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Enhanced Fire Events Database to Support Fire PRA

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Abstract: This paper provides a description of the updated and enhanced Fire Events Data Base (FEDB) developed by the Electric Power Research Institute (EPRI) in cooperation with the U.S. Nuclear Regulatory Commission (NRC). The FEDB is the principal source of fire incident operational data for use in fire PRAs. It provides a comprehensive and consolidated source of fire incident information for nuclear power plants operating in the U.S. The database classification scheme identifies important attributes of fire incidents to characterize their nature, causal factors, and severity consistent with available data. The database provides sufficient detail to delineate important plant specific attributes of the incidents to the extent practical. A significant enhancement to the updated FEDB is the reorganization and refinement of the database structure and data fields and fire characterization details added to more rigorously capture the nature and magnitude of the fire and damage to the ignition source and nearby equipment and structures

Keywords: Fire Events Database (FEDB), Fire Probabilistic Risk Assessment (FPRA), Fire Protection, Fire Risk

1. INTRODUCTION

The Electric Power Research Institute's (EPRI) Fire Events Data Base (FEDB) is the principal source of fire incident operational data for use in fire PRAs as described in EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities [1]. It provides a comprehensive and consolidated source of fire incident information for nuclear power plants operating in the U.S. The database classification scheme identifies important attributes of fire incidents to characterize their nature, causal factors, and severity consistent with available data. The database will provide sufficient detail to delineate important plant specific attributes of the incidents to the extent practical.

The updated FEDB is intended to bring to current the original FEDB that was last formally issued as complete through CY 2000 [2]. In addition to providing more current data, the updated FEDB will have expanded and improved data fields, coding consistency, incident detail, Quality Assurance (QA), and reference data source traceability. The improvement will be designed to better support several fire PRA (FPRA) uses determined from experience gained in the National Fire Protection Association standard, NFPA 805 [3] pilot plant applications and some other near term fire PRAs in currently in preparation. Specifically the FEDB upgrades are intended to provide more current and useable data for Fire PRA applications to support:

- updated, realistic fire frequencies
- treatment of detection & suppression effectiveness
- add credibility by reducing "undetermined" data
- improve fire event severity characterization and classification for reduced uncertainty in estimates of damaging fire frequencies

The project to update the FEDB was a cooperative effort lead by EPRI with NRC under a Memorandum of Understanding [4]. The principal data sources include: plant records, e.g. condition reports and available reports from Nuclear Electric Insurers Limited (NEIL) fire incident reporting

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database, supplemented with Licensee Event Reports from the NRC (LERs), Equipment Performance Information eXchange (EPIX) data from the Institute for Nuclear Power Operations (INPO) database.

A more complete description of the updated FEDB is provided in reference [5].

2. IMPROVEMENTS TO THE FEDB

The principal improvements to the FEDB involve (1) database design and structure; (2) quality of data; (3) Fire Ignition Source Details; (4) Fire Detection and Suppression Response Details and Timelines; and (5) Fire Event Severity Characterization and Classification.

2.1. Improved Database Structure

A significant enhancement to the updated FEDB is the reorganization and refinement of the database structure and data fields. This includes:

- Plant/system descriptive: Factual information about the plant where the fire incident occurred.
- Event descriptive: These are "facts" about the fire incident provided by plant staff in the source documents.
- Event derived/inferred: Evaluated "data" derived or inferred from the incident descriptive information provided in the source documents. The evaluations are performed by FEDB reviewers using pre-established criteria and guidance.
- QA/traceability: Provides documentation of incident review and coding quality assurance including traceability of factual and evaluated data to the original source documents.

Other aspects of the updated database that emanate from the redesigned database structure are discussed below.

2.2. Improved Quality of Data (Facts, Detail, Classification, Source Information)

The updated FEDB has been improved from a quality standpoint by its revised design expanding both the breadth and depth of data captures. Factual information and supporting details have been standardized and expanded using generally accepted terminology from NRC and NFPA sources. These apply to fire location, ignition source descriptions, secondary combustibles, causal factors, incident timeline, detection, suppression, and associated damage. Information and details are collected to the extent possible with standardized lists. Data that may not be covered by list options can be entered directly. The lists were derived from both standardized and free format data entries in the original FEDB, NFPA reporting standards, the NEIL reporting forms, and NRC fire information sources. Free form data entry was generally limited to comment fields in the updated FEDB to ensure data consistency.

