary cooling using the SGs or by opening the PPORVs.

In some PWR plants, the charging pumps of the charging system are used for HPI. For these plants, RCS makeup (as that required for HPI conditions) can be provided at above system pressure without requiring RCS depressurization. (It should be noted that for the plants equipped with separate CHPI and HPI pumps, the CHPI pumps may be able to provide sufficient RCS makeup under some accident conditions.)

The HPI pumps take suction from the RWST. The HPI is placed in the recirculation mode of operation (HPR) if the RWST level is low. The HPI pumps cannot usually be aligned to take suction directly from the containment sump; they must take suction from the discharge of the LPI/LPR pumps. This requires tandem operation of the LPI/LPR pumps and the HPI/HPR pumps. The IPE database reflects this relationship by assigning an "A" dependency of HPR on LPR. In addition, since the same pumps are used for both HPI and HPR, a semicolon (;) is assigned to the SEMI_OR_S field and "HPR" is assigned to the OTHER_FUNC field of the record pertaining to HPI. "CHPI" is also entered in the OTHER_FUNC field if the same pumps are used for both CHPI and HPI. ("BI" is also entered if it uses the same CHPI pumps.)

Operator action (e.g., manual alignment of the RHR system and alignment of the HPR to take suction from the LPR) is usually required for HPR operation. Consequently, the IPE database reflects an "A" dependency in the HUM field for the record pertaining to HPR in the B-DEPEND or DEPENTAB database table.

The dependence on electric power and cooling for the HPI pumps is similar to that described above for the CHPI pumps.

B.2.8 Low-Pressure Safety Injection System

The low pressure injection (LPI) for the ECCS uses the pumps for the RHR system. The safety injection signal starts the RHR pumps and lines up the RHR system to take its suction from the RWST. The system will begin to deliver water to the RCS as soon as the RCS pressure drops below the RHR pump shutoff head (about 350 to 400 psi). Upon depletion of the RWST water, the suction of the LPI pumps is switched to the containment sump for the low-pressure recirculation (LPR) mode of operation. In LPR, the sump water is cooled by the RHR heat exchangers to remove the core decay heat. However, the sump water, and thus the RCS coolant makeup, could be lost (through evaporation) if the RHR heat exchanger fails to function. Successful LPR operation therefore requires proper functioning of the RHR heat exchangers. In addition, since the same pumps are used for both LPI and LPR, a semicolon (;) is assigned tc the SEMI_OR_S field and "LPR" is assigned to the OTHER_FUNC field of the record pertaining to LPI. Since these pumps may also supply containment spray in recirculation mode (CSR), "CSR" may also be assigned to the OTHER_FUNC field for LPI. (For some PWR plants, the containment spray pumps, which are separate from the RHR pumps, can only take suction from the RWST. After depletion of the RWST water, the RHR pumps are used to provide water to the containment spray in recirculation mode.)

The RHR system can also perform in a shutdown mode. In this mode, the RHR system takes suction from the RCS loop hot leg, pumps the coolant through the RHR heat exchangers for decay heat removal, and injects the cooled fluid back to the RCS. (The heat exchanger may be bypassed for heat removal rate control.) In the IPE database, this mode of operation is included as part of the LPR, or can be assigned as an alternate recirculation mode system (e.g., AR1 or AR2).

Some plants use different pumps for LPI and RHR, but the LPI pumps can only take suction from the RWST. The RHR pumps, separated from the LPI pumps, are used for recirculation mode operation. Other plants use different pumps for LPR and RHR. (For example, in Indian Point 2, containment recirculation pumps are the primary means for LPR, with RHR pumps as the backup means.) For such plants, the IPE database assigns AR1 to represent RHR.

The dependence on electric power and cooling for the LPI pumps is similar to that described above for the HPI pumps.

B.2.9 Accumulators

The accumulator (or a safety injection tank) system provides a means for the passive injection of borated water into the RCS in the event of a LOCA. The accumulators are normally isolated from the RCS by two check valves in series. The check valves open and the content of the accumulators discharges to the RCS when the RCS pressure drops below the accumulator tank pressure (600 to 800 psi). Each accumulator is also equipped with a normally open block valve, which closes to isolate the accumulator and prevent unwanted accumulator injection during plant cooldown and depressurization.

The number entered into the NO_TRAINS field in the B-DEPEND or DEPENTAB database table is the number of accumulator tanks. The accumulator system is a passive system and does not depend on any other frontline or support system.

B.2.10 Alternate Injection and Recirculation

The B-DEPEND or DEPENTAB database table lists all additional injection sources, other than the charging and safety injection systems, for which the IPE submittal takes credit. These may include use of the service water cross-tie, fire water, and cross-tie from another unit. AI1 or AI2 may also be used for the small-capacity charging pump (e.g., PDCP, which does not have sufficient flow rate for coolant injection) if the IPE submittal considers the pump for seal injection. In addition, AR1 may be used to represent RHR if LPR and RHR use different pumps.

B.2.11 Steam Generator Safety Valves and SG Atmospheric Dump Valves

The SG safety valves (SGS, spring-operated) and SG atmospheric dump valves (ADVs, power-operated) are mounted on the main steam line (MSL) upstream of the main steamline isolation valve (MSIV). These valves are designed for MSL over-pressure protection. The ADVs (or SG PORVs) are also designed to provide a means for plant cooldown when the condenser steam dump (through the turbine bypass valves) is not available (for example, in an MSIV closure event).

The values assigned to the NO_TRAINS field for SGS and SGA are the total number of valves that are usually evenly distributed in all of the MSLs in the plant. Since the actuation of SGAs for RCS cooldown requires operator action, the IPE database indicates an "A" dependency of SGA on HUM absolutely. (Note: A "D" dependency may also be used because the SGA will open at a pressure set point, which can be manually controlled.) The SGA valves usually require DC or VAC for control ("P" and "S" dependencies on DC and EDC, respectively, or "A" dependency on VAC) and pneumatic power for operation ("A" dependency on IA, or "P" and "S" dependencies on IA and an alternate air system, such as SA).

B.2.12 Turbine Trip Valves, Main Steam Isolation Valves, and Turbine Bypass Valves

The turbine trip system serves to isolate the main turbine from the steam supply by closing the turbine stop valve (or turbine trip valve) and the turbine control valve in each steamline. After the turbine is isolated from the steam supply, the turbine bypass valves are opened to dump the steam to the main condenser, thereby bypassing the main turbine. The MSIVs are between the SG and the TT and TB valves. The main steamline is isolated from the main turbine and the main condenser after the MSIV is closed.

Most of the IPE submittals do not specify the number of these valves, but the number of MSIVs and TT valves is generally the same as the number of main steamlines, which is usually the number of SG loops. To show that the system is considered in the IPE submittal, a value of "1" is used in the IPE database if the number of valves for the system is not given in the IPE submittal.

The valves usually require DC or VAC for control and pneumatic power for motive power, and they are usually in a fail-safe (or fail-closed) position upon loss of control and motive power. Therefore, their dependence on the power system may not be an "A" dependency (probably a "D" dependency). However, under certain conditions, the MSIV and TB valves need to be opened to prevent core damage. The opening of these valves requires both the control and the pneumatic power, so the database reflects an "A" dependency for the power systems, and "P" and "S" dependencies for DC and EDC, respectively.

The MSIVs and the TB valves can be controlled either by some signals or by operator action. Consequently, the database reflects "P" and "S" dependencies on ESAS1 and HUM, respectively.

B.2.13 Steam Generators, Main Feedwater, and Auxiliary Feedwater

The auxiliary feedwater (AFW) system provides water to the steam generators (SGs) to remove heat when the main feedwater (MFW) system is not available. The AFW usually consists of two motor-driven pumps and one turbine-driven pump and is initiated either automatically (e.g., on safety injection or AMSAC signals) or manually from the main control room ("P" and "S" dependencies on ESAS1 and HUM, respectively). The AFW pumps are aligned to take suction from the condensate storage tank (CST). Alternate water sources to the AFW pumps include service water or other raw water sources (e.g., deep well).

The main feedwater pumps can be either turbine-driven ("A" dependency on STM) or motor-driven ("A" dependency on AC, not loaded on EAC). The steam-driven AFW (SDAFW) has an "A" dependency on STM, and the motor-driven AFW has a "P" and "S" dependencies on AC and EAC, respectively. The control power for the feedwater systems comes from either DC or VAC ("P" and "S" dependencies on DC and EDC, respectively, or "A" dependency on VAC).

Unless the MFW flow is interrupted by the nature of the transient, the MFW system should continue to supply water to the SGs for decay heat removal. However, if MFW is lost, operator action is required to recover it. The normal water source for the MFW is the condenser hotwell, which can be exhausted if the main condenser is not available or if the main steam bypass path is not open (which requires the opening of both the MSIV and the TB valves). Since, under certain conditions, operator action is needed to make MFW available; hence, the database usually reflects a "D" dependency on HUM for MFW.

B.2.14 Alternate Feedwater Makeup

Alternate feedwater supplies to the SGs can be provided by the condensate pumps, from cross-tie of AFW from other units in a multi-unit site, or from diesel-driven fire water. The alternate water supplies are used if the AFW system is not available (e.g., because of failure of all AFW pumps). Because the alternate feedwater supply may not have sufficient pressure head, its use may require SG depressurization (using SGA).

B.2.15 Containment Sprays in Injection and Recirculation Modes

The containment spray pumps take suction from the RWST during the injection phase (CSI) or from the containment sump during the recirculation phase (CSR). The system is normally in standby with the pump suction aligned to the RWST. The discharge side of the pump is normally isolated from the spray headers by motor-operated valves (MOVs). The valves open and the pumps start to provide spray water to the containment atmosphere via the spray nozzles upon receiving a high-high containment pressure signal (a "P" dependency on ESAS1). The system can also be manually controlled from the main control room (an "S" dependency on HUM).

Manual alignment is usually required to put the system in recirculation mode operation (an "A" dependency on HUM). The CS pumps take suction from the containment sump in recirculation mode operation (through the RHR system discharge for some plants, an "A" dependency on LPR for these plants). However, the containment spray pumps cannot take suction from the sump in some plants. In such instance, spray flow, if required after the depletion of the RWST, is provided by the RHR pumps operating in recirculation mode. For other plants, CSI and the CSR pumps are separate, and the CSI (quench spray) pumps can take suction only from the RWST while the CSR (recirculation spray) pumps can take suction only from the sump.

The containment heat removal (CHR) capability for containment spray is provided by either the fan coolers or the (RHR) heat exchangers in the recirculation loop.

The dependency on electric power and cooling for the CSI pumps is similar to that discussed above for the LPI pumps.

B.2.16 Fan Coolers

The reactor containment fan coolers (FCs), the containment air coolers (CACs), or containment air recirculation cooling (CARC) system provide heat removal for the containment atmosphere under normal and emergency conditions. The FC system normally consists of a few air recirculation cooling units (or air handlers), and the service water system (SW) usually provides the cooling to the tube side of the cooling coils in the cooling units (an "A" dependency). Some FCs operate during normal operations to maintain proper containment temperature; additional FCs and increased SW flow rate may be required for accident conditions. FC operation under accident conditions may be initiated by an SFAS signal or by plant operators, so the database reflects "P" and "S" dependencies on ESAS1 and HUM, respectively.

The fans for the FC system require AC motive power ("P" and "S" dependencies on AC and EAC, respectively) and DC control power (a "P" and "S" dependencies on DC and EDC, respectively).

B.2.17 Containment Isolation

The containment isolation system (CIS) minimizes the release of radioactive material to the environment in the event of failure of the RCS. Containment isolation occurs upon receiving the appropriate ESFAS isolation signal or in response to operator action ("P" and "S" dependencies on ESAS1 and HUM, respectively).

Double barriers are usually provided for electrical penetrations, and two isolation valves are used for piping penetrations that need to be isolated upon receiving an isolation signal. (2 is assigned as the NO_TRAINS in the database.) The valves are usually air-operated and fail-safe on loss of the support systems ("D" dependency on DC or VAC for control power, and on IA for pneumatic power). However, some CI components may require ac power for motive force ("P" and "S" dependencies on AC and EAC, respectively).

Other important penetrations include the personnel hatch and equipment hatch, each of which has a double door that is normally closed. (An interlock prevents both doors from being open simultaneously.)

B.2.18 Ice Condenser Ignitors and Recirculating Fans

Ice condenser ignitors and recirculating fans are used in an ice condenser containment. There is usually one ice condenser with two ice beds. The NO_TRAINS in the IPE database is thus assigned either as "1" or "2."

A hydrogen ignitor system (IGN) is provided for an ice condenser containment to ensure adequate hydrogen control in the containment during a degraded core cooling event. The IGN usually uses electrical resistance heating elements (glow plugs) located throughout the containment building. Two trains of ignitors are supported by independent electric divisions, with each train having many plugs. In the database, the NO_TRAINS is therefore assigned a value of "2," with the number of plugs in each train provided in the NOTES/SOURCE field of the IPE database.

