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

November 20, 1992

MEMORANDUM FOR: Ashok Thadani, Director
Division of Systems Safety and Analysis

FROM: Conrad McCracken, Chief
Plant Systems Branch
Division of Systems Safety and Analysis

SUBJECT: SUMMARY OF NOVEMBER 18, 1992, MEETING BETWEEN NRC STAFF AND NUMARC ON FIRE ENDURANCE TESTING ACCEPTANCE CRITERIA

NRC staff met with representatives of the Nuclear Utilities Management and Resources Council (NUMARC) on November 18, 1992, to discuss the NRC staff's proposed fire barrier testing acceptance criteria that had been presented in summary form to the Commission on November 13, 1992. Enclosure 1 is a list of the attendees.

NRC staff provided NUMARC with the proposed criteria (Enclosure 2) nd solicited technical and programmatic questions from the meeting attendees. The NRC staff also discussed the Thermo-Lag combustibility issues and informed NUMARC of plans to issue an information notice on the results of combustibility tests.

The staff stated that the proposed criteria would be issued through the normal regulatory process, providing an opportunity for public comment. However, if any attendees had significant initial comments, the staff requested that they be submitted within about two weeks. NUMARC representatives stated that they plan to provide the NRC with comments on the staff proposed acceptance criteria within this time period.

C. McCrack

Conrad E. McCracken, Chief
Plant Systems Branch
Division of Systems Safety and Analysis

Enclosures:
As stated

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Meeting Attendees Enclosure 1

Name	Affiliation
C. McCracken	USNRC
C. Berlinger	USNRC
R. Architzel	USNRC
P. Gill	USNRC
I. Moghissi	USNRC
M. Widmann	USNRC
I. Moghissi	USNRC
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A. Masciantonio	USNRC
S. West	USNRC
A. Marion	NUMARC
B. Bradley	NUMARC
M. Schreim	NUMARC
D. Alemayehu	Pacific Nuclear
R. Beller	Pacific Nuclear
P. Lersey	Pacific Nuclear
A. Cohlmeyor	Pacific Nuclear
M. Powell	Arizona Public Service
R. Oehlberg	EPRI
F. Ozysz	Penn. Power & Light
D. Smith	Florida Power & Light
C. Fisher	Florida Power & Light
R. Allen	Union Electric
P. Gunter	NIRS
J. MacGregor	Winston & Strawn
R. Huston	Tennessee Valley Authority
T. Meisenheimer	Bechtel
C. Skinker	Bechtel
J. Raleigh	STS
J. Stephens	Miller & Chevalier
R. Licht	3M
T. Dinh	HNUS
P. Boulden	Virginia Power
D. Notley	SAIC
D. Perramt	self-employed

