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Fire Barrier Penetration Seals in Nuclear Power Plants

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

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ABSTRACT

As part of fire protection defense in depth, nuclear power plants are divided into separate fire areas by fire-rated structural barriers. Fire-rated penetration seals are installed to seal certain openings in these barriers. The seals maintain the fire-resistive integrity of the barriers and provide reasonable assurance that a fire will be confined to the area in which it started. The staff of the Fire Protection Engineering Section, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, conducted a comprehensive technical assessment of penetration seals to address reports of potential problems, to determine if there were any problems of safety significance, and to determine if NRC requirements, review guidance, and inspection procedures are adequate. The staff did not find plant-specific problems of safety significance or concerns with generic implications. The staff concluded that the general condition of penetration seal programs in industry is satisfactory. The staff also concluded that actions it had taken in 1988 and 1994 to address potential penetration seal problems increased industry awareness of such problems and resulted in more thorough surveillances, maintenance, and corrective actions. These previous staff actions, together with continued licensee upkeep of existing penetration seal programs and continued NRC inspections, are adequate to maintain public health and safety. The staff recommended several minor revisions to the NRC fire protection regulation and review guidance.

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EXECUTIVE SUMMARY

As part of fire protection defense in depth, nuclear power plants are divided into separate fire areas by fire-rated walls and fire-rated floor-ceiling assemblies. These fire barriers offer reasonable assurance that a fire will not spread from one plant area to another. Openings in these fire barriers, which are known as penetrations, allow such items as cables, conduits, cable trays, pipes, and ducts to pass from one fire area to another. Fire barrier penetration seals are installed to seal these openings and maintain the fire-resistive integrity of the fire barriers. Penetration seals are not technically complex, nor are they unique to the nuclear industry. In fact, they are universally accepted building components that are used in a variety of residential, commercial, and industrial buildings wherever fire-resistive separation is needed. The same penetration seal materials, fire test standards, and installation techniques that are used by the nuclear industry are used in these other industries. A large body of fire test results (nuclear and non-nuclear) and fire experience (non-nuclear) has proven the fire-resistive capabilities and effectiveness of penetration seals.

In about 1985, the staff had become aware of the possibility that some licensees may not have been complying with U.S. Nuclear Regulatory Commission (NRC) requirements and guidance for fire barrier penetration seals. In response to these concerns, in 1987 and 1988, the NRC staff had assessed aspects of fire barrier penetration seals. The staff had reviewed such relevant data as licensee event reports, inspection findings, and fire test reports; interviewed industry staff; inspected licensees and vendors; and reviewed a sample population of as-built fire barrier penetration seal installations and the substantiating documentation. Although it did not find widespread problems or safety-significant generic issues, the staff addressed potential problems in a series of information notices.

Since 1992, potential problems have again been reported. In response, the Office of Nuclear Reactor Regulation (NRR) conducted a second technical assessment of fire barrier penetration seals. The principal purposes of the second assessment, which is documented here, were to address potential problems, to determine if there were any problems of safety significance or with generic implications, and to determine if NRC regulatory requirements, review guidance, and inspection procedures for penetration seals are adequate. In support of this assessment, the staff conducted inspections at reactor and vendor facilities; witnessed fire endurance tests of penetration seals; reviewed operating experience and previous NRC inspection and assessment results; and assessed the data and information obtained from the field work and document reviews.

The staff found several minor weaknesses with some of the plant-specific penetration seal programs that it reviewed. However, these weaknesses did not result in problems with the penetration seals installed in the plants. On the basis of the totality of the information it found and assessed, including the "Report on the Reassessment of the NRC Fire Protection Program" that had been conducted by NRR, the review of fire barrier penetration seals that had been conducted by the Office for Analysis and Evaluation of Operational Data (AEOD), reports that had been prepared by Sandia National Laboratories on the population of fire barrier types installed in nuclear power plants and penetration seal aging, and the other documents referenced in this report, the staff concluded that the general condition of penetration seal programs in industry is satisfactory. The staff did not find plant-specific problems of safety significance or concerns with generic implications.

Even though the staff found the condition of penetration seal programs in industry to be satisfactory, it expects that minor plant-specific deficiencies will occasionally be found during future licensee surveillances and NRC inspections. However, potential fire barrier penetration seal problems are understood; industry consensus fire test standards are available and are followed; and fire test results and qualified fire-resistant seal materials and designs are available. Therefore, licensees have the means to correct problems, and staff oversight will continue to ensure corrections on a case-by-case basis. Fire protection defense in depth provides reasonable assurance that such deficiencies will not present an undue risk to public health and safety. Finally, the staff concluded that the actions it had taken in 1988 and 1994 to address potential penetration seal problems increased industry awareness of such problems and resulted in more thorough surveillances, maintenance, and corrective actions. These actions, together with continued licensee upkeep of existing penetration seal programs and continued NRC inspections, are adequate to maintain public health and safety.

On the basis of the technical assessment documented here, the staff recommends the following: (1) revise the NRC fire protection guidance documents to reflect the current National Fire Protection Association position on testing laboratories (Section 3.2); (2) delete the noncombustibility criterion for seal materials from the NRC fire protection regulation and review guidance (Section 5.8); (3) develop guidance for comparing fire-tested penetration seal configurations to as-built configurations (Section 5.12); and (4) make this assessment report available to the general public and industry (Section 7).

The Fire Protection Engineering Section of NRR conducted the technical assessment documented here. The Special Inspection Branch of NRR and Brookhaven National Laboratory helped with the reactor and vendor inspections. Staff of NRR, AEOD, the Office of Nuclear Material Safety and Safeguards (NMSS), Region I, Region II, Region III, and Region IV conducted a peer review of this assessment report. An Independent Management Review Panel chaired by NRR and represented by NMSS and the Office of Nuclear Regulatory Research conducted a final review of this report.

The staff of the Fire Protection Engineering Section made presentations on fire barrier penetration seals and this assessment at the International Conference on Fire Protection and Prevention in Nuclear Facilities, Barcelona, Spain (December 5 through 7, 1994); the Nuclear Energy Institute Fire Protection Forum, St. Petersburg, Florida (January 29, 1996); and NRC Regulatory Information Conferences (May 1994 and April 1996). On March 7, 1996, the staff of the Fire Protection Engineering Section presented the results of this technical assessment to the Advisory Committee on Reactor Safeguards, Fire Protection Subcommittee.

In addition, the staff informed the Commission of the findings of this report in SECY-96-146, "Technical Assessment of Fire Barrier Penetration Seals in Nuclear Power Plants," dated July 1, 1996. That paper is appended to the text.

1 DISCUSSION

1.1 Defense in Depth and the Role of Penetration Seals

Nuclear power plants licensed to operate by the U.S. Nuclear Regulatory Commission (NRC) use the defense-in-depth concept of echelons of fire protection features to achieve a high degree of fire safety. The objective of defense in depth is to (1) prevent fires from starting; (2) detect rapidly, control, and extinguish promptly those fires that do occur; and (3) provide protection for structures, systems, and components important to safety so that a fire that is not promptly extinguished will not prevent the safe shutdown of the plant. The multiple layers of fire protection provided by the defense-in-depth concept provide reasonable assurance that weaknesses or deficiencies in any echelon will not present an undue risk to public health and safety. To achieve defense in depth, each operating reactor has an NRC-approved fire protection program.[1] The licensees have designed the fire protection programs by analyses that (1) considered potential fire hazards, (2) determined the effects of fires in the plant on the ability to safely shut down the reactor or on the ability to minimize and control the release of radioactivity to the environment, and (3) specified measures for fire prevention, fire confinement, fire detection, automatic and manual fire suppression, and post-fire safe-shutdown capability. To confine a fire and limit fire damage, licensees divide nuclear power plant buildings into separate fire areas. These are generally rooms or plant areas that have fire-rated walls and fire-rated floor-ceiling assemblies. These fire-rated walls and floor-ceiling assemblies (structural fire barriers) have sufficient fire resistance to withstand the fire hazards located in the fire area and, as necessary, to protect important equipment within the area from a fire outside the area. Most nuclear power plant fire barriers are of substantial reinforced-concrete construction and have a fire-resistance rating of 3 hours (see Section 3). This passive fire protection concept, which is called "compartmentation," is a fundamental fire safety measure. It is not unique to nuclear power plants. The fire barriers, which accomplish their intended design function simply by being in place during a fire, are important because they are the first and last lines of defense against a fire. That is, during the early stages of a fire, the barriers confine the fire and protect important equipment until the fire detection and automatic fire suppression systems operate. In addition, in the unlikely event that an automatic fire protection system fails to operate, the structural barriers continue to provide passive fire protection.

Penetrations are openings in structural fire barriers that allow such services as piping and instrument tubing; conduits, cables, and cable trays; and heating, ventilation, and air conditioning ducts to pass from one fire area to another. Penetrations may also be left empty for future modifications. To maintain the fire-resistive integrity of the fire barriers, fire-rated penetration seals are installed in the penetrations and in the gaps and annular spaces around the penetrating items.[2] The seals are one element of fire protection defense in depth and, like the structural fire barriers in which they are installed, are passive fire protection features. Their design function is to confine a fire to the area in which it started or to protect important equipment within the area from a fire outside the area.

Fire barrier penetration seals are not technically complex, nor are they unique to the nuclear industry. In fact, they are universally accepted building components that are used in residential, commercial, and industrial buildings wherever fire-resistive separation is needed.[3] The same penetration seal materials, fire test standards, and installation techniques that are used by the nuclear industry are used in these other industries. A large body of fire test results and fire experience (non-nuclear), spanning decades, has proven the fire-resistive capabilities and effectiveness of penetration seals. (As an example, in the 1995 edition of its *Fire Resistance Directory*,[4] Underwriters Laboratories, Incorporated (UL), listed more than 800 penetration seal designs that

[1]When properly designed, implemented, and maintained, a fire protection program satisfies Section 50.48, "Fire protection," of Title 10 of the *Code of Federal Regulations*, Part 50.

[2]Fire doors and fire-rated duct dampers are also used to close fire barrier penetrations. These fire protection features are not addressed here.

[3]Outside the nuclear industry, penetrations are sometimes called "poke-throughs," penetration seals are commonly called "firestops," and sealing fire barrier penetrations are called "fire stopping."

[4]Architects, engineers, building code officials, and others use the *Fire Resistance Directory* to identify fire-tested penetration seal designs.

it had tested and approved.) It is generally accepted among fire protection engineers, building code officials, and other professionals responsible for building design and fire safety, that properly designed, tested, installed, inspected, and maintained penetration seals provide reasonable assurance that the fire-resistive integrity of the fire barriers in which they are installed will be maintained.

The effectiveness of structural fire barriers is largely dependent on their inherent fire resistance, details of construction, and protection of penetrations. Some fire barriers (both structural barriers and penetration seals) are more important to fire protection defense in depth than others. The importance of specific fire barriers depends on many factors, such as the importance of the equipment in the fire area (and adjacent areas); the configuration and location of combustible materials and other fire hazards, if any, in the areas; the potential for fire growth in the areas; the other fire protection features installed in the areas; and the accessibility of the areas to the plant fire brigade. The importance of specific penetration seals depends on these factors and on such factors as their size, their location or position in the fire barrier, and the number and sizes of the other seals in the barrier.

In order of overall importance to fire protection defense in depth, structural fire barriers are generally more important than fire barrier penetration seals. Qualified fire protection engineers determine the significance of individual fire barriers by fire hazards analyses. Although a detailed discussion of such analyses is beyond the scope of this report, the following discussion illustrates this point.

If a structural fire barrier fails and collapses under fire exposure, the adjacent fire area can become involved in the fire in a short period of time. (Because of the substantial construction of nuclear power plant fire barriers and fire protection defense in depth, the staff does not consider this a credible fire scenario.) Failure of a penetration seal is generally not as significant a fire threat as a failure of a structural fire barrier. In most cases, a seal failure would initially create a localized hot spot in the adjacent fire area in the area of the seal. If there are no combustible materials in the adjacent fire area in the vicinity of the failed seal (for example, if the penetration seal is for a pipe), smoke and hot gases will move into the adjacent area, but the spread of fire into the area will be limited. Conversely, if there are combustible materials in the vicinity of the failed seal (for example, if the penetration seal is for a loaded cable tray), the fire could spread into the adjacent area more readily. In this instance, a more detailed fire hazards analysis is needed to assess the effects of the fire spread. The staff, in Generic Letter 86-10, "Implementation of Fire Protection Requirements," April 24, 1986, provided guidance for evaluating fire area boundaries (see Section 4.3.3).

1.2 Background

In about 1985, the staff had become aware of the possibility that some licensees may not have been complying with NRC requirements and guidance for fire barrier penetration seals. In response to these potential problems, in 1987 and 1988, the NRC staff had assessed aspects of fire barrier penetration seals. The staff had reviewed such relevant data as licensee event reports, inspection findings, and fire test reports; interviewed industry staff; inspected licensees and vendors; and reviewed a sample population of as-built fire barrier penetration seal installations and the substantiating documentation. In parallel with these efforts, the staff had formed an NRC roundtable group to assess what it had found and to determine whether or not regulatory action was warranted.

The staff did not find widespread problems or safety-significant issues. Following its assessment, the staff issued a series of information notices.[5] Information Notice (IN) 88-04, "Inadequate Qualification and Documentation of Fire Barrier Penetration Seals," February 5, 1988, addressed what the staff had found during its assessment and summarized existing staff guidance related to fire barrier penetration seals. It did not address or identify plant-specific problems.
IN 88-56, "Potential Problems With Silicone Foam Fire Barrier Penetration Seals," August 4, 1988, informed licensees that nonconforming conditions such as splits, gaps, voids, and lack of fill might exist in silicone foam penetration seals. IN 88-04 Supplement 1, "Inadequate Qualification and Documentation of Fire Barrier Penetration Seals," August 9, 1988, addressed several plant-specific cases of misapplication of silicone foam materials. (Later, the staff issued IN 94-28, "Potential Problems With Fire Barrier Penetration Seals," April 5, 1994, to inform licensees of potential problems that

[5]Each licensee maintained a program for reviewing information notices and determining whether or not the information is applicable to its facilities. The staff reviewed these programs during NRC inspections. Therefore, the staff decided that information notices were an appropriate vehicle for disseminating what it learned during its assessment.

could go undetected as a result of inadequate surveillance inspection procedures and inadequate acceptance criteria.) Appendix A is a summary of NRC generic communications related to fire barrier penetration seals.

Since 1992, new potential problems with penetration seals have been reported. In response, the Fire Protection Engineering Section of the Office of Nuclear Reactor Regulation (NRR) conducted a second technical assessment of fire barrier penetration seals. The principal purposes of the second assessment, which is documented in this report, were to address potential problems, to determine if there were any widespread problems of safety significance or with generic implications, and to determine if NRC requirements, review guidance, and inspection procedures for penetration seals are adequate. The staff audited the fire barrier penetration seal programs at two nuclear power plants, inspected the fire barrier penetration seal programs at four nuclear plants, inspected the manufacturer and supplier of the most widely used seal materials, and inspected two contractors that installed penetration seals. The staff also witnessed fire endurance tests of penetration seals, reviewed operating experience and previous NRC inspection results, assessed the data and information obtained from the document reviews and field work, sought out any commonality or correlation of evidence that may suggest additional technical problems or trends; and determined whether or not there are generic problems of safety significance. Appendix B is a summary of the staff action plan for the technical assessment documented here.

