United States General Accounting Office

GAO

Report to the Honorable Edward J. Markey, House of Representatives

April 2000

FIRE PROTECTION

Barriers to Effective Implementation of NRC's Safety Oversight Process

GAO/RCED-00-39

Contents

Abbreviations

NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission

GAO
Accountability * Integrity * Reliability

United States General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Ecomonic Development Division

B-284198

April 19, 2000

The Honorable Edward J. Markey
House of Representatives

Dear Mr. Markey:

Concern over the risk of fire in commercial nuclear power plants increased after a fire at the Browns Ferry nuclear plant in Alabama in 1975. The fire damaged a relatively small area but adversely affected the functioning of one of the plant's safety systems and the operator's ability to monitor the status of the plant. As a result of that fire, the Nuclear Regulatory Commission (NRC) and the nuclear utility industry have taken various actions to help ensure that nuclear plants are safe from the threat of fires and that utilities can safely shut these plants down should a fire occur. NRC's fire protection regulations are intended to (1) prevent fires from starting; (2) rapidly detect, control, and extinguish fires that do occur; and (3) protect a nuclear power plant's structures, systems, and components so that a fire that is not promptly extinguished will not prevent its safe shutdown. According to NRC's regulations, these activities are designed to provide reasonable assurance that any deficiencies occurring in one activity will be backed up by another system so there is no undue risk to public health and safety.

In recent years, NRC has been moving from its traditional regulatory approach, which was largely developed without the benefit of quantitative estimates of risk, to an approach—termed risk-informed regulation—that considers relative risk in conjunction with engineering analyses and operating experience.[1] This risk-informed approach is also being applied to NRC's regulation of fire protection at nuclear power plants. One component of the new regulatory approach is an oversight process that was implemented in April 2000, which will combine inspection results, risk assessments,[2] and performance indicators to determine a plant's overall safety performance, including fire protection. NRC believes that this approach will reduce unnecessary regulatory burden on licensees and reduce their costs without reducing safety while increasing the agency's effectiveness and efficiency.

In the context of NRC's move to risk-informed regulation, you asked us to examine various issues related to fire protection at commercial nuclear power plants. As agreed with your office, this report provides information on (1) NRC's efforts to improve its oversight of fire protection at nuclear power plants and (2) any potential barriers to the successful implementation of the risk-informed oversight process for fire protection. In addition, you asked us to provide information on the extent to which fire risk assessments consider the possible failure of passive fire barriers (walls) and penetration seals (material used to seal openings in barriers) and whether the cumulative effect of granting exemptions (alternative actions to comply with regulations) has increased the risk of fire at nuclear power plants.

Results in Brief

Over the last several years, NRC has undertaken several activities to improve fire protection at commercial nuclear power plants. For example, from June 1997 through October 1998, NRC conducted special fire inspections at 10 of the nation's 103 nuclear power plants. NRC found

[1]NRC differentiates between "risk-informed" and "risk-based" regulation, noting that the latter approach relies solely on the numerical results of risk assessments. NRC does not endorse a risk-based approach.

[2]Risk assessments systematically examine complex technical systems to identify and measure the public health, environmental, and economic risks of nuclear power plants. These assessments attempt to quantify the probabilities and consequences of an accident's occurrence. By their nature, risk assessments are statements of uncertainty that identify and assign probabilities to events that rarely occur.

various problems at the plants and required the utilities to correct them. More importantly, NRC concluded that its oversight of the utilities' fire protection programs needed to be improved. For example, NRC identified four areas that had not been included in its inspection program, such as assessing the ability of the utilities to safely shut down a plant if a fire occurred. As part of its efforts to implement a risk-informed approach for fire protection, NRC plans to include these four areas in its inspection program and train its staff to effectively inspect them.

Although NRC will proceed with its new risk-informed safety oversight process, its effectiveness for fire protection could be hampered because important components will not be in place when implementation begins in April 2000. Under the new oversight process, NRC will use the risk assessments of the utilities to establish thresholds of performance and inspections and indicators to assess whether performance meets the thresholds. NRC is working with industry to develop a standard to help ensure the quality, the scope, and the adequacy of the utilities' fire risk assessments but does not expect to have such a standard until about 2 years after the new oversight process is implemented. Performance indicators for fire protection are also under development. This summer, the nuclear utility industry plans to pilot test them, and it hopes to provide some agreed upon indicators to NRC in October 2000, 6 months after the new oversight process will have been implemented. Until NRC finalizes the standard and develops the performance indicators, it will implement the new oversight process by relying on its inspection program to monitor the utilities' fire protection efforts.

NRC's review of risk assessments for 38 nuclear power plants found that the failure of passive fire barriers (walls), active fire barriers (doors), and penetration seals had not been considered. However, most of the assessments assumed a small fire, and NRC concluded that the failure to include barriers and seals was not important because a small fire would not adversely affect them. In addition, NRC used the risk assessments at 13 plants to determine whether the cumulative effects of exemptions (alternative actions to comply with regulations) that it had granted since 1983 increased the risk of a fire and generally found them not risk significant.

Background

Before the 1975 fire at Browns Ferry, NRC did not inspect the fire protection programs of nuclear power utilities. At that time, NRC relied on independent insurance carriers to ensure that the utilities used and followed good fire protection practices at nuclear power plants. To resolve some issues identified by the investigation of the Browns Ferry fire and technical disagreements with utilities, in November 1980, NRC issued regulations for fire protection. When it promulgated these regulations, which applied to commercially operating plants and those under construction, NRC recognized that compliance with some of the requirements would not significantly enhance the level of fire safety at some operating plants. In those cases, if the utility could demonstrate that existing or alternative fire protection features were providing a level of safety equivalent to that imposed by the new regulations, the utility could apply for an exemption. According to NRC, the exemption process provided the utilities with the flexibility to meet the performance objectives of its fire safety regulations through alternative means.