Enclosure 2

U.S. Nuclear Regulatory Commission

Meeting on

Fire Endurance Test Acceptance Criteria

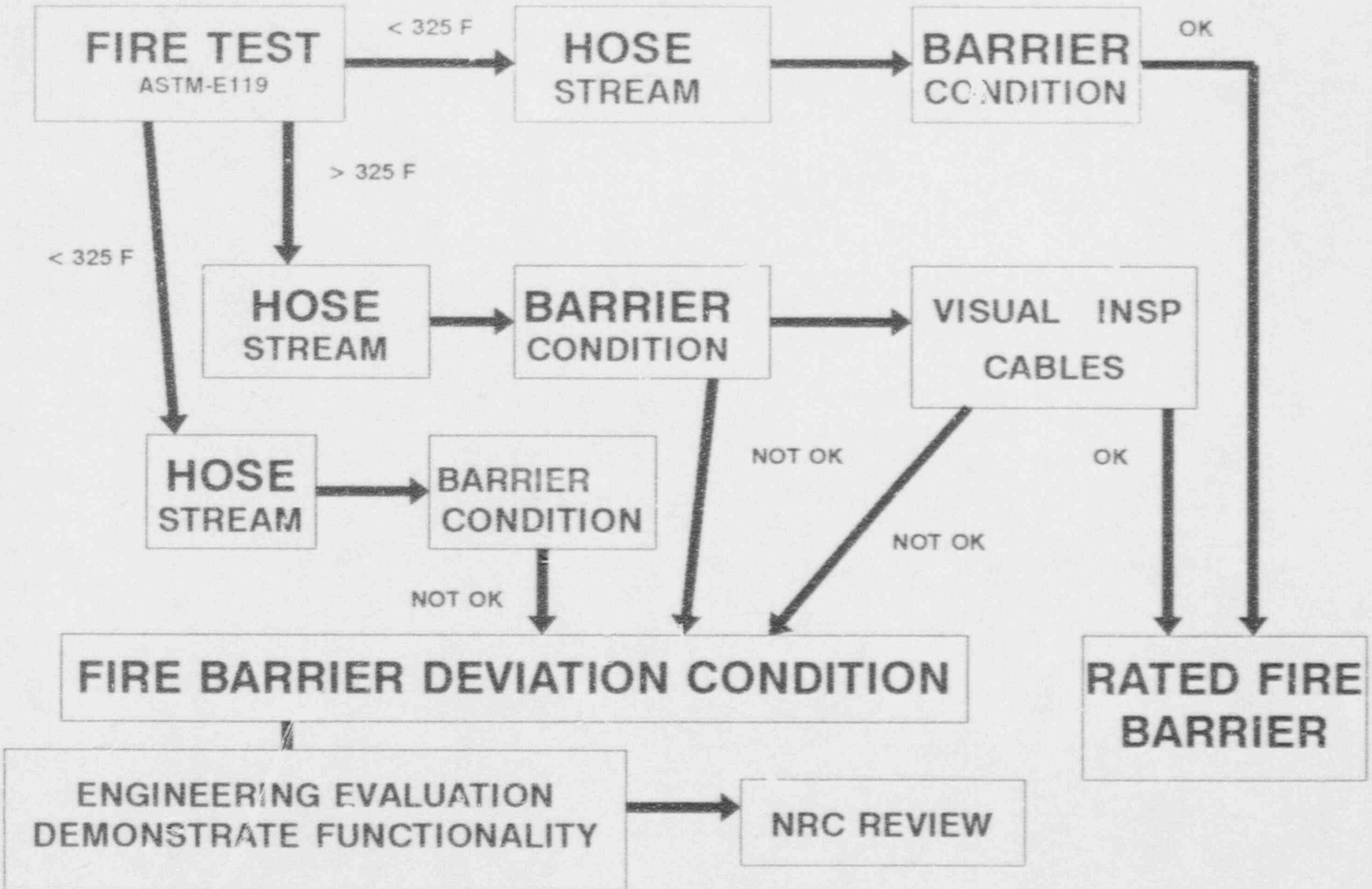
With the

Nuclear Management and Resources Council

November 19, 1992

FIRE BARRIER TESTING ACCEPTANCE CRITERIA

PROPOSED



SUMMARY OF PROPOSED FIRE ENDURANCE TESTING CRITERIA
FOR FIRE BARRIERS SYSTEMS USED TO SEPARATE
SAFE SHUTDOWN FUNCTIONS WITHIN THE SAME FIRE AREA

PROPOSED CRITERIA	PREVIOUS CRITERIA	RATIONAL FOR CHANGE
Temperature, as measured on the external surface of the Raceway, should not exceed 325°F (Note 1). This temperature is determined by averaging temperature readings of similar series of thermocouple (e.g., cable tray side rail). (Note 2)	**Temperature**, as measured on the unexposed side of the fire barrier material, should not exceed 325°F.	**Temperature** - Difficult to measure a uniform temperature on the fire barrier material surface. Raceway temps provide good indication of internal temp-rise and potential barrier failure locations during the test.
Barrier Condition - Raceway fire barrier shall remain intact. No visible signs of conductor or raceway after fire and hose stream test.	**Barrier Condition** - The barrier shall have withstood the fire and hose stream test without the passage of flame or hot gasses hot enough to ignite cotton waste.	**Barrier Condition** - Cotton waste has not been used in raceway fire barrier testing as an indicator of barrier failure. Visual inspection process provides a better indication of barrier condition after the fire and hose stream test.
Hose Stream testing is required. (solid stream test as required by NFPA 251 on second test specimen after being subjected to a fire exposure of 1/2 duration (Note 4) or a fog stream after the full fire exposure.)	**Hose Stream** testing is required. (solid stream test as required by NFPA 251)	**Hose Stream** - To reflect alternative methods found acceptable (Note 3). The use of a fog nozzle for the hose stream at the end of a full duration of the fire test provides a good method for testing erosion and cooling effects.

PROPOSED CRITERIA	PREVIOUS CRITERIA	RATIONAL FOR CHANGE
Cable condition - If the above temperature limit is exceeded, the cable condition must be visually inspected. Cables when inspected should show no signs of degraded conditions resulting from the thermal affects of the fire exposure.	**Cable condition** - No consideration given to determining the material condition of the cable.	**Cable condition** - The objective of these fire barriers is to assure that thermal damage to protected safe shutdown cables or components does not occur.

GUIDANCE - ENGINEERING EVALUATIONS JUSTIYING DEVIATIONS FROM THE FIRE BARRIER ACCEPTANCE CRITERIA

Functionality is needed to be demonstrated if the preceding criteria are exceeded (Note 5). Recommended method includes: - Megger test - Hi-Pot test (60%) Demonstration of functionality should also co ider operating temperature of the cables inside the fire barrier at the onset of the fire exposure.	**Functionality** - N guidance provideo p to licensees to demonstrate by engineering analysis. Analysis kept on file for NRC review. Engineering analysis generally based on internal temperature below the ignition temperature. No consideration given cable operating temperatures within the barrier at the onset of the fire exposu.e.	**Functionality** is considered to be a deviation from the acceptance criteria and must be justified on a case-by-case basis which includes an assessment of cable jacket material.

Combustibility of a fire barrier system should be demonstrated by testing to ASTM-E136. Certain applications of fire barriers materials (e.g., radiant energy heat shield inside containment) are required by Appendix R to be non-combustible.

Note 1 - The 325°F temperature condition was established by allowing the internal temperature on the raceway surface to rise a maximum of 250°F above ambient laboratory air temperature, assumed to be 75°F, during the fire test.

Note 2 - NFPA 251/ASTM-E119 allows the temperature condition to be determined by averaging the thermocouple readings. The conditions of acceptance are also placed on the temperature conditions measured by a single thermocouple. Under these conditions of acceptance, if any single thermocouple exceeds 30% above the maximum allowable temperature rise (i.e., max. allowable 250°F + 75°F = 325°F) the test is considered to have exceeded the criteria temperature limit.

