Fire Induced Circuit Failure – Technical Issues Resolutions

August 27, 2008

Topics

- Overview
- Proposed Boundaries
- Tools
- MSO List
- Diagrams

Proposed Boundaries

Safe Shutdown Success Path Components – "Green Box"
The reactivity control function shall be capable of achieving and maintaining cold shutdown reactivity conditions. (10 CFR 50, Appendix R, III.L)
The reactor coolant makeup function shall be capable of maintaining the reactor coolant level above the top of the core for BWRs and be within the level indication in the pressurizer for PWRs. (III.L)
The reactor heat removal function shall be capable of achieving and maintaining decay heat removal. (III.L)
The process monitoring function shall be capable of providing direct readings of the process variables necessary to perform and control the above functions. (III.L)
The supporting functions shall be capable of providing the process cooling, lubrication, etc., necessary to permit the operation of the equipment used for safe shutdown functions. (III.L)
Significant diversion paths from flow path – Full flow, bypass
A common power source with the alternative shutdown equipment and the power source is not electrically protected from the post-fire shutdown circuit of concern by coordinated circuit breakers, fuses or similar devices (Generic Letter 81-12)
A common enclosure, e.g., raceway, panel, junction box, with alternative shutdown cables and are not electrically protected from the post-fire shutdown circuits of concern by circuit breakers, fuses or similar devices (Generic Letter 81-12)
Power Supplies

Proposed Boundaries Continued

Components Important to Safe Shutdown – "Orange Box"
Supply tank spurious drain or bypass
RHR type valves, when not part of safe shutdown success path
HVAC Systems
PORVs, SRVs when not part of safe shutdown success path
Spurious start of equipment not relied upon for safe shutdown success path, which could cause overfill conditions
Small diversion paths from flow path – sample lines, instrument taps, drain valves that could not affect safe shutdown success path
A connection to circuits of equipment whose spurious operation will adversely affect the shutdown capability, e.g., RHR/RCS Isolation Valves (Generic Letter 81-12)

Tools

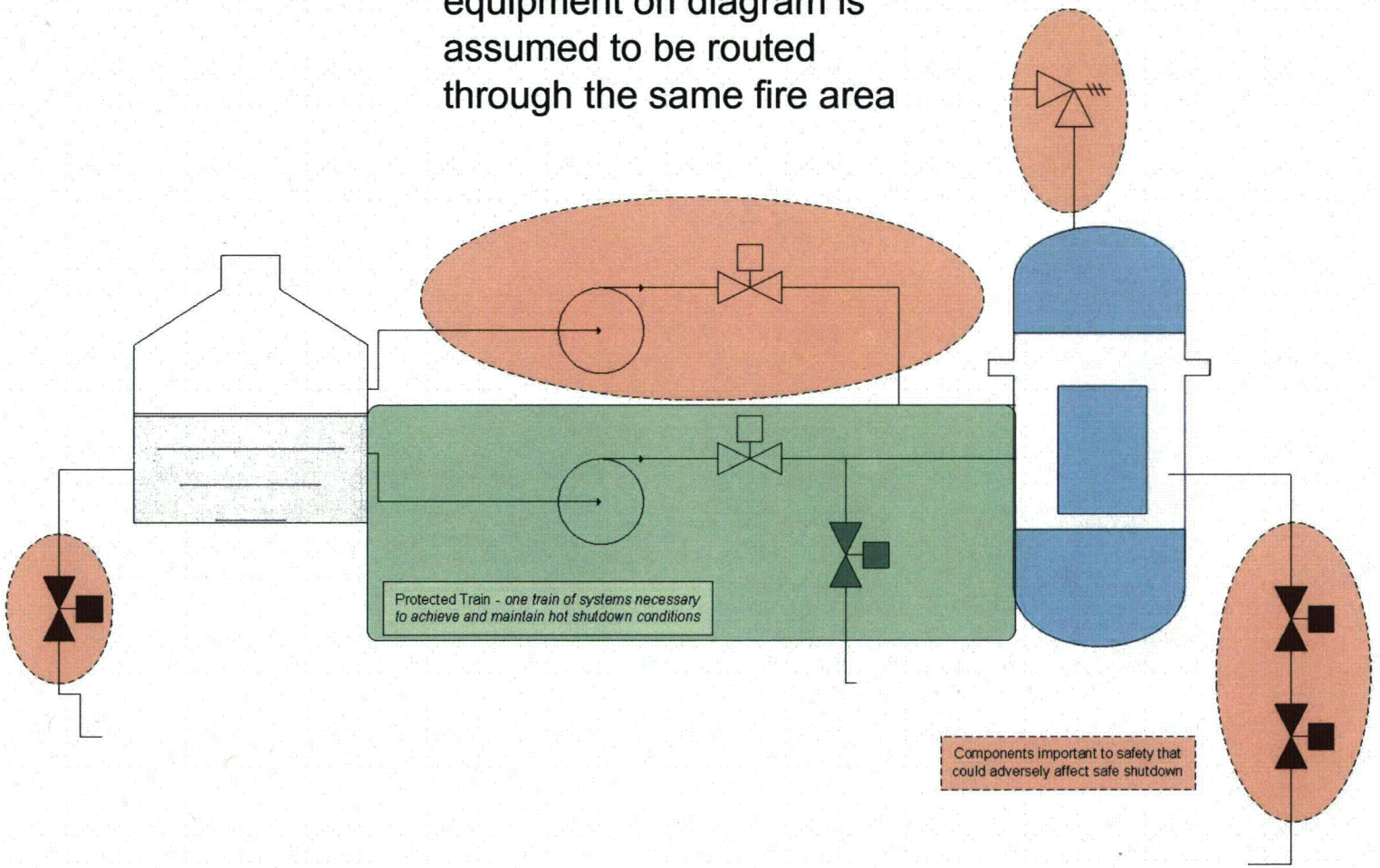
- Safe Shutdown (SSD) Success Path Components "Green Box"
  - III.G type protection
  - Exemption or amendment to use other tools
    - "Orange Box" tools are available and also risk-informed analysis in accordance with R.G. 1.174/1.200
- Components Important to SSD "Orange Box"
  - III.G type protection
  - Feasible/reliable manual actions w/defense-in-depth (DID)
  - Fire modeling analysis w/DID
  - Exemption or amendment to use other tools

