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The Updated Fire Events Database: Description of Content and Fire Event Classification Guidance

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The Updated Fire Events Database: Description of Content and Fire Event Classification Guidance

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ABSTRACT

This report provides a description of the updated and enhanced Fire Events Database (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 data for use in fire probabilistic risk assessments (FPRAs) as described in *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities* (EPRI report 1011989 and NUREG/CR-6850). It provides a comprehensive and consolidated source of fire incident information for nuclear power plants operating in the United States that covers experience from 1990 through 2009. 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 that these details were obtainable.

This report provides an updated description of the FEDB and coding guidance details that were used during the data acquisition, coding, and classification phases of the project. The development of the FEDB was a joint project between EPRI and NRC's Office of Nuclear Regulatory Research (RES) according to the EPRI-NRC memorandum of understanding.

Keywords
Fire Events Database
Fire probabilistic risk analysis
Fire protection
Fire risk

EXECUTIVE SUMMARY

This report contains a description of the updated and enhanced Fire Events Database (FEDB) for U.S. nuclear power plants last published in EPRI report 1003111 in November of 2001. The FEDB is the principal source of fire incident data for use in fire probabilistic risk assessments (FPRAs). It is intended to be the most comprehensive and consolidated source of fire incident information available for nuclear power plants operating in the United States.

A significant enhancement to the updated FEDB is the reorganization and refinement of the database structure and data fields. This includes: plant/system description, event description, event derived/inferred information (evaluated "data" derived or inferred from the incident description), and traceability (which provides documentation of the incident review and coding review).

The updated FEDB is intended to capture fire event history up through 2009. In addition to providing more current data, the updated FEDB has expanded and improved data fields, coding consistency, incident detail, data review fields, and reference data source traceability. The improvement is designed to better support several fire PRA (FPRA) uses. The project has an additional objective of updating fire ignition frequency trends and bin frequencies. That task is not reported here, but it is a part of the overall project.

Updating the FEDB

EPRI initiated a program in 1995 to enhance FPRA technology by providing the technical basis and the engineering tools necessary to support the transition to a risk-informed/performance-based (RI/PB) fire protection program.

Key elements of the plan to update the FEDB involved the refinement of the database structure and data fields, collection and processing of new data, updating existing data where needed and practical, coding of data, reviewing entries (in cooperation with NRC), documenting the FEDB, and providing a user's data set.

Meetings were held between EPRI and its contractors and the NRC and their national laboratory consultants to identify necessary areas for improvement of the existing FEDB. An initial beta test version of the database software was developed, and initial event coding and classification trials were performed. Insights were derived from these trials to improve the beta version of the database software and the coding and classification guidance.

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1
INTRODUCTION

This report provides a description of the updated and enhanced Fire Events Data Base (FEDB) [2] developed by the Electric Power Research Institute (EPRI) in cooperation the U.S. Nuclear Regulatory Commission (NRC) [6]. The 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 provides sufficient detail to delineate important plant specific attributes of the incidents to the extent they are available and practical to acquire.

This report provides an updated description of the FEDB and coding guidance details that were used during the data acquisition, coding, and classification phases of the project. The development of the FEDB was a joint project between EPRI and NRC's Office of Nuclear Regulatory Research (RES) per the EPRI-NRC memorandum of understanding.

1.1 Purpose and Intended Use

The FEDB provides the principal source of fire incident operational data for use in fire PRAs. It is intended to be the most 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 they are available and practical to acquire. The unabridged version of the FEDB contains proprietary information provided by nuclear power plant owners and operators. Therefore, access to the FEDB is limited. However, Appendices C through G of this report contain reports from the FEDB that includes fire event data from the FEDB that is pertinent to fire PRAs.

The development of the FEDB was a joint project between EPRI and NRC Office of Nuclear Regulatory Research (RES) per the EPRI-NRC memorandum of understanding. The specific areas of cooperation included scope and content of the project, definitions and classification criteria, development of the initial revision of the original FEDB, and data review. EPRI was responsible for all data collection, coding, classification, review, and preparation of the unabridged FEDB and non-proprietary summary reports provided in Appendices C through G. The NRC provided comprehensive "audit" reviews of key coded fire event information and all fire event severity classifications.

The updated FEDB is intended to add an additional 10 years of fire events to the existing FEDB that was last formally issued. That version of the FEDB was primarily based on the fire incident data reported in the Nuclear Electric Insurers Limited (NEIL) fire incident database, licensee

event reports (LERs), emergency notifications (ENs), equipment performance information exchange system (EPIX), and other available sources. The documentation and traceability of many data entries and event classifications was not rigorously provided. The updated FEDB uses data collected directly and specifically from the plants with explicit traceability to source documents and classification bases and audit of the data records.

In addition to providing more current data, the updated FEDB includes expanded and improved data fields, coding consistency, incident detail, and reference data source traceability. The improvement will be designed to better support several fire PRA (FPRA) uses determined from experience gained in the NFPA 805 [3] pilot plant applications and some other near term fire PRAs currently in preparation.

The intended uses of the updated FEDB are as follows:

1. Improve data quality for regulatory acceptance in FPRA applications (facts, details, classification).
2. Support final resolution of frequently asked question (FAQ) 08-0048. Specifically to:
   - Confirm/dispute trends indicated in response to the FAQ as reported in reference [5],
   - Provide updated fire ignition frequency parameters and trends for existing equipment and location bins utilizing data up to and including calendar year 2009, and
   - Assess the value of improved classification of severity (ensure that any implementation does not prevent resolution of the FAQ).
3. Collect data and establish updated fire ignition frequencies and trends on a continual or periodic basis.
4. Provide data to support improvements to manual suppression modeling and associated parameter estimation (generic, plant specific). Examples include:
   - Account for plant personnel early detection and intervention actions,
   - Distinguish between those fires suppressed by the full fire brigade and other plant personnel,
   - Characterize fires observed to be in early stages (e.g. the pre t-square stage) to assess potential for realistic modeling of early detection and intervention actions, and
   - Provides actuarial benchmarks to support development of empirical correlations and/or to support validation and verification (V&V) of more advanced “mechanistic” modeling of early detection, suppression, or intervention actions (e.g. response by fire watches, plant personnel in the vicinity, fire brigade).
5. Provide data to support enhanced fire ignition frequency modeling to provide better representation of bin elements/components where significant differences in fire ignition frequencies are expected based on engineering, operational, and location factors (generic, plant specific). Examples include:
   - Pumps normally running or on standby,
   - Transient combustibles,
   - Electrical components normally powered or not powered, and

   – Ignition source counts.

6. Provide improved fire event severity characterization and classification for reduced uncertainty in estimates of damaging fire frequencies.
7. Provide actuarial estimates of key fire severity occurrence rates as generic benchmarks for PRA perspective comparisons including timelines for fire stages, detection, suppression, and extent of fire indications.
8. Provide fire incident benchmarks to help test, adjust, and validate fire growth timeline and severity/damage modeling assumptions.

The FEDB is not intended to be a general use database software program. Its content is proprietary and restricted. Its operational features and capability were designed and implemented for the sole purpose of performing data collection, coding, and classification tasks of the project. This report contains a text representation the FEDB. It is intended for general use.

1.2 Scope of FEDB Update and General Content

Key elements of the plan to update the FEDB involved the following activities:

- Refine database structure and data fields to enhance quality and usability (in cooperation with NRC),
- Revise FEDB software (via ACCESS®) to implement refinements and improve user interfaces (with INL as lead programmer under the EPRI-NRC MOU),
- Collect new data directly from plants, update existing data where needed,
- Code data and review entries (in cooperation with NRC),
- Document FEDB in a user's manual (this report), and make the updated FEDB data available to users per EPRI agreements.

This report provides details of the specific data structure, definitions, classification criteria, and software improvements that have been implemented in the updated FEDB. Chapter 2 describes the improvements that were incorporated to enhance the potential uses of the FEDB ranging from in situ details, to fire descriptive information, fire severity classification criteria, and traceability of the data. Chapter 3 provides the basic descriptions of the data fields with supplemental definition details provided in Appendix A. Chapter 4 provides bases and logical descriptions for the fire severity classification scheme and associated criteria with additional details provided in Appendix B. Chapter 5 provides details on the data sources and processes that were used to acquire and code updated fire event data including implantation of traceability requirements. Chapter 6 provides a description of the FEDB software design that was used to collect and process the updated FEDB. Chapter 7 provides a summary of the content of the updated FEDB.

2
IMPROVEMENTS TO THE UPDATED FEDB

Multiple meetings and teleconferences were held between EPRI and its contractors and NRC and their national laboratory consultants to identify necessary areas for improvement of the existing FEDB. Input was also sought from the NEI task force on fire PRA. The following conclusions were drawn:

- The purpose and use of the updated FEDB should be an underlying consideration in the development of updated FEDB content.
- A reorganization of the FEDB should be considered to improve information flow to potential users.
- Fire event identification information, factual characteristics, and derived data have different roles and should not be confounded nor should the ability to scrutinize be obscured. The implementation of the updated FEDB should maintain the distinction between "reported" facts and those data base entries derived from factual data and classification criteria.
- A database description, classification, and coding manual should be made available to those performing data entry function and future users.
- The updated FEDB data fields should be designed in consideration of the availability of the source information from which entries will be made.
- Some additional data fields to capture fire severity information need to be developed. There is also a need to enhance the fire severity classification scheme to reduce the number of "undetermined" events thereby reducing the uncertainty in fire ignition frequency estimates.
- Some data fields that are deemed important enough to add to the updated FEDB may require enhanced data sources or may be flagged for future data acquisition dependent on implementing changes in reporting requirements.
- Not all NEIL data will be presented in the primary FEDB data fields; however, all raw source data should be available in the updated FEDB, even if these data must remain proprietary and are accessible only to a limited set of users or administrators.

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 were performed by FEDB reviewers using pre-established data field coding criteria and guidance.
- Traceability: Provides documentation of incident review and coding quality assurance including traceability of factual and evaluated data to the original source documents.

The specific data fields are described more fully in Chapter 4. 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 captured. 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. Fire event information and details were collected to the extent possible with standardized lists. Data that could not be captured by list options was being 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 was specifically identified and a link to the original source document provided for reviewer and user accessibility. The addition of source documents necessarily added to the size (storage) of the database, but it improves traceability and available event data details. Some of the source documents are proprietary (e.g., utility incident reports) while others are a matter of public record (e.g., LERs and 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 was sought directly from plants and incorporated into the database. A concerted effort was also included 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 reduces uncertainties associated with fire ignition frequency estimates.

Additional details on quality improvements can be found in Chapters 3, 4, 6, and 7.

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 have been associated with specific locations, areas, systems, and components as well as the types and forms of the initiating and secondary combustibles involved. The ignition source data fields are described in detail in Section 3. The type of information compiled in the FEDB 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 plant condition reports using the narratives, or secondary indicators.

The terminology used in the FEDB and data collection and classification has been defined in a manner consistent with the NEIL database and with NFPA standards. In particular, data fields used by NFPA 901 [7] 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 [8], and other NFPA standards. Appendix A provides the key definitions that apply to determining the type, severity, and duration of a particular fire event.

The data associated with the type of combustible, ignition factor, and the extent of damage are 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 4 and Appendix B.

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 associated data fields are described in detail in Section 3. 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 directly in the classification of the event severity (challenging, potentially challenging, or not challenging) as described in Section 4 and Appendix B.

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 4 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 PRA important component[1] 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 are provided in Appendix A and were used as a consistent means of classifying fire event information.

The event severity was initially determined automatically in the FEDB using an algorithm described in Chapter 4 and Appendix B that uses the FEDB data field list and actual event entries. The automatic fire event determination was provided to analysts and reviewers as a guide to ensure consistency in classifications and documentation of bases. After extensive application, there were indications that the automatic event classification algorithm provided a somewhat conservative estimate of the event severity classification for certain types of fire events. Therefore, criteria were developed and implemented to manually "override" conservative classifications to reasonably match specific intentions. The final determination of the fire severity was in general confirmed by analyst inspection of the data and comment fields and subsequent reviews by both EPRI and NRC.

[1] A PRA important component is a component that is modeled in a fire PRA. The fires referred to do not have to actually damage such a component. They just need to have advanced to the point where it is reasonably certain that it would have propagated to or damage the PRA component, if it were present.

3
REPORT DATA FIELD DESCRIPTIONS AND DEFINITIONS

This chapter provides a summary and description of the reports generated from the data collected in the updated FEDB. Five reports have been generated from the fire events database. Each report covers different aspects of fire characteristics, severity and plant response. A summary of each report is provided in the section below. Content within the each report and a description of the fields within each report is also discussed in the sections below. The reports are provided in Appendices C through G.

The reports contain four fields common to each report. These fields are:

- FireID: A unique identifier for record
- Event Data: Date of fire event
- Disposition: Describes classification of fire (either challenging, potentially challenging, not challenging, undetermined (NC-PC), not evaluated or undetermined (PC-CH)).
- Review Status: Either preliminary, final or final with disagreement. Preliminary indicates the record went through EPRI review, but was not validated by the plant associated with the record. Final indicates the record completed the review process including the NRC audit and categorization. Final with disagreement indicates progress up through the audit, but EPRI and the NRC disagreed with categorization.

In the following sections, some of the fields are annotated with a reference to the classification algorithm that is Appendix B. The annotations is of the format [AR x], where "x" is the number of the algorithm reference used in tables B-1, B-2, and B-3 (e.g. "[AR 10]" means that the field is marked as algorithm reference #10 in the tables in Appendix B). In addition, some field choices are accompanied by the term "(specify)". In these cases, the specification would be listed in the "Comments" field that is described in Section 3.1 unless another location for the elaboration is listed in the field description.

3.1 FEDB Fire Summary Report

The FEDB Fire Summary Report provides the title and a brief summary of the potential fire event. The location of the fire to a specific area (Battery Room, Switchgear Room, etc.) and/or plant location (Turbine Building, Control Building, etc.) are provided. Lastly, this report provides a summary of the system, component group and component when available. Horsepower or kVA are filled in when available.

Unique fields in this report include:

- Fire description – A brief description of fire event.

- Comments – notes added by analyst, typically detailed description of event. This field is also used to document additional information requested by some field choices.
- Outside PA– Outside area relevant to PRA analysis (plant protected area and any additional areas within the plant). Options are "Yes" or "No".
- Plant area – Specific plant area of fire event. Options are any of the following:
    a) Main Control Room
    b) Battery Room
    c) Cable Spreading Room
    d) Switchgear Room
    e) Containment/Drywell
    f) Fuel Handling Area
    g) Cable Vault/Tunnel Area
    h) N/A
- Building – Plant building fire started in. Options are any of the following:
    a) Reactor Building (BWR)
    b) Auxiliary Building (PWR)
    c) Turbine Building
    d) Radwaste Building
    e) Diesel Generator Building
    f) Service Water Pump House
    g) Circulating Water Pump House / Intake Structure
    h) Main Transformer or Switch Yard
    i) Drywell (BWR)
    j) Containment (PWR)
    k) Control Building
    l) Other (specify in comments)
- System – System fire started in (if applicable). Options are any of the following:
    a) Auxiliary/Emergency Feedwater System (PWR)
    b) Cable Raceway System
    c) Closed/Component Cooling Water
    d) Condensate System
    e) DC Power System
    f) DC Power System, Class 1E

g) Diesel Fuel Oil System
h) Emergency Onsite Power Supply System
i) Essential Service Water System
j) Feedwater System
k) Heat Rejection System (Circulating Water)
l) High Pressure Core Spray System (BWR)
m) High Pressure Safety Injection System (PWR)
n) Hydrogen Supply System
o) Instrument and Uninterruptible Power System
p) Instrument and Uninterruptible Power System, Class 1E
q) Low Pressure Core Spray System (BWR)
r) Low Voltage Power System (600V and less)
s) Low Voltage Power System, Class 1E
t) Lube Oil System
u) Main Generator Hydrogen Cooling System
v) Main Generator Output Power System
w) Main Generator System
x) Main Turbine System
y) Medium Voltage Power System (601V to 35kV)
z) Medium Voltage Power System, Class 1E
aa) Non-Essential Service Water System
bb) Offgas System (BWR)
cc) Raw Water Makeup System
dd) Reactor Coolant System
ee) Reactor Core Isolation Cooling System (BWR)
ff) Reactor Recirculation System (BWR)
gg) Residual Heat Removal / Low Pressure Coolant Injection System (BWR)
hh) Residual Heat Removal / Lowe Pressure Safety Injection System (PWR)
ii) Switchyard System
jj) Turbine Lube Oil System

- Component Group – General type of component that the fire started in (if applicable). Options are any of the following:

a) Pumps

b) Electric Motor (exclude pump motors)
c) Generators
d) Boilers
e) Lube oil system
f) Transformers
g) Electrical panel or distribution equipment
h) Batteries
i) Electrical cable/wiring (voltage, material type, IEEE qualified)
j) Dryers
k) Air Compressors
l) Junction Boxes
m) Outlets
n) Lighting Ballasts
o) Crane
p) Bus Ducts
q) Other (specify)

- Component – The specific component that the fire started in. Options are any of the following:
    a) No breakdown (used for Batteries, Cable/Wiring, Lube Oil, Junction Boxes, Lighting Ballasts, Outlets, Cranes and Other)
    b) Electric Motors:
        i. MG set
        ii. Fans
        iii. Motor-operated valve
        iv. Crane motor
        v. Elevator motor
        vi. Other (specify in the "Comments" field)
    c) Electrical Panel:
        i. Electric bus bar or bus duct
        ii. Switchgear
        iii. Motor control center
        iv. Load center
        v. Circuit breaker or other distribution panel

vi. Inverter
vii. Battery charger
viii. Main control board (horseshoe)
ix. Other instrument/control cabinet
x. Relay rack
xi. Wall mounted or Sealed
xii. Other (specify in comments)

d) Generator:
   i. Exciter
   ii. Main turbine generator
   iii. Class 1A emergency generator
      i. Other (specify in comments)

e) Pumps:
   i. Electric motor driven
   ii. Diesel-driven
   iii. Turbine-driven

f) Transformers:
   i. Oil-filled transformer
   ii. Dry transformer
   iii. Other (capacitor voltage, potential, etc.)

g) Auxiliary or Heating Boiler (Boiler):

h) Bus Ducts:
   i. Segmented bus duct
   ii. Iso-phase bus duct
   iii. Other

- Voltage – Voltage of the component identified above (if relevant and available). Options 'a' through 'h' are associated with AC equipment and options 'b' through 'l' are associated with DC equipment. Options are:
  a) 110V
  b) 220V
  c) 480V
  d) 600V
  e) 4KV

f) 7KV

g) 13 KV or greater

h) Other (specify)

i) 24-48VDC

j) 125VDC

k) 250VDC

l) Other (specify)

m) N/A

- Current – Type of current of the component identified above (if relevant and available). Options are:

  a) AC

  b) DC

  c) N/A

- Hp or kVA – Horsepower or kilovolt-amps (if relevant and available).

3.2 FEDB Fire Attributes Report

The FEDB Fire Attributes Report provides a high level assessment of the potential fire event. Fire cause, combustibles involved and fire type are reported. Smoke effects and temperature effects are discussed. Extent of damage and if collateral damage occurs is also shown in this report.