Note 3 - SRP 9.5.1 recognizes the use of a fog stream as an alternative hose stream testing method for qualifying fire barrier penetration seals.

Note 4 - The application of this hose stream test method provides assurance that the fire barrier system has sufficient structural integrity to resist fire related barrier breaches caused by falling objects.

Note 5 - A fire barrier system which does not meet the performance conditions of the fire endurance acceptance criteria is considered not to be a rated fire barrier. For those performance conditions (i.e., high raceway temperature, barrier openings, water projection, cable damage) which deviate from this acceptance criteria, an engineering analysis which clearly demonstrates the functionality of the protected component or cables can be submitted to the staff for review. These deviations will be evaluated by the staff on a case-by-case basis.

PROPOSED POSITION - November 19, 1992

FIRE ENDURANCE TEST ACCEPTANCE CRITERIA FOR
FIRE BARRIER SYSTEMS USED TO SEPARATE SAFE SHUTDOWN FUNCTIONS
WITHIN THE SAME FIRE AREA

I. BACKGROUND

In 1975, the Browns Ferry Nuclear power plant experienced a serious electrical cable fire. This fire had a significant impact on the operators response to the event from a safety perspective. The fire caused spurious instrumentation indications and affected the control of several safety systems. As a result of this fire, the NRC issued the following fire protection guidelines and regulations concerning fire protection programs at nuclear power plants:

May 1, 1976	Branch Technical Position (APCSB) 9.5-1, "Fire Protection Program."
February 24, 1977	Appendix A to Branch Technical Position APCSB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1, 1976."
February 19, 1981	10 CFR 50.48, "Fire protection."
February 19, 1981	Appendix R to 10 CFR 50, "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1979."
July 1981	NUREG-0800, Standard Review Plan (SRP), 9.5.1, "Fire Protection for Nuclear Power Plants."

In addition to the above fire protection guidance and regulations, the NRC, in an effort to clarify its fire protection requirements to the industry, issued Generic Letter (GL) 81-12, "Fire Protection Rule (45 FR 76602, November 19, 1980)," February 20, 1981; GL 83-33, "NRC Position on Certain Requirements of Appendix R to 10 CFR 50," October 19, 1983; and GL 86-10, "Implementation of Fire Protection Requirements," April 24, 1986. GL 86-10, which took precedence over previous staff guidance, provided staff interpretations to Appendix R and answers to industry questions relating to the implementation of Appendix R. The NRC, in an effort to give the licensees more flexibility to make changes to their plant specific fire protection program, issued GL 88-12, "Removal of Fire Protection Requirements From Technical Specifications." Through the implementation and the adoption of a standard license condition a licensee can make changes which do not adversely affect a plant ability to achieve and maintain post-fire safe shutdown to their fire protection program in accordance with 10 CFR 50.59.

The aforementioned NRC documents provided the industry with NRC staff guidance concerning fire barriers separating plant fire areas, including the fire resistance (endurance) ratings for these barriers and the qualification

testing that establishes their fire resistance ratings. In addition, these documents provided guidance on combustibility of structural materials and the testing required to demonstrate low flame spread properties.

The following sections of this document provide the objective for providing safe shutdown related fire barriers in nuclear power plants, definition of fire protection terms related to fire barriers, and the NRC's fire endurance testing acceptance criteria for fire barriers used to separate safe shutdown functions within the same fire area.

II. OBJECTIVE OF FIRE BARRIERS USED TO SEPARATE SAFE SHUTDOWN FUNCTIONS WITHIN THE SAME FIRE AREA

Fire rated barriers are used in nuclear power plants to provide fire area separation between redundant safety related components and safe shutdown functions. They provide fire resistance protection, as required by Appendix R[1], to one safe shutdown train in those fire areas which contain both trains. The objective of the safe shutdown related Appendix R fire barrier is to ensure that a safe shutdown train is conservatively protected from fire-related thermal damage. The necessity for these fire barriers has been verified by multiple PRAs. These PRAs indicate, even with these fire barriers installed, fires provide a major contribution to core melt probabilities.

It is the position of the Plant Systems Branch that fire endurance ratings of building construction and materials are demonstrated by testing fire barrier assemblies in accordance with the provisions of the applicable sections of NFPA 251, "Standard Methods of Fire Tests of Building Construction and Materials," and ASTM E-119, "Fire Test of Building Construction and Materials." Assemblies which pass specified acceptance criteria (e.g., standard time-temperature fire endurance exposure, unexposed side temperature rise, and hose stream impingement) are considered to have a specific fire resistance rating.

Enclosure 1 to GL 86-10, Interpretations of Appendix R, provided additional guidance with respect to the term "free from fire damage." Interpretation 3, "Fire Damage," states, "In promulgating Appendix R, the Commission has provided methods acceptable for assuring that necessary structures, systems, and components are free from fire damage (see Section III.G.2a, b, and c), that is, the structure, system or component under consideration is capable of performing its intended function during and after the postulated fire, as needed."

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[1] For advanced reactor designs, redundant safe shutdown functions are required to be located in separate 3-hour fire areas.

GL 86-10, Question 3.2.1, also stated that "The resulting 325 °F cold side temperature criterion is used for cable tray wraps because they perform a fire barrier function to preserve the cables free from fire damage. It is clear that cable that begins to degrade at 450 °F is free from fire damage at 325 °F." (Emphasis added.) In addition, the staff's response stated that "for newly identified conduit and cable trays requiring such wrapping new materials which meet the 325 °F criterion should be used, or justification should be provided for the use of material which does not meet the 325 °F criterion. This may be based on an analysis demonstrating that the maximum recorded temperature is sufficiently below the cable insulation ignition temperature." (Emphasis added.)

