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1CAN071501

July 21, 2015

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

SUBJECT: 90-Day Response to Request for Additional Information
Adoption of National Fire Protection Association Standard NFPA-805
Arkansas Nuclear One, Unit 1
Docket No. 50-313
License No. DPR-51

Dear Sir or Madam:

By letter dated May 5, 2015 (Reference 2), the NRC requested additional information associated with the Entergy Operations, Inc. (Entergy) request to amend the Arkansas Nuclear One, Unit 1 (ANO-1) Technical Specifications (TS) and licensing bases to comply with the requirements in 10 CFR 50.48(a), 10 CFR 50.48(c), and the guidance in Regulatory Guide (RG) 1.205, "Risk-Informed Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants." The amendment request followed Nuclear Energy Institute (NEI) 04-02, "Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program under 10 CFR 50.48(c)." This submittal described the methodology used to demonstrate compliance with, and transition to, National Fire Protection Association (NFPA) 805, and included regulatory evaluations, probabilistic risk assessment (PRA), change evaluations, proposed modifications for non-compliances, and supporting attachments.

Based on the complexity of the questions included in the Reference 2 letter, the NRC established response due-dates of 30, 60, 90, or 120 days, from the date of the ANO-1 NFPA 805 Audit Exit Meeting, April 23, 2015. Responses to the 30-day and 60-day RAIs were included in References 3 and 4, respectively. One 60-day RAI (SSA RAI 02) was included in the 30-day response and two 90-day RAIs (FM RAI 03 and PRA RAI 02.c) were included in the 60-day response. Enclosed are responses to the remaining 90-day RAIs.

Changes or additional information, as detailed in this letter, with respect to the original Entergy request (Reference 1) have been reviewed and Entergy has determined that the changes do not invalidate the no significant hazards consideration included in the Reference 1 letter.

In accordance with 10 CFR 50.91(b)(1), a copy of this application is being provided to the designated Arkansas state official.

No new commitments have been identified in this letter.

If you have any questions or require additional information, please contact Stephenie Pyle at 479-858-4704.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on July 21, 2015.

Sincerely,

ORIGINAL SIGNED BY JEREMY G. BROWNING

JGB/