Conf-940312--49
BNL-49077

RISK ANALYSIS OF ENVIRONMENTAL HAZARDS AT THE HIGH FLUX BEAM REACTOR*

J. L. Boccio, V. S. Ho,** D. H. Johnson**
Brookhaven National Laboratory
Upton, New York 11973

Introduction/Background

In the late 1980s, a Level 1 internal event probabilistic risk assessment (PRA) was performed for the High-Flux Beam Reactor (HFBR), a U. S. Department of Energy research reactor located at Brookhaven National Laboratory. Prior to the completion of that study,[1] a level 1 PRA for external events was initiated, including environmental hazards such as fire, internal flooding, etc.

Although this paper provides a brief summary of the risks from environmental hazards, emphasis will be placed on the methodology employed in utilizing industrial event databases for event frequency determination for the HFBR complex. Since the equipment in the HFBR is different from that of, say, a commercial nuclear power plant, the current approach is to categorize the industrial events according to the hazard initiators instead of categorizing by initiator location. But first a general overview of the analysis.

Approach/Overview

The overall HFBR environmental hazards analysis was performed in two steps: spatial interaction and detailed risk analysis. The first stage largely begins with the identification of potential environmental hazards at a broad level and ends with an extensive list of hazard scenarios at each location within the complex. These are scenarios that could be potentially significant to risk and their corresponding worst case impact. The results from the spatial interaction phase of the overall analysis[2] identified over one hundred hazard scenarios.

---

* This work was performed under the auspices of the U. S. Department of Energy.

** Pickard, Lowe and Garrick, Newport Beach, California

These were screened based on their conditional core damage frequency and a number of these scenarios were retained for a more detailed analysis.

The detailed risk analysis stage[3] is itself a two-phase process. First, occurrence frequencies for the retained scenarios were estimated using actual commercial nuclear industry experience and HFBR specific experience. The unconditional core damage frequency for each scenario was determined, and the scenarios were then evaluated for the importance based on this frequency. Those scenarios that remain were evaluated in further detail in the second phase of the analysis by now considering the interactions between the hazards, mitigation features and other facility recovery actions. This "top-down" approach to risk assessment minimizes the effort in quantifying the risk associated with unimportant locations. Therefore, the scenarios that are identified during the spatial interactions analysis are as comprehensive as possible, and they remain at a manageable number for the subsequent detailed analyses. In practice, experience has shown that the two stages of the analysis must be closely coordinated and that they are somewhat iterative.

Fourteen fire scenarios were retained as a result of this approach; only three flood scenarios were found to be quantitatively significant. This pruning process was based on the utilization of generic data collected from a variety of databases.

Database Development/Utilization

A PLG database for fire events[4] provided the generic input for the assessment of fire event frequencies. This database contains summaries of more than 400 fire events that occurred through July 1987 at more than 65 U.S. nuclear power plant sites. These event summaries were derived from U.S. Nuclear Regulatory Commission (NRC) Licensee Event Report (LER) data, American Nuclear Insurer data, and plant-specific data that have been collected by PLG during previous PRA studies. The internal flooding event frequencies were derived from a similar PLG database for plant flooding events.[5]

A thorough review of the industry experience was used to develop a "specialized" generic database that accounts for design features of the HFBR and characteristics of the associated hazard sources. Special efforts were made to categorize fire events that involve equipment and occupancy unique to the HFBR facility.

The specialized generic database contained only those hazards events that were relevant to the HFBR for the specific operating conditions being evaluated, and for the specific scope of the functional impact locations and hazard sources that were considered in this analysis. The fire events were categorized into the following fire hazards sources:

- Battery-Related Fires
- Battery Charger-Related Fires
- Control Room-Related Fires
- Heating, Ventilating, and Air Conditioning (HVAC)-Related Fires
- Human Error-Related Fires
- Logic Cabinet-Related Fires
- Motor Control Center (MCC)- Related Fires

- Power and Control Cables-Related Fires
- Pumps-Related Fires
- Switchgear-Related Fires
- Transformer-Related Fires

The fire events were categorized into hazard source types instead of by location of occurrence. This approach provides a more realistic categorization of past events. We refer to these fire hazard types as component-based fire hazard sources and to the associated occurrence frequencies as the component-based fire frequencies.