The basic premise of the NRC fire resistance criteria is that fire barriers which do not exceed 325 °F (163 °C) cold side temperature and pass the hose stream test provide adequate assurance that the shutdown capability is protected without further analyses. If the temperatu criteria is exceeded, sufficient additional information is needed to perform an engineering evaluation to demonstrate that the shutdown capability is protected.

III. DEFINITIONS

In order to support the understanding of the technical terms used throughout this document, the following definitions are provided. (These terms and definitions are consistent with those used in NUREG 0800, SRP 9.5.1, "Fire Protection for Nuclear Power Plants.")

Approved - tested and accepted for a specific purpose or application by a nationally recognized testing laboratory.

Combustible Material - Material that does not meet the definition of non-combustible.

Fire Barrier - Those components of construction (walls, floors and their supports), including beams, joists, columns, penetration seals or closures, fire doors, and fire dampers that are rated by approving laboratories in hours of resistance to fire and are used to prevent the spread of fire.

Raceway Fire Barrier - Non-bearing partition type envelope system installed around electrical components and cabling that are rated by approving laboratories in hours of resistance to fire and are used to maintain safe shutdown functions free from fire dam...

Fire Resistance Rating - The time tha materials of test assemblies have withstood a fire exposure as established in accordance with the test procedures of "Standard Methods of Fire Tests of Building Construction and Materials," (NFPA 251).

Noncombustible Material - (a) Material which in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat; (b) Material having a structural base of noncombustible material, with a surfacing not over 1/8-inch thick that has a flame spread rating of not higher than 50 when measured using ASTM E-84 Test "Surface Burning Characteristics of Building Materials." (Note - There is an exception to this definition as defined by BTP Appendix A, Position D. 1. d. This position allows the use of combustible interior finishes when listed by a nationally recognized testing laboratory, such as Factory Mutual or Underwriters Laboratories, Inc. for a flame spread, smoke and fuel contribution of 25 or less in its use configuration.)

IV. FIRE ENDURANCE TESTING ACCEPTANCE CRITERIA FOR FIRE BARRIER WALLS, FLOORS, AND CEILINGS USED TO SEPARATE SAFE SHUTDOWN FUNCTIONS WITHIN THE SAME FIRE AREA

To demonstrate the adequacy of fire barrier walls, floors, ceilings, and enclosures, barrier designs should be verified by fire endurance testing. NRC fire protection guidance refers to the guidance of NFPA 251 and ASTM E-119 as acceptable test methods for demonstrating fire endurance performance.

The following are the fire endurance testing acceptance criteria for the subject fire barriers:

The fire barrier design has withstood the fire endurance test without the passage of flame or the ignition of cotton waste on the unexposed side for a period of time equivalent to the fire resistance rating required of the barrier;

The temperature levels recorded on the unexposed side of the fire barrier are analyzed and demonstrable that the maximum temperature does not exceed 250 °F above ambient; and

The fire barrier remains intact and does not allow projection of water beyond the unexposed surface during the hose stream test. (For acceptable hose stream test methods and time of application - See Section VII.)

If the above criteria are met for fire barrier walls, floors, and ceilings separating safe shutdown functions within the same fire area, the barrier is considered to be acceptable.

NRC fire protection guidance also ensures that door and ventilation openings and penetrations are properly protected. The guidance requires that these openings be protected with fire doors and fire dampers which have been fire tested and listed by a nationally recognized testing laboratory (e.g., Underwriters Laboratories or Factory Mutual). In addition, the construction

and installation techniques for door and ventilation openings and other penetrations through these fire barriers should be appropriately qualified by fire resistive testing.

The guidance of NFPA 251 and ASTM E-119 should be consulted with regard to construction, materials, workmanship, and details such as dimensions of parts, and the size of the specimen(s) to be tested. In addition, NFPA 251 and ASTM should be consulted with regard to the placement of thermocouples on the specimen.

V. ELECTRICAL RACEWAY AND COMPONENT FIRE BARRIER SYSTEMS FOR SEPARATING SAFE SHUTDOWN FUNCTIONS WITHIN THE SAME FIRE AREA

The NRC provided guidance in Appendix A to Branch Technical Position 9.5-1, Position D.3.(d), for cable tray fire barriers. This fire protection guidance states that the design of fire barriers for horizontal and vertical cable trays should, as a minimum, meet the requirements of ASTM E-119, "Fire Test of Building Construction and Materials," including hose stream test. On November 19, 1980, the NRC issued Appendix R to 10 CFR 50. The technical basis for Section III.M, "Fire Barrier Penetration Seal Qualification," states that "Fire barriers are 'rated' for fire resistance by being exposed to a 'standard test fire.' This standard test fire is defined by the American Society of Testing and Materials in ASTM E-119." In addition, this technical basis stated that "If specific plant conditions preclude the installation of a 3-hour fire barrier to separate the redundant trains, a 1-hour fire barrier and automatic fire suppression and detection system for each redundant train will be considered the equivalent of a 3-hour barrier."