Discussion on NEI 00-01, Rev.2 Multiple Spurious Actuation List

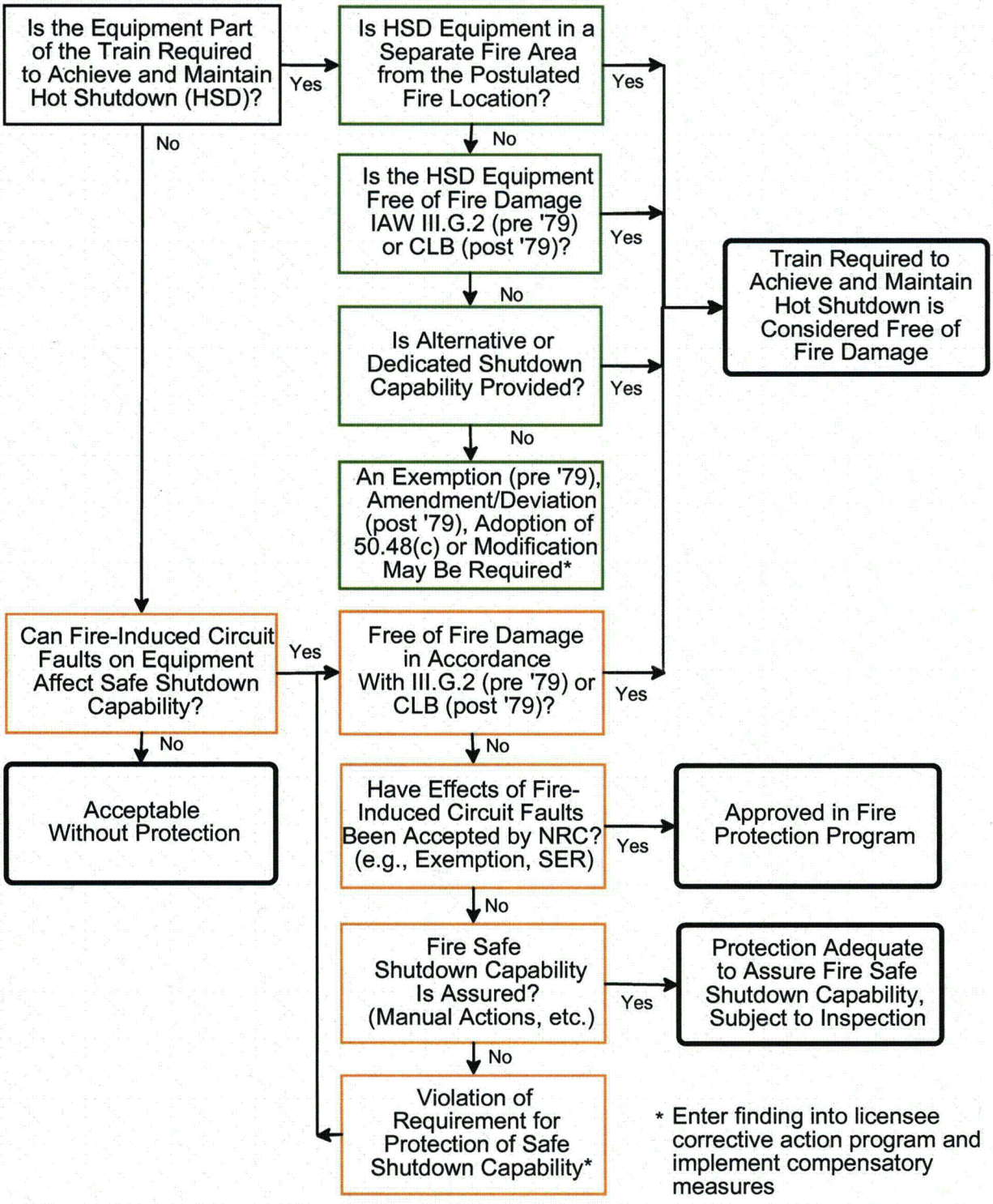
- Consistency between BWR and PWR lists
- Application of lists

