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THE IPE DATABASE: PROVIDING INFORMATION ON PLANT DESIGN, CORE DAMAGE FREQUENCY AND CONTAINMENT PERFORMANCE

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ABSTRACT

A database, called the IPE Database has been developed that stores data obtained from the Individual Plant Examinations (IPEs) which licensees of nuclear power plants have conducted in response to the Nuclear Regulatory Commission's (NRC) Generic Letter GL88-20. The IPE Database is a collection of linked files which store information about plant design, core damage frequency (CDF), and containment performance in a uniform, structured way. The information contained in the various files is based on data contained in the IPE submittals. The information extracted from the submittals and entered into the IPE Database can be manipulated so that queries regarding individual or groups of plants can be answered using the IPE Database.

I. BACKGROUND

The development of the IPE Database is based on the contents of the IPE submittals as prescribed in NUREG-1335 [1]. The key results called for in NUREG-1335 are the plant-specific dependence table, the dominant accident sequences, and release category information. The level of detail presented in these areas varies to some extent among different submittals since licensees have been given substantial freedom in the presentation of this information. The present development of the Database reflects the level of detail which can be reasonably expected to be found in the majority of the submittals.

There are two sections of the IPE Database, corresponding to the Level 1 analysis in the IPE submittals and the Level 2 analysis.

The titles of the Level 1 files, indicating the focus of the information contained in each, are the following: General Plant Information, Front-Line Systems, Support Systems, Dependency Table, Core Damage Prevention Strategies,

Mission Success Paths, and the Accident Sequence Table. The link between these files is a basic list of BWR and PWR systems, in terms of which:

- (a) the design of any BWR or PWR can be described with reasonable fidelity (General Plant Information, Front-Line Systems, Support Systems, Dependency Table),
- (b) plant-specific dominant accident sequences can be described accurately (Accident Sequence Table), and
- (c) the success paths assumed in the IPE (i.e., its mission success criteria) can be tabulated (Core Damage Prevention Strategies, Mission Success Paths).

The Level 1 portion of the IPE Database is connected to the Level 2 portion through the Plant Damage States. The Level 2 files in the IPE Database are the following: Plant Damage State Definitions, C-matrix, (containment performance), Source Terms, and Level 2 Analysis Parameters, (source term characteristics).

Another data file, containing high level information on core damage frequency (CDF) contributors, as well as containment failure modes, was added to the above structure and coupled to the rest of the IPE Database files. This additional file contains summary information found in each IPE submittal regarding initiating event frequencies and the total contribution to core damage from each initiating event, as well as total containment failure mode frequency and conditional failure probability. Because of the way information was reported in the submittals, the previously existing accident sequence files of the IPE Database contain only partial results regarding the contribution to core damage and containment failure modes. The summary information file remedies this situation.

The IPE Database is designed to provide helpful information for general questions like: What features does each submittal take credit for? How does this factor into the core damage frequency and/or containment performance of the

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plant? If two plants in basically the same class have markedly different CDF and/or containment performance, what is responsible for this? If a class of plants seems to share a particular contributor to risk, what design features are responsible for this?

Substantial progress has been made on the IPE Database over the last two years. Entries into the IPE Database from the original submittals reporting results of the IPE internal events examination have been finished with information from all IPE submittals entered. The information in the Database is that reported by the licensee. It has not been checked or verified by those performing the entry. Also, since level of detail and types of results reported vary a notably among the IPE submittals, some entries required significant engineering judgement from the analysts performing the entry.

II. THE IPE DATABASE MENU SYSTEM

The IPE Database currently is a collection of Microsoft Access tables which store information about plant design, core damage frequencies (CDFs), and containment performance in a structured way. 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 classes of plants by the use of Microsoft Access queries. Since the design of queries require familiarity of both the Microsoft Access program and the detailed structure and contents of the Database tables, a menu system has been developed to provide easy access to the Database. The menu system assumes no previous familiarity of the database program or the IPE Database. It provides a user friendly interface for the user to explore the contents of the Database and to obtain answers to some simple questions. Queries that address more complicated but commonly asked questions are being included in updated versions of the menu system. Questions that are not included in the menu system can be answered by constructing queries using the Microsoft Access program or other database programs.

