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

NOV 12 1998

MEMORANDUM TO: Gary M. Holahan, Director
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

FROM: Ledyard B. Marsh, Chief
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Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF NRC WORKSHOP ON POST-FIRE SAFE SHUTDOWN CIRCUIT ANALYSIS HELD ON JULY 23, 1998

On July 23, 1998, the Plant Systems Branch, Division of Systems Safety and Analysis, NRR, sponsored a 1-day workshop on post-fire safe-shutdown circuit analysis at the Bethesda Marriott Hotel in Bethesda Maryland. About 170 people attended, about 140 of them worked for licensee, engineering, or industry groups and the rest were from NRR, RES, and each of the regional offices, and one person was from Nuclear Information and Resource Service.

The main purpose of the workshop was to discuss with the stakeholders a variety of safety, technical, and regulatory issues associated with post-fire safe-shutdown circuit analyses and staff plans to address the issues In sum, the issues involve potential fire-induced electrical circuit failures that could either prevent the operation or lead to malfunction of equipment needed to achieve and maintain post-fire safe shutdown, or in some manner interfere with the achievement of post-fire safe shutdown. The underlying objectives of the workshop were to bound the issues, to achieve an understanding of the stakeholder positions on the issues, and to impart to the stakeholders an understanding of the staff's positions and concerns. The discussions focused on safety, technical, and regulatory issues, the assumptions that go into circuit analyses; and the terminology used to discuss the issues.

The NRC staff gave presentations on the history of post-fire safe-shutdown circuit analysis and safety significance and circuit analysis problems identified through inspection, licensing actions, and event experience The staff also summarized its Circuit Analysis Resolution Plan (CARP) and informed the workshop participants that it would consider the results of the workshop in recommending to NRR management a final plan for resolving any issues of circuit analysis The Nuclear Energy Institute (NEI) summarized its views on the regulatory history and industry positions There were also six industry presentations on various technical subjects related to circuit analyses, two NRC and industry panel discussions on circuit analysis process and completeness, and a question/answer and comment session for an NRC staff and industry panel open to all attendees The staff also accepted for post-workshop consideration issue papers and written and oral questions and comments during the workshop

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In response to NRC questions about safety, technical, and regulatory issues associated with post-fire safe-shutdown circuit analysis, industry representatives expressed the following varied and opposing viewpoints (1) licensees have effectively implemented the applicable regulatory requirements, and the issues raised by the staff either do not exist or are outside of the regulatory requirements, (2) licensees have made "good faith" efforts to implement the applicable regulatory requirements, but implementation may not have been 100 percent effective for a variety of reasons (e.g., confusing or conflicting staff positions and guidance and a lack of awareness by licensees and/or the regulator of some of the types of circuit failure effects that may be experienced in nuclear power plants), or (3) the circuit analysis issues raised by the staff are covered by the existing regulatory requirements, and to the extent they have not been implemented, additional action by the NRC is warranted.

On the basis of the large number and variety of comments made and questions asked at the workshop, it is clear that additional staff and industry effort is needed to fully resolve the post-fire safe-shutdown circuit analysis issue. There was general agreement by workshop participants including the NRC staff, that any plant-specific safety-significant circuit analysis issues should be identified and resolved, and that risk information and risk insights should be considered in any generic resolution of the circuit analysis issue. Some industry participants suggested that any issues that are found to be not safety significant should be excluded from NRC and industry resolution efforts At the conclusion of the workshop, NEI told the attendees that it would form an issue task force to work with the staff and the industry to resolve the issues NEI stated that its effort would focus on the safety and risk significance of fire-induced circuit failures.

Attachment 1 is the workshop agenda Attachment 2 is a list of workshop attendees. Attachment 3 is a compendium of the slides for the 10 formal presentations delivered during the workshop, a letter handed out to all attendees by the NRC staff (a March 11, 1997, letter from Samuel Collins, NRR, to Ralph Beedle, NEI), two documents handed out to all attendees by members of industry, and a letter dated August 7, 1998, from the Fire Protection Clearinghouse on issues discussed at the workshop. Attachment 4 is a high-level summary of key industry and public messages received by the staff. Attachment 5 is a detailed summary of the questions, comments, opinions, and suggestions from industry and public participants in the workshop (from which Attachment 4 was derived).

The workshop provided an excellent forum for the stakeholders to air their views and recommendations regarding post-fire safe-shutdown circuit analysis We will place this summary in the NRC Public Document Room and send copies to everyone who attended the workshop In the ne.. future, we will revise the CARP and make public our plans on how we intend to proceed with this issue

Attachments As stated

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POST-FIRE SAFE SHUTDOWN CIRCUIT ANALYSIS WORKSHOP AGENDA

Location: Bethesda Marriott Hotel, Pooks Hill

Date: July 23, 1998

7:30 - 8:00	Registration/Acceptance of Papers/Input from Industry and Public/Handout of Agenda
8:00 - 8:10	Introduction/Presentation of Agenda/Discussion of Workshop Purpose Tad Marsh, Chief, Plant Systems Branch, NRR
8:10 - 8:20	Introductory Remarks by an Industry Representative Fred Emerson, Nuclear Energy Institute
8:20 - 9:00	NRC Presentation of U.S. Commercial Nuclear Reactor Plant Post-fire Safe Shutdown Circuit Analysis History and Safety Significance. NRC Discussion of the Potential Severity of Fire-induced Reactor Plant Transients Pat Madden, Fire Protection Engineering Section, NRR Ken Sullivan, Brookhaven National Laboratory
9:00 - 9:15	Summary of Industry Views of the Regulatory History of the Post-fire Safe Shutdown Circuit Analysis Issues Fred Emerson, Nuclear Energy Institute
9:15 - 9:30	NRC Presentation of Post-fire Safe Shutdown Circuit Analysis Issues as Recently Identified through Inspection, Licensing and Event Experience Steve West, Chief, Fire Protection Engineering Section, NRR
9:30 - 9:45	Break
9:45 - 11:45	Industry and Public Presentations on Selected Technical Topics (six, 10 minute talks, each with a 5 minute Q&A period) 1 Bryan Ford, Entergy Operations, Inc.: "Review of Brown's Ferry Fire" 2 Vince Bacanskas, Entergy Operations, Inc.: "Safety Significance of Multiple Spurious SRV Operation 3 Nicholas Rivera, PE, SPAD Engineering Company: "Multiple High Impedance Faults/Analysis of Conditions for Self-sustaining Arcing Faults" 4 Jim Lechner, Nebraska Public Power District: "Circuit Analysis" 5 Stephen Maloney, Devonrue LTD: "Technological Overview of Associated Circuits Analysis" 6 Edward F. Sproat, Philadelphia Electric Company: "Risk Observations on the Current Fire Protection Regulation Conservatisms"

11:45 - 1:15 Lunch Break

1:15 - 2:15 Panel Discussion on: **The Circuit Analysis Technical Process** (Fault Terminology, and the Types of Assumptions Necessary Regarding Multiple Spurious Electrical Faults, Signals and/or Actuations in a Single Fire)(panel member introductions by the Moderator, issue introduction by NRC, questions from the floor)

Pat Madden, Fire Protection Engineering Section, SPLB/NRR
Ken Sullivan, Brookhaven National Laboratory
Fred Emerson, Nuclear Energy Institute
Tommy Barnett, Entergy Operations, Inc.
Phil Brady, Pennsylvania Power and Light

2:15 - 2:30 Break

2:30 - 3:30 Panel Discussion on: **Circuit Analysis Completeness** (the Necessary Components and Features of an Adequate Post-fire Safe Shutdown Circuit Analysis and Resultant Plant Modifications, and the Likelihood and Consequences of Circuit Damage Which Affects Post-fire Safe Shutdown Capability)(panel member introductions by Moderator, issue introduction by NRC, questions from the floor)

Phil Qualls, Fire Protection Engineering Section, SPLB/NRR
Ken Sullivan, Brookhaven National Laboratory
Greg Krueger, Philadelphia Electric Company
Chris Pragman, Philadelphia Electric Company
Francesco Pellizzari, Engineering Planning and Management, Inc.

3:30 - 3:45 Break

3:45 - 4:40 Question and Answer Session

Steve West, Chief, Fire Protection Section, NRR
Pat Madden, Fire Protection Section, NRR
Fred Emerson, Nuclear Energy Institute
Wade Larson, Engineering Planning and Management, Inc.
Industry Representative TBD

4:40 - 4:50 Industry Closing Remarks

Fred Emerson, Nuclear Energy Institute

4:50 - 5:00 NRC Closing Remarks and Adjourn

Tad Marsh, Chief, Plant Systems Branch, NRR

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ATTACHMENT 3

TEN SETS OF PRESENTATION SLIDES, NRC STAFF LETTER TO INDUSTRY (HANDOUT), TWO INDUSTRY HANDOUTS, AND POST-WORKSHOP LETTER TO THE NRC STAFF FROM INDUSTRY

Introductory Remarks by Industry

NRC Post-Fire Safe Shutdown
Circuit Analysis Workshop

July 23, 1998

NEI

Industry View

- This workshop is a positive development in the resolution of safe shutdown circuit analysis issues
- Resolution will be enhanced if we can shift the focus from interpretive disagreements to consideration of safety significance

NEI

Fire-Induced Circuit Failure Issues

- Circuit failure modes (Information Notice 92-18)
- Multiple spurious actuations

NEI

Industry Goals for NRC Workshop

- Initiate development of objective measurement of safety significance of fire-induced circuit failure issues
  - PSA-based tools
  - Other objective measures
- Based on safety significance, begin developing regulatory/industry agreement on bounds to the issues

NEI

POST-FIRE SAFE SHUTDOWN CIRCUIT ANALYSIS HISTORY, SAFETY SIGNIFICANCE AND EXPECTATIONS

presented at

NRC / INDUSTRY

Post Fire Safe Shutdown Circuit Analysis Workshop
(Bethesda Marriott, Pooks Hill)

July 23, 1998

by

Patrick M. Madden
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and

Kenneth Sullivan
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Overview

- Issue
- Safety
  - Objective
  - Design Concepts
  - Concern
- Browns Ferry Fire (March 22, 1975)
  - Fire
  - Fire Damage
  - Operational Impact
  - Systems lost during the fire
- Evolution of Regulatory Criteria / Guidance
- Technical Safety Issues
- Specific Circuit Analysis Issues

ISSUE

- Potential weaknesses in the fire protection features provided for structures, systems and components important to safe shutdown.

- Failing to adequately identify circuits, components; and systems required to achieve and maintain safe shutdown and protect them from the affects of fire, could result in ...