Unique fields in this report include:

- Fire cause [AR 9] – Options are:

  a) Electrical failure resulting in overheating materials

  b) Electrical failure resulting in an arcing fault

     i. High Energy Arc Fault (HEAF)

     ii. Electrical arcing or sparks (non-HEAF)

  c) Overheated material (lube oil, pump packing, thermal insulation, etc.)

  d) Explosion (hydrogen gas ignition, fuel vapor ignition)

  e) Hot work (e.g., sparks or slag from welding, cutting or grinding)

  f) Suspicious

  g) Other (other personnel error, natural effect, etc. specify in comments)

  h) False actuation of detector, no ignition or overheat condition

  i) Unknown

j) Personnel error: Misuse of material ignited

k) Personnel error: Misuse of heating devices

l) Mechanical equipment malfunction/failure

m) Personnel error during test and maintenance activity

- Primary combustible group, type and form - First combustible to ignite outside of the component of origin. May be cable combustible or other intervening combustible. The type and form are the lower level lists. Form and type are not applicable for groups f) – h). Options are:

  a) Liquid – Flammable or combustible liquid:

    i. Type of liquid:

      a. Lube oil or grease

      b. Fuel oil

      c. Transformer oil

      d. Cleaning solvents or paint

      e. Other (specify)

    ii. Form of liquid:

      a. Pressurized spray

      b. Leak – oil soaked insulation

      c. Spill confined by curbs or other physical features

      d. Contained within reservoir

      e. Contained within component

      f. Unconfined spill

      g. Other (specify)

  b) Insulation – Cable jacketing or electrical insulation materials:

    i. Type of cable material:

      a. Thermoplastic

      b. Thermoset

      c. Mixed

      d. Type not specified

    ii. Form of cable materials:

      a. Multiple bundles

      b. Cable tray stack

c. Multiple cables not in tray or bundle
d. Stored unused cables
e. Single bundle
f. Single cable tray
g. Single cable
h. Unknown
i. Other (specify)

c) In-situ – Other solid in-situ materials:
   i. Type of in-situ material
      a. Other electrical or electronic equipment
      b. Thermal insulation material
      c. Interior finish
      d. Other (specify)
d) Transient – Other solid transient materials:
   i. Type of other solid transient material
      a. Celluosic materials including wood, paper or other solid transients
      b. Temporary electrical wiring or equipment
      c. Plastic Sheets
      d. Temporary thermal insulation materials
      e. Trash (i.e. solid refuse collected for disposal)
      f. Other (specify)
e) Gas – Flammable or combustible gas
   i. Type of gas:
      a. Hydrogen
      b. Other (specify)
   ii. Form of gas when ignited:
      a. Pressurized in container
      b. Jet from a pressurized source
      c. Ambient pressure, within a compartment
      d. Ambient pressure, within a component
      e. Unconfined liquid spill

f. Confined liquid spill

g. Other (specify)

f) Transient (Liquid) – Transient Liquids

g) Transient (Gas) – Transient Gas

h) Unknown – Source combustible is unknown

- Secondary combustible group, type and form -Additional combustible(s) to ignite outside of the component of origin and primary combustible. The options are the same as those listed above in the "Primary combustible group, type and form" fields. The most relevant secondary combustible should be chosen (if any).
- Fire type [AR 11] – This field notes the most severe type of combustion between ignition and extinction observed during the fire event. Options are:
  a) Flaming combustion – external to component
  b) Flaming combustion – internal to component
  c) Smoldering combustion – external to component
  d) Smoldering combustion – internal to component
  e) Overheating – no smoldering or flaming combustion
  f) Fully developed compartment fire
  g) Explosion
  h) Arc/electric discharge
  i) No fire – false actuation of detection device
  j) Fire not observed and fire type indeterminate from post-inspection
     i. Fire suppressed by fixed suppression
     ii. Fire self-extinguished
     iii. Fire contained within a component
     iv. Room entry not possible before mitigation
     v. Other (specify)
  k) Other (specify)
  l) Unknown
- Fire type unknown – If fire type unknown, description of why fire type was unknown (e.g. fire put out by fixed suppression or fire contained within component).
- Smoke [AR 12] – Field to characterize the most severe smoke conditions observed during the fire. See Appendix A for additional discussion and classification of smoke conditions. Options are:

a) No smoke present

b) Light smoke coming from ignition source – minor or no visibility reduction in vicinity of fire

c) Moderate smoke coming from ignition source - visibility significantly reduced in vicinity of fire; equipment on fire is still easily located.

d) Heavy smoke coming from ignition source - smoke obscures vicinity of fire such that it is difficult to locate the origin of the fire, room entry is still possible with SCBA

e) Severe smoke coming from source - visibility near zero in small room, severe degradation of visibility for relatively large room, room entry would require full turn out gear

f) Outside area, smoke only in fire plume

g) Unknown

- Temperature [AR 13] – Most severe temperature conditions noted in the area containing the fire. See Appendix A for additional guidelines for use and detailed description. Options are:

  a) None or insignificant – temperature at or close to ambient

  b) Moderate – temperature increase detectable but protective clothing not needed for room entry

  c) High – protective clothing needed for room entry

  d) Severe – room entry not possible without venting or mitigation

  e) Fully developed room fire – flames outside the compartment

  f) Outside area, elevated temperatures only in the fire plume

  g) Unknown

- Damage extent [AR 15] – Overall categorization of fire influence. Options are:

  a) Confined to the object of origin

  b) Confined to part of room or area of origin

  c) Confined to room of origin

  d) Confined to fire rated compartment of origin

  e) Confined to floor of origin

  f) Confined to structure of origin

  g) Extended beyond structure of origin

  h) No damage

  i) Unknown

  j) Confined to the object of origin (broad/extensive damage)

k) Confined to the object of origin (localized/single subcomponent)

l) Not available

- Collateral Damage [AR 16] – Other damage reported for the fire. Options are:

a) Heat

i. Scoring

ii. Charring

iii. Warping

iv. Melting

b) Smoke

c) Evidence of secondary ignition

d) Effects from fire suppression of original fire source

e) Vertical distance of collateral damage [Specify distance]

f) Lateral distance of collateral damage [Specify distance]

- Detail – additional text entered if collateral damage occurred.

3.3 FEDB Fire Severity Evaluation Report

The FEDB Fire Severity Evaluation Report provides the automatic determination of fire events based on the fire incident severity algorithm. The criteria for automatic determination of fire severity is listed Table 4-2. The standard override field is used to correct the classification as needed. Categories for re-classification from potentially challenging to non-challenging are listed in Table 4-3.

Unique fields in this report include:

- Standard override – If filled out indicates if the override criteria listed in Table 4-3 was used to re-classify the fire event.
- Comments on disposition – Optional field used to provide a basis for the override, to note differences of opinion between analyst and NRC analyst, and general comments surrounding the classification of the fire event.
- Automatic determination – Automatic classification as provided by the algorithm.
- Automatic determination basis – Displays data fields that satisfy criteria for general classifications of fire (challenging, potentially challenging, etc).

3.4 FEDB Fire Timeline Report

The FEDB Fire Timeline Report provides timing information from ignition and discovery, brigade response, and extinction. This report also classifies if the fire duration was known, estimated or unknown. The fire duration in minutes is provided. Detection method and performance along with suppression method and agent are also discussed in this report.

See timeline discussion in Appendix A for additional information on the documentation of the timeline. All times are reported in the form hour:minute.

Unique fields in this report include:

- Ignition time [AR 10.a]
- Discovery time [AR 10.b]
- Report time [AR 10.c]
- Brigade dispatch time [AR 10.d]
- Brigade arrival time [AR 10.e]
- Brigade first action time [AR 10.f]
- Controlled time [AR 10.g]
- Extinguished time [AR 10.h]
- Scene release time [AR 10.i]
- Duration certainty [AR 10.k] – Either known, estimated or unknown based on reporting plant information.
    a) 1-Known
    b) 2-Estimated
    c) 3-Unknown
- Duration [AR 10.m] – Fire duration in minutes.
- Estimated duration [AR 10.l] – Provided in minutes if duration certainty was estimated.
- Detection method [AR 18] – This field describes how the fire was discovered (either via plant personnel, fire detection or other plant response). Options are:
    a) Fire watch
    b) Main control room staff (e.g., control/instrumentation failures)
    c) Other plant personnel (in vicinity or passerby)
    d) Thermal detector (e.g., temperature or rate of rise)
    e) Smoke detector
    f) Ultraviolet flame detector
    g) Gas ionization
    h) Failed equipment alarm (tripped pump, ground, low lube oil etc.)
    i) Very early smoke detection system (incipient detection)
    j) Sprinkler or fire-water system flow alarm

k) Unknown

l) Installed fire detection, type not specified

m) Roving fire watch

n) Staff conducting test/maintenance on equipment of fire origin

- Detection performance [AR 19] – This field describes the performance of fire detection system. Options are:

  a) Plant area had installed detection which actuated

  b) Plant area had installed detection which did not actuate, fire was detected visually or by other means – no indication of system failure

  c) Plant area had installed detection which did not actuate, fire was detected visually or by other means – system failure indicated

  d) Plant area did not have installed detection capability

  e) Unknown

- Suppression method [AR 20] – This field shows the methods used to suppress the fire. All options that apply should be marked. Options are:

  a) Automatic fixed suppression – thermally actuated

  b) Automatic fixed suppression – smoke detector actuated

  c) Automatic fixed suppression – actuation not specified

  d) Fixed suppression – manual

  e) Fixed suppression system – deluge (automatic)

  f) Hose stream or hose reel

  g) Portable manual system (e.g. CO_2 cart)

  h) Single portable fire extinguisher

  i) Multiple portable fire extinguishers

  j) Power supply removed

  k) Fuel supply removed

  l) Supervised burn out

  m) Self-extinguished (no plant staff intervention)

  n) Other [specify]

  o) Unknown

  p) Power supply removed by maintenance staff (craft activity required)

  q) Fuel supply removed by maintenance staff (craft activity required)

r) Air supply cut off (smothered, covered)

s) Other simple: (e.g. blown out, stamped out; specify in comments)

t) Power supply removed (simple manual action e.g. open circuit breaker)

u) Fuel supply removed (simple manual action e.g. valve turn off)

- Suppression agent [AR 21] – All suppression efforts except for portable fire extinguishers. Options are:

  a) Water
  b) CO_2
  c) AFFF foam
  d) Halon
  e) Other [specify]

- Suppression agent used [AR 22] – Suppression efforts for portable fire extinguishers only. Options are:

  a) Water
  b) CO_2
  c) Dry Chemical
  d) Halon
  e) Other [specify]

3.5 FEDB Plant Response Report

The FEDB Plant Response Report provides a high level summary of the plant state prior and after the potential fire event. Fields of interest include mode prior/after, power level prior/after and emergency action level.

Unique fields in this report include:

- Mode Prior [AR 23] – Plant mode prior to fire (specify 1 through 6).
- Mode After [AR 25] – Plant mode after fire occurred (specify 1 through 6).
- Power Level Prior [AR 24] – Plant power level prior to fire (specify 0% to 100%).
- Power Level After [AR 26] – Plant power level after occurrence of fire (specify 0% to 100%).
- Power Effect [AR 29] – This field describes the effect that the fire had on plant operation. Options are:

  a) SCRAM
  b) Turbine Trip
  c) Reduced Power
  d) LOOP

e) Entered LCO

f) None

- EAL Declaration – This field is populated if alert or unusual event was declared.
  a) Yes [specify EN number]
  b) No

4
FIRE SEVERITY CLASSIFICATIONS

One of the objectives of this project was to re-examine and improve where needed and practicable the severity classification of the fire incidents. The severity classification exercise is aimed primarily at the first application of the database; namely, the calculation of fire event frequencies for fire PRA. This improvement is intended to better characterize and assess the significance of fire incidents contained in the FEDB. The fire severity classifications are also known as the challenging determination. This section describes the original fire incident severity classifications and the revision being implemented in the beta version of the FEDB.

The primary objective of the severity classification exercise is to filter the set of reported fire events and to identify those fire events that are judged to be relevant, or conversely not relevant, to the calculation of fire PRA fire frequencies. In practice, the intent is to identify that subset of the reported fire events that either did present or, under foreseeable alternate circumstances, could have presented a potential to damage fire PRA targets (equipment and cables) beyond the initiating fire ignition source itself. Many of the events reported as fires can be judged to lack this potential, and such events should not be counted when calculating fire ignition frequencies.

NUREG/CR-6850, EPRI 1011989 used a three-tiered classification scheme which is described in Section 4.1. The updated FEDB uses a five-tiered classification scheme which is described in Section 4.2. A structure for making preliminary classification assignments based on the data field entry values is described in Section 4.3.

4.1 NUREG/CR-6850 Event Severity Classifications

In NURGEG/CR-6850 each event was classified as “potentially challenging,” “not challenging,” or “undetermined.” Events were classified as “potentially challenging” if they met the criteria specified in that report. Events were classified as “not challenging” when it could be determined with reasonable certainty that the criteria reflecting a potentially challenging event were not met. Events where the information was found insufficient to make a determination were classified as “undetermined.”

The potentially challenging classification was meant to capture any fire ignition incident within the scope of the specified data “bins” that either did or could have evolved into a damaging fire if pre-emptive suppression actions were not taken in a timely manner. The criteria are summarized as follows:

4.1.1 Objective Criteria – Potentially Challenging

Any of the following:

- A hose stream, multiple portable fire extinguishers, and/or a fixed fire suppression system (either manually or automatically actuated) were used to suppress the fire.

- One or more components outside the boundaries of the fire ignition source were affected where the term "outside the boundaries of the fire ignition source" will depend to some degree on the specific ignition source (see further discussions in NUREG/CR-6850).
- Combustible materials outside the boundaries of the fire ignition source were ignited (with a similar use of the term "outside the fire ignition source" implied).

Any two of the following:

- Actuation of an automatic detection system,
- A plant trip was experienced,
- A reported loss of greater than $5,000 (not including any lost business damages), or
- A burning duration or suppression time of 10 minutes or longer.

4.1.2 Subjective Criteria – Potentially Challenging

- There are indications that flames or heat were generated of sufficient intensity and duration to cause the ignition of secondary combustibles outside the fire ignition source, had such been in close proximity to the ignition source.
- Substantial smoke was generated (e.g., a room was reported to be smoke-filled when first responders arrived on the scene, or the report includes a description such as "heavy" or "dense" smoke).

4.2 Revised Fire Incident Severity Classifications

In order to better characterize and assess the significance of fire events contained in the EPRI Fire Events Database (FEDB), three fire severity categories are proposed. These are challenging, potentially challenging, and non-challenging. 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:** Challenging (CH) 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. The size of the fire is not the only determining characteristic, but rather the ability of the fire to adversely affect components beyond the initial fire source. These include fires in the growth, fully developed, and decay stages as defined in Appendix A. 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 (e.g. an explosion and resulting fire at a main transformer that is limited to the main transformer would be classified as challenging).

- **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 could include failure of any successful defense in depth fire protection measure, delays in successful intervention actions, and occurrence of a similar fire involving an alternate fire ignition source[2]. 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 a challenging fire.

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 essentially 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 using the criteria provided in Appendix B. Another typical example of non-challenging would include component overheating incidents with light or moderate smoking but without any flaming. 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 (e.g., an automobile fire in an on-site parking lot or an off-site grass fire). Fires that occurred during plant construction would also be classified as non-challenging. (See additional discussion and criteria in Appendix B, Section 2.5).

The "Undetermined" classification has been divided into two categories to represent the events that do not have sufficient information to classify as challenging, potentially challenging, or non-challenging as follows:

- **Undetermined (PC-CH)**: These are fire events that are considered at least potentially challenging based on available information, but there is insufficient information to reasonably determine if the fire should be classified as challenging.
- **Undetermined (NC-PC):** These are <u>potential</u> fire events where there is insufficient information to determine if the event should be classified as potentially challenging or non-challenging.

[2] For example, a fire occurring in an unvented electrical cabinet might be contained within the cabinet and have relatively low severity; however, if it had occurred in a vented cabinet the potential for a more severe fire that could damage nearby cabinets would exist. Therefore the unvented cabinet fire is likely to be "potentially challenging".

Note that the fire severity classifications cascade downward from most severe to least. This allows for identification of mutually exclusive classifications and gives preferential classification precedence to the higher severity categories.

Table 4-1
Characteristics of the Events used to Characterize and Event from the Available Fields in the FEDB

Event Classification	Event Sub-classifications
CHALLENGING (CH) 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 would have readily occurred had the fire been in a different location.
	Damage to or ignition of an adjacent object, cable, or component could have occurred if significant suppression actions[1] had not been taken.
UNDETERMINED (PC-CH)	At least a PC fire, with insufficient information available to make a definitive CH finding.
POTENTIALLY CHALLENGING (PC) 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[1] 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[1] were not taken in a timely manner. Delayed detection could lead to a delay in taking such actions.
UNDETERMINED (NC-PC)	Potentially a fire, with insufficient information available to make a definitive PC finding.
NOT CHALLENGING (NC) 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.
	Other specific smaller fire incidents with specific characteristics[2].

Note 1: Significant suppression actions include as the manual use of hose streams and the automatic/manual activation of sprinklers, deluge systems, Halon systems, or CO_2 systems. Minor suppression activities include lesser actions such as the use of a single portable extinguisher or other relatively simple and prompt actions to suppress the fire. Section 4.3 and Appendix B provide additional discussion and examples.

Note 2. See Table 4.3 for a list of specific PC to NC override types of fire events and Appendix B for discussion of specific criteria used to determine PC to NC override classifications.

Based on these classification descriptions, a set of sub-classifications that were derived as summarized in Table 4-1. These were used to establish rules for identifying specific characteristics by which the event classifications could be made. The event sub-classifications in the table form a logical structure under which an event severity may be classified. The intent of Table 4-1 is to provide a logical structure for placing various events into one of the severity categories using sub-classification definitions. The sub-classifications provide a broad definition that logically progresses from the most obvious to the least. The specific event characteristics that would support an event classification into one or another severity group are described in detail in Appendix B. Section 4.3 describes a logical structure for making preliminary severity classification determinations based on the entry values for various data fields. 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 (with appropriate documentation of the rationale for the final characterization which is not always available in the previous database).

4.3 Fire Incident Severity Determination Algorithm

The fire severity determination criteria originally developed in NUREG/CR-6850 and refined in this report are only connected in a general way to the FEDB data elements. Therefore the FEDB data fields and definitions were examined to determine how they could be applied more directly in a logical and objective manner to make a preliminary fire severity classification determination. The intention was to quickly help the analyst focus on aspects of the fire that support or are missing in the fire severity determination. The fire severity classification criteria and guidance in Appendix B was used to identify the individual and combinations of specific data fields applicable to each fire severity classification. Some data fields were modified to better capture fire severity details that relate the classifications. Others were removed when their use and value could not be established in consideration of the effort to collect and maintain such data. Table 4-2 provides a summary of the data field elements that apply to the fire severity classifications.

Table 4-2
Relationship of Fire Severity Determination and FEDB Data Elements

Challenging Criteria (CH):

Any of the following:

High Energy Arcing Fault

Explosion

Fully developed compartment fire

Severe Smoke or High room temperature– full protective clothing needed for room entry

Severe room temperature – room entry not possible without venting or mitigation

Fully developed room fire – flames outside the compartment

Fire damage beyond the component of origin

Evidence of collateral damage due to heat (scoring, charring, warping, melting)

Evidence of secondary ignition

Detection due to heat sensor – thermal detector, ultraviolet flame detector, sprinkler flow alarm

Suppression by – automatic fixed suppression systems (thermally actuated or unknown), deluge, hose stream or AFFF Foam

Specified combinations of the following:

Suppression modes: Automatic fixed suppression – smoke detector; Fixed suppression – manual; Portable manual system; multiple portable fire extinguishers

Room states: Moderate smoke; Heavy smoke; Moderate temperature – protective clothing not needed

Fire brigade involvement for fire durations typically $\geq$ 10 minutes

Potentially Challenging Criteria (PC):

Not Challenging AND one of the following:

Open flaming (small); Flaming internal or external to component that does not meet the automatic override criteria for hot work or test and maintenance fires

Combination of smoldering combustion and moderate smoke or temperature in room

Heavy smoke –SCBAs needed

Combination of Moderate Smoke and power supply removed

Suppression by: manual actuation of fixed suppression system; portable manual system (e.g. CO_2 cart); multiple portable extinguishers

Fire fighting duration $\geq$ 30 minutes for events where fire brigade provides initial attack

OR

Fire fighting duration $\geq$ 30 minutes for events where first responders provide initial attack:

OR

Any two of the following combinations. The four combinations are: detection (smoke detector, gas ionization, automatic fixed...) plant condition (SCRAM, TT, LOOP) fire fighting (brigade >10) fire fighting (first responder >10)
Not Challenging Criteria (NC): Not Challenging, Not Potentially Challenging, and no unknowns that would change event to PC or CH Overheating – no smoldering or flaming combustion Self – extinguished without ANY intervention
Undetermined Criteria [U(PC-CH) or U(NC-PC)] : One or more "unknown" fields exist which could result in challenging (CH), potentially challenging (PC), or not challenging (NC) classification.

The specific data field elements were then used to develop an "algorithm" that related the FEDB data fields inputs to the severity classifications. The relationship between the data field elements and values are not precise, and are not considered definitive. The algorithm is intended to be used to assist an analyst by providing an initial assessment of the severity of fire events based on the factual data in the coded fields for each event in the updated FEDB. A logical description of the fire severity classifications for challenging (CH), potentially challenging (PC), and non-challenging (NC) were developed.

The overall logic proceeds from most severe (CH) to least severe (NC) with the requirement that an event has to be deemed not to be challenging (CH) before it can be deemed potentially challenging (PC). Similarly, an event must be deemed not to be potentially challenging (PC) before it can be deemed non-challenging (NC). In the cases where information is lacking to ensure that an event doesn't meet either the CH or PC criteria, it is given an initial classification of U and additional information is sought from the plant where the event occurred in order to make a more definitive severity classification. The undetermined fire incidents are classified as such when the reported information is missing, incomplete, or is otherwise not definitive for data fields that pertinent to the outcome of a logic grouping. This approach designates the event as being undetermined as either U (NC-CH) or U (PC-CH), depending on available information in the data fields for the incident. Additional discussion and detail providing the logical connection of fire reporting data fields to the fire severity criteria are provided in Appendix B.

