Technical Advisory Committee of the Nuclear Risk Research Center
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SUBJECT: FIRE RESEARCH ACTIVITIES

Dear Dr. Apostolakis:

During the third meeting of the Technical Advisory Committee of the Nuclear Risk Research Center (NRRC), May 25-29, 2015, we were briefed by representatives of your staff on selected research and testing activities related to fire protection and fire risk assessment. This letter report provides our observations and recommendations on the scope and planned direction of those research programs.

RECOMMENDATIONS

1. NRRC should increase priority for fire research and testing programs in the following areas to improve the information that is available to support development and application of realistic assessments of the risk from fires in Japanese nuclear power plants.

   - Development of realistic estimates of ignition frequencies, fire growth times, and heat release rates based on physical characteristics of electrical cabinets

   - Development of realistic estimates of ignition frequencies, fire growth times, and heat release rates based on physical characteristics of transient combustible materials

   - Testing to measure the response times and effectiveness of incipient fire detection systems in prototypical nuclear power plant electrical cabinets

BACKGROUND

The Central Research Institute of the Electric Power Industry (CRIEPI) is conducting research and testing to improve the understanding of fire prevention, detection, suppression, and propagation to reduce the impacts from fires that may affect nuclear power plant safety. We were briefed on several issues related to guidance for the development and implementation of fire risk assessments in Japan. Those issues were discussed in the context of specific topics that are addressed in NUREG/CR-6850, which provides methods and data for use in fire risk assessments that are currently being performed in the United States.

During this meeting, we were briefed on the current status of CRIEPI research and testing in the following areas:

- High energy arcing fault (HEAF) tests
- Heat and smoke propagation between adjacent rooms (multi-room fire tests)
- Lubricating oil fire tests
- Cable fire extinguishing system tests
- Impacts of smoke and soot deposition on electrical control systems
- Verification of fire propagation analysis codes

DISCUSSION

Experience from numerous detailed fire risk assessments performed in the United States and Europe has shown that a few general types of scenarios typically account for most of the fire risk. The following items briefly discuss those contributions and their relationship to fire research and testing programs.

Electrical Cabinet Fires

A predominant contribution to the total fire risk at many nuclear power plants is from fires that originate in electrical cabinets and propagate to nearby cable trays. The specific impacts from fire damage and the corresponding event sequences depend on the plant-specific design and the configuration of cabinets and cables in each fire area. However, these types of scenarios collectively often account for much more than half of the total plant-specific fire risk.

An important observation about these scenarios is that they most often involve fires that originate in intermediate voltage AC power buses or motor control centers, low voltage AC or DC power distribution cabinets, or instrumentation and control cabinets. Although high energy electrical faults contribute to the risk in some plant-specific locations, HEAF damage scenarios are typically a rather modest contribution to the overall fire risk at most plants.

Fire risk analysts often identify two related issues in the methods and data from NUREG/CR-6850 as sources of potential conservatism in these assessments. The first issue is that the general "electrical cabinet" fire category in NUREG/CR-6850 contains a broad variety of very different cabinets. For example, it contains cabinets that range from digital instrumentation and control cabinets with power supply voltages as low as 24V DC to plant-level AC power supply switchgear with voltages of 13.8kV or higher. No distinction is made in NUREG/CR-6850 regarding the type of cabinet, its typical configuration or circuitry, or general internal energy content. The total plant-level frequency of these "electrical cabinet" fires is derived from all fires that occur in any cabinet, and it is then subsequently distributed equally among all cabinets. Experience from the compilation of actual fire event data does not support these uniform assumptions.

The second related issue is that NUREG/CR-6850 recommends the use of similar heat release rates (HRRs) and growth times for fires that originate in any "electrical cabinet". These HRRs and growth times are further based on limited data derived from very conservative electrical cabinet fire tests that were performed for different research objectives. The U.S. Nuclear Regulatory Commission Office of Nuclear Regulatory Research has acknowledged that further testing is needed to measure realistic HRRs and fire growth times for a representative range of electrical cabinet types and configurations. Initial testing for a limited sample of cabinets has been completed and a draft report has been published (NUREG-2178).

Targeted research and testing in the following areas will provide valuable data and information to support more realistic assessments of the risk from fires that originate in electrical cabinets.

The general "electrical cabinet" fire category in NUREG/CR-6850 should be subdivided to account for the actual types of cabinets that are present in a typical nuclear power plant. For example, five or six subcategories may be defined, based on general voltage level, energy content, and types of circuits (e.g., power supply, instrumentation and control). Generic and plant-specific data for fire ignition frequencies should then be compiled separately for each cabinet subcategory. To the extent possible, the fire event data should also describe the severity, detection and suppression times, and observed extent of damage from each documented fire.