  (1) both trains of systems needed to achieve and maintain safe shutdown being damaged by fire; and

  (2) the ability to safely shutdown the plant and maintain it in a safe shutdown condition being impaired.

Safety

Objective

- Protection of the health and safety of the public
- ***Risk*** **from normal operation, anticipated transients, and accidents must be *acceptably low***
- **The *likelihood of accidents more severe* than those postulated must be *extremely small***

Design

- **Redundancy of equipment and subsystems that perform essential safety functions**
- **Separation of redundant equipment and subsystems into redundant divisions / trains**

Concern

- **Fire may cause common mode failures of more than one redundant division / train of essential equipment or subsystems**

Browns Ferry Fire (March 22, 1975)

The Fire

- The fire began in a bank of cable trays in an area of the cable spreading room where these trays passed through a wall penetration

  (Fire was started by a air flow leak test method - used a candle flame to detect air flow)

- Fire spread through the penetration / wall separating the cable spreading room from the reactor building

Fire Damage

- Major amount of fire damage was in the reactor building (area affected 40 feet by 20 feet)

- Temperature in some areas was as high as 1500 °F

- More than 1600 cables routed in 117 conduits and 26 cable trays were fire damaged. 628 of these cables were safety related.

Browns Ferry Fire (March 22, 1975) - continued

Examples of operational impact from operator interviews

- RCIC, HPCI, LPCI and CS spuriously initiated because of cable damage
- ADS annunciators alarmed and timers were running
- 250 volt dc, Reactor MOV and 480 volt shutdown boards were lost
- Cable Spreading Room carbon dioxide fire suppression system failed due to power loss

- Some of the spurious control room annunciators initially noted were
  - reactor low level auto blowdown permissive,
  - CS and RHR pumps running,
  - core cooling system diesel generators initiate
  - HPCI, RCIC running
  - alarms from various shutdown panels

- Annunciations in the control room were strange and unexplainable

- RHR and CS pumps spuriously started and stopped

- Recirculation pumps ran back to slowest speed for no apparent reason

Browns Ferry Fire (March 22, 1975) - continued

<u>Operational Impact - continued</u>

- **Indicating lights over valve and pump control switches (panel 9-3) were glowing brightly, dimming, and going out. The control circuits lights for ECCS pumps and valves were lost.**

- **Smoke conditions in the reactor building required operators and others to wear air packs to perform manual actions (air packs and their short duration of air hindered the ability to perform manual actions)**

<u>Systems Lost During the Fire</u>

- HPCI
- RHR Systems 1A, 1B, 1C, and 1D
- CS Systems 1A, 1B, 1C, and 1D
- SLC pumps 1A and 1B plus Squibb valves
- RCIC
- RPS MG sets 1A and 1B

Evolution of Regulatory Criteria and Guidance

- Browns Ferry fire demonstrated the need for a more specific ***fire protection criteria*** which would extend the safety principles of "***defense-in-depth***".

- 10 CFR Part 50, Appendix A, GDC 3
  BTP APCSB 9.5-1, Appendix A
  50.48, Fire Protection
  10 CFR Part 50, Appendix R
  Generic Letter 81-12
  NUREG-0800, SRP 9.5.1
  Generic Letter 86-10

- Purpose of requirements and guidance promulgated since Browns Ferry is to assure that one train of equipment and their associated circuits needed to achieve and maintain safe shutdown remains free of fire damage

- Needed electrical cables and circuits typically are:
  - circuits and cables of equipment that is needed for post-fire safe shutdown
  - associated circuits that may affect the ability of the post-fire safety function from being performed.
  - circuits and cables needed for cold shutdown

Regulatory Requirements

- Appendix R uses the term "Free of fire damage." Methods acceptable for assuring that necessary structures, systems and components (SSCs) are free of fire damage are specified by Appendix R (Section III.G.2a, b, and c). These methods provide reasonable assurance that the SSC under consideration is capable of performing its intended function during and after the postulated fire, as needed.

- Cables (circuits) whose failure could prevent the operation or cause the mal-operation of redundant systems needed to achieve and maintain post-fire safe shutdown are required by Appendix R Section III.G.2 to be identified and provided with fire protection which ensures one of the redundant trains is free of fire damage.

- Appendix R Section III.G.3 requires that alternative or dedicated shutdown capability and its associated circuits, independent of cables, systems, or components in the area under consideration, be provided where the protection of systems whose function is required for hot shutdown does not satisfy the separation and protection requirements of Appendix R Section III.G.2.

- Post - 1979 plants in general were reviewed against similar criteria

TECHNICAL SAFETY ISSUES

Intent of Regulatory Requirements

Ensure that one train of equipment and associated circuits used to achieve and maintain safe shutdown conditions will remain free of fire damage

Fundamental Principles

- Electrical cables and circuits that are exposed to the effects of fire will be damaged
- It is not deemed possible to accurately predict the manner in which damaged cables or circuits may fail
- Various types of electrical failure modes (e.g., hot shorts, open circuits, shorts to ground) are assumed to occur as a result of fire damage

Circuits of Concern

- Electrical circuits or cables whose damage due to fire could:
  - ❑ disable the operability of required shutdown systems, equipment or cables; or
  - ❑ initiate transients that may preclude the successful accomplishment of required shutdown functions; or
  - ❑ initiate transients that could place the plant in an unrecoverable condition

Analysis Expectations

- Circuits of concern to post-fire safe shutdown are

  - ✔ identified,
  - ✔ evaluated, and
  - ✔ potentially disabling conditions are prevented or appropriately mitigated.

Resolution Options

- Meet regulatory criteria (Section III.G); or
- Assume cable damage will cause equipment under consideration to fail in an undesired manner and provide appropriate means to prevent or mitigate the consequences of failure as necessary; or
- Perform a detailed circuit analysis which conclusively demonstrates an equivalent level of fire safety to that which would be achieved through compliance with regulatory protection criteria; or
- Provide technical justification sufficient to support an exemption from the specific protection requirements of the regulation

SPECIFIC ANALYSIS ISSUES

Number of Circuit Faults to be Considered

- Browns Ferry fire demonstrated that a high number of circuit faults may occur in a relatively short period of time
- Circuits and cables involved in or exposed to fire should be considered damaged
- It is not deemed possible to accurately predict the manner in which damaged cables or circuits may fail
- Therefore, one or a combination of possible circuit failure modes (hot shorts, open circuits, shorts to ground) should be considered in the evaluation

Fire Induced Hot Shorts

- Circuit failure mode (short circuit) which causes voltage to be backfed from an energized circuit to an unenergized circuit

- Typical Examples:

  ✔ cable-to-cable

  conductors of energized cable contacting conductors of a different cable

  ✔ conductor-conductor

  shorts between individual conductors located within a single multi-conductor cable or logic circuit

Fire Induced Hot Shorts (Cont.)

- 3 Phase AC Motor Circuits

  Considered in evaluation of Hi/Low pressure interface boundaries only

- Ungrounded DC Circuits

  ✔ Cable-to-cable:

  Except for Hi/Low pressure interface boundaries, component need not be further considered if two hot shorts of proper polarity are needed to cause spurious actuations

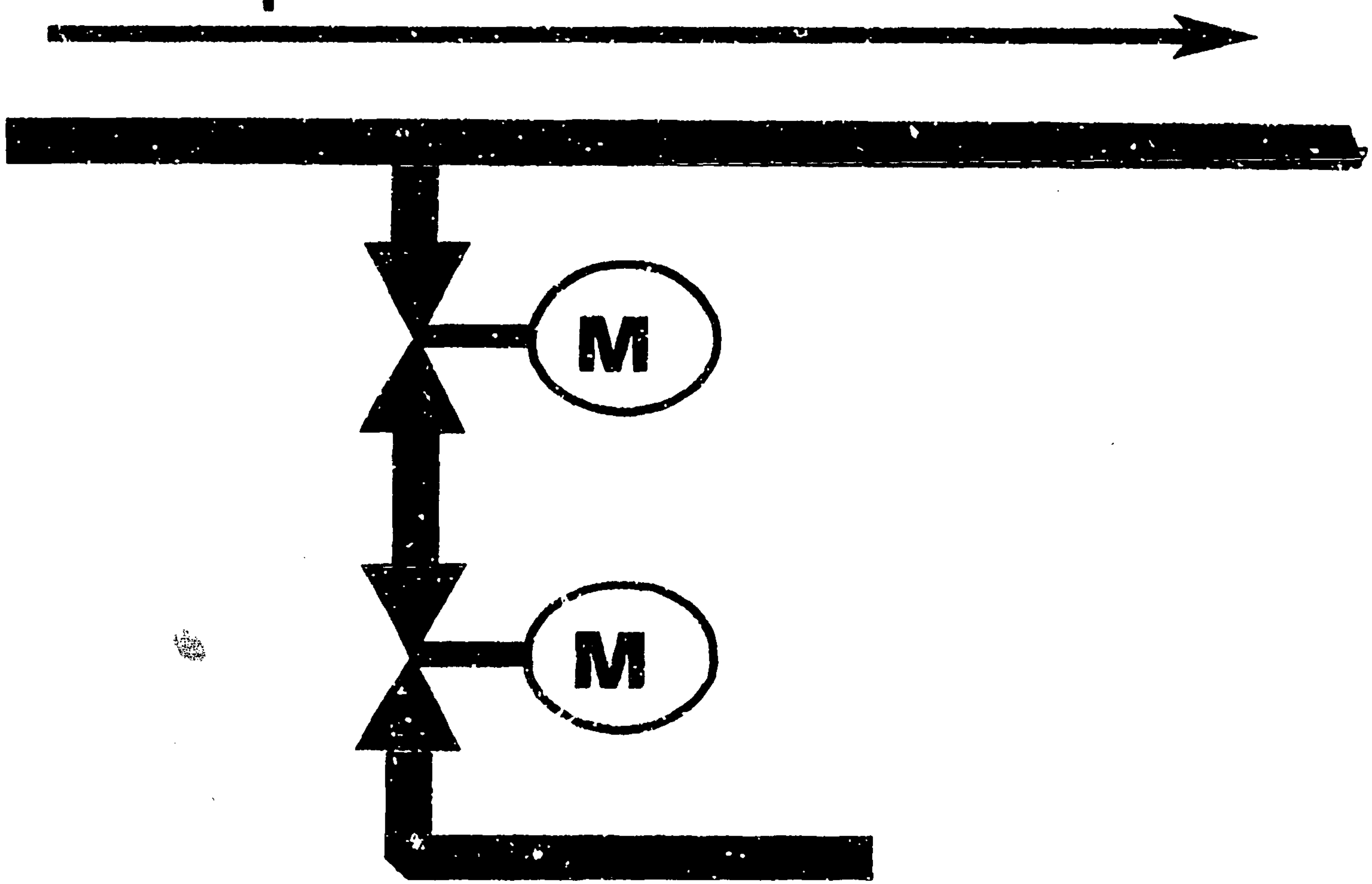
  ✔ Multi-conductor cables

  Potential for fire to cause multiple hot shorts in a single multi-conductor cable is deemed credible, and should be considered in the evaluation