With the implementation of its fire protection regulations, NRC conducted one-time inspections to develop a baseline of each utility's fire protection program and developed a routine inspection program for NRC staff. As part of the routine inspection program, NRC had expected to inspect each operating plant every 3 years to help ensure that the utility could safely shut it down if a fire occurred. However, NRC did not follow through with the triennial inspections; it inspected less than 10 operating plants. Moreover, throughout the 1980s and 1990s, NRC inspectors focused their efforts on such areas as ensuring that utilities had administrative controls for combustible materials, maintained and tested fire extinguishers, and provided required training for and tested the response of the fire brigade (the on-site fire department). NRC acknowledges that it became complacent about fire protection over about a 10-year period.

To comply with NRC's regulations and to confine a fire and limit its damage, utilities divide the buildings at nuclear power plants into separate fire areas, which generally are rooms or plant areas with walls and floor-to-ceiling structural barriers that have been rated by fire resistance tests. During the early stages of a fire, the barriers are expected to contain it and prevent damage to important equipment until the automatic detection and suppression (sprinkler) systems operate. If these systems fail to operate, the barriers provide passive fire protection for important equipment until specially trained plant personnel can begin to extinguish the fire. In addition, a utility must have automatic detection and suppression systems and either a 20-foot separation between electric cable trays or a 1-hour fire-rated barrier between them to help ensure the reliability of the electrical systems that are needed to safely shut down a plant. If a plant does not have automatic detection and suppression systems, the fire-rated barriers must provide at least 3 hours of protection. (App. I provides additional information on fire barriers.)

In addition, openings in fire barriers, which are known as penetrations, allow such items as cables, conduits, pipes, and ducts to extend from one fire area to another. Penetration seals close these openings to maintain the effectiveness of the fire barriers. Penetration seals help confine a fire to the area in which it started and protect important equipment from a fire within or outside that area. Penetration seals are neither technically complex nor unique to the nuclear power industry–they have been used in residential, commercial, and industrial buildings. According to NRC's documents, it is generally accepted among fire protection professionals that properly designed, tested, installed, inspected, and maintained seals will provide reasonable assurance of the integrity of fire barriers. The importance of fire barriers and penetration seals depends on a number of factors, including the importance of the equipment and its accessibility to a plant's firefighters. NRC's documents state that fire barriers are generally more important to fire protection than penetration seals. (App. I provides additional information on penetration seals.)

The regulation of nuclear power plants, including fire protection systems, is changing. Since the early 1980s, NRC has been increasing the use of risk information in its regulatory process. In August 1995, NRC issued a policy statement advocating certain changes in the development and the implementation of its regulations for these plants through a risk-informed approach. Under this approach, NRC and the utilities would give more emphasis to those structures, systems, and components deemed more significant to safety. Moreover, in January 1999, NRC proposed a new oversight process to respond to past criticisms about the lack of a consistent, objective, and transparent method to assess the safety performance of nuclear plants. The process will combine risk-informed performance indicators, inspection results, utilities' self-assessments, and clearly defined objective thresholds to determine a plant's overall safety performance. NRC tested the new process at 13 plants between May and November 1999 and implemented it nationwide on April 2, 2000. Under the new oversight process, utilities will assume greater responsibilities for ensuring compliance with NRC's regulations.

NRC Has Activities Underway to Improve Its Oversight of Fire Protection at Nuclear Power Plants

Over the last several years, NRC has undertaken a number of activities to improve the fire protection programs at individual nuclear power plants. NRC found various problems at the plants, but, more importantly, it concluded that its oversight of the utilities' fire protection programs needed to be improved. NRC plans to include the identified improvements as part of its efforts to implement a risk-informed approach for fire protection.

To determine the extent to which utilities complied with NRC's requirements and could safely shut down a nuclear power plant if a fire occurred, NRC conducted special fire inspections at 10 plants from June 1997 through October 1998.[3] (App. II lists the plants NRC included in these inspections.) During its inspections, NRC identified weaknesses with the fire fighting personnel, the analyses and the procedures to shut down a plant should a fire occur, the analyses of the electrical circuits in the plants, and the attention to fire protection by utility management.[4] NRC required the utilities to correct these weaknesses and concluded that they

- would not have been uncovered by its routine inspection program;
- could exist in one or more of the three aspects of fire protection–prevention, detection, and suppression–at any given plant; and
- indicated a need for future fire protection inspections to include the following four new review areas: (1) the ability of utilities to safely shut down a plant if a fire occurred; (2) the design of fire detection and suppression systems; (3) the design of fire barriers; and (4) the actions utilities have reported to NRC to correct problems with a specific type of fire barrier material, called Thermo-Lag.[5]

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[3]NRC included the inspections at 10 plants in its final report on the special inspections, even though it inspected 3 plants using the same criteria but not with the same level of detail and assessed the utility's self-assessment at 2 plants.

[4]In *Nuclear Regulation: Preventing Problem Plants Requires More Effective NRC Action* (GAO/RCED-97-145, May 30, 1997), we recommended that NRC assess the competency and the performance of utility management. NRC disagreed and will not implement this recommendation. In addition, NRC has determined that it will not develop performance indicators for its new reactor oversight program to assess the management performance and competency of utilities. NRC says that it will continue to infer these qualities from its inspection, assessment, and event follow-up activities.

[5]Thermo-Lag is a fire barrier material that was used on electric cable trays and other plant equipment. App. I provides a brief history of the issues surrounding this material.