1.3 Fire Protection Program Reassessment

In 1993, the staff of NRR had completed a reassessment of the reactor fire protection program. NRR had documented that reassessment in "Report on the Reassessment of the NRC Fire Protection Program," February 27, 1993. The staff had concluded that licensees were complying with regulatory requirements and that there were no major or recurring issues with penetration seals. The report had recommended that the staff confirm the adequacy of the NRC review and inspection programs to address fire barrier elements, including fire barrier penetration seals. However, it made no recommendations regarding penetration seal operability.

1.4 AEOD Penetration Seal Review

The Office for Analysis and Evaluation of Operational Data (AEOD) had performed a review of fire barrier penetration seals which it documented in a memorandum of May 23, 1995, from C.E. Rossi, AEOD, to G.M. Holahan, NRR. It had included reviews of the Dow Corning Part 21 silicone cure issue (see Section 5.1) and of ongoing NRR activities relating to the technical assessment documented here. AEOD had reached many of the same conclusions about penetration seals that NRR had found. AEOD did, however, raise questions about NRC procedures for inspecting penetration seals (see Section 4.4) and aging of silicone seals (see Section 5.10).

2 FIRE BARRIER PENETRATION SEAL MATERIALS

2.1 Population and Types of Seals

Most of the fire barrier penetration seals installed in nuclear power plants are designed to achieve a fire-resistance rating of 3 hours. Penetration seals with fire-resistance ratings of 1 hour and 2 hours are also used. Seals are generally classified as either mechanical penetration seals or electrical penetration seals depending on the seal penetrants, e.g., piping or cable trays, respectively. The results of a survey of 32 nuclear power units conducted by Sandia National Laboratories (SNL) and reported in a letter report of May 29, 1992, entitled "A Determination of the Population of Fire Barrier Types in Generating Stations," is summarized in Table 1. The objective of the survey was to identify the fire barrier materials installed in nuclear power plants. The survey revealed that silicone-based materials are the predominant penetration seal materials. The survey also revealed that the average number of penetration seals per nuclear power plant unit is about 3000 and a single unit can have up to 10,000 seals. The selection of materials for a particular penetration seal depends on a number of factors, including the fire resistance needed, the type of penetrants, the environment, and the need for the seal to serve multiple functions (e.g., radiation protection, pressure boundary, and flood protection).

Table 1 Representative Population of Seal Types

Seal Material	Average Installations per Unit	Range of Installations per Unit
Silicone foam	1668	0 - 3700
Silicone elastomer	820	0 - 8500
Mineral wool	436	0 - 2000
Cement (mortar and grout)	424	0 - 3502
Mechanical	33	0 - 250

2.2 Silicone Foams

The silicone foam most widely used in nuclear power plants is manufactured and supplied by Dow Corning Corporation (product information available from Dow Corning, Midland, MI). Silicone foam is also manufactured by General Electric and others. The vendors that install fire barrier penetration seals purchase silicone foam from the manufacturers, add proprietary ingredients, and resell the material under proprietary trade names. For example, ingredients can be added for radiation protection, to increase the density of the materials, or to change the cure rate.

Silicone foam seals are formed in place. The formulation has two components which are mixed in a 1:1 ratio, by weight or volume, by a special mixing apparatus that combines the two parts at the point of application. For small applications, special applicator kits are available that allow the two parts to be mixed shortly before application. The chemical reaction that occurs after the two components are mixed causes the foam to rise or expand in volume. Because the silicone foam material expands as it cures, a tight-fitting seal forms in the penetration opening. The continued transition of the seal material from the liquid to the solid state is referred to as "curing." Silicone foam cures in 2 to 24 hours. Shrinkage of the foam material is normal within 24 to 48 hours after it is injected in the penetration. Gaps created by shrinkage are filled with adhesive/sealant (see Section 2.5).

2.3 Silicone Elastomers

After silicone foam, the most common seal materials are low-density silicone elastomers (LDSEs) and high-density silicone elastomers (HDSEs). Some vendors also supply medium density silicone elastomers. SNL reported that the average number of elastomer penetration seals per nuclear power plant unit exceeds 800. The silicone elastomers most widely used in nuclear power plants are manufactured and supplied by Dow Corning Corporation. As with silicone foam, vendors add proprietary ingredients to the elastomer material to increase density or add various capabilities to the elastomer, such as radiation protection properties.

Like silicone foam seals, elastomer seals are formed in place from two components which are mixed in a 1:1 ratio, by weight or volume, either manually or by a special mixing apparatus at the point of application. The mixed components form a dense, firm, rubber-like material that cures in from 10 minutes to 8 hours, depending on the formula of the elastomer and conditions at the place of installation. Unlike silicone foam, silicone elastomers do not expand appreciably when curing. Generally, because of the higher density, structural strength, and thermal stability of silicone elastomer materials, less thickness is needed in a silicone elastomer seal than in a silicone foam seal, to achieve a similar fire rating.

2.4 Silicone Gels

Another silicone product used in penetration seal applications is silicone gels. Gels display characteristics of both liquids and solids, and they have a specific gravity similar to that of water. With added fillers, the silicone gel is also an effective fire/radiation barrier. The gel material is usually held together in field applications by a flexible boot. Gel is supplied to vendors as a two-component clear material that is mixed together, usually in a 1:1 ratio. Gel seals are used to allow significant penetrant movement and are less widely used than the silicone foam and silicone elastomers.

2.5 Other Sealants

A silicone adhesive product, usually supplied in caulking gun tubes, is used to repair visible shrinkage in foam seals, seal openings that are too small for an injection of other firestop materials, and flexible boot seal applications.

In addition to silicone-based materials, fire-rated penetration seals are also made of cement materials (grouts and mortars) and such fire-retardant materials as Flammastic. In most cases, these materials are installed after packing the penetrations with fire-resistant materials such as mineral wool (e.g., Kaowool).

Mechanical penetration seals are also used. Such seals are typically incorporated in concrete walls during construction or are retrofitted by drilling out wall material and casting a seal housing in place. They perform their sealing function by mechanically compressing a resilient, fire-resistant synthetic material around the penetrating item.

2.6 Damming Materials

Damming materials are used to close the cross-sectional areas of barrier penetrations that are to be sealed. Damming materials, which may be either permanent or temporary, are used to contain the seal material until it has cured or hardened. Permanent damming materials, which are left in place as integral parts of the penetration seal assembly, are fire resistant and have low thermal conductivity and, therefore, contribute to the overall fire-resistance rating of the seal assembly. In general, the damming materials are left in place if they were part of the fire-tested penetration seal assembly (see Section 3.1). Examples of permanent damming materials include ceramic fiber (alumina-silica), ceramic fiber blankets (e.g., Johns-Manville Corporation Cerafiber), ceramic fiberboard, and calcium silicate board (e.g., Johns-Manville Corporation Marinite board). Temporary damming materials include particle board, plywood, duct tape, and rigid foams. These materials are removed after the seal has cured.

3 QUALIFICATION TESTS OF PENETRATION SEALS

3.1 Test Methods and Acceptance Criteria

To gain reasonable assurance that a fire barrier penetration seal will have the required fire-resistance capability or fire rating (1, 2, or 3 hours), a representative penetration seal test assembly is subjected to a qualification fire endurance test. (Fire tests are also conducted for research purposes and for product development.) The test methods involve the furnace-fire exposure of a full-scale fire barrier penetration seal test specimen. The test specimens are representative of the construction for which a fire-resistance rating is desired, as to materials, workmanship, and such details as the dimensions of parts. The heat input to the test furnace is controlled so that the average temperature in the furnace follows as closely as possible the time-temperature curve specified in the test standard. In the United States, the standards used to test and rate penetration seals specify the standard time-temperature curve defined in American Society for Testing and Materials (ASTM) E-119, "Standard Test Methods for Fire Tests of Building Construction and Materials." This time-temperature curve, which is generally accepted for evaluating and rating the fire resistance of all types of building fire barriers, is considered to represent a severe fire exposure. However, the fire endurance tests are not intended to model any specific room fire or the conditions under which the seals will be exposed during a fire, but rather provide a specific standard fire exposure against which similar fire-rated assemblies can be evaluated.

The test standards and the NRC regulations and guidance documents specify fire test acceptance criteria that involve the measured response of the test specimen at the time into the standard fire exposure that corresponds to the desired barrier rating. In most cases, the test specimen is also exposed to a hose stream test after the fire exposure. For example, a fire barrier penetration seal design is said to have a fire-resistance rating of 3 hours if the tested specimen meets the specified acceptance criteria during at least 3 hours of the standard fire exposure and the hose stream test. In this example, the fire-resistance rating qualifies the seal design for use as a 3-hour fire-rated barrier.

The staff has accepted the following industry standards for qualifying penetration seals: (1) ASTM E-119; (2) National Fire Protection Association (NFPA) 251, "Standard Methods of fire Tests of Building Construction and Materials"; (3) ASTM E-814, "Standard Method of Fire Tests of Through-Penetration Fire Stops"; and (4) Institute of Electrical and Electronics Engineers (IEEE) 634, "Standard Cable Penetration Fire Stop Qualification Test." In addition, UL tests and approves penetration seals in accordance with American National Standards Institute/UL 1479, "Fire Tests of Through-Penetration Firestops," and other organizations, such as American Nuclear Insurers (ANI) and Factory Mutual (FM), also have test methods and standards for conducting penetration seal fire endurance tests. The staff has also accepted the installation of penetration seals that had been qualified in accordance with these test standards.

There are variations between the test standards and the test acceptance criteria. Therefore, assessments of fire test results consider both the test standard that was used and the acceptance criteria that apply. In general, the acceptance criteria ensure that the penetration seal does not burn through during the fire exposure, remains in place during the fire and hose stream exposure, prevents the passage of flames or gases hot enough to ignite combustibles that may be on the nonfire side of the test specimen, and limits the transmittal of heat through the seal and any penetrating items (as determined by measuring the temperature rise on the nonfire side of the seal and any penetrating items). Section 4 gives the acceptance criteria that are specified in the NRC regulations and guidance documents. Appendix C provides a summary and comparison of the fire barrier penetration seal fire endurance test standards that have been endorsed or accepted by the staff.

The ability of a particular penetration seal design to achieve a specific fire rating is configuration dependent. The type and thickness of the penetration seal material is a significant factor. Moisture content; material density; presence or absence of filler materials or damming materials; cross-sectional area and free area of seal material; number, type, and arrangement of penetrants; seal orientation (horizontal or vertical); and construction methods also influence the fire-resistance rating. Specific design considerations for penetration seals are discussed in Section 5.12 of this report.

Decades of experience with the test standards by the nuclear and general building industries have provided adequate assurance that they are appropriate for qualifying fire barrier penetration seals. Hundreds of qualification-type fire endurance tests of a wide variety of penetration seal designs and materials have been performed by material manufacturers, installation contractors, test laboratories, research organizations, licensees, and others. The staff observed fire endurance tests of fire barrier penetration seals and reviewed fire test reports during licensing reviews and inspections. On the basis of these eyewitness accounts and reviews, the staff has concluded that fire endurance tests have established the fire-resistive capabilities of the penetration seal materials, designs, and configurations installed in nuclear power plants.

3.2 Fire Testing Laboratories

During this assessment, the staff did not find technical issues or problems regarding fire testing laboratories. However, there has been confusion about NRC regulatory requirements and review guidance regarding such laboratories. It has been suggested, for example, that fire endurance tests that are not performed by a nationally recognized testing laboratory cannot meet NRC fire protection regulatory requirements.

NRC fire protection regulations[6] do not cover either fire endurance testing or fire test laboratories. NRC fire protection guidance documents address these topics in a limited fashion. For example, they define "fire barrier" as "components of construction...that are rated by approving laboratories." They also define "approved" as "tested and accepted for a specific purpose or application by a nationally recognized testing laboratory."

The mission of the National Fire Protection Association, which was organized in 1896, is to safeguard people, property, and the environment from fire using scientific and engineering techniques and education. More than 225 NFPA committees, which are represented by affected interests, develop and publish standards intended to minimize the possibility and effects of fires. NFPA is the principal source of fire protection standards and codes in the United States. When the staff developed its fire protection guidance documents in the 1970s, it adopted a large number of NFPA standards by reference in its guidance documents. At that time, the staff adopted the term "nationally recognized testing laboratory" from

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[6]The NRC fire protection regulations are contained in General Design Criterion 3, 10 CFR 50.48, and Appendix R to 10 CFR Part 50. NRC fire protection review guidance is contained in various branch technical positions and the Standard Review Plan (NUREG-0800). The regulations and guidance are discussed at length in Section 4.

NFPA. Neither NFPA nor NRC defined the term.[7] Consequently, there has been recurring confusion about what constituted a nationally recognized testing laboratory. In the 15th edition of the *Fire Protection Handbook*, 1981, NFPA stated that it had dropped the term "nationally recognized testing laboratory" from documents it published because there was always a doubt about the definition of a nationally recognized testing laboratory. The staff did not update its guidance documents to reflect this NFPA position.

There is no regulatory requirement that fire tests be conducted by a nationally recognized testing laboratory. Historically, during licensing reviews, the staff had accepted the use of fire barriers without reviewing the fire test results if the barriers were tested and approved by UL or FM. Such barriers included fire doors, fire walls, and penetration seals. As discussed in Section 4, the guidance documents present approaches that are acceptable to the staff for meeting regulatory requirements. However, licensees can use approaches that differ from those specified in the guidance document. Therefore, the staff had also accepted barriers that were tested by organizations other than UL and FM. In such cases, the staff may have reviewed the fire test results.[8]

NRC does not certify or accredit testing laboratories and has not issued guidance for evaluating or assessing the acceptability of fire testing laboratories to perform fire tests. In the 17th edition of the *Fire Protection Handbook*, 1991, NFPA stated that there are many laboratories in the United States capable of performing fire-related research and fire testing. These include private and industrial laboratories, university laboratories, and government laboratories. NFPA indicated that evaluations of laboratories should be based on criteria that generally focus on their overall operation, including organization and technical direction, ethical and professional business practices, and the quality control system used by the laboratory. Other more specific criteria focus on the personnel, equipment, facility, procedures, and recordkeeping for performing and reporting test results. The industry fire test standards also provide guidance for the conduct and documentation of fire endurance tests.

The term "nationally recognized testing laboratory" is undefined and obsolete. In addition, national prominence is not needed to conduct valid fire endurance tests. Finally, satisfactory ways of selecting suitable test facilities are available within the fire protection engineering community. Therefore, the staff recommends that the NRC fire protection guidance documents be revised to reflect the current NFPA position.

4 FIRE PROTECTION REGULATIONS, GUIDANCE, AND INSPECTION PROCEDURES

4.1 Background

NRC requirements and guidelines for penetration seals are contained in a number of documents. The extent to which these requirements or guidelines are applicable to a specific plant depends on the age of the plant and the commitments established by the licensee in developing its fire protection plan. Some of the potential problems that were raised about penetration seals reflected a poor grasp of NRC fire protection regulations and guidance and the regulatory process. For example, Appendix R, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, was thought to be a generically applicable set of requirements; staff review guidance had been mistaken for regulatory requirements, and the flexibility afforded by guidance documents had not been recognized.

In 1971, the Atomic Energy Commission (AEC) promulgated General Design Criterion (GDC) 3, "Fire protection." GDC 3 states, in part, "structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat-resistant materials shall be used wherever practical throughout the unit, particularly in such locations as the containment and control room." The AEC did not issue guidelines for implementing GDC 3.