The IGN requires ac power ("P" and "S" dependencies on AC and EAC, respectively), and is manually actuated from the control room when called upon by the emergency operating procedures (an "A" dependency on HUM). It may also require DC or VAC for control.

The containment air recirculation system is designed to provide a general recirculation of the containment atmosphere between the upper and lower containments of an ice condenser containment, and to prevent hydrogen accumulation in restricted areas following a LOCA event. It usually consists of two redundant independent systems, which include fans, back-draft dampers, valves, piping, and ductwork. (NO_TRAINS is assigned a value of "2" in the database.) The system is normally in standby mode and is actuated automatically on receiving an appropriate ESFAS signal, or manually from the control room ("P" and "S" dependencies on ESAS1 and HUM). The system requires AC motive power ("P" and "S" dependencies on AC and EAC) and DC or VAC control power (a "P" and "S" dependencies on DC and EDC, respectively, or an "A" dependency on VAC).

3. Support Systems

B.3.1 Engineered Safety Features Actuation System

The ESFAS senses accident situations and provides automatic actuation of the necessary engineered safeguards systems to prevent or mitigate damage to the core and ensure containment integrity. The actuation signal is usually generated by a solid-state protection system (SSPS, see RPS description). The SSPS usually contains two redundant logic trains that are physically and electrically independent. The SSPS receives input from the instrumentation signal, field contacts, and main control room switches.

Depending on the values of the input parameters, the ESFAS generates and transmits a variety of signals, which may include the safety injection actuation signal (SIAS), containment isolation signal (CIS), containment spray actuation signal (CSAS), SG isolation signal (SGIS), under-voltage signal (UV), and recirculation actuation signal (RAS). ESAS1 requires DC or VAC power for signal processing and transmission ("P" and "S" dependencies on DC and EDC, or an "A" dependency on VAC). Proper function of ESAS1 may also require sufficient room cooling (a "P" dependency on HVAC).

B.3.2 Electric Power Systems

B.3.2.1 AC System

The onsite electric power system comprises both non-Class 1E system (which supplies non-safety loads) and the Class 1E system (which supplies safety systems). During normal operation, the onsite electric power is supplied from the output of the main generator and/or the offsite grid. The onsite AC electric power system includes 6.9 and/or 4.16 kV buses and 480V motor control centers. The NO_TRAINS for the AC system in the IPE database is the number of 6.9/4.16 kV buses, including both Class 1E and non Class 1E buses.

AC in the IPE database represents the power supply (e.g., offsite or main generator) and the associated ac buses for power delivery. Since the operation of the AC bus requires DC control power (e.g., switch gear control), AC has "P" and "S" dependencies on DC and EDC, respectively. Proper functioning of the AC system may require adequate cooling, as reflected in the IPE database by a dependency on the service water (e.g., ESW) or room cooling (e.g., HVAC).

B.3.2.2 Emergency Diesel Generators

Diesel generators (DGs) are standby ac power sources for the Class 1E portion of the onsite electric power system. The DGs supply power to the emergency 6.9/4.16 kV buses upon loss of normal power supply. The DGs start automatically on receipt of a safety injection signal, a station blackout signal, or under-voltage on the 6.9/4.16 kV bus served by the DG.

The entry for NO_TRAINS is the number of DGs for the unit (if the DGs are dedicated to the unit), or the total number of DGs for all units at the site (if the DGs are shared by the units). In the latter case, a semicolon (;) in the SEMI_OR_S field of EAC to show that the DGs are shared.

In the IPE database, EAC represents the DGs and associated AC buses for power delivery. Since the operation of the AC bus requires DC control power (e.g., switch gear control), EAC has "P" and "S" dependencies on DC and EDC, respectively. The emergency DGs may require plant service water for cooling (e.g., an "A" dependency on ESW) and/or station dc power for starting and control (e.g., "P" and "S" dependencies on DC and EDC). They may also have their own battery and cooling system, in which case they do not depend on plant SW or DC power.

The DGs are actuated upon receiving an ESFAS signals (e.g., SI or under-voltage signal). They can also be started manually by plant operators. This is represented in the IPE database by "P" and "S" dependencies of ESAS1 and HUM, respectively.

B.3.2.3 DC System, Batteries, and Vital AC System

Batteries are standby DC power sources. During normal operation, the batteries are maintained fully charged by battery chargers which also supply the dc power loads. Most DC loads are supplied from 125V DC buses, although some plants may also have 250V DC buses. The 125V vital (or instruments) AC is normally powered by the 125V DC system through inverters. The 125V VAC may also be directly supported by plant AC power.

DC in the IPE database represents the DC bus and the supporting power source (i.e., AC and EAC). It therefore has "P" and "S" dependencies on AC and EAC, respectively. EDC in the IPE database represents the station batteries and the bus that delivers the battery power to the equipment. Since the batteries remain fully charged, they do not depend on ac power to function.

However, without AC charging power, the batteries will be depleted after a few hours of operation. Both DC and EDC will be lost if the associated DC bus fails, and the DC system may require room cooling.

The NO_TRAINS for the DC system in the IPE database is the number of 125/250 V DC buses, while the NO_TRAINS for EDC is the number of 125/250 V batteries, and the NO_TRAIN for VAC is the number of 125V instrument AC buses in the unit.

B.3.2.4 Backup for onsite Electric Power Supply

Additional onsite power supplies are represented in the IPE database by ACBU1, ACBU2, and ACBU3. For example, a swing diesel that is shared by multiple units at the site can be designated in the database as ACBU1. If each unit has two dedicated DGs and one swing DG, the NO_TRAINS is 2 for EAC and 1 for ACBU1. In addition, since the swing DG is shared, an "S" is assigned to the SEMI_OR_S field of ACBU1.

ACBUx may also be used to represent a particular electric bus or motor control center (MCC) that has special importance in the IPE submittals.

B.3.2.5 Electric Power Dependency

Only safety systems are loaded on the DGs upon loss of normal power supply. The systems that are supported only by normal power supply (e.g., main feed water pumps) have an "A" dependency on AC. The systems that are loaded on the DGs (e.g., safety injection pumps) have "P" and "S" dependencies on AC and EAC, respectively.

The dependency on DC power is generally "P" and "S" on DC and EDC dependencies, respectively. This is because the DC power is usually supplied by the AC through the batteries and their chargers. The batteries supply the DC power loads when the AC power supply to the battery chargers is lost.

The availability of AC power requires both the power supply source (e.g., offsite power or DGs) and the AC bus. Since DC power provides the control power for AC bus switchgear breakers, AC power is lost upon a loss of all DC control power. Consequently, AC power has "P" and "S" dependencies on DC and EDC, respectively. The AC power may also be lost upon the loss of all switchgear room cooling (a dependency on HVAC).

The DC power is normally provided by the AC power through battery chargers, so DC power has "P" and "S" dependencies on AC and EAC, respectively. Although the batteries are charged by AC power, they remain fully charged and their availability does not depend on availability of the AC power. Consequently, the batteries (EDC) do not depend on any other electric power; however, after a loss of AC charging power, the batteries can only supply the required DC power for a limited time (2 to 8 hours).

B.3.3 Open Cycle Cooling Systems

B.3.3.1 Service Water System

For some plants, the service water (SW) system provides cooling water to both safety related and nonessential heat exchangers and equipment. Under accident conditions, the pumps normally in standby mode start, and the non-safety loads are automatically isolated upon receipt of ESFAS signals. Since the same pumps are used for both normal operation and emergency conditions (i.e., NSW and ESW, respectively), the system is designated in the IPE database as ESW, and the NO_TRAINS in the IPE database is the number of SW pumps.

Other plants use separate pumps for NSW and ESW. In such applications, the NSW system is in service during normal plant operations with the ESW system in standby. Under accident onditions, the NSW is automatically isolated upon receipt of an ESFAS signal (e.g., safety injection signal), and the ESW takes the cooling loads for safety-related systems. If no ESFAS signal is generated under accident conditions, the ESW loads can usually be supplied by the NSW pumps. On the other hand, if the operating NSW pump fails, the ESW pumps automatically start as a result of low head pressure.

For plants that have separate NSW and ESW systems, one of the systems is assigned as ESW and the other is assigned as SW2 in the IPE database. It is preferred that the SW system that takes the cooling loads for safety-related equipment during accident conditions be referred to as the ESW in the IPE database. Since the success of the SW system (or the number of SW pumps required for its success) depends on successful load isolation and/or system actuation, the ESW system may have "P" and "S" dependencies on ESAS1 and HUM, respectively. A "D" dependency on ESAS1 may also be used if failure of load isolation and/or system actuation will not cause the loss of the essential cooling water.

The ESW depends on AC motive power ("P" and "S" dependencies on AC and EAC, respectively) and DC control power (a "P" and "S" dependencies on DC and EDC, respectively). An "S" is assigned to the SEMI_OR_S field of the IPE database if the system is shared by the units in a multi-unit site.

One major load for the SW system is the cooling of the closed-loop component cooling water (CCW) system. The SW may also be used to provide a backup supply to the suction of the AFW pumps. The SW system in some plants is a closed system.

B.3.3.2 Alternate Service Water

Alternate service water for the cooling of the safety-related systems under accident conditions may be supplied by the normal service water, the fire water, cross-tie from another unit, or the circulating water system. If ESW is used in the IPE database for normal service water, alternate

SW can be used in the IPE database to indicate the emergency service water system of the plant.

B.3.4 Closed Cycle Cooling Systems

B.3.4.1 Component Cooling Water System

The CCW system transfers heat from components in various systems to the SW system during all phases of plant operations, as well as during accident conditions. The CCW system supplies cooling water to the RCP thermal barrier coolers, the RHR heat exchangers, ECCS pumps, and other components and heat exchangers. CCW flow to the nonessential loads are isolated upon receipt of an ESFAS signal (e.g., safety injection signal). The signal also starts the standby CCW pump.

Because the CCW system requires the SW system to remove its heat loads, CCW will have an "A" dependency on SW. The CCW system will also have "P" and "S" dependencies on ESAS1 and HUM (operator actions), respectively, or a "D" dependency on ESAS1 if failure of load shedding and/or failure to start the standby CCW pump is not critical to its success.

The CCW depends on AC motive power ("P" and "S" dependencies on AC and EAC, respectively) and DC control power "P" and "S" dependencies on DC and EDC. An "S" is assigned to the SEMI_OR_S field of the IPE database if the system is shared by the units in a multi-unit site.

B.3.4.2 Auxiliary Cooling

Alternate CCW can be provided by an additional CCW system, cross-tie from another unit, or fire water. CCW provides pump cooling to various systems in the plant. In general, these systems are lost on loss of CCW cooling, so they have an "A" dependency on CCW ("P" and "S" dependencies on CCW and an alternate CCW system). However, in some IPE submittals, failure of CCW does not automatically lead to system failure, and a "D" dependency on CCW is assigned in the database.

B.3.5 Compressed Air Systems

B.3.5.1 Instrument Air and Station Air Systems

The instrument air (IA) system provides high-quality air at adequate pressure to support plant instrumentation and component requirements. The IA system is classified as a non-safety system. Although no plant safety function or system is defeated by failure of the IA system, a loss of IA disables non-safety backup systems which may be utilized as alternatives to safety systems. Its loss may also affect the ability of plant operators to perform preventive or mitigative actions in response to an accident (e.g., opening a closed MSIV).

For some plants, the IA system is a subsystem of the station air (SA) system and, as such, the IA and SA systems share the same compressors. For plants where the IA and the SA systems use separate compressors, cross-tie is usually available so that the compressors of the SA system can be aligned to provide compressed air to the IA system. These different arrangements are reflected in the IPE database by assigning proper values in the SEMI_OR_S field, the OTHER_FUNC field, and the CROSSTIE field.

The IA (or SA) system is in service during normal plant operations providing compressed air to the IA (or SA) headers to be used throughout the plant. The air compressors maintain receiver air pressure at about 100 psig. The system functions the same under accident conditions; IA operation is affected by accident conditions only to the extent that a containment isolation signal isolates the IA line to the equipment inside the containment (including the PPORVs).

Some of the compressors may be supported by the emergency buses and, therefore, may be available during loss of offsite power (but a manual restart may be required because of load shed). "P" and "S" dependencies on AC and EAC, respectively, are assigned in the IPE database for such arrangements. An "A" dependency on AC is assigned if the compressors are not loaded on the diesel generator. The system may require DC for control power ("P" and "S" dependencies on DC and EDC, respectively) and cooling for the compressors and after-coolers from the cooling water system ("A" or "D" dependencies on ESW or CCW, respectively).

For plants where the plant compressed air system requires cooling, the cooling water to the compressed air system may be isolated upon receiving an ESFAS signal. Operator action is then required to reestablish the cooling system and the supply of compressed air to the air system. Since the compressed air is still available for some time after the compressed air supply is terminated (using the compressed air in the headers) and operator actions can be used to reestablish air supply, the database reflects a "D" dependency on ESAS1.