Fire-Induced Spurious Actuations

- Faults between conductors of fire affected cables or circuits may cause multiple components to spuriously actuate
- Components in a single Hi/Low pressure boundary are assumed to spuriously actuate simultaneously
- Evaluation of other components (non Hi/Low) should consider "any and all" spurious actuations on a "one-at-a-time" basis, where:
  - ✔ All potential spurious operations are identified for each fire area;
  - ✔ Potential for multiple spurious actuations to occur as fire progresses is considered and evaluated; and
  - ✔ Appropriate actions are implemented to prevent occurrence (fire protection features) or mitigate its consequences (e.g., timely manual actions)

Required Flow



Summary of Industry Views of the Regulatory History of Post-Fire Safe Shutdown Circuit Analysis Issues

NRC Post-Fire Safe Shutdown Circuit Analysis Workshop

July 23, 1998

NEI

Fire-Induced Circuit Failure Issues

- Circuit failure modes (Information Notice 92-18)
- Multiple spurious actuations

NEI

Evolution of Industry Positions

- 1981 Appendix R
- GL 81-12 interpretations
- 1981-1986. Resolution of Appendix R issues for some plants
- Regional workshops, GL 85-01 draft
- GL 86-10 interpretations
- Late '80s - early '90s Submittal ' approval remaining issues/plants

NEI

Evolution of Industry Positions

- 1992: Information Notice 92-18
- 1992-1994: Licensee review of IN 92-18
- 1994-1996: GL 89-10 inspections addressing IN 92-18
- 1997
  - Industry survey
  - NEI and NRC letters on NRC and industry positions
- Recently: Inspections identifying multiple spurious actuations as a regulatory concern

NEI

Utility Positions

- NEI surveyed utility positions on
  - Response to IN 92-18
  - Mechanistic vs functional failures
  - Multiple spurious actuations
  - Recommended industry actions
- More than 95 plants represented in survey results

NEI

IN 92-18 Failure Modes

- Industry position stated in response to Question 3 in May 30, 1997 NEI letter
  - Position based on GL 86-10, Question 5 3 1

    "For consideration of spurious actuation, all possible functional failure states must be evaluated, that is, the component could be energized or de-energized by one or more of the above failure modes. Therefore, valves could fail open or closed, pumps could fail running or not running, electrical distribution breakers could fail open or closed."

NEI

IN 92-18 Failure Modes

- Most licensees believe IN 92-18 constituted a fundamental change of NRC views on circuit failure modes
  - Information Notice not appropriate vehicle for conveying change in regulatory views
  - Conflicted with licensing bases founded on approved safe shutdown analyses
  - Conflicted with previous staff guidance
    - Plant-specific
    - Generic guidance (GL 86-10)

NEI

Multiple Spurious Actuations

- Position based on GL 86-10, Question 5.3.10

"Per the criteria of Section III L of 10CFR50 Appendix R, a loss of offsite power shall be assumed for a fire in any fire area concurrent with the following assumptions

a. The safe shutdown capability should not be adversely affected by any one spurious actuation or signal resulting from a fire in any plant area, and

b. The safe shutdown capability should not be adversely affected by a fire in any plant area which results in the loss of all automatic function (signal, logic) from the circuits located in the area in conjunction with one worst case spurious actuation or signal resulting from the fire, and "

NEI

Multiple Spurious Actuations

- Industry position stated in response to Questions 1, 4, and 5 of May 30, 1997 NEI letter
  - The underlying guidance (GL 86-10, Questions 5.3.1 and 5.3.10) treats both the III L and III G areas consistently This guidance is interpreted to mean
    - Analyze consequences of possible spurious actuations
    - One at a time, not sequentially, simultaneously, or with cumulative effects
    - Except for high/low pressure interfaces, where effects of simultaneous spurious opening of redundant valves analyzed

NEI

In Closing

- Further discussion of differing industry and regulatory interpretations not likely to resolve these issues
- NRC staff have taken positive steps toward generic resolution
  - Circuit analysis resolution plan
  - This workshop
- Must focus regulatory and industry resources on real safety issues

NEI

POST-FIRE SAFE SHUTDOWN CIRCUIT ANALYSIS ISSUES

Steven West, Chief
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Office of Nuclear Reactor Regulation

July 23, 1998

TYPES OF PROBLEMS

- MOV Mechanical Damage
- Associated Circuits
- Common Enclosure
- Fuse/Breaker Coordination
- Short Circuits
- Spurious Operations
- Transfer and Isolation Capability
- High-Pressure/Low-Pressure Interfaces
- Multiple High Impedance Faults

Browns Ferry Fire

Bryan Ford
Entergy
Workshop on Post-Fire Safe Shutdown
Circuit Analysis
July 23, 1998

Background

- March 22, 1975
- Fire was started in a penetration in the cable spreading room by a candle used for leak checks
- Fire spread through the penetration separating the cable spreading room from the reactor building
- Fire extended 30 to 40 feet into the reactor building and 2 to 5 feet in the cable spreading room
- Unit 1 was the most affected unit.
- Reactor level was maintained using 1 CRD pump, the Condensate System, and 4 relief valves.

Background

- Most losses of electric power an equipment failures occurred approximately 1 hour into the event
- Some power was restored after about 4 1/2 hours.
- The relief valves used to control pressure were lost about 6 hours into the event and were restored about 3 1/2 hours later
- Fire burned for approximately 7 1/2 hours.
- Torus cooling established after about 13 hours.
- Shutdown cooling established after about 16 hours.

Fire Impacts

- Damaged approximately 1600 cables (684 safety related)
-
- Smoke and fumes entered the control room
-
- Power was lost to multiple control boards. Only 1 Reactor MOV board was available.
-
-

Circuit Failures

- Spurious signals
  - Low level Blowdown Permissive
  - ECCS pump running
  - ADS Timer started
  - Recirculation pumps runback
  - High reactor water level signal to feedpump control

Circuit Failures

- Spurious Actuations
  - ECCS pumps started (RHR, CS, HPCI, and RCIC) and were tripped by the operator
  - ECCS pumps restarted (RHR, CS, and HPCI) and were tripped by the operator
  - Shutdown cooling MOV may have changed state
- Random indicating lights became very bright and then went dim or out
- Spurious annunciators

Circuit Failures

- Multiple instruments became inoperable
  - Neutron Monitoring (2 SRMs were restored with temp. connections in about 1 hour)
  - Torus temp., level, and pressure (Temp. indication restored with temp. instruments)
  - Some reactor level and pressure
  - Some feedwater flow, steam flow
  - etc.
- Some breakers would not operate due to shorts preventing the coils from operating
-

Circuit Failures

- Inoperable equipment
  - All ECCS and RCIC
  - MSIVs and feedwater pumps
  - 7 relief valves
  - Reactor Building Closed Cooling Water
  - RWCU
  - SBGT B
  - DG C
  - 8 Drywell Blowers
  - SBLC

Circuit Failures

- The 4 relief valves being used to control reactor pressure failed. Solenoid valve supplying control air had failed. Personnel bypassed solenoid within 3 1/2 hours of the failure

What Worked

- HPCI and RCIC autostarted and restored water level following the reactor scram even though they had spuriously started twice previously. Following shutdown by the operator they could not be restarted.
- All but one DG autostarted.
- Condensate and Condensate booster pumps
- One CRD pump
- 4 relief valves were used to reduce reactor pressure

Conclusions

- Event shows differences between traditional design analysis and actual events:
  - Fires involving low flammability combustibles progress slowly (e.g., damage is not instantaneous).
  - Some systems within the fire area may be available to be used to mitigate the event.

    Systems affected by the fire may be successfully used to mitigate the event for substantial periods of time
  - Repairs without procedures may be successful.
  - Multiple spurious signals can be generated but may have low safety impact (e.g., operator may mitigate).
- The Appendix R analyses like the UBA analyses contain simplifying assumptions which may be different than actual events while still providing an adequate level of safety.

SAFETY SIGNIFICANCE OF MULTIPLE SPURIOUS SRV OPERATION

Vincent P. Bacanskas
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Safety Significance

<u>Introduction</u>

- Safety significance of Postulated Fire Induced simultaneous opening of 16 SRV's
  - Probability of event
    - Outside Control Room
    - Inside Control Room
  - Thermal/Hydraulic Analysis
  - Cable Fire Testing

Probability Analysis

Fire Area C-6

- General area control building elevation 70'
- Fire ignition frequency 6.9E-4/yr
- Fire induced multiple SRV lift 3.12E-10/yr
- CDF contribution 2.94E-11/yr
- Non-Risk Significant

Probability Analysis

<u>Main Control Room C-25</u>

- Fire ignition frequency 9.5E-3/yr
- Fire induced multiple SRV lift 1.6E-7/yr
- CDF Contribution 1.5E-8/yr
- Non-Risk Significant

Thermal/Hydraulic Analysis

Plant Response

- Three scenarios were evaluated
  - Fire outside Main Control Room, Bounding
  - Fire in Main Control Room, Mechanistic
  - Fire in Main Control Room, Bounding

Thermal/Hydraulic Analysis

Fire Outside Main Control Room

- Assumes all 16 SRV's Lift
- Assumptions based on Safe Shutdown Analysis system availability
  - Reactor Scram (Level 3)
  - Credit Div. I (RHR-A, LPCS)
- Operators can close SRV's from control room
- Safe shutdown achieved and maintained

Thermal/Hydraulic Analysis

Fire Inside Main Control Room - Mechanistic

- Assumes all 16 SRV's lift
- Mechanistic assumptions
  - Automatic scram
  - Automatic initiation of LPCS, LPCI
  - MSIV's close on low pressure
- Operators evacuate and assume Div. I control from Remote Shutdown Panel
- Results are essentially the same as for Fire Outside MCR with multiple SRV lift

Thermal/Hydraulic Analysis

Fire Inside Main Control Room - Bounding

- Assumes all 16 SRV's lift
- Safe Shutdown Analysis assumptions
  - Manual scram, evacuate control room
  - Remote shutdown panel control
    - No injection for 10 minutes
    - RHR-A Only Injection

Thermal/Hydraulic Analysis

<u>Fire Inside Main Control Room - Bounding</u>

- Steam cooling
- Limiting fault type event
- PCT less than 1500°F
- Well within 10CFR50.46 PCT limit of 2200°F
- No core damage
- Safe shutdown achieved and maintained