Because the fire severity algorithm is imprecise and tends to conservatively interpret the FEDB data field values with respect to fire severity classification, some additional fire severity classification "override" criteria were developed for cases where non-challenging classification

would be more appropriate than potentially challenging. The "override" criteria categories are listed in Table 4-3. The detailed guidance for applying override categories are provided in Appendix B. While not incorporated directly into the algorithm due to their interpretive nature, the override criteria are noted in a pick list box adjacent to the analyst review outcome box. The guidance on applying the override is provided in Appendix B.

Table 4-3
Fire Severity Override Categories (Potentially Challenging to Non- Challenging)

Hot Work Fires Extinguished by a Posted Fire Watch
Equipment Failures during Monitored Test and Maintenance Activities
Materials Overheating on a Diesel Generator Exhaust Manifold
Smoking Materials on a Hot Pipe or Bearing Housing
Individual Sub-Component Failures Not Resulting in Flaming Combustion
Lighting Ballast, Wall Outlet and Switch Failure Events (110/220 VAC)
Self Extinguished Events (clarification)
Outside Protected Area (not fire PRA applicable)
Other basis (specified for each event application)

4.4 Implementing the Fire Incident Severity Determination

The new FEDB automatically provides a preliminary severity classification once the factual coding for the event is entered. This algorithm described in Section 4.3 was developed to make a preliminary assessment based on the factual information coded into the FEDB for each fire event. The analyst was responsible for review of the preliminary classification as well as the final classification for algorithm derived non-challenging classifications and potentially challenging classifications that did not receive an override. All overrides, challenging event classifications, and events with questionable coding or classification criteria applicability were reviewed and signed off by a senior analyst. The analysts were trained and received written and verbal guidance throughout the significance determination phase by senior analysts with significant knowledge of nuclear power plants, risk assessment, and data collection/evaluation as it relates to fire PRA.

The process for implementing the fire severity determination was as follows:

- Upon completion of the coding of event details, the algorithm based incident classification is automatically generated and displayed based on completed data field inputs. The data fields that satisfy the criteria are also displayed.
- The analyst reviewed the event documentation, algorithm output, and supplemental classification criteria (see Appendix B).

- After reviewing all the event description documentation and fire severity algorithm output, the analyst could accept or "override" the algorithm based classification;
    - The analyst could accept the classification as indicated by the algorithm; additional classification criteria with basis could also be provided in the comment field.
    - The analyst may reject the algorithm based classification and "override" the fire severity algorithm output; the basis for the override that relates to specific classification criteria must be provided in the comment field.
- Results of the fire severity classifications were reviewed by a senior analyst and/or by NRC audits (also senior analysts).
- Differences of opinion were resolved and documented as appropriate in the comment field.

5
FIRE EVENT DATA ACQUISITION, CODING, CLASSIFICATION PROCESS

The data acquisition and coding process discussion provided below was based on a new approach to obtain fire event data directly from plants. The more traditional sources were found to have both content and accessibility issues that could not be overcome to meet schedule, data quality, and content requirements.

5.1 Fire Event Data Sources

The original FEDB contained fire event data for the period 1968 through 2000. Two informal, partial updates were recently made. The first update added NEIL and some LER data up through 2004. Another update included some NEIL data up through 2008. In each case there were limitations in the ability to ensure data completeness for the update periods. In addition, the updated data was recognized as a start to the eventual more rigorous FEDB update.

The FEDB has now being updated through 2009 and plans have been developed to periodically update the FEDB with newer data in cooperation with the Institute for Nuclear Power Operations (INPO). The data from the period 1968 through 1989 was retained as "archived" records; meaning the form, content, and quality are being maintained as is, and are available for search and extraction from the proprietary version of the full FEDB. The existing data from 1990 through 2000 has been "upgraded" where practical to be consistent with the newer data (post 2000 period) for both factual details and fire event severity classifications. This aspect of the updated FEDB is discussed further below. The newer data has been collected and maintained in accordance with the revised FEDB data fields and classification schemes to the extent such information is available or can be reasonably obtained. Future data is expected to be collected and maintained in accordance with the full set of updated data fields.

The FEDB data sources consist of the following: NEIL fire incident reports, Licensee Event Reports and other sources from NRC (e.g. Emergency Notifications, Inspection Reports), Equipment Performance Information Exchange data, fire PRA data, and plant fire incident reports. Brief descriptions of these data sources are provided below.

NEIL Fire Incident Reports:

NEIL maintains a database that captures fire incidents for which insurance claims have been made, and other lesser fire incidents reported by nuclear plants. The reporting of fire incidents with claims of $100,000 or greater are required, but events with much lower claims are also voluntarily reported. A detailed and structured reporting form and associated database have been implemented by NEIL to capture this data. This data source is proprietary to NEIL and its members.

Licensee Event Reports and Other Sources from NRC:

Public fire event records are available that are reported to the U.S. Nuclear Regulatory (NRC) under the requirements of 10 CFR 50.73. NRC requirements for LER's are documented in NUREG-1022, Event Reporting Guidelines. The 10 CFR 50.73 reporting requirements were not specifically written for fire events; however fires are reported in LERs in any of the following three situations:

- The fire is part of an accident sequence that causes the manual or automatic activation of any reactor protection system listed in 10 CFR 50.73(10CFR50.73(a)(2)(iv)(A)).
- The fire is part of a plant condition that requires reporting, e.g. principal safety barriers are seriously degraded or creates a condition prohibited by Technical Specifications (10CFR50.73(a)(2)(i)(B) or 10CFR50.73(a)(2)(ii)).
- The fire poses an actual threat to the safety of the nuclear power plant or significantly hampered site personnel in the performance of duties necessary for the safe operation of the plant (10CFR50.73(a)(2)(iii)).

The following types of events may be reported in ENs per 10CFR50.72.

- The declaration of any of the Emergency Classes specified in the licensee's approved Emergency Plan (10CFR50.72(a)(1)(i)).

Equipment Performance Information Exchange (EPIX) Data:

EPIX is an equipment failure and performance database that provides information at the component level failures that can affect component reliability. It is operated by the Institute for Nuclear Power Operations (INPO). The data is proprietary to INPO and its members. EPIX is not a fire incident reporting system, but captures equipment failures that are caused by or initiated by fires. Therefore it has limited fire incident detail.

Fire PRA Data:

At the time of the writing of this report, at least two PRAs have been completed to support NFPA 805 requirements, and several others were in progress. One element of the PRA process as described in NUREG/CR-6850 is to collect plant specific fire incident data. This data is a potential source of information to ensure completeness and provide some missing information that may be needed for fire incident records derived from NEIL, NRC, and INPO data sources.

Plant Fire Incident Reports:

Plants have a variety of operational data collection and internal reporting systems. Fire incidents are captured in these systems, most typically in "condition reports" (CRs). Detailed reporting of fire incidents varies, but it is sufficient to support NEIL, NRC, INPO, and fire PRA activities and requirements. These reports may have more descriptive information and details than are needed to support the other fire reporting activities, and may be appended to reports in those systems for clarification. This data source is the most complete and has been selected as the principal data source upon which to build the updated FEDB.

5.2 Fire Event Data Acquisition Process

After an assessment of the suitability of the existing fire event data sources, it was determined that the limitations in event detail and completeness of reporting fire events would require an alternative approach to acquiring the high quality and complete data to support FPRA activities identified above. In order to ensure completeness and quality of detail commensurate with the importance of fire events, a data collection, screening, and assessment process was selected that allows for "complete" accounting of real fire events and acquisition of fire details on the most significant of fire events consistent with FPRA needs and in accordance with the classification criteria provided in Chapter 4.

This approach has been depicted as an inverted pyramid data collection, screening, and evaluation scheme shown in Figure 5-1. The process starts with a broad and course screening of fire related events obtained by plants using a fire related keyword search of corrective action program or equivalent databases. The keyword fire records data search was performed at each participating plant in accordance with specified keywords (e.g. fire, smoke, burn, explosion, extinguish and their variants). Only rudimentary event identification information was requested at this stage (date, identification number, title) for event descriptions that include at least one of the keywords. No event review or screening by plant personnel was requested. The idea was for plant contacts to search their database(s) for fire data and return a list of all events identified that contain any of the keywords. A fire event search template was prepared to facilitate this activity. Between 1000 and 5000 keyword search record hits were typically obtained for each plant.

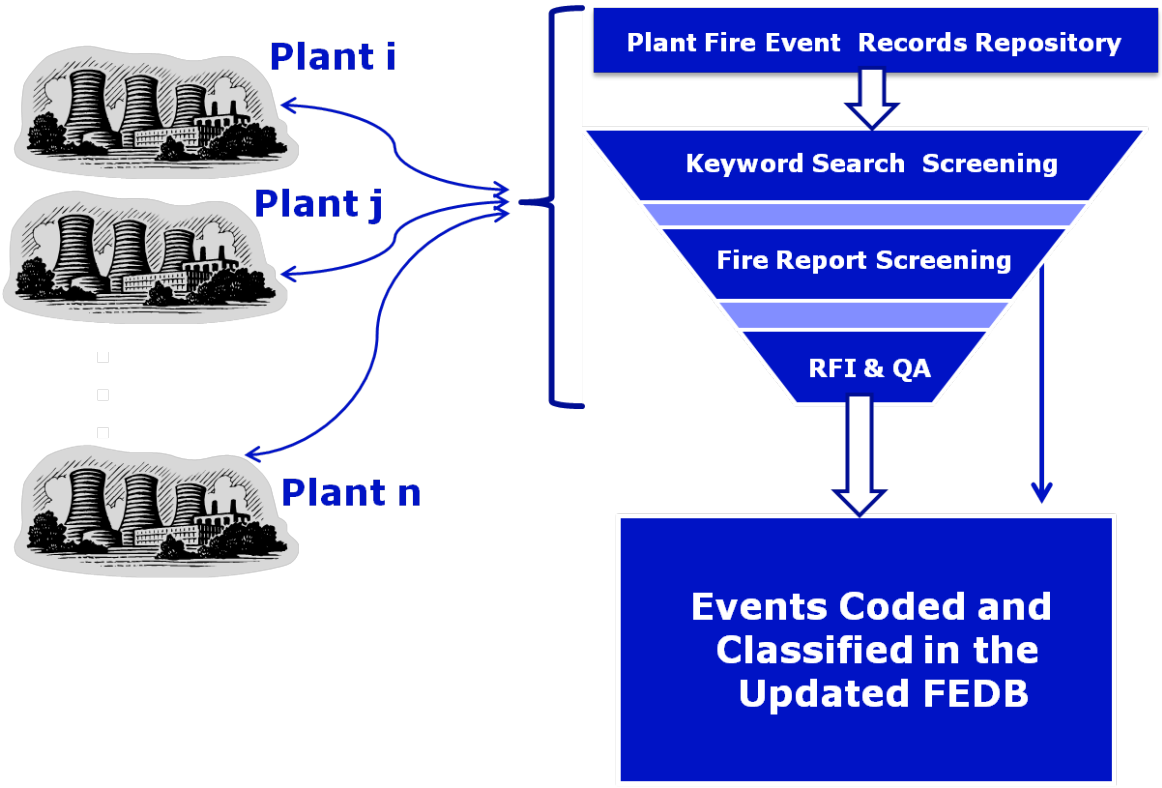

Figure 5-1
Conceptual Fire Event Data Collection and Screening "Inverted Pyramid"

The results of the fire event keyword search were provided to EPRI for further screening. The PWR and BWR Owner's Groups assisted EPRI in performing that screening to identify potentially "real" fires. This substantially reduced the number of fire events that require more detailed review to about 100-300 events per plant. After that screening was completed, the plants were contacted again to obtain the full reports (as available) for the selected potentially "real" fire event records. Then EPRI performed a review of these more detailed fire event records to identify "real" fires. The screened real fire events are retained and coded within the updated FEDB. This resulted in the selection of around 5-50 events per plant that were coded into the FEDB. As the event records were typically condition reports that were not intended to collect fire event details desired for the FEDB, it was necessary to request additional event information from plants for the most important fire events where key fire severity classification information was missing or ambiguous. As part of the request for information (RFI) the plants were requested to perform a check on the coding or exiting information from the CRs in the FEDB.

This process was applied to fire event data collection for the period 2000-2009. There were additional fire events in the FEDB from the 1990-1999 time period that were retained from the original FEDB. Many had missing or questionable coding. They were also included in the plant fire record RFIs, again on an as available and practical basis. In addition, the plants were asked to identify and provide reports on any other fire events in that period that they were aware of including NEIL and EPIX reports.

During and after the RFI process, many calls and emails were made to plants to ensure that the information was provided in as complete and accurate a manner as reasonably possible given the age of the information being requested.

5.3 Fire Event Data Processing

5.3.1 Keyword Search Screening

The screening review of the keyword search results provided by each participating plant was to determine which events are possibly real fires. The keyword search screening review was performed by the PWR and BWR Owner's groups. ERIN performed an audit check of the screening results for quality purposes and to capture the data in a temporary fire event data repository.

Fire related events with any of the following characteristics (affirmative criteria) were selected for further review and disposition:

- A valid fire alarm was actuated (manual or automatic).
- Active fire suppression or fire control actions occurred (manual or automatic).
- Actual flames or smoke were observed.
- Actual fire damage (smoke or heat) was noted.
- An active decision was made to allow the fire event burn out without suppression or intervention.
- Any of the above conditions are possible but information provided is inconclusive.

The magnitude or severity of the fire condition was not used as a screening factor.

The following are exclusion criteria were also used for excluding events from selection for further consideration as potentially real fires (negative criteria).

- False alarms,
- Fire protection equipment malfunctions that were not associated with the occurrence of an actual fire event.
- Compliance deficiencies (such as barrier deficiencies, fire program deficiencies, or alarm/suppression system capability deficiencies that were not associated with the occurrence of an actual fire event),
- Events related to fire protection equipment testing and/or drills that were not associated with the occurrence of an actual fire event.

Any events that are considered uncertain regarding whether or not they meet the selection criteria and do not meet the exclusion criteria were included (selected for processing into the FEDB).

5.3.2 Screening Potential Fire Reports

A second screening of potential fire events selected from the keyword search was performed based on the full fire event report applying the criteria below. The intention is to capture fire related events using broad definitions of what constitutes a fire event and exclude only those events that were obviously not fire events from the database.

Events were screened in with the following characteristics:

- Fire observed- Events screened in due to observation of a fire automatically go into the FEDB regardless of size, duration or suppression. Fire is defined broadly and includes smoldering, electrical arcing or sparks, and any flaming combustion.
- Valid Fire Alarms – Events screened in due to a valid fire alarm automatically go into the FEDB. Some alarms may be determined to be false based on the report.
- Collateral damage – Events screened in with damage occurred beyond the source of the event automatically go into the FEDB even if no flame is observed.

When none of the above "screen in" criteria apply, events may be screened out if they meet one of the exclusion criteria provided below:

- False Alarms – Reports may state that an alarm was a malfunction. These may be screened out if there is no sign of fire.
- Fire protection equipment malfunctions – Cannot be associated with the occurrence of an actual fire event.
- Compliance deficiencies – Examples include barrier deficiencies, fire program deficiencies, or alarm/suppression system capability deficiencies that were not associated with the occurrence of an actual fire event.
- Events related to fire protection equipment testing and/or drills – Cannot be associated with the occurrence of an actual fire event.

- Not a fire related event – This criterion cannot be used if there is any smoke, sparking, arcing, smoldering, overheating, or a valid fire alarm. This criterion should be used to screen out events such as alarms that did not involve fire related physical conditions such as spilling or leaking of flammable fluids and equipment malfunctions that did not cause any fire related physical conditions or smoke.
- Outside fire PRA scope – Some events occur in areas or involved sources that were outside the scope of the internal hazards fire PRA. Fire related events in the turbine building and switchyard were INCLUDED, screened in, even if they were outside the Appendix R scope.
- Self-Extinguished events – Events may be excluded if the event involves a post mortem observation of fire related damage to a small portion or sub element of the component and no human intervention or active suppression was required to prevent the spread of damage. There should be no indication of sparking, arcing, smoldering or flaming for these events, nor any indication of active fire suppression, if the event is screened out. This criterion is intended to screen out incidents involving "burnt" resistors, contacts, relays, and electronic cards. When in doubt or uncertain, the events were screened in for further evaluation by EPRI.
- Smoke Events – Events due to smoke from overheating may be screened out if the smoke produced is light and there is no evidence of flaming combustion. Events with sparking, arcing, smoldering or flaming should be screened in for coding in the FEDB. Light smoke is defined as a thin low-density plume of light-colored (white or light grey) smoke. Smoke would dissipate quickly and have a negligible effect on the room conditions for even a relatively small room. Human intervention to stop light smoke events prior to becoming actual fires is acceptable when screening these events out from the FEDB, if personnel were continuously present during the evolution leading to the smoking condition such as a surveillance test, maintenance work, or other activity. For example, if something is overheating during a test producing light smoke and gets turned off before anything more severe occurs, it may be screened out and does not go into the database. In cases where the discovery of the smoking event occurs by happenstance (a person who happens to walk by a component and smells or sees smoke), then the event should be screened in. The intent is to distinguish between events where personnel are continuously in the vicinity of the event from those where the event occurs without regard to human presence at the time of the event. When in doubt or uncertain, the events were screened in for further evaluation by EPRI.
- "Other" – Events may be screened out under the other criterion **with a written explanation**. The two common examples are:
    - Operating Experience – Many events were screened out that described operator experience at other plants.
    - Duplicates – Some events are described in multiple reports. Provide the report(s) that best describe the fire.

When in doubt or uncertain, the events were screened in for further evaluation by EPRI.

5.3.3 Fire event data coding, RFI, and Associated Review

The fire event data that passed the keyword screening and supplemental fire event report screening became the primary source of new data for the FEDB for the period 2000-2009. The factual information from those fire event reports was reviewed and details were extracted to fill the factual and incident descriptive data fields of the FEDB. The coded factual data and any additional descriptive information collected provides the information needed to derive or infer input to the evaluated data fields, especially the fire event severity classification. The data fields are described in Chapter 3 and detailed definitions are provided in Appendix A. The fire event severity classification is discussed further in Chapter 4.

Key elements of the of the data coding process were acquisition of fire event data source records (reports), coding fire event report information in accordance with written guidance to reviewers, making derived and inferred data evaluations, and data coding and traceability of the data field entries to source documents. The fire event report reviews, coding, and review were carried out by trained nuclear power engineering and operations professionals using detailed coding guidance derived from Chapters 3 and 4, and Appendices A and B. Senior nuclear power engineering and operations professionals made the final determinations required for the derived or inferred data fields that relate to the fire severity determination.

There were several elements of quality assurance that were incorporated into the data processing activities. These included: completeness assessment of the incidents within the data collection period for the various data sources; completeness evaluation of the data source material for each incident; rectification of discrepancies between sources for the same incident; documentation of data entry judgments that are not clearly traceable to data source material and coding guidance; reviews to ensure that the intended coding has been entered correctly; traceability of data field inputs to source data; and identification of responsible data coders and reviewers. An FEDB integrity plan was prepared and implemented to ensure that these quality issues were incorporated into the process as necessary and practical to achieve an essentially error free and complete fire event database.

Missing and uncertain information that was important to the incident description and determination of event severity was identified for further follow up and documentation. This was implemented through a Request For Information (RFI) and review by the plant point of contacts that supplied the fire event reports initially. They were specifically asked to perform a plant specific review of the fire event information extracted from the fire event reports and coded in a working draft version of the FEDB. They were also requested to provide some specific additional information that may be available for these events to help clarify or add details to enhance the FEDB completeness as may be "reasonably available and obtainable". This specific information request was targeted to help more accurately establish the severity of each fire event and its applicability for use in fire PRA's including development of updated fire frequencies, non-suppression probabilities, and fire modeling benchmarks.

The RFI also included the older FEDB data from 1990-2000, but recognized the potential difficulty in checking the completeness of that data set or obtaining additional clarifying details. Source documentation for these older events that was extracted from the original FEDB and compiled in the updated FEDB was provided to the plants. The additional information requested for this data set was also targeted to support fire event severity determinations and requested on an as "reasonably available and obtainable" basis. Not unexpectedly, the supplemental fire event

information available and provided was quite a bit less than that for the fire events of the more current time period.

5.4 NRC Audits

An important aspect of the FEDB quality assurance was the audits that were conducted by the NRC Office of Research with consultant support from Sandia National Laboratories and Idaho National Laboratory under the NRC-EPRI memorandum of understanding. This helped assure accuracy and completeness of the database as well as achieving a strong degree of agreement on the fire severity determinations. Three NRC audits were conducted.