Additional fire testing should be performed for a larger selection of typical electrical cabinets, including low voltage instrumentation and control cabinets containing varying types and amounts of cables, AC and DC power distribution panels, circuit breaker cubicles for intermediate voltage AC buses and motor control centers, and high voltage AC switchgear. The fire tests should not use external accelerants to ignite or fuel each fire, and the subsequent fire growth rates and HRRs should be measured. To the extent possible, multiple tests should be performed to provide information about the variability and uncertainty in the measured parameters. These tests should build on the experience from the initial testing reported in NUREG-2178 and should take advantage of international collaboration.

Transient Combustible Fires

Fires from transient combustibles are often identified as an important contribution to overall fire risk or as a source of resource-intensive fire modeling and analyses that are needed to develop realistic estimates of the actual risk. These fires are most often important contributors to the risk in locations that contain electrical cabinets, instrumentation and control cables, and occasionally the Main Control Room.

Similarly to the discussion about electrical cabinet fires, risk analysts often identify two related issues in the methods and data from NUREG/CR-6850 as sources of potential conservatism in these assessments. The first issue is that the ignition frequencies for these fires are compiled only for very broad categories of building types and personnel activities. Those frequencies are then distributed among all normally accessible plant locations, according to general assessments of the frequency and types of personnel activities that are conducted in each location. Refinements that have been made to the original NUREG/CR-6850 guidance for allocation of these fires permit limited credit for administrative controls that should restrict the presence of transient combustibles in specific locations. However, fire analysts have indicated that these prescribed fire allocations are not consistent with actual operating experience.

The second related issue is that NUREG/CR-6850 recommends the use of a limited number of HRRs and growth times for transient combustible fires. These HRRs and growth times are based on selected fire test data for specific types and quantities of materials that may not be representative of actual nuclear power plant transient fire experience. We are not aware of any currently sponsored fire testing to further refine these HRRs and growth times for a more representative sample of transient combustible materials that may be present in various locations in a nuclear power plant.

Targeted research and testing in the following areas will provide valuable data and information to support more realistic assessments of the risk from transient combustible fires.

Generic and plant-specific data for fires that involve transient combustible materials should be better categorized to describe the type of activity that was involved in personnel-caused fires, the ignition source for equipment-caused fires, the specific material that was ignited, the plant location, and the fire protection administrative controls that applied for that location. To the extent possible, the fire event data should also describe the severity and extent of damage from each documented fire. This information will improve the assessment of transient combustible fire frequencies and their causes, and will provide improved bases for the allocation of these fires among plant-specific locations.

Additional fire testing should be performed for more representative types and quantities of transient combustible materials that may be present in nuclear power plants, based on the fire operating experience and documented plant walkdowns. The fire tests should use representative ignition sources, and the subsequent fire growth rates and HRRs should be measured. To the extent possible, multiple tests should be performed to provide information about the variability and uncertainty in the measured parameters.

Incipient Fire Detection Systems

As a consequence of detailed fire risk assessments, several U.S. nuclear power plants have installed or proposed to install sensitive incipient fire detection systems. These systems are intended to provide early warning of an impending fire before the development of significant smoke, heat, or open flames. Because electrical cabinet fires are a predominant source of the fire risk in many plants, these systems are most often proposed for low voltage instrumentation and control cabinets and selected AC or DC power distribution panels.

Current fire risk assessment guidance permits only limited credit for the effectiveness of incipient detection systems to alert plant personnel to the source and location of an impending fire with sufficient time to take preventive actions before a damaging fire is ignited (e.g., deenergize the affected circuit). If Japanese nuclear power plants conclude that such systems will improve safety, additional testing of these systems in prototypical nuclear power plant cabinet configurations and fire ignition sources is needed to provide better data for their quantitative evaluation in fire risk assessments.

We recommend that NRRC should consider extension of the current CRIEPI fire research and testing programs to address these issues in a timely manner to support the development and application of realistic assessments of the risk from fires in Japanese nuclear power plants.

Sincerely,

John W. Stetkar
Chairman

REFERENCES

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4. NUREG-2178, EPRI 3002005578, "Refining And Characterizing Heat Release Rates From Electrical Enclosures During Fire (RACHELLE-FIRE)," Volume 1, Peak Heat Release Rates and Effect of Obstructed Plume, U.S. Nuclear Regulatory Commission and Electric Power Research Institute, Draft Report for Comment, March 2015.