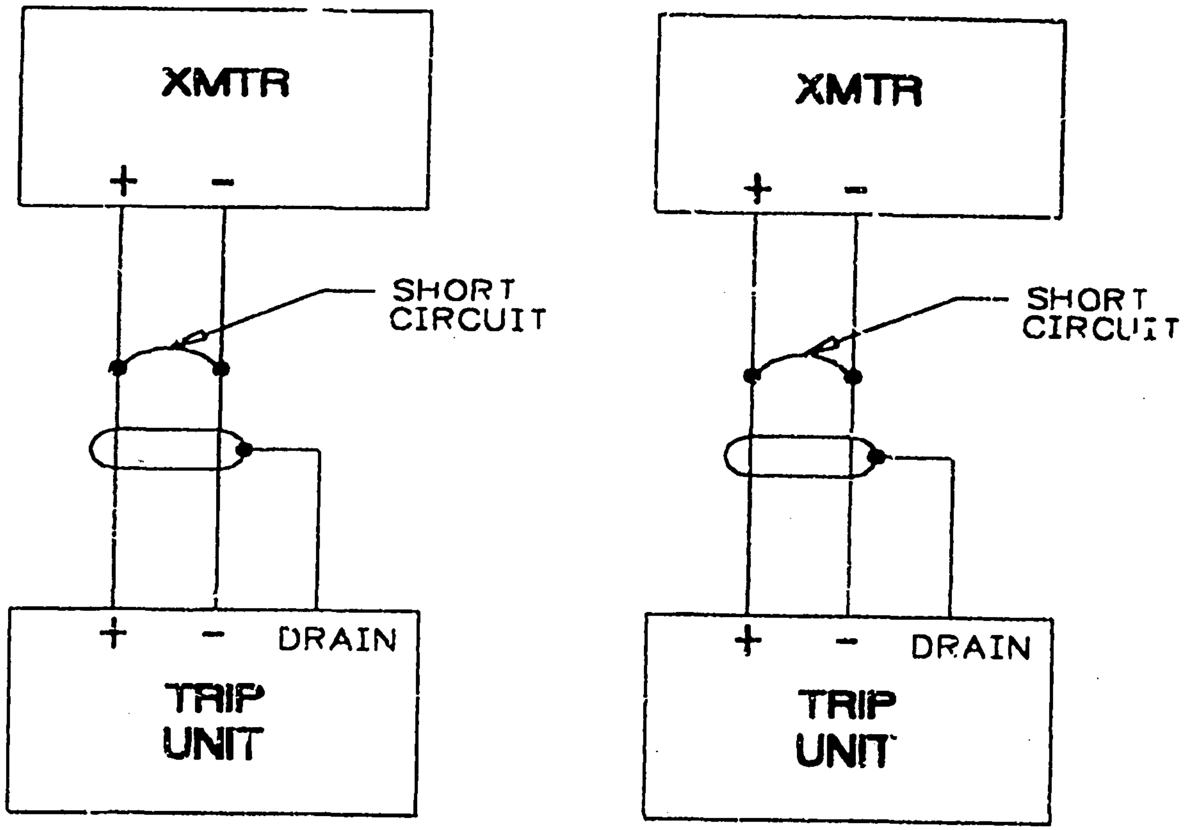
Safety Significance

Conclusion

- Fire-Induced Opening of Multiple SRV's:
  - Low CDF of ≤3.9E-8/yr
  - PCT <1500°F, therefore no core damage
  - For all scenarios evaluated, safe shutdown is achieved and maintained
- Risk-Informed Conclusion
  - Insignificant contribution to plant risk

CABLE FIRE TEST

Single Division SRV Simplified Logic Diagram



SRI Cable Fire Testing

- Performed at independent testing laboratory
- Used Rosemount transmitters/trip units
- Four continuously monitored circuits
- Used IEEE STd. 383-1974 Protocol with exceptions
- Fire testing at three heat rates
  - Three tests at full heat rate
  - One test at one-half and one test at one-third heat rate

SRV Cable Fire Testing

Test Results

- For full heat rate (~70,000 BTU/HR)
  - 12 of 12 circuits failed to shield in first few minutes of test (< 5 minutes)
  - Cable self-extinguished when flame was removed
- One-half and one-third heat rate
  - No shorts, no open circuits

SRV Cable Fire Testing

Conclusions

- Conductor to Conductor Short DID NOT OCCUR
- Conductor to Shield Only Failure Mode Observed
- Lower Heat Rates did not change failure mode
- Cable extinguished when burner was extinguished after 20 minute exposure

Presentation: NRC Workshop 7/23/98

1. Introduction
Name: Nicholas N. Rivera PE
Company: SPAD Engineering Company

Background:

BSEE electric machinery, power and controls. MS work on electric power system analysis. Electric Power and Instrumentation and Control since 1962. Started in 1962 as a design engineer, high voltage switchyards, protective relaying and control systems. Over past 32 years have investigated over 25 electric fires, many of which involved arcing faults.

Inventor of U.S. Patent No. 4,658,322 Arcing Fault Detector, Apr. 14,1987. This device is in use in all U.S. Navy ships having nuclear propulsion. Was Head of the Nuclear Submarine Electrical Systems Branch of the Naval SEA Systems Command. Thus, well recognized as a marine electrical engineer in the U.S. and Canada.

Have worked in the nuclear electric power generation industry since 1984, as consultant to NRC performing plant audits and inspections and as contractor to several nuclear plants.

2. Subject of the talk:

Electric fault analysis in nuclear plant cableways and systems involving exposures to fires and correlation with design basis calculations

Fault analysis conditions, high current faults and high impedance faults

Conditions for self-sustaining arcing faults

Protective device performance under fault conditions caused by exposure to fires.

10 CFR 50 Appendix R and NRC Generic Letter 86-10 on "Multiple High Impedance Faults"

3. Fault Analysis - Background Information

Design basis calculations for circuit protection follow the criteria in IEEE Stds. 741, 141 and 242. IEEE 242 has most of the detailed criteria and is referenced by the other two standards.

The design basis criteria defined bounding conditions for postulating faults in all circuits. This may include simultaneous faults supplied by any source, where the bounding condition is defined by the lowest impedance fault. Such fault will absorb (hog) practically all of the short circuit capacity of the source, such that other possible faults are effectively shunted out. Thus the circuit having the lowest impedance (highest current) fault will be isolated first. Any other faulted circuits will be isolated sequentially thereafter.

Two kinds of faults: CONTACT (vice BOLTED) and ARCING (high impedance)

CONTACT fault current levels are always sufficiently high to activate the protective device in the short range or instantaneous range.

High impedance faults, with some exceptions have current levels limited by concentrated resistance at the faulted point. That resistance either becomes an arc or degrades into a contact (low impedance, high current) fault level in a shot time because fault energy will destroy most conductive materials.

Example: 20 amp. fault @ 480 Vac will dissipate energy at 9.6 kW, 1 ph. or 16.6 kW, 3 ph.

Arcing faults, conditions to be self-sustaining. Some defined in IEEE Std.242-1986.

Voltage threshold; must be above 277 volts, peak (from results of research on arcing faults). Thus, self-sustaining arcing faults cannot exist in 120 Vac, 250/125 Vdc circuits.

High instantaneous energy delivery - fault power factor must be high. X/R ratio must be above 4.

If X/R ratio is low, there will not be enough circuit capacity to maintain fault voltage above the self-sustaining threshold. Small branch circuit ratios have low X/R ratios and tend not to be the arcing type (Art. 14.6, p. 547)

Typically, minimum self-sustaining arcing fault current is 38% of the circuit's maximum fault current (Art. 8.8.2.2, p. 363 and Art. 14.6, p. 547). This is above the pickup level of the protective device.

X/R ratios of 250/125 Vdc circuits are very low. The battery represents a resistive source impedance, which precludes self-sustaining arcing faults. Battery chargers are current limited, resulting in a low fault energy source.

Resistance grounded systems (6.9 kV, 4.16 kV and 480 Vac) limit the magnitude of ground fault currents (Art.7.2.4, p.276) and, thus, have very low X/R ratios to ground. This is evidenced by accelerated rates of decay (Art. 8.4 1.4, p. 328) and prevention of overvoltages (Art. 7.2.4, p. 276).

4. Survey of X/R ratios of several nuclear power stations, based on short circuit calculations done with AFAULT and ETAP:

480 Vac switchgear buses showed X/R ratios slightly above 2.5, less than 3.0

The largest 480 Vac feeder circuits to motor control centers and pressurizer heaters showed X/R ratios of less than 2.5.

6.9 kV and 4.16 kV circui[illegible] X/R ratios were well above 4.0 (7.0 to 24.+).

5 Characteristics of protective devices when exposed to external heat sources.

The high thermal conductivity of copper or aluminum conductors in cables exposed to fires will increase the temperature rise of circuit protective devices.

Thermal-magnetic direct acting trip devices are rated for normal internal heat dissipation in a 40° C ambient (ANSI C37.13). Conducted heat from external fire exposures by circuit conductors may derate the trip devices.

Fused circuits may be derated by conducted heat from external fire exposures by circuit conductors.

Intermediate voltage (6.9 kV and 4.16 kV), open frame and molded case using solid-state electronic overcurrent trip devices operated by current transformers will not be significantly affected by conducted heat from circuit fire exposures.

6. Conclusions:

Based on the above detailed definitions and survey information on the characteristics of faults as found in standard criteria and experience, the existing design basis of nuclear plants for electric fault analyses are sufficiently bounding with respect to all credible fault conditions.

High impedance faults are not likely to be self-sustaining and will become "CONTACT" faults in short order, thus resulting in fast, coordinated fault clearing.

Self-sustaining arcing faults will not credibly exist in 480Vac, 120 Vac and 250/125 Vdc circuits.

Self-sustaining arcing line-to-line faults may exist in 4.16 and 6.9 kV circuits. Arcing ground faults will not exist in resistance grounded circuits.

The above precludes the conditions for multiple high impedance faults as defined in NRC Generic Letter 86-10.

J. E. Lechner

Nebraska Public Power District
Cooper Nuclear Station
Senior Staff Engineer - Fire Protection

ASSUME NOTHING

X-Files

PERFORMANCE GOALS

- Plant response should be consistent with a loss of normal AC power.
- No such thing as a *Normal* loss of AC power.
- Somewhere between Station Black Out and a LOOP.

ASSUME

- No Credit for Automatic Initiation of Help Yous
- Automatic Initiation of Hurt Yous
- No offsite power for Help Yous
- Offsite power available for Hurt Yous
- Manual valves, piping, heat exchangers, check valves unaffected by fire.