The first NRC audit focused on the data acquisition and screening process as described in Section 5.3. It included a review of the screening guidance and criteria as well as initial implementation of the process. Issues were identified and recommendations for modifications were made to provide a somewhat broader fire event screening criteria that captured more events for second phase reviews or supplemental data requests (RFIs).

The second NRC audit included a review of the modifications made to process and specific data identified in the first audit, but focused more on the initial implementation of the fire severity determination and associated criteria. Some special rules were discussed based on the initial preliminary for severity determinations for making algorithm overrides on specific types of smaller fire events that were being inadvertently classified as potentially challenging. Some specific examples of events that should be overridden and those that had questionable classifications were identified for later resolution.

The third NRC audit focused on the proposed final fire severity classifications and how the override rules were implemented. Additionally, fire events that were retained in the FEDB from the original FEDB for the time period 1990-1999 were also reviewed. The outcome of the audit identified a relatively small subset of events where fire severity classifications were questioned and ultimately resolved.

In the end, the NRC audit findings were addressed for specific event coding and severity classification discrepancies as well as guidance and criteria for fire event coding and severity classifications. Given the data limitations with respect to details (completeness), the NRC audits were considered an integral part of achieving a practical level of FEDB quality and credibility.

6
FEDB SOFTWARE AND USERS REPORTS

This section describes the software that was used to process and store data for the updated FEDB and the FEDB reports that are available for general use.

6.1 FEDB Software

The updated FEDB software was used to process raw fire event data records into the FEDB data fields and to perform the fire severity classification activities. This updated FEDB is proprietary due to the plant specific identification associated with raw fire event data records that are an integral part of the FEDB. In addition, the FEDB software contains the fire severity algorithm which is only intended for EPRI use and NRC audits in accordance with the EPRI-NRC MOU.

6.1.1 FEDB Software Platform and Design

The updated FEDB was implemented in Microsoft Office Access 2007. Microsoft Access was chosen for compatibility with the original FEDB and to facilitate data acquisition process activities without relying on any specialized or otherwise unique software and servers. Microsoft Access is also widely available and fully capable of handling the data requirements of the FEDB.

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 functions that ensure data integrity. 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”, “NEIL” and “Other”.

The conceptual elements of the FEDB software are depicted in Figure 6-1.

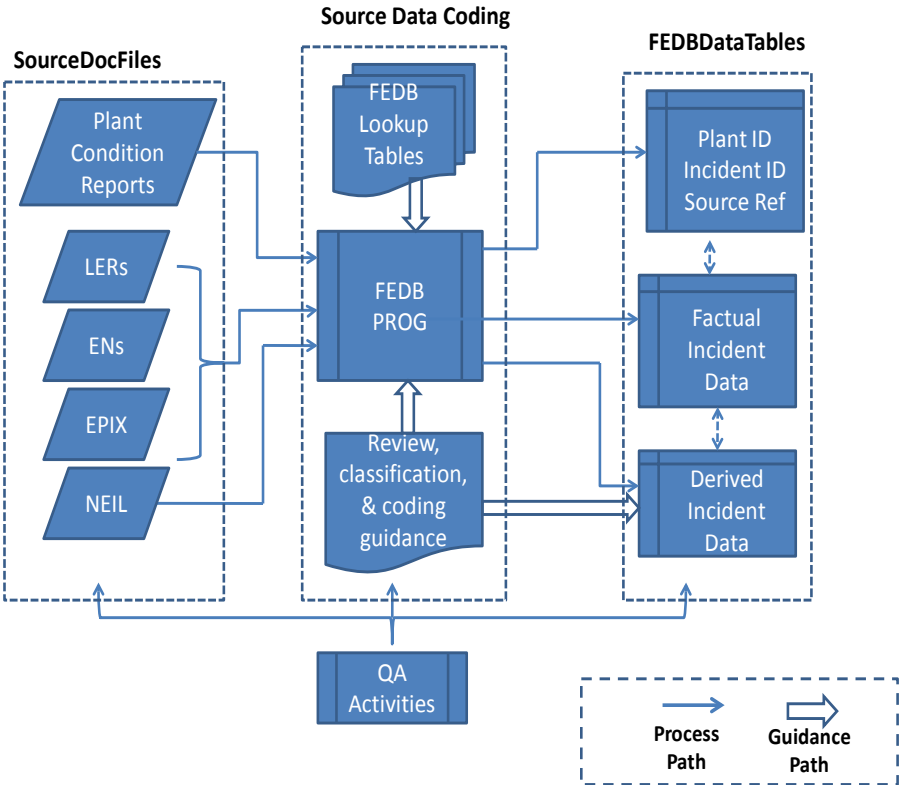

Figure 6-1
FEDB Conceptual Design

6.1.2 Direct Extraction of Data from Original Data Sources

Copies of all original data sources (raw fire event data records) are maintained in the folder "SourceDocFiles". A module in the FEDB program keeps a list of all the source document information such as docket, event date, source document number and filename. When creating a new record, a source document must be attached to the record. Built in routines only allow the selection of a source document which belongs to that docket for which the record was created. By double clicking on the source document number in the FEDB record, the original source document will be displayed. Any applicable data that can be extracted from the source document is then entered into the FEDB fire record. Often multiple data sources may be available for a single event, and each document should be reviewed to ensure as much data as possible is extracted.

6.1.3 FEDB Internal Software Validation

Initial testing of the software functionality was performed at the Idaho National Laboratory (INL). After initial testing was performed, the software was distributed to staff at the NRC, Sandia National Laboratory (SNL) and EPRI contractor staff at ERIN Engineering and Research (ERIN), Science Applications International Corporation (SAIC), and Hughes Associates for further beta testing. These additional users tested the ability of the software to be downloaded, setup and used by new users with the instructions provided in the quick start guide. Additionally, the compatibility with MS Access 2007 was verified. Initial beta testing was

performed using Licensee Event Reports (LERs) from 2000 through 2008 as well as approximately 10 events from 1990 through 1996 that had previously been categorized as "undetermined" in previous fire PRA efforts. Initial beta testing checked the functionality of the software, as well as the validity of the data fields. Several users coded the same source document material so that comparisons could be made about the repeatability of data coding using the available coding guidance. During this process, refinements were made to the data software as well as the pick lists.

6.1.4 Verification of the FEDB Fire Severity Determination Algorithm

The high level conceptual logic for classifying fire events as challenging, potentially challenging, non-challenging, or undetermined provided in Table 4-1 is logically structured and appears to be complete. The logical structure derives from the fact that it is necessary to rule out the more severe classifications before proceeding to the next lower severity and the characteristics for each classification clearly specify the properties that allow inclusion of an event in that classification.

The conceptual algorithm presented in Table 4-2 represents a method for implementing the fire event classification scheme in Table 4-1 based on factual data entries into the new FEDB. It presumes that the fire event reporting information is sufficient to allow coders to enter values in each of the key fields. On that basis, the algorithm as defined in Table 4-2 and discussed in more detail in Appendix B is consistent with the characteristics in Table 4-1 to allow classification of the severity of fire events.

6.2 FEDB Users Reports

The non-proprietary data records of the FEDB are available to the FEDB users in Appendices C through G of this document. The reports include the fire event data fields and associated coded data from PRA countable fire events except those fields that contain plant identifier information. The FEDB reports do not contain the raw fire event data records that are proprietary to the individual plants. The appendices are structured in accordance with the data field structure provided in Section 3 of this report. PRA countable fire events include those events with greater than "Non-Challenging" fire severity determinations. The content includes events classified as "Undetermined".

In some fields, the text included by the analysts contains information that could be used to identify plants, utilities, or individuals. This text has been redacted in the users reports. Redaction is in the form of "ooooooooo".

7
OVERVIEW OF UPDATED FEDB CONTENT FOR INITIAL ISSUE

This section provides summary descriptions of the content of the updated FEDB in the form of tables and figures that characterize the counts and nature of the events in the FEDB. The updated FEDB contains data from the period 1990-2009; however, the data collection process was different for the period 1990-1999 and 2000-2009, with one overlap year. The data collection process is described in Section 5. The original FEDB was the principal data source for the period 1990-1999; however, some additional data was collected for that period. On the other hand, some of the original FEDB data for period 1990-1999 was reclassified, in most cases to a non-challenging fire severity category, but not always. Therefore the data characterization summaries provided below have been divided into 1990-1999 and 2000-2009 periods.

A second distinction has been made for fire event data provided in the updated FEDB. This is for fire events that have undergone the complete review and audit process. Fire event data that still has outstanding requests to the plants for event details and plant reviews are compiled separately and not discussed further in this report. Therefore, the data characterization summaries are provided for fire events that have completed the process.

Table 7-1 provides the data collection and review status for all plants and a complete accounting of "All" fire events contained in the FEDB.

Table 7-1
Completion Status of Plants Participation in the FEDB Data Collection and Associated Fire Events

Fire Events Included in FEDB	# Plants	# Events
Complete FEDB internal review and NRC review & sign off	84	1695
Complete FEDB internal review except for audits	-	21
CRs provided and coded, RFI response incomplete	16	256
Total number of fire plants/events contained in the FEDB	100	1972
Fire Events Not Included In FEDB		
Short event description provided, CRs not received	2	317
Incomplete response to request for fire events	2	-

7.1 Number of Events in Fire Severity Categories

This section provides the high-level tally of fire event counts in the updated FEDB and their current fire severity determination status. Table 7-2 provides the count summaries for the fire events that have had complete NRC review and sign off of fire severity determination. Note that Undetermined PC-CH is included in the PC category (this grouping is used throughout this section). The table provides tallies for the period 1990-2009. The "All" group includes all categories of fire including "non-challenging" fires.

Table 7-2
Summary of the Fire Events Counts that have completed the review and audit process

PERIOD	Fire Event Classification Totals in the FEDB			
	All	Challenging	Potentially Challenging	Undetermined
2000-2009	1497	23	194	74
1990-1999	198	5	77	50
Total	1695	28	271	124

7.2 Types of Fires, Extent of Damage

The next set of FEDB fire event characterizations and comparisons provides indication of the sources of fire events in the FEDB and the extent of damage that was observed for those fire events. The comparisons are made for the 1990-1999 and 2000-2009 time periods for the fire events that have had complete NRC review and sign off of fire severity determination.

The extent of the fires is characterized in the following charts. Figure 7-1 provides the extent of damage for fire events other than hot work and transient combustibles. Figure 7-2 provides the extent of damage for the hot work and transient combustible fire events. Non-challenging fires are not included in these comparisons. These charts show that the majority of fires were confined to the object of origin at the time they were extinguished. That is, they did not damage nearby components, nor did they propagate to other combustibles. However, it was not possible to tell if such components or combustibles were in nearby proximity.

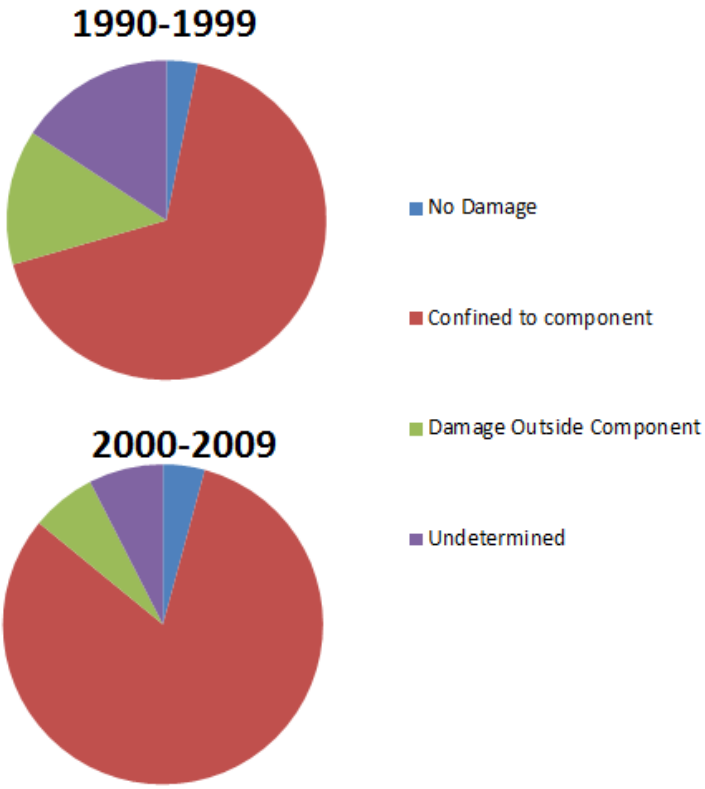

Figure 7-1
Extent of Damage for Fires Excluding Hot Work and Transient Fires

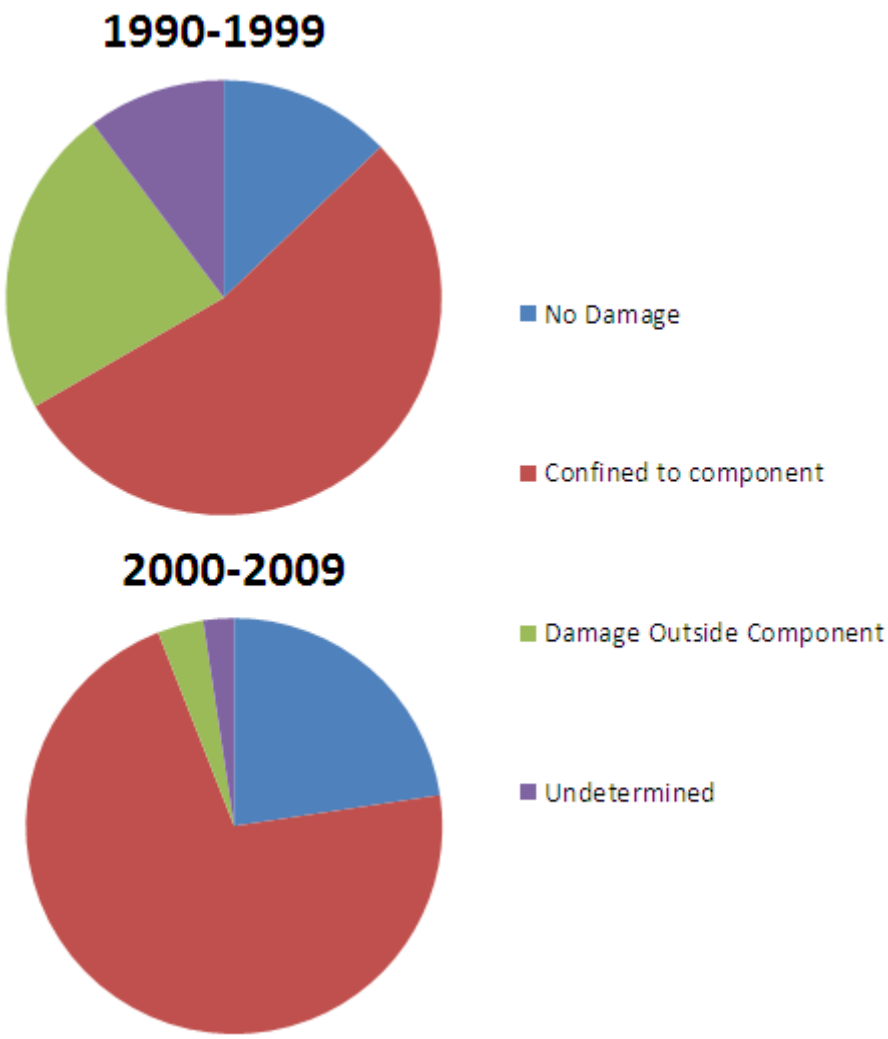

Figure 7-2
Extent of Damage for Hot Work and Transient Fires

7.3 Detection and Suppression Characteristics

The next set of FEDB fire event characterizations and comparisons provides indication of the detection and suppression methods reported for the fire events in the FEDB. The comparisons are made for the 1990-1999 and 2000-2009 time periods for the fire events that have had complete NRC review and sign off of fire severity determination. Non-challenging fires are not included in these comparisons. In both time periods, "other plant personnel" that were in the vicinity or passing by were the first to identify the fire. Removal of a power source and use of a single fire extinguisher were to two predominate fire extinguishment modes.

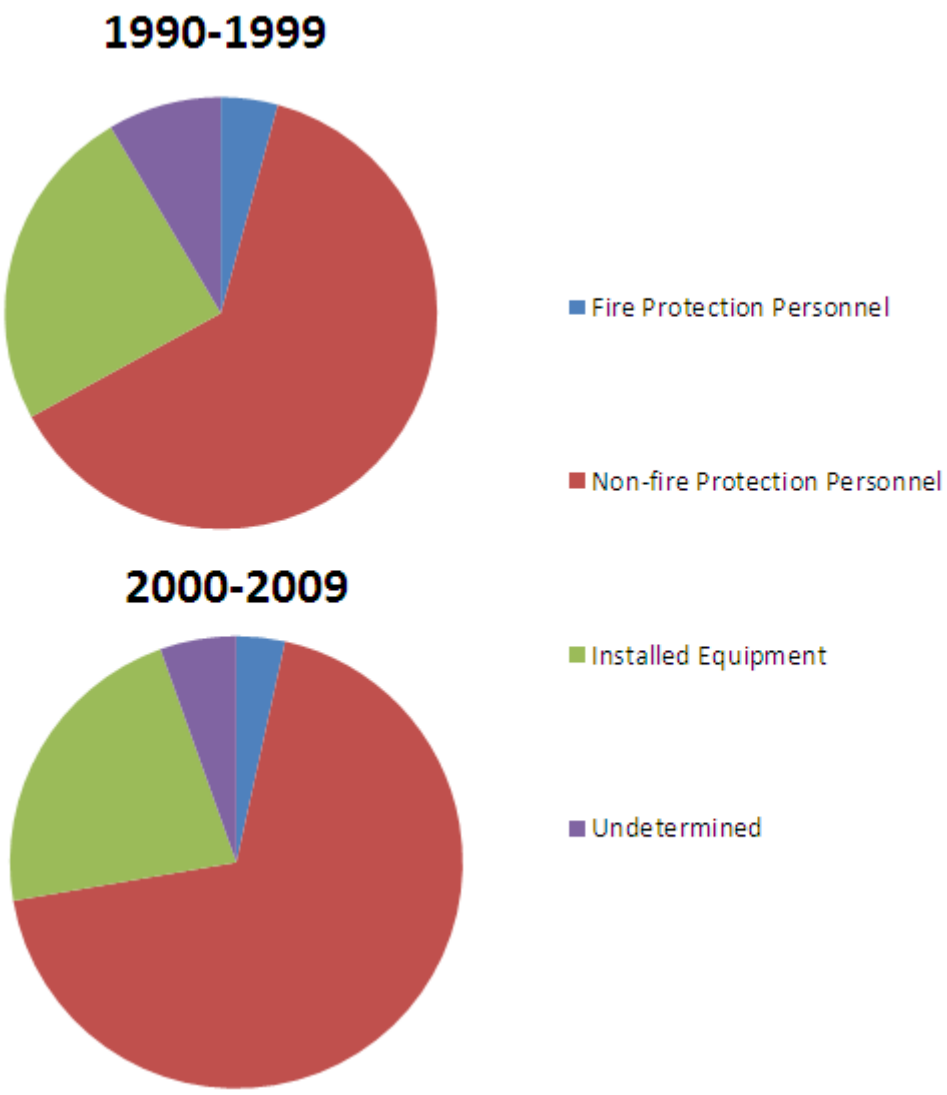

Figure 7-3
Fire Detection Method (first indication) Excluding Hot Work and Transient Fires

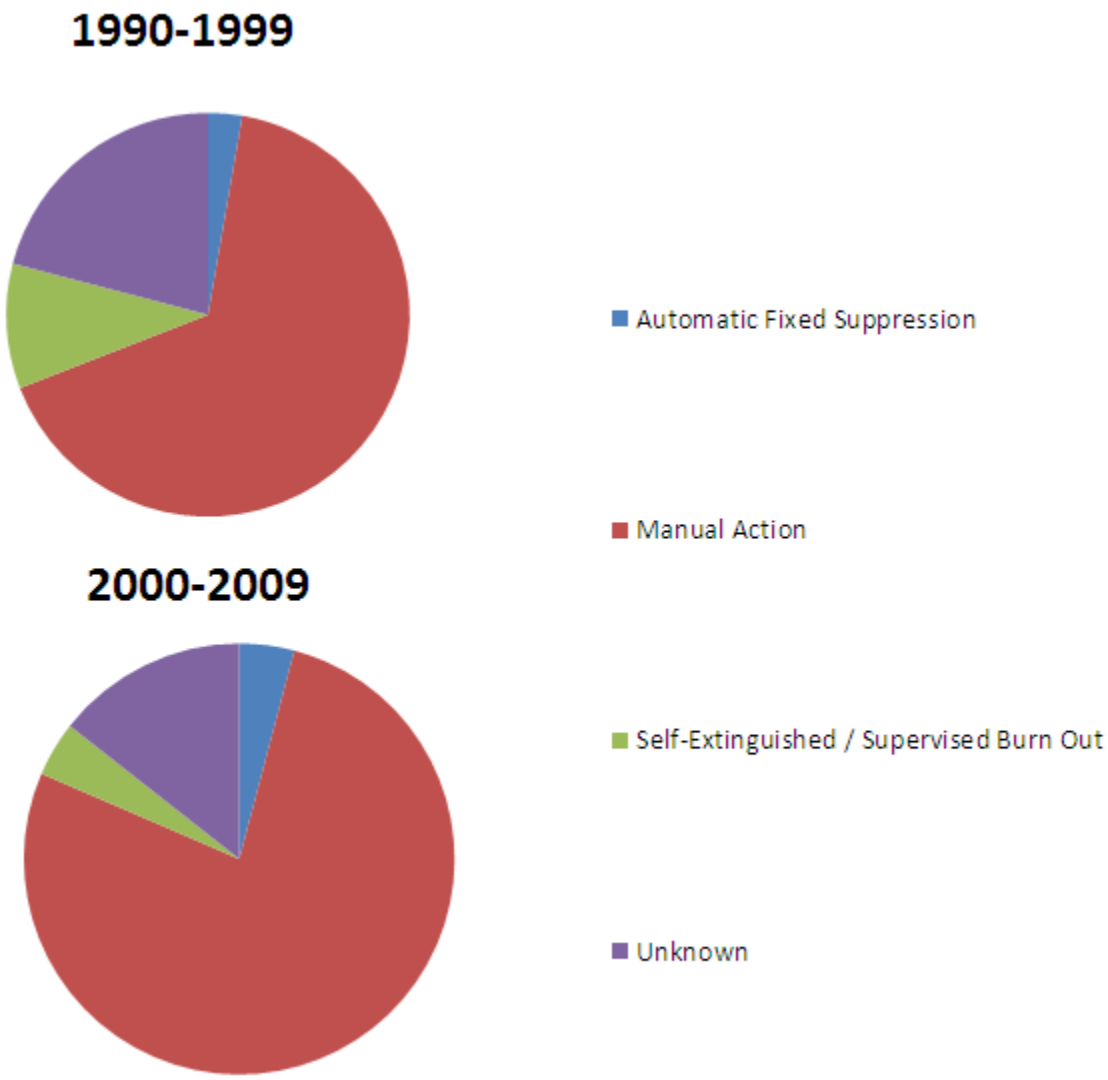

Figure 7-4
Fire Suppression Method Excluding Hot Work and Transient Fires

8
REFERENCES

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A
ABBREVIATIONS, ACRONYMS AND SUPPLEMENTAL DEFINITIONS

This appendix provides abbreviations and acronyms, and supplemental definitions and their reference sources for fire descriptive and related terms. They are used in the updated FEDB data fields, guidance, or may reasonably be expected to be used by data provides and/or FEDB data coders and reviewers in comment fields.