B.3.4.2 Alternate Air Systems

An alternate compressed air supply may be provided by cross-tie from another unit or additional compressors. In addition, a nitrogen storage tank, bottled nitrogen, or accumulators may be used as a primary pneumatic power supply to some safety-related systems (e.g., PPORVs), with the IA system serving as an automatic backup. Since NIT is a passive system, it does not depend on any support system; however, because of its limited supply, the system may only be able to support a limited number of valve actuations.

B.3.5 Environmental Control Systems

The environmental control system removes the heat gain within various rooms to enable the equipment in the rooms to function as designed, and to provide adequate ventilation for personnel access to the rooms during normal and accident conditions. The HVACs that are considered to be important and are modeled in the IPE submittals include those associated with the emergency diesel generators, the emergency switchgear room, the battery room, the various pump rooms, and the control room.

The HVAC depends on AC motive power ("P" and "S" dependencies on AC and EAC, respectively) and DC control power ("P" and "S" dependencies on DC and EDC, respectively). The HVAC systems may require a cooling water system for heat removal (an "A" dependency on ESW or CCW, or "P" and "S" dependencies on ESW or CCW and an alternate cooling water system). Proper operation of the system may also require an ESFAS signal and/or operator action. Appropriate values are assigned for ESAS1 and /or HUM dependency in the database.

B.4 Core Damage Prevention Strategies and Mission Success Paths

B.4.1 Safety Functions for CDPSs

In the database, a core damage prevention strategy (CDPS) specifies (or records) the minimum safety functions required to prevent core damage. The following safety functions are considered in the IPE database (as fields for the STRATEGY or B-STRAT file):

- SINT secondary integrity
- SDEP secondary depressurization
- SSMU secondary makeup
- RCS-BOR RCS boration and reactivity control
- RCS-INT RCS integrity
- HPI RCS high-pressure injection
- HPR RCS high-pressure recirculation (including decay heat removal)
- LPI RCS low-pressure injection
- LPR RCS low-pressure recirculation (including decay heat removal)
- CPSI containment pressure suppression injection
- CPSR containment pressure suppression recirculation
- CIF containment isolation
- VENT containment venting.

The strategies that can be used to prevent core damage depend on accident initiators. For example, the use of secondary cooling (i.e., SSMU) alone may be a successful strategy for a transient initiator event, but RCS injection must be available to prevent core damage for a LOCA event.

B.4.2 CDPSs and MSPs - General Discussion

A CDPS in the IPE database presents a minimum combination of the above safety functions that can be used to prevent core damage. For example, one strategy to prevent core damage for a small LOCA initiator is to use HPI for short-term injection (using RWST water) and HPR for long-term recirculation injection (using sump water). Therefore, both HPI and HPR are checked in the IPE database for this small LOCA core damage prevention strategy. Additional safety functions may be available and beneficial, but they are not checked in the IPE database because core damage is prevented if both HPI and HPR are available. For example, secondary heat removal by SSMU is not checked for the above strategy even if it is available.

In some IPE submittals, HPR takes suction from LPR, and HPR fails if LPR fails. This dependency is presented in the B-DEPEND or DEPENDTAB. However, in B-STRAT or STRATEGY database file of the IPE database, LPR is not checked as one of the required safety functions for a strategy where HPR is required. The requirement of LPR in support of HPR for a CDPS is reflected in the mission success paths (MSPs) of the strategy by assigning a value of "1S" (S for support) for LPR in B-MISSUC or MISSUC database file.

The safety functions used in B-STRAT or STRATEGY database file (or fields for IPE database file STRATEGY) are related to the safety systems (or frontline systems in the IPE database system table) presented in B-MISSUC or MISSUC database file. There may be more than one safety systems that can be used to satisfy a particular safety function. For example, both main feedwater (MFW) and auxiliary feedwater (MDAFW and SDAFW) can be used for secondary side makeup (SSMU).

The MSPs in the IPE database are constructed from the "Level 1 event tree" (which describes the safety systems or safety functions required for successful core damage prevention) and the "success criteria" (which describe the number of pumps, or trains, required to satisfy a safety function) presented in the IPE submittals. The CDPS for a MSP shows the safety functions required for the success path. There can be many MSPs for a CDPS because many safety systems can perform the same safety functions.

B.4.3 Accident Initiators

Identification of the initiating events for assessment is one of the first tasks addressed in an IPE submittal. An initiating event is defined as an occurrence which causes a plant disruption resulting in a challenge to one or more of the plant systems required to maintain the plant in a safe, stable state, and initiates a reactor trip or shutdown, either automatically or by manual action.

An initiating event for a PWR plant can be classified as a transient (including those initiated by support system faults), loss of coolant accident (LOCA), steam generator tube rupture (SGTR), interfacing systems LOCA (ISLOCA or V sequence), or internal flood. Event trees are usually developed for the above initiators for core damage sequence analysis. An event tree is also developed for an ATWS event, which occurs when an automatic reactor trip does not occur following the existence of a reactor trip condition such as a transient event. The CDPSs and MSPs for the above events and the conventions used in the IPE database are discussed in the following.

B.4.4 Transient Initiators

The transient initiators considered in this section include both initiating events that pose a direct challenge to front-line system functions and those caused by the loss of a support system. The transient initiators considered in the IPE submittals (the acronym used in the IPE database is given in the parenthesis) include reactor trip (T-RX), turbine trip (T-TT), loss of ultimate heat sink (T-UHS), reactor coolant pump trip (T-RCP), loss of normal RCS makeup (T-LNMU), loss of main feedwater (T-LMFW), excessive feedwater addition (T-EXFW), steamline break (T-SLBOC or T-SLBIC), spurious valve opening (T-IORV), spurious safety injection (T-SSI), loss of a support system or other plant system/function (T-Acronym, the acronym is the one used in the IPE database to designate the particular support or frontline system). The important support systems include the loss of a DC or AC bus (T-DC or T-AC), loss of service water (T-ESW), the loss of component cooling water (T-CCW), loss of instrument air (T-IA), and loss of offsite power (T-LOOP). Station blackout (SBO) is considered in the IPE database as a special case for T-LOOP, and T-LOOP is used as the initiator for an SBO event.

In general, a single transient event tree is developed in the IPE submittal to analyze the accident sequences for transient initiators. Although individual event trees may be developed for individual transient initiators, their primary differences are the availability of the safety systems associated with the initiators. The initiators (or challenges) used in the CDPS and MSP files of the IPE database (STRATEGY and MISSUC database files) are the initiators used in the IPE event trees. If only a single transient event tree is used in the IPE submittal (sometimes named in the IPE submittal as a general transient event tree), then the initiators used in the IPE database file can be either T-RX or T-TT. The strategies and mission success paths in the IPE database are developed from this general event tree (for initiator T-RX or T-TT). The strategies and mission success paths for other transients will be the same as those for T-RX or T-TT except that certain safety functions and systems are not available for some of the transients because of their initiators (e.g., MFW may not be available to provide the SSMU function for a loss of MFW initiator).

Following a transient initiator, the first plant challenge is to terminate the nuclear chain reaction, reducing core power to decay heat level. Correspondingly, the first safety function that is asked in a Level 1 event tree is reactivity control. The failure of the reactor protection system (RPS) to shutdown the reactor will result in an ATWS event and a serious challenge to the plant's ability to maintain adequate heat removal and RCS integrity.

Reactivity control may also be required for a small or a medium LOCA event, but is not needed for a large LOCA event because the fast RCS depressurization following a large LOCA results in significant voiding in the core, causing the reactor to go subcritical. Since the reactivity control top event is included in the event tree as a means of identifying an ATWS event, which has its own event tree, the requirement for reactivity control is not included as one the safety functions for the CDPSs in the database. Accordingly, RPS is not checked as one of the safety systems required for the MSP in the database. Reactivity control is assumed in the IPE database to be successful for a transient, small LOCA, or medium LOCA event.

After a successful reactor trip, the RCS integrity is challenged early in a transient event. The rise of RCS pressure immediately after a transient initiator may cause the RCS safety relief valves to lift. A failure of the valves to reclose will result in a transient-induced LOCA (TIL). RCS integrity is also challenged if both the RCP seal injection (by the charging system) and the RCP thermal barrier cooling (by CCW) are lost. A RCP seal LOCA will develop early if the operator fails to trip the RCP, and late (about one hour), if the operator trips the RCP within a few minutes after the loss of all cooling to the seals. (It should be noted that, in some IPE submittals, seal LOCA is assumed not to occur if the RCPs are tripped early, even with the loss of all cooling.) The accident progression following both of the above TILs is similar to that following a (small) LOCA event and is usually addressed by the LOCA event tree. In the IPE database, the requirement of successful opening and closing of the pressurizer PORVs and PSRVs and the elimination of a seal LOCA (i.e., RCS-INT) is not included as one of the safety functions required for the CDPSs of a transient event. Accordingly, PPORV, PSRV, and RCPS are not checked in B-MISSUC or MISSUC database file. Early RCS integrity is assumed to be maintained for a transient event. The CDPSs and MSPs for a small LOCA event apply if the RCS integrity is not maintained early in the transient.

As discussed above, the CDPSs and the MSPs included in the IPE database are derived from the event trees and the corresponding success criteria presented in the IPE submittals. Since the safety functions are the same for all transients, the CDPSs and MSPs are similar for all transient initiators (or challenges). After the reactor is successfully shutdown and the RCS integrity is maintained, the important plant response is to maintain decay heat removal. This can be achieved by secondary side cooling using either main feedwater (MFW, if available) or auxiliary feedwater (AFW). The steam produced in the SGs can be dumped either to the condenser (if available) through the turbine bypass valves (MSIVs need to be open) or to the atmosphere through the main steam line safety valves (SGS) or atmospheric dump valves (SGA). The atmospheric dump valves can be opened by the operator to release the steam at a pressure lower than the set point and thus increase the heat removal rate.

Secondary side cooling is represented in the IPE database by checking SSMU in B-STRAT or STRATEGY database file. Correspondingly, the number of steam generators (SG) required and the number of MFW or AFW pumps required for decay heat removal are specified in B-MISSUC or MISSUC database file. The requirement for steam dump may not be specified in the IPE database (or in the IPE submittals) because usually there are sufficient number of SGS valves that will open at their pressure set point for steam release. Additionally, steam can be dumped through the turbine bypass valves (TB) or the atmospheric dump valves (SGA). However, a secondary depressurization (SDEP) is checked in B-STRAT or STRATEGY database file if the SGA (or TB) valves need to be opened by the operator to depressurize the secondary side such that low pressure pumps (e.g., condensate pumps) can be used for feedwater supply. Accordingly, the number of SGA (or TB) valves that are required to open for an adequate secondary depressurization is specified in B-MISSUC or MISSUC database file. Since the opening of the SGA (or TB) valves requires operator actions, an "H" is affixed to the number of valves required (e.g., 1H).

It should be noted that the minimum number of SGS (or SGA valves which also have pressure set point) valves required to open for adequate steam release is given in some of the IPE submittals. This number is assigned to SGS in B-MISSUC or MISSUC database file. Sometimes, a value of "1" is assigned to SGS to show the requirement of the SGS valves. However, no value is usually, assigned to SGS because of the large number of SGS valves and the other options for steam dump as discussed above.

RCS heatup will occur if secondary cooling is not available. The operator is instructed to initiate primary feed-and-bleed cooling before the plant reaches prescribed conditions. Usually, a feed-and-bleed cooling requires the operator to open the PPORVs to reduce the RCS pressure (RCS-DEP in the CDPS database table). When the RCS pressure is sufficiently low, safety injection pumps (HPI, or CHPI if they use separate pumps) can be used to provide cool water to the RCS. The operator needs to establish recirculation injection (HPR, or CHPR if the charging system can also be operated in recirculation mode) before the RWST water is depleted. Usually, the HPR (and CHPR if available) pumps cannot take suction directly from the containment sump and must take suction from the LP at the discharge of the LP heat exchangers. Although LP is required for HPR function, LP is not checked in B-STRAT or STRATEGY database file; it is checked in B-MISSUC or MISSUC database file as a support system (e.g., 1S). Recirculation injection may not be required if secondary side cooling (SSMU) is recovered before RWST water is exhausted.

Although decay heat is removed by HPR through LP (or RHR) heat exchangers for most plants, it may also be removed from the containment by the containment spray system (which takes suction from the containment sump, cools the sump water through heat exchangers, and returns the water to the sump through containment spray). The reader should also note that containment spray heat removal is the only means of decay heat removal for some plants; for those plants, CPSR is required, in addition to HPR, for successful feed-and-bleed cooling.

Since steam is discharged to the containment in feed-and-bleed cooling, some IPE submittals assume that containment heat removal is required for the longterm. Consistent with this assumption, CPSR (and/or CPSI) is checked in B-STRAT or STRATEGY database file. Correspondingly, containment spray (CSI or CSR) and containment fan coolers (FCs) are assigned in the B-MISSUC or MISSUC database file.