On March 22, 1975, the Browns Ferry Nuclear Power Plant had the worst fire ever to occur in a commercial nuclear power plant operating in the United States. Two

[7] At that time, it appeared that UL and FM, two organizations with historical preeminence in the fire testing field, were generally considered to be nationally recognized testing laboratories.

[8] The staff review of the Watts Bar Nuclear Power Plant fire protection program was a recent example of this (see Sections 5.5.6 and 5.6.3).

recommendations made by the Special Review Group that investigated the Browns Ferry fire pertained to assurance that the fire protection programs at operating nuclear power plants conform to GDC 3. The first recommendation was that NRC should develop specific guidance for implementing GDC 3. The second was that the NRC should review the fire protection program at each operating plant comparing it to the guidance developed per the first recommendation.

In response to the first recommendation, the staff developed Branch Technical Position (BTP) Auxiliary Power Conversion Systems Branch (APCSB) 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants," May 1, 1976; and its appendix, "Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1, 1976," Appendix A, February 24, 1977. In response to the second recommendation, each operating plant compared its fire protection program to either the guidelines of BTP APCSB 9.5-1 or to the guidelines of Appendix A to BTP APCSB 9.5-1 and the staff reviewed the fire protection programs for compliance with the guidance. Most licensees complied with most of the implementing guidance. However, the staff and some licensees disagreed on 17 issues. To resolve the contested issues, on May 29, 1980, the NRC proposed 10 CFR 50.48, "Fire protection," and Appendix R, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979," to 10 CFR Part 50 (45 FR 36082). The NRC published in the *Federal Register* (45 FR 76602) the final fire protection rule (10 CFR 50.48) and Appendix R to 10 CFR Part 50 on November 19, 1980.

4.2 Regulations

4.2.1 GDC 3 and 10 CFR 50.48

The basic fire protection regulation for nuclear power plants is Section 50.48 of 10 CFR Part 50. It requires, in part, that each operating nuclear power plant have a fire protection plan that satisfies GDC 3. It references Appendix R to 10 CFR Part 50 and several NRC fire protection guidance documents. GDC 3 and 10 CFR 50.48 do not explicitly address penetration seals.

4.2.2 Appendix R to 10 CFR Part 50

When the staff proposed Appendix R, it intended that the requirements be applicable only for the resolution of unresolved disputed fire protection features. The staff did not intend that the requirements be applicable to features that it had previously accepted. However, when it issued Appendix R, the Commission decided, as a result of its continuing review of fire protection matters, to retroactively apply the requirements for fire protection of safe-shutdown capability, emergency lighting, and reactor coolant pump oil collection systems to all plants operating prior to January 1, 1979, even if the staff had previously approved an alternative approach. The remaining sections were backfit to plants only to the extent needed to resolve the contested issues, the Commission having decided that the features previously approved by the staff provided an equivalent level of safety to that provided under these specific provisions of Appendix R.

Section III.M, "Fire barrier cable penetration seal qualification," of Appendix R resolved the disputed issue of fire barrier penetration seals and is, therefore, of interest here. It applied to 13 nuclear power plants.

Section III.M states that penetration seal designs shall utilize only noncombustible material (see Section 5.8) and shall be qualified by tests that are comparable to tests used to rate fire barriers. Section III.M contains the following acceptance criteria:

(1) Cable fire barrier penetration seal has withstood the fire endurance test without passage of flame or ignition of cables on the unexposed side.

(2) Temperatures recorded on the unexposed side are analyzed and the maximum temperature is sufficiently below the ignition temperature of the cable insulation temperature.

(3) The fire barrier penetration seal remains intact and does not allow a projection of water beyond the unexposed surface during the hose stream test.

4.3 Review Guidance

The staff did not backfit Appendix R to plants licensed to operate after January 1, 1979. For these plants, the staff reviewed the fire protection programs during licensing against the licensees' commitments. Most licensees for plants licensed to operate after January 1, 1979 committed to meet the combination of the guidance of Appendix A to BTP APCSB 9.5-1 and the criteria of certain sections of Appendix R. In such cases, the sections of Appendix R that the licensee committed to meet apply to the plant as licensing commitments, but not as regulatory requirements. The other licensees committed to meet the guidelines of Section 9.5-1, "Fire Protection Program," of NUREG-0800, "Standard Review Plan" (SRP), which incorporated the guidance of Appendix A to BTP

APCSB 9.5-1 and the criteria of Appendix R. Therefore, plants licensed to operate after January 1, 1979, can *implement the guidance contained in SRP Section* 9.5-1 to establish a fire protection program that complies with 10 CFR 50.48 and GDC 3. In either case, the fire protection programs are essentially equivalent from plant to plant. However, the regulatory process used to establish the program can differ.

The NRC guidance documents do not have the same status as NRC regulations or regulatory requirements. Rather, the purpose of the guidance documents is to ensure the quality and uniformity of NRC staff reviews and to present a set of acceptable methods of complying with the NRC regulations. The guidance documents present solutions and approaches that are acceptable to the staff, but they do not represent the only possible approaches to solutions. Licensees can use approaches that differ from those specified in the guidance document. In these cases, the staff performs more detailed reviews to ensure that the alternative approaches are equivalent to the guidance.

4.3.1 Appendix A to BTP APCSB 9.5-1

In Position D.1.(j) of Appendix A to BTP APCSB 9.5-1, the staff specified that floors, walls, and ceilings enclosing separate fire areas should have a fire rating of 3 hours. Penetrations in these fire barriers, including conduits and piping, should be sealed or closed to provide a fire-resistance rating at least equal to that of the fire barrier itself. In Position D.3.(d), the staff also specified that cable and cable tray penetrations through fire barriers should be sealed to give protection at least equivalent to that of the fire barrier itself.

4.3.2 Standard Review Plan (NUREG-0800)

In SRP Section 9.5-1, "Fire Protection Program," Position C.5.a, "Building Design," paragraph 3, the staff stated that openings through fire barriers for pipes, conduits, and cable trays which separate fire areas should be sealed or closed to provide a fire-resistance rating at least equal to that required of the barrier itself. In conduits larger than 4 inches in diameter, openings should be sealed at the fire barrier penetration. In conduits 4 inches or less in diameter, openings should be sealed at the fire barrier unless the conduit extends at least 5 feet on each side of the fire barrier and is sealed either at both ends or at the fire barrier with noncombustible material to prevent the passage of smoke and hot gases. Fire barrier penetrations that must maintain environmental isolation or pressure differentials should be qualified by test to maintain the barrier integrity under such conditions.

In addition, Position C.5.a, paragraph 3, specifies that penetration designs should utilize only noncombustible materials (see Section 5.8 of this report) and should be qualified by tests. The tests use the time-temperature exposure curve specified by ASTM E-119. The test acceptance criteria include:

(1) The penetration seal has withstood the fire endurance test without passage of flame or ignition of cables on the unexposed side for the period of time equivalent to the fire-resistance rating required of the barrier.

(2) The temperature levels recorded on the unexposed side are analyzed and the maximum temperature does not exceed 325 °F.

(3) The seal remains intact and does not allow projection of water beyond the unexposed surface during the hose stream test. The hose stream can be delivered through a 1½-inch nozzle set at a discharge angle of 30 degrees with a nozzle pressure of 75 pounds per square inch (psi) and a minimum discharge of 75 gallons per minute (gpm) with the tip of the nozzle a maximum of 5 feet from the exposed face; or the stream can be delivered through a 1½-inch nozzle set at a discharge angle of 15 degress with a nozzle pressure of 75 psi and a minimum discharge of 75 gpm with the tip of the nozzle a maximum of 10 feet from the exposed face; or the stream can be delivered through a 2½-inch national standard playpipe equipped with a 1⅛-inch tip, nozzle pressure of 30 psi, located 20 feet from the exposed face.

4.3.3 Generic Letter 86-10

Generic Letter (GL) 86-10, "Implementation of Fire Protection Requirements," April 24, 1986, provided guidance for satisfying NRC regulatory requirements for fire protection. Enclosure 1 to GL 86-10 included interpretations of Appendix R requirements. Interpretation 4, "Fire Area Boundaries," stated, in part:

> The term "fire area" as used in Appendix R means an area sufficiently bounded to withstand the [fire] hazards associated with the area and, as necessary, to protect important equipment within the area from a fire outside the area. In order

> to meet the regulation, fire area boundaries need not be completely sealed floor-to-ceiling, wall-to-wall boundaries. However, all unsealed openings should be identified and considered [in] evaluating the effectiveness of the overall barrier. Where fire area boundaries are not wall-to-wall, floor-to-ceiling boundaries with all penetrations sealed to the fire rating required of the boundaries, licensees must perform an evaluation to assess the adequacy of fire boundaries in their plants to determine if the boundaries will withstand all hazards associated with the area.

This regulatory position established that certain penetration seals need not have the same fire rating as the barrier in which they are installed. Licensees evaluate such seals on a case-by-case basis. The engineering evaluations performed to assess the effectiveness of the penetration seals are based on the expected fire-resistive performance of the seal and on the fire hazards and fire protection features in the fire area.

4.4 Inspection Procedures

NRC fire protection inspection procedures are contained in NRC Inspection Manual Inspection Procedure 64704, "Fire Protection Program," March 18, 1994; Inspection and Enforcement Manual Inspection Procedure 64100, "Post-Fire Safe Shutdown, Emergency Lighting and Oil Collection Capability at Operating and Near-Term Operating Reactor Facilities," March 16, 1987; and Inspection and Enforcement Manual Inspection Procedure 64150, "Triennial Post-Fire Safe Shutdown Capability Reverification," March 16, 1987.

The NRC inspection procedures do not give specific guidance for inspecting fire barrier penetration seals. However, the staff has routinely inspected fire barrier penetration seal programs during fire protection program and other inspections (see Section 5.3). Nevertheless, the staff concluded that the lack of inspection guidance could be viewed as a potential weakness in the NRC reactor fire protection program. The staff is now preparing the new Fire Protection Functional Inspection (FPFI) Program that it had described in SECY-95-034, "Status of the Recommendations Resulting from the Reassessment of the NRC Fire Protection Program," February 13, 1995. The staff will include guidance for inspecting fire barrier penetration seal programs in the FPFI procedures and guidelines for use by NRC inspectors on an as-needed basis.

5 TECHNICAL ASSESSMENT

5.1 Review of Penetration Seal Part 21 Reports

NRC maintains a database of reports submitted in accordance with 10 CFR Part 21, "Reporting of Defects and Noncompliance." The staff searched the database to find reports that involved penetration seal materials that had been submitted since it completed its first penetration seal assessment in 1988. The staff found only two Part 21 notifications. These were submitted by Dow Corning Corporation.[9]

On November 17, 1994, Dow Corning submitted a Part 21 notification concerning Dow Corning 96-081 RTV Adhesive/Sealant and on November 28, 1994, it submitted a Part 21 notification concerning SYLGARD 170 Silicone Elastomer and SYLGARD 170 Silicone Fast Cure Elastomer. According to the notifications, certain lots of the RTV Adhesive/Sealant deviated from Dow Corning sales specifications for flame self-extinguishing time and certain lots of SYLGARD deviated from Dow Corning sales specifications for cure rate. Dow Corning also informed each of its customers of the deviations.

Later, on the basis of its testing and analysis, Dow Corning determined that the deviations were traceable to a pigment that was contaminated with sulphur. Dow Corning also concluded that the deviations were limited to specific lots. As part of its technical review of the Dow Corning Part 21 notifications, the staff met with Dow Corning representatives at NRC Headquarters during a public meeting on January 31, 1995. The staff also inspected Dow Corning facilities (see Section 5.6.1) and witnessed fire endurance testing activities that were performed at UL to determine if the deviations adversely impacted the fire-resistance performance of seals, if any, that used the contaminated component.

By letter of July 21, 1995, Dow Corning submitted the UL fire test results. On the basis of the fire endurance tests, which consisted of side-by-side tests of test specimens constructed with suspect and nonsuspect

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[9]As explained in Section 5.6.1 of this report, the deficiency reporting requirements of 10 CFR Part 21 are not applicable to the products that Dow Corning supplied to nuclear power plant fire barrier vendors. However, Dow Corning has conservatively elected to inform the NRC and its customers of potential product deviations.

materials, UL concluded that there were no significant deviations or irregularities in fire barrier performance between the penetration seal materials. UL also concluded that these materials would not be precluded from being used in UL-classified penetration seals. The staff reviewed the test results and concurred with the conclusions made by UL. The staff also concluded that the material deviations regarding self-extinguishing time and cure rate do not have a significant affect on material performance as a fire barrier. On the basis of its document reviews, fire test observations, inspection activities, and discussions with Dow Corning manufacturing and corporate personnel, the staff also concluded that the actions taken by Dow Corning to address the issues were appropriate, timely, and satisfactory.

5.2 Review of Reactor Operating Experience

5.2.1 Review of Licensee Event Reports

Oak Ridge National Laboratory maintains a licensee event report (LER) database for the NRC. In 1994, the database contained about 58,000 LERs that had been submitted since 1980. SNL searched the database in 1994 and found that 318 LERs, or about 0.5 percent of the LERs in the database involved fire barrier penetration seals. In support of the assessment documented here, the staff searched the LER database and found that licensees for about 20 plant sites had submitted 141 LERs related to fire barrier penetration seals between 1989 and 1993, inclusive.[10] Since almost one-half of the LERs related to penetration seals have been submitted during this four-year period, it appeared that staff efforts to alert licensees to potential penetration seal problems in 1988 (see Section 1.2) increased industry's awareness of penetration seal problems and resulted in more thorough surveillances. The types of problems that had been reported by the licensees are shown in Table 2.

The staff found that the predominant problems involved improper installation, seal degradation, and seal breach. Most of the problems associated with installed penetration seals involved seals constructed of silicone foam. To a lesser extent, problems involved the failure to install seals where required. It appeared that most problems concerning improper seal construction and failure to install seals occurred during original plant construction. In some cases, it appeared that licensees may have conservatively reported such superficial problems as surface imperfections, and small cracks, splits, and gaps. Such conditions would not have precluded the seals from performing their intended fire protection design function. In many other cases, the inherent fire-resistive capabilities of the penetration seal materials installed in nuclear power plants would have provided some measure of fire protection. For example, weaknesses with fire test documentation or missing a scheduled surveillance would not adversely impact the fire-resistive capabilities of the penetration seals.

The LERs did not indicate generic problems with penetration seal materials. In addition, the staff found no reports of safety-significant failures of penetration seals. On the basis of its review of LERs, the staff concluded that licensee penetration seal surveillance programs have been effective in revealing penetration seal deficiencies. The staff also concluded that licensees appeared to be taking timely and appropriate actions to correct identified discrepancies.[11] It is the staff's opinion that continued licensee surveillances in accordance with existing plant procedures are adequate to ensure that penetration seal problems are discovered and resolved. See also Section 5.3.

5.2.2 Review of Reactor Fire Experience

The staff reviewed the fire event databases compiled by SNL, which contained data from 1965 thorough 1985, and the Electric Power Research Institute, which contained data from 1965 through 1988. The staff found no reports of nuclear power plant fires that challenged the ability of fire-rated structural barriers or fire-rated penetration seals to confine a fire in accordance with their fire protection design function. The staff also reviewed the LER database discussed in Section 5.2.1, which includes data from 1980 to the present, and again, found no reports of nuclear power plant fires that caused the failure of a fire-rated structural barrier or a fire-rated penetration seal.

[10]This was the period of time between when the staff had completed its first penetration seal assessment (1988) and when it started its substantive work on the technical assessment documented here (1994).

[11]The staff also used the insights it gained from its LER review to help plan the vendor and plant site inspections discussed in Sections 5.5 and 5.6.