For each fire incident, the source information is now specifically identified and a link to the original source document provided for reviewer and user accessibility. The addition of source documents necessarily adds to the size (storage) of the database, but it can be used for searches and other coded data manipulations without the source data included. Some of the source documents will be proprietary (e.g., utility incident reports) while others are a matter of public record (e.g., LERs and Event Notifications (ENs)). Also, additional guidance has been developed to allow more consistent coding of incident information.

In some cases, additional information beyond that provided in the source documents may also be sought and incorporated into the database. For key events additional detail may be sought from knowledgeable plant personnel. A key event would be an event that lends particular insight into fire event behaviors or one that is unique in some regards (e.g., a unique fire source or fire timeline). A concerted effort is also planned to resolve events initially categorized as "unknown" in the fire

severity context by gathering additional information beyond the initial source documents. Reducing the number of "unknown" events will reduce uncertainties associated with fire ignition frequency estimates.

2.3. Improved Fire Ignition Source Details

The updated FEDB has improved the characterization of the fire ignition source both in terms of organization and terminology. The ignition source data are associated with specific locations, areas, systems, and components as well as the types and forms of the initiating and secondary combustibles involved. The type of information is either routinely collected after an event and thus will be contained in NEIL records, LERs, or other input raw data or may be derived from the raw data using the narratives, or secondary indicators.

The updated FEDB provides lists of the most common selections are provided which standardizes the input and allows for sorting, filtering, and comparison operations on the data to identify trends and patterns. Events involving locations, areas, systems, or components that are not covered by a list option may be entered directly and would be tracked as an 'other' type option. The lists are readily expanded, and continual updates of the FEDB will likely adjust the list options as necessary.

The terminology has been defined in a manner consistent with the NEIL database and with NFPA standards. In particular, data fields used by NFPA 901 [6] describing the type of combustible, the ignition factor and fire cause, event timeline, extent of damage, and various avenues of smoke and fire spread have been adopted. Definitions of ignition, smoldering, fire stages, and fire suppression have been made consistent with NFPA 901, NFPA 921 [7], and other NFPA standards.

The data associated with the type of combustible, ignition factor, and the extent of damage is expected to be useful for fire model validation or analysis. Data addressing the damage extent is structured specifically to allow for determining whether the event was challenging, potentially challenging, or not challenging as described in Section 5.

2.4. Improved Fire Detection and Suppression Response Details and Timelines

The updated FEDB has improved the characterization of fire detection, fire suppression, and all event timelines. Redundant information has been eliminated and the data is entered in related groups using standardized lists and fixed times. The type of information is either routinely collected after an event and thus will be contained in NEIL records, LERs, or other raw input data or may be derived from the raw data using the narratives, or secondary indicators.

The event timeline has been consolidated into a single data field containing ten components that are consistent with the event description used by NFPA 901. Rather than entering a mix of times and time differentials, key sub-events are identified and a fixed time is provided if known. Differentials are computed internally when determining the fire duration and suppression duration.

The fire detection and fire suppression data has been expanded to include additional systems and features. Redundant information has been eliminated or consolidated into related data fields. Suppression times, detection times, and suppression intervals have been consolidated into the aforementioned event timeline data field. The data is also structured in such a way to be used in directly in the classification of the event severity (challenging, potentially challenging, or not challenging) as described in Section 5.

The additional detail provides for a better determination fire containment and control that can potentially be used to improve the fire suppression timing and probability estimates currently used in fire PRAs.

2.5. Improved Fire Event Severity Characterization and Classification

The updated FEDB contains an expanded classification method for each event that may be derived directly from the data fields in the updated FEDB as described in Chapter 5 and Appendix B. The classification method associates each event with the appropriate severity level, if possible. The severity levels used in the updated FEDB are challenging, potentially challenging, and not challenging. The challenging and potentially challenging classifications are essentially equivalent to the NUREG/CR-6850 potentially challenging classification. A distinction is now made between fires that were capable of damaging a critical component and those that were not capable, but in the absence of automatic or manual suppression would have become capable. The subdivision of the NUREG/CR-6850 potentially challenging category into challenging and potentially challenging allows for an experientially based estimate of damaging fire frequencies that can be used as an observational check on PRA estimates generated from fire growth modeling assumptions. It also potentially provides data to improve and benchmark actuarially based methods for the estimation of fire progression probabilities.