SPURIOUS OPERATIONS

- Generally Hurt Yous
- One at a Time
- The "Single Failures" of Appendix R Analyses
- Lasts as long as it takes to regain positive control or clear the fault

CIRCUIT FAULTS

- Ground
- Open
- Impressed Voltage/Current (Hot Short)

QUESTIONS

- Can more than one fault per conductor be assumed?
- Within multiple conductor cables, how many simultaneous faults and of what type needs to be assumed?
- What about multiple cables in a raceway?

ASSUME

- Multiple Grounds - Eventually, all conductors in all cables will ground to the raceway.
- Multiple Opens - Eventually, all conductors in all cables will burn through or activate circuit isolation/protection devices.

ASSUME

- The answer to Question 5.3 10 of Generic Letter 86-10 is correct and only one worst case spurious operation occurs at a time.
- The number of "hot shorts" necessary to get the spurious operation you don't want. It usually only takes one.

SUCCESS

- Safe Shutdown Performance Goals Met
- Manual Actions Specified for each *potential* spurious operation
- Ability to perform each manual action within time limits specified by analyses
- Emergency Lighting and smoke/fire free path for each manual action exists

NO SUCCESS

- No redundant path - provide "Alternative" or "Dedicated" capability
- If you are close - An Exemption may be an option.

CONCLUSIONS

- Assume Utilities know how to do Circuit Analysis
- Let us know what the other assumptions should be.

"THE TRUTH IS OUT THERE"

X-Files

A Technological Overview of Associated Circuit Analysis

NRC Public Meeting
Bethesda, Maryland
July 23, 1998

Stephen Maloney
Devonrue LTD
smaloney@devonrue.com

Industry's Path to Generic Letter 86-10

- From 1982-1986, Nuclear Utility Fire Protection Group (NUFPG) standardized safe shutdown analytical assumptions, properties and methods.
- NUFPG procedures are reflected in several Staff guidance documents, including draft Generic Letter 85-01 and Generic Letter 86-10.
- I recount GL 86-10 considerations -- focusing on the compelling imperatives to simplify the analysis, and my recollection of the multiple circuit failure issue.

I Take the Blame

- If you were wondering where all this stuff came from, I'll take the responsibility for everything wrong, inconsistent and unclear in GL 86-10.

- This Was Bismarck's Sausage: I proposed topics and positions to NUFPG members, reconciled utility comments, negotiated language with my counterpart at CRGR who took it back to NRR -- a lot of back and forth.

Reactor Design and Construction Practices Were Erratic At Best

- "In the beginning, ..." original construction provided minimal separation, and mostly at the component level (e.g., pumps and valves).
- More so in 1975, but even today, electrical circuit separation and isolation is problematic.
- Fires, floods, and high-energy pipe breaks (e.g., a drain pipe lets go in certain locations) can disable redundant shutdown methods.

Browns Ferry and the Aftermath

- Browns Ferry revealed the inadequacy of electrical isolation and physical separation methods and practices.
- Industry reviews performed in 1975-1980 often provided a simplistic or inconsistent treatment of safe shutdown functionality and associated circuit effects.
- By 1980, pummeled by UCS petitions, its resources diverted to TMI, and facing a fast approaching deadline, NRC codified in Appendix R contemporary Staff positions.

The BTP 9.5.1 Era -- After the Fire

- Expanded equipment set to include support and non-safety components
- Reviewed power cable routing drawings and applied measures in high congestion areas (The Black Art of coatings, "shields," and auto suppression)
- Some instrumentation and control circuits were evaluated under static conditions
- Analysis typically assumed stable plant, and overlooked normally energized state or transient

Appendix R -- Adding Robustness

- Dynamic set of associated circuits -- contents vary with fire damage propagation, component actuation, system lineups, operator action, and fault isolation methods.
- Dynamic safe shutdown scenarios and equipment sets -- associated with fire location, system parameters, operator action and scenario timing.
- Some validation of circuit routings and physical separation -- but still an issue 18 years later.

But, Robust Means Rising Complexity -- at Nonlinear Rates

- The number of fire damage subsets is defined specified by a "power set:"

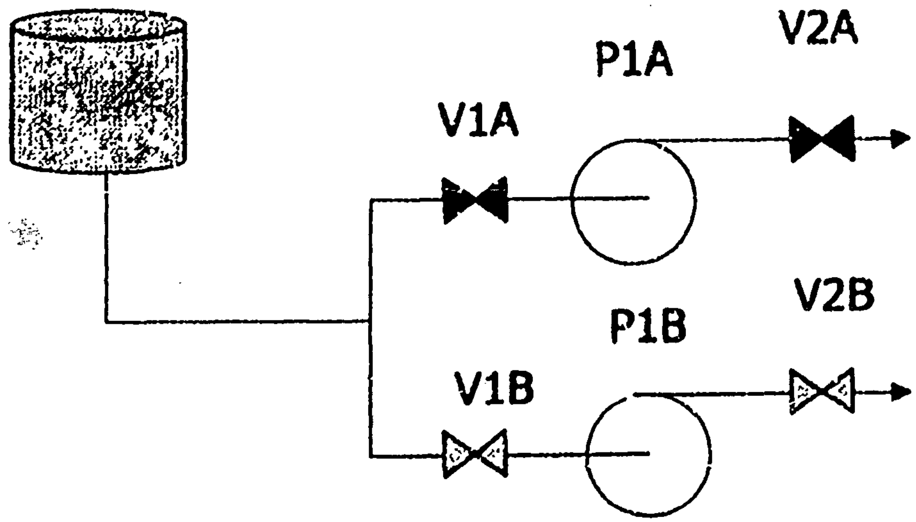
$$SubsetNumber = 2^n$$

- Example:

  Appendix R maps 2 components in a fire area into 4 subsets: {No damage or "null set"}, {Comp-A damaged}, {Comp-B damaged}, {Comp-A damaged, Comp-B damaged}

Complexity Is Nonlinear

- Tripling the component considered can result in 16 times as many combinations -- or more



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The Sigma Algebra

- Component States: Looking for the 15 success paths among the 64 possible subsets for a 6-component set

  1 subset entirely damage free

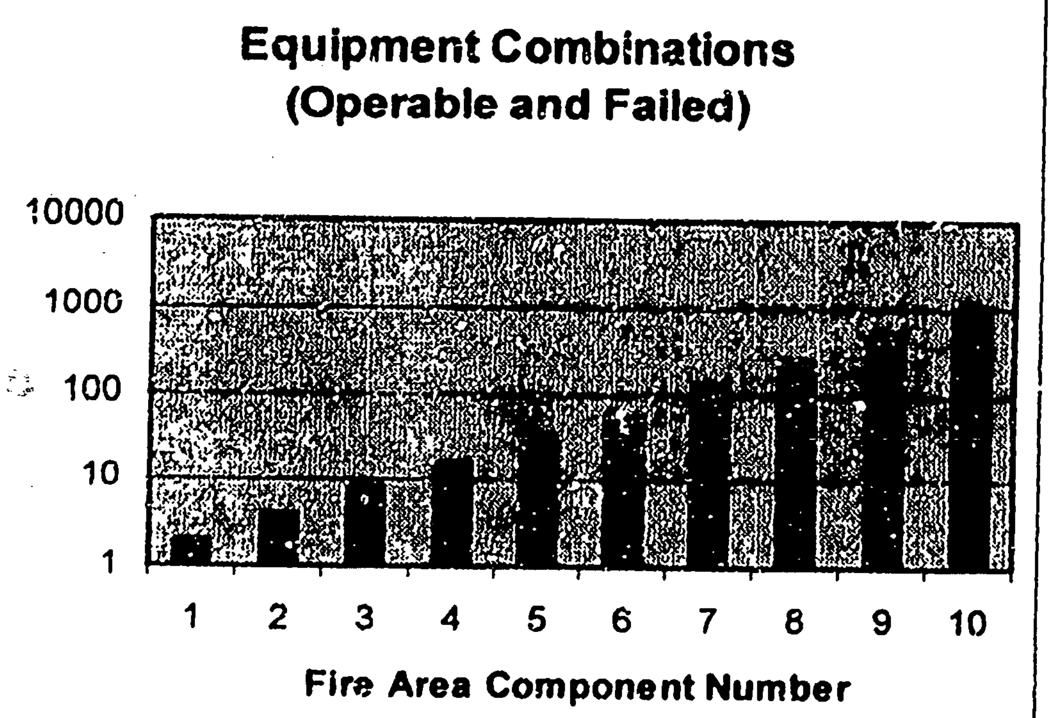
  6 subsets with a single component damaged

  15 subsets with 2 components damaged (6 comply, 9 fail protection criteria)

  20 subsets with 3 components damaged (2 comply, 20 fail protection criteria)

  22 subsets with 4 or more components damaged (all result in loss of redundant trains)

Adding Circuits Quickly Increases Complexity to Unmanageable Levels



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Sets Are Dynamic

- What You Have Changes --- As scenarios run-out, some hot shutdown equipment become less relevant.
- What You Need Changes --- As scenarios run-out, you need different equipment to control the plant.
- While Things Become More Integrated --- As scenarios run-out, primary and support components coalesce into essential clusters.

Associated Circuits Effects

- Appendix R associated circuits can amplify the number of circuits in the power set requiring analysis and protection.

- More circuits means more complexity.

- Doubling unprotected/unmitigated associated circuits can expand the safe shutdown damage sets by orders of 10 or more.

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Other Ways to Add Complexity

- Instrumentation and control circuits (vs.. local indication)
- Support equipment (e.g., HVAC) (vs. portable systems)
- Multiple shutdown scenarios and paths (vs. simple trees)
- Centralized shutdown operations (vs. remote stations)
- EDGs as power source (vs. SBO/AAC DGs)

- In a crisis, a "lobotomized" plant can be easier to manage than one that thinks it knows what's happening.

GL 86-10 Sought to Thin the Sets

- Filtering unnecessary subsets reduces the "noise" and simplifies shutdown analyses.

- Shutdown studies faced constraints -- cost of field validation, number of potentially affected components, changing design, limited pool of professionals qualified to maintain and validate complex computer models, steadily rising Appendix R budgets year after year.

Remember: This Was 1984

- Appendix R implementations were at a critical stage in 1984 -- Staff differing professional opinions required resolution, compliance deadlines were fast approaching, significant capital was already committed
- It was already 3-4 times longer than the 1980 Commissioners expected -- this had to end now!
- NUFPG was uniquely qualified to propose standardized analytical methods.