Working Diagram

Circuits for all active equipment on diagram is assumed to be routed through the same fire area



Fire-Induced Circuit Failure Compliance Flow Chart



NRC-NEI Meeting on Post-fire Safe Shutdown Methodology

NEI CF ITF

August 27, 2008

Agenda

- NRC Proposal for addressing MSOs
- Industry III.G.1 & III.G.2 Proposal
- Industry III.G.3 Proposal
- Status of NEI 00-01 Revision 2 (a)
- Summary and Conclusion

NRC Proposal

- **Green Box Components**
  - Part of Train required to achieve and maintain post-fire hot shutdown
  - Must meet Appendix R Sections III.G.1, 2, 3 or CLB
- **Orange Box Components**
  - Not part of Train required to achieve and maintain post-fire hot shutdown, but can impact the ability of green box components to perform their safe shutdown function (could mal-operate).
  - Additional mitigation tools can be applied, such as operator manual actions and fire modeling

Industry III.G.1 / III.G.2 Proposal

- NEI CF ITF conceptually agrees with NRC Proposal
  - **Green Box Components** - systems and components required to perform safe shutdown functions (required).
  - **Orange Box Components** – potential to impact required systems and components (Associated Circuits per GL 81-12)

Key Concepts

- Spurious Operations Currently Evaluated on a "One at a Time" Basis
- NRC Position and, to some extent, Cable Fire Tests, suggest "multiple simultaneous failures" need to be considered.
- Industry III.G.1 and 2 Proposal
  - Supplement Current SSA
  - Evaluating "Multiple Simultaneous Failures"
    - Using Chapter 4 Process
    - Appendix B – Circuit Failure Criteria
    - Appendix G – List of Generic MSOs

Key Elements

- Acceptance of the Generic MSO List and the Expert Panel Process
- Addressing the impact of each MSO Scenario individually
- Acceptance of the Industry Approach for classifying Green (required) and Orange (associated circuit) components
- Application of Circuit Failure Criteria detailed in NEI 00-01, Appendix B
- Appropriate use of all Orange Box tools
- Acceptance of Industry's Proposed Treatment of 10 CFR 50 Appendix R, III.G.3 Areas