The event classification criteria for not challenging or undetermined categories are consistent with NUREG/CR-6850. The definitions for key terms used to determine whether a fire could be non challenging, including 'incipient', 'flaming combustion', 'smoldering', and 'ignition' are now defined in accordance with NFPA 901, NFPA 921, and other NFPA standards and publications. These definitions help provide a consistent means of classifying an event.

3. SOFTWARE PLATFORM AND DESIGN

This section describes the software for the beta testing version of the updated FEDB. It is used to develop and refine the software, and to test and refine data field details, definitions, criteria, and guidance for coders and users. It is expected that the production version of the updated FEDB will be a modest evolution in development from the beta test version.

3.1. Software Platform

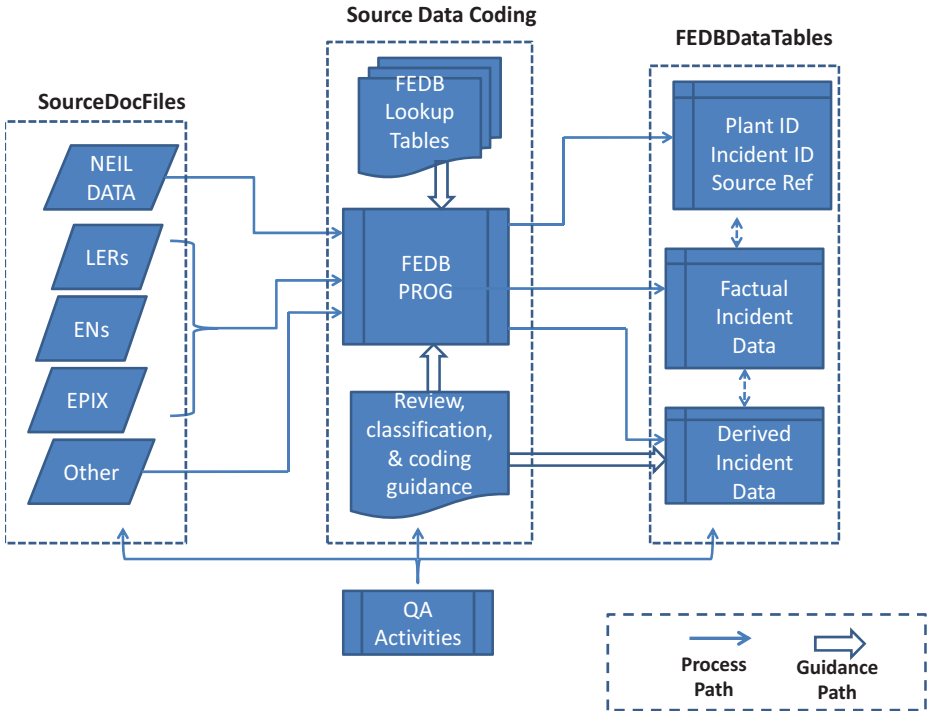
The updated FEDB is maintained in Microsoft Access. The new database was developed in Microsoft Office Access 2003 and has been tested for compatibility in Microsoft Office Access 2007. Microsoft Access was chosen to facilitate users within multiple organizations without relying on any corporate servers. Microsoft Access is also widely available and fully capable of handling the required data requirements of the FEDB.

3.2. Software Design

The updated FEDB is comprised of four main elements; "FEDBprog", "FEDBLookupTables", "FEDBDataTables" and "SourceDocFiles". The "FEDBprog" file launches the program and contains several modules for controlling FEDB users, adding or deleting records, linking the various tables located in the other files, controlling and maintaining source document links and performs several quality assurance functions. The "FEDBLookupTables" file contains the look up tables used by the main data entry form drop down pick lists. The use of pick lists ensures consistent data entry and allows for accurate binning of events. The look-up tables are stored in a separate file to allow for easier modification and distribution of changes throughout the beta testing phase as well as future revisions to the database. The "FEDBDataTables" file contains all the data which is coded using the program. Storing the data in a separate file, allows the program to be modified and updates distributed to the users without losing any coded data. Using a separate file for the coded data also allows users to share their coded data with others without having to send the entire FEDB. This reduces the amount of data required to be sent and allows the use of email to transfer the data. The file "SourcDocFiles" contains a copy of any source documents used as a source of data in the FEDB. The source document files are linked to the individual records to facilitate quick retrieval. Maintaining the original source documents is essential to maintaining data quality. Subfolders under "SourceDocFiles" are setup for

the main source documents used in the FEDB. The subfolders under "SourceDocFiles" are: "EN", "EPRI", "LER" and "NEIL". A schematic representation of the software design is shown in Figure 1.