The PPORVs are usually used for RCS depressurization for feed-and-bleed cooling. Since this requires operator action, an "H" is appended to the number of PPORVs required for a successful depressurization in B-MISSUC or MISSUC database file (e.g., 2H for PPORV). However, some IPE submittals assume that PPORV depressurization is not necessary for successful feed-and-bleed cooling in because the shutoff head of high-pressure injection is above PSRV setpoint (usually for plants using the same pumps for CHPI and HPI). The number of PSRVs (or PPORVs) required for successful feed-and-bleed cooling is therefore assigned to PSRV (without the "H" appended) of B-MISSUC or MISSUC database file of the IPE database.

B.4.5 LOCA Initiators

The LOCA initiators considered in the IPE submittals and the IPE database includes large LOCA (A), medium LOCA (S1), small LOCA (S2), and small-small LOCA (S3). Excessive LOCA which is beyond the ECCS capability (including RCS rupture), included with large LOCAs (A) in the IPE database. In addition, since an excessive LOCA is beyond the ECCS capability, core damage is assured, and no CDPS is available.

The break sizes of the various LOCA events may be defined differently (in terms of system requirement) in different IPE submittals. For example, a LOCA with a sufficiently large break area to permit decay heat removal through the break is defined as a medium LOCA in most IPE submittals, but it is defined as a small LOCA in other IPE submittals that also consider very small LOCAs, which are similar to the small LOCAs in most IPE submittals. The LOCA definitions used in the following discussion are consistent with those defined in most IPE submittals.

Large LOCA (A)

A large break LOCA is defined as a break equivalent to the size that resulted from a double-end guillotine break of RCS loop piping (in excess of 6 to 12 inches). The large-break LOCA results in a rapid depressurization of the primary system and a significant voiding within the core such that the reactor goes sub-critical. Therefore, the reactor trip function is not required, and the RCS will sufficiently depressurize to allow injection of the accumulators and the low-pressure injection system.

In general, both passive accumulator injection and low pressure injection are required to prevent core damage. The IPE database reflects this requirement by checking LPI in the STRATEGY or B-STRAT database file, and assigning the numbers of LPI pumps and accumulators required for successful core damage prevention in the MISSUC or B-MISSUC database file.

It should be noted that some IPE submittals assume that accumulators are not to be required to prevent core damage. Specifically, the plants that do not require accumulator injection for a large LOCA can be identified by specific query conditions, including an “A” for the INITIATOR field and an “ ” (i.e., empty space) for the ACC_M field of MISSUC or B-MISSUC database file.

Transition from injection to cold-leg recirculation is required before the RWST water is depleted. In recirculation cooling, the safety injection HPI pumps (which are used during the RWST-to-sump suction transition in some IPE submittals) take suction from the discharge of the low-pressure RHR pumps, which are realigned to take suction from the reactor sump. In addition to this piggyback arrangement, low-pressure systems can also be used directly for recirculation cooling.

Hot-leg recirculation may be required to prevent boron precipitation and subsequent core damage if recirculation cooling needs to be maintained for an extended period. This may be required if shutdown cooling system entrance conditions are not met within a certain time. The IPE database reflects these requirements by checking HPR and/or LP in B-STRAT or STRATEGY database file, and assigning the number of HPI and/or HPR pumps required for successful recirculation injection in MISSUC or B-MISSUC database file. If switching from the injection mode to the recirculation mode requires operator action (as is usually the case), an "H" is appended to the number of pumps required (e.g., 1H for LP). In cases where HPR is required and depends on LP to provide the suction source, an "S" is appended to the number of LP pumps in MISSUC or B-MISSUC database file to indicate that they are required to support the HPR function. The "S" is not needed if LP is used to directly provide RCS injection.

In some IPE submittals, containment heat removal (CHR) is required to prevent core damage. These IPE submittals assume that failure of containment cooling will result in an early loss of containment integrity, flashing of the sump inventory, and (consequently) failure of RCS recirculation cooling. In other IPE submittals, plant operators are required to terminate the containment sprays to conserve RWST inventory and extend the time during which recirculation is needed. The IPE database reflects the requirement of containment spray (or fan coolers) for CHR by checking CPSI and/or CPSR in B-STRAT or STRATEGY database file, and assigning the number of spray pumps and fan coolers required for successful CHR in MISSUC or B-MISSUC database file. An "H" is appended to the assigned number if operator actions are required and an "S" is appended if the system is required to support the performance of another system.

For some plants, recirculation injection (which takes suction from the sump) does not have heat removal capability, instead, containment sprays perform the decay heat removal function by removing heat from the sump water for these plants. Since containment sprays perform a supporting function, CPSR and/or CPSI is not checked in B-STRAT or STRATEGY database file. However, the number of CSR (or CSI and FC) pumps (with the heat exchangers) required for sufficient heat removal is assigned (with an appended "S") in B-MISSUC or MISSUC database file.

Medium LOCAs (S1)

The break size for a medium LOCA is assumed to be sufficiently large to allow decay heat removal from the break without requiring secondary cooling or the opening of the PPORVs if sufficient coolant makeup is available. A reactor trip is usually required in a medium LOCA, but accumulator injection is not as critical as in large LOCA events if high-pressure injection is available. Secondary cooling (SSMU) and RCS depressurization (using the PPORVs) also is generally not required if high pressure injection (HPI) is available. However, if HPI is not available, then either secondary heat removal (SSMU) or RCS depressurization (RCS-DEP), or both, is required to allow adequate coolant makeup using low pressure injection systems before the core is uncovered. Accumulator injection also becomes more critical in the latter case. The IPE database considers accumulator injection to be part of the LPI safety function (i.e., checking LPI in B-STRAT or STRATEGY database file).

Although most IPE submittals assume that HPI required, other IPE submittals assumed that the RCS pressure immediately after the blowdown is below the LPI pump shutoff head and the break area is sufficiently large that LPI is required early to prevent core damage. Some IPE submittals also assume (according to the success criteria) that both HPI and LPI are required to cover the full range of medium LOCAs.

The IPE database reflects the early coolant injection requirement for a medium LOCA by checking the required safety functions in B-STRAT or STRATEGY database file, which include the required injection source (HPI, LPI, or both), the RCS-DEP requirement, the SSMU requirement, and the SDEP requirement for more aggressive secondary cooling and more rapid primary depressurization using SSMU. The safety systems that can be used to achieve these safety functions are presented in B-MISSUC or MISSUC database file as is the number of pumps (or trains) required to accomplish the safety functions.

For secondary cooling, the B-MISSUC or MISSUC database file also identifies system requirements regarding the number of steam generators and the number of AFW (either MDAFW or SDAFW) pumps for SSMU, and the number of SGA valves that need to be opened for a successful SDEP. (Turbine bypass or TB valves can also be used for steam dump. However, this requires opening the MSIV and, thus, is less likely to succeed than SGA, so it is not considered in most IPE submittals). Since operator action is required for aggressive secondary cooling using SGA, an "H" is appended to the number of SGA valves required for SDEP. By contrast, operator action is not required for normal secondary cooling, in which the SG safety (SGS) valves can be opened at their pressure setpoint for steam release. In this case, the number of SGS valves required is assigned in B-MISSUC or MISSUC database file (without the "H" appended). SDEP is not checked if a manual depressurization of the secondary side is not required.

Recirculation mode operation is required following the depletion of the RWST water. In this situation, HPR or LP may be required for recirculation cooling, depending on the treatment used in the given IPE submittal. In general, high-pressure recirculation is required if high-pressure injection is required. Low-pressure recirculation can be used if the RCS is sufficiently depressurized before the RWST water is exhausted. (This is more likely to occur if secondary cooling is available.) Containment cooling is required to prevent the failure of recirculation cooling in some IPE submittals similar to that considered in these IPE submittals for large LOCA.

According to the success criteria developed in the IPE submittal, HPR and/or LP may be checked in B-STRAT or STRATEGY database file. In addition, an "H" is appended to the number of pumps required in B-MISSUC or MISSUC database file if operator action is required to switch from injection to recirculation mode. By contrast, an "S" is appended to the number of LP pumps if they are required to provide suction to the HPR pumps. CPSI and/or CPSR is checked in B-STRAT or STRATEGY database file if containment sprays and/or containment heat removal are required to prevent core damage. The number of pumps (or trains) for the systems that can be used to accomplish these safety functions is specified in the appropriate fields (e.g., CSI, CSR, and FC) in B-MISSUC or MISSUC database file.

Small LOCA (S2)

By definition, the primary coolant leakage rate for a small LOCA exceeds the makeup capability of the normal charging system, but on the other hand, the energy flow rate through the break is too small to remove decay heat. The functions required to prevent core damage in a small LOCA include reactivity control, RCS inventory control, and decay heat removal. Reactivity control failure causes the event to be transferred to an ATWS event, and reactivity control is not considered as a required safety function here.

To prevent core damage, a small LOCA requires both HPI and SSMU. If HPI is not available, plant operators may use aggressive secondary cooling (e.g., secondary depressurization, or SDEP, using SGA valves) to depressurize the RCS sufficiently to allow the use of LPI for coolant makeup. (Depending on the IPE submittals and the calculations, primary depressurization using PORVs or pressurizer sprays and coolant makeup from accumulator injection may also be needed.) On the other hand, if secondary side heat removal is not available but safety injection is functioning, plant operators can use the PPORVs (if controllable) as a bleed path to establish feed-and-bleed cooling.

RHR shutdown cooling (SDC) can be used if shutdown cooling conditions can be reached before the RWST is depleted. Otherwise, recirculation cooling needs to be established before the RWST inventory is depleted. Depending on the analysis results used in the IPE submittals, the RCS pressure at the time of RWST depletion can be either high or low and, as a consequence, either high-pressure or low-pressure pumps can be used for recirculation cooling.

Containment cooling is generally not considered essential for a small LOCA because early containment failure and flushing of sump inventory is not a concern for a small LOCA event. In addition, some IPE submittals do not consider the effect of containment spray on the success for recirculation switchover.

The SSMU and HPI safety functions are checked in B-STRAT or STRATEGY database file of the IPE database if both SSMU and HPI are available. SDEP is checked if an aggressive secondary depressurization is required. In cases where SSMU is not available, RCS-DEP is checked for bleeding and HPI is checked for feeding. LPI is checked if the RCS can be sufficiently depressurized to allow low-pressure injection before core uncovery. HPR and/or LP is checked for recirculation mode operation and CPSI and/or CPSR is checked if containment spray or containment heat removal is required. The systems required to accomplish these safety functions are presented in B-MISSUC or MISSUC database file and the conventions used to assign the values to the various fields of B-MISSUC or MISSUC database file are similar to those discussed above for medium LOCAs.

In addition, some IPE submittals consider RWST makeup as a success path. This is usually reflected with a note in the IPE database, but it can also be represented by checking HPR or LP (depending on whether HPR or LP is used) in B-STRAT or STRATEGY database file, but with no corresponding entries in B-MISSUC or MISSUC database file for HPR or LP.

B.4.6 Steam Generator Tube Rupture Initiator

The rupture of a SG tube results in leakage of the RCS inventory to the secondary side, bypassing the containment. The leakage rate is similar to that of a small LOCA and, as a result, both coolant makeup and decay heat removal are required to prevent core damage. Coolant makeup can be provided initially by HPI (or CHPI, which may not have sufficient flow capacity and may need SSMU) and later (after the RWST water is exhausted) by recirculation. Decay heat removal can also be provided by the secondary side heat removal (SSHR), by the primary feed-and-bleed cooling using recirculation injection, or by the RHR system in the shutdown cooling (SDC) mode.

Isolation of Faulted SG

Since the primary coolant lost through the ruptured SG tube will not be available for recirculation, the operator must reestablish adequate RCS integrity as soon as possible to minimize the loss of the primary coolant. This can be achieved by isolating the affected steam generator (SINT) and reducing the RCS pressure to that below the main steamline safety valve (SGS) setpoint. Successful early isolation requires the operator to identify and isolate the ruptured SG by closing the MSIV and some other valves (e.g., the main feed isolation valve, the AFW blowdown and sample isolation valves, and the atmospheric dump valves).

In the database, SG isolation is represented by checking SINT in B-STRAT or STRATEGY database file and assigning a value of "1I" for MSIV in B-MISSUC or MISSUC database file.

Aggressive Secondary Cooling

With a successful secondary isolation (SINT), the ruptured SG becomes an extension of the primary system. Primary coolant leakage to the secondary side stops if the RCS pressure is reduced to below the setpoint of the SGS valves. Steam generator (SG) cooling is the preferred means to achieve this objective. The operator can open the SG atmospheric dump valves (SGA) on the intact SGs and initiate an aggressive RCS cooldown and depressurization (through a secondary depressurization, SDEP). As an alternative, secondary cooling can also be performed using the condenser dump (instead of the SGAs), which may require the operator to open the MSIVs, but some IPE submittal do not consider this alternative. The PPORVs (or sprays) can be used with secondary cooling to expedite RCS depressurization, or used alone if secondary cooling fails.