Table 2 Penetration Seal Problems Reported in LERs

Reported Problems	Number of LERs	% of total LERs
Seal inoperable or deficient due to improper installation, degradation, or seal breach	82	58
Seal not installed or missing	37	26
Seal surveillances not performed	14	10
Inappropriate or unqualified penetration seals	6	4
Temporary or improper seal installed	2	2
Total number of LERs	141	

5.3 Review of Previous NRC Inspection Results

The staff reviewed region-based and resident inspector-based reactor inspections that addressed penetration seal programs.[12] These inspections are identified in Table 3.

The inspections of Calvert Cliffs, Diablo Canyon (see Section 5.4.4), Ginna, Haddam Neck, San Onofre, Susquehanna, and Washington Nuclear Project 2 (see Section 5.5.5) were routine fire protection program inspections which included inspections of the penetration seal programs. The inspections of Indian Point 3 (IP3), Oyster Creek, and River Bend Station (RBS) were special or routine resident inspector inspections. The inspectors reviewed the adequacy of penetration seal installations, qualification, and surveillances. They also followed up on issues reported in LERs and weaknesses noted during previous NRC inspections.

The inspection reports for San Onofre and Haddam Neck stated that the licensees had completed penetration seal reevaluation programs in response to NRC and industry concerns regarding the adequacy of fire barrier penetration seals in 1988. The inspection reports indicated that these programs were comprehensive, timely, and acceptable.

At RBS, the inspectors had found that the licensee's corrective actions were not adequate in response to the misapplication of seal material in 1991. The seals were not designed for the high ambient temperatures to which they were exposed; therefore, the seals degraded. Later, during the 1995 inspections, the inspectors concluded that the licensee had addressed the seal degradation effectively, and the inspectors closed the unresolved item. At IP3, the inspectors had questioned the methodology used by the licensee to determine the self-ignition temperature of cables that pass through penetration seals. However, the inspectors had found the licensee's penetration seal analyses and supporting documentation to be generally sufficient.

The NRC is currently tracking corrective actions for penetration seal deficiencies at Diablo Canyon and IP3.

The inspection reports, like the LERs summarized in Section 5.2.1, revealed that licensees occasionally find plant-specific deficiencies; However, the inspection reports also indicated that the licensees maintained satisfactory fire barrier penetration seal programs and have taken appropriate and timely actions to correct any penetration seal deficiencies found during surveillances. The NRC inspection reports did not reveal widespread or potentially generic problems of safety significance.

5.4 Review of Plant-Specific Corrective Action Programs

The staff reviewed the status of the penetration seal programs at several plants that had undertaken penetration seal corrective action programs since it completed the first penetration seal assessment. The staff had originally reviewed the programs for two of these plants (Wolf Creek Generating Station and V.C. Summer Nuclear Station) during its first penetration seal assessment. Two other plants (Vermont Yankee Nuclear Power Station and Diablo Canyon Nuclear Power Plant) initiated programs after the staff issued the information notices in 1988 that addressed the findings of the first assessment.

[12] Unlike the audits and inspections summarized in Section 5.5, the staff did not conduct these inspections as part of this assessment.

Table 3 NRC Inspections of Penetration Seal Programs

Plant	Report Dates
Calvert Cliffs Nuclear Power Plant	May 6, 1994
Diablo Canyon Nuclear Power Plant Units 1 and 2	March 15, 1994 and May 1, 1995
R.E. Ginna Nuclear Power Plant	June 13, 1994
Haddam Neck Power Station	June 19, 1995
Indian Point 3 Nuclear Power Plant	July 26, 1995
Oyster Creek Nuclear Generating Station	July 21, 1995
River Bend Station	March 8, May 3, and June 9, 1995
San Onofre Units 2 and 3	January 28, 1994
Susquehanna Steam Electric Station	July 31, 1995
Washington Nuclear Project 2	February 25 and November 9, 1994; and June 29, 1995

The LERs discussed in Section 5.2.1, the NRC inspections discussed in Section 5.3, and the plant-specific corrective action programs summarized below showed that the licensees knew and understood the fire resistive capabilities of the penetration seal materials and configurations; potential penetration seal testing, design, installation, inspection, and maintenance problems; and possible remedies and corrective actions. These findings also indicated that the actions taken by the staff in 1988 had increased industry awareness of possible penetration seals problems, leading industry to more comprehensive inspections, maintenance, and corrective actions.

5.4.1 Wolf Creek Generating Station

In December 1984, the licensee had issued a nonconformance report because 22 penetration seals lacked document traceability. The licensee had completed corrective actions in 1985. Later, in early 1987, Promatec, the penetration seal installation contractor, notified the NRC that 20 of 40 seals inspected exhibited voids and shrinkage of the silicone foam material. It was found that the problems had involved installation methodology, inadequate quality control (QC) methods, and rapid chemically induced silicone foam material expansion. The licensee issued LER 87-010 on February 6, 1987. Several other nuclear reactors were affected by this problem. Promatec informed the industry of the problems and submitted a Part 21 notification. Later, after the first penetration seal assessment, the NRC had issued IN 88-56 to advise licensees of the problems discovered at Wolf Creek.

In 1987, the licensee had established a task force to develop a corrective action plan. The inspection plan included the removal of damming boards and inspection of accessible foam penetrations. The scope of the program included inspections of more than 1700 silicone foam penetration seals. As a result of the inspections, the licensee repaired more than 600 seals during 1987. Since 1987, the licensee has found only minor problems during routine inspections. The licensee addressed these problems promptly.

5.4.2 Virgil C. Summer Nuclear Station

In February 1987, after a vendor inspection at Brand Industrial Services Company, Incorporated (see Section 5.6.2), the licensee for V.C. Summer Nuclear Station, had performed an evaluation of silicone foam penetration seals. During the evaluation, which it completed in July 1987, the licensee evaluated 642 seals. It found that about 94 percent of the seals were 3-hour qualified on the basis of fire endurance test results. It had also accepted the configurations of 21 seals on the basis of engineering evaluations and modified 15 seals to achieve acceptable configurations.

Problems identified earlier by visual inspections involved only minor degradation of the seal material; these were readily repaired. During inspections of the fire protection program in 1987 and 1988, the regional staff inspected a sampling of fire barrier seals and reviewed the inspection procedures which are used by the licensee to perform periodic visual inspections. No problems were noted during these inspections.

5.4.3 Vermont Yankee Nuclear Power Station

On March 19, 1992, during an inspection of fire barrier penetration seals at Vermont Yankee Nuclear Power Station, the licensee found a penetration containing unapproved material. The next day, another penetration seal was found to be degraded. The licensee implemented compensatory measures and began an investigation into the cause of the degradation. Later, while implementing corrective actions in December 1992, the licensee found additional problems. It performed additional seal inspections and found that the seal discrepancies were more widespread than originally believed. On January 15, 1993, the licensee issued LER 93-001. The licensee declared 57 penetration seals inoperable and established a task force to inspect all fire barrier penetration seals. Ultimately, the licensee repaired more than 900 of the 1400 fire barrier penetrations installed at Vermont Yankee and upgraded almost 300 penetrations. The licensee attributed most of the as-found unacceptable penetrations to inadequate design or installations made by the installation contractor between 1979 and 1980. (The seal contractor is no longer in business.) The licensee attributed the failure to identify these issues to inadequate surveillance procedures. The licensee completed the repairs to affected barriers and the required surveillances in May 1993.

5.4.4 Diablo Canyon Nuclear Power Plant

In January 1994, the licensee for Diablo Canyon Nuclear Power Plant, found that certain fire barrier penetration seals may not have met the required 3-hour fire rating because damming boards were not installed on both sides of silicone foam seals. This deficiency was discovered and reported by utility construction personnel during routine repair of an existing penetration seal. The seal that needed the damming board was repaired and an engineering review revealed that many of the silicone foam seals needed damming boards to meet the 3-hour criterion. A walkdown of additional seals was conducted and revealed approximately 100 representative silicone foam fire barrier penetration seals with missing damming boards. The licensee initiated roving fire watches as a compensatory measure. It was believed that this condition had existed since the plant was constructed. On February 24, 1994, the licensee issued LER 1-94-001-00.

The licensee has established a program to qualify the penetration seals with respect to fire endurance tests or representative plant fire hazards, has completed walkdowns to document the adequacy of penetration seal configurations, has reviewed design and installation procedures for penetration seals, has reviewed engineering procedures and design change documents, and has clarified responsibilities for control of penetration seals. The staff had followed up on the licensee's activities during inspections in February 1994 and March 1995. The inspectors concluded that the licensee had taken appropriate corrective actions. The staff is continuing to follow the licensee's actions.

5.5 Focused Audits and Inspections of Nuclear Plants

In support of this generic assessment, the staff audited the penetration seal programs at Davis-Besse Nuclear Power Station and Waterford 3 Nuclear Power Plant and inspected the penetration seal programs at Susquehanna Steam Electric Station, Calvert Cliffs Nuclear Power Plant, and Washington Nuclear Project 2 (WNP2). In addition, as part of its licensing review of the Watts Bar Nuclear Power Plant (WBN), the staff reviewed and inspected the WBN fire barrier penetration seal program in detail. The staff selected these plants on the basis of reports of problems (Davis-Besse, Waterford 3, and Susquehanna), combination of old and new seal installations (Calvert Cliffs), significant corrective action program and rework by licensee after self-identification of problems (WNP2), and new construction including testing and engineering (WBN).

During these audits and inspections, the staff (1) followed up on potential problems regarding fire barrier penetration seals; (2) gathered information on qualified penetration seals; and (3) assessed whether the seals were designed, tested, installed, inspected, and maintained in accordance with licensee commitments, NRC fire protection requirements and guidance, and standard industry practice. The staff selected seals for inspection on the basis of several factors, including (1) seal type and material, (2) seal location, (3) seals that had been repaired or reworked, and (4) seals for which there were potential technical problems. The staff examined procurement documentation for penetration seal materials, seal compatibility with barriers in which they were installed, fire endurance tests associated with the seal qualification designs, and training programs for seal installers and inspectors, and reviewed penetration seals installed at the plant sites, the QC and quality assurance (QA) programs relating to installation and maintenance of penetration seals, deviations of installed seals from NRC requirements, and surveillance requirements and programs for technical specification penetration seals.

During some of these audits and inspections the staff found several minor weaknesses. However, the staff concluded that the weaknesses did not result in deficiencies with the installed penetration seals. The staff did not find safety-significant problems or potential problems with generic implications. Moreover, during these activities, the staff found that the licensees and vendors are aware of and familiar with the possible problems that can exist with penetration seals, that fire test results and qualified fire-resistant penetration seal designs and materials are widely available, and that licensees have the means to correct penetration seal deficiencies and problems. The results of the plant site audits and inspections are summarized below.

5.5.1 Davis-Besse Nuclear Power Station

From May 9 through 12, 1994, NRR staff audited the penetration seal program at the Davis-Besse Nuclear Power Station. On the basis of the audit, the staff concluded that the licensee had implemented and maintained an acceptable fire barrier penetration seal program and that no significant problems existed with the fire barrier penetration seal installations at Davis-Besse. The staff did not find information that suggested problems with generic implications.

5.5.2 Waterford 3 Nuclear Power Plant

NRR staff audited the Waterford 3 penetration seal program from July 11 through 14, 1994. The staff found several minor weaknesses with fire test results and training records. The staff concluded, however, that the fire barrier penetration seal program was satisfactory and that the discrepancies did not create any problems with the penetration seal installations at Waterford 3. The staff did not find safety-significant problems or evidence to suggest that generic problems existed with penetration seals.

5.5.3 Susquehanna Steam Electric Station

From January 30 through February 1, 1996, NRR staff inspected the fire barrier penetration seal program at Susquehanna Steam Electric Station. The inspectors found the damming material missing from one penetration seal. The licensee took immediate corrective actions. The inspectors concluded that the licensee had implemented and maintained an acceptable fire barrier penetration seal program. The inspectors did not find safety-significant problems or evidence of generic problems with penetration seals.

5.5.4 Calvert Cliffs Nuclear Power Plant

From February 13 through 15, 1996, the NRR staff inspected the fire barrier penetration seal program at Calvert Cliffs Nuclear Power Plant. The inspectors concluded that the licensee had an acceptable fire barrier penetration seal program. The inspectors did not find safety-significant problems or evidence of generic problems. Ongoing licensee efforts to improve the penetration seal program were seen as positive.

5.5.5 Washington Nuclear Project 2

In December 1993, the licensee for WNP2 started a review of issues related to its penetration seal inspection program. The licensee found deficiencies with the original installations, periodic inspections, and repairs. Licensee evaluations of the deficiencies involving original seal construction found that some seals did not meet existing acceptance criteria and design drawings and that work practices were not in accordance with the installation procedures. The licensee identified five major contributing factors: (1) inadequate construction, (2) inadequate management methods, (3) inadequate design configuration and analysis, (4) inadequate work practices, and (5) inadequate training. The licensee declared all penetration seals at WNP2 inoperable, established compensatory measures, and initiated a comprehensive penetration seal upgrade program.

The penetration seal upgrade program included seal calculations backed by fire endurance tests; new seal design guide, typical seal details, and barrier functional list; revised plant specifications and procedures which reference the aforementioned documents; closure of penetration seal impairments; GL 86-10 engineering evaluations for certain non-rated barriers; updated installation and surveillance procedures for training seal installers and inspectors; and qualified and operable penetration seals.

NRC Region IV had identified the penetration seal problems as an unresolved issue pending completion of the penetration seal upgrade program and had conducted three inspections of the program (see Section 5.3). The inspectors had concluded that the licensee was taking aggressive corrective action to resolve this issue. Later, from August 7 through 17, 1995, in support of the technical assessment documented here, an NRC integrated assessment team inspected the licensee activities mentioned above. The team assessed licensee effectiveness in identifying issues, performing root cause analyses, and implementing corrective actions. The inspection focused on the areas of maintenance and engineering. The team inspected activities involving procurement, storage, installation, quality control, and long-term maintenance associated with the installation and maintenance of penetration seals. The team concluded that the licensee's current performance in the areas of receipt inspection and storage control, quality control, and inspection and surveillance was adequate. The assessment team also considered the licensee's corrective action program on penetration seals to be a strength.

5.5.6 Watts Bar Nuclear Power Plant

As part of its licensing review of the WBN fire protection program, and in support of this technical assessment, the staff reviewed and inspected the fire barrier penetration seal program for WBN in detail. As part of its review, the staff observed a penetration seal fire endurance test program conducted by the licensee and Promatec (see Section 5.6.3). The staff also reviewed the WBN engineering report on the penetration seal program, audited a number of typical seal details and the corresponding fire qualification test reports, and inspected in-plant penetration seal configurations.

The fire barrier penetration seal materials installed at WBN consist of silicone foam, silicone elastomers, and boot-type seals. Each mechanical and electrical fire barrier penetration seal was fabricated to a specific design detail and each design detail is supported by one or more fire endurance tests. In addition, for about 4 percent of the mechanical penetration seals, which deviated from the typical design details, the licensee performed additional engineering evaluations in accordance with GL 86-10. The evaluations either addressed the adequacy of the seals as designed or their adequacy to perform their intended design function on the basis of the fire hazards and the fire protection features in the area.

The staff had documented its review and evaluation of the WBN fire penetration seal program in Section 9.5.1, "Fire Protection Section," of NUREG-0847, "Safety Evaluation Report Related to the Operation of Watts Bar Nuclear Plant, Units 1 and 2." On the basis of its comprehensive safety evaluation of the WBN penetration seal program, the staff had concluded that the program satisfied applicable NRC requirements and guidelines.