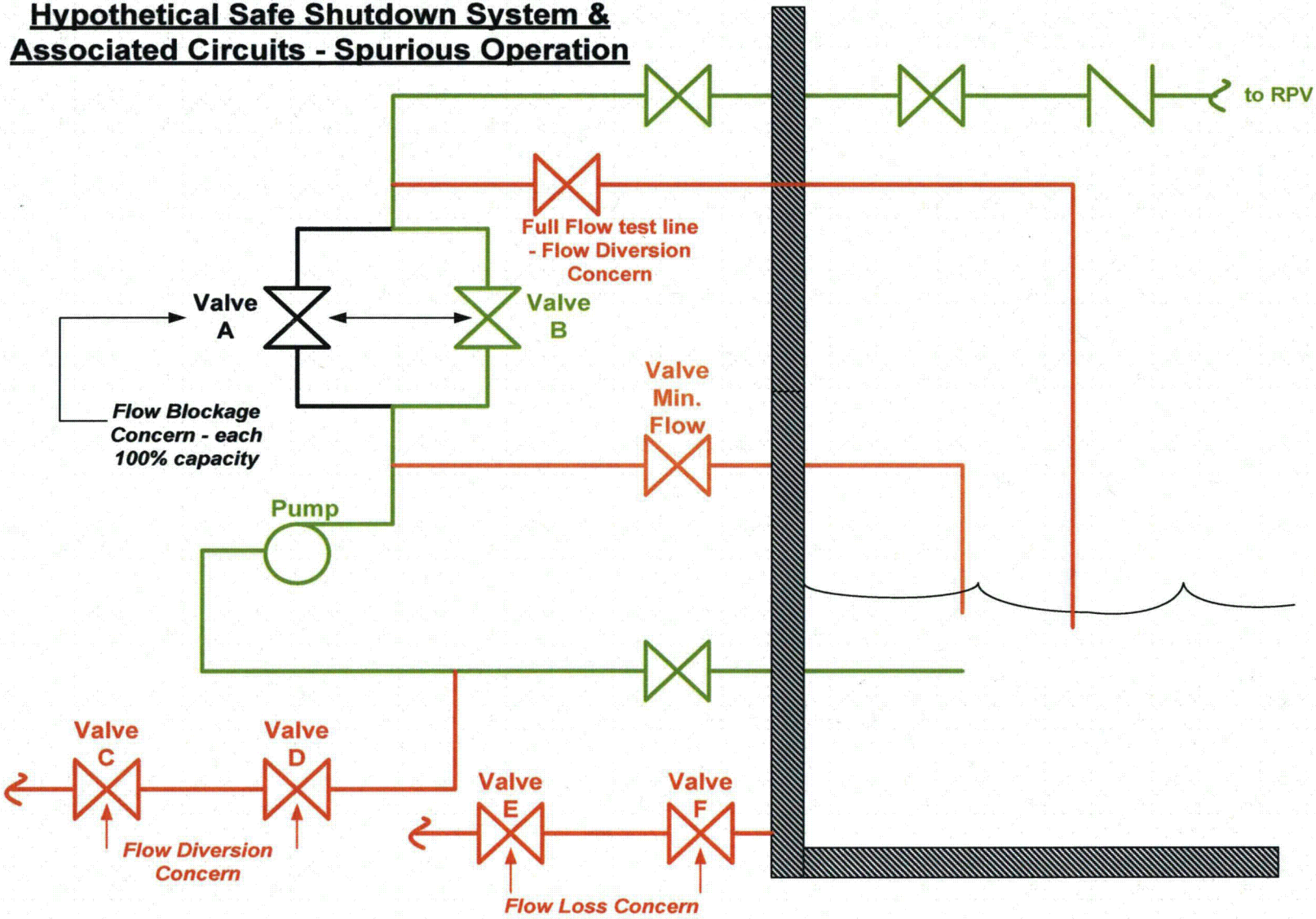
Industry III.G.1 / III.G.2 Proposal

- **All Flow Diversion are** Orange
  - The application of sound engineering principles will dictate where III.G.2 is / is not required.
  - Provides an approach that can be consistently applied and inspected.
    (Technically Sound and Traceable Regulatory Framework)
  - Allows use of additional tools for disposition where technically justified
  - Reduces the number of deviation / exemption requests to permit operator manual actions where determined to be feasible and reliable.

Industry III.G.1 / III.G.2 Proposal

- **Full Flow Test Valve Case**
  - If adequate time or engineering justification does not exist, then III.G.2 mitigation schemes are to be used.
  - If adequate time and engineering justification does exist, Operator Manual Actions may be used to isolate the flow diversion