In previous fire risk analyses, the industrial events were categorized according to the location of fires regardless of the actual plant component that was involved. Events that were categorized as auxiliary building fire events usually consisted of pump-related fires, motor generator-related fires, cable fires, and MCC-related fires that occurred in the auxiliary buildings. Similarly, switchgear room fire events included switchgear fires and any other fires that occurred inside the switchgear rooms of different nuclear power plants. Such an approach assumed that plant-to-plant variability of the content in different plant areas was low. The applicability of this approach is uncertain to plants that have different component contents in different plant locations compared to a "generic plant" in the industrial event database. Since the equipment content in HFBR is different from that of a generic nuclear power plant, a more rational application of the industrial event database was needed. The approach used categorized industrial events according to the fire initiators instead of plant location. For example, a pump-related fire in the auxiliary building of plant X is categorized as a pump-related fire event, and a cable-initiated fire in the auxiliary building of plant Y is categorized as a cable-related fire event. As a result, the fire events included in the HFBR specialized industrial event database were categorized according to the above component-based fire hazard source categories.

A two-stage Bayesian analysis was performed to combine this industry data with actual experience at the HFBR. The first stage of this analysis developed a generic frequency distribution for each hazard source that consistently accounted for the observed site-to-site variability in the industry experience data. The second stage updated this generic frequency to account specifically for the actual historical experience at the HFBR.

To account properly for the observed site-to-site variability in the industry experience data, it was necessary to have detailed information about the specific sites at which each event has occurred; e.g., site X has had N1 fire events of hazard type A in X1 years; site Y has N2 fire events of hazard type A in Y1 years; etc. Unfortunately, some of the industry data sources that compile hazard event reports do not identify the specific sites at which these events have occurred.

A probabilistic weighing process was used to consistently account for these unidentified hazard events within the framework of the first-stage Bayesian analysis. Several hypotheses were developed for each unidentified event.

The actual number depended on factors such as the observed variability in the identified plant experience and the actual number of unidentified events. Each hypothesis can result in a slightly different allocation of the total number of documented hazard events among the available plant sites. Each allocation is then input to the first-stage Bayesian analysis to develop a probability distribution that would apply for the hazard frequency if the corresponding hypothesis were true. Thus, a number of possible generic event frequency distributions were developed that corresponded to the number of hypotheses for the unidentified events. Each distribution was assigned a probabilistic weight that accounts for the likelihood that the corresponding hypothesis is true. The final generic probability distribution for the component-based hazard event frequency was obtained by merging the hypothesis distributions in a manner that preserves the underlying database uncertainty.

The development and evaluation of these hypotheses added a degree of complexity to the frequency analysis for some hazards. However, this complexity is justified by the fact that most hazard events are quite rare. For many hazards, the entire industry experience database contains fewer than 10 events. This is in contrast to other types of data that are used in the PRA, such as internal initiating events, component failures, and component maintenance events, for which hundreds or thousands of individual events may be documented. Thus, a single, unidentified hazard event may represent a relatively large fraction of the total documented experience base. A consistently conservative assignment of these events to the worst plants results in cumulative hazard frequencies that do not represent actual industry experience. On the other hand, simple removal of these anomalies may result in frequencies that are too optimistic. Consistent accounting for the unidentified events in the hypotheses-based approach provides the best available generic data, including the inherent uncertainties in those data.

Because of the lack of available operational data from plants similar to HFBR, the specialized generic component-based frequency was adjusted according to the smaller scale of the HFBR. To account for the difference, an approach was adopted that assumes a worst case scenario by retaining the upper bound associated with typical nuclear power plant generic data while reducing the median (50th percentile) to reflect a more realistic model of the HFBR. Based on the revised parameters, a new value for the lower bound (5th percentile) is determine. The revised generic prior distributions were then combined with applicable HFBR plant-specific experience via a Bayesian update to obtain component-based fire or flood frequencies.

Summary/Conclusions

The fire events database used in this study summarizes incidents from a variety of sources: an NRC License Event Report, the American Nuclear Insurer, and plant-specific data collected from previous PRA studies.[4] Over 400 fire events were screened for HFBR-specific applicability. In this case applicability is determined by the composition of the HFBR with a typical commercial nuclear power plant.