In the IPE database, aggressive secondary cooling is represented by checking SDEP and SSMU in B-STRAT or STRATEGY database file, and assigning the number of SGA valves (with an appended "H") required for SDEP and the number of SGs and AFW pumps required for SSMU.

Isolation Failure

Isolation of the faulted SG (SINT) may be lost if RCS cooling and depressurization is not successful. The safety valves in the faulted SG will open, and may stick open, if the pressure in the faulted SG reaches the safety valve setpoint. A stuck-open SG valve (SGS) will cause uncontrolled secondary depressurization and leakage of the primary coolant to the atmosphere. Isolation (SINT) failure also occurs if the ruptured SG is used for RCS cooling and depressurization, as considered in some IPE submittals.

If the faulted SG is not isolated, the SG pressure will eventually be reduced to that of the atmosphere and, accordingly, the RCS pressure also needs to be reduced to that of the atmosphere to stop coolant loss. If coolant loss can be terminated before all coolant makeup is lost, decay heat can be removed either by shutdown cooling (considered LPR in the IPE database) or by low-pressure feed-and-bleed cooling (LPR and RCS-DEP in the database). Since this stable plant condition may not be attained at before the RWST is emptied, means to refill the RWST may be required to prevent core damage.

The safety functions required to prevent core damage include early coolant injection (HPI), primary and a secondary depressurization (RCS-DEP and SDEP with SSMU), and RWST makeup. These safety functions are checked as appropriate in B-STRAT or STRATEGY database file. The safety systems that can be used to accomplish these safety functions and the number of pumps or valves required are identified in B-MISSUC or MISSUC database file. Since the IPE database does not consider RWST makeup as one of the available safety systems, it is represented by checking HPR in B-STRAT or STRATEGY database file and no entries in B-MISSUC or MISSUC database file.

Long-term Cooling

Whether the faulted SG is isolated or not, the RCS will eventually be sufficiently depressurized (by either secondary side cooling or RCS depressurization) to allow use of the low-pressure RHR system (LPR in the database) for long-term decay heat removal. Long-term decay heat removal can also be provided by the secondary side heat removal (SSMU). This may require a long-term AFW suction source because the CST may be exhausted. These long term cooling methods are represented in the IPE database by checking LPR and SSMU in B-STRAT or STRATEGY database file and the corresponding systems in B-MISSUC or MISSUC database file.

Some IPE submittals also discuss containment spray in the SGTR event tree. In general, this only affects the time available and, thus, the failure probability for the operator to switch from injection to recirculation mode.

B.4.7 ATWS Events

An ATWS occurs when the automatic reactor trip does not occur following the existence of a reactor trip condition (such as a transient event). Although the initiator for an ATWS event can be any transient, T-ATWS is used as the initiator (or challenge) in B-STRAT or STRATEGY database file. The major distinction between the different initiating events is the expected pressure increase. Usually, the transient event that causes the most severe pressure transient is used in the IPE submittals to define the success criteria for an ATWS event. Another factor that is considered in the analysis of an ATWS event for some IPE submittals is the power level at the time of the event. A power level of less than 40% is assumed not to cause a significant pressure challenge. As a result, the challenge and the strategies to prevent core damage are different for different initial reactor power levels.

Following the ATWS event, plant operators may be able to terminate the ATWS by initiating a manual scram. This action can be taken from the main control room and, if successful, the accident sequence would progress similar to a normal transient event. If the manual trip fails, the pressure in the RCS will rapidly increase and challenge the RCS relief valves. RCS overpressurization failure occurs if the pressure relief capability is not sufficient. The RCS integrity may also be lost if the relief valves fail to reclose. To indicate that the relief valve must open to preserve reactor integrity, RCS-INT is checked in B-STRAT or STRATEGY database file. In addition, the IPE database indicated the minimum number of valves required to open for successful pressure relief by assigning the required numbers to the PPORV and/or PSRV fields of the MSP table.

The peak RCS pressure that occurs in an ATWS event depends on many factors. One of these factors is the moderator temperature coefficient (MTC), which may not be sufficiently negative during the early part of the fuel cycle to prevent the RCS pressure from rising above the RCS failure pressure (at about 3200 psi) without additional mitigation. For cases involving an adverse MTC, the RCS pressure is expected to exceed the failure pressure and core damage is assumed to occur. No strategy is available to control the pressure increase resulting from an adverse MTC.

RCS peak pressure also depends on the secondary side heat removal capability. A turbine trip is required if main feed water is not available. A turbine trip failure causes the steam generator (SG) level to drop quickly and, consequently, leads to a significant reduction of RCS to secondary heat flow. The turbine trip requirement can be reflected in the IPE database by assigning an appropriate value for the TT field of B-MISSUC or MISSUC database file. (This requirement is not currently represented in the IPE database in this manner; usually, it is simply shown as a note.) Correspondingly, the SINT (for lack of a better designator) is checked in B-STRAT or STRATEGY database file of the database.

After the RCS survives the initial pressure challenge, the operator continues to try to regain reactivity control. This can be achieved by manual rod insertion. The success of this operation reduces the AFW and RCS pressure relief needed to mitigate the ATWS.

For the plant to reach a stable state, reactor shutdown needs to be achieved in the long term. Emergency boration can be used to achieve reactivity control if all of the above efforts for control rod insertion fail. Reactivity control is represented in the IPE database by checking RCS-BOR in B-STRAT or STRATEGY database file. The systems that can be used for reactivity control include RPS and BI, as indicated in B-MISSUC or MISSUC database file. A value of "1H" is assigned to the RPS field of B-MISSUC or MISSUC database file if a manual trip is used, and a value of "1H" (or "2H" if two BI pumps are needed) is assigned to the BI field of B-MISSUC or MISSUC database file if emergency boration is used. (The "H" is not appended if operator action is not required.)

B.5 IPE Database Convention and Query Conditions for Transient Events

The plant functions that are challenged after the occurrences of a transient event include reactivity control, RCS integrity, and decay heat removal. Failure to control the reactor power using the reactor protection system (RPS) will result in an ATWS event, and the ensuing accident progression is usually addressed by an ATWS event tree. In the IPE database, failure of reactivity control is represented by including "ATWS" in the ATTRIBUTES, and by checking the RPS with an asterisk (*) or a "C."

The RCS integrity is challenged immediately after the initiating event. The RCS pressure rise immediately after the transient initiator may cause the RCS safety relief valves to lift. In addition to the pressure challenge, a subsequent failure of the valve to reclose will result in a transient-induced LOCA (TIL). RCS integrity is also challenged if both RCP seal injection (by charging) and RCP thermal barrier cooling (by CCW) are lost. An RCP seal LOCA will develop early if the operator fails to trip the RCP, and late (about one hour) if the operator trips the RCP within a few minutes after the loss of all cooling to the seals. The accident progression following both of the above TILs is similar to that following a small LOCA event and is usually addressed by the LOCA event tree. In the database, a transient-induced LOCA is characterized by including "RCS-INT" in the FAILED FUNCTIONS field, "TIL" in the ATTRIBUTES field, and by entering with a "C" or a "*" for PPORV or PSRV if there is a stuck-open valve or RCPS if there is a seal LOCA.

If the reactor is successfully shutdown and RCS integrity is maintained, the challenge to reactor safety is then the removal of decay heat. Secondary side cooling, using either the main feed water (MFW, if not isolated) or the auxiliary feedwater (AFW), is the normal and preferred means to remove decay heat. The water source for the MFW is the condenser, and for the AFW the condensate storage tank (CST). Alternative water sources (e.g., SW cross-tie or fire water) may be required if the primary water sources are not adequate for the mission time. The steam generated in the steam generators (SGs) can be rejected to the condenser through the condenser dump valves (TB, if MSIVs are not closed), or to the atmosphere through the atmospheric dump valves (SGA) or the main steamline safety valves (SGS). Although the loss of secondary cooling can be caused either by the loss of steam dumping paths or feedwater supplies, the primary reason is the loss of the feedwater systems. In the IPE database, the loss of secondary cooling is represented by including "SSMU" in the FAILED FUNCTIONS field and by entering a "C" or a

"*" for MDAFW, SDAFW, or MFW.

Coolant injection is not needed if RCS integrity is maintained and secondary side cooling is successful. If secondary cooling fails, primary feed-and-bleed cooling can be used to prevent core damage for some plants. Upon receiving indication of the loss of secondary cooling, the procedures direct plant operators to actuate safety injection and establish the required bleed path using the primary PORVs. In the database, the failure of feed-and-bleed cooling is indicated by including "RCS-DEP" in the FAILED FUNCTIONS and entering a "C" or a "*" for PPORV "bleed" failure; or by including "HPI" in the FAILED FUNCTIONS and entering a "C" or a "*" for HPI (and/or CHPI) "feed" failure.

In primary feed-and bleed cooling, the injection source must be transferred from the RWST to the reactor sump before the RWST water is depleted. In general, RCS pressure will be above the RHR shutoff head and, as a result, HPR is required. The high-pressure pumps usually take suction from the RHR (LPR) discharge (downstream of the RHR heat exchangers) and use the RHR heat exchangers for heat removal. In addition to supporting the HPR system, low-pressure RHR recirculation (LPR) can be used alone for long-term feed-and-bleed cooling if the RCS has been sufficiently depressurized. In the database, the failure of recirculation feed-and-bleed cooling is indicated by including "HPR" in the FAILED FUNCTIONS field and entering a "C" or a "*" for HPR (and/or CHPR). The failure of low-pressure recirculation feed-and-bleed cooling is indicated in the IPE database by including "LPR" in the FAILED FUNCTIONS field and entering a "C" or a "*" for LPR (and/or SDC if separately designated in the database). In general, the switchover from injection to recirculation requires operator actions; "HUM" is included in the ATTRIBUTES in this case.

The operation of containment sprays, which in injection mode also take suction from the RWST, affects the time available for the operator to make a successful transfer from injection to recirculation and is considered in the transient event tree in some IPE submittals. This is reflected in the IPE database by including "CPSI" in the FAILED FUNCTIONS and checking CSI with a "C" or a "*." Containment sprays (particular CPSR) are also considered in some of the transient event trees to provide information on containment status for Level 2 analyses. Although they do not have any effect on Level 1 core damage sequences, their failure may be presented in the IPE database as "CPSR" in the FAILED FUNCTIONS field.

Containment heat removal is required in some IPE submittals to prevent core damage. These IPE submittals assume that failure of containment cooling will result in early loss of containment integrity and flashing of the sump inventory, leading to failure of RCS recirculation cooling. The failure of containment cooling is indicated in the IPE database by including "CPSR" (or CPSI if specified) in the FAILED FUNCTIONS and checking CSR, CS1, or FC (or CSI) with a "C" or a "*."

The following conventions are used in the IPE database:

(1) Safety functions that fail because of the failure of the support systems shown in the LOST SUPPORTS field of the IPE database may not be presented in the FAILED FUNCTIONS field. The loss of the functions can be inferred from the dependency table of the database. For example, the loss of CCW causes the loss of HPI for some plants. If "CCW" is identified in LOST SUPPORTS, "HPI" may not be included in the FAILED FUNCTIONS in the accident sequence table.

(2) If secondary cooling fails, the convention is to assign "SSMU" as one of the FAILED FUNCTIONS. The loss of secondary cooling usually involves the loss of feed water. MDAFW and/or SDAFW is checked with a "C" or a "*." MFW may also be checked with a "C" or a "*."

(3) If the failure of the feed-and-bleed cooling is caused by loss of the high-pressure injection system, "HPI" is designated the FAILED FUNCTIONS and HPI (and/or CHPI) is checked with a "C" or a "*." By contrary, if the failure of the feed-and-bleed cooling is caused by depressurization failure, "RCS-DEP" is designated the FAILED FUNCTIONS and PPORV is checked with a "C" or a "*." "HUM" may also be included as one of the ATTRIBUTES because control of the primary PORVs usually requires operator action.

(4) For feed-and-bleed recirculation cooling, "HPR" is designated as one of the FAILED FUNCTIONS if the suction source is not switched from the RWST to the reactor sump before the RWST water is depleted. (This indicates the failure of a successful transfer to HPR.) HPR (and/or CHPR) is then checked with a "C" or a "*." "HUM" may also be included as one of the ATTRIBUTES because transfer from injection to recirculation usually requires operator action. By contrary, "LPR" is designated is included as one of the FAILED FUNCTIONS if long-term low pressure recirculation (or SDC) fails, and LPR (or SDC if separately designated in the database) is checked with a "C" or a "*."

(5) If a core damage sequence involves operator error (including failure to take appropriate actions according to the procedures, "HUM" is included in the ATTRIBUTES field and "*" is assigned to the HUM field. "CCF" is included in the CAUSES field if the core damage sequence involves common-cause failure.