Hypothetical Safe Shutdown System & Associated Circuits - Spurious Operation

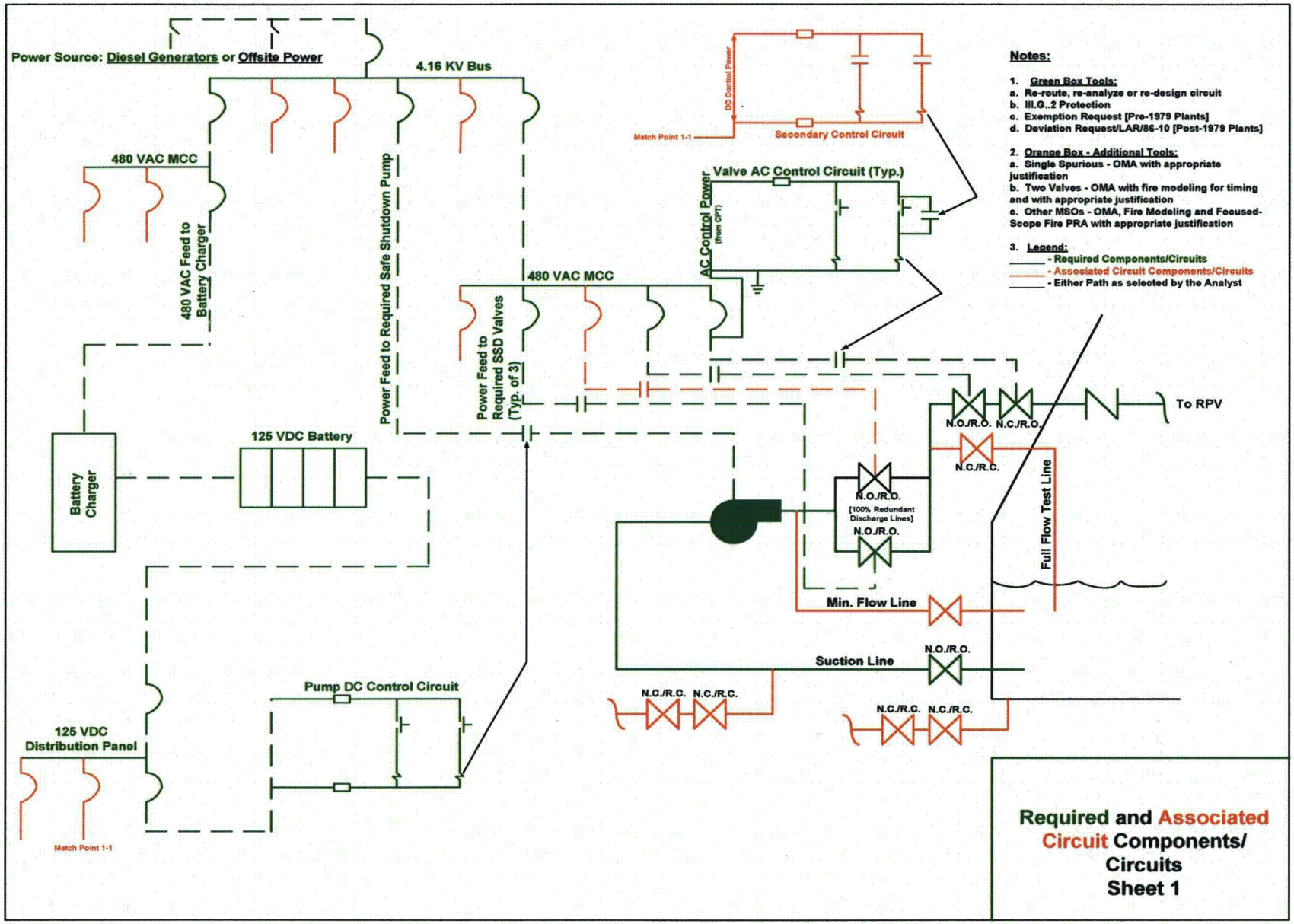


Industry III.G.1 / III.G.2 Proposal

- Process Monitoring Instrumentation provided in Section IX of the enclosure to NRC IN 84-09 will be considered part of the required train.
- HVAC Room Cooling Components are considered associated circuits (Orange Box).
  - Sound engineering principles dictate where III.G.2 is / is not required
  - Engineering analysis is required to determine components important to safe shutdown
- Cooling Water, Lube Oil and Instrument Air Systems required for Safe Shutdown Components are part of the required Train (Green Box).
  (10 CFR 50 Appendix R, III.L.2)

Industry III.G.1 / III.G.2 Proposal

- Electric Power and Control, if necessary, for a Green Box Mechanical Component in the required train is Green.
  - Green Box Boundary extends back to Offsite Power or Diesel Generators
    - Includes Buses, Batteries, MCC / LCC, etc.
- Associated Circuits; Spurious Operations, Common Power Supply and Common Enclosure are Orange
- Electric Power and Control, if necessary, for Orange Box Components are Orange


Power Source: Diesel Generators or Offsite Power
4.16 KV Bus
480 VAC MCC
480 VAC Feed to Battery Charger
Power Feed to Required Safe Shutdown Pump
480 VAC MCC
Power Feed to Required SSD Valves (Typ. of 3)
Valve AC Control Circuit (Typ.)
AC Control Power (from CPT)
DC Control Power
Match Point 1-1
Secondary Control Circuit
Notes:
1. Green Box Tools:
a. Re-route, re-analyze or re-design circuit
b. III.G..2 Protection
c. Exemption Request [Pre-1979 Plants]
d. Deviation Request/LAR/86-10 [Post-1979 Plants]
2. Orange Box - Additional Tools:
a. Single Spurious - OMA with appropriate justification
b. Two Valves - OMA with fire modeling for timing and with appropriate justification
c. Other MSOs - OMA, Fire Modeling and Focused-Scope Fire PRA with appropriate justification
3. Legend:
- Required Components/Circuits
- Associated Circuit Components/Circuits
- Either Path as selected by the Analyst
To RPV
N.O./R.O.
N.C./R.O.
N.C./R.C.
N.O./R.O.
[100% Redundant Discharge Lines]
N.O./R.O.
Full Flow Test Line
Min. Flow Line
Suction Line
N.O./R.O.
N.C./R.C.
N.C./R.C.
N.C./R.C.
N.C./R.C.
125 VDC Battery
Battery Charger
Pump DC Control Circuit
125 VDC Distribution Panel
Match Point 1-1
Required and Associated Circuit Components/ Circuits
Sheet 1