In 1984 Appendix R workshops held with industry, and later in GL 86-10, the staff provided guidance related to fire barrier designs for raceways. In Enclosure 2, Question and Answers, to this GL, Question 3.2.1., "Acceptance Criteria," the staff provided guidance on the cold side temperature for fire barrier cable tray wraps. In response to this question the staff stated that the acceptance criteria contained in Chapter 7 of NFPA 251, "Standard Methods of Fire Tests of Building Construction and Materials," pertaining to non-bearing fire barriers was applicable to cable tray fire barrier wraps. Chapter 5 of NFPA 251 explains the conduct of the fire test.

The following is the NFPA 251 acceptance criteria:

- The wall or partition shall have withstood the fire endurance test without the passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired;

- The wall or partition shall have withstood the fire and hose stream test as specified in Chapter 5, without passage of flame, or gases hot enough to ignite cotton waste, or of the hose stream. The

assembly shall be considered to have failed the hose stream test if an opening develops and permits projection of water from the stream beyond the unexposed surface during the hose stream test; and

- Transmission of heat through the wall or partition during the fire endurance test shall nct have been such as to raise the temperature on its unexposed surface more than 250 °F (121 °C) above its initial temperature.

The staff considers the fire endurance qualification test to be successful if the following conditions are met:

- The internal temperature of the fire barrier system, as measured on the exterior surface of the raceway or component, did not exceed 250 °F (121 °C) above its initial temperature[2]; or

  (Staff Guidance: NFPA 251/ASTM-E119 allows this temperature to be determined by averaging thermocouple temperature readings. For the purposes of this criteria, thermocouple averaging can be used providing similar series of thermocouples (e.g., cable tray side rail) are averaged together to determine temperature performance of the raceway fire barrier system. In addition, the conditions of acceptance are also placed on the temperatures measured by a single thermocouple. Under the conditions of acceptance, if any single thermocouple exceeds 30 percent of the maximum allowable temperature rise (i.e., 250 °F + 75 °F = 325 °F) the test is considered to have exceed the criteria temperature limit.)

- Where the above thermal limits are exceeded, a visual inspection of the of the cables[3] is required. Cables when inspected shall not

[2] The 325°F temperature condition was established by allowing the internal temperature on the raceway to rise 250°F above ambient laboratory air temperature, assumed to be 75°F, during the fire test.

[3] For components, when the temperature criteria is exceeded, an assessment of component operability at the temperature conditions which would be experienced by the component during the fire test is required that is, fire endurance tests which are judged acceptable on the basis of a visual inspection may not be applied to other components without a specific evaluation.

show signs of degraded conditions[4] resulting from the thermal affects of the fire exposure; and

(Staff Guidance: For those cases where signs of thermal degradation to the cables is present, it is considered that the fire barrier did not perform its intended fire resistive function. For those barriers which are not capable of performing their intended function, a deviation based on demonstrating that the functionality of thermally degraded cables was maintained and that these cables would have adequately performed their intended function during and after a postulated fire exposure may be granted. The attachment to this proposed position provides a suggested methodology for demonstrating the functionality of safe shutdown cabling during and after a fire test exposure.)

- The raceway fire barrier system shall have remained intact during the fire exposure and water hose stream test without developing any openings through which the electrical conductor or raceway is visible. Section VII identifies acceptable hose stream test methods and the time of application.

The test specimen shall be representative of the construction for which the fire rating is desired, as to materials, workmanship, and details such as dimensions of parts, and shall be built under representative conditions. Raceway fire barrier systems being subjected to qualification fire endurance testing should be representative of the end use. For example, if it is intended to install a cable tray fire barrier system in the plant without protecting the cable tray supports, then the test program should duplicate these field conditions. In addition, the fire testing program should bound the raceway sizes and various configurations for those fire barrier systems installed in the plant. It should be noted that several test specimens will be required in order to qualify various sizes of horizontal and vertical runs of cable trays and conduits, junction boxes and pull boxes, etc. The raceway design used for testing should be constructed with materials and configurations representative of in plant conditions (e.g., mass associated with typical steel conduit, steel cable trays).

Due to the poor thermal conductivity of cable jacket and insulation material, measuring cable temperatures is not considered a reliable means for determining excessive temperature conditions which may occur at any point along the length of the cable during the fire test. In lieu of measuring the unexposed surface temperature of the fire barrier test specimen, methods which

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[4] Examples of thermal cable degradation; jacket swelling, splitting, cracking, blistered, melted, or discoloration; shield exposed; conductor insulation exposed, degraded, or discolored; bare copper conductor exposed.

will adequately measure the surface temperature of the raceway (e.g., exterior of the conduit, side rails of cable trays, bottom and top of cable tray surfaces, junction box external surfaces) can be considered as equivalent if the raceway components used to construct the fire test specimen represent plant specific components and configurations. The metal surfaces of the raceway, under fire test conditions, exhibit good thermal conductivity properties. Temperatures measured on these surfaces provide a reliable indication of the actual temperature rise within the fire barrier system.

ANI criteria for testing fire barriers recommends the cable temperatures be monitored by thermocouples. Industry considers this the proper location for determining the temperature rise within the raceway fire barrier system. Since cable jackets have a low thermal conductivity, the actual temperatures of the cable, indications of barrier failure, and internal fire barrier temperature rise conditions during the fire exposure are masked. Monitoring cable temperatures can give indications of low internal fire barrier temperature conditions during the fire endurance test. Using this temperature monitoring approach, cable damage can occur without indication of excessive temperatures on the cables. This linked with no loss of circuit integrity would give indications of a successful test. The staff considers monitoring the cable temperature as the primary means of determining barrier performance to be nonconservative. As discussed above, temperatures monitored on the exterior surface of the raceway provide a more representative indication of fire barrier performance.