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Set Pruning Concepts in GL 86-10

- Section 5.3 Safe Shutdown and Fire Damage
  - 5.3.1 Circuit Failure Modes
  - 5.3.2 "Hot Short" Duration
  - 5.3.8 Short Circuit Coordination Studies
  - → 5.3.10 Design Basis Plant Transients
- These and other sections restrict the number of transition scenarios that might increase the components driving runaway power set mathematics

Did GL 86-10 Limit Spurious Actuations to Just 1 "Event?"

- The Short Answer:

No

1 Worst Case Event ... AT A TIME

- The longer answer:

(1) The GL repeatedly uses the phrase in the Q&A section -- "one spurious actuation or signal."

(2) The single "non-mechanistic" spurious actuation is "non-mechanistic" -- merely fire-associated.

(3) The single signal is taken to its logical conclusion -- it may cascade into multiple events, actuations, and damage mechanisms -- it is not arbitrarily truncated.

Final Thoughts

- Simplicity is central to low-cost Appendix R compliance -- protect too much and power set mathematics wrestle you to the ground.
- Complicated data management systems, complex shutdown scenarios, and intricate analyses are too often unstable, unmanageable, and uneconomical for the real world -- not to mention unnecessary and avoidable.

Final Thoughts

- Think of an Appendix R safe shutdown model as a computer operating system -- it must be maintained and updated continuously. Unless you're Microsoft (or wanna-be), keep it simple.
- An Appendix R safe shutdown model was never about how you prefer to fly the plane with a fire -- but it is the ultimate way you might have to fly it if fire takes out the hydraulics.

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Risk-Based Resolution of Fire-Induced Circuit Failures

Ward Sproat
Director-Engineering
PECO Nuclear

So Why Are We All Here?

- Are spurious operations due to FICF's a significant safety issue?
- Do we agree on how to analyze for spurious operations due to FICF's?
- Do you want to resolve this issue expeditiously?
- Did EGM 98-002 get your attention?

Conditions Needed for FICF's

- Ignition Source
- High BTU Transient Combustible
- Direct Impingement on Cable
- Significant heat source for extended period of time

How Likely are FICF's?

- Current Regulatory Interpretation
  - Probability =1
- Qualitative Risk Analysis
  - Probability << 10E-9

How Do We Resolve This Issue?

- Do Nothing?
- Testing Program?
- Circuit-Unique Deterministic Analysis?
- Change the regulation?
- Risk Based Analysis?

Recommended Course of Action

- Use FICF's as the pilot for Risk-Based Approach to Fire Protection Regulation
- Use NEI FPWG as Industry focal point for methodology development
- NRC to review several plant analyses performed to NEI methodology
- NRC to issue final resolution guidance based on review of submittals

Conclusion

- Let's get real about the risk this issue presents to our plants
- We need to spend our resources on issues which improve system and component reliability.

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

March 11, 1997

Mr. Ralph E. Beedle
Senior Vice President and
Chief Nuclear Officer
Nuclear Energy Institute
1776 I Street, NW, Suite 400
Washington, DC 20006-3708

Dear Mr. Beedle:

I am responding to your letter of January 14, 1997, concerning U.S. Nuclear Regulatory Commission (NRC) Information Notice (IN) 92-18, "Potential For Loss of Remote Shutdown Capability During a Control Room Fire," February 28, 1992. As you are aware, IN 92-18 addressed conditions, found and reported by several licensees, that could have resulted in the loss of capability to achieve and maintain safe shutdown conditions in the event of a control room fire. Specifically, the circuit logic associated with certain motor-operated valves, when subjected to a single fire-induced hot short, could have resulted in a spurious permissive signal. The spurious signal could have caused the valve to operate, bypassing the protective features, and resulting in mechanical valve damage. Such fire-induced damage could have impaired the capability to shut down the plant and maintain it in a safe shutdown condition.

During a public meeting on February 7, 1997, the NRC staff discussed with you and other representatives of the Nuclear Energy Institute (NEI) the questions and issues raised in your letter. During the meeting, the staff indicated that it agreed with your position that information notices should not be used to impose new requirements on licensees or to dispense new staff positions or guidance. The staff presented its positions regarding fire-induced hot shorts and spurious signals and its position that the safety issue addressed in IN 92-18 (the potential for fire-induced hot shorts to impair the capability to achieve and maintain safe shutdown) is within the scope of the existing fire protection regulation. The staff also explained how the regulation and published staff positions and guidance support this position and why its review and inspection of the technical and safety issues addressed in IN 92-18 does not constitute a plant-specific backfit.

During the meeting, the staff stated that it also agreed with your position that enforcement actions should not be taken against a licensee for failure to comply with information notices. Although specific enforcement actions were not discussed during the meeting, the staff acknowledged that it had recently issued notices of violation to several licensees in response to findings of post-fire safe shutdown deficiencies involving hot shorts. In each case, the enforcement actions were dependent on the circumstances of the case and were taken against a licensee for failure to comply with the applicable regulatory requirements, consistent with established regulatory positions, and not for failure to comply with an information notice.

The staff treated your concerns in accordance with its procedures for managing backfits. After considering the information you submitted in your letter, the discussions with NEI and licensee representatives during the meeting of February 7, 1997, and re-evaluating the fire protection regulation and applicable staff positions and guidance the staff concluded that its position (that the technical issue addressed in IN 92-18 is within the scope of the existing fire protection regulation) is justified On this basis, the staff has also concluded that its continued review and inspection of fire protection issues, including such technical and safety issues as those addressed in IN 92-18, is appropriate In addition, the staff is considering the need to take further action to ensure that licensees understand and comply with the applicable regulatory requirements

With respect to enforcement actions, the staff will continue to enforce the Commission's requirements in accordance with the guidance of NUREG-1600, "General Statement of Policy and Procedures for NRC Enforcement Actions," and the "NRC Enforcement Manual" As you are aware licensees that question enforcement actions may contest them in accordance with the procedures in 10 CFR Part 2, Subpart B Furthermore, licensees that believe a staff position is a backfit with regard to its facilities may raise such claim in accordance with established NRC policies and procedures This includes submitting the claim in writing to either the Director of NRR or the Regional Administrator supervising the NRC employee who issued the staff position in question with a copy to the NRC Executive Director for Operations

The staff's response to the technical issues you raised in your letter are enclosed Because you alleged in your letter that the staff was inappropriately backfitting new positions or interpretations regarding fire-induced hot shorts and spurious signals, I have referred your letter to the NRC Office of the Inspector General If you have questions about the staff positions or IN 92-18, please have your staff contact the NRC point of contact for fire protection matters, Steven West, Chief, Fire Protection Engineering Section Mr West can be reached at 301-415-1220 If you disagree with the NRC staff positions, or you wish to further your backfitting claim you can appeal to the NRC Executive Director for Operations

Sincerely, /S/

Samuel J Collins, Director
Office of Nuclear Reactor Regulation

Enclosure As stated

cc w/encl See next page Project No 689

<u>DISTRIBUTION</u> See attached list

DOCUMENT NAME NEI92_18 RSP

Letter reviewed by STreby OGC
Comments incorporated

*See previous concurrence

To receive a copy of this document indicate in the box C = copy without attachment/enclosure E = copy with attachment/enclosure N = no copy

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OFFICE	D NRR	D OE	D NRR		
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DATE	01/31/97	02/24/97	03/06/97		

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BWR Owners' Group

NRC / NEI Workshop
July 23, 1998

- BWR Owners' Group has begun preparation of a safe shutdown analysis guidance document to assist BWROG members in performing Appendix R circuit analysis.

- The BWROG is in the process of developing position statements and methodology which will be discussed with the NRC staff during development of the guidance document .

- The guidance document is currently scheduled for completion and submittal to the NRC as a Licensing Topical Report at the end of the 2nd Quarter of 1999.

- The guidance document is also intended to assist BWROG members in addressing future NRC correspondence (e.g., NRC Generic Letter).

- The BWROG has communicated these plans with NEI and other Owner's Groups and plans to continue this interface.

Post-Fire Safe Shutdown Circuit Analysis

NRC Workshop – July 23, 1998

ISSUE: SPURIOUS OPERATION

1 Assume that the spurious start of an ECCS pump such as the RHR pump A in a boiling water reactor is a concern. Further, assume that the spurious start of this pump requires three short circuits to occur on separate conductors. The separation analysis shows that control cables associated with these conductors may be affected due to a common fire. Is starting of the pump considered to be a valid spurious operation that needs to be addressed?

One position is that each cable fault is considered to be one spurious signal and therefore this situation is not evaluated as a valid spurious operation concern, since only one spurious operation/signal is considered for each fire scenario.

The alternative position is that multiple cable faults must be considered where they can result in the spurious operation of a component or the initiation of a spurious signal (i.e. LPSI initiation for a BWR) For all but high/low pressure interface valves, this excludes properly sequenced hot shorts on three phase AC power cables and two hot shorts of the proper polarity on ungrounded DC systems.

What is the NRC position on this?

2 Suppose in the case of the above scenario, the pump start is due to the three cable failures; and that the control cables associated with the suction valve for the pump are in the same fire area that causes the spurious start of the pump (This can be considered to be the second spurious operation as a result of this fire.)

In order to address this scenario

1) Does the analyst not pursue the issue since there is no need to consider more than one spurious operation? or,

2) Does the analyst pursue the issue and require the control room operator to take positive actions post-fire to secure the pump (i.e., stop) such that it does not start or if it has started, stop the pump to ensure that the second spurious operation (i e , the valve closure) will not destroy the pump

3) Is there a need to protect the circuits associated with the pump and the valve such that spurious operation of the pump and the valve do not occur simultaneously

Recognizing the interpretation provided in the Inspection Plan 64100 wherein part it states

"Licensees to analyze for any and all spurious actuations or failures where no such spurious actuations or failures occur simultaneously,"

it would seem that #2 above should be the way this scenario is to be ˙ ed and addressed.

What is the current NRC position on this?

3 Assume two valves in series (non High/Low pressure interface) that are normally closed and are required to remain closed post-fire. Each valve has a separate control cable located in the same fire area. If the control cables are internally shorted, these valves may spuriously open post-fire.

1) Does the analyst pursue the issue since he/she does not need to consider more than one spurious operation at a time? And therefore, only one valve may spuriously open post-fire?

2) Does the analyst consider spurious opening of both valves eventually? And therefore, the need exists to take positive action to close one if practical, or to disconnect the power feed to both valves if the control cables are affected due to fire?

3) Does the analyst require protection of the control circuits associated with both valves such that spurious operation of both valves does not occur simultaneously?

Again, recognizing the interpretation provided in Inspection Plan 64100, should #2 above be the way this scenario is analyzed and addressed?

What is the NRC position on this?