NRC expects to include these four review areas in its new inspection program, which is part of the new risk-informed oversight process, and to conduct triennial fire inspections at all 103 operating nuclear power plants. However, because NRC's inspections will assess the completed and ongoing actions utilities have taken to correct their Thermo-Lag problems, its inspectors may not have the expertise to verify the utilities' actions. In the past, with the exception of NRC's Region II in Atlanta, Georgia, NRC inspectors at the plants and in its regional offices did not have the expertise needed to verify the utilities' actions.

In March 2000, NRC began training regional staff to carry out the new inspection program. According to staff, NRC has developed a training program for about 40 fire protection, mechanical, and electrical engineers who will conduct the triennial inspections, beginning in April 2000. Subsequently, NRC might develop training for other inspectors that would include the same knowledge factors but would not be as detailed as the training provided to the members of the triennial inspection team. NRC expects to conduct the first of the triennial inspections at a minimum of seven nuclear power plant sites. The staff also said that NRC headquarters staff with extensive fire protection expertise would assist inspectors, when necessary. However, starting in October 2000, NRC headquarters staff will no longer assist regional staff with any type of inspections. Instead, all inspection personnel will be based in the regional offices.

Several Barriers Could Impede the Effective Implementation of the New Risk-Informed Oversight Process for Fire Protection

In moving toward a risk-informed regulatory approach, NRC and the nuclear utility industry view risk assessments as one of the main tools to identify and focus on those structures, systems, and components of nuclear plant operations that pose the greatest risk. This is because these assessments attempt to quantify the probability of an accident's occurrence and the how it would impair a plant's operations. Under its new oversight process, NRC will use the risk assessments of the utilities to establish thresholds of performance and indicators to assess whether their performance meets these thresholds. However, neither NRC nor the nuclear utility industry has a standard that defines the quality, the scope, and the adequacy of risk assessments. While NRC and the industry have a number of activities underway to develop a standard, it is not expected to be completed it until about 2 years after the new oversight process has been implemented. Furthermore, as part of NRC's new oversight process, the frequency and the number of inspections of utilities' fire protection programs would be predicated on performance indicators. The nuclear utility industry plans to pilot test performance indicators this summer and provide some agreed upon indicators to NRC in October 2000. Again, however, this will be 6 months after the new oversight process has been implemented.

A Standard for Risk Assessments Is Being Developed

Since 1998, NRC has been working with the National Fire Protection Association to develop a standard for the quality of fire risk assessments. Before the Association issues a final standard, the Nuclear Energy Institute (NEI) plans to conduct a 1- to 2-week pilot test on the proposed standard at two nuclear power plants. NEI wants to determine whether the proposed standard would change the licensing basis of the plants; such a change would require NRC's approval. NEI also expects that the pilot test will help identify parts of the standard that might adversely affect the plants as well as areas that have not been considered in the proposed standard. The National Fire Protection Association expects to incorporate feedback from these tests before obtaining public comments on the proposed standard. The Association expects to publish a final standard by April 2001. NRC plans to adopt the standard, including obtaining public comments on it, by March 2002.

However, more needs to be done to ensure that an effective standard is developed. For example, in February 1999, the Advisory Committee on Reactor Safeguards notified NRC that the proposed standard is "not a bold step in the direction of risk-informed fire protection" because it focuses on existing fire protection requirements and only minimally considers the use of risk information and performance criteria.[6] NRC staff recognize that limitations and uncertainties exist with certain aspects of fire risk assessments, fire modeling, and performance measurement techniques. In part to address such limitations, NRC initiated research efforts to improve, among other things, the qualitative and quantitative understanding of the risk that fires contribute to the probability and consequences of an accident in nuclear power plants and to improve its fire risk assessment methods and tools.[7] In addition, because NRC staff believe that the National Fire Protection Association standard may not address or amplify some fire protection issues, the research staff have proposed that they develop fire risk assessment guidance that will be more detailed than the standard under development.

In commenting on NRC's research efforts, in July 1999, the Advisory Committee on Reactor Safeguards told NRC that it lacked a plan to undertake the research activities that would result in the types of tools it needs to move forward with a risk-informed approach for fire protection. The Advisory Committee noted that NRC has not developed the in-house capabilities to quantitatively assess the impact of its research activities, prioritize them, and allocate resources to them. Subsequently, NRC provided a plan to the Advisory Committee, and the staff expects to discuss

[6]The Advisory Committee on Reactor Safeguards is a statutory committee established to advise NRC on the safety aspects of proposed and existing nuclear facilities as well as to perform other duties as the Commission may request.

[7]NRC also has research underway to (1) improve the estimates of the frequencies of severe fires; (2) improve fire-modeling tools; (3) identify scenarios for which smoke might pose a significant risk; (4) improve the estimates of the probabilities of fires and their containment, including the effects of active and passive barriers; (5) develop estimates of the probability of failure of fire dampers, doors, and penetration seals during a severe fire; (6) determine the extent to which fire risk assessment methods can confidently be used to prioritize the selection of penetration seals for inspections; (7) improve human risk assessment tools for fire scenarios; (8) develop reliability estimates for configuration- and condition-sensitive fire protection systems; (9) improve the tools to assess the risk impacts of a fire that might simultaneously affect multiple plants at a site; (10) determine the frequency and the characteristics of switchgear and transformer fires; (11) determine the risk significance of turbine building fires; and (12) improve the understanding of the implications of actual fire events for risk assessments.

the plan and other fire protection issues with the Advisory Committee in the spring of 2000. According to Advisory Committee staff, one issue that will be discussed is that the research plan does not specify how NRC would integrate the results of its research into its overall risk-informed regulatory approach.

Performance Indicators Will Not Be Finalized

Along with risk assessments, performance indicators are another important aspect of NRC's new risk-informed oversight process. The process is predicated on NRC's conducting minimal inspections at first but then increasing them when indicators and inspections show that a utility's performance has deteriorated below the thresholds established by NRC. For example, if three unplanned automatic or manual shutdowns is the performance indicator and a plant had more than three, NRC would then increase its inspection efforts until the indicator is within its prescribed limits. In essence, the indicators would provide NRC with an early warning about a nuclear plant's performance. Although NEI is developing performance indicators for fire protection, they will not be finalized until at least about 6 months after NRC implements the new oversight process.