The following are suggested placement of thermocouple on raceway fire barrier enclosures:

Conduits - measure the temperature of the conduit by placing the thermocouples every 6-inches on the conduit surface underneath the fire barrier material.

Cable Trays - measure temperature rise of cable tray by placing the thermocouples on the exterior surface of the tray side rails underneath the fire barrier material. In addition to placing thermocouples on the side rails, thermocouples should be attached to two 14 gage bare copper conductors. The first copper conductor should be installed on the bottom of the cable tray rungs along the entire length of the cable tray run. The second conductor should be installed along the outer top surface of the cables closest to the top and towards the center of the fire barrier. The bare copper wire is more responsive, than cable jackets, to temperature rise within the fire barrier enclosure. The temperature changes measured along the bare copper conductors provide indication of joint failure or material burn through conditions. Thermocouples should be placed every 6-inches along the cable tray side rails and along the bare copper conductors.

In addition, thermocouples should be placed every 12-inches on the surface of the outer cables nearest to the raceway and on the surface of the cables nearest to the underside of the top of the fire barrier.

The temperature conditions on the raceway during the fire test should be determined by averaging the temperatures measured by the thermocouples. In determining the raceway temperature conditions, the thermocouples measuring similar fire barrier areas of performance should be averaged together and the basis of acceptance should be based on these individual averages. The following method of averaging should be followed:

Conduits - The thermocouples applied to the outside metal surface of the conduit should be averaged together.

Cable Trays - The thermocouples on the cable tray side rail should be averaged separately. For example, thermocouples placed on one side rail should be averaged separately from the other side rail. In addition, the temperature conditions measured by thermocouples on the bare copper conductors should be averaged separately.

Cables - The thermocouples used to measure individual cable temperatures should be used for engineering purposes and should not be used for evaluating the performance of the fire barrier system.

For each thermocouple group, the averages should not exceed 250 °F above the initial temperature at the onset of the fire endurance test. In addition, the temperature of each individual thermocouple should be evaluated. Individual thermocouple conditions should not exceed the 250 °F limit by 30 percent (75 °F).

VI. HOSE STREAM TESTING

NFPA 251 and ASTM E-119 allow some flexibility in hose stream testing. The standards allow the hose stream test to be performed on a duplicate test specimen subjected to a fire endurance test for a period equal to one-half of that indicated as the fire resistance rating, but not for more than 1 hour (e.g., 30 minute fire exposure to qualify a 1-hour fire rated barrier).

For safe shutdown related fire barrier systems, the staff would find the hose stream application specified by the NFPA 251 acceptable. NFPA 251 requires the stream of water to be delivered through a 2½-inch (6.4 cm) hose discharging through a standard 1⅛-inch (2.9 cm) playpipe nozzle onto the test specimen after the fire exposure test. The stream is applied with the nozzle orifice positioned 20 feet (6.1 meters) away from the center of the test specimen at a pressure of 30 psi (207 Kpa). The application of the stream is to all exposed parts of the specimen for a minimum duration of 1 minute for a 1-hour barrier and 2½ minutes for a 3-hour barrier.

As an alternate, the application of the hose stream test on the test specimen can be performed immediately after the completion of the full fire endurance test period. If this method is used to satisfy the hose stream testing criteria, the following hose stream applications would be considered acceptable:

- The stream applied at random to all exposed surfaces of the test specimen through a 2½-inch (6.4 cm) national standard playpipe with a 1⅛-inch (2.9 cm) orifice at a pressure of 30 psi (207 Kpa) at a distance of 20 feet (6.1 meters) from the specimen, (Duration of the hose stream application - 1 minute for a 1-hour barrier and 2½ minutes for a 3-hour barrier); or

- The stream applied at random to all exposed surfaces of the test specimen through a 1½-inch (8.3 cm) fog nozzle set at a discharge angle of 30 degrees with a nozzle pressure of 75 psi (517.5 Kpa) and a minimum discharge of 75 gpm (284 lpm) with the tip of the nozzle at a maximum of 5 feet (1.5 meters) from the test specimen. (Duration of the hose stream application - 5 minutes for both 1-hour and 3-hour barriers); or

- The stream applied at random to all exposed surfaces of the test specimen through 1½-inch (8.3 cm) fog nozzle set at a discharge angle of 15 degrees with a nozzle pressure of 75 psi (517.5 Kpa) and a minimum discharge of 75 gpm (284 lpm) with the tip of the nozzle at a maximum of 10 feet (3 meters) from the test specimen. (Duration of the hose stream application - 5 minutes for both 1-hour and 3-hour barriers.)

VII. FIRE BARRIER COMBUSTIBILITY

The NRC's fire protection guidelines and requirements establish the need for each nuclear power plant to perform a plant-specific fire hazard analysis. The fire hazard analysis should consider the potential for in-situ and transient fire hazards and combustibles. With respect to building materials (e.g., cable insulation and jackets, plastics, thermal insulation, fire barrier materials), the combustibility, ease of ignition, and flame spread over the surface of a material should be considered by the fire hazards analysis. One method of determining combustibility is by subjecting a sample of the fire barrier material to a small scale vertical tube furnace as described by ASTM E-136. The flashover ignition temperature, as determined by ASTM-D1929, and the flame spread characteristics, as determined by ASTM E-84, of the fire barrier material should be evaluated. The potential heat release of the material should also be determined and factored into the fire hazards analysis. The heat release of the material can be determined by testing to the provisions of ASTM D-3286 or NFPA 259.