(It should be noted that the data presented in the IPE submittals usually apply to sequences, which may include contributions from many cutsets with different failure modes. For example, the failure of HPI in a sequence may include cutsets both with and without operator error or CCF, and the failure of feed-and bleed cooling may be attributable to hardware failure or lack of operator action, although lack of operator action to open the pressurizer PORVs is the more likely failure mode. The information presented in the IPE database reflects the dominant cutsets in the sequence as presented in the IPE submittals. As a result, the information presented in the IPE database for human or common-cause failure may not be entirely accurate.)

(6) Feed-and-bleed cooling may not be available for some plants where the pressurizer safety relief valves cannot be controlled by the operator (e.g., some CE plants), and core damage occurs if secondary cooling (SSMU) is lost. For these plants, feeding (i.e., safety injection or recirculation) is required in the event of a TIL. However, secondary cooling may be required to cool and depressurize the RCS to allow adequate coolant makeup.

(7) If containment spray is considered in the PRA model as affecting the probability of core damage, "CPSI" is assigned as one of the FAILED FUNCTIONS and CPI is checked with a "C" or a "*."

B.6 IPE Database Conventions and Query Conditions for LOCAs

In general, core damage occurs in a LOCA event when core injection (including recirculation injection) is lost. For a PWR plant, there are both high- and low-pressure ECCS injection systems. The high-pressure system may include both the charging pumps, which have a shutoff head above the pressurizer valve set pressure but low flow capacity, and the high-pressure safety injection (HPSI) pumps, which have a lower shutoff head (about 1500 psi) but higher flow capacity. The low-pressure pumps have an even lower pressure head (about 400 psi) and a much higher flow capacity.

Depending on the size of the break and the RCS pressure, high-pressure or low-pressure injection is required to prevent core damage. For LOCA events where the RCS pressure remains high and high-pressure injection is not available (e.g., small or small-small LOCA with loss of HPI or with the RCS pressure above the HPSI shutoff head) RCS depressurization is required to allow the use of low-pressure system (or HPSI pumps) for core injection. This can be achieved by either RCS depressurization (RCS-DEP) using the PPORVs or sprays (feed-and-bleed cooling) or, in some IPE submittals, by the use of an aggressive secondary side cooldown (or core cooling recovery, using SSMU). It should be noted that feed-and-bleed cooling is normally performed using the HPSI pumps, and the RCS may not have sufficient depressurization capability to allow the use of the LPI. It should also be noted that RCS injection may not be required for some very small LOCAs; consequently, some IPE submittals assume that secondary side cooling (SSMU) alone can bring the reactor to a cool-down condition before significant coolant is lost (or with the normal charging, which is considered adequate).

Following a large LOCA, the RCS rapidly depressurizes, allowing the use of the low-pressure system for core coolant makeup. The rapid loss of reactor coolant requires accumulator injection (at a pressure of about 600 psi) to prevent core damage. Accumulator injection (ACC in the database) may also be required for some medium LOCA events.

Core coolant makeup needs to be switched to the recirculation mode (which takes suction from the reactor sump) after the initial injection mode (which takes suction from the RWST). Recirculation is required because the RWST water supply is being depleted and the RHR heat exchangers (which are part of the recirculation mode) are required to remove the decay heat from the reactor coolant system. In the recirculation mode, the low-pressure system pumps (LPR) take suction from the reactor sump and transport the coolant to the reactor through the RHR heat exchangers, where the decay heat is transferred to the ultimate heat sink. The high-pressure injection pumps (for the HPR) generally cannot take suction directly from the reactor sump, and must take suction from the low-pressure pump discharge (normally at the discharge of the heat exchangers). Switching from injection mode to recirculation mode usually requires operator action (HUM in the database).

In the recirculation mode, the coolant is initially injected to the cold leg of the RCS. Some IPE submittals assume that long-term operation of cold leg injection will result in boron precipitation and consequential flow blockage in the reactor core, thereby leading to core damage. The IPE database treats this scenario as a loss of recirculation injection (e.g., LPR).

A significant amount of steam may be generated in the core and released to the containment atmosphere even with the operation of the RHR heat exchangers (which remove heat from the sump water). As a result, some IPE submittals assume the need for containment heat removal by containment sprays or containment fan coolers (CPSI or CPSR). In addition to including CPSI or CPSR in the FAILED FUNCTIONS field, CSI, CSR, or FC will be checked in the IPE database for the following sequences:

(1) <u>Large LOCAs (A)</u>: A large-break LOCA is defined as a break equivalent to the size that resulted from a double-end guillotine break of RCS loop piping (in excess of 6 to 12 inches). The large-break LOCA results in a rapid depressurization of the primary system and significant voiding within the core such that the reactor goes sub-critical. The reactor trip function is therefore not required, and the RCS will sufficiently depressurize to allow the injection of the accumulators and the low-pressure injection system.

In general, both passive accumulator injection and low pressure injection are required to prevent core damage. Transition from injection to cold-leg recirculation is required before the RWST water is depleted. In recirculation cooling, the safety injection pump (which in some IPE submittals is used during the RWST to sump suction transition) takes suction from the discharge of the low-pressure RHR pumps, which are realigned to take suction from the reactor sump. In addition to this piggyback arrangement, low pressure systems can also be used alone for recirculation cooling.

Hot-leg recirculation may be required to prevent boron precipitation and subsequent core damage if recirculation cooling needs to be maintained for an extended period. This may be required if the shutdown cooling system entrance condition is not met within a certain time.

In some IPE submittals, containment heat removal is required to prevent core damage. These IPE submittals assume that failure of containment cooling will result in an early loss of containment integrity, flashing of the sump inventory, and (consequently) failure of

RCS recirculation cooling. In other IPE submittals, plant operators are required to terminate the containment sprays to conserve RWST inventory and extend the time when recirculation is needed.

In the IPE database, the INITIATING EVENT for a large LOCA is "A." The failure of the initial injection phase for a large LOCA event is indicated by including "LPI" in the FAILED FUNCTIONS, and checking LPI (with a "C" or a "*") if the low-pressure injection system fails or ACC if there is insufficient accumulator injection.

For recirculation failure (including failure to switch to hot-leg recirculation) "LPR" is included as one of the FAILED FUNCTIONS and LPR is checked with a "C" or a "*." Operator action is generally required for the switchover from injection to recirculation cooling mode (for realignment of suction source and/or heat exchanger cooling), so "HUM" is included as one of the ATTRIBUTES and HUM is checked with a "*" if operator action is required.

For IPE submittals that require containment cooling, the IPE database indicates failure of containment cooling by including "CPSR" (or CPSI if specified) in the FAILED FUNCTIONS and checking CSR, CS1, or FC (or CSI) with a "C" or a "*."

For IPE submittals that consider the effect of containment sprays on the success of recirculation cooling, the failure of timely termination of the containment sprays is reflected in the IPE database by including "CPSI" in the FAILED FUNCTIONS and checking CSI with a "C" or a "*."

(2) Medium LOCAs (S1): Unlike a large LOCA, reactor trip is required, but accumulator injection is not essential (although it is required in some IPE submittals), in a medium LOCA. The RCS pressure immediately after the blowdown in a medium LOCA event can be either above or below the RHR pump shutoff head, depending on the treatment in the IPE submittals. Consequently, either high pressure or low-pressure injection systems are required for coolant injection to prevent core damage. However, in all IPE submittals, the break size is sufficiently large to allow decay heat removal from the break without secondary cooling or the opening of the PPORVs (if sufficient RSC coolant makeup is provided).

Most IPE submittals assume that HPI is required immediately after the initiating event, but secondary cooling (SSMU) and RCS depressurization (using the PPORVs) is generally not required if HPI is available. However, if HPI is not available, either SSMU or RCS depressurization (RCS-DEP), or both, is required to allow adequate coolant makeup using low-pressure injection systems before the core is uncovered. Accumulator injection also becomes more critical in the latter case.

As with injection, the requirement for either HPR or LPR for recirculation cooling also depends on the treatment used in the IPE submittals. In general, high-pressure recirculation is required if high-pressure injection is required. Low-pressure recirculation can be used if the RCS is sufficiently depressurized before the RWST water is exhausted. (This is more likely to occur if secondary cooling is available.) In addition, some IPE submittals require containment cooling to prevent the failure of recirculation cooling in some IPE submittals, similar to the requirement considered for large LOCA in these IPE submittals.

In the IPE database, the INITIATING EVENT for a medium LOCA is "S1." The failure of the initial injection phase for a medium LOCA event is indicated by including either "LPI" or "HPI" (depending on the treatment of the IPE) in the FAILED FUNCTIONS and, correspondingly, checking either LPI or HPI with a "C" or a "*."

For recirculation failure (including failure to switch to hot-leg recirculation) either "LPR" or "HPR" is included as one of the FAILED FUNCTIONS and, correspondingly, either LPR or HPR is checked with a "C" or a "*." Operator action is generally required for the switchover from injection to recirculation cooling mode (for realignment of the suction source and/or heat exchanger cooling), so "HUM" is included as one of the ATTRIBUTES and HUM is checked with a "*" if operator action is required.

For IPE submittals that require containment cooling, the IPE database indicates a failure of containment cooling by including "CPSR" (or "CPSI" if specified) in the FAILED FUNCTIONS and checking CSR, CS1, or FC (or CSI) with a "C" or a "*."

For IPE submittals that consider the effect of containment sprays on the success of recirculation cooling, the IPE database reflects the failure of timely termination of the containment sprays by including "CPSI" in the FAILED FUNCTIONS and checking CSI with a "C" or a "*."

(3) Small LOCAs (S2): By definition, the primary coolant leakage rate for a small LOCA exceeds the makeup capability of the normal charging system, but the energy flow rate through the break is too small to remove decay heat. Consequently, the functions required to prevent core damage in a small LOCA include reactivity control, RCS inventory control, and decay heat removal. The failure of reactivity control causes the event to become an ATWS event, which is not discussed here.

To prevent core damage, a small LOCA requires both high-pressure safety injection (HPI) and secondary heat removal (SSMU). If HPI is not available, the plant operators may use aggressive secondary cooling to sufficiently depressurize the RCS (e.g., SDEP using SGA) in order to allow the use of low-pressure injection (LPI) for coolant makeup. (Depending on the IPE submittals and the associated calculations, primary depressurization using PORVs or pressurizer sprays may also be needed along with coolant makeup from accumulator flow). If secondary side heat removal is not available, but safety injection is functioning, however, the operator can use the pressurizer PORVs (if controllable) as a bleed path to establish feed-and-bleed cooling.

RHR shutdown cooling (SDC) can be used if the shutdown cooling condition can be reached before the RWST inventory is depleted. Otherwise, recirculation cooling needs to be established before the RWST inventory is depleted. Depending on the IPE submittals and the associated analysis results, the RCS pressure at the time of RWST depletion can be either high or low and, consequently, either high-pressure or low-pressure pumps can be used for recirculation cooling.

Containment cooling is generally not considered for a small LOCA because early containment failure and flushing of the sump inventory is not a concern. However, some IPE submittals do consider the effect of containment spray on the success of recirculation switchover.

In the IPE database, the INITIATING EVENT for a small LOCA is "S2," and failure of secondary cooling is indicated by including "SSMU" in the FAILED FUNCTIONS and checking MDAFW, SDMFW, or MFW with a "C" or a "*." Failure of the initial injection phase for a small LOCA event is indicated by including "HPI" in the FAILED FUNCTIONS and checking HPI with a "C" or a "*."

Failure to aggressively depressurize the RCS (such that the low-pressure injection system can be used for coolant makeup) is indicated in the IPE database by including "SDEP" (and/or RCS-DEP depending on the IPE requirements) in the FAILED FUNCTIONS and checking SGA (and/or PPORV if RCS-DEP is required) with a "C" or a "*." If an aggressive depressurization is successful but the low-pressure system fails, the IPE database included in the FAILED FUNCTIONS by checking "LPI" with a "C" or a "*." (It should be noted that HPI would have already failed.)

For recirculation failure (including failure to switch to hot-leg recirculation if needed), either "LPR" or "HPR" (depending on the IPE) is included as one of the FAILED FUNCTIONS, and either LPR or HPR is checked with a "C" or a "*." In addition, operator action is generally required for the switchover from the injection to the recirculation cooling mode (for realignment of suction source and/or heat exchanger cooling), so "HUM" is included as one of the ATTRIBUTES and HUM is checked with a "*" if operator action is required.

For IPE submittals that consider the effect of containment sprays on the success of recirculation cooling, the failure of timely termination of the containment sprays is reflected in the IPE database by including "CPSI" in the FAILED FUNCTIONS and checking CSI with a "C" or a "*."

(4) Small-small LOCAs (S3): The small-small LOCA is usually defined as a LOCA with a break size sufficiently small such that safety injection may not be needed to prevent core damage. With the availability of secondary cooling, the operator can reduce the RCS leakage rate (by depressurizing the RCS using SDEP) to a level such that core coolant can be maintained by normal charging.