Industry III.G.1 / III.G.2 Proposal (Orange Box Examples)

- Operator Manual Action (OMA) [with hydraulic analysis]
  - Spurious opening of a single full flow diversion valve
- OMA + Fire Modeling
  - Spurious opening of two series flow diversion valves
    - OMA with fire modeling to justify timing
- OMA + Fire Modeling + Focused-Scope FPRA
  - RPV inventory loss through RWCU to Condenser Hotwell
  - HPCI drain down of Suppression Pool to CST
  - Spurious HPCI start with loss of hi level trip

Industry III.G.1 / III.G.2 Proposal

- With respect to a Deterministic Analysis approach,
  - Traditional Fire Protection DID ensures that fire-induced damage to cables is unlikely (defense in depth).
- Existing Safe Shutdown Analysis:
  - Safe Shutdown Analysis (SSA) performed per NEI 00-01, Chapter 3, for single spurious operations have addressed most MSOs.
  - Inclusion in the SSA of generic MSOs, supplemented with an Expert Panel review, would address additional potentially significant MSOs.
- Fire-Induced Hot Shorts,
  - take time to develop, allowing time for operator response
  - have a very limited duration.
  - are not likely to co-exist in separate cables simultaneously.
    - minimizes concerns with multiple hot shorts from multiple cables within a single components control circuitry and between primary and secondary control circuits.