The IPE Database menu system is written in the Microsoft Visual Basic program language and operates under the Microsoft Windows operating system. The major parts of the IPE Database menu system package include two Database files, *ipe.mdb* and *freq.mdb*, and the Visual Basic program *ipe.exe*. The installation and the running of the menu program are standard for the Windows operating system and instructions for them can be found in the users manual for the Windows operating system.

Figure 1 shows the screen after the IPE Database menu system is started. This screen allows the selections of the plant or a group of plants for data search. Plants can be selected

individually by plant names (using the top box) or selected by their common properties (using the middle box). The search and display of data can be further restricted by additional conditions. One can restrict the selection and display of data for plants that have CDFs satisfying a particular condition, or one can restrict the selection and display of the data associated with particular accident initiators. Individual BWR classes or PWR loops can be selected or de-selected by clicking the individual items using the left mouse button. All items under BWR Class or PWR Loops can be selected or de-selected by clicking on the heading of the BWR Class or the PWR Loops using the left mouse button. A Reset button is provided at the upper left corner of the screen to clear the screen for making new selections. The menu items shown at the top of the screen are in general common to the menu items for other Window programs. The menu item that is special for this program is the top menu for "IPE Information". This menu item is selected after the plants are selected and is also shown in Figure 1, which indicates the sub-menu items for this top menu item. These items are summarized in the following sections. They are described in more detail in the IPE Database Menu System User's Manual [2].

A. General Plant Information

The example in Figure 1 shows the selection of four-loop Westinghouse PWRs for data display, and Figure 2 shows the results of selecting "General Plant Characteristics" of the "IPE Information" menu item. As shown in Figure 2, data are displayed only for four-loop Westinghouse plants. Data displayed for "General Plant Characteristics" are plant name, plant type, nuclear steam supply system vendor, number of loops for PWRs, BWR types for BWRs, plant output, containment type, number of units, total core damage frequency, and, if a multi-unit site, are support systems shared, does crosstie capability exist, and is there a common control room. The arrows at the top of the screen can be used (by clicking the left mouse button) to scroll the data to the left or right of the screen, and the buttons at the bottom of the screen can be used to scroll the data up and down the screen. Clicking any of the column headings will cause the data to be sorted by the contents of the Database field represented by the heading. For example, clicking "Total CDF/R_Y" will cause the data to be displayed in an ascending order of core damage frequencies (CDFs).

B. Plant Systems

When this item is selected, a further choice appears of "Front Line Systems" or "Support Systems." When one of these is chosen, for instance front line systems, another screen appears for the selection of the frontline systems for display. (Space does not permit the display of this screen here). Descriptions of the systems represented by the acronyms in this screen can be displayed by pointing to the acronym and

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pressing the right mouse key. The systems are selected by checking the boxes to the left of the system acronym, and multiple systems, up to all front line systems for the selected plant or plants, can be selected for display.

C. Level 1 Information

Four different choices are available under this menu item: Mission Success Paths, System Dependencies, Accident Sequences, and Core Damage Prevention Strategies.

Figure 3 shows the selection screen for system dependencies. As with other categories, the selection of the plants are made in the Welcome to the IPE screen shown in Figure 1. The systems in the "Systems" box are the dependent systems and the systems in the "Supporting Systems" box are the independent systems. The dependency of the dependent system on the independent system can be any one of the types in the "Dependency Type" box. Descriptions of the systems can be obtained by pointing to the system acronym and pressing the right mouse button. Figure 4 shows the results of the selection - the dependency of some selected systems from the "Systems" box to those in the "Supporting Systems" box for North Anna 1&2. Figure 4 shows that the HPI system has a "Primary" dependence on AC and a "Secondary" dependence on EAC (i.e., the diesel generators). It also shows that HPR (safety injection - recirculation) has an "Absolute" dependence on LPR (low pressure injection - recirculation) - indicating that HPR takes suction from LPR and does not work if LPR fails. The dependence of RCPS (Reactor Coolant Pump Seal) on both CCW and CHPI indicates that a seal LOCA would develop only if both the component cooling water and the charging systems fail.