In October 1999, NEI provided NRC with some suggested performance indicators related to fire protection. NEI also noted that NRC and the nuclear utility industry face a number of challenges in developing performance indicators for fire protection. The challenges include ensuring the availability of data that will be needed for the indicators; determining the effects of measures taken to compensate for degraded, inoperable, or nonexistent equipment (compensatory measures); and ensuring that the performance indicators for fire protection are commensurate with those for other activities at nuclear power plants. NEI expects to pilot test the performance indicators at plants beginning in July 2000 and submit those that the industry believes have merit to NRC in October 2000.

Information on Assumptions in Utilities' Risk Assessments

In June 1991, NRC asked nuclear power utilities to identify and report to the agency all plant-specific vulnerabilities to severe accidents that could be caused by earthquakes, high winds, floods, and fires. In response, NRC received 70 risk assessments for the 103 operating plants. In January 1998, NRC staff reported on their preliminary review of 24 fire risk assessments for 38 plants. (App. II indicates which plants were included in the preliminary review.) The purpose of NRC's review was not to validate or verify the results of the utilities' assessments but to determine their quality and their underlying assumptions.

NRC's review identified a number of weaknesses in the utilities' risk assessments. For example, NRC found that practically none of the 24 assessments considered the possible failure of passive fire barriers (walls) or properly modeled active fire barriers (doors) or considered the effects that penetration seals might have on containing or spreading a fire. However, NRC concluded that these weaknesses were not significant because utilities had assumed a small fire in their risk assessments and such a fire would not adversely affect a plant's barriers or seals. While this assumption is consistent with an NRC study showing that the probability of a large fire that would adversely affect a nuclear power plant is low, NRC and the nuclear utility industry continue to debate the size and the type of fire to assume in these risk assessments. The results of a fire risk assessment depends on whether a utility assumes a large fire that most likely would not occur, but would adversely affect a plant's safety systems, or a small fire that would more likely occur but would be less likely to adversely affect those systems.

NRC also found that although the routing of cables is one of the most important elements of a fire risk assessment, almost none of the risk assessments indicated that the utilities had verified their information on cable routing. In addition, NRC found that the assessments had not considered the actions and the effectiveness of the utilities' fire fighting staff (except in analyzing a control room fire). Because of this omission, the utilities had not taken into account the effects of smoke on the fire fighting staff or the potential damage to equipment that could result from their actions.

NRC staff asked the utilities to provide additional information on the weaknesses identified and other issues in the risk assessments. On the basis of their preliminary review of these assessments and the additional information provided, NRC staff said that the fire risk assessments for some of the remaining 65 plants were similar to the assessments for the 38 plants it had already reviewed. NRC expects to issue a final report on its evaluation of the fire risk assessments for all 103 plants in October 2001. NRC staff also noted that more than half of the utilities improved their fire protection efforts as a result of the assessments; the other utilities had already taken actions to improve their fire protection programs or had sufficient fire protection designed into the plants.

With regard to the alternative actions (exemptions) NRC had approved for nuclear power utilities to comply with fire regulations, the utilities did not explicitly specify that their fire risk assessments examined these alternatives. However, NRC staff said the exemptions were an inherent part of the assumptions made in the risk assessments. This is because granting an exemption would include the utilities' changing a structure, system, or component as an alternative way to comply with NRC's regulations and the utilities had made these changes before preparing their risk assessments.

In addition to reviewing assumptions in risk assessments, NRC used them as a basis to review the cumulative effects of granting exemptions. (App. II indicates which plants were included in this analysis). NRC granted most of the more than 1,300 exemptions from 1983 through 1987. Although granting an exemption could increase fire risk, NRC did not consider the cumulative effects of exemptions for individual plants until June 1998—about 15 years after it had started to grant them. NRC staff told us that, until the utilities completed their fire risk assessments, the agency did not have a tool to determine the synergistic effects of the exemptions.

Using information from the risk assessments for 13 plants, NRC concluded that the cumulative effects of most of the exemptions were not risk significant. For example, NRC staff concluded that only 5 of the 169 exemptions granted to the 13 plants were potentially risk significant–the utilities had sought the exemptions because they had not installed automatic fire suppression systems in high-risk areas. They found that 143 exemptions created a small or very small fire risk and they could not determine the impact of the remaining 21 exemptions because the risk assessments did not contain sufficient information. NRC acknowledges that a number of uncertainties exist with this analysis, in part, because the quality of the risk assessments varied among the plants and because of information gaps in the risk assessments that NRC had used to prepare the analysis. According to NRC staff, they could not project their findings to the remaining 90 operating plants. They noted, however, that the synergistic impact of the exemptions on the 90 plants would be small because the estimated accident frequency for them was lower than for the plants that had been examined.

Conclusions

Over the last several years, NRC has undertaken several activities to improve fire protection at nuclear power plants. The success of NRC's efforts to implement a risk-informed regulatory approach and its new oversight process for fire protection depends in large part on the quality and the scope of the risk assessments prepared by nuclear utilities because NRC will use these assessments to determine the appropriate thresholds and performance indicators to decide the frequency and the number of its inspections. However, NRC will have neither a risk assessment standard nor the performance indicators when it implements its oversight process in April 2000. Until NRC finalizes this standard and develops performance indicators, it will implement its oversight process by relying on its inspection program to monitor the utilities' fire protection efforts.