5.6 Vendor Inspections

The staff inspected Dow Corning Corporation; Brand Fire Protection Services, Incorporated; and B&B Progressive Materials and Technologies, Incorporated (Promatec), in support of this assessment. In general, the areas reviewed during these inspections were seal materials, dedication of commercial-grade seal materials, storage and shelf life of materials, procurement documentation control, quality assurance and quality control, design control, and methods for qualifying penetration seal configurations. The inspectors also considered aspects of the vendors' programs that were in place during the 1980s, when most nuclear power plant penetration seals were installed, and those that are in place today. As documented in the NRC inspection reports, and summarized below, the inspectors did not find problems that could adversely affect reactor safety or the quality of the services and materials that the vendors provide to the nuclear industry.

5.6.1 Dow Corning Corporation

Dow Corning Corporation is the primary supplier of silicone-based fire barrier seal materials to the nuclear industry. The NRC inspected Dow Corning facilities in Midland, Michigan, and Elizabethtown, Kentucky, during March 23 through 24 and April 3 through 5, 1995. The inspectors did not find any problems that could adversely affect reactor safety and determined that Dow Corning effectively executed the portions of the product manufacturing controls that were reviewed.

A significant aspect of the inspection was the review of Dow Corning's processes and procedures for reporting and resolving potential product defects (see also, Section 5.1). The inspectors determined that Dow Corning had not employed unique nuclear requirements for design, manufacture, testing, or supply of its silicone-based penetration seal products. Some customers had contractually imposed the requirements of 10 CFR Part 21 on Dow Corning for products supplied for use in nuclear power plant fire barrier penetration seals. However, the inspectors determined that the seal products were neither safety-related nor basic components (as described in 10 CFR Part 21). Therefore, from a regulatory standpoint, the deficiency reporting requirements of Part 21 are not applicable. However, the inspectors determined that the Dow Corning defect reporting system appeared to provide a mechanism for informing the fire barrier installation vendors of potential deviations of the penetration seal materials manufactured by Dow Corning Corporation.

5.6.2 Brand Fire Protection Services, Incorporated

During January 1987, in support of its first penetration seal assessment, the staff inspected Brand Industrial Services Company (BISCO). The staff found that penetration seal test documentation used by certain nuclear plants may not have represented the as-built penetration seal configurations. The staff communicated this finding to the potentially affected licensees and included the issue in IN 88-04. Later, this issue was reviewed during NRC penetration seal inspections of licensees (see Sections 5.3, 5.4, and 5.5).

BISCO is now Brand Fire Protection Services, Incorporated (Brand). In support of the assessment documented here, the staff inspected Brand facilities in Addison, Illinois, from November 6 through 9, 1995. The inspectors determined that the areas that were inspected were satisfactory. The inspectors did not find issues that could adversely affect reactor safety or the quality of the services and materials that Brand provides to its nuclear power plant customers.

5.6.3 B&B Progressive Materials and Technologies, Incorporated

From December 6 through 9, 1995, the staff inspected B&B Progressive Materials and Technologies, Incorporated (Promatec), facilities in Cypress, Texas. As part of this inspection, the staff also witnessed the construction and testing of 14 cable slot penetration seal test specimens at Omega Point Laboratories (OPL), Elmendorf, Texas. Six of the cable slots contained control and instrumentation cables, six slots contained power cables, and two slots were empty spares (no cable fill). The penetration seals consisted of fire-resistive permanent damming boards and silicone foam. The test specimens were subjected to a 3-hour fire endurance test which conformed to the ASTM E-119 standard time-temperature curve followed by a fog nozzle hose stream test. The acceptance criteria of IEEE 634 were used to evaluate the fire-resistive performance of the seals. All of the test specimens met the acceptance criteria. On the basis of its observation of the construction and testing of the test specimens, and its review of the fire test reports, the staff concluded that the silicone cable slot penetration seals were acceptable for installation at WBN.

During its inspection of the Promatec facilities in Cypress, Texas, and the fire test program at OPL, the inspectors did not find problems that could affect reactor safety or the quality of the services and materials that Promatec provides to nuclear power plants. The inspectors determined that the areas inspected were satisfactory. This inspection also provided a real-time example of a penetration seal vendor's ability to conduct a satisfactory penetration seal fire test program.

5.7 Installation, Surveillance, Maintenance, and Repair

Proper installation, surveillance, maintenance, and repair are important to the ability of penetration seals to perform their intended fire protection design function. Potential problems include (1) incomplete or inadequate fire test documentation, (2) in-plant penetration seal configurations not bounded by fire tests, (3) seals not installed where required, (4) seals not installed properly, (5) seals not repaired, (6) seals repaired improperly, (7) seals modified without a supporting engineering evaluation, and (8) seals not inspected in accordance with plant surveillance procedures.

The licensees have fire barrier penetration seal surveillance and maintenance programs that are governed by written procedures. In general, the licensees inspect a portion of the total population of seals every refueling outage (about every 18 months). If penetration seals are found to be degraded or inoperable (e.g., breached, degraded, or improperly repaired), the licensees document the deficiencies and take appropriate corrective actions. If such conditions are found during power operations, the licensees establish such NRC-approved compensatory measures as fire watches until the degraded condition is corrected.

During this assessment, the staff reviewed procedures, specifications, and training programs for installation, surveillance, maintenance, and repair of penetration seals at both plant sites and seal vendor facilities. Most of the problems associated with installed penetration seals found by the staff involved silicone foam seals. Potential installation problems include voids within the seal, splits or gaps in foam caused by contamination or poor installation techniques, and failure to find installation problems because they are hidden by permanent damming materials.

Silicone foam and silicone elastomer seals with voids or holes can be repaired using like materials or silicone caulk. In general, procedures developed by penetration seal vendors for repair of silicone seals specify that repairs of holes or voids greater than 0.5 inch can be made using silicone caulk. Vendors have conducted satisfactory fire tests for this type of repair. Repairs of holes or voids greater than 0.5 inch should be made using the same seal material as that used to construct the original penetration seal. Using materials other than the original seal material could render the seal inoperable if the repaired configuration is not qualified by a fire test or justified with an engineering evaluation. For example, if a seal of a given depth and given seal material density was qualified as a 3-hour seal, it may not be acceptable to use a different seal material to repair the original seal unless the alternative material was qualified in a similar configuration.

Although the staff observed several minor weaknesses during some of its plant site inspections, it did not find evidence that the weaknesses resulted in problems with installed penetration seals. Overall, the staff concluded that licensees and vendors are aware of the importance of proper design, installation, surveillance, maintenance, and repair of penetration seals, including installer and inspector training. During its review of repair records and plant walkdowns, the staff did not find any instances of repairs using improper or dissimilar seal materials.

The staff had previously addressed potential problems in IN 88-04, IN 88-56, and IN 94-28 (see Appendix A). On the basis of the assessment documented here, it is the staff's view that existing licensee and vendor seal installation programs are adequate to prevent potential penetration seal installation problems. In the event seals are improperly installed or breached, or become degraded, existing licensee surveillance, maintenance, and repair programs are adequate to reveal and correct potential problems.

5.8 Combustibility of Silicone-Based Seal Materials

Although silicone-based penetration seal materials are fire resistant, they are classified as "combustible" when tested in accordance with ASTM E-136, "Behavior of Materials in a Vertical Tube Furnace at 750 °C,"[13] which is a combustibility test method accepted by the NRC. It has been asserted that silicone-based seals should not be installed in nuclear power plants because (1) NRC fire protection regulations prohibit the use of combustible materials in nuclear power plants and (2) Appendix R and the SRP specify that penetration seal materials be noncombustible.

Section 50.48 of 10 CFR Part 50 does not address the use of combustible materials. GDC 3 states that noncombustible and heat-resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room. However, GDC 3 does not preclude the use of combustible materials. Examples of combustible materials that are installed in nuclear power plants are cable insulation and cable jacket materials, diesel generator fuel oil, turbine-generator lubricating and hydraulic control fluids, reactor coolant pump lubricating oils, charcoal and other filters, and flammable gases and liquids. In general, when such materials are properly managed, are accounted for in the plant design and operation, and are incorporated as integral components of the plant fire protection program, including the fire hazards analysis, they are acceptable.

The staff evaluated the potential fire hazards associated with silicone-based penetration seal assemblies and concluded that properly tested, configured, installed, and maintained silicone-based penetration seal assemblies are not credible fire hazards. Silicone-based penetration seal materials are usually distributed throughout the fire area (as opposed to representing concentrations of combustibles), are relatively difficult to ignite, and burn slowly. The rate of combustion and flame propagation depends on factors such as seal location and configuration, total mass, surface area, surface covering (such as fire-resistant damming boards), if any, and the air supply present. For the typical nuclear power plant design, silicone-based penetration seal materials contribute only a little to the overall combustible load in terms of both quantity of material and surface area. For example, in many nuclear power plant fire areas, the surface area of the penetration seals is much less than the surface area of the cable jackets in the vicinity of the seals. In addition, the potential amount of fuel that can be contributed by silicone-based penetration seal materials is less than the fuel that could be contributed by the cable jacket and insulation materials. Moreover, despite the fact that a silicone-based penetration seal assembly could contribute some fuel to a fire, its relative contribution to the overall fire severity would be negligible.

In the unlikely event that a large fire exposes a silicone-based penetration seal to high temperatures for an extended period of time, the silicone-based material will decompose and be replaced with char or ash. Due to the nature of the silicone-based materials and the limited air supply present within the seal assembly (as opposed to the air present around the burning combustibles outside the seal), the propagation of the fire through the seal assembly will be very slow. Again, this has been observed during and demonstrated by full-scale qualification fire endurance tests of a wide variety of silicone-based penetration seal configurations.[14] These tests have also demonstrated that silicone-based seals can provide the necessary fire resistance and the reasonable assurance that a fire will not spread from one side of the fire barrier to the other in configurations where cables, pipes, conduits, ducts, and other combustible and noncombustible entities penetrate the silicone-based penetration seal.

Silicone foam and silicone elastomer can be combined with other materials to form radiological shields; fill complex irregular openings (e.g., around cables in cable trays) and adhere to the penetration and the penetrants; cure rapidly; and can be removed and restored to their original effectiveness (e.g., when making such plant modifications as installing new cables); have high-temperature stability; are flexible; and resist the effects of radiation exposure and aging. Silicone elastomers can also be used as flood and pressure seals. A wide variety of silicone-based penetration seal designs have been tested and listed by material manufacturers and installers: by UL in its *Fire Resistance Directory* and by FM in its *Factory Mutual System Approval Guide*. It is also notable that other countries, government agencies,

[13]Dow Corning Corporation had reported the results of ASTM E-136 tests in a paper entitled "Flammability Characteristics of a New Silicone RTV Foam," Kathy M. Kelly, Society of Plastics Engineers, Progress in Plastics Through Education, 34th Annual Technical Conference, April 26–29, 1976, Atlantic City, New Jersey.

[14]For example, when exposed to an ASTM E-119 fire, which is a severe fire exposure, silicone foam burns at a rate of about 3 inches of thickness per hour. Silicone elastomer burns at a slower rate.

insurance bodies, and building codes accept the use of silicone-based penetration seals. For these reasons, silicone foam and silicone elastomers are accepted for use in penetration seals in a wide variety of residential, commercial, and industrial buildings where fire-resistive separation is needed.[15]

The staff concluded that qualified silicone-based fire barrier penetration seals can accomplish their intended design function and are not credible fire hazards. The staff also concluded that the benefits of the silicone-based penetration seal materials outweigh any potential concerns regarding material combustibility.

The staff also reviewed the requirements of Appendix R to 10 CFR Part 50 and the guidance of SRP Section 9.5.1. The staff reviewed the record for Appendix R (and interviewed the principal author of Appendix R) and found no technical basis for including the noncombustibility criterion in Appendix R. The noncombustibility criterion is included in the SRP because the SRP simply embodied the criterion of Appendix R. The staff noted that the noncombustibility criterion is not included in BTP APCSB 9.5-1, Appendix A to BTP APCSB 9.5-1, or the industry fire endurance test standards. The ability of a particular penetration seal to achieve its intended design function (i.e., to contain a fire), as determined by a fire endurance test conducted in accordance with an industry standard (see Section 3.1), is the foremost design consideration. In addition, because of the severity and duration of the fire exposure, the industry standards would ensure that fire-resistant seal materials are used and would preclude the qualification of materials that present fire hazards. The staff recommends, therefore, that the material noncombustibility criterion be removed from Appendix R and the SRP.

5.9 Dow Corning Corporation Silicone Foam Formulation Change

In a letter of November 12, 1984, Dow Corning informed its customers that it had reformulated Dow Corning 3-6548 Silicone RTV Foam. During a meeting with the staff on January 31, 1995, Dow Corning representatives informed the staff that it changed the formula to improve the manufacturing process by allowing wider tolerances for the amounts of several of the basic ingredients used in the foam.

To demonstrate that the fire resistance of the modified formulation was equivalent to that of the old formulation, Dow Corning conducted comparison tests at Construction Testing Laboratories (CTL). The staff reviewed the results of five 3-hour fire endurance tests (10 test specimens) and supporting information regarding the formulation change to determine if the change adversely affected the fire-resistive performance of Dow Corning 3-6548 Silicone RTV Foam in the tested configurations.[16]

The test specimens were subjected to the standard time-temperature fire exposure specified in ASTM E-119. Hose stream tests were performed at the end of the full 3-hour fire exposure and used a solid hose stream. On the basis of its review of the test reports, the staff concluded that the tests were conducted in accordance with accepted industry standards. On the basis of its evaluation of interface, cable, cable tray, and seal temperatures, the thicknesses of unburned silicone seal materials, and the other observations documented in the test reports, the staff concluded that the change in formulation of Dow Corning 3-6548 Silicone RTV Foam did not materially affect the fire-resistive performance of the foam in the tested configurations. The staff also concluded that the tests were an appropriate method for assessing the effects of the formulation change.

5.10 Aging and Shrinkage

In its letter report entitled "Aging of Fire Barriers in Nuclear Power Plants," September 30, 1994, SNL reported that many fire barrier materials are resistant to thermally accelerated aging and that the material properties of silicone-based materials, which dominate the industry, are particularly age independent. SNL concluded that these materials are not expected to exhibit problems as they age. Moreover, on the basis of its review of operating experience and the technical literature, SNL did not find any penetration seal problems that were directly related to aging. SNL reported that it did not find information on thermal aging

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[15]There are configurations for which silicone-based materials may not be appropriate. For example, it may not be appropriate to seal a diesel generator exhaust pipe penetration with silicone foam because during operation the exhaust pipe could exceed the upper temperature limit for the silicone foam (see IN 88-04, Supplement 1).

[16]The NRC staff reviews nuclear power plant fire protection features within the scope of nuclear power plant-specific applications after the licensee has determined that the feature meets NRC regulations and its licensing commitments. Therefore, staff comments on the CTL tests should not be interpreted as NRC staff approval or rejection of the test results for specific nuclear power plant applications.

or radiation testing of grout, cement, and gel-type seals. SNL did not recommend an experimental aging program.