The Core Damage Prevention Strategies and Mission Success Paths items are related. The core damage prevention strategy (CDPS) shows what combinations of safety functions are needed to prevent core damage, given a particular challenge, i.e. accident initiator. Each unique combination of functions is termed a core damage prevention strategy for that challenge. Any particular challenge may be addressed by one or more strategies. The mission success path (MSP) Database table shows what success paths the IPE assumed in its reported results. The MSPs are related to the CDPSs in that they show the plant systems that can be used to achieve the CDPS. There may be many MSPs for a CDPS because different plant systems can be used to achieve the same safety function. For example, for PWRs, secondary heat removal can be achieved by the use of either the motor-driven auxiliary feed water system or the steam-driven AFW, and, in some cases, the pumps used for normal feed water supply. Space limitations prevent the inclusion of the selection and result screens for the CDPS and MSPs in this paper. The user can select CDPS and MSPs for plants and initiators chosen from the screen shown in Figure 1. Additional selection screens

are provided so that CDPSs can also be selected by particular safety functions and MSPs can be selected depending on what particular frontline equipment they include.

The Database table for accident sequences stores dominant accident sequences from each submittal. The object is to record which systems failures in the sequence lead to core damage, what functional failures go along with these failures, and the frequency of the sequence. The screen used to select the plants and the accident initiators for accident sequences is the same as that shown in Figure 1. After the sub-menu item Accident Sequences is selected from the choices under Level 1 Information, another selection screen as that shown in figure 5 is displayed. The top part of this selection screen allows selection of sequences which fail particular systems. The bottom part shows the selection of the support systems, the attributes, and the causes for the accident sequences. Only those sequences that satisfy the selected properties in these boxes will be displayed. For example, if SBO is checked in the Attributes box, only sequences involving SBO will be displayed. Figure 6 shows the results of the selection for a large LOCA initiator. Since no items are selected in Figure 5, all large LOCA sequences for the selected plants are displayed. For Ginna, six sequences are displayed. Their frequencies (Sequence CDF on the screen), the total frequencies of the six selected sequences (total Seq CDF), and the fractions of the sequence frequency to the total frequency (the ratio of the above two numbers) is shown. More detailed information of the sequences can be displayed by pointing to the plant name of the sequence and pressing the right mouse button. Figure 7 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 low pressure recirculation (LPR) is due to the failure of other systems, and in this case, an operator error. The data in the Notes field describes the failure as due to "operator fails to establish low pressure recirculation". The screen also shows that the sequence does not involve the failure of any support system or any cause that are indicated in the selection screen. HUM appears in the Attributes field to indicate that the sequence involve human error.

D. Level 2 Information

Four sub-menu choices are available under this menu item: Containment Performance (C-Matrix), Plant Damage States (PDS), Release Classes, and Source Terms. The Level 2 portion of the IPE Database is connected to the Level 1 portion through the Plant Damage States (PDS). In the Level 2 analysis, 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 by allocating a separate Database table to each element of the Level 2 analysis.

After the sub-menu item "Plant Damage States" is selected on the selection screen the selection screen for PDSs is displayed (Figure 8). Figure 8 shows the parameters that are commonly used in the IPEs to define PDSs and the possible values for these parameters. It should be noted that the definition of PDSs used in the various IPEs vary and some of the values shown in Figure 8 are not provided in some of the IPE submittals. In general, the first two parameters, reactor coolant system (RCS) pressure and containment conditions, are provided in almost all IPE submittals. In the display of Figure 8, only the values of the first three boxes are shown. The user can click the heading of the other boxes to see the values available for these boxes. Figure 9 displays the results of the selection shown in Figure 8 (As in other selection screens, all PDSs are selected if no items are selected in the selection screen). Since "High Pressure" and "Intermediate Pressure" are selected in the RCS Pressure box, and "Isolated" and "Bypassed" are selected in the Containment Condition box, only the PDSs that satisfy these conditions are displayed.