If the accident initiator is a LOCA (i.e., A, S1, S2, S3, T-SORV, or T-IORV for the INITIATOR field), "RCS-INT" is not entered into the FAILED FUNCTIONS field of the IPE database. However, if the LOCA can be isolated, or if the small LOCA condition is aggravated by a concurrent seal LOCA or a stuck-open SRV (SORV), the corresponding seal LOCA and SORV conditions described in the IPE database convention and query conditions for TIL applies, as illustrated by the following examples:

(1) Large LOCA: The accident INITIATOR for a large LOCA is "A." The INITIATOR for RPV rupture (or excessive LOCA) is also "A." To distinguish this type of accident event from a normal large LOCA event, "RCS-INT" is assigned as one of the FAILED FUNCTIONS.

IPE database conventions: INITIATOR is "A."
FAILED FUNCTIONS include "RCS-INT" if it involves RPV rupture or excessive LOCA.

Query conditions:

(a) For large LOCA (excluding RPV rupture and excessive LOCA), "A" is the INITIATOR, and "RCS-INT" is not included in the FAILED FUNCTION field.

(b) For large LOCA with unacceptable accumulator failure, "A" is the INITIATOR, "RCS-INT" is not included in the FAILED FUNCTION field, and ACC is checked with a "C" or a "*."

(c) For RPV rupture or excessive LOCA, "A" is the INITIATOR, and "RCS-INT" is included in the FAILED FUNCTIONS.

(2) Medium (or Intermediate) LOCAs

IPE database convention: INITIATOR is "S1."

Query conditions: (a) "S1" is the INITIATOR.

(b) For medium LOCA with unacceptable accumulator failure, "S1" is the INITIATOR, ACC is checked with a "C" or a "*."

(3) Small LOCAs

IPE database convention: INITIATOR is "S2."

Query conditions: (a) "S2" is the INITIATOR.

(b) For small LOCA with is aggravated by a concurrent seal LOCA or stuck-open SRV, "S2" is the INITIATOR, and seal LOCA or SORV query conditions apply.

(4) Small-small LOCAs

IPE database convention: INITIATOR is "S3."

Query conditions: (a) "S3" is the INITIATOR.

(b) For small LOCA with is aggravated by a concurrent seal LOCA or stuck-open SRV, "S3" is the INITIATOR, and seal LOCA or SORV query conditions apply.

B.7 IPE Database Convention and Query Conditions for Transient-Induced LOCAs

The RCS integrity is challenged immediately after a transient initiated event. The RCS pressure rises immediately following the transient initiator may cause the RCS safety relief valves to lift. In addition to the pressure challenge, a subsequent failure of the valve to reclose results in a transient-induced LOCA (TIL). RCS integrity is also challenged if there is a loss of both RCP seal injection (by charging) and RCP thermal barrier cooling (by CCW). An RCP seal LOCA develops early if the operator fails to trip the RCP, and late (about one hour) if the operator trips the RCP within a few minutes after the loss of all cooling to the seals. The accident progression following both of the above TILs is similar to that in a (small) LOCA event and is usually addressed by the LOCA event tree. In the IPE database, a TIL characterized by including "RCS-INT" in the FAILED FUNCTIONS field, "TIL" in the ATTRIBUTES field, and by checking PPORV or PSRV with a "C" or a "*" if there is a stuck-open valve, or RCPS if there is a seal LOCA.

In some IPE submittals, under certain conditions, the injection of the cold RWST water into the vessel is assumed to cause a pressurized thermal shock (PTS) and an induced large LOCA. This type of TIL is indicated in the IPE database by including "RCS-INT" in the FAILED FUNCTIONS field and "TIL" in the ATTRIBUTES field.

The following examples illustrate these database conditions and query conditions:

(1) Seal LOCA

IPE database conventions: ATTRIBUTES include "TIL."
FAILED FUNCTIONS include "RCS-INT." (RCS-INT may not need to enter if FAILED FUNCTIONS have reached three, the maximum allowed in the IPE database.)
RCPS is checked with a "*" or a "C."

Query conditions: (a) RCPS is checked with a "*" or a "C."

or

(b) "TIL" for ATTRIBUTES and "*" for RCPS or "TIL" for ATTRIBUTES and "C" for RCPS.

(2) Stuck-open SRV or PORV

IPE database conventions: ATTRIBUTES include "TIL."
FAILED FUNCTIONS include "RCS-INT." (RCS-INT may not need to enter if FAILED FUNCTIONS have reached three, the maximum allowed in the IPE database.)
PSRV or PPORV is checked with a "*" or a "C."

Query conditions: Enter "TIL" for ATTRIBUTES and "*" for PSRV
or
"TIL" for ATTRIBUTES and "C" for PSRV
or
"TIL" for ATTRIBUTES and "*" for PPORV
or
"TIL" for ATTRIBUTES and "C" for PPORV.

(3) Induced large LOCA

IPE Database Convention: ATTRIBUTES include "TIL."
FAILED FUNCTIONS include "RCS-INT." (RCS-INT may not need to enter if FAILED FUNCTIONS have reached three, the maximum allowed in the IPE database.)

Query conditions: (a) "TIL" for ATTRIBUTES
" " for RCPS, PSRV, and PPORV

(b) Induced large LOCAs may also occur in an ATWS event, which has "ATWS" as one of the ATTRIBUTES.

(4) Other LOCA or RPV Integrity Failure Events

(a) LOCA events - If the accident initiator is a LOCA (i.e., A, S1, S2, or S3 for the INITIATOR field), "TIL" and "RCS-INT" are not entered. However, if the LOCA can be isolated, or if the small LOCA condition is aggravated by a concurrent seal LOCA or an SORV, the corresponding seal LOCA and SORV conditions apply as described above. (See LOCA IPE database conventions and query conditions for additional information.)

(b) RPV rupture events - The initiator for accidents resulting from RPV rupture (or excessive LOCA) is usually "A" (for large LOCA). To distinguish this type of accident event from a normal large LOCA event, "RCS-INT" is assigned as one of the failed functions in the IPE database. The QUERY conditions for this event are therefore, "A" or "S1" in the INITIATOR field and "RCS-INT" in the FAILED FUNCTION field. (See LOCA IPE database conventions and query conditions for additional information.)

(c) RCS failure resulting from inadequate RCS pressure control - This usually occurs in an ATWS event when the RCS pressure relief capability is insufficient to maintain the RCS pressure below the RCS pressure capability (about 3200 psi). This can happen if there is an adverse MTC, an insufficient number of SRV or PORV openings, a turbine trip failure, or insufficient secondary heat removal. Both RCS-INT and "TIL" are entered into the IPE database for this event. (See ATWS IPE database conventions and query conditions for additional information.)

B.8 IPE Database Conventions and Query Conditions for SGTR Events

The rupture of a SG tube results in leakage of the RCS inventory to the secondary side, bypassing the containment. The leakage rate is similar to that of a small LOCA and, as a result, coolant makeup and decay heat removal are required to prevent core damage. Coolant makeup can be provided initially by HPI (or CHPI, which may not have sufficient flow capacity and may need SSMU), and later by recirculation, after the RWST water is exhausted. Decay heat removal can be provided by the secondary side heat removal (SSHR), the primary feed-and-bleed cooling using recirculation injection, or the RHR system in the SDC mode.

Since the primary coolant lost through the ruptured SG tube is not available for recirculation, the operator must reestablish adequate RCS integrity as soon as possible to minimize the loss of primary coolant. This can be achieved by isolating the affected steam generator (SINT) and reducing the RCS pressure below the main steam line safety valve (SGS) setpoint. Successful early isolation requires the operator to identify and isolate the ruptured SG by closing the MSIV and some other valves (e.g., the main feed isolation valve, the AFW blowdown and sample isolation valves, and the atmospheric dump valves).

With successful secondary isolation (SINT), the ruptured SG becomes an extension of the primary system. Primary coolant leak to the secondary side will stop if the RCS pressure is reduced to below the setpoint of the SGS valves. Steam generator (SG) cooling is the preferred means to achieve this objective. The operator can open the SG atmospheric dump valves (SGA) on the intact SGs and initiate an aggressive RCS cooldown and depressurization (SDEP). Instead of using SGA, secondary cooling can also be performed using condenser dump, which may require the operator to open the MSIVs. (This is not considered in some IPE submittals.) The PPORVs (or sprays) can be used with secondary cooling to expedite RCS depressurization, or used alone if secondary cooling fails.

Isolation of the faulted SG (SINT) may be lost if RCS cooling and depressurization is not successful. The safety valves in the faulted SG will open, and may stick open, if the pressure in the faulted SG reaches the safety valve set point. A stuck-open SG valve (SGS) will cause an uncontrolled secondary depressurization and a leakage path of the primary coolant to the atmosphere. Isolation (SINT) failure also occurs when the ruptured SG is used for RCS cooling and depressurization, as considered in some IPE submittals.

If the faulted SG is not isolated, the SG pressure will eventually be reduced to that of the atmosphere and, accordingly, the RCS pressure must also be reduced to that of the atmosphere to terminate coolant loss. To prevent core damage, coolant injection must be maintained before the coolant loss is terminated and the RHR shutdown cooling condition (LPR in the database) is attained or a low-pressure feed-and-bleed operation (LPR and RCS-DEP in the database) can be maintained. Since this stable plant condition may not be attained before the RWST is emptied, means to refill the RWST are required to prevent core damage (assigned as HPR in the database).

In the long term, the RCS will be sufficiently depressurized (by either secondary side cooling or RCS depressurization) to allow use of the low-pressure RHR system (LPR in the IPE database). Long-term decay heat removal can also be provided by the secondary side heat removal (SSMU). This may require a long-term AFW suction source because the CST may be exhausted.

Some IPE submittals also discuss containment spray in the SGTR event tree. In general, this only affects the time available and, thus, the failure probability for the operator to switch from injection to recirculation mode.

In the IPE database, the INITIATING EVENT for an SGTR event is "T-SGTR." Since this initiator already indicates that the RCS integrity is lost, "RCS-INT" is not included as one of the FAILED FUNCTIONS, as follows:

(1) Assign "SINT" as one of the FAILED FUNCTIONS if the faulted SG is not isolated or is used for secondary cooling.

(a) Check MSIV if the operator fails to identify and isolate the faulted SG. (Although isolation failure may involve other valves, MSIV is checked for this early isolation failure.)

(b) Check SGS if there is a SG overfill resulting in a stuck-open SG safety valve. (Use SGS although the stuck-open valve may be either the MSSV or the atmospheric dump valve.)

(c) Check SGS if the faulted SG is used for secondary cooling. (If the faulted SG is used for cooling, isolation is generally not maintained and the RCS must be further cooled down to prevent coolant leakage to the secondary side.)

(d) In some cases, the IPE submittal does not distinguish between early and late isolation failures. Check SGS for these cases.

(2) Assign "SDEP" and/or "RCS-DEP" as the FAILED FUNCTIONS if there is an early RCS cooling and depressurization failure(or before SG overfills). Since SDEP is the preferred cooling method, use "SDEP"; use "RCS-DEP" only if the IPE submittals specify the use of PPORVs (or sprays).

(a) Check SGA if SDEP is assigned as one of the FAILED FUNCTIONS. (Although in some IPE submittals condenser dump may also be used for SDEP, check TB as an option for this case.)

(b) Check PPORV (or PAD1 for pressurizer sprays if used in the database) if RCS-DEP is assigned as one of the FAILED FUNCTIONS.

(3) Assign "RCS-DEP" as one of the FAILED FUNCTIONS if there is a late depressurization failure (i.e., after early depressurization failure and isolation failure). The RCS is required to be depressurized to about atmospheric pressure to prevent coolant loss. Check PPORV for this case.

(4) Assign "SSMU" as one of the FAILED FUNCTIONS and check MDAFW and SDAFW (and MFW) if all SG cooling (including the faulted SG) is lost.

(5) Assign "HPI" as one of the FAILED FUNCTIONS and check HPI (and CHPI) if high-pressure injection is lost at the beginning of the accident.

(6) Assign "LPR" as one of the FAILED FUNCTIONS and check LPR (or AR1 if AR1 is assigned for SDC) if there is a failure of the RHR SDC or a failure of low-pressure feed-and-bleed cooling after the RCS is successfully depressurized. Accumulators may also be needed before the RCS is sufficiently depressurized to allow use of the LPR. Check ACC if accumulator injection is not successful.

(7) Assign "HPR" as one of the FAILED FUNCTIONS and check HPI if the RWST is depleted and transfer to recirculation fails because of lack of sump water. If the operator fails to makeup the RWST water supply, assign "HUM" as one of the ATTRIBUTES and check HPR with a "C" and HUM with a "*."

(8) In general for SGTR, core damage will result in the release of the fission products to the environment, bypassing the containment. Assign "BYPASS" as one of the ATTRIBUTES. However, bypass release may not occur if the secondary side is successfully isolated and the primary side is depressurized to below the SG valve set point. Core damage in this case may be caused by the failure of the low-pressure ECCS (or SDC) system. The assignment of the sequence to the plant damage state (PDS) for Level 2 analysis can also be used to determine the assignment of "BYPASS" as one of the ATTRIBUTES.