The staff reviewed additional information on shrinkage of silicone foam penetration seals after they are installed. As discussed in Section 2.2, some shrinkage is normal. Dow Corning, the major manufacturer of silicone-based materials, has informed its customers that shrinkage occurs and has stated that shrinkage at interfaces of ⅛-inch-wide or less while extending not more than one-third of the seal thickness (into the seal) is acceptable for fire protection purposes. On the basis of the information that the staff has reviewed, and the experience of the industry regarding shrinkage in silicone penetration seals, the staff has concluded that normal shrinkage does not have a significant impact on the function and capabilities of silicone foam or elastomer as a fire barrier penetration seal material.

It is the staff's position that vendor and licensee penetration seal surveillance and repair programs, as described in Section 5.7, are adequate to address potential penetration seal problems associated with seal aging and shrinkage.

5.11 Silicone-Based Material Curing

As part of this assessment, the staff considered potential curing problems in silicone-based penetration seal materials. Vendors may add ingredients (such as lead fines and iron oxide) to the basic silicone components to impart special properties to the finished penetration seals (such as radiation shielding). Silicone foams, elastomers, and gels use a platinum catalyst that causes the two components to react and solidify. The catalytic mechanism can be adversely affected by moisture and contaminants. Sulphur is the most prevalent contaminant. When present at high enough levels, sulphur can inhibit the curing of silicone-based materials during penetration seal installation. Some amines can also inhibit cure. In one case that the staff is aware of, a seal vendor tested a sample of a filler product from a supplier and found it to be satisfactory according to the vendor's specifications. It was later discovered that the vendor received an inferior product from the supplier, and the sample that the vendor tested was not representative of what it had received. The use of this contaminated filler led to curing problems in some silicone products. Dow Corning has experienced cure time deviations with its 96-081 RTV Adhesive/Sealant, SYLGARD 170 Silicone Elastomer, and SYLGARD 170 Silicone Fast Cure Elastomer (see Section 5.1). These problems were also traced to sulphur contamination.

In addition to cure inhibition that can be caused by material contamination, certain cable jacket types can prevent silicone seal materials from curing in the immediate vicinity of the cable jacket (the silicone material is affected but the cable jacket is not). Seal installers prevent this condition by coating the cable jackets with a releasing agent before installing the penetration seal materials.

During its vendor inspections, the staff found that seal materials vendors are well aware of conditions and circumstances that can cause curing problems and take appropriate steps to avoid or correct such problems. For example, the vendors have strict controls on the fillers and other ingredients that they use in their penetration seals. The vendors also send random samples of the materials they receive to independent laboratories for analysis against their design specifications and test samples of their finished products for structure and density, to ensure that they have cured properly.

The staff also reviewed this issue during its plant site audits and inspections. The staff addressed a potential problem that material impurities could have affected the original installation of penetration seals. The inspectors found that sufficient material controls were in place during the installation of penetration seals to prevent cure inhibition. Evidence of incomplete curing, such as cold flow (a slow flowing or creeping of the seal material from the penetration due to retarded or incomplete curing) or other seal deficiencies, was not found in direct seal inspections by the NRC, or in the seal surveillance records reviewed by NRC inspectors. Interviews with licensee and vendor personnel indicated that these types of problem were rare, and most personnel could not recall having ever encountered such problems.

In its review of LERs (see Section 5.2), the staff found no reports of problems related to lead content, cure time, or reactions between cable jackets and penetration seal materials. Although certain cable jacket materials can inhibit or prevent curing at the cable jacket-seal interface, the staff found no operating experience to indicate that this is a problem within industry. It has been asserted by some that cure inhibition is created simply by the addition of lead fines to the silicone materials. However, for the reasons stated above, this assertion appears to be wrong.

The staff concluded that industry, including material manufacturers, penetration seal installers, and licensees, are well aware of the potential causes and problems associated with cure inhibition.

5.12 Comparison of Tested to As-Built Configurations

As discussed in Sections 3 and 4 of this report, to provide reasonable assurance that a fire barrier penetration seal can accomplish its intended fire protection design function, a penetration seal test assembly is subjected to a fire endurance test. The accepted industry standards specify that the penetration seal test specimens be representative of the design and construction for which a fire rating is desired. However, in view of the large numbers of possible penetration seal configurations that are installed throughout the nuclear industry (e.g., a change in the cable fill in a cable tray penetration represents a change in configuration), the staff recognized that it was not practical to test and qualify each and every penetration seal configuration installed in nuclear power plants. Therefore, the staff has accepted the results of fire test programs that included a limited selection of test specimens that had been specifically designed to encompass or bound the entire population of in-plant penetration seal configurations.

Using such test results, licensees and vendors have performed engineering evaluations (such as those addressed in GL 86-10) to demonstrate that in-plant fire barrier penetration seals are comparable to or bounded by fire-tested configurations. In some cases, the vendors or licensees had used the results of two or more fire endurance tests to justify a single in-plant penetration seal configuration. In such cases, the engineering evaluation that the licensee had performed to justify the in-plant seal design considered the results of fire tests for a number of test specimens that were similar but not identical to the in-plant seal assembly. Design parameters and attributes that should have been considered in such evaluations are not explicitly stated in existing NRC fire protection regulations or review guidance. It is the staff's opinion that, in general, the fire test standards themselves and good engineering practice were adequate to identify the penetration seal design parameters that should have been considered in such engineering evaluations. Nevertheless, the lack of specific NRC review guidance for comparing tested configurations to as-built configurations can lead to technical questions regarding the adequacy of a particular seal design. This is a potential, albeit minor, weakness in the NRC fire protection program.

As part of the assessment documented here, the staff revisited a draft version of IN 88-04 that it had prepared in 1987. The draft contained general considerations about the use of fire test results to qualify fire barrier penetration seal designs. Even though these considerations were not included in the final version of the information notice, the draft information notice appears to be widely available to industry. In addition, industry fire protection engineers informed the staff that some licensees follow the considerations stated in the draft information notice even though the staff did not issue them. This indicates that such guidance would be useful to the industry for future penetration seal design evaluations.

On the aforementioned bases, the staff recommends that guidance be included in any future fire protection guidance document (e.g., a regulatory guide) to clarify the important parameters for designing and qualifying fire barrier penetration seals. Examples of the design considerations that could be included as guidance are presented in the following subsections. These considerations are not existing staff positions, but are proposed as starting points for preparing guidelines that could be used for designing fire test programs, for assessing fire test results, and for performing engineering evaluations of penetration seal designs installed in the future.

5.12.1 Size of Sealed Opening

In some cases, a successful fire endurance test of a particular fire barrier penetration seal configuration for a particular size opening may be used to justify the same configuration for smaller openings. The converse may not be true.

5.12.2 Penetrating Items

In some cases, a satisfactory test of a seal configuration that contains a particular pattern of penetrating items can be used to qualify variations of the tested pattern. Variations that may be acceptable without additional testing include eliminating or repositioning one or more of the penetrating items, reducing the size (cross-sectional area) of a particular penetrating item, or increasing the spacing between penetrating items. However, because penetrating items provide structural support to the seal, the free area of the seal material and the dimensions of the largest free span may also be factors that affect the fire-resistive performance of the seal assembly. In some cases, the thickness of the seal material needed to obtain a particular fire rating may also be a function of the free area or the distance between the penetrating items and outside edge of the seal assembly. In other cases, consideration of the penetrating items takes on special importance because of the heat sink they provide.

5.12.3 Cable Type and Fill

In some cases, a satisfactory test of a seal configuration with certain electrical penetrations containing a specified cable fill ratio (cable cross-sectional area divided by the cable tray or conduit cross-sectional area) and cable type (power, control, or instrumentation) can be used to qualify similar configurations containing the same or a smaller cable fill ratio and the same cable jacket material or a less combustible jacket material. The thermal conductivity of the penetrating cables is also important. For example, a penetration seal fire test of a cable tray with a 30-percent power cable fill would be more challenging (thermally) than a test of a tray with a 30-percent instrumentation cable fill due to the higher thermal mass of the power cables.

5.12.4 Damming Materials

The fire-resistive performance of a given seal configuration can be improved if a fire-resistant damming material covers one or both surfaces of the seal. A satisfactory test of a seal configuration without a permanent fire-resistant dam can be used to qualify the same configuration with a permanent fire-resistant dam, all other seal attributes being equal. The converse is not true.

5.12.5 Configuration Orientation

A satisfactory test of a particular seal configuration in the horizontal orientation (with the test fire below the seal) can be used to qualify the same configuration in a vertical orientation if the symmetry of the design configurations are comparable. For example, if a nonsymmetric penetration seal configuration (e.g., a seal with a damming board on the bottom, but not on the top) is qualified for a floor-ceiling orientation with the damming board on the fire side of the test specimen, the configuration could only be qualified for a wall orientation if a damming board was installed on both sides of the seal or if the potential fire hazard is limited to the side with the damming board.

5.12.6 Material Type and Thickness

Satisfactory testing of a particular seal configuration with a specific seal material thickness can be used to qualify the same configuration with a greater seal material thickness of the same type of seal material. However, the converse is not true.

5.12.7 Type Testing

In cases in which a single test of a particular seal configuration is to serve as a qualification test for the same or similar design configurations with different design parameters, the tested configuration should be the worst-case design configuration with the worst-case combination of design parameters. This would test and qualify a condition that would fail first, if failure occurs at all. Successful testing of the worst-case condition can then serve to qualify the same or similar design configurations for design parameters within the test range. In some cases, it could be appropriate to conduct multiple tests to assess a range of design parameters.

5.13 Comparison of Thermo-Lag Fire Barriers to Penetration Seals

During this assessment, it was reported that there are similarities between Thermo-Lag fire barriers and penetration seals with respect to technical issues and potential problems. The staff evaluated these assertions.

The principal purpose of Thermo-Lag fire barriers differs from that of penetration seals. Thermo-Lag fire barriers are typically used to enclose one train of redundant electrical cables that are located in the same plant fire area and needed to achieve and maintain shutdown after a fire. The intended design function of the Thermo-Lag barrier is to provide reasonable assurance that the safe-shutdown train it encloses will remain free of fire damage despite the fire and, therefore, will remain available to achieve shutdown.[17] Penetration seals are used to close openings through such structural fire barriers as walls and floor-ceiling assemblies. The intended design function of the penetration seal is to confine a fire to the area in which it started and to protect important equipment within the area from a fire outside the area. This difference in design function is significant. Protecting the functionality of a component located within a relatively small Thermo-Lag enclosure (as compared to the volume of the fire area), which is designed to be totally engulfed in a fire, is technically more challenging than preventing the spread of fire through a fire-resistive barrier that is exposed to the fire on only one surface.

Thermo-Lag fire barriers, which were manufactured and tested by one company, Thermal Science, Incorporated (TSI), have been installed in most plants. In 1991, when the staff first identified generic concerns with Thermo-Lag fire barriers, it questioned the validity of the available fire test data and the fire-resistance ratings of the Thermo-Lag fire barriers. For example, the staff could not find evidence that Thermo-Lag had been tested and certified as a fire wrap by third-party testing laboratories, such as FM and UL. (Although such tests are not required by the NRC, the results of such tests can help establish the capabilities and limitations of products absent other credible information and data.) Conversely, a number of companies manufacture, test, and install penetration seals and a large number of penetration seal designs and penetration seal materials have been tested and approved by UL and FM.

[17] Fire barriers that are used to enclose safe shutdown equipment are commonly called "fire wraps."

In addition, in 1991, there were questions regarding the test standards, methods, and acceptance criteria that had been used to conduct fire endurance tests of the Thermo-Lag fire barriers for the protection of electrical raceways. On the other hand, at that time, industry consensus test standards, methods, and acceptance criteria for determining the fire-resistance ratings of penetration seals had existed for decades. Furthermore, fire endurance tests conducted by the staff and the nuclear industry after the staff raised concerns about Thermo-Lag revealed that many Thermo-Lag fire barrier configurations, even when installed in accordance with the procedures recommended by the vendor, could not achieve their intended fire-resistance ratings. These tests also demonstrated that certain Thermo-Lag fire barriers were susceptible to structural failure. Conversely, a large body of qualification-type fire endurance tests of a wide variety of penetration seal materials and designs that are used in the nuclear industry have been successfully completed by various manufacturers, installers, and test laboratories. On the basis of its direct observations of fire endurance tests and its reviews of numerous fire endurance test reports, the staff has concluded that suitable fire endurance tests have established the fire endurance ratings of a large number of fire barrier penetration seal designs, configurations, and materials. Properly designed penetration seals are not susceptible to structural failure.

On these bases, the staff concluded that the technical issues and potential problems associated with fire barrier penetration seals and Thermo-Lag fire barriers are not comparable. The staff also concluded that the Thermo-Lag experience does not in any way provide bases for questioning the ability of fire barrier penetration seals to achieve their fire protection design function.

6 SUMMARY OF FINDINGS

(1) Fire barrier penetration seals are not unique nuclear components. They are universally accepted for use in residential, commercial, and industrial buildings wherever fire-resistive separation is needed.

(2) There are no reports of fires that challenged the ability of nuclear power plant fire-rated structural barriers or fire-rated penetration seals to confine a fire.

(3) There is no evidence of problems with the materials used to construct nuclear power plant fire barrier penetration seals.

(4) The general condition of penetration seal programs in industry (licensees and vendors) appears to be satisfactory.

(5) Plant-specific deficiencies have been, and will continue to be found on occasion during licensee surveillances and NRC inspections. Fire protection defense in depth provides reasonable assurance that such deficiencies will not present an undue risk to public health and safety.

(6) A large body of fire endurance tests has established the fire-resistive capabilities of the penetration seal materials, designs, and configurations installed in nuclear power plants. The test results support the conclusion that the regulatory requirements can be met by these materials.

(7) If penetration seals are properly designed, tested, configured, installed, inspected, and maintained, there is reasonable assurance that they will provide the fire resistance of the tested configuration, maintain the fire-resistive integrity of the fire barriers in which they are installed, and confine the fire to the area of origin.[18]

(8) Operating experience and inspection results show that the licensees and vendors understand the fire-resistive capabilities and limitations of the penetration seal materials and configurations; potential penetration seal testing, design, installation, inspection, and maintenance problems—and possible remedies and corrective actions.

(9) The term "nationally recognized testing laboratory" is undefined and obsolete. There is no need for the NRC fire protection guidance to

[18]"Properly tested" means that a representative seal had been tested in accordance with an accepted fire endurance test standard. "Properly configured" means that the design of the installed seal had been determined by a fire test and/or an engineering evaluation. "Properly installed" means that the seal had been installed in accordance with the methods and procedures used to construct the test specimen (typically the seal vendor's recommended installation procedures). "Properly maintained" means that the quality and configuration of the barrier had been maintained through routine surveillances and, as appropriate, maintenance and repair.

reference fire endurance tests by a nationally recognized testing laboratory.

(10) There is no basis for the criterion in Appendix R and the SRP that specifies that penetration seal materials be noncombustible.

(11) Overall, satisfactory staff review guidance and industry practices, methods, and procedures are available and are used to meet the regulatory requirements for fire barrier penetration seals. New guidance for comparing fire tested seal configurations to as-built configurations may be useful to the industry.

(12) The potential problems that were raised about penetration seals have been addressed. The staff did not find safety-significant plant-specific problems nor did it find problems with potential generic implications.

7 CONCLUSIONS

On the basis of the totality of the information it found and assessed, including the "Report on the Reassessment of the NRC Fire Protection Program" that had been conducted by NRR, the review of fire barrier penetration seals that had been conducted by AEOD, reports that had been prepared by SNL on the population of fire barrier types installed in nuclear power plants and penetration seal aging, and the other documents referenced here, the staff concluded that the general condition of penetration seal programs in industry is satisfactory. The staff did not find plant-specific problems of safety significance or concerns with generic implications.