A.1 Abbreviations and Acronyms

AFFF	Aqueous Film-Forming Foam
BWR	Boiling Water Reactor
CR	Condition Report
CSNI	Committee on the Safety of Nuclear Installations
CY	Calendar Year
EAL	Emergency Action Level
EDG	Emergency Diesel Generator
EN	Emergency Notifications
EPIX	Equipment Performance Information Exchange System
FAQ	Frequently Asked Question
FEDB	Fire Events Data Base
FEMA	Federal Emergency Management Agency
HEAF	High Energy Arcing Fault
IEEE	Institute of Electrical and Electronic Engineers
INL	Idaho National Laboratory
INPO	Institute for Nuclear Power Operations
LCO	Limiting Condition for Operation
LER	Licensee Event Report
NEA	Nuclear Energy Agency
NEIL	Nuclear Electric Insurers, Limited
NFPA	National Fire Protection Association

OER	Operating Event Report
PRA	Probabilistic Risk Analysis
PWR	Pressurized Water Reactor
SCBA	Self-contained breathing apparatus
SNL	Sandia National Laboratories
SOER	Significant Operating Event Report
SSC	System, Structure, and Components
UE	Unusual Event
V&V	Validation and Verification

A.2 Definitions

Defining a Fire

From NEI 99-01 [1], a fire is defined as:

Combustion characterized by heat and light. Sources of smoke such as slipping drive belts or overheated electrical equipment do not constitute fires. Observation of flame is preferred but is NOT required if large quantities of smoke and heat are observed.

From CSNI R(2009)6 [2], a fire is defined as:

- A process of combustion characterized by the emission of heat accompanied by (open) flame or smoke or both;
- Rapid combustion spreading in an uncontrolled manner in time and space.

From NEI 99-01:

Describing Types of Combustion

An **explosion** is defined as: A rapid, violent, unconfined combustion that imparts energy of sufficient force to potentially damage or ignite combustible materials of nearby structures, systems, or components.

From NFPA Handbook [3], Section 2-4:

Flaming combustion: Energy production from fuel vapor mixture with air to support the presence of a flame.

From NFPA 921 [4]:

Glowing combustion: Luminous burning of solid material without a visible flame.

From NFPA 921:

Smoldering: Combustion without flame, usually with incandescence and smoke.

A **fire incident** is an event that involves any stage of fire development. NFPA 901 [5] defines a fire incident as an event involving fire to which the reporting agency responds or should have responded.

Fire Ignition is the process of initiating self-sustaining combustion [4]. Ignition occurs at the point when the first flame appears or the onset of observable (including post mortem indications) heat and smoke occur. CSNI R (2009)6 defines fire ignition as the initiation of combustion evidenced by glow, flame, detonation, or explosion, either sustained or transient. Fire ignition is also defined as the initiation of combustion [6].

Fire Progression

From the NFPA Handbook, Section 2-4 and NUREG/CR-6850 Appendix G, **general fire stages** are; Incipient, Fire Growth, Steady State, and Fire Decay.

- The incipient stage includes the time from which an overheating condition occurs with potential to cause fire ignition where there is smoldering but insufficient flaming for established burning. CSNI R (2009)6 defines an incipient fire condition as a small or initial phase of fire that can evolve to a fully developed fire, if nothing is done.
- The fire growth stage occurs just after fire ignition and involves fuel controlled burning during which the heat release rate is increasing over time (e.g. t-squared burning).
- In the fully developed fire stage the heat release rate is essentially constant. The heat release rate may be controlled by the fuel package size and geometry or by the available ventilation to support the combustion.
- In the fire decay stage the heat release rate is decreasing over time as fuel depletion occurs or due to ventilation limitations.

Fire Control and Damage

Definitions used to describe fire control and containment [7]:

- **Fire Controlled Time**. The actual month, day, year, and time of day when the fire is brought under control or the incident is stabilized and does not require additional emergency resources. “Controlled” is the time when the incident commander determines that the fire will not escape from its containment perimeter.
- **Fire Contained**. That point in time when fire spread is stopped, but the fire is not necessarily under control.
- **Fire Extinguished**. That point in time when there is no longer any abnormal heat or smoke being generated in material that was previously burning.
- **Fire Under Control.** That point in time when a fire is sufficiently surrounded and quenched so that in the judgment of the commanding officer it no longer threatens destruction of additional property.

Visible (observable) damage to equipment or structures involves physical degradation that is readily observable without measurements, testing, or analysis. Damage is sufficient to cause concern regarding the continued operability or reliability of the affected structure, system, or component. Example damage includes: deformation due to heat or impact, denting, penetration,

rupture, cracking, and paint blistering. Surface blemishes (e.g., paint chipping, scratches) should not be included [1].

A.3 Supplemental Data Field Definitions

Type of fire

This field is to describe the most severe type of combustion associated with the fire during the time between ignition and final extinguishment. Select the description that best characterizes the most severe type of combustion that existed based on staff observations during the fire event and post event examinations at the fire site.

An explosion is defined as: A rapid, violent, unconfined combustion that imparts energy of sufficient force to potentially damage or ignite combustible materials of nearby structures, systems, or components.

High energy arcing fault (HEAF): energetic arcing, explosive in nature, with actual or potential severe thermal damage to nearby components and structures including prompt ignition of secondary combustibles.

A fully developed fire is one that enveloped the component of origin and a substantial amount of the fuel source has been combusted. This is the point in the fire growth where significant heat is generated with potential for or actual damage to nearby components may occur. The component of origin is the "component start" drop down pick list selection in the Location/Source tab.

Flaming combustion: The presence of a flame, no matter how small.

Smoldering: Combustion without flame, usually with incandescence and smoke. Also include Glowing combustion under this category: Luminous burning of solid material without a visible flame.

Overheating without flaming combustion or smoldering applies to events in which a heat source other than a fire produced thermal damage such as melting and discoloration, and may also include smoke, but did not result in flaming or smoldering (see above definitions) of the affected combustible materials.

Fires that have been detected and extinguished quickly or fires that slowly developed may have been limited in extent to a small portion of the fire component of origin ("Component Start"). For larger and more complex components such as electrical cabinets, this could involve a fire ignited by malfunction a small subcomponent within the cabinet that was detected and extinguished before it could propagate within the cabinet and result in fire damage or propagation to secondary combustibles external to the cabinet. Such fires should be classified as flaming or smoldering (as appropriate) combustion internal to the component. A small fire within a motor housing might be another example. Similarly, smaller fires that initiate external to the component of origin and involve a small portion of the component but are exterior to it may be classified as flaming or smoldering (as appropriate) combustion external to the component. An example would be a small piece of thermal insulation near a pump or on a diesel generator exhaust pipe that has had some flammable liquid (e.g. lube oil) deposited on it catches on fire but does not begin to grow and/or propagate before it is extinguished. A fire that involves a larger portion of the component of origin, or has flame and heat characteristics that have caused damaged or ignited nearby components would normally be considered a fully developed fire.

Extent of Source Damage

This field is intended to describe the maximum extent of the fire to help determine whether the fire conditions were sufficient to propagate to or damage equipment beyond the component (or object) of origin. The object of origin is the selection made in the "component start" pick list located in the "LOCATION/SOURCE" tab. Some components in the list are very large and contain many subcomponents or sub-elements within the "boundary" of the component of origin cited in the pick list. Those subcomponents or sub-elements may be the specific point at which fire ignition occurred within the component of origin. These may include relays, terminal points, wire/cable, and other such piece parts. For the purpose of describing "extent of source damage" they are considered part of the component (or object) of origin. In the case of hot work, the component of origin is defined as the component associated with the material that initially caught fire, not the cutting or welding sparks or slag.

Fires that are considered to be "confined to the component (or object) of origin" generally do not result in flames or significant heat output external to that component (or object) where the fire started. That is, the fire did not result in nor was there indication that it could have damaged or propagated to nearby components, even if such nearby components were not present. Fires that originate in a small sub-elements or subcomponents within the component of origin and do not spread or propagate within the component to other to sub-elements or subcomponents should be designated as "confined to the object of origin (localized/single component)." Fires that damage or spread to other sub-elements or subcomponents within the component of origin, but remain within the component of origin, are considered to have been "confined to the component of origin." If the fire damage or spread within the component of origin is significant and/or extensive, but fire effects and indications are not external to the component, they should be classified as "confined to the object of origin (broad/extensive damage)."

A small surface fire that originated on the exterior of the component (or object) of origin and does not substantially envelope the component (or object) of origin may also be considered to be "confined to the component (or object) of origin." This could include transient combustibles such as rags, duct tape, flammable liquids, trash, etc. Such fire should result in no more than small scorch marks on structural elements or other piece parts no further than about 2 inches from the external surface of the component of origin, without indication of flame propagation or functional damage to the nearby structural elements or other piece parts. If the fire involves only a very small portion of the source component, it may be classified as "confined to the object of origin (localized/single component)." If the fire involves a substantial part of the source component or grew noticeably then it should be classified as "confined to the object of origin (broad/extensive damage)."

A fire that more substantially envelopes the object of origin and has indications of flame and/or or heat effects that did or could have resulted in damage or fire propagation to nearby plant equipment, structures or other combustible materials should be considered to extend outside the component of origin. If the fire damages or propagates to a small subset of the nearby equipment, structures or other combustible materials within the room or origin, but does not involve a large portion of the room than it may be classified as "confined to part of the room of origin." A fire that has spread to and damaged a larger portion of the equipment, structures or other combustible materials in the room of origin, but has not spread outside the room, should be classified as "confined to the room of origin."

In all cases please select the description that best characterizes the maximum extent of the fire that existed based on staff observations during the fire event and post event examinations at the fire site. Note that the category "Confined to the object of origin" has two more specific choices to better describe the extent of the fire where possible. Please select the most appropriate choice when this option is/should be selected.

Suppression Method

Select the option(s) that best describes the fire suppression method that extinguished the fire. This is intended to help indicate the magnitude of the fire suppression effort needed and whether it involved/required manual or automatic actions. More than one fire suppression option may be selected when a combination of methods was used to extinguish the fire.

Note that suppression categories power or fuel supply removed have been separated into two cases:

1) Those simple manual or remote manual actions that can be taken promptly by most plant staff (e.g. flip a switch, trip a circuit breaker, turn off a valve) that may have been dispatched to investigate the condition, or were already in the vicinity of the fire, or by calling the control room to request a power or fuel supply to be remotely turned off.
2) More complicated actions that require a maintenance technician or similarly skilled staff to perform the task and may require adherence to pre-existing or specially developed procedures to deal with the situation.

Also note that self extinguished (no plant staff intervention) is only applicable when a fire is extinguished without any active suppression and manual actions including removal of fuel or power supplies. Self extinguished may include automatic actuation of protective devices such as circuit breaker or automatic fuel supply cut-off valve closure, or may include consequential disruption of power or fuel supplies. The key difference between power supply removed and self-extinguished is human action. If someone trips a breaker and the fire self-extinguishes, the suppression method was power supply removed. If the breaker automatically trips and the fire self-extinguishes, the suppression method is self-extinguished. The suppression method can never be both.

Supervised burnout is differentiated from self extinguished fires by the presence of fire monitoring and preparedness to take more aggressive fire suppression actions as needed while the fuel source for the fire is depleted (burns out). It may include steps taken to limit fire spread or damage while the fire source burns out.

A.4 Drop Down Pick Lists

Fire Cause Start drop down pick list

This field identifies the direct or proximate cause of the fire or smoke event. The fire cause factors are generally not based on root cause determinations. The classifications include the following:

Mechanical and electrical malfunctions and degradations

- Mechanical equipment malfunction/failure

- Electrical failure resulting in overheating materials
- False actuation of detector, no ignition or overheat condition
- Electrical arcing or sparks (non-HEAF)
- Overheated Material (lube oil, pump packing, thermal insulation, etc.)

Explosive or highly energetic failures and conditions

- High Energy Arc Fault (HEAF)
- Explosion (hydrogen gas, fuel vapor, other volatile fluid vapor ignition)

Personnel errors that directly result in a fire or smoke condition

- Errors during test and maintenance activities
- Misuse of heating devices
- Misuse of material ignited
- Other

Other causes

- Natural/external effect
- Suspicious
- Other (specify)
- Cause unknown

The unknown cause classification should only be used when the direct or proximate cause cannot be identified. If the cause is known but not listed in the drop down, select other and describe in the comment field.

Combustible drop down pick list

This field is for describing the fire ignition material that exhibited the characteristics of fire (e.g. flaming, smoking) when it started. For example, for hot work, the initial combustible is material near the hot work activity that caught on fire, or exhibited fire conditions (e.g. smoke). For instance, consider welding slag falling on a piece of cloth which caught on fire. In this case the initial combustible is the piece of cloth, not the welding torch or the slag that fell on the cloth. Select from one of the drop down menu choices. Select "Other" if none apply; then describe in the comment field.

Timeline tab choices

The fire duration and time to suppress or to extinguish a fire can be described by several points in a time line.

The ones used in this database are:

a. Ignition time

b. Discovery or detection time

c. Report time

d. Fire brigade, department, or other responder dispatch time

e. Fire brigade, department, or other responder arrival time

f. Fire brigade, department, or other responder first action time

g. Fire control time

h. Fire out/extinguishment time

i. Scene release time

This data field tab is intended to capture the available information on the fire event timeline to the extent it is available or can be determined. Two options are provided for capturing fire duration and timing information as may be available: (1) **Event Timeline Entry** or (2) **Estimated Duration**. When no fire event timing or estimated fire duration information is available, indicate **Unknown** in the **Fire Duration Basis** check box.

Event Timeline Entry should be used when the specific times of fire related events in the timeline list are known or can be reasonably estimated. In many or most cases one or more of the exact times are unknown, or were not recorded, and fire durations and suppression times are/or have been estimated. Enter any of the available time points and select "Known" or "Estimated" for each, as appropriate. Select "Unknown" for any time points that are not able to be provided or that may not apply. Several times may be the same, e.g. ignition time and discovery time may be the same if the fire ignited in the presence of plant staff or immediately actuated a fire detector (normally only for large energetic fires). In the case of the fire ignition time, it is appropriate to enter an estimated time that is the same time as the discovery time when there is an explosion, electrical fault, etc. that is nearly simultaneous to the discovery time. The fire brigade arrival and first action time may also be essentially the same for some fire events. In selecting the fire out time, it is possible that a fire can be put out initially and then re-flash and be extinguished a second (or more) time. In those cases, enter the time that the fire was finally extinguished, not the time it was first extinguished. If available information is inconclusive for any event time point entry, mark the time point as "unknown".

The duration of the fire event from time of detection until final extinguishment may be based on an estimate derived from fire responder observations. For this option check **Estimated Fire Duration** and select the appropriate interval provided in the **Fire Duration Estimated** drop down menu. For example, if the fire was extinguished immediately upon discovery, choose < 5 minutes selection from the drop down menu. In the case where the fire was extinguished prior to 15 minutes; choose the 10-15 minutes interval in the drop down menu.

When limited information is available, it is desirable to have both the individual times entered (if available) as well as the estimated duration.

Type of fire drop down pick list

This field is to describe the most severe type of combustion associated with the fire during the time between ignition and final extinguishment. Select the description that best characterizes the most severe type of combustion that existed based on staff observations during the fire event and post event examinations at the fire site.

An **explosion** is defined as: A rapid, violent, unconfined combustion that imparts energy of sufficient force to potentially damage or ignite combustible materials of nearby structures, systems, or components.

High energy arcing fault (HEAF): energetic arcing, explosive in nature, with actual or potential severe thermal damage to nearby components and structures including prompt ignition of secondary combustibles. These energetic or explosive electrical equipment faults are characterized by a rapid release of energy in the form of heat, light, vaporized metal and pressure increase due to high current arcs between energized electrical conductors or between energized electrical components and neutral or ground. An ensuing fire may follow a HEAF event.

A **fully developed fire** is one that enveloped the component of origin and a substantial amount of the fuel source has been combusted. This is the point in the fire growth where significant heat is generated with potential for or actual damage to nearby components may occur. The component of origin is the "**component start**" drop down pick list selection in the **Location/Source** tab.

Flaming combustion: The presence of a flame, no matter how small.

Smoldering: Combustion without flame, usually with incandescence and smoke. Also include **Glowing combustion** under this category: Luminous burning of solid material without a visible flame.

Fires that have been detected and extinguished quickly or fires that slowly developed may have been limited in extent to a small portion of the fire component of origin ("**Component Start**"). For larger and more complex components such as electrical cabinets, this could involve a fire ignited by malfunction a small subcomponent within the cabinet that was detected and extinguished before it could propagate within the cabinet and result in fire damage or propagation to secondary combustibles external to the cabinet. Such fires should be classified as **flaming** or **smoldering** (as appropriate) **combustion internal to the component**. A small fire within a motor housing might be another example. Similarly, smaller fires that initiate external to the component of origin and involve a small portion of the component but are exterior to it may be classified as **flaming** or **smoldering** (as appropriate) **combustion external to the component**. An example would be a small piece of thermal insulation near a pump or on a diesel generator exhaust pipe that has had some flammable liquid (e.g. lube oil) deposited on it catches on fire but does not begin to grow and/or propagate before it is extinguished. A fire that involves a larger portion of the component of origin, or has flame and heat characteristics that have caused damaged or ignited nearby components would normally be considered a **fully developed fire.**

Smoke drop down pick list

This field is for the most severe smoke condition of the fire event during the time between ignition and final extinguishment. Select the description that best characterizes the most severe smoke condition that existed based on staff observations during the fire event and based on post event examinations at the fire site.