Agency Comments and Our Evaluation

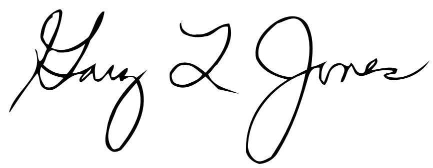
We provided a draft of this report to NRC for its review and comment. While neither agreeing nor disagreeing with the report's message, NRC said that it does not need a risk assessment standard to implement its new oversight process. Instead, NRC will rely on existing techniques. However, NRC as well as the Advisory Committee on Reactor Safeguards have noted that existing risk techniques for fire risk assessments are not as developed as those for assessing the risk of other accident initiators in a commercial nuclear power plant. Therefore, we continue to believe that the successful implementation of the new oversight process for fire protection could be adversely affected without better and more consistent fire risk assessments. NRC also provided other technical comments and clarifications that we included in the report, where appropriate.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the Honorable Richard A. Meserve, Chairman, Nuclear Regulatory Commission; the Honorable Nils J. Diaz, the Honorable Greta Joy Dicus, the Honorable Edward McGaffigan, Jr., and the Honorable Jeffrey S. Merrifield, Commissioners, Nuclear Regulatory Commission; and the Honorable Jacob J. Lew, Director, Office of Management and Budget. We will make copies available to others on request.

We conducted our work from April 1999 through March 2000 in accordance with generally accepted government auditing standards. Appendix IV provides details on our scope and methodology.

If you or your staff have any questions about this report, please call me at (202) 512-8021. Other key contributors to this report are Mary Ann Kruslicky, Philip Olson, and Michael Rahl.

Sincerely yours,



(Ms.) Gary L. Jones
Associate Director, Energy,
Resources, and Science Issues

Background on Passive Barriers and Penetration Seals

Passive Fire Barriers

To confine a fire and limit its damage, utilities divide nuclear power plant buildings into separate fire areas, which generally are rooms or plant areas that have walls and floor-to-ceiling structural barriers that have been rated based on fire resistance tests. These structural barriers are supposed to have sufficient resistance to protect the rooms or areas from the hazards of a fire. Such compartmentalization is not unique to nuclear power plants. According to studies by the Nuclear Regulatory Commission (NRC), fire-rated barriers are the first and last lines of defense for a fire. During the early stages of a fire, the barriers contain the fire and protect important equipment until the automatic detection and suppression systems operate. If these systems fail to operate, the barriers provide passive fire protection for important equipment. To help ensure the reliability of the electrical systems needed to safely shut down a plant that are located outside containment, nuclear utilities must have automatic detection and suppression systems and either a 20-foot separation between electric cable trays or a 1-hour fire-rated barrier between them. If a plant does not have automatic detection and suppression systems, the barriers must provide at least 3 hours of protection. NRC has other requirements to protect electric cables that are inside containment.

In 1981, NRC began to receive requests from nuclear utilities to use a specific type of passive fire barrier, a concrete-like substance called Thermo-Lag, to satisfy its regulatory requirements, which stated that one method to help ensure the safe shutdown of a nuclear power plant was to enclose electric circuits with fire-rated barriers. Ultimately, utilities installed the material in more than 85 plants. In 1987, a utility verbally notified NRC that electric cable insulation was being degraded at a higher rate than reported by Thermo-Lag's manufacturer because of the heat build up caused by the material. Subsequently, utilities reported other problems to NRC, including that the material did not meet NRC's 1- or 3-hour fire resistance requirements and that the manufacturer had falsified test results to gain NRC's approval. In June 1991, NRC established a special team to review issues related to Thermo-Lag and recommend actions to resolve the problems found. In December 1991, NRC conducted its first inspection of Thermo-Lag's manufacturer. In 1992, NRC's Office of the Inspector General found, among other things, that NRC had not followed up on any of the allegations reported by the utilities.

In response, NRC required utilities to provide information to verify that their Thermo-Lag fire barriers complied with NRC's requirements. NRC also instituted efforts to help ensure that electric cable insulation had not degraded because of the installation of Thermo-Lag. For example, in December 1992, the Commission required utilities to report on the types of systems and components insulated by Thermo-Lag, the fire-endurance tests that had been conducted on the material, the reduction in cable current required to compensate for the increased heat, and the corrective actions that had been completed or were scheduled to comply with NRC's regulations. NRC required the utilities to provide this information by April 1993 or the reasons they could not do so and asked them to provide a schedule for completing the needed corrective actions. Since then, utilities have taken various actions to address the design deficiencies with Thermo-Lag. NRC's documents show that some utilities replaced the material with another passive fire barrier, which was developed by a different manufacturer, in some areas of the plants; rerouted or replaced cables in the plants; and applied a different material or more Thermo-Lag. To resolve this issue, in 1994, NRC issued orders to 17 plants to complete their Thermo-Lag corrective actions. Turkey Point Units 3 and 4 in Florida, scheduled for December 2001, will be the last to do so.

A number of reasons exist for the time that it has taken utilities to complete their Thermo-Lag corrective actions. First, substitute material had not been tested and approved for their use. Second, it took more time, effort, and money to correct the problem than NRC and the utilities had estimated. Third, NRC allowed the utilities to defer the corrective actions until the plants were shutdown for refueling (about every 18 to 24 months) to avoid undue disruptions with normal plant operations. Fourth, NRC and the utilities placed a higher priority on other safety-related activities because Thermo-Lag provided some degree of fire protection and the utilities had implemented fire watches to help ensure the early detection of fires in areas where the material had been installed.[1] NRC staff noted, for example, that Thermo-Lag could withstand the rigors of a fire for between 20 and 40

[1]Fire watches are utility personnel trained to look for fire hazards and conditions that could lead to a fire, summon the fire brigade, and start suppression activities if a fire occurs. NRC allows utilities to compensate for degraded or inoperable equipment. In the fire protection area, compensatory measures can include enhanced controls over combustible materials, briefing operators and the fire brigade on the nonconforming condition, implementing temporary operating procedures, installing temporary fire protection features, undertaking temporary repairs and temporary power interconnections, and the manual operation of motor driven valves. The most common compensatory measure is fire watches. NRC's regulations, however, do not expressly discuss the compensatory measures that utilities can take. Instead, the compensatory measures are set out in the NRC-approved plant technical specifications and fire protection plan as well as administrative procedures and license conditions.

minutes. An NRC study of fires that have occurred since Browns Ferry indicates that most fires are extinguished within 10 to 15 minutes; and since the temperature would likely be less severe during the initial stages of a fire, the fire watch would have time to notify the fire brigade and/or begin to suppress the fire; and the barrier would provide a level of protection until the fire is extinguished.