The Database table for the definition of release classes (RCs) store information on containment failure modes and other parameters that are important to fission product releases (i.e., the source terms). This Database table is connected to the rest of the Database through the release category designators. The Database table for source terms relates the release category designators identified in the IPE Database table for release classes 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. Each record in the Containment Performance, or C-Matrix, table contains a plant name, a plant damage state designator, frequency, and split fractions which allocate the indicated plant damage state over the following possibilities: 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 containment performance table (the C-Matrix) to the source term table. Again, space does not permit the inclusion of the selection and result screens for these files in this paper. Figure 10 shows an example of the results screen of the C-Matrix file showing the allocation of PDSs to release classes and containment failure modes. The single screen shows only partial results but the rest can be obtained by clicking on the right or left arrows and the "next" or "previous" buttons.

E. Summary Information

Three items are available: Total CDF by Initiators, total Containment Failure Probability, and total CDF by accident class. The following are the accident classes: (1) Station Blackout (SBO), (2) Anticipated Transient Without Scram (ATWS), (3) Transient, (4) LOCA, (5) Steam Generator Tube Rupture (SGTR), (6) Interfacing System LOCA (ISLOCA), and Internal Flooding (IFL). Plants or groups of plants are again selected with the screen of Figure 1.

III. CONCLUSION

In its present form, the IPE Database serves as a tool to store, examine and compare the large amount of information contained in the body of IPEs, and can enhance the future use of this information for various applications.

The remaining work on the IPE Database involves updating the information contained in it, based on responses received from the licensees to requests for information generated during the NRC's review of the individual submittals. In addition, information from the external events examination part of the IPE process, the IPEEE, may eventually be incorporated into the IPE Database.

ACKNOWLEDGMENTS

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REFERENCES

1. NUREG-1335, "Individual Plant Examination: Submittal Guidance," Final Report, USNRC, August 1989.
2. IPE Database Menu System User's Manual (to be published).

Figure 1. The Selection of the Top Menu Items

Figure 2. The Display Screen for General Plant Information

Individual Plant Examination - [General Plant Information]

File Edit IPE Information **Queries** Windows

Plant Name	Vendor	Type	BWR Class	Total CDF/Pyr	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		5.88E-05	ICE
COMANCHE PEAK 1&2	W	PWR		6.72E-05	L-DRY
D.C. COOK 1&2	W	PWR		6.26E-05	ICE
DIABLO CANYON 1&2	W	PWR		6.88E-05	L-DRY
HADDAM NECK	W	PWR		1.38E-04	L-DRY
INDIAN POINT 2	W	PWR		3.13E-05	L-DRY
INDIAN POINT 3	W	PWR		4.46E-05	L-DRY

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First Previous Next Last Close

Figure 3. The Selection of System Dependencies for Display

Individual Plant Examination - [Dependencies]

File Edit IPE Information Windows

Select to Query Functional Dependencies. Then Click "OK". Click "Close" to Exit.

Systems

- LPR
- MSAPW
- MSV
- MSV
- MSV
- NT
- QA3
- QA4
- PA01
- PA02
- PPORV
- PSRV
- HCPS
- PF
- RP0

Supporting Systems

- AC
- CCW
- CHPI
- DC
- LAC
- EDC
- ESAS1
- LSW
- HUM
- REACT
- SA
- LPR
- QA3
- SA
- STM

Dependency Type

- A Absolute
- D Partial
- P Primary
- S Secondary

Figure 4. The Display of System Dependencies

Individual Plant Examination - [Dependencies]

File Edit IPE Information Windows

Plant Name	Sepp Syst	AC	CCW	CHPI	DC	LAC	EDC	ESAS1	LSW	HUM	LPR	QA3	SA	STM
NORTH ANNA 1&2	AC	P	P	P										
NORTH ANNA 1&2	CCW													
NORTH ANNA 1&2	CHPI													
NORTH ANNA 1&2	DC	P	P	P	P									
NORTH ANNA 1&2	LAC	D	S	D										
NORTH ANNA 1&2	EDC	D	S	D	S									
NORTH ANNA 1&2	ESAS1	P	P	P										
NORTH ANNA 1&2	LSW	P	P											
NORTH ANNA 1&2	HUM	D	S	D	A									
NORTH ANNA 1&2	LPR		A											

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Figure 5. Selection Screen for Accident Sequences

Individual Plant Examination - [Accidents]

File Edit IPE Information Windows

Select the Item(s) from the Accident Sequence(s). Then Click "OK". Click "Close" to Exit.