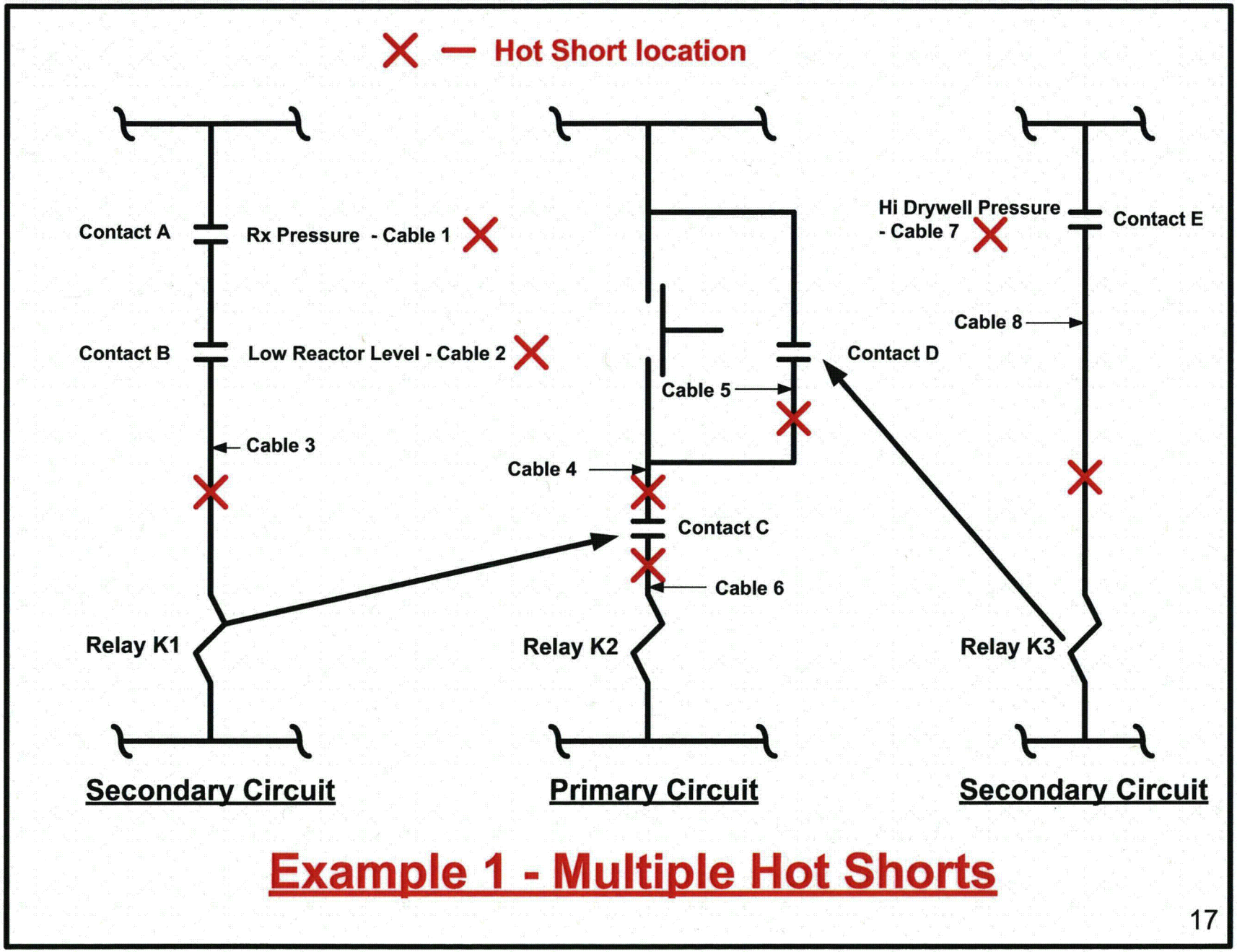
Industry III.G.1 / III.G.2 Proposal

- Cable Fire Test Results:
  - Temperatures in the vicinity of the cable must reach
    - 400 to 500°F for Thermo-Plastic Cables
    - 600 to 700°F for Thermoset Cables
  - Reaching these temperature thresholds does not guarantee a spurious operation
    - Proximity to the fire source is the key parameter in determining the occurrence of spurious operations.
    - Although spurious operations did occur in the testing, concurrent spurious operations in separate multi-conductor cables in the same cable tray in the same test were unlikely.
  - Time is required to reach failure, even at the threshold temperatures.
  - The duration of spurious operations is limited to a few minutes.

Industry III.G.1 / III.G.2 Proposal

- Primary Control Circuits
  - Consider an individual, single hot short on each conductor in each affected cable in the primary circuit
  - Consider the combined effects of hot shorts if conductors are located in the same multi-conductor cable in the primary circuit

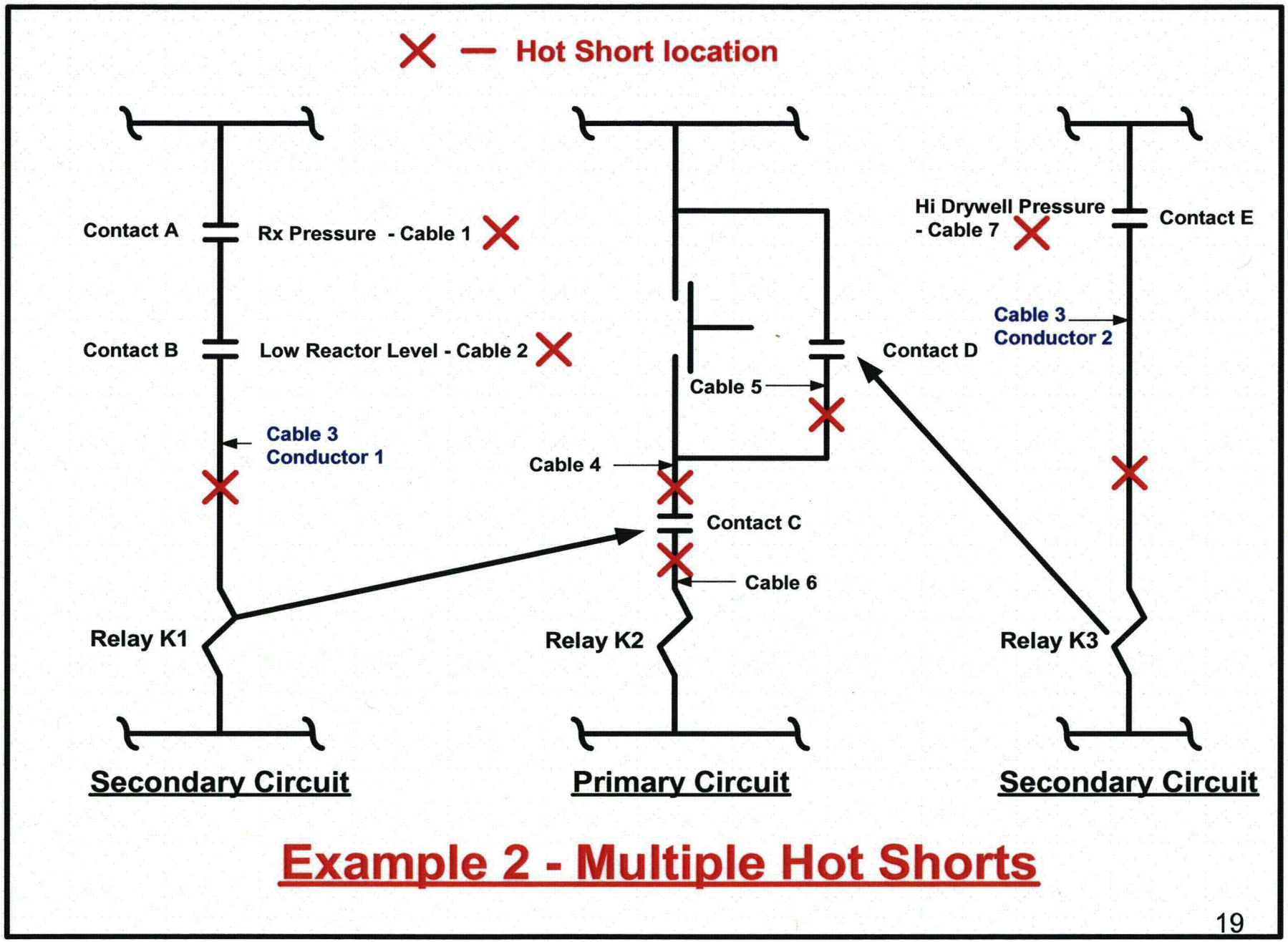
- Secondary Control Circuits
  - Same as primary control circuits
  - Impact to cables in the secondary control circuits do **not** need to be combined with separate cable effects in the primary circuit.