Public interest groups contend that fire watches are not a substitute for passive barriers. In various documents, NRC acknowledged that fire watches cannot replace fire barriers and cannot act as physical shields but concluded that the watches are an acceptable compensatory measure for utilities to implement. Although NRC found that Thermo-Lag could not meet the required fire endurance rating and that fire watches did not compensate for the barrier's shortcomings, NCR concluded that the combination of Thermo-Lag and fire watches help ensure public health and safety until the utilities have completed their corrective actions. Even after the utilities have completed their Thermo-Lag corrective actions, they will likely continue to use fire watches to supplement other fire detection systems. Although utilities instituted fire watches to compensate for inoperable fire barriers, they also use them during routine maintenance activities at the plants.

Penetration Seals

Openings in structural fire barriers, which are known as penetrations, allow such items as cables, conduits, pipes, and ducts to pass from one fire area to another. Penetration seals close these openings and maintain the effectiveness of the fire barrier. Penetration seals help confine a fire to the area in which it started and protect important equipment from a fire within or outside the area. Penetration seals are not technically complex nor are they unique to the nuclear industry–they are used in residential, commercial, and industrial buildings. According to NRC's documents, it is generally accepted among fire protection professionals that properly designed, tested, installed, inspected, and maintained seals will provide reasonable assurance of the integrity of the fire barriers in which they are installed. The importance of fire barriers and penetration seals depends on a number of factors, including the safety significance of the equipment and its accessibility to a fire brigade.

NRC's documents state that fire barriers are generally more important to fire protection than penetration seals. In some cases, NRC does not require penetration seals to have the same fire resistance rating as the barriers in which they are installed. In fact, NRC does not require that all penetrations be sealed. According to NRC's documentation, a nuclear power plant can have up to 10,000 penetration seals, but the reported instances of breached seals are rare. Although NRC does not require its inspectors or utilities to destroy seals to inspect them, NRC staff said that some utilities have conducted such inspections.

About 1985, NRC became aware that some utilities may not have been complying with its requirements to properly test, install, inspect, and maintain the penetration seals and subsequently sent them information notices about potential problems with the seals. However, information notices do not require utilities to take any actions or report their actions to NRC. In 1992, NRC again identified potential problems with the testing, installation, inspection, and maintenance of penetration seals and initiated a review of them. NRC wanted to determine if the potential problems presented a significant safety or industrywide concern and if it needed to issue additional regulatory requirements related to penetration seals. On the basis of its review, NRC concluded that utilities generally had satisfactory programs to install, maintain, and inspect the seals. NRC also determined that the seals were not an industrywide problem and concluded that it and the nuclear power industry understood the potential problems with the seals, an industry fire test standard was available and followed by the utilities, and qualified fire-resistant seal materials and appropriate designs were available to correct potential problems. Despite these conclusions, NRC staff recommended that the agency confirm the adequacy of its inspection program for penetration seals.

In 1995, NRC's former Office for Analysis and Evaluation of Operational Data reported on its assessment of penetration seals. That office reached many of the same conclusions as NRC had raised in its 1992 effort and again raised questions about NRC's procedures to inspect penetration seals. NRC requires utilities to have written procedures to inspect and maintain penetration seals. According to NRC documentation, utilities inspect some seals during every refueling outage (about every 18 or 24 months). If the utility identifies breached, degraded, improperly repaired, or inoperable seals while the plant is operating, the utility is required to establish an NRC-approved compensatory measure until the degraded condition is corrected. NRC inspectors are expected to review a sample of the utilities' documentation.

In addition, in July 1996, NRC issued a report on the results of a comprehensive technical assessment of penetration seals and in January 1999, issued a report that, among other things, discussed problems with penetration seals reported by utilities and found during 153 inspections at 87 plants. In the latter report, NRC concluded that potential penetration seal deficiencies are not a safety concern and do not result in undue risks to public health and safety. In both reports, NRC concluded that the utilities' penetration seal programs appear to be satisfactory, the problems are understood, and fire-resistant penetration seal material is available to correct the problems the utilities identify.

Nuclear Power Plants Included in NRC's Various Assessments

Plant	Preliminary review of utilities' fire risk assessments	Special inspections	Cumulative effect of exemptions
Brunswick 1	X		
Brunswick 2	X		
Callaway	X		
Calvert Cliffs 1			X
Catawba 1	X		
Catawba 2	X		
Clinton		X	
Comanche Peak 1	X		
Comanche Peak 2	X		
Cook 1	X		
Cook 2	X		
Diablo Canyon 1	X		
Diablo Canyon 2	X		
Dresden 2			X
Dresden 3			X
Farley 1			X
Farley 2			X
Fort Calhoun	X		
Haddam Neck[a]	X		
Kewaunee	X		X
LaSalle 1	X		
LaSalle 2	X		
Limerick 1	X		
Limerick 2	X		
McGuire 1	X		
McGuire 2	X		
Millstone 3	X		
Nine Mile Point 2	X		
Palisades	X		X
Pilgrim	X		
Point Beach 1	X		
Point Beach 2	X		
Prairie Island 1		X	
Prairie Island 2		X	

Continued

Plant	Preliminary review of utilities' fire risk assessments	Special inspections	Cumulative effect of exemptions
Quad Cities 1		X	
Quad Cities 2		X	
River Bend		X	
Robinson 2	X		X
St. Lucie 1	X	X	X
St. Lucie 2	X	X	X
Seabrook	X		
Sequoyah 1	X		
Sequoyah 2	X		
South Texas 1	X		
South Texas 2	X		
Summer			X
Susquehanna 1	X	X	
Susquehanna 2	X	X	
Turkey Point 3	X		X
Turkey Point 4	X		X

Continued from Previous Page

[a]In 1996, the Connecticut Yankee Atomic Power Company decided to cease operations and decommission this plant.