Fire barrier materials used as radiant energy heat shields inside containment and used to achieve a combustible free zone are required to be noncombustible as defined in Section III.

VIII. REFERENCES

Nuclear Regulatory Commission

1. May 1, 1976 — Branch Technical Position (APCSB) 9.5-1, "Fire Protection Program."
2. February 24, 1977 — Appendix A to the Branch Technical Position APCSB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1, 1976."
3. February 19, 1981 — 10 CFR 50.48, "Fire protection."
4. February 19, 1981 — Appendix R to 10 CFR 50, "Fire Protection for Nuclear Power Plants."
5. February 20, 1981 — "Staff Position - Safe Shutdown Capability," (Generic Letter 81-12)
6. July 1981 — NUREG - 0800, Standard Review Plan (SRP), 9.5.1, "Fire Protection for Nuclear Power Plants."
7. October 19, 1983 — "NRC Positions on Certain Requirements of Appendix R to 10 CFR 50," (Generic Letter 83-33)
8. April 24, 1986 — "Implementation of Fire Protection Requirements," (Generic Letter 86-10)

American Society for Testing and Materials (ASTM)

1. ASTM E-84 Test "Surface Burning Characteristics of Building Materials."
2. ASTM E-119, "Fire Test of Building Construction and Materials."
3. ASTM E-136, "Behavior of Materials in a Vertical Tube Furnace at 750°C."
4. ASTM D-1929, "Test Method for Ignition Properties of Plastics."
5. ASTM D-3286, "Test Method for Gross Calorific Value of Solid Fuel by the Isothermal-Jacket Bomb Calorimeter."

American Nuclear Insurers (ANI)

1. July 1979, ANI Information Bulletin No. 5 (79) test criteria for "Fire Endurance Protective Envelope Systems for Class 1E Electrical Circuits."

National Fire Protection Association (NFPA)

1. NFPA 251, "Standard Methods of Fire Tests of Building Construction and Materials."

2. NFPA 259, "Standard Test Method for Potential Heat of Building Materials"

[CRITERIA.009]

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ATTACHMENT

ACCEPTABLE METHODS FOR DEMONSTRATING FUNCTIONALITY OF CABLES PROTECTED BY RACEWAY FIRE BARRIER SYSTEMS DURING AND AFTER FIRE ENDURANCE TEST EXPOSURE

a. INTRODUCTION

The NRC considers fire barrier systems, which do not exceed the acceptance criteria, to provide the level of safety required to meet the NRC's fire protection regulations. Based on an engineering assessment of the conservatism (defense-in-depth) factored into the NRC's fire protection regulations and guidance, there is reasonable assurance that sensible heat from the unexposed side of the fire barrier will not be transmitted to the protected cable. Under such conditions, where the fire barrier system does not meet the intended fire rating, the margin of fire safety is not considered equivalent to the level required by the regulations or fire protection guidelines. The licensee, under these conditions, can submit an engineering analysis to the staff that clearly demonstrates the functionality of the protected cable(s). This engineering analysis should consider the cable insulation type, actual voltage and current conditions, cable function, and thermal affects on the cable and it's ability to function. This evaluation should also consider cable operating temperatures within the fire barrier at the onset of the fire exposure.

b. CABLE CIRCUIT INTEGRITY TESTING

ANI Criteria

In 1981, American Nuclear Insurers (ANI) developed a fire endurance test criteria for raceway fire barrier systems. This criteria, "Fire Endurance Protective Envelope Systems for Class 1E Electrical Circuits," specifies a circuit integrity test. The intent of this test was to identify the onset of fire damage to the cables within the raceway fire barrier test specimen during the fire endurance test period. The circuit integrity test voltage is 8 to 10 volts DC, therefore the loss of circuit integrity under these voltage conditions may only occur as a result of a dead short or open circuit.

During actual fire testing conditions of raceway fire barrier systems thermal damage to the cables has resulted. This thermal damage has led to cable jacket and insulation degradation without the loss of circuit integrity as monitored using ANI criteria. Since cable voltages used for ANI circuit integrity testing do not replicate cable operating voltages, loss of cable insulation conditions can exist during the fire test without a dead short occurring. It is expected if the cables were at rated power and current a fault would propagate. Therefore, the use

of ANI circuit integrity monitoring during the fire endurance test is not considered a valid method for demonstrating that the protected shutdown circuits are capable of performing their required function during and after the test fire exposure.

c. CABLE INSULATION TESTING

The two principal materials used as cable insulation and cable jackets by the nuclear industry are thermoplastics and thermosetting polymeric materials. A thermoplastic material can be softened and resoftened by heating and reheating. Conversely, thermosetting cable insulation materials cure by chemical reaction and do not soften when heated. Under excessive heating thermosetting insulation becomes stiff and brittle. Electrical faults may be caused by softening and flowing of thermoplastic insulating materials at temperatures as low as 300 °F (149 °C). Thermosetting electrical conductor insulation materials usually retain their electrical properties under short-term exposures to temperatures as high as 500 °F (260 °C). Insulation resistance (Megger) testing provides an indication of the condition of the cable insulation resistance, whereas the high potential (Hi-Pot) test provides assurance that the cable has sufficient dielectric strength to withstand the applied rated voltage. A cable insulation failure usually results from two breakdown modes: one failure mode is excessive dielectric loss which is due to low insulation resistance, and the other failure mode is overpotential stress which is due to loss of dielectric strength of the insulation material.