Figure 1: Software Design: Database Structure



4. DATA FIELD CONTENT

This section provides a description of the updated data fields. For the purpose of this project they have been divided into four groupings:

- Plant/system descriptive: Factual information about the plant where the fire incident occurred.
- Event descriptive: These are "facts" about the fire incident provided by plant staff in the source documents.
- Event derived/inferred: Evaluated "data" derived or inferred from the incident descriptive information provided in the source documents. The evaluations are performed by FEDB reviewers using pre-established criteria and guidance.
- QA/traceability: Provides documentation of incident review and coding quality assurance including traceability of factual and evaluated data to the original source documents.

The data fields include the following:

4.1. Plant/System Descriptive

- Date of event
- Plant identification information

4.2. Event Descriptive

4.2.1. Event Summary Description

4.2.2. Location and Source Characteristics

- Plant building fire started in
- Specific plant areas of involved (if applicable)
- System fire started in (if applicable)
- Component fire started in (if applicable)
- Voltage of component identified in (if applicable)
- Initiating combustible
- Secondary combustibles
- Ignition factor and/or fire cause

4.2.3. Fire Duration, Growth, and Damage Descriptive Details

- Event timeline
- Type of fire at its most severe point
- Most severe smoke conditions observed in the area containing the fire
- Most severe temperature conditions noted in the area containing the fire
- Avenue of smoke transport to adjacent areas
- Fire event characteristics
- Extent of fire/smoke damage
- Extent of collateral damage
- Estimated cost to repair damage

4.2.4. Detection: Time(s), Systems & Equipment, Fire Brigade and Other Personnel Role

- Fire detection method
- Fire detection performance

4.2.5. Suppression: Time(s), Systems & Equipment, Fire Brigade and Other Personnel Role

- Fire suppression method(s) used
- Who put out fire
- Suppression Agent Used
- Fixed/installed fire suppression system performance

4.3. Event Derived/Inferred and Plant Response/Safety Impact

4.3.1. Event Derived/Inferred (See Section 5)

4.3.2. Plant Response and Safety Impact

- Unit mode prior to event
- Power level prior to event
- Unit mode after event
- Power level after event
- Power effect
- Plant system affected
- Emergency declaration (Unusual Event or Alert), if made

4.4. QA/Traceability

- Source document identifiers
- Electronic copy of cited source documents

- Plant point of contact
- Data coder and data coding reviewer

Additional detail on content of data fields is provided in reference [5].

5. FIRE SEVERITY CLASSIFICATION

One of the objectives of this project was to re-examine and improve the fire severity classification of the fire incidents. This "improvement" is intended to better characterize and assess the significance of fire incident data. The fire severity classification is primarily intended to support the calculation of fire event frequencies for fire PRA.

Three fire severity categories have been proposed. These are referred to challenging, potentially challenging, and non-challenging using definitions and intent similar to NUREG/CR-6850. The undetermined fire severity classification is also retained. The principal structural difference with NUREG/CR-6850 is the differentiation of the potentially challenging fire from those that were of a nature to actually be challenging in terms of real or potential damage to nearby equipment. The classification criteria provided in NUREG/CR-6850 were used to the maximum extent possible, but with some modifications to better capture the severity differences of the revised classification scheme and to take advantage of the improvements to the database fields.

A high level description of each category is as follows:

- **Challenging:** The challenging (CH) fire category captures significant fires in a classical fire protection sense. Challenging fires are those that had an observable and substantive effect on the environment outside the initiating source regardless of where in the plant the fire occurred, what was potentially under threat, or what was actually damaged by the fire. These include fires in the growth, fully developed, and decay stages. Data fields considered here include those associated with the observed fire characteristics, the means of suppression applied, ignition of secondary combustibles, and the fire-induced environmental conditions. It should be emphasized that damage to additional components beyond the initiating source does not have to occur to meet this condition.