The result of this screening forms the specialized generic database, a sample of which is shown in Table 1. For each fire event listed, information is included about fire initiator (equipment or fuel), location, cause, ignition source and type, affected equipment and comments regarding the applicability of this fire event to the HFBR scenario analyses.

As indicated previously, fourteen fire scenarios were analyzed in depth. Three flood scenarios were found from the screening process to be quantitatively significant. The total mean core damage frequency due to environmental hazards was $4.15(10)^{-5}$ per year. The contribution from internal events is approximately an order of magnitude higher.

References:

1. Brookhaven National Laboratory, "Level 1 Internal Event PRA for the High Flux Beam Reactor," prepared for the U. S. Department of Energy, Rev. 1, July 1990.

2. Johnson, D. H., et al., "Spatial Interactions Analysis of the High Flux Beam Reactor," prepared for Brookhaven National Laboratory, PLG-0823, PLG, Inc., August 1991.

3. Ho, V. S., et al., "Risk Analysis of the Environmental Hazards at the High Flux Beam Reactor, prepared for Brookhaven National Laboratory, PLG-0906, PLG, Inc., January 1993.

4. Pickard, Lowe and Garrick, Inc., "Database for Probabilistic Risk Assessment for Light Water Nuclear Power Plants," Proprietary, PLG-0500, Vol. 8, July 1989.

5. Pickard, Lowe and Garrick, Inc., "Database for Probabilistic Risk Assessment for Light Water Nuclear Power Plants," Proprietary, PLG-0500, Vol. 9, July 1989.

Table 1. HFBR Specialized Generic Fire Event Database

Category	PLG Index	Plant	Incident Date	Operation Mode	Fire Location	Fire Initiators	General Description	Comments
Battery	190	Robinson Unit 2	07/16/78	Power Operation	Battery Room	Battery	Plastic tops of two operation cells of a staion battery caught fire; caused by resistance heating of a terminal connection during the heavy DC load of the emergency oil pump.	Include in HFBR fire empirical experience database.
	217	Palisades	04/04/79	Power Operation (100%)	Battery Room	Battery	A test lead being used to take battery voltage readings fell and struck a battery connector, causing a spark that ignited hydrogen gas.	Include in HFBR fire empirical experience database.
Battery Charger	320	Brunswick Unit 1	11/27/82	Power Operation (68%)	Battery Room	Capacitor	Battery charger capacitor caught fire for unknown reason.	Include in HFBR fire empirical experience database.
	357	Duane Arnold	08/02/85	Power Operation	Switchgear Room	Capacitor	A failing capacitor in an RCIC static inverter caused RCIC to be inoperable and failure of a reactor level indicator.	Include in HFBR fire empirical experience database.
Control Room	225	Three Mile Island Unit 2	07/12/79	Cold Shutdown	Control Room	Resistor	Overheated resistor caused rfire in a radiation-monitoring readout panel. Fire was extinguished immediately.	Include in HFBR fire empirical experience database.
	323	McGuire Unit 2	02/19/83	Construction	Control Building	Fan	Household fan caught fire in the control building. Smoke propagated to control room area.	Not applicable; construction event and fire-initiated equipment not found in HFBR.
	397	Dresden Unit 2	11/01/81	Power Operation	Control Room	Relay	Defective relay burnt out. Fuse blown. Relay replaced	Not applicable; factory defective relays, component failure only, not an actual fire event.
	398	Hatch Unit 1	12/01/81	Power Operation	Control Room	Relay	Loose terminal connection shorted; insulation overheated. No additional damage resulted.	Not applicable; fire precursor only, not an actual fire event.
HVAC	338	Unknown	04/22/84	Construction	Other Building	Air Conditioner	Short circuit in wall-mounted air conditioning unit caused the fire.	Not applicable; construction event.
	348	Unknown	11/21/84	Construction	Temporary Building	Air Conditioner	Air conditioner in trailer overheated and ignited.	Not applicable; construction event.
Logic Cabinet	129	Unknown PWR	05/15/76	Power Operation	Auxiliary Building	Cabinet Cover	Electrical short ignited a plastic covering on instruments. Fire put out by employees with portable dry chemical.	Include in HFBR fire empirical experience database.