If megger tests are not performed at frequent intervals during the fire exposure, indications of insulation damage in insulation may go undetected. Insulation, when removed from elevated temperatures will reset. Megger testing of insulated cables after the fire endurance test and after the cable has sufficiently cooled may not detect degradation in the insulation resistance. Therefore, wet or dry megger of cables after a fire exposure does not provide reasonable assurance that the cables would have functioned as intended during the fire exposure.

To provide reasonable assurance that the cables would have functioned during and after the fire exposure, megger tests need to be performed before the fire test, at multiple time intervals during the fire exposure (i.e, every 20 minutes during the 1-hour fire test and every hour during the 3-hour fire test) for instrumentation cables only, and after fire endurance test to assess the cable insulation resistance levels. This testing will assure that the cables will maintain sufficient insulation resistance levels necessary for proper operation of instruments.

The megger tests (pre-fire, during the fire [if performed], and immediately after the fire test conditions) should be done conductor-to-

conductor for multi-conductor and conductor-to-ground for all cables. The minimum acceptable insulation resistance (IR) value, using the test voltage values as shown in the table below, is determined by using the following expression:

$$IR\ (\text{Mega-ohms}) \geq \frac{\{[(1\ \text{Mega-ohm per KV}) + 1\ ] * 1000\ (\text{ft})\ \}}{\text{Length (ft)}}$$

Additionally, in determining the insulation resistance levels required for nuclear instrumentation cables, an assessment of the minimum insulation resistance value (e.g., one mega-ohm) and its potential impact on the functionality of these cables should be evaluated.

In addition, an AC or DC high potential (Hi-Pot) test for power cables greater than 1000 volts should be performed after the post-fire megger tests to assess the dielectric strength. This test provides assurance that the cable will withstand the applied voltage during and after a fire. The high potential test should be performed for a five minute duration at 60 percent of either 80 volts/mil ac or 240 volts/mil dc (e.g., 125 mil conductor insulation thickness x 240 volts dc x 0.6 =18,000 volts dc).

The table below summarizes the megger and Hi-Pot test voltages which, when applied to power, control and instrumentation cables, would constitute an acceptable cable functionality test.

TYPE	OPERATING VOLTAGES	MEGGER TEST VOLTAGE	HIGH POTENTIAL TEST VOLTAGE
POWER	≥ 1000 vac	2500 vdc	60% x 80 V/mil (ac) 60% x 240 V/mil (dc)
POWER	< 1000 vac	1500 vdc #	NONE
INSTRUMENT AND CONTROL	≤ 250 vdc ≤ 120 vac	500 vdc	NONE

A megger test voltage of 1000 vdc will be acceptable provided a Hi-Pot test is performed after the megger test for power cables rated at less than 1000 vac.

d. CABLE THERMAL EXPOSURE THRESHOLD

The following is a proposed analysis method for evaluating the cable functionality.

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This analysis is based on determining whether a specific insulation material will maintain the electrical integrity and operability within a raceway fire barrier system during and after an external fire exposure. In order to determine cable functionality, it is necessary to consider the operating cable temperatures within the fire barrier system at the onset of the fire exposure and the thermal exposure threshold (TET) temperature of the cable. For example, if the TET of a specific thermoplastic cable insulation (Brand X) is 300 °F (149 °C) and the normal operating temperature within the fire barrier system is 150 °F (66 °C), then the maximum temperature rise within the fire barrier system should not exceed 150 °F (66 °C) during exposure to an external fire of a duration equal to the required fire resistance rating of the barrier. For this example the TET limit for Brand X cable is 150 °F (66 °C) above the cable operating temperatures within the fire barrier system at the onset of the external fire exposure. Because of the non-uniformity of cable insulation materials and variations in the manufacturing process, the cable insulation has inherent weak spots. Therefore, the cable TET limits in conjunction with a post test visual cable inspection and the Hi-Pot test described above should readily demonstrate the functionality of the cable circuit during and after a fire.

The cable normal operating temperature can be determined by subjecting cable specimens installed within a thermal barrier system and loaded at rated voltage and current. The TET temperature limits for most cable insulation may be obtained from the manufacturer's published data which is given as the short-circuit rating limit. With the known TET and normal operating temperature for each thermal barrier system configuration, the maximum temperature rise limit within a fire barrier system may then be determined.

Due to poor thermal conductivity of cable insulation, measuring cable insulation temperatures is not considered a reliable means for determining temperature conditions which may occur along the entire length of the cable during the fire test. However, as an alternate to measuring the unexposed surface temperature of the fire barrier test specimen, methods which will adequately measure the surface temperature of the raceway (e.g., exterior of the conduit, side rails of cable trays, bottom and top of cable tray surfaces, junction box external surfaces) are considered equivalent. The steel surfaces of the raceway, under fire test conditions, exhibit good thermal conductivity properties. Temperatures measured on these surfaces provide a reliable indication of actual temperature rise within the fire barrier system.