- **Potentially challenging:** The potentially challenging (PC) fires are those events that were not judged to be CH events, but that could, under foreseeable alternate circumstances, have reached a CH state. That is, PC fires could have led to fire growth, fire spread, equipment damage or cable damage beyond the fire ignition source had the circumstances of the fire event been different. Foreseeable alternate circumstances would be those that arise had some action not been taken. Such actions would include suppressing the fire at an incipient stage with a single fire extinguisher or de-energizing a circuit, either manually or automatically. Data fields considered in the PC determination are the same as those considered in the CH fire category, but for the PC case, the fire didn't develop into such a classically severe fire, or damage components beyond the initiating source.

  The key features for PC are a) the fire was small; or b) the fire could have become larger had some action not been taken. Some interpretation is necessary to sort those where the fire would not have become large even if the action were not taken (passive features or self-extinguish without target damage) from those where the action was essential for preventing transition to CH.

- **Non-challenging**: Fires that did not cause or would not have caused adjacent objects or components to become damaged or ignite regardless of location for any amount of time. These fires could be detected automatically by an incipient fire detection system and could be related to component failures involving ignition of the component followed by self-

extinguishment without any required intervention. Fires that remained in a smoldering state with no apparent potential for open flaming might also be classified as non-challenging. The non-challenging classification is also applied to fires of a type or in a location that would not be considered relevant to a fire PRA.

- **Undetermined**: insufficient information to classify as challenging, potentially challenging, or non-challenging.

A set of sub-classifications that were used to establish rules for identifying specific characteristics by which the event classifications can be made are summarized in Table 1. Note that the fire severity classifications cascade downward from most severe to least to undetermined. This allows for identification of mutually exclusive classifications and gives preferential classification precedence to the higher severity categories. The event sub-classifications in the table form a logical structure under which an event severity may be classified. Specific event attributes and characteristics that may be used to determine the severity as available from the data fields were identified and used to develop a logical structure for placing various events into one of the severity categories using sub-classification definitions. The specific event characteristics that would trigger an event classification into one or another severity group are described in detail in reference 4. This logical structure is intended to make the process more scrutable and more fact-based where feasible, but will still allow for analyst judgment to supersede the logic-based outcome where appropriate with justification.

Table 1: Sub-Classifications Used to Characterize Fire Event Severity in the FEDB

Event Classification	Event Sub-classifications
CHALLENGING One of the following:	Damage to or ignition of an adjacent object, cable or component occurred. This includes ignition of secondary combustibles.
	Damage to or ignition of an adjacent object, cable, or component could have occurred if the fire were in a different location.
	Damage to or ignition of an adjacent object, cable, or component could have occurred if significant suppression actions had not been taken.
POTENTIALLY CHALLENGING Not "challenging" and one of the following:	Damage to or ignition of an adjacent object, cable, or component could have occurred if minor suppression actions were not taken in a timely manner. Delayed detection could lead to a delay in taking such actions.
	Damage to or ignition of an adjacent object, cable, or component could have occurred if the fire were in a different location and if minor suppression actions were not taken in a timely manner. Delayed detection could lead to a delay in taking such actions
NOT CHALLENGING Not "potentially challenging" and one of the following:	Overheat condition only; no smoldering or flaming combustion
	Smoldering fire self-extinguishes without any active intervention.
	Fire involves an ignition source that would not be expected in any area of interest to the fire PRA or in a location that has no relevance to plant operations or safety.
UNDETERMINED	Any fire event that does not have sufficient information to classify as challenging, potentially challenging, or not challenging. Those fires which fall into the undetermined category will be examined further.

6. CURRENT STATUS AND FUTURE PLANS

The initial software and data coding and event classification guidance beta testing has been completed. Adjustments have been made to data field elements and classification criteria to implement limited enhancements as indicated from the beta testing. Long term plans include automating the severity classification using logic routines built into the software. The logic structure has been developed and testing will occur in the next beta test to ensure the logic is valid before modification of the software is completed. The analyst will still be able to override the automatic classification based on engineering judgement and provide justification for the determination. Another long term idea under consideration is to develop a data submittal form which will allow more direct input of the factual data into the database without relying on an analyst interpret and transfer pertinent event information.

Plans to acquire more current data more directly from plants are also in development.

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