The following provide additional description as to intent of the smoke descriptive data field selections:

a. No smoke present: The source of the original fault or fire was identified but, if a fire had occurred, it had already self-extinguished and there was no smoke visible. First responders might note an odor (e.g., that associated with an electrical component failure) but there would be no degradation of visibility or habitability even in a small room.

b. Light smoke: The source of the fire was observable and a thin low-density plume of light-colored (white or light grey) smoke was visible. First responders would note the odor of a fire or electrical failure, but the smoke would dissipate quickly and have a negligible effect on the room conditions for even a relatively small room.

c. Moderate smoke: The source of the fire was observable and thicker or denser plume of grey to black smoke was visible. The smoke at this level might significantly reduce visibility in vicinity of fire, but the source of the fire should still be easily located. Habitability conditions in a small-to-moderate size room might be degraded, but entry without protective equipment should still be possible. If the fire occurs in a large or open room (e.g., a turbine hall) there might be minimal degradation of the general room visibility or habitability but a more pronounced effect near the fire source would be expected.

d. Heavy smoke: The source of the fire was observable and a thick plume of dark grey or black smoke was visible. Occasional flaming may be visible in the smoke plume (intermittent open flaming). Alternatively, the source of the fire was not observable but smoke in the room of fire origin was thick enough to substantively reduce visibility in the room. Unless the fire occurred in a very large room or open location, smoke would likely obscure the vicinity of fire such that it was difficult to locate origin of fire. Room entry would still possible with use of SCBA for even a relatively small room.

e. Severe smoke: The source of the fire was observable and was producing a thick black and turbulent plume of smoke with intermittent-to-continuous open flaming. Smoke at this level would be associated with severe degradation of the room environment for even a relatively large room. Visibility would be near zero in a small-to-moderate size room. Room entry would require full turn-out gear.

f. Fire in an outside area: The fire occurred in an outdoor location, typically the switch yard.

g. Unknown: No report of smoke conditions is available.

Temperature Indications drop down pick list

This field is to describe the most severe thermal condition of the fire event during the time between ignition and final extinguishment. Select the description that best characterizes the most severe thermal condition that existed based on staff observations during the fire event and based on post event examinations at the fire site.

Select the fire type based on the totality of the fire event observations. Small fires that are put out using a single portable extinguisher, fire blanket, a gloved hand, or similar methods, and have no other indications of elevated room temperatures, may be inferred to have negligible effect on room temperature and “None” should be selected absent event observations to the contrary. “Moderate” should be selected when event observations indicate that the room temperature was elevated but not to the point that protective clothing was necessary for fire fighters to attack the fire. When protective clothing is necessary due to room temperature, “High” should be selected. When conditions are worse and it is impossible to enter the room without venting or other

mitigation, then "Severe" should be selected. For fires in outside areas where elevated temperatures are only expected in the vicinity of the fire plume, "Outside" should be selected. In the cases where the event report provides no information allowing one of the above selections, the "Unknown" selection should be made.

Extent of fire drop down pick list

This field is intended to describe the maximum extent of the fire determine whether the fire conditions were sufficient to damage equipment beyond the point of origin. Select the description that best characterizes the **maximum extent** of the fire that existed based on staff observations during the fire event and post event examinations at the fire site.

Fire Detect Method drop down pick list

Select the option that best describes the fire detection method that provided the first notification of the fire or fire condition for which a fire suppression response was initiated.

Fire Suppression Method pick list

Select the option(s) that best describes the fire suppression method that extinguished the fire. This is intended to help indicate the magnitude of the fire suppression effort needed and whether it involved/required manual or automatic actions. More than one fire suppression option may be selected when a combination of methods was used to extinguish the fire.

Note that suppression categories **power or fuel supply removed** have been separated into two cases:

1) Those simple manual or remote manual actions that can be taken promptly by most plant staff (e.g. flip a switch, trip a circuit breaker, turn off a valve) that may have been dispatched to investigate the condition, or were already in the vicinity of the fire, or by calling the control room to request a power or fuel supply to be remotely turned off.
2) More complicated actions that require a maintenance technician or similarly skilled staff to perform the task and may require adherence to pre-existing or specially developed procedures to deal with the situation.

Also note that **self extinguished (no plant staff intervention)** is only applicable when a fire is extinguished without any active suppression and manual actions including removal of fuel or power supplies. Self extinguished may include automatic actuation of protective devices such as circuit breaker or automatic fuel supply cut-off valve closure, or may include consequential disruption of power or fuel supplies.

Supervised burnout is differentiated from self extinguished fires by the presence of fire monitoring and preparedness to take more aggressive fire suppression actions as needed while the fuel source for the fire is depleted (burns out). It may include steps taken to limit fire spread or damage while the fire source burns out.

A.5 References for Appendix A

1. Methodology for Development of Emergency Action Levels NEI 99-01, Nuclear Energy Institute, February 2008.
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6. American Society for Testing and Materials (ASTM) E 176-05, Standard Terminology of Fire Standards, 2005 Edition.
7. National Fire Incident Reporting System (NFIRS) 5.0, Complete Reference Guide FEMA and U.S. Fire Administration, National Fire Data Center, January 2008.

B
FIRE SEVERITY DETERMINATION SUPPLEMENTATION DETAILS AND DISCUSSION

In order to better characterize and assess the significance of fire incidents contained in the updated EPRI Fire Events Database (FEDB), four fire severity categories were defined. These are **challenging, potentially challenging, incipient or non-challenging, and undetermined** fires. A simple definition of each category is provided in Chapter 5 followed by additional discussion of the characteristics intended to be included within the category. The classification criteria provided in NUREG/CR-6850 [1] are used to the maximum extent possible, but with some modifications to better capture the severity differences of the revised classification scheme. Additional information needed to support the revised classification is intended to be derived from the updated fire incident factual data fields.

This appendix provides additional details and discussion to that in provided in Chapter 5 in order to better indicate the criteria and intent of the classifications.

B.1 Supplemental Discussion of Intent for Fire Incident Severity Determination

B.1.1 Supplemental Guidance for Determining Challenging Fire Incidents

These are fires (or explosions) that are of a magnitude that nearby SSCs were or would have been damaged, if present, or the fire was or could have propagated to nearby combustible equipment or structures. This classification is intended to identify incidents involving actual fires that have demonstrated actual fire risk potential through direct observations of the fire and/or damage caused by it. These include the following general characteristics:

Challenging General (CG) 1. Fire was observed with substantial and self-sustained flaming combustion.

CG2. Fire would have damaged a nearby component or spread to combustible material within several feet had it not been suppressed.

CG3. Fire resulted in observable damage (including propagation) to nearby components or combustible material.

CG4. Fire resulted in substantial damage to the ignition source indicative of heat released with potential to damage or propagate to nearby components (within several feet).

Evidence of these characteristics should be derivable from proposed updated FEDB data fields, especially those under the heading **Fire duration, growth, and damage descriptive details (Chapter 4)** and may include additional information cited at the end of this appendix. Fires that meet the emergency classification criteria for an Alert or Unusual Event [2] would be expected to be captured within this classification. Using criteria developed from NUREG/CR-6850 that

most closely captures these characteristics, the challenging fires would be classified according to the following objective criteria:

Challenging Objective (CO) 1. A hose stream, multiple portable fire extinguishers, and/or a fixed fire suppression system (either manually or automatically actuated) were used to suppress the fire. In order for a fire scenario to meet this criterion when it is suppressed by fixed fire suppression systems actuated by smoke detection, the fire would have had to produce a detectable temperature increase in the general area.

CO2. One or more components outside the boundaries of the fire ignition source were affected where the term "outside the boundaries of the fire ignition source" will depend to some degree on the specific ignition source (see further discussions below).

CO3. Combustible materials outside the boundaries of the fire ignition source were ignited (with a similar use of the term "outside the fire ignition source" implied).

A fire is classified as challenging if there are sufficient indications to determine that the actual fire was self-sustaining or that it might have affected components or led to ignition of materials outside the fire ignition source. This judgment may be based on the general tone of the event report or on the observation of specific aspects of a fire event report. In general, observations of the following features in an event report are indicative of a challenging fire:

Challenging Subjective (CS) 1. It is apparent that active intervention was needed to prevent potential spread.

CS2. There are substantive indications that heat was generated of sufficient intensity and duration to affect components outside (beyond) the boundaries of the fire ignition source, had such been in close proximity to the ignition source.

CS3. There are substantive indications (**Visible (observable) damage**) that flames, heat fluxes, or hot gases were generated that could have caused the ignition of secondary combustibles outside the boundaries of the fire ignition source, had such been in close proximity to the ignition source.

Note: A discussion of "outside the boundaries of the fire ignition source" and for interpretation of intent for classifying challenging fires from NUREG/CR-6850, Appendix C and provided later in this report. It should be referred to when applying the classification criteria. Also, the ignition component is defined per the bin and component definitions in NUREG/CR-6850, Appendix C. This should not be confused with the ignition source subcomponent or ignition source combustible material which may be, and usually is, piece of the ignition component.

B.1.2 Clarification of "outside the boundaries…" for interpretation of intent for classifying fires (derived from NUREG/CR-6850, Appendix C)

With regard to the term "outside the boundaries of the fire ignition source," the intent is to establish the frequency of fires that could cause a threat beyond the boundaries of the ignition source. However, what exactly one means by the boundaries of the ignition source may need some use of judgment. This term is relatively obvious when applied to a familiar scale–i.e., to objects of an ordinary size. However, if applied with an excess of literal interpretation to very large (e.g., the turbine generator or a diesel generator) or very small objects (e.g., an individual

resistor on a circuit card), the intent can be misconstrued. The following provides case-specific examples to illustrate the intent.

Outside Boundaries (OB) 1. For self-ignited cable fires: Any fire where the failure of, or an overload on, one cable caused at least one other cable to ignite and/or fail should be identified as challenging.

OB2. For heavy electrical equipment panels such as switchgear and breaker panels: Any fire in one cubicle that caused damage and/or ignition in a second cubicle or to overhead cables should be identified as challenging. If the damage was confined to a single cubicle and had little or no potential to spread beyond that cubicle, the fire can be classified as either potentially challenging (little potential) or non-challenging (no potential). Care should be taken when fortuitous configuration factors contributed to the lack of fire spread or damage (e.g., the cubicle happened to be at the top of a stack of cubicles, in which case it would be potentially challenging).

OB3. For relay/control panels: For solid-state devices, any fire that caused the fire spread/damage beyond the initiating circuit card is potentially challenging. For electromechanical devices (e.g., control relays), consider fire damage or spread extending beyond the initiating component as potentially challenging. For example, if an event report identifies a resistor on a circuit board as the ignition source and the fire self-extinguished without causing damage beyond that one circuit card, the ignition source should be considered the circuit card, and in this case the event would be classified as non-challenging or incipient. A self-extinguished fire involving only a single electromechanical relay would also be classified as non-challenging or incipient (the "smoked relay" case).

OB4. For diesel generators: A fire that causes substantial damage to the diesel generator but does not damage or spread to any other components should be classified as challenging if under a different design configuration the fire could have propagated or caused damage to nearby components. On the other hand, a small or smoldering manifold fire (very common) would be considered potentially challenging if it spread to a secondary fuel or if the initial fuel source is continuous (i.e., an ongoing fuel or oil leak, rather than a glob of grease), but did not cause the kind of substantial damaged described in the prior case. A small or smoldering manifold fire without potential to spread would be considered non-challenging.

OB5. Hot-work fires: An event is classified as potentially challenging if some active intervention appeared necessary to suppress the fire (i.e., if the fire watch put it out quickly, but clearly a fire was started and had the potential to grow, this is a potentially challenging fire event). The use of a single fire extinguisher should not be the only indicator of a potentially challenging fire.

A final point is related to certain types of general electrical equipment fires. Care was taken in the classification of certain self-extinguished electrical fires. In particular, electrical fires may self-extinguish after plant personnel de-energize the impacted equipment. De-energizing the electrical equipment is one mechanism of active intervention by plant personnel; hence, such events were generally classified as potentially challenging.

B.1.3 Supplemental Guidance for Determining Potentially Challenging Fire Incidents

These are small, non-propagating fires that could have reasonably been expected to develop into challenging fires, if mitigation actions were not taken in a timely manner (about a 15-20 minute

timeframe after detection). These include fires of lesser magnitude, growth, and impact than the "challenging fires" cited above. They also have lesser immediate risk significance than the challenging fires. And their risk potential is more uncertain. They satisfy the less severe potentially challenging fire criteria from NUREG/CR-6850, Appendix C, as recently modified to removal repair costs. The proposed classification criteria are:

Potentially Challenging (PC) 1. Substantial smoke was generated (e.g., a room was reported to be smoke-filled when first responders arrived on the scene, or the report includes a description such as "heavy" or "dense" smoke). Smoke events with substantial heat effects would be captured as a challenging fire event under the subjective criteria for challenging fires.

PC2. A fire should be classified as potentially challenging if two or more of the following features are cited in an event report:

a) Actuation of an automatic detection or suppression system.

b) A plant trip was experienced due to fire effects on the ignition component, where visible evidence of fire ignition is present.

c) A burning duration or suppression time of 10 minutes or longer that does not meet the challenging classification criteria.

d) A single portable fire extinguisher was used.

PC3. In addition, a potentially challenging fire may be identified considering subjective indications of the type cited under challenging fires, but of lesser severity.

For additional insights see discussion of "outside the boundaries" for additional clarification of "challenging" and "potentially challenging" fire incidents.

B.1.4 Fire Severity Override Guidance

In order to achieve a more consistent and standardized treatment for the screening of condition reports for applicability to fire PRA, a set of common override cases has been defined based on early experience with the screening process. The override conditions provide a standardized approach based on the event characteristics to reassigning certain events from an initial CH or PC ranking (as determined by the automated severity classification algorithm) to the NC category.

The genesis for these override rules came from the last NRC audit. During this audit, the audit team identified a few areas where simple rules could be established in order to streamline the severity classification process. Such rules will make the severity classification of these events readily overridden and recognizable by database users. This override effort has been taken with caution so that no legitimate fire events will be screened out as non-challenging fires. The NRC team has proposed override rules for the following issues:

Materials Overheating on a Diesel Generator Manifold

A fire event will be categorized as NC if it is related to a limited quantity of material accumulated on a diesel generator manifold (i.e., either the exhaust or turbocharger manifold) that "burned off" during the next run of the diesel generator. This override condition would be applied to events where:

- the incident involved material directly associated with the diesel generator itself (typically a light accumulation of grease, fuel oil, lubricating oil or paint);
- the material generated no more than light smoke; and
- a small open flame may be observed but that flame originated on and remained attached to the surface of the manifold itself, did not spread to any other material or location, and was no more than about 2 inches in length.[3]

This override will *not* be applied (i.e., the initial classification will nominally stand) IF ANY of these bullets are met:

- an ongoing source of the burning material was present such as leaking/dripping fuel or oil lines (i.e., the fuel material was not 'limited' but rather was fed by an ongoing supply source);
- a substantial quantity (i.e., on the order of a pint or more[1]) of material had accumulated;
- material accumulated anywhere other than the manifold surface (e.g., "pooling" or "oil-soaked insulation");
- fire spread to any other nearby material;
- open flames with a length of more than about 2 inches were observed[1];
- the fire brigade was called in and actively suppressed the fire; or
- the smoking/burning material was anything not directly associated with the diesel generator itself (e.g., refuse, protective clothing, work materials, storage materials, roofing materials, penetration seal materials) that came in contact with the manifold and began to smoke or ignited.

Smoking Materials on a Hot Pipe or Bearing Housing

A fire event generally characterized by smoke but may involve a small visible flame will be categorized as NC if it is related to a limited quantity of combustible material on a hot pipe or on the housing of a motor, generator or pump bearing that was reported as generating smoke. This override condition would be applied to events where:

- the incident involved combustible materials directly associated with source item (typically a light accumulation of grease, lubricating oil, or a new coating of paint);
- the material "burned off" generating no more than light smoke; and
- a small open flame may be observed but that flame originated on and remained attached to the surface of the manifold itself, did not spread to any other material or location, and was no more than 2 inches in length.

This override case will *not* be applied IF ANY of these bullets are met:

- a continuous source of the burning material was present such as leaking oil lines;

[3] The detail is provided for perspective only. Precise indication does not need to be provided in the event report. The application of analyst judgment is expected.

- open flames with a length of more than about 2 inches were observed[1];
- fire spread to any nearby materials;
- any nearby item or component was damaged;
- active intervention was needed to prevent potential fire spread;
- any fixed fire suppression system was activated (either automatically or manually);
- the fire brigade was called in and actively suppressed the fire;
- a substantial quantity of combustible material had accumulated anywhere other than on the pipe or housing surface (e.g., the report cites pooling of a liquid or involves "oil-soaked insulation"); or
- the smoking/burning material was anything not directly associated with the source item itself (e.g., the materials were associated with refuse, protective clothing, work materials, storage materials, roofing materials, penetration seal materials, etc.).

Individual Sub-Component Failures Not Resulting in Flaming Combustion

A fire event will be categorized as NC if it is related to an individual sub-component failure (e.g., motor windings, a terminal block, a single printed circuit card, a light or light socket, indicator, control switch, relay, motor contactor, etc.) that does not indicate the potential for development of a spreading fire. This override condition would be applied to events where:

- there may have been evidence of sub-component overheating (e.g., discoloration or scorch marks on the sub-component, some melting of the failed sub-component itself);
- there may have been evidence of localized charring on the failed sub-component itself; and
- the failure/overheating process was self-mitigated (e.g., it was disrupted by automatic circuit protection features such as tripping a fuse, breaker or overheat interrupter).

This override case will *not* be applied IF ANY of these bullets are met:

- a fixed fire suppression system actuated (either manually or automatically);
- upon discovery, an open flaming condition was observed and active intervention by plant personnel disrupted the further development of a fire (e.g., manually de-energizing equipment, use of any means of manual fire suppression, activation of any automatic suppression system) even if those actions were taken promptly (i.e., during the incipient stage);
- there is any evidence of flaming combustion external to the sub-component;
- the incident involved a high-energy arc fault;
- damage occurred to any other nearby object, material or component;
- substantial smoke was observed coming from the faulting object (e.g., based on the use of descriptive words such as "heavy," "dark," "dense" or "black" smoke); or
- fire spread to adjacent materials including charring damage to adjacent materials.

Equipment Failures during Monitored Test and Maintenance Activities

A fire event will be categorized as NC if it is related to a small or incipient fire that occurs during, and as a direct result of, a monitored/manned test and maintenance (T&M) activity and that is promptly suppressed by the personnel involved in that T&M activity. Examples might include cases where an error is made by the T&M personnel resulting in a small fire or cases where a pre-existing fault in a device is revealed during a return to service test. This override condition would be applied to events where:

- The incident involved a monitored (manned) test or maintenance type activity and the proximate cause of the incident was an undetected fault/deficiency in the device being tested or serviced. Also, the undetected fault/deficiency could not have resulted in ignition of a fire at a time when the equipment was not directly monitored (e.g., due to automatic or remote equipment operation during normal or emergency operation.
- Examples:
    1) An operator/technician inadvertently makes an error in performing his task that directly and promptly leads to a fire. An example would be a test technician performing work that creates a fire at his immediate working location while he is still at his task.
    2) An operator/technician inadvertently makes an error in performing his task that creates a condition that causes a fire at his immediate work location that occurs during PMT. The fire could be due to incorrect restoration of equipment or other condition that occurred during the maintenance activity. In this case the condition must be one that would be detected via the PMT with high likelihood. An example would be a maintenance technician inadvertently mis-wiring circuits. When the circuit/component is energized as part of the PMT, an electrical short occurs resulting in a fire at the immediate work location of the operator/technician in the presence of crew performing the PMT.
- The incident involved a component failure during a continuously manned T&M activity;
- the fire occurred at the immediate location of the return to service or T&M activity;
- the fire was quickly detected (e.g., within about 30 seconds) by the personnel involved in the activity (e.g., the technician performing the work, an operator observing the activity, a posted fire watch, etc.); and
- the fire was extinguished by a posted and designated fire watch posted to the T&M activity using no more than a single fire extinguisher (or the equivalent) or the fire was extinguished by other general personnel involved in the activity (e.g. and electrical technician) by taking actions no more involved than isolating the source power locally (e.g., turning a switch, pulling a plug, removing test leads or removing test jumpers), requesting that control room operators isolate power to the failing device, or isolating the fuel source locally (e.g., shutting off a valve on a leaking gas or oil line) or other minor manual fire suppression actions such as readily blowing out or patting out the fire (not to include use of a fire extinguisher by anyone other than a posted fire watch).