PWR Systems				BWR Systems			
☐ RPS	☐ ACC	☐ TT	☐ CSR	☐ RPS	☐ TBY	☐ CS	☐ CIZ
☐ BI	☐ AI1	☐ MSIV	☐ CST	☐ API	☐ RDC	☐ CTS	☐ VENT
☐ PSRV	☐ AI2	☐ TB	☐ FC	☐ SLC	☐ RWCJ	☐ LP1	☐ DWIGN
☐ PDRV	☐ CHPR	☐ NIGP	☐ IC	☐ CRDS	☐ MPW	☐ LPE	☐ WWIGN
☐ PAD1	☐ HPR	☐ MPW	☐ CI	☐ RECIRC	☐ ASPC	☐ SPC	☐ HUM
☐ PAD2	☐ LPI	☐ MDAPW	☐ CIZ	☐ SRVS	☐ HP1	☐ DWS	☐ LP3
☐ RCP3	☐ API	☐ SGAPW	☐ IGN	☐ ADS	☐ HP2	☐ DWC	☐ LP4
☐ CIP1	☐ API2	☐ AM1	☐ HF	☐ ADEP	☐ LPC	☐ IC3	☐ CONDA
☐ HP1	☐ SG	☐ AM2	☐ HUM	☐ MBIV	☐ HPC/HPCS	☐ CI	
☐ LP1	☐ SGA	☐ CSI					

All Clear

Loss Supp	Attributes	Causes
☐ AC	☐ ATWS	☐ IFL
☐ ACBU1	☐ IND-SGTR	☐ FIRE
☐ ACBU2	☐ BYPASS	☐ DCF
☐ ACBU3	☐ TIL	
☐ ALDC2	☐ HUM	

OK Close

Figure 6. The Display of Accident Sequences

Individual Plant Examination - [Accident Sequence CDF]

File Edit IPE Information Windows

Plant	Sequence	Sequence CDF	Total Seq CDF	Fraction
GBINA	21	7.80E-07	3.12E-06	6.41E-02
GBINA	22	1.50E-06	3.12E-06	4.81E-01
GBINA	23	1.40E-06	3.12E-06	4.49E-03
GBINA	24	1.40E-06	3.12E-06	4.49E-01
GBINA	25	3.10E-08	3.12E-06	9.94E-04
GBINA	26	4.20E-10	3.12E-06	1.35E-04
KEWALINEE	10	1.39E-06	2.25E-06	6.18E-01
KEWALINEE	16	4.57E-07	2.25E-06	2.03E-01
KEWALINEE	19	3.00E-07	2.25E-06	1.33E-01
KEWALINEE	23	1.80E-07	2.25E-06	4.44E-02
POINT BEACH 1&2	1	2.57E-05	2.54E-05	9.73E-01

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First Previous Next Last Summary Close

Figure 7. Detailed Display of Accident Sequences

Individual Plant Examination - [Accident Sequence Details]

File Edit IPE Information Windows

Plant	Seq	Sub Seq Desc	PDS	Initiator	Loss Supp
KEWAUNEE	18	ILD-2	LFFAA	A	

Cause	Attributes	Seq CDF	Yot Seq CDF	Fraction	Plant CDF
	HUM	1.33E-06	2.25E-06	6.18E-01	6.66E-06

Systems

Close

System	State	Initiator	Loss Supp
LPR	C		
HUM	*		

Notes

OPERATOR FAILS TO ESTABLISH LOW PRESSURE RECIRCULATION

Figure 8. Selection of PDSs for Display

Individual Plant Examination - [Plant Damage States]

File Edit IPE Information Windows

RCD Pressure

High Pressure
Intermediate Pressure
Low Pressure
Not Prov

Principal Attributes

Containment Condition

Isolated
Small Isolation Fail
Large Isolation Fail
Wynns
Not Prov

Containment Systems

CHR Available
Spray Available
Both Available
None Available
Not Prov
Not Appl

Other Attributes

RWST/CBT

Hole Local

SG Cool Cap

OK

PDS

ATWG
HBIF
HGIP
HIBP
HLBF
HRI
HRSF

Close

Individual Plant Examination - [Plant Damage States]

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Individual Plant Examination - [Containment Performance]

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