Comments From the Nuclear Regulatory Commission

Note: GAO comments supplementing those in the report's text appear at the end of this appendix.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 24, 2000

Ms. Gary Jones
Associate Director, Energy,
Resources, and Science Issues
U.S. General Accounting Office
Washington, DC 20548

Dear Ms. Jones:

I am responding to your letter of March 15, 2000, requesting the U.S. Nuclear Regulatory Commission (NRC) to review and comment on the draft report "Fire Protection: Barriers to Effective Implementation of NRC's Safety Oversight Process" (GAO/RCED-00-39). The NRC has completed its review of this report and our comments are enclosed for your consideration.

We appreciate the opportunity to comment on this report, as well as your incorporation of many of our prior comments in the previous version. The NRC staff is available to discuss the enclosed comments at your convenience. If you have any questions, please contact Edward A. Connell at 301-415-2838.

Sincerely,

William D. Travers
Executive Director
for Operations

Enclosure: As stated

U.S. Nuclear Regulatory Commission Review of U.S. General Accounting Office Draft Report, "Fire Protection: Barriers to Effective Implementation of NRC's Safety Oversight Process" (GAO/RCED-00-39)

Now on pp. 5 and 9.

(1) Pages 2 and 6 of the report state that the NRC is working with industry to develop a standard to help ensure the quality, scope, and adequacy of the utilities' fire risk assessments but does not expect to have such a standard until about 1-1/2 years after the new oversight process is implemented. The report states that the oversight process begins in April 2000.

See comment 1.

The staff is participating with industry in the development of National Fire Protection Association (NFPA) Standard 805, "Performance Based Standard for Fire Protection for Light Water Reactor Generating Plants," expected to be published in March 2001. Although this future NFPA standard will include guidance on acceptable methods for performing probabilistic fire safety assessments, the new NRC reactor oversight process procedure for fire protection inspection does not rely upon the future NFPA 805 standard. Rather, the fire protection baseline procedure uses existing risk information techniques.

Now on p. 5.

See comment 2.

(2) On page 2, the report implies that fire risk assessments simply assume small fires, and that the NRC takes that assumption at face value. Actually, both fire risk assessment analysts and reviewers do look at the fire scenarios postulated and see if they make sense for the room occupancy. Fire risk assessments also look at the possibility of growth beyond initial size; this is a major portion of the assessment. The NRC generally believes that the likelihood of fires which are severe enough to fail intact, rated barriers is very small - this is based on knowledge of typical room occupancies (which affect how fires behave), the increasing likelihood of fire suppression with time, and the historical record (which has very few severe fires). The NRC has research tasks aimed at improving our confidence in a number of areas relevant to multi-area fires (e.g., the reliability/availability of barriers, fire modeling).

Now on p. 5.

(3) Page 3 states that the NRC did not have fire protection regulations before the Browns Ferry fire in 1975.

See comment 3.

General Design Criterion (GDC) 3, "Fire protection," was issued as part of Appendix A to 10 CFR Part 50 in 1971. GDC 3 specifies that structures, systems, and components important to safety be designed and located to minimize, consistent with other safety requirements, the probability and effects of fires and explosions. The GDC also specifies that fire detection and firefighting systems of appropriate capacity and capability be provided to minimize the adverse effects of fires on structures, systems, and components important to safety.

Now on p. 11.

(4) Page 7 states that the ACRS told the NRC that it did not have a plan to undertake research activities that would result in the type of tools the NRC needs to move forward with a risk-informed approach for fire protection.

See comment 4.

The ACRS critique stated that the NRC doesn't have a plan for implementing the results of the fire risk assessment research.

Now on p. 13.

(5) Page 9 states that none of the risk assessments addressed cable routing.

See comment 5.

Almost all of the fire risk submittals stated that cable routing information was considered during the evaluation. This information generally did not have to be developed as part of the fire risk

Enclosure

Now on pp. 5, 12, and 14.

See comment 6.

2

assessment because this information was already available to licensees as part of the work to demonstrate compliance with the NRC's fire protection requirements (e.g., Appendix R to 10 CFR Part 50).

(6) There is a factual misunderstanding that affects the report in a number of places (i.e., pages 2, 7, 8 & 10). The report states that the baseline inspection frequency is adjusted as a result of performance indicators. The report does not recognize that there is only one baseline inspection and that the baseline inspection is the minimum level of inspection performed at all commercial nuclear power plants regardless of licensee performance. The frequency of the baseline inspection is not adjusted based upon performance indicators or inspection findings. The report also does not recognize that performance indicators and baseline inspection together form the basis for assessing licensee performance and determining the need for additional inspection beyond the baseline.

GAO's Comments

The following are GAO's comments on the Nuclear Regulatory Commission's letter dated March 24, 2000.