This override case will *not* be applied IF ANY of these bullets are met:

- a fixed fire suppression system was activated (either manually or automatically);

- one or more portable fire extinguishers were used to extinguish the fire by anyone other than a designated and posted fire watch attached to the T&M activity (i.e., use of a fire extinguisher by an electrical technician that was not designated as a fire watch would not be an acceptable condition for application of the override);
- the fire brigade extinguished the fire (note that the brigade may respond to the scene but should not be required to fight an ongoing fire);
- flames greater than two inches in length[1] were observed, except for cases where a portable extinguisher is applied by a posted and designated fire watch;
- the total fire duration was greater than five minutes;
- the fire occurred in a location that was not under immediate observation by the personnel involved in the T&M activity;
- the fire occurred in a related device, but not the device that was the subject of the T&M activity (e.g., a fault in the device being returned to service cause a fault/fire in a power supply breaker in another location);
- fire spread or damage occurred to materials beyond the object of origin; or
- the activity involved surveillance testing (i.e., versus return to service activities discussed above) of a component that can auto-start, or start via a remote manual start, under normal circumstances such that the same faulting/fire behaviors would have occurred had the component auto-started while unattended.

Lighting Ballast Events

A fire event will be categorized as NC if it is related to a fault/failure of a lighting ballast. This override condition would be applied to events where:

- a lighting ballast overheats/fails creating only odors and smoke; or
- a lighting ballast fails creating small flames (no more than 2 inches[1]) that remain confined to the lighting fixture.[1]

This override case will *not* be applied IF ANY of these bullets are met:

- flames extended outside the light fixture;
- actions other than switching off power to the light were required to suppress an ongoing flaming fire; or
- any nearby material not a part of the lighting fixture itself was ignited or damaged.

110/220 VAC Wall Sockets and Switches

A fire event will be categorized as NC if it is related to a fault/failure within an electrical wall box permanently mounted to, or embedded within, facility structures (i.e., 110VAC room lighting switchbox or a fixed 110/220VAC electrical outlet box). This override condition would be applied to events where:

- overheating remains confined to those devices within the mounted electrical box (some smoke may be generated);

- evidence of scorching may be observed only on the devices within the box or at the margins of the outlet or switch box; or
- the fault results in charring or discoloration of the contents only of an outlet or switch box.

This override case will *not* be applied IF ANY of these bullets are met:

- the fault occurred in outlets or lighting sockets on a temporary or portable extension cord;
- there was any observed ignition of, or charring or other damage to, nearby materials that were not a part of the electrical outlet or switchbox itself; or
- electrical panels of any kind other than 110/220VAC electrical outlet and lighting switchboxes.

Hot Work Fires Extinguished by a Posted Fire Watch

A fire event will be categorized as NC if it is related to a fire caused by a hot work activity that is promptly detected by a posted fire watch and is then promptly suppressed by the fire watch using no more than a single fire extinguisher. This override will apply to cases where:

- the fire occurred as a direct result of hot work activity (i.e., the fire was not a coincidental fire unrelated to the hot work that happened to occur in the vicinity of a hot work activity);
- there are no indications that the fire was caused by hot work activity that was not properly permitted and a fire watch was posted consistent with normal plant practices;
- the fire occurred in the immediate vicinity of the hot work activity (i.e., within the direct field of view of the hot work fire watch); [such detail may not be provided in the fire report, judgment should be used when evaluating the fire scenario.]
- the fire was detected promptly by the fire watch or another member of the hot work crew (e.g., the welder); and
- the fire was suppressed promptly by the fire watch or another member of the hot work crew using no more than a single fire extinguisher or the equivalent (i.e., any lesser means of suppression such as stomping out the fire, blowing out the fire, patting out the fire with a gloved hand, use of a fire blanket, etc. are acceptable conditions for application of the override).

This override will *not* be applied IF ANY of these bullets are met:

- any means of fire suppression more extensive than use of a single fire extinguisher or the equivalent were applied;
- the fire was detected by someone other than the posted fire watch or the hot-work workers themselves (e.g., the fire was detected by a passerby and then brought to the attention of the fire watch);
- the fire was extinguished by anyone other than the fire watch or other members of the hot work crew (e.g., if a welder "pats out" a small fire that they themselves ignited that would be an acceptable override case);
- the fire caused damage to any nearby equipment or cables or spread to materials other than those originally ignited;

- there were oversights or failures associated with the hot work activity that actually did aggravate the conditions of the fire or fire response (e.g. violations of the hot work permit, failure of a staged fire extinguisher, violation(s) of work procedures that acted as a proximate cause of the fire being ignited or which led to delayed fire suppression, etc.); or
- the total fire duration was greater than 5 minutes.

Other exceptions

Other exceptions to the algorithm fire severity classification have been found to exist, but have been treated on a case by case basis. The exceptions are documented in the fire severity determination comments for the specific events. They generally involve a holistic assessment of the fire event documentation by a senior analyst and collaborative review by a peer. In the case of the FEDB the peer was the NRC and its contractors from INL and SNL.

B.1.5 Supplemental Discussion of Non-Challenging Fire Incidents

There are no non-challenging classification criteria, per se. Normally, the challenging and potentially challenging classification criteria would be applied first, and if not applicable, the event would be classified as non-challenging by default. However, the non-challenging characteristics may also be considered in determining the applicability of the more challenging classification criteria

Non-challenging fire incidents are meant to include all other fire incidents that do not satisfy challenging and potentially challenging fire criteria and are not undetermined. These would include incipient fire ignition conditions that cannot reasonably be expected to develop into challenging fires due to physical circumstances of the component design or operation, or incipient fire conditions that can be detected but develop very slowly into fires after detection and have not developed potentially challenging fire characteristics. This would include smoldering incidents and small flaming fires at that involve a small part of the ignition component and have apparent self limiting features that affect their heat release rate growth. These may also include fires involving a self-extinguishing material (extinguishes upon removal of ignition source). It would also include incidents in which incipient fire detection systems actuated and a “routine” fire preventive action was taken.

B.1.6 Supplemental Discussion of Undetermined Fire Incidents

These incidents have insufficient information to make a reasonable classification into one of the above categories. Due to the nature of the challenging fires, they are not very likely to be undetermined by lack of information on fire severity details. It does not seem credible that a real challenging fire that meets the challenging criteria would not be sufficiently reported via a NEIL report, a LER, an EN, a NRC inspection report, an EPIX report, or a plant incident report in a manner sufficient to make a definitive challenging classification, especially in the post 1990 time period. For an event to be undetermined and a candidate for challenging classification level, at a minimum, sufficient information should be available to strongly imply that the event was at least potentially challenging. Therefore, the missing or uncertain information that would necessary to definitively determine the classification would involve challenging or potentially challenging factors.

On the other hand, based on experience with the original FEDB undetermined fire incidents and the information argument offered above, the undetermined fire incidents are most likely to be candidates for potentially challenging or non-challenging classifications, but have insufficient information to be definitively placed in either classification. Past experience suggests they fall into one of the following categories: a) the evidence more strongly indicates a potentially challenging fire (e.g. there are some subjective indications of the type cited under challenging fires, but of inclusive severity); b) the evidence more strongly indicates an incipient/non-challenging fire incident (e.g. there are some subjective indications of the type cited under challenging fires, but appear to be of lesser severity); or c) there is insufficient evidence related to either classification.

In consideration of the above discussion there are three credible and mutually exclusive undetermined classification resolution outcomes:

1) The event satisfies the potentially challenging criteria and has plausible indications that it could be challenging but some information is missing, incomplete, or is otherwise not definitive.
2) The event information available does not satisfy the challenging or potentially challenging criteria but has plausible indications that it could be potentially challenging but some information is missing, incomplete, or is otherwise not definitive.
3) The event does not have sufficient information or evidence to indicate it could plausibly be classified as potentially challenging.

Therefore, each undetermined fire severity classification event should fall within one of the above categories. Additional classification criteria would need to be developed in order to implement this approach in a manner that produces consistent event classifications.

B.2 Severity Classification Logical Connection to FEDB Data Fields

Tables B-1 through B-3 provide a cross-reference between the FEDB data field elements provided in Section 3 and their relevance to the fire severity determination guidance provided in Section B.2. This connection of the fire event data fields to the fire severity determination was used to develop the fire severity algorithm discussed in Chapter 5 and presented in Table 5-2. It is intended to be consistent with the fire severity classifications delineated in Table 5-1. The logical approach for making the severity determination starts from the most severe characterization, namely challenging fires, and works down by exclusion to the less challenging and undetermined categories. For example, once a data field is found that suggests a given event can be classified as “challenging”, it is no longer possible to be classified as “potentially challenging”, “not challenging” or “undetermined”. Tables B-1 through B-3 have been developed accordingly.

Table B-1
Cross-Reference between Elements of the Severity Determination Algorithm and Fire Severity Classifications – Challenging Events

Note that if Fire Type, 11 ("Not a fire"), is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
Any of the following elements			
Fire Cause	9	High Energy Arcing Faults	Section B.1.1, General Class CG1
		Explosion	Section B.1.1, General Class CG4 Section B.1.1, Subjective Classification Criteria CS2 and CS3
Fire Type	11	Fully Developed Compartment Fire	Section B.1.1, Subjective Classification Criteria CS2 and CS3
		Explosion	Section B.1.1, General Class CG4 Section B.1.1, Subjective Classification Criteria CS2 and CS3
Smoke	12	Severe Smoke	Section B.1.1, Subjective Classification Criteria CS3
Temperature	13	High	Section B.1.1, Subjective Classification Criteria CS2 and CS3
		Severe	
		Fully developed room fire	
Damage Extent	15	Confined to part of room or area of origin	Section B.1.1, General Class CG2 Section B.1.1, Objective Classification Criteria CO2 and CO3 Section B.1.1, Subjective Classification Criteria CS2 and CS3
		Confined to room of origin	
		Confined to fire rated compartment of origin	
		Confined to floor of origin	
		Confined to structure of origin	
		Extended beyond structure of origin	

Note that if Fire Type, 11 ("Not a fire"), is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
Collateral Damage	16	Heat (scoring, charring, warping, or melting)	Section B.1.1, General Class CG3
		Evidence of secondary ignition (above or laterally)	Section B.1.1., Objective Classification Criteria CO2 and/or CO3
Detection Method	18	Thermal detector actuation	Section B.1.1, General Class CG2
		Ultraviolet flame detector	
		Sprinkler or water flow alarm	
Suppression Method	20	Automatic fixed suppression – thermally actuated	Section B.1.1, Objective Classification Criteria CO1
		Fixed suppression – actuation not specified	
		Automatic fixed suppression – deluge system	
		Hose stream or hose reel used	
Foam Suppression	22	AFFF Foam	Section B.1.1, Objective Classification Criteria CO1
Combinations of the following elements			
Combination of suppression method, and Smoke or Temperature [20 and (12 or 13)]			Section B.1.1, Objective Classification Criteria CO1
Suppression Method	20	Automatic suppression system actuated by a smoke detector	Possible element of Objective Classification Criteria CO1 (Section B.1.1)
		Manually operated fixed suppression system actuated	
		CO2 system other than a fire extinguisher or fixed system used or actuated	
		Multiple fire	

Note that if Fire Type, 11 (“Not a fire”), is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
		extinguishers used	
Smoke	12	Moderate	Possible element of Objective Classification Criteria CO1 (Section B.1.1)
		Heavy	
Temperature	13	Moderate	Possible element of Objective Classification Criteria CO1 (Section B.1.1)
Combination of fire type or suppression, and fire duration greater than 10 minutes when fire watch, first responder or other plant personnel provide first attack on fire. [(11 or 20) and Fire Duration > 10 minutes and 21]			Section B.1.1, Subjective Classification Criteria CS1
Fire Type	11	Flaming combustion external to component	Element of Objective Classification Criteria CS1 (Section B.1.1)
Suppression Method	20	CO2 system other than a fire extinguisher or fixed system used or actuated	Element of Objective Classification Criteria CS1 (Section B.1.1)
		Multiple fire extinguishers used	
Fire Incident Time Line [MIN(Control, extinguishment time) – MIN(fire ignition, discovery, report time)] ≥ 10 minutes	10	Fire control time	Possible element used to determine condition for Subjective Classification Criteria CS1 (Section B.1.1)
		Fire extinguishment time	
		Fire ignition time	
		Fire discovery / detection time	
		Report time	
Who put fire out (first attack)?	21	First responder	Possible element used to determine condition for Subjective Classification Criteria CS1 (Section B.1.1)
		Fire watch	
		Other plant personnel	
Combination of fire type or suppression and fire duration greater than 10 minutes when fire brigade provides first attack [(11 or 20) and Fire Extinguish time > 10 minutes and 21]			
Fire Type	11	Flaming combustion external to component	Element of Objective Classification Criteria CS1 (Section B.1.1)
Suppression Method	20	CO2 system other than a fire extinguisher or fixed system used or actuated	Element of Objective Classification Criteria CS1 (Section B.1.1)
		Multiple fire	

Note that if Fire Type, 11 (“Not a fire”), is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
		extinguishers used	
Fire Incident Time Line [MIN(Control, extinguishment time) – MAX(fire brigade dispatch, fire brigade arrival, fire brigade first action)] ≥ 10 minutes	10	Fire Control time	Possible element used to determine condition for Subjective Classification Criteria CS1 (Section B.1.1)
		Fire extinguishment time	
		Fire brigade dispatch time	
		Fire brigade arrival time	
		Fire brigade first action time	
Who put fire out (first attack)?	21	Fire Brigade	Possible element used to determine condition for Subjective Classification Criteria CS1 (Section B.1.1)
		Fire Brigade with outside support	

Table B-2
Cross-Reference between Elements of the Severity Determination Algorithm and Fire Severity Classifications – Potentially Challenging Events

Note that if Fire Type, 11 ("Not a fire") is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
Any of the following elements			
Suppression Method	20	Fixed Suppression – manual	Potentially Challenging Criteria PC3 (Section B.1.3)
		Portable manual system	
		Multiple portable fire extinguishers used	
Reactor Power Effect	29	SCRAM	Possible element of potentially challenging PC2 criteria (Section B.1.3)
		Turbine Trip	
		LOOP	
Any TWO of the following elements			
Multiple features that alone would not constitute potentially challenging	Various	Non-thermal detection	Potentially challenging criteria PC2 (Section B.1.3)
		Reactor power effects	
		Excessive duration (plant personnel, fire watch, or first responder)	
		Excessive duration (fire brigade team or outside help)	
Combinations of the following elements			
Flaming combustion that does not meet the hot work / T& M override criteria. [11 and (15 or Fire duration $\geq$ 5 minutes or 9 (FALSE) or 18 or (20 and 18.a. or 18.n FALSE) or 21)]			Section B.1.4 Fire Severity Override Guidance
Fire Type	11	Smoldering fire – external to component	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance
		Smoldering fire – internal to component	
Fire Incident Time Line [MIN(Control, extinguishment time) – MAX(fire brigade dispatch, fire brigade arrival, fire brigade first action)] $\geq$ 5 minutes	10	Fire control time	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance
		Fire extinguishment time	
		Fire brigade dispatch time	
		Fire brigade arrival time	
		Fire brigade first action time	
Damage Extent	15	Confined to the object of origin (broad damage)	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance

Note that if Fire Type, 11 (“Not a fire”) is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
Fire Cause (FALSE)	9	Hot work	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance
		Personnel error during T&M	
		Personnel error: misuse of material ignited	
		Personnel error: misuse of heating devices	
Detection Method	18	Main control room staff	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance
		Other plant personnel	
		Failed equipment alarm	
		Very early smoke detection system	
		Installed fire detection, type not specified	
		Roving fire watch	
Suppression Method	20	Automatic fixed suppression – smoke detector actuated	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance
		Power supply removed	
		Fuel supply removed	
		Other	
		Power supply removed; maintenance staff	
		Fuel supply removed; maintenance staff	
Who put fire out (first attack)?	21	Plant fire brigade -first responder	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance
		Plant fire brigade – team response	
		Plant fire brigade with outside support	
		Other plant personnel	
		Other	
		Plant personnel that discovered the fire (NOT)	
NOT Detection Method	18 (NOT)	Fire watch (18.a)	Possible element used to determine condition for Section B.1.4 Fire Severity Override Guidance
		Staff conducting maintenance on equipment of fire origin (18.n)	
Combination of Fire Type and Smoke [11 and 12]			Section B.1.3: small or incipient fire could have developed into a challenging fire if mitigating actions were not taken in a timely manner.
Fire Type	11	Smoldering fire – external to component	Possible element used to determine if fire was small or

Note that if Fire Type, 11 ("Not a fire") is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
		Smoldering fire – internal to component	incipient (Section B.1.3)
Smoke	12	Moderate smoke generated – visibility significantly reduced in vicinity of fire but equipment on fire is easily identified	Element used to determine if fire could have grown to challenging (Section B.1.3).
		Heavy smoke – smoke obscures vicinity of fire such that origin of fire is difficult to locate room entry possible with SCBA.	Potentially Challenging Criteria PC4 (Section B.1.3)
Combination of Suppression Method and Smoke [20 and 12]			Potentially Challenging Criteria PC5
Suppression Method	20	Power supply removed as a means of suppressing the fire	Element used to determine if fire could have grown to challenging (Section B.1.3).
Smoke	12	Moderate smoke generated – visibility significantly reduced in vicinity of fire but equipment on fire is easily identified.	Element used to determine if fire could have grown to challenging (Section B.1.3).
Detection by non-thermal means [18 or 20]			Condition of potentially challenging criteria PC2 (Section B.1.3)
Detection Method	18	Smoke detector actuated	Possible element of potentially challenging PC2 criteria (Section B.1.3)
		Gas ionization detector actuated	
Suppression Method	20	Automatic suppression actuated by a smoke detector	Possible element of potentially challenging PC2 criteria (Section B.1.3)
Combination of fire duration greater than 10 minutes when plant personnel first responders provide initial attack. [Fire Extinguish time > 10 minutes and 21]			Condition of potentially challenging criteria PC2 (Section B.1.3)
Fire Incident Time Line [MIN(Control,	10	Fire control time	Possible element of potentially challenging PC2 criteria (Section B.1.3)
		Fire extinguishment time	

Note that if Fire Type, 11 ("Not a fire") is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
extinguishment time) – MIN(fire ignition, discovery, report time)] ≥ 10 minutes		Fire ignition time	
		Fire discovery / detection time	
		Report time	
Who put fire out (first attack)?	21	First attack on fire by first responder	Possible element of potentially challenging PC2 criteria (Section B.1.3)
		First attack on fire by fire watch	
		First attack on fire by other plant personnel	
Combination of fire duration ≥ 10 minutes and initial attack by the fire brigade team with or without outside help.			Condition of potentially challenging criteria PC2 (Section B.1.3)
Fire Incident Time Line [MIN(Control, extinguishment time) – MAX(fire brigade dispatch, fire brigade arrival, fire brigade first action)] ≥ 5 minutes	10	Fire control time	Possible element of potentially challenging PC2 criteria (Section B.1.3)
		Fire extinguishment time	
Who put fire out (first attack)?	21	First attack on fire by plant fire brigade – team response	Possible element of potentially challenging PC2 criteria (Section B.1.3)
		First attack on fire by plant fire brigade with outside support	
		Fire brigade dispatch time	
		Fire brigade arrival time	
		Fire brigade first action time	
Combination of excessive fire duration after manual efforts have begun to suppress or extinguish initial attack by the fire brigade team with or without outside help. [Fire brigade fire fighting ≥ 30 minutes and 21]			Condition of potentially challenging criteria PC3 (Section B.1.3)
Fire Incident Time Line [MIN(fire extinguishment time, scene release time) – MIN(fire brigade/ department dispatch	10	Fire extinguishment time	Possible element of potentially challenging PC3 criteria (Section B.1.3)
		Scene release time	
		Fire brigade/ department dispatch time	

Note that if Fire Type, 11 (“Not a fire”) is set to true the algorithm will set the event to Not Challenging and will not consider anything in the chart below.

Element	Algorithm Reference	State	Criteria
time/first action time/first attack)] ≥ 30 minutes		Fire brigade/ department arrival time	
		Fire brigade/ department first action time	
Who put fire out (first attack)?	21	First attack on the fire by the fire brigade team	Possible element of potentially challenging PC3 criteria (Section B.1.3)
		First attack on fire by the fire brigade team with outside support	
Combination of excessive fire duration after manual efforts have begun to suppress or extinguish initial attack by plant personnel, a fire watch, or a fire brigade first responder. [Fire duration ≥ 30 minutes and 21]			Condition of potentially challenging criteria PC3 (Section B.1.3)
Fire Incident Time Line [MIN(fire extinguishment time, scene release time) – MIN(fire discovery or detection time, time first reported)] ≥ 30 minutes	10	Fire extinguishment time	Possible element of potentially challenging PC3 criteria (Section B.1.3)
		Scene release time	
		Fire discovery or detection time	
		Time fire is reported	
Who put fire out (first attack)?	21	First attack on fire by a fire brigade first responder	Possible element of potentially challenging PC3 criteria (Section B.1.3)
		First attack on fire by a fire watch	
		First attack on fire by other plant personnel	

Table B-3
Cross-Reference between Elements of the Severity Determination Algorithm and Fire Severity Classifications – Not Challenging Events

Note that if Fire Type, 11 ("Not a fire"), is set to true the algorithm will set the event to Not Challenging (NC) and will not consider anything in the chart below. Also, if there are no blanks or unknowns in fields that affect the severity algorithm and nothing sets the event to >NC the event will be set to NC.