The following examples illustrate the IPE database conventions and query conditions that apply to various SGTR events:

(1) <u>SGTR Events</u>

<u>IPE Database Convention</u>: INITIATOR is "T-SGTR."

<u>Query Conditions</u>: (a) "T-SGTR" for INITIATOR

(b) For SGTR events that result in a containment bypass use"T-SGTR" for INITIATOR and "BYPASS" for ATTRIBUTES

(2) <u>SGTR events with depressurization failure</u>

<u>IPE Database Conventions</u>: INITIATOR is "T-SGTR."

FAILED FUNCTIONS include "SDEP" or "RCS-DEP." SGA (for SDEP) or PPORV (for RCS-DEP) is checked with a "C" or a "*."

<u>Query Conditions</u>: (a) "T-SGTR" is for INITIATOR
"SDEP" or "RCS-DEP" is for FAILED FUNCTIONS,
or
(b) "T-SGTR" is for INITIATOR, and
"C" or "*" is for SGA or PPORV.

<u>Note</u>: "SDEP" is usually used for early depressurization, before the SG is overfilled. "RCS_DEP" is used for a late depressurization when the RCS needs to be further depressurized (when there is an isolation failure). However, in some IPE submittals,

PPORV is specified alone for early depressurization, and "RCS-DEP" is assigned in FAILED FUNCTIONS for the failure of early depressurization for these IPE submittals.

(3) SGTR events with isolation failure

IPE database conventions: INITIATOR is "T-SGTR," and FAILED FUNCTIONS include "SINT," and (a) MSIV is checked with a "C" or a "*" if the operator fails to identify and isolate the faulted SG, or (b) SGS is checked with a "C" or a "*" for other isolation failure cases, including cases where the faulted SG is used for secondary cooling.

Query conditions: (a) "T-SGTR" for INITIATOR, and
"SINT" for failed functions

(Note: For some IPE submittals, SINT is implied if RCS depressurization fails. SINT is therefore not included as one of the failed functions for these IPE submittals and, as a result, the above query conditions may not give all of the isolation sequences for these IPE submittals.)

(b) For operator failure to identify and isolate faulted SG

"T-SGTR" for INITIATOR, and
"SINT" for FAILED FUNCTIONS, and
"C" or "*" for MSIV

(Note: Some IPE submittals do not distinguish between early and late isolation failures. The above query conditions apply only for those IPE submittals where they are distinguished.)

(c) For isolation failures other than Item (b) above

"T-SGTR" for INITIATOR
"SINT" for FAILED FUNCTIONS
"C" or "*" for SGS

(4) SGTR events with failure of the low-pressure recirculation system or the shutdown cooling system

IPE database conventions: INITIATOR is "T-SGTR"
FAILED FUNCTIONS include "LPR"
"C" or "*" for LPR or AR1 (for SDC)

Query conditions: (a) "T-SGTR" for INITIATOR
"LPR" for FAILED FUNCTIONS
or
(b) "T-SGTR" for INITIATOR
"C" or "*" for LPR or AR1

Note: These are cases where depressurization is successful (either early depressurization with a successful isolation, or late depressurization to shutdown condition), but the low-pressure recirculation system or shutdown cooling system fails.

(5) SGTR events with RWST makeup failure

IPE database conventions: INITIATOR is "T-SGTR"
FAILED FUNCTIONS include "HPR"
HPR is checked with a "C" or a "*"

Query conditions: (a) "T-SGTR" for INITIATOR
"HPR" for FAILED FUNCTIONS
or
(b) "T-SGTR" for INITIATOR
"C" or "*" for HPR

Note: The above conditions apply only for those IPE submittals that consider RWST makeup as one of the success paths.

B.9 IPE Database Conventions and Query Conditions for ATWS Events

According to the treatment in the IPE submittal, the ATWS events in the IPE database include both those with ATWS as an initiator and those with other initiators (e.g., LMFW). In both cases, "ATWS" is assigned as one of the ATTRIBUTES in the database. The causes of core damage include either an inadequate RCS pressure relief or a lack of reactivity control. The former causes the loss of RCS integrity and, therefore, "RCS-INT" is assigned as one of the FAILED FUNCTIONS and "TIL" is assigned as one of the ATTRIBUTES in the IPE database. The latter involve the loss of reactivity control (by emergency boration) after the RCS survives the initial pressure load. Some IPE submittals assume the loss of reactivity control eventually leads to core damage and "RCS-BOR" is assigned as one of the FAILED FUNCTIONS for this case.

In some IPE submittals, the lack of RCS pressure control (or pressure relief) is assumed to lead to a stuck-open SRV (or PORV) and the loss of injection. In this case, PSRV or PPORV is also checked in the IPE database in addition to "RCS-INT" and "TIL."

RCS overpressurization can be caused by an adverse MTC, failure of some of the SRVs to open, failure of turbine trip, or insufficient FW flow or steam generator cooling. In addition to "RCS-INT" and "TIL," failed functions are assigned in the IPE database to distinguish these different cases (as presented below). Since ATWS will become a problem only if the power conversion system (including the MFW) is lost, MFW is not checked for an ATWS event. In addition, "SSMU" is assigned as a LOST FUNCTION only if AFW is lost.

The following IPE database conventions and query conditions apply to the various ATWS events:

(1) <u>Adverse MTC or insufficient pressure relief</u>

(This includes cases in which SRVs fail to open; PSRV and PPORV are not checked to avoid confusion with SORV cases, see Case 4 below.)

<u>IPE database conventions</u>: ATTRIBUTES include "ATWS" and "TIL"
FAILED FUNCTIONS include "RCS-INT"
RPS is checked with a "*"

<u>Query conditions</u>:

(a) "ATWS" for ATTRIBUTES
"RCS-INT" for FAILED FUNCTIONS
and
"SINT" and "SSMU" not included as FAILED FUNCTIONS PSRV and PPORV not checked
or

(b) "ATWS" and "TIL" for ATTRIBUTES
and
"SINT" and "SSMU" not included as FAILED FUNCTIONS, PSRV and PPORV not checked

(2) <u>Turbine trip failure</u>

<u>IPE database conventions</u>: ATTRIBUTES include "ATWS" and "TIL"
FAILED FUNCTIONS include "RCS-INT" and "SINT"
RPS is checked with a "*"
TT is checked with a "*" or a "C"

<u>Query conditions</u>:

(a) Enter "ATWS" for ATTRIBUTES and "SINT" for FAILED FUNCTIONS
or

(b) "ATWS" for ATTRIBUTES and "C" OR "*" for TT
or

(c) "ATWS" and "TIL" for ATTRIBUTES, and "SINT" for FAILED FUNCTIONS
or

(d) "ATWS" and "TIL" for ATTRIBUTES and "C" OR "*" for TT

or

(e) "ATWS" for ATTRIBUTES and "RCS-INT" and "SINT" for FAILED FUNCTIONS

or

(f) "ATWS" for ATTRIBUTES, "RCS-INT" for FAILED FUNCTIONS and "C" OR "*" for TT

(3) Insufficient FW flow or SG Cooling

IPE database conventions: FAILED FUNCTIONS include "RCS-INT" and "SSMU."
ATTRIBUTES include "ATWS" and "TIL."
RPS is checked with a "*."
MDAFW and SDAFW are checked with "C" or a "*."
(Other FW sources may also be checked.)

Query conditions: (a) Enter "ATWS" for ATTRIBUTES, "RCS-INT" and "SSMU" for FAILED FUNCTIONS.

or

(b) "SSMU" for FAILED FUNCTIONS, "ATWS" and "TIL" for ATTRIBUTES

or

(3) "ATWS" for ATTRIBUTES and "RCS-INT" for FAILED FUNCTIONS, and "*" or "C" for MDAFW or SDAFW

or

(4) "ATWS" and "TIL" for ATTRIBUTES, and "*" or "C" for MDAFW or SDAFW

(4) Inadequate pressure control with stuck-open SRVs

IPE database conventions: ATTRIBUTES include "ATWS" and "TIL."
FAILED FUNCTIONS include "RCS-INT."
RPS is checked with a "*."
PSRV or PPORV is checked with a "C" or a "*."

Query conditions: (a) Enter "ATWS" for ATTRIBUTES and "RCS-INT" for FAILED FUNCTIONS.

and

PSRV or PPORV is checked with a "C" or a "*"

or

(b) "ATWS" and "TIL" for ATTRIBUTES

and

PSRV or PPORV checked with a "C" or a "*"

(5) Failure of reactivity control (or failure of emergency boration) without initial RCS overpressure

IPE database conventions: ATTRIBUTES include "ATWS."
FAILED FUNCTIONS include "RCS-BOR"
RPS is checked with a "*"
BI is checked with a "C" or a "*."

Query conditions: (a) Enter "ATWS" for ATTRIBUTES and "RCS-BOR" for FAILED FUNCTIONS

or

(b) "ATWS" for ATTRIBUTES and "*" or "C" for BI

(6) All ATWS events

Query conditions: Enter "ATWS" for ATTRIBUTES.

B.10 IPE Database Conventions and Query Conditions for Other Initiators

The accident progression following an initiator associated with the loss of support system (e.g., IA, CCW, or ESW) is similar to that for a transient event. However, in the loss-of-support-system accident, some safety functions are lost as a consequence of the loss of the support system. The loss of these safety functions can be inferred from the systems dependency tables and may not be presented as one of the FAILED FUNCTIONS in the IPE database.

Because of its importance, the loss of AC power is treated separately from the loss of other support systems. The most important initiator associated with a loss-of-ac-power initiator is the loss-of-offsite-power (LOOP), which causes a loss of the normal power supply to all AC buses, or the loss of one of the AC buses. If all of the emergency diesel generators (EDGs) are also lost in a LOOP event, the event becomes a station blackout (SBO).

In the IPE database, "T-LOOP" is assigned as the INITIATOR for a LOOP event. "SBO" is included as one of the ATTRIBUTES if all EDGs are lost in an event or if all AC power supplies (i.e., both AC and EAC) are lost in other events. By contrast, "T-AC" is assigned as the INITIATOR if the initiator involves the loss of only one AC bus. The loss of all normal AC power supply is indicated by including "AC" as one of the LOST SUPPORTS, and the loss of EDGs for AC power supply is indicated by including "EAC" as one of the LOST SUPPORTS. In some SBO sequences, core damage is caused by the additional loss of DC power as a result of battery depletion. For these sequences, both "EAC" and "EDC" are included in LOST SUPPORTS.

The progression for an accident that involves internal flood (IFL) is similar to that for a transient event. Such accident sequences are identified by assigning "IFL" in the CAUSES field of the IPE database. The initiator can be either "T-IFL" or "T-xx," where "xx" is the acronym for the system (e.g., ESW) where the internal flood starts. Depending on the flood location, various support systems or safety functions will be lost in an IFL event.

In this case, the IPE database lists the lost support systems in the LOST SUPPORTS field and the lost safety functions are listed in the FAILED FUNCTIONS field. The safety functions lost as a result of the loss of the support system and can be inferred from the systems dependency table and may not be presented among one of the FAILED FUNCTIONS in the IPE database sequence table.

Because of the low probability of ISLOCAs, an event tree is in general not constructed in the IPE submittal to evaluate the associated core damage frequency. The only question usually asked following the initiation of an ISLOCA is the probability of isolation. If the break is not isolated, core damage is assured.

The IPE database indicates an ISLOCA by assigning "V" or "V-xx" as the INITIATOR, where xx is the system acronym denoting where the break is located. The break location may also be identified by including the system (e.g., LPI) in the FAILED FUNCTIONS field and/or by checking the function (e.g., LPI) with a "*." In general, an ISLOCA causes a bypass release, so "BYPASS" is typically included as one of the ATTRIBUTES. In addition, since RCS integrity is lost, "RCS-INT" is also included as one of the FAILED FUNCTIONS.

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11. ABSTRACT *(200 words or less)*

The individual Plant Examination (IPE) database stores structured information about plant designs, core damage frequency (CDF) and containment performance. It records the presence or absence of hardware in each design, characterizes its functional dependencies, and relates these features to the CDF and containment performance. The IPE database supports detailed inquiries into these characteristics for a specific plant or class of plants. In particular, the IPE database is designed to answer questions that enable interested parties to compare the CDF and containment performance of boiling- and pressurized- water reactors (BWRs and PWRs) as a function of their design features, on the basis of information found in the IPE submittals. To query the IPE database, two programs have been developed. The first is a self-contained, user friendly, menu-driven program written in Microsoft's Visual Basic language. This program answers the "basic queries" most often asked about the IPEs, through a process of sorting records within the IPE database. Queries of this type can be improvised on the spot. Other "advanced queries" that call for calculations, linking of data files, and ranking or sorting on the basis of calculation can be performed using the programming language within such personal computer data management applications as dBase, Access, or Paradox. This IPE database user's guide provides guidance for formulating basic and advanced queries. The guidance for advanced queries is given in terms of Microsoft Access 2.0.

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