1. NRC said that it does not need the risk assessment standard being developed by the National Fire Protection Association to implement the new oversight process. Rather, the Commission will rely on existing risk techniques. However, NRC as well as the Advisory Committee on Reactor Safeguards have noted that existing techniques are not as well developed as those for assessing the risk of other accident initiators in a commercial nuclear power plant. Therefore, we continue to believe that the successful implementation of the new oversight process for fire protection could be adversely affected without better and more consistent fire risk assessments.

2. NRC said risk assessments consider the possibility that a fire will grow beyond its initial size, but it believes the likelihood that a fire will become severe enough to result in the failure of fire barriers is small. NRC also noted that it has research relevant to multiarea fires within a nuclear power plant. We believe that the report sufficiently discusses both the continuing debate over the size of the fire that nuclear utilities should consider in their fire risk assessments as well as NRC's research efforts. Therefore, we made no change to the report.

3. We have revised the report by deleting the reference to the lack of fire protection regulations before 1975.

4. The July 1999 Advisory Committee on Reactor Safeguards report (p. 12) states: "There is not, however, a well-developed plan to show that these research activities will, in fact, yield the kinds of tools that the agency will need in its move toward risk-informed regulation." This is the same information as shown in our report. Therefore, we have not changed the report as NRC suggests.

5. In its January 1998 report, NRC states that almost invariably the utilities said that they considered cable routing information in their fire risk assessments. However, on the basis of its analysis, NRC later noted in the report that almost none of the risk assessments indicated that the utilities had verified cable routing or other fire-related information. We have revised the report to note that almost none of the utilities had indicated that they had verified cable routing information.

6. We agree that performance indicators and baseline inspections form the basis to determine the need for additional inspections and where appropriate, we have added "inspection" to the report.

Objectives, Scope, And Methodology

Representative Edward J. Markey asked us to examine various issues related to fire protection at nuclear power plants. On the basis of discussions with his office, we agreed to answer the following three questions: What has the Nuclear Regulatory Commission (NRC) done to improve its oversight of fire protection at nuclear power plants? What are some of the barriers that NRC needs to resolve to successfully implement the risk-informed oversight process for fire protection? Did utilities consider passive fire barriers, penetration seals, and exemptions in their fire risk assessments? We reviewed relevant sections of the Atomic Energy Act of 1954, as amended; NRC's regulations; staff requirement memorandums; and various analyses provided by the staff for the Commission's consideration.

To determine the actions that NRC has taken to improve its oversight of fire protection, we reviewed an NRC Office of the Inspector General report, *Adequacy of NRC Staff's Acceptance and Review of Thermo-Lag 330-1 Fire Barrier Material* (Case No. 91-04N, Aug. 12, 1992) and met with the staff responsible for this report. We also reviewed transcripts of March 1998 and February 1999 Commission briefings on fire protection issues, information on the results of a February 1999 public workshop to develop a method to assess the risk significance of fire protection deficiencies, and a May 1999 memorandum from the Executive Director for Operations on the results of the fire protection functional inspections and the recommendations for future inspections. In addition, NRC provided us a computer disc of FIREDAT, its database of exemptions granted to nuclear power plants. We used this database to determine the number and the types of exemptions that NRC had granted to nuclear power plants. We did not validate the information in the database, and a June 1999 report by the Department of Energy's Sandia National Laboratories stated that NRC had not validated the information. Nevertheless, Sandia used the information in its analysis of exemptions. We also reviewed a July 1999 memorandum from the Executive Director for Operations to the Commissioners on the cumulative effects of exemptions on fire risk. We also examined a June 1996 technical assessment of fire barrier penetration seals in nuclear power plants and two reports on *Fire Barrier Penetration Seals in Nuclear Power Plants* (NUREG-1552, July 1996 and Supplement 1, Jan. 1999). We reviewed semiannual reports on the status of the utilities' corrective actions related to Thermo-Lag fire barriers; information notices that addressed such issues as the types of passive fire barriers, compensatory measures, penetration seals, and postfire circuit analyses; and generic letters that addressed such issues as fire protection regulations, implementation of fire protection requirements, and endurance tests for passive fire barriers. We also met or talked with NRC staff in the Offices of Nuclear Reactor Regulation and Nuclear Regulatory Research as well as officials from the Nuclear Energy Institute, the Union of Concerned Scientists, the Nuclear Information and Resource Service, and the Institute of Nuclear Power Operations.

To determine the issues NRC needs to resolve to successfully implement the new oversight process for fire protection, we reviewed information on NRC's fire risk research program and a draft report, *Technical Review of Risk-Informed, Performance-Based Methods for Nuclear Power Plant Fire Protection Analyses* (NUREG-1521, July 1998). In addition, we examined proposed standards being developed by the National Fire Protection Association and talked with the Association's Chairman, Nuclear Facilities Committee, and Chairman, Standard 805 Subcommittee. We also obtained information and attended public meetings regarding NRC's proposed risk-informed baseline inspection program for fire protection and post-fire safe shutdown of nuclear plants. We also met with NRC staff in the Offices of Nuclear Reactor Regulation and Nuclear Regulatory Research as well as officials from the Nuclear Energy Institute, the Union of Concerned Scientists, and the Nuclear Information and Resource Service. We also talked with a private individual that has had a long-standing interest in nuclear plant fire protection as well as officials from American Nuclear Insurers and Nuclear Electric Insurance Limited—companies that market nuclear plant fire protection insurance.

To determine whether utilities included fire barriers, penetration seals, and exemptions in their risk assessments, we reviewed NRC's January 1998 preliminary report on risk assessment that utilities had prepared for 38 nuclear plants. We met with NRC staff in the Offices of Nuclear Reactor Regulation and Nuclear Regulatory Research as well as officials from the Nuclear Energy Institute, the Union of Concerned Scientists, and the Nuclear Information and Resource Service. We also reviewed transcripts of March 1998 and February 1999 Commission briefings on fire protection issues.

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