Even though the staff found the condition of penetration seal programs in industry to be satisfactory, it expects that plant-specific deficiencies will occasionally be found during future licensee surveillances and NRC inspections. However, potential fire barrier penetration seal problems are understood; industry consensus fire test standards are available and are followed; and fire test results and qualified fire-resistant seal materials and designs are available. Therefore, licensees have the means to correct problems, and staff oversight will continue to ensure corrections on a case-by-case basis. Fire protection defense in depth provides reasonable assurance that such deficiencies will not present an undue risk to public health and safety. Finally, the staff concluded that the actions it had taken in 1988 and 1994 to address potential penetration seal problems increased industry awareness of such problems and resulted in more thorough surveillances, maintenance, and corrective actions. These actions together with continued licensee upkeep of existing penetration seal programs and continued NRC inspections are adequate to maintain public health and safety.

The technical assessment documented here has been the subject of substantial public and industry interest. The staff informed the Commission of the findings of this report in SECY-96-146, "Technical Assessment of Fire Barrier Penetration Seals in Nuclear Power Plants," dated July 1, 1996. (See Appendix E.)

8 RECOMMENDATIONS

(1) Revise the NRC fire protection guidance documents to reflect the current NFPA position on testing laboratories. (Section 3.2)

(2) Remove the noncombustibility criterion from Appendix R to 10 CFR Part 50 and SRP Section 9.5.1. (Section 5.8)

(3) Develop and issue guidance for comparing fire test configurations to as-built configurations. (Section 5.12)

(4) Make this technical assessment report available to the general public and industry.

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Appendix A

Summaries of NRC Generic Communications Regarding Penetration Seals

The NRC has issued a number of generic communications regarding fire barrier penetration seals. This included Generic Letter (GL) 86-10, "Implementation of Fire Protection Requirements," April 24, 1986 (see Section 4.3.3 of technical assessment report), and four information notices (INs). Summaries of the issues that were addressed in the information notices are presented below.

Information Notice 88-04

Information Notice 88-04, "Inadequate Qualification and Documentation of Fire Barrier Penetration Seals," February 5, 1988, informed licensees that some installed fire barrier penetration seal designs may not be adequately qualified for the design rating of the penetrated fire barriers. The IN also indicated that deficiencies included test qualification documentation being unavailable, incomplete, or inadequate. The IN also summarized existing staff guidance related to seals.

Information Notice 88-04, Supplement 1

Information Notice 88-04, Supplement 1, "Inadequate Qualification and Documentation of Fire Barrier Penetration Seals," August 9, 1988, addressed misapplication of silicone foam materials and resultant exposure of penetration seal materials to ambient temperatures above design specifications. Specific examples of this included Diablo Canyon where seal material in place around a diesel generator exhaust pipe caught fire, and Davis-Besse where a penetration seal around a main steam line baked and pulled away from the pipe.

Information Notice 88-56

Information Notice 88-56, "Potential Problems With Silicone Foam Fire Barrier Penetration Seals," August 4, 1988, informed licensees of the possibility that silicone foam penetration seals may contain nonconforming conditions such as splits, gaps, voids, and lack of fill. Specific example was the May 1987, Part 21 notification by B&B Promatec regarding nonconforming silicone foam seals at Wolf Creek. The IN stated that the "NRC believes that if generic problems exist, then they may be limited to only silicone foam fire barrier penetration seals but not to any particular vendor or installer."

Information Notice 94-28

Information Notice 94-28, "Potential Problems With Fire Barrier Penetration Seals," April 5, 1994, informed licensees of potential problems that could go undetected as a result of inadequate surveillance inspection procedures and inadequate acceptance criteria. Plants specifically mentioned were Nine Mile Point, James A. Fitzpatrick, and Vermont Yankee, where nonconforming or degraded conditions were discovered during licensee inspections of penetration seals. The IN listed where NRC requirements and guidelines for fire barrier penetrations could be found.

Appendix B

Action Plan Summary
Technical Assessment of Fire Barrier Penetration Seals

Description: Action plan for technical assessment of fire barrier penetration seals installed in nuclear power plants.

Background: In 1988, the staff had completed an assessment of fire barrier penetration seals. Since 1992, the NRC received new reports of potential problems regarding seals. On the basis of the assessment it had completed in 1988, NRC inspections, and licensee event reports, the staff assumed that it would find plant-specific deficiencies regarding documentation of fire tests, comparisons of in-plant seals to fire tests, seals not installed where required, seals not installed or repaired properly, seals modified without a supporting engineering evaluation, and seals not inspected in accordance with plant surveillance procedures. The staff initiated a technical assessment to determine if the actions it had taken in 1988 to address potential penetration seal problems had increased industry awareness of such problems, if there were any widespread or generic problems of safety significance, and if NRC requirements, review guidance, and inspection procedures for penetration seals are adequate.

Proposed Actions: Inspect reactor and vendor penetration seal programs; observe fire endurance tests, review operating experience and previous NRC inspection results; assess the data and information obtained from the field work and document reviews; identify commonality or correlation of evidence, if any, that suggests trends, widespread plant-specific problems, or generic concerns of safety significance; determine if NRC requirements, review guidance, and inspection procedures for penetration seals are adequate; and determine if existing industry (licensee and vendor) programs are adequate.

Regulatory Assessment: Each reactor uses the defense-in-depth concept to achieve a high degree of fire safety. Each reactor has an NRC-approved fire protection program that, if properly designed, implemented, and maintained, satisfies Section 50.48, "Fire protection," and General Design Criterion 3, "Fire protection," of Title 10 of the *Code of Federal Regulations* Part 50. Therefore, each reactor has an adequate level of fire safety pending completion of the assessment.

SUMMARY TASK	NOTES
1. Identify types of seals installed in nuclear power plants.	Sandia National Laboratories, Letter Report of May 29, 1992, from William Lowrey, for NRC, "A Determination of the Population of Fire Barrier Types in Generating Stations."
2. Identify and prioritize potential technical issues and problems.	Materials. Seal design and configuration. Qualification tests. Comparisons of tested to as-built. Installation. Surveillances and inspection. Maintenance and repairs. Configuration control. Aging.
3. Determine whether or not there are safety-significant problems with penetration seal materials.	Obtain data from licensee event reports, NRC inspection reports, Part 21 database regarding reports of materials problems. Conduct a vendor inspection of a materials manufacturer. (Dow Corning Corporation was selected, in part, because (1) it is the principal manufacturer of the silicone-based penetration seal materials and (2) it had submitted Part 21 reports.) Conduct vendor inspections of seal installation vendors. (Brand and Promatec were selected, in part, because of the length of time in business, volume of business, and current activities.)
4. Determine whether or not there are safety-significant problems regarding seal design, qualification tests, seal installation, seal surveillances and inspection, seal maintenance and repairs, and configuration control.	Review results of previous NRC inspections of penetration seals. Observe fire endurance tests. Review during vendor inspections and during new focused inspections at representative sample of nuclear plants. Review reported concerns, if any; gather information on qualified seals; and determine if the seals were designed, tested, installed, inspected, and maintained in accordance with licensee commitments and NRC requirements. Examine procurement documents, seal compatibility with barriers, fire endurance tests associated with the seal qualification designs, engineering evaluations, installer and inspector training programs, sample of installed seals, quality control and quality assurance programs for installing and maintaining seals, deviations from NRC requirements, and surveillance requirements, and programs for technical specification seals. Select seals for inspection based, for example, on seal type and material; seal location; seals that had been inspected, repaired or reworked; and seals for which there were reports of specific concerns. Select plants based on reports of problems (Davis-Besse, Waterford 3, and Susquehanna), old and new seal construction (Calvert Cliffs), significant rework by licensee after self-identification of problems (WNP2), and new construction including testing and engineering (Watts Bar).

SUMMARY TASK	NOTES
5. Determine whether or not there are concerns or problems regarding comparisons of tested to as-built seal configurations.	Review industry standards. Review NRC review guidance. Review industry practice during vendor and plant site inspections. Review in real time during Watts Bar licensing.
6. Identify and assess sundry technical issues.	Silicone foam formulation change. Dow Corning Part 21 reports. Combustibility of silicone-based seal materials.
7. Assess potential problems regarding seal aging.	Sandia National Laboratories, Letter Report of September 30, 1994, from Tina J. Tanaka, to NRC, "Aging of Fire Barriers in Nuclear Power Plants."
8. Assess the data and information obtained from the field work and document reviews; identify commonality or correlation of evidence, if any, that suggests trends, widespread problems, or generic concerns of safety significance.	
9. Determine if NRC requirements, review guidance, and inspection procedures for penetration seals are adequate.	
10. Document results of technical assessment with recommendations.	Technical assessment report. Peer review. Independent management review panel. NUREG-1552 report.

Appendix C

Comparison of Industry Fire Endurance Test Standards

Standard	ASTM E-119	ASTM E-814	ANI 4/76	UL 1479	IEEE 634
Title	Standard Test Methods for Fire Tests of Building Construction and Materials	Standard Test Method for Fire Tests of Through-Penetration Fire Stops	NEL-PIA/MAERP Standard Method of Fire Tests of Cable and Pipe Penetration Fire Stops	Standard for Fire Tests of Through-Penetration Fire Stops	IEEE Standard Cable Penetration Fire Stop Qualification Test
NRC Reference	NUREG-0800, Standard Review Plan, Section 9.5.1 (1981)	Information Notice 88-04	None	None	Information Notice 88-04
Test Specimen Construction	8. The test specimen shall be truly representative of the construction for which the classification is desired, as to materials, workmanship, and details such as dimensions of parts, and shall be built under conditions representative of those obtaining as practically applied in building construction and operation. The physical properties of the materials and ingredients used in the test specimen shall be determined and recorded.	7. Construction of the test fire stops shall be of sufficient size and include all conduits, pipes, cables (jacket types, sizes, conductor types, percent fills) required supports, or other through-penetrating items so as to produce a truly representative fire stop for which the evaluation is desired	2.A.1 A wall or floor construction of previously proven fire resistance rating of at least 3 hours is to be used for the test. It may be modified to a minimum acceptable size of 3' by 3' with the understanding that this will result in approval by NEL-PIA/MAERP for restricted size applications in the field. 2.A.2 Size and configuration of test penetrations to be as shown in test standard.	4.1 Each representative construction type of through-penetration firestop for which rating is desired shall be tested. When a through-penetration firestop is intended for use in both floor and walls, each orientation is to be tested unless it is demonstrated that testing in a single orientation does not affect the test results. 4.2 Penetrating items are to be installed so that they extend 12 ± 1 inch from the exposed side, and 36 ± 1 inch from the unexposed side. The extended portions of the penetrating items on the unexposed side are to be supported by methods intended to be employed in field installation.	5.2.2 Selection of the sizes, construction, and materials of the cable penetration opening fill to be used in the test shall be representative of the cables used in the fire stop under actual installed conditions. It is not the intent that different construction types, that is, instrumentation and medium voltage power cable, be installed in the same test cable penetration unless this is indicative of actual conditions.
Time Temp Curve	ASTM E-119	ASTM E-119	ASTM E-119	ASTM E-119	ASTM E-119

Standard	ASTM E-119	ASTM E-814	ANI 4/76	UL 1479	IEEE 634
Temperature Acceptance Criteria	17.1.3 Transmission of heat through the wall or partition during the fire endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250 °F above its initial temperature 6.4 Where the conditions of acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire endurance period shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30% in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire endurance period judged as ended.	10.2.1 A fire stop shall be considered as meeting the requirements for the T rating when it remains in the during the fire test...within the following limitations: 10.2.1.1 The transmission of heat through the fire stops during the rating period shall have not been such as to raise the temperature of any thermocouple on the unexposed surface of the fire stop or on any penetrating item more than 325 °F above its initial temperature. Also the fire stops shall have withstood the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the fire stops.	C.2 No individual thermocouple of the unexposed surface of the fire stop shall exceed 325 °F above ambient conditions.	For a T rating: 7.1 A through-penetration firestop shall remain in the opening during the fire test...and shall comply with the following: A. The transmission of heat through the sample during the rating period shall not raise the temperature measured by any thermocouple on the unexposed surface of the fire stop or on any penetrating item more than 325 °F above its initial temperature.	Foreword - The maximum allowable temperature selected for a cable penetration fire stop should be based on the self-ignition temperature of the outer cable covering the fire stop materials in contact with the cable penetration fire stop, whichever has the lower self-ignition temperature. For cable penetration fire stops the self-ignition temperatures of the outer cable covering and fire stop material are generally above 700 °F. The maximum allowable temperature is the actual measured temperature on the unexposed side and not the temperature rise. 6.1.2 Transmission of heat through the cable penetration fire stop shall not raise the temperature on its unexposed surface above the self-ignition temperature as determined in ANSI K65.111-1971 of the outer cable covering, the cable penetration fire stop material, or material in contact with the cable penetration fire stop, etc.

Standard	ASTM E-119	ASTM E-814	ANI 4/76	UL 1479	IEEE 634
Flame Criteria	17.1.1 The wall or partition shall have withstood the endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.	10.1.1 A fire stop shall be considered as meeting the requirements for an F rating when it remains in the opening during the fire test and hose stream test within the following limitations: 10.1.2 The fire stops shall have withstood the fire test for the rating period without permitting the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the fire stops. 10.1.3 During the hose stream test, the fire stop shall not develop any opening that would permit a projection of water from the stream beyond the unexposed side. 10.2.1 A fire stop shall be considered as meeting the requirements for the T rating when it remains in the during the fire test and hose stream test within the following limitations: 10.2.1.2 ...the fire stops shall have withstood the fire test during the rating period without permitting the passage of flame through the openings, of unexposed side of the fire stops. 10.2.1.2 See 10.1.3 above	C.1 Fire shall not propagate to the unexposed side of the test assembly nor shall any visible flaming be observed.	For an F rating: 6.1 A through-penetration firestop shall remain in the opening during the fire test and hose stream test and shall comply with the following: A. The sample shall withstand the fire test for the rating period without the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the sample. B. The sample shall not develop any opening during the hose stream test that would permit a projection of water from the stream beyond the unexposed side. For a T rating: A. ...the sample shall withstand the fire test during the rating period without permitting the passage of flame through openings, or the occurrence of flaming on any element of the unexposed side of the sample. B. See B above	6.1 The test can be considered acceptable and the cable penetration fire stop suitable for use in accordance with the fire rating provided the following is met: 6.1.1 The cable penetration fire stop shall have withstood the fire endurance test as specified without passage of flame or gases hot enough to ignite the cable or other fire stop material on the unexposed side for a period equal to the required rating

Standard	ASTM E-119	ASTM E-814	ANI 4/76	UL 1479	IEEE 634
Thermocouple Locations	<u>Outside Furnace</u> 6.2 Temperature readings shall be taken at not less than 9 points on the surface [wall, floor,etc.]. Five of these shall be symmetrically disposed, one to be...at the center of the specimen, and four at...the center of its quarter sections. The other four shall be located at the discretion of the testing authority to obtain representative information on the performance of the construction under test. None of the thermocouples shall be located nearer to the edges of the test specimen than one and one-half times the thickness of the construction, or 12 in. <u>Inside Furnace</u> 5.1 The temperature fixed by the curve shall be deemed to be the average temperature obtained from the reading of not less than nine thermocouples for a floor, roof, wall, or partition and not less than eight thermocouples for a structural column symmetrically disposed and distributed to show the temperature near all parts of the sample, etc.	<u>Outside Furnace</u> As specified in test standard, "Temperature Measurement Locations" <u>Inside Furnace</u> 6.2.1 Minimum of three thermocouple with not fewer than five thermocouples per 100 ft^2 of floor surface and not fewer than nine thermocouples per 100 ft^2 of wall specimen surface.	Thermocouple locations not specified; However, ANI/MAERP Standard Fire Endurance Test Method to Qualify A Protective Envelope for Class 1E Electrical Circuits states in Section 3.4.4.5 "Thermocouples shall be located strategically on the surface and at one foot intervals in the cable system and temperatures recorded throughout the test."	<u>Outside Furnace</u> 4.14 Temperature measurements are to be made by thermocouples placed on the unexposed side of the test sample and test assembly. <u>Inside Furnace</u> 4.9 A minimum of three thermocouples are to be used, and there are to be no fewer than five thermocouples per 100 square feet of floor surface, and no fewer than nine thermocouples per 100 square feet of wall surface. The floor surface or wall surface area is to be the gross area of test-assembly and sample areas.	<u>Outside Furnace</u> 5.3.10 Temperatures on the penetration cold side surfaces shall be measured with thermocouples. A minimum of three thermocouples shall be located on the surface of each fire stop under test. The maximum temperature on the face of the cable penetration fire stop shall be measured. As a minimum, temperatures shall be measured at the cable jacket, cable penetration, fire stop interface, the interface between the fire stop and through metallic components, other than the insulated cable conductor, and on the surface of the fire stop material. <u>Inside Furnace</u> 5.3.7 The temperature fixed by the curve shall be deemed to be the average temperature obtained from the reading of not less than three thermocouples symmetrically disposed and distributed to show the temperature for each cable penetration fire stop. Additional thermocouples shall be used as necessary, for larger test specimens.