Example 1 - Multiple Hot Shorts

1. **A hot short on Cable 6.**
2. A hot short on Cable 4 in combination with a hot short on Cable 3.
3. A hot short on Cable 4 in combination with a hot short on Cables 1 & 2.
4. A hot short on Cable 5 in combination with a hot short on Cable 3.
5. A hot short on Cable 5 in combination with a hot short on Cables 1 & 2.
6. A hot short on Cable 7 in combination with a hot short on Cable 3.
7. A hot short on Cable 7 in combination with a hot short on Cables 1 & 2.
8. A hot short on Cable 8 in combination with a hot short on Cable 3.
9. A hot short on Cable 8 in combination with a hot short on Cables 1 & 2.

Example 1 - Spurious Operation - Hot Short Combinations



Example 2 - Multiple Hot Shorts

1. **A hot short on Cable 6.**
2. A hot short on Cable 4 in combination with a hot short on Cable 3 – Conductor 1.
3. A hot short on Cable 4 in combination with a hot short on Cables 1 & 2.
4. A hot short on Cable 5 in combination with a hot short on Cable 3 – Conductor 1.
5. A hot short on Cable 5 in combination with a hot short on Cables 1 & 2.
6. A hot short on Cable 7 in combination with a hot short on Cable 3 – Conductor 1.
7. A hot short on Cable 7 in combination with a hot short on Cables 1 & 2.
8. **A hot short on Cable 3 – Conductor 1 in combination with a hot short on Cable 3 – Conductor 2.**
9. A hot short on Cable 3 – Conductor 2 in combination with a hot short on Cables 1 & 2.

Example 2 - Spurious Operation - Hot Short Combinations

Industry III.G.3 Proposal

- Case 1 – Accepted by the NRC in an SER
  - No additional actions are required
  - Considering a voluntary effort using any available assessment tools to evaluate and disposition vulnerabilities
- Case 2 – Changed by the licensee using the Standard Fire Protection License Condition or the 1989 Rule Change
  - Treat the same as III.G.1 and III.G.2 areas

Industry III.G.3 Proposal

- Based on NRC Generic Letter 86-10 – Question 5.3.10
  - Evaluate for single worst-case spurious operation
- Enhancement under consideration
  - Define additional, feasible and reliable, operator manual actions to enhance safety for pre-defined, risk significant scenarios with a reasonable potential of occurrence
    - not based on circuit analysis
    - not subjected to timing considerations/margins

NEI 00-01 Status

- Industry Feedback on proposed method generally positive
- NEI 00-01 revision 2(a) is mostly complete.
  - MSO lists updated based on recent industry expert panels.
  - New Appendix H with Orange Box/Green Box high level discussions.
- Draft planned for September 2008

Summary and Conclusions

- The proposed approach for III.G.1, III.G.2, and III.G.3 is technically sound with a traceable regulatory footprint.
  - Approach addresses results of Industry Cable Fire Tests
  - The overall likelihood of fire-induced spurious operation is low and requires specific characteristics.
- Protection of Equipment Performing Safe Shutdown Functions is assured.
- Actions to mitigate the effects of associated circuits are pre-planned and feasible.
- Low risk and low safety significance issues are appropriately dispositioned.