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August 7, 1998

Ledyard B. Marsh
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Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation
Mail Stop 08D1
Washington, DC 20555

Re: **Comments By The Fire Protection Clearinghouse (Clearinghouse) On The Issues Discussed At The Nuclear Regulatory Commissioner's (NRC) Workshop On Post-Fire Safe Shutdown Circuit Analysis**

Dear Mr. Marsh:

This provides comments by the Fire Protection Clearinghouse (Clearinghouse) on the issues discussed at the Nuclear Regulatory Commissioner's (NRC) workshop on post-fire safe shutdown circuit analysis. The members of the Clearinghouse appreciate the opportunity to participate in the exchange of views on this issue. Although the Clearinghouse did not make a presentation at the workshop, we understand that follow-up position papers, like this one, will be considered by the NRC.

As discussed in detail below, the Clearinghouse is heartened by the NRC's willingness to consider risk in determining how to proceed with fire protection requirements. However, the Clearinghouse is concerned that the current reinterpretation of regulatory requirements is continuing without full attention to the disciplined processes which are applicable to any changes in regulatory requirements. NRC reliance on historical events at Browns Ferry, recollections of participants in the rulemaking process for 10 C.F.R. 50.48 and Appendix R to Part 50, and on overconservative interpretations of regulations by some licensees does not substitute for the rigor of the processes which are applicable to reinterpretations of NRC regulations. Of particular concern in this regard is the NRC's apparent unwillingness to follow clear Commission precedent on the exclusion of incredible scenarios when determining regulatory compliance. We hope that the NRC will consider these factors in its follow up actions to the recent workshop.

A review of the statements by the workshop participants at the recent workshop shows that many of the comments, questions, and observations substantially repeated the content of prior interactions between the NRC and industry members. Under these circumstances, the Clearinghouse applauds the NRC's efforts to move forward by focusing on the risk significance of the potential challenges of fire-induced circuit failures. However, the Clearinghouse is concerned that the focus on risk without a concurrent focus on the procedural processes which have been adopted to assure the disciplined consideration of such risk could lead to untoward results. Only if the NRC's processes show that a regulatory response is needed to address those risks should the agency consider taking a regulatory response.

Recent experience suggests that current NRC initiatives on fire protection requirements lack a disciplined, scrutable process for considering risk. In place of a risk-based, transparent process, NRC fire protection regulations and guidance are being reinterpreted selectively to now include new concerns. These new concerns are not found in either the evaluations which initially supported either the NRC's adoption of those regulatory requirements or their subsequent interpretations. Evidence that new positions are being interpreted into the fire protection requirements is provided by the circumstance that the need to consider two hot shorts under specific, highly unlikely circumstances was not included in Generic Letter 86-10 but appears to have first been discussed in an internal NRC memorandum in 1988. Moreover, there is no agreed upon methodology for analyzing any or all spurious operations. Nor has any such methodology been identified by the NRC.

In addition to this rulemaking by reinterpretation, in some cases, imperfect recollections by participants in the NRC's formulation of its requirements appear to be relied on to justify new positions.[1] The inconsistencies among these recollections reinforces the need to subject any new positions on the analysis of circuits in fire conditions to the discipline of either rulemaking or a backfit analysis <u>before</u> those positions are adopted by the NRC. NRC adherence to these processes is not optional but is required in order to obtain a reasoned result.

The Clearinghouse also finds troubling the NRC's persistent harkening back to the fire at Browns Ferry. The lessons learned from that event have been extensively applied over the twenty-three years since it occurred. Therefore, any evaluation of fire risk today must start from the baseline established by implementing the regulatory requirements which the NRC has adopted since 1975. Indeed, the NRC itself has recently taken just such an approach in NUREG-1552, Supplement 1. The current risk of a Browns Ferry type situation involving penetration seals was found to be

---

[1] The Clearinghouse is particularly sensitive to the vagaries of memory because its counsel participated substantially in the processes which led to the adoption of Appendix R, the litigation over Appendix R, and the adoption of Generic Letter 86-10.

minimal because of the lesson learned that water can be used to promptly extinguish an electrical cable fire This and all of the other lessons that have been learned from Browns Ferry and applied by all licensees need to be taken into account in any reference to Browns Ferry as a basis for taking yet additional actions to further enhance fire protection at nuclear power plants.

As a legal and regulatory matter, the Clearinghouse also questions NRC reliance on the circumstance that certain licensees are in "compliance" with the NRC's latest views on the intent of certain fire protection requirements. The fact that a few licenses may have interpreted requirements as consistent with current NRC views does not imply that these views accurately reflect the scope of current regulations and regulatory guidance. Licensees' variability in the interpretations of requirements is well-known That some licensees have interpreted requirements in a way that the NRC now claims is correct does not make those interpretations correct. Licensees have been known to over-commit Moreover, differences in safety margins among licensees is well-known and has been accepted as an unavoidable result of the substantial differences among plant designs.

The Clearinghouse believes that some licensees' interpretations exceed current regulatory requirements and reflect an over-conservative approach to fire protection. Aside from the fact that the NRC agrees with those excessive positions, there is no more basis for the NRC to rely on those interpretations than on the more common, less expansive interpretations of the same requirements by a significant number of other licensees. The NRC must interpret its rules on the basis of the Commission's intentions when those rules were adopted and not rely on selected licensee views

Finally, a review of the history of NRC regulatory philosophy, which was fully in force when the fire protection requirements were adopted, shows that the Commission did not intend licensees to consider the very low probability events which the NRC now expects licensees to include in their analyses for evaluating the effects of fires Although the fire protection rule is deterministic and prescriptive, it is only one of many such deterministic and prescriptive NRC rules The fact that a rule is deterministic and prescriptive does not mean (and never meant) that all possible events needed to be analyzed in order to demonstrate compliance with that rule For example, a cut off was adopted years ago when Class 9 accidents were excluded from consideration Since then, the Commission has consistently refused to consider low probability events A specific Commission application of this regulatory philosophy, which has been upheld in the courts, is provided by the licensing of Diablo Canyon In the licensing proceeding for that plant, the Commission explicitly determined that there was no need to consider low probability events That Commission regulatory framework should be reaffirmed and applied to analyses of fire protection requirements

ATTACHMENT 4

SUMMARY OF KEY MESSAGES EXPRESSED BY STAKEHOLDERS AT THE WORKSHOP ON POST-FIRE SAFE-SHUTDOWN CIRCUIT ANALYSIS HELD ON JULY 23, 1998

1 Judgments of risk and safety significance are largely absent from the NRC's approach to post-fire safe-shutdown circuit analysis, and an objective means of measuring the safety significance of fire-induced circuit failure (FICF) issues will enhance resolution of these issues Spurious actuation from FICFs is not a risk-significant safety issue One speaker expressed the opinion that the existence of nuclear reactor plant conditions severe enough to cause FICFs (ignition source, high heat release combustibles, direct flame impingement on cables for significant periods of time) is rare

2 Various industry representatives recommended a risk-based approach to the fire protection regulation, stating their belief in the capability of "risk tools" to augment deterministic fire analyses It was stated that the establishment of a minimum core damage frequency (CDF) "cutoff" value would indicate when "victory" could be declared with respect to circuit analysis fire safety Another industry representative made the point that risk considerations are already implicit in the fire protection regulation and are explicit in approved exemptions (e.g., safety evaluation wordings such as "the event has a low probability") Some industry representatives suggested that licensees use Regulatory Guide 1 174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Current Licensing Basis," to prioritize circuit analysis related plant design changes. A concern was expressed that the assumptions, bases, and specifications of any new risk-based approach to fire protection may constitute a new licensing basis that is enforceable upon licensees.

3 The answer to Generic Letter (GL) 86-10, Question 5.3.10, supports the position held by some licensees that they need postulate only one spurious component actuation per fire event per fire area.

4 <u>Mechanistic</u> motor-operated valve damage (inability of the valve stem to move) from fire-induced control circuit failure as discussed in Information Notice 92-18 is a change from the NRC's answer to GL 86-10, Question 5 3 1 , which referred to the analytical consideration of "all <u>functional</u> failure states "

5 Except for high-/low-pressure interface components, possible spurious actuations should be analyzed one at a time, not sequentially or with cumulative effects

6 The Brown's Ferry fire showed that cable jacket fires progress slowly so that some systems within a fire-affected area may be available to mitigate a fire event, and that even systems affected by a fire may be successfully used to mitigate a fire event The Brown's Ferry fire experience also indicates that repairs (without procedures prepared in advance) may be successful and that multiple spurious signals may be generated by a fire but have a low safety impact (e g , the operator may mitigate their effects)

7 One speaker stated that he believes that multiple high-impedance faults (MHIFs) will quickly become high-current ("contact") faults, resulting in fast, coordinated fault clearing

8 One workshop speaker stated that "hot short" duration would be limited by conductor grounding to cable trays, or conductor burn- through, or the activation of isolation/protection devices. A number of industry representatives stated that, realistically, circuit faults need not necessarily be assumed to be of long-term duration Further, they stated their belief that there are conceivable situations in which reactor plant circuit analysis shows that time would separate spurious openings of (for example) high-/low-pressure interface valves in series, and that licensees should be allowed to take credit for such analyses. They continued by indicating that possibly some assumed standard time between independent actuations could be identified and/or endorsed by the NRC (even in the cases of control rooms or cable spreading rooms)

[During a question and answer session, the NRC staff stated that its use of the term "simultaneous" in the post-fire safe-shutdown circuit analysis context refers to overlap in the durations of circuit faults and/or spurious actuations, and does not refer to circuit faults and/or spurious actuations that are necessarily initiated at the same moment in time Further, the staff stated that any and all fire-induced spurious actuations or signals resulting from a fire in a given area could occur, but their likelihood to occur simultaneously (initiating at the same moment of time) is low However, since it is not possible to predict when spurious signals or actuations could occur, it is conservative to consider that multiple spurious signals or actuations may exist simultaneously when evaluating the functionality of a required safe shutdown component.]

9 For any given fire area, there were questions regarding which analytical assumptions are necessary for the number of faults per fire-affected conductor, the number of conductors faulted simultaneously within a fire-affected multi-conductor cable the number of simultaneous non-multi-conductor cable electrical conductor faults per fire, the number of simultaneous spurious signals per fire, and the number of simultaneous spurious component actuations per fire Questions were also raised about how analytical assumptions should vary if the components at issue are part of high-/low-pressure interfaces, or if there are differences in the electrical design characteristics of the subject circuits (e g , three-phase ac motor windings, ungrounded dc circuits, or dc control circuitry)

10 One workshop speaker, who served as an industry representative during the development of GL 86-10, stated that the Nuclear Utility Fire Protection Group (NUFPG), with respect to GL 86-10, Section 5 3 10, "Circuit Failure Modes," Section 5 3 2, "Hot Short" Duration," Section 5 3 8, "Short Circuit Coordination Studies," and Section 5.3 10, "Design-Basis Plant Transients," intended only to provide standardized analytical methods to "filter" numerous unnecessary equipment damage sets and shutdown scenarios from the circuit analysis Also, this speaker stated that there was no intent by NUFPG to limit spurious actuations to just one "event" per fire And lastly he stated that there was recognition by NUFPG that a single signal should be taken to its logical conclusion including component damage or multiple actuations

11 Some attendees questioned whether there were test reports that specify the causes, types and modes of circuit failures (MHIFs, three-phase hot shorts, etc.) that can occur in a reactor plant.