Standard	ASTM E-119	ASTM E-814	ANI 4/76	UL 1479	IEEE 634
Hose Stream Test	10.1 Where required by the condition of acceptance, subject a duplicate specimen to a fire exposure test for a period equal to one half of that indicated as the resistance period in the fire endurance test, but not for more than one hour, immediately after which subject the specimen to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, changes in direction being made slowly. 10.4 The stream shall be delivered through a 2½ in. hose discharging through a National Standard playpipe of corresponding size equipped with a 1-1/8 in. discharge tip of the standard-taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of application shall be as described in Table 1: "Conditions For Hose Stream Test," of the standard. From Table 1: For a desired resistance period of greater than 2 hours and less than four hours, the pressure at the base of the nozzle is to be 30 psi with 2-1/2 minute duration for each 100 ft² exposed area.	9.3.1 Subject a duplicate specimen to a fire exposure test for a period equal to one half of that indicated as the resistance period in the fire test, but not more than 60 minutes, immediately after which subject the specimen to the impact, erosion, and cooling effects of a hose stream as described in Table 1: "Pressure and Duration - Hose Stream Test." The stream is directed first at the middle and then at all parts of the exposed face, with changes in direction being made slowly. 9.3.2 The test sponsor may elect with the advice of the testing body, to have the hose stream test made on the specimen subjected to the fire test and immediately following the fire test. 9.3.3 Deliver the stream through a 2½ in. hose and discharge through a National Standard playpipe of corresponding size equipped with a 1-1/8 in. discharge tip of standard taper, smooth bore pattern without a shoulder at the orifice. The water pressure and duration of application shall be as specified in Table 1 (of the standard).	B. Immediately following the fire endurance test the fire stops shall be subjected to a hose stream applied to the exposed surface for a period calculated on the basis of 2½ minutes for each 100 sq. ft of exposed area. The hose stream shall comply with one of the following procedures: 1. The stream shall be delivered through a 1½ inch nozzle set at a discharge angle of 30° with a nozzle pressure of 75 psi and a minimum discharge of 75 gpm with the tip of the nozzle a maximum of 5 ft. from the exposed face OR 2. The stream shall be delivered through a 1½ inch nozzle set at a discharge angle of 15° with a nozzle pressure of 75 psi and a minimum discharge of 75 gpm with the tip of the nozzle a maximum of 10 ft. from the exposed face OR 3. The stream shall be delivered through a 2½ inch National Standard playpipe equipped with 1° inch tip, nozzle pressure of 30 psi, located 20 feet from the exposed face For acceptance: No opening develops that permits a projection of water beyond the unexposed surface during the hose stream test.	5.3 The stream is to be delivered through 2½ inch hose and discharged through a National Standard playpipe of corresponding size equipped with a 1-1/8 inch discharge tip of the standard-taper, smooth bore pattern without a shoulder at the orifice. The water pressure and duration of application is to be as specified in Table 5.1, "Pressure and Duration - Hose Stream Test."	5.3.12 A hose stream test shall be conducted immediately following the end of the fire endurance test and removal, if necessary of the test slab. For power generating stations including nuclear-generating stations, a 1½ in. hose discharging through a nozzle approved, for use on fires in electrical equipment producing a long-range narrow-angle (30-90° set at 30° angle) high velocity spray only shall be used. The hose stream shall be applied to the exposed side. The water pressure shall be 75 psi, calculated, at the base of the nozzle and minimum flow of 75 gal/min with a duration of application of 2½ minutes per 100 ft² of test slab.

Standard	ASTM E-119	ASTM E-814	ANI 4/76	UL 1479	IEEE 634
Nozzle Distance	10.5 The nozzle orifice shall be 20 ft from the center of the exposed surface of the test specimen if the nozzle is so located that when directed at the center its axis is normal to the surface of the test specimen. If otherwise located, its distance from the center shall be less than 20 feet by an amount equal to 1 foot for each 10° of deviation from the normal.	9.3.4 The nozzle orifice shall be 20 feet from the center of the exposed surface of the test specimen if the nozzle is so located that when directed at the center, its axis is normal to the surface of the test specimen. If otherwise located, its distance from the center shall be less than 20 feet by an amount equal to 1 foot for each 10° of deviation from the normal.	See Hose Stream Test section above for Nozzle Distance specifications	5.4 The nozzle orifice is to be 20 feet from the center of the exposed surface of the test specimen if the nozzle is so located that, when directed at the center, its axis is normal to the surface of the test specimen. If otherwise located, its distance from the center is to be less than 20 feet by an amount equal to 1 foot for each 10° of deviation from the normal.	5.3.12 The nozzle distance shall be 10 ft from the center of the exposed surface of the test specimen

Appendix D

Acronyms and Abbreviations

AEC	Atomic Energy Commission
AEOD	Office for Analysis and Evaluation of Operational Data
ANI	American Nuclear Insurers
ANSI	American National Standards Institute
APCSB	Auxiliary Power Conversion Systems Branch
ASTM	American Society for Testing and Materials
BISCO	Brand Industrial Services Company
BTP	Branch Technical Position
CFR	*Code of Federal Regulations*
CTL	Construction Testing Laboratories
FM	Factory Mutual
FPFI	Fire Protection Functional Inspection
GDC	General Design Criteria
GL	generic letter
HDSE	high-density silicone elastomer
IEEE	Institute of Electrical and Electronics Engineers
IN	information notice
IP3	Indian Point 3
LER	licensee event report
LDSE	low-density silicone elastomer
NFPA	National Fire Protection Association
NMSS	Office of Nuclear Material Safety and Safeguards
NRC	U.S. Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
OPL	Omega Point Laboratories
PSTS	penetration seal tracking system
QA	quality assurance
QC	quality control
RBS	River Bend Station
SNL	Sandia National Laboratories
SRP	Standard Review Plan
TSI	Thermal Science, Incorporated
UL	Underwriters Laboratories, Incorporated
WBN	Watts Bar Nuclear Power Plant
WNP2	Washington Nuclear Project 2

Appendix E

Technical Assessment of Fire Barrier Peneteration Seals in Nuclear Power Plants

POLICY ISSUE
(Information)

July 1, 1996 SECY-96-146

FOR: The Commissioners

FROM: James M. Taylor
Executive Director for Operations

SUBJECT: TECHNICAL ASSESSMENT OF FIRE BARRIER PENETRATION SEALS IN NUCLEAR POWER PLANTS

PURPOSE:

To inform the Commission that the U.S. Nuclear Regulatory Commission (NRC) staff has completed its technical assessment of nuclear power plant fire barrier penetration seals. The staff documented its assessment in a report entitled: "Technical Assessment of Fire Barrier Penetration Seals in Nuclear Power Plants," June 14, 1996. A copy of the report is attached.

BACKGROUND:

As part of fire protection defense in depth, nuclear power plants are divided into separate fire areas by fire-rated walls and fire-rated floor-ceiling assemblies. These fire barriers offer reasonable assurance that a fire will not spread from one plant area to another. Openings in these fire barriers, known as fire barrier penetrations, allow such items as cables, conduits, cable trays, pipes, and ducts to pass from one fire area to another. Fire barrier penetration seals are installed to seal these openings and maintain the fire-resistive integrity of the fire barriers. Penetration seals are not technically complex, nor are they unique to the nuclear industry. In fact, they are universally accepted building components that are used in a variety of residential, commercial, and industrial buildings wherever fire-resistive separation is needed. The same penetration seal materials, fire test

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NOTE: TO BE RELEASED AT COMMISSION MEETING ON TUESDAY, JULY 9, 1996 standards, and installation techniques that are used by the nuclear industry are used in these other industries. A large body of fire test results and fire experience (non-nuclear) has proven the fire-resistive capabilities and effectiveness of penetration seals.

In about 1985, the staff had become aware of the possibility that some licensees may not have been complying with NRC requirements and guidance for fire barrier penetration seals. In response to these concerns, in 1987 and 1988, the NRC staff assessed fire barrier penetration seals. This assessment involved reviewing relevant data such as licensee event reports, inspection findings, and fire test reports; interviewing industry staff; inspecting licensees and vendors; and reviewing a sample population of as-built fire barrier penetration seal installations and the substantiating documentation. Although it did not find safety-significant generic issues, the staff identified potential problems. These included, for example, incomplete test documentation and improper seal installation techniques. The staff addressed the potential problems in a series of information notices that it issued in 1988.

Since 1992, similar potential problems have again been reported. In response, the Office of Nuclear Reactor Regulation (NRR) conducted a second technical assessment of fire barrier penetration seals. The principal purposes of the second assessment were to address the potential problems, to determine if there were any problems of safety significance or with generic implications, and to determine if NRC regulatory requirements, review guidance, and inspection procedures for penetration seals were adequate.

DISCUSSION:

In support of its second technical assessment of penetration seals, the staff inspected reactor and vendor facilities; witnessed fire endurance tests of penetration seals; reviewed operating experience and previous NRC inspection and assessment results; and assessed the data and information obtained from the field work and document reviews.

The staff found several minor weaknesses with some of the plant-specific penetration seal programs that it reviewed. These included, for example, inadequate documentation of seal installer training and failure to mark in-plant seals with their seal identification numbers. The staff also found several potential weaknesses with the NRC fire protection inspection and review guidance. These potential weaknesses, which were also minor, included: (1) the NRC fire protection guidance documents do not reflect the current National Fire Protection Association (NFPA) position on fire testing laboratories; (2) there is no technical basis for the noncombustibility criterion for penetration seal materials that is specified in the NRC fire protection regulation and review guidance; (3) there is no staff guidance for comparing fire-tested penetration seal configurations to as-built configurations. (See recommendations below.) Neither the plant-specific nor the programmatic weaknesses caused concerns that the penetration seals installed in the plants would not accomplish their fire protection function.

On the basis of its review and assessment of available information, including the "Report on the Reassessment of the NRC Fire Protection Program" that had been conducted by NRR, the review of fire barrier penetration seals that had been conducted by the Office for Analysis and Evaluation of Operational Data (AEOD), reports that had been prepared by Sandia National Laboratories on the population of fire barrier types installed in nuclear power plants and penetration seal aging, and the other documents referenced in its assessment report, the staff concluded that the penetration seal programs in industry remain satisfactory. The staff found neither plant-specific problems nor generic problems of safety significance.

The staff expects that plant-specific deficiencies will occasionally be found during future licensee surveillances and NRC inspections. However, licensees know what potential fire barrier penetration seal problems to look for during surveillance inspections; industry consensus fire test standards are available and are followed; and fire test results and qualified fire-resistant seal materials and designs are available. Therefore, licensees have the means to correct problems as they are found, and staff oversight will continue to ensure corrections on a case-by-case basis. In addition, the multiple layers of protection provided by the fire protection defense in depth concept provide reasonable assurance that penetration seal deficiencies will not present an undue risk to public health and safety. Finally, the staff concluded that actions it had taken in 1988 to address potential penetration seal problems increased industry awareness of such problems and resulted in more thorough surveillances, maintenance, and corrective actions. These actions together with continued licensee upkeep of existing penetration seal programs and continued NRC inspections are adequate to maintain public health and safety.

On the basis of the results of its second technical assessment the staff will: (1) revise the NRC fire protection guidance documents to reflect the current National Fire Protection Association position on testing laboratories; (2) delete the noncombustibility criterion for penetration seal materials from the NRC fire protection regulation and review guidance; (3) develop guidance for comparing fire-tested penetration seal configurations to as-built configurations; and (4) issue an Information Notice that summarizes this Commission paper and states that the attached technical assessment is available in the public document room.

The Fire Protection Engineering Section of NRR conducted the technical assessment documented in the report. The Special Inspection Branch of NRR and Brookhaven National Laboratory helped with the reactor and vendor inspections. Staff of NRR, AEOD, the Office of Nuclear Material Safety and Safeguards (NMSS), Region I, Region II, Region III, and Region IV conducted a peer review of the assessment report. An Independent Management Review Panel that was chaired by NRR and represented by NMSS and the Office of Nuclear Regulatory Research conducted a final review of this report.

The staff of the Fire Protection Engineering Section made presentations on fire barrier penetration seals and this assessment at the International Conference on Fire Protection and Prevention in Nuclear Facilities, Barcelona, Spain (December 5-7, 1994); the Nuclear Energy Institute Fire Protection Forum, St. Petersburg, Florida (January 29, 1996); and NRC Regulatory Information Conferences (May 1994 and April 1996). On March 7, 1996, the staff of the Fire Protection Engineering Section presented the results of this technical assessment to the Advisory Committee on Reactor Safeguards, Fire Protection Subcommittee.

The technical assessment report addresses concerns identified in outstanding penetration seal allegations. The staff will use the assessment report as the basis to close these allegations. The staff will also provide copies of the assessment report to cognizant technical staff. This completes the staff actions on its technical assessment of nuclear power plant fire barrier penetration seal programs.

James M. Taylor
Executive Director
for Operations

Attachment: As stated

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11. ABSTRACT *(200 words or less)*

Nuclear power plants are divided into separate fire areas by fire-rated structural barriers. Fire-rated penetration seals are installed to seal certain openings in these barriers. The seals maintain the fire-resistive integrity of the barriers and provide reasonable assurance that a fire will be confined to the area in which it started. The U.S. Nuclear Regulatory Commission conducted a comprehensive technical assessment of penetration seals to address reports of potential problems, to determine if there were any problems of safety significance, and to determine if NRC requirements, review guidance, and inspection procedures are adequate. The staff did not find plant-specific problems of safety significance or concerns with generic implications. The staff concluded that the general condition of penetration seal programs in industry is satisfactory. The staff also concluded that actions it had taken in 1988 and 1994 to address potential penetration seal problems increased industry awareness of such problems and resulted in more thorough surveillances, maintenance, and corrective actions. These previous staff actions, together with continued licensee upkeep of existing penetration seal programs and continued NRC inspections, are adequate to maintain public health and safety.

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