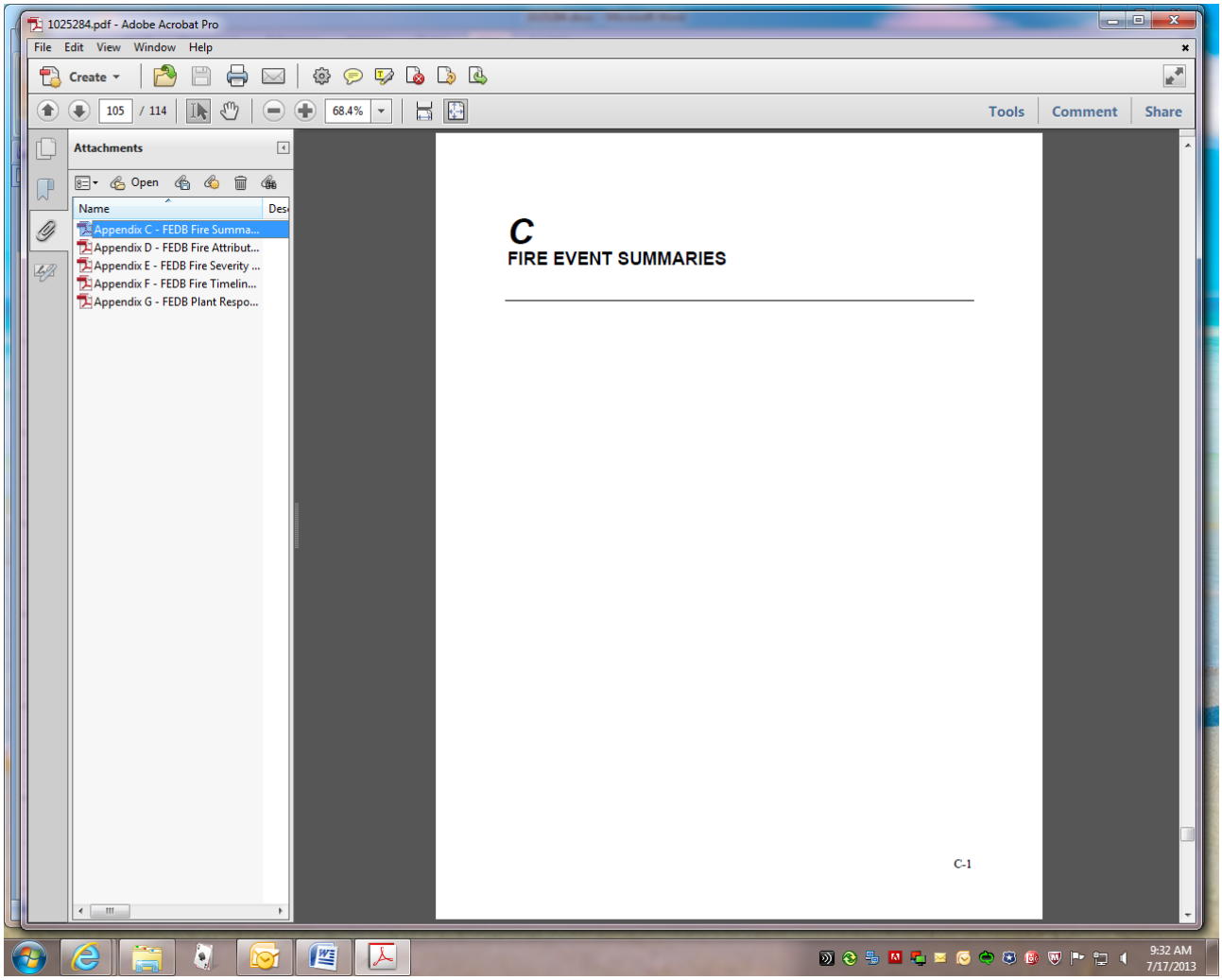
Element	Algorithm Reference	State	Criteria
Fire Type	11	Overheating (most severe condition observed)	Section B.2.4: incipient fire condition that cannot reasonably be expected to develop into a challenging fire
Suppression Method	20	Self-extinguished without intervention	Section B.2.4: incipient fire condition that cannot reasonably be expected to develop into a challenging fire

B.3 References for Appendix B

1. *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities.* Electric Power Research Institute (EPRI), Palo Alto, CA, and U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research (RES), Rockville, MD: 2005. EPRI - 1011989 and NUREG/CR-6850.
2. Methodology for Development of Emergency Action Levels NEI 99-01, Nuclear Energy Institute, February 2008.

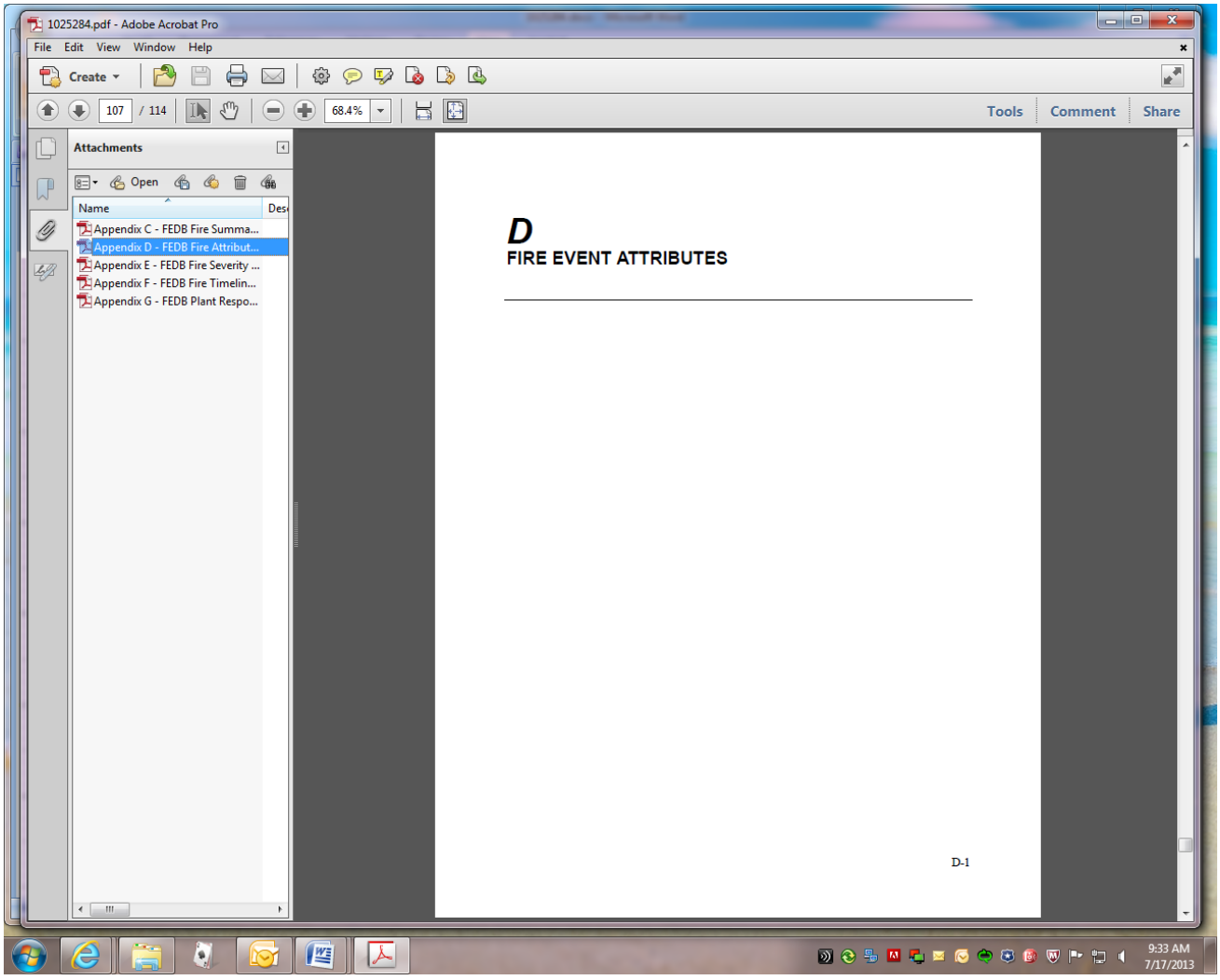
C
FIRE EVENT SUMMARIES REPORT

Appendix C is attached as a separate file. To access, click on Appendix C pdf file in the Attachments tab.



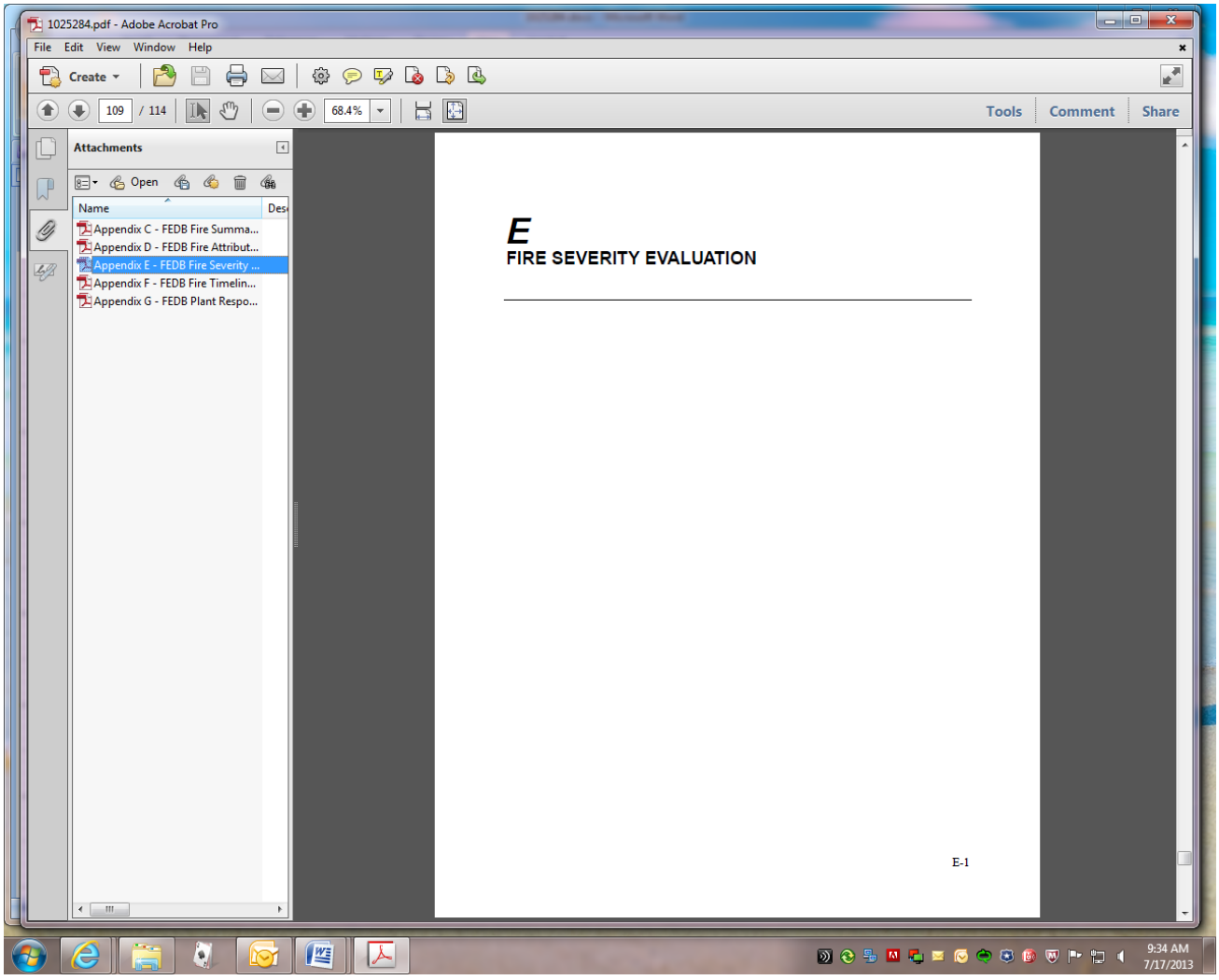
D
FIRE EVENT ATTRIBUTES REPORT

Appendix D is attached as a separate file. To access, click on Appendix D pdf file in the Attachments tab.



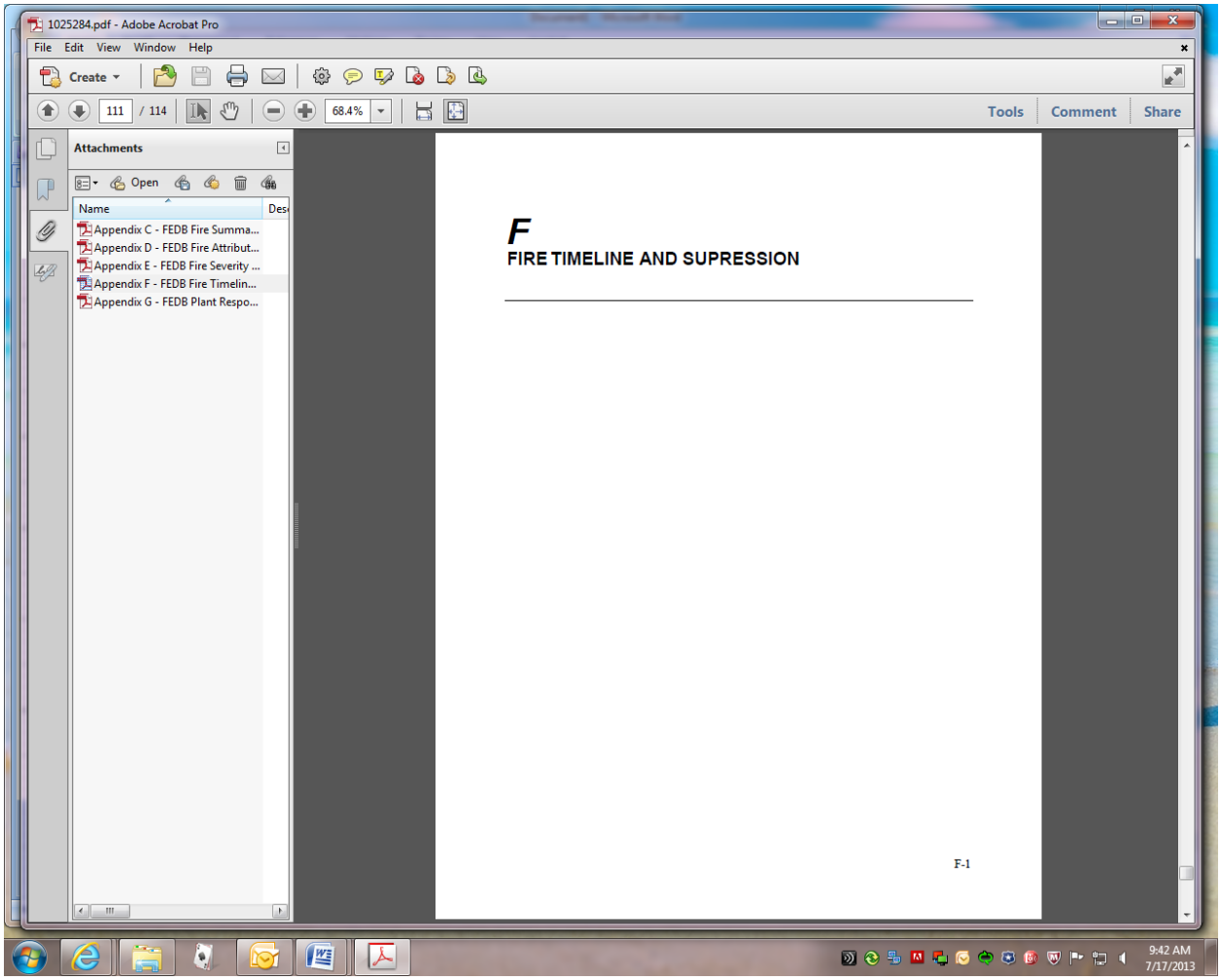
E
FIRE SEVERITY EVALUATION REPORT

Appendix E is attached as a separate file. To access, click on Appendix E pdf file in the Attachments tab.



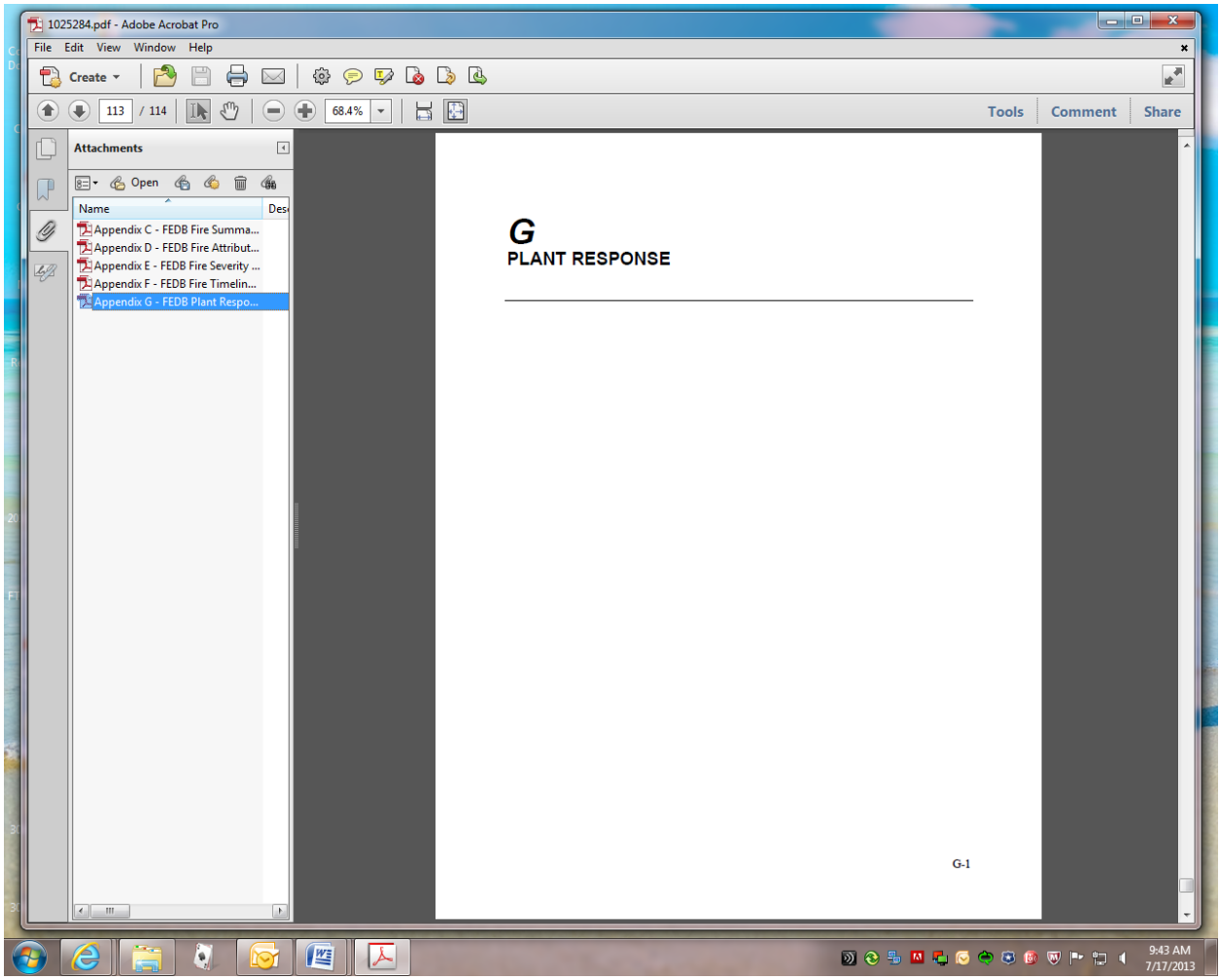
F
FIRE TIMELINE AND SUPRESSION REPORT

Appendix F is attached as a separate file. To access, click on Appendix F pdf file in the Attachments tab.



G
PLANT RESPONSE REPORT

Appendix G is attached as a separate file. To access, click on Appendix G pdf file in the Attachments tab.



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