12 Numerous requests were made for the NRC to provide detailed circuit analysis assumption and methodology guidance, and to clarify phrases such as "any and all, one at a time," which could have various interpretations (e.g., "any and all combinations of circuit faults acting on one component at a time," or "any and all circuit faults are considered, but only one fault is assumed to be in effect during any specific time interval").

13 An industry representative asked whether post-fire safe-shutdown analyses need to address and mitigate possible situations in which a protected safe-shutdown component may be out of service (e g., in a Limiting Condition for Operation statement) at the time of a postulated fire, which may damage the unprotected redundant component.

14 One participant stated that in light of the Thermo-Lag issue, it is essential that licensees ensure that they have performed adequate circuit analyses

ATTACHMENT 5

VERBATIM LIST OF QUESTIONS, COMMENTS, OPINIONS, AND SUGGESTIONS EXPRESSED BY STAKEHOLDERS AT THE WORKSHOP ON POST-FIRE SAFE-SHUTDOWN CIRCUIT ANALYSIS HELD ON JULY 23, 1998

[NRC CLARIFICATIONS BRACKETED]

Circuit Failure Numerical Credibility

- Is there a general and arbitrary cutoff to the number of circuit faults or failures which should be assumed per fire and/or per fire area?
- How many circuit failures must be considered to occur simultaneously or sequentially per spurious component actuation? 1, 2, 3, 100?
- The issue of boundary isolation valves (two valves in series) has changed from the GL 86-10 era.

Circuit Failure Timing, Duration, and Sequencing/Simultaneity

- What is the time between multiple spurious actuations as a fire progresses? This will affect the time available to take positive actions in response to fire-induced failures. How would one analyze areas such as the control room, containing many thousands of circuits faulting randomly, and in any combination?
- The NRC stated in its presentation that at Brown's Ferry a high number of circuit failures occurred within a "short" period of time. How soon did unexpected or unexplained conditions occur, and how soon did fire suppression occur?
- The NRC stated that analysts need not consider spurious operations occurring simultaneously, but that they should consider multiple spurious operations being in their potentia., problem [problematic] positions during the same time interval [failure states overlapping in time, but not occurring simultaneously]. In terms of pump damage, this would mean [that] the analyst should consider and take action regarding spurious pump run and [concurrent] spurious valve closure. Is this correct? [See Key Message #8 in Attachment 4 for staff input on this important issue].

Circuit Fault Numerical/Combination Credibility

- Do we have to consider in our analysis a hot short (from one conductor) and a short to ground (from another conductor) simultaneously to energize a component?
- How are three normal fire-induced circuit failures materially different from three 3-phase circuit failures of the proper polarity?

- What is the difference between a 3-phase ac circuit failure (which is basically three conductors from one cable connecting with 3 conductors from another cable (three hot shorts), and three hot shorts on three separate cables for three MOVs [motor-operated valves]? Similarly for ungrounded dc circuits Why the distinction for analysis?

- Do the special cases of 3-phase ac circuits and ungrounded dc circuits demonstrate some general limitation on the type and number of circuit failures which are appropriate to be considered?

- For a non-high-/low-pressure interface multiple conductor cable experiencing hot shorts, do we assume that any conductor in the cable can short to any other conductor in the cable?

- For an ungrounded dc circuit, do we assume [that] a positive conductor shorts to one unenergized conductor, while a negative conductor shorts to another unenergized conductor thereby energizing the circuit of the two previously unenergized conductors?

- With respect to slide #16 of the NRC presentation, must we not consider two hot shorts of the proper polarity (on ungrounded dc circuits) resulting from internal cable shorts? This appears to be a change from GL 86-10. Please explain or justify.

- Guidance on high-/low-pressure interfaces. The AEOD [Office for Analysis and Evaluation of Operational Data] report on initiating event frequency indicates the ISLOCA [interfacing systems loss-of-coolant accident] concern is overemphasized Facts: low pressure pipe has an approximate factor of safety of 3. For BWRs [boiling water reactors], low-pressure ECCS [emergency core cooling system] pipe design pressure is 450 psi Thus, the ultimate burst pressure is less than 1200 psi Because BWR operating pressure is approximately 1100 psi, no pipe break will occur (although pressure relief valves may lift, licensee analysis may show the relief flow rate will not interfere with post-fire safe shutdown)

- The NRC's two cases of hot short guidance are insufficient. What about multiple cable-to-cable hot shorts on grounded ac control circuits? Do we assume 1, 2, or more? If a hot short is required on the primary circuit and another hot short on the auxiliary circuit, both are required for spurious actuation Isn't this another low probability of occurrence situation like the ungrounded dc hot short? The NRC should provide guidance on what constitutes an incredible number of faults on grounded ac circuits To assume an unlimited number of hot shorts on multi-conductor cables is not realistic. It goes beyond the credible occurrence of two ungrounded dc hot shorts of proper polarity A possible solution would be to assume one hot short for each component's circuitry In the case of multiple components spuriously actuating because each has spurious cables in a fire-affected area, an acceptable numerical limit should also be defined

Circuit Fault Characteristics Credibility

- The prediction of fire-induced circuit faults should consider the effects of suppression, smoke, and other combustion products
- What is the data on correlating the degree of thermal exposure and the nature of false instrument signals and/or indication readings?
- Have the circuit failures postulated by the rule [Appendix R] been experienced through testing? If so, where and when? Is there a test report available for public review and comment? If licensees must provide technical basis, so should the NRC when postulating modes of circuit failures. Has the NRC considered establishing an expert panel of electrical technical experts to evaluate the technical validity of the NRC's postulated circuit failure modes?
- No one has provided an actual example of a credible cable or conductor failure using IEEE [Institute of Electrical and Electronics Engineers] 383 cable

Circuit Failure Spurious Actuations/Operations

- How many functionally related [simultaneous] spurious component actuations must be considered (2, 3, 4, 5, or an infinite number)? Consider, for example, that significant damage of a plant's electrical distribution system could occur from a certain set of DG [diesel generator] auto starts and breaker closures. Is this a scenario which needs to be considered?
- If the IN 92-18 [Information Notice 92-18] issue of MOV failure is valid from a control power circuit failure perspective (which has happened in testing due to incorrect wiring), then the issue is plausible, fits the current regulation, and the NRC should just issue a paper with an industry time for compliance to ensure safe shutdown can be achieved.
- The NRC staff needs to provide more detailed requirements for associated circuit analysis in the area of MOV damage (limit switch/torque switch) due to a "smart short." The staff has added new or previously ill-defined assumptions. Further, during FPFIs [fire protection functional inspections], the staff should not just note findings against plant-specific analyses. Rather, the staff should offer "staff-acceptable solutions" without violations or enforcement

Circuit Analysis Assumptions and Completeness

- For the phrase "Any at all, one at a time" with respect to a fire in a fire area, does this mean -
    - For each component with fire-affected cables any and all combinations of circuit faults are considered, but only for the spurious actuation of one component at a time, or

- For each component, any and all circuit faults are considered, but only one circuit fault at a time (meaning that if multiple faults are required to cause an actuation, the fault need not be considered)?

- With respect to ECCS System automatic initiation logic, is the one hot short assumption operative except for high/low pressure interfaces?

Multiple High-Impedance Faults (MHIFs)

- Based on Mr Rivera's talk, are multiple high-impedance (arcing) faults (and therefore the tripping of major upstream circuit breaker devices) credible? How does the NRC intend to re-address MHIF based on Mr. Rivera's talk?

Use of PRA [Probabilistic Risk Assessment] /Risk Information

- Is there a risk or safety significance cutoff for fire initiation, fire spread, or fire damage below which analysis is not necessary? How would such a cutoff be reconciled with the deterministic features prescribed in 10 CFR [Part] 50, Appendix R? There has to be a CDF [core damage frequency] number that is so low that the consequences of the accident are irrelevant.

- PRA approaches are currently being considered in the NFPA [National Fire Protection Association] 805 process Have the likelihood of multiple high impedance faults (MHIFs) and "three-phase hot shorts" been considered? Have these scenarios actually been experienced in industry? If so, where and when?

- Safety significance must be a concern. However, the probability of occurrence must also be applied to bring some conclusion or completeness to the analysis.

- Some industry representative seem to want to replace deterministic rules with PSA [probabilistic safety assessment] or PRA numbers. It seems that they have a disconnect between probability and severity.

- A staff comment that "even if probability is very low, if consequences are high you should fix it" suggests lack of understanding of competing issues that need attention at commercial reactor plants If the regulation doesn't explicitly address low probability, it should Continue the focus on safety significance versus literal compliance.

- If the staff is going to pursue the "hot short" issue, it should be done through licensee PSA analysis which is standardized plant to plant, followed by a safety evaluation report stating that licensee safety-significance determinations are acceptable

- PSA seems to be a powerful tool It would be a shame if we were deprived of it to resolve this issue

Risk and Licensing Basis/Enforceability

- Will tools to measure the safety significance (risk) of fire-induced circuit failures encompass inspection finding highlighted configurations currently designated by the NRC as "unacceptable," as well as encompass problems reported by the licensees themselves?

- Would the assumptions, bases, and specifications used to establish proposed risk-based approach to the fire protection regulation constitute a new licensing basis enforceable upon a licensee?

The Brown's Ferry Lessons

- Reactor plants no longer have physical characteristics of the 1975 Brown's Ferry plant since today's plants maintain train separation, have fire-retardant seals and cable jackets, and have cables enclosed in 1-hour and 3-hour fire barriers. Also, administrative controls, fire brigade equipment, and training are better today. Given this, should we not move away from Brown's Ferry (credit subsequent plant design and procedural changes, such as timeliness of suppression with water) and determine what is important now?

Appendix R and Technical Specifications

- Example: One EDG [emergency diesel generator] is out for maintenance under a limiting condition for operation. A fire occurs, damaging the other redundant EDG, and a loss of offsite power occurs. Therefore, an inadequate power supply exists for the conduct of the post-fire safe shutdown. Is this a situation which must be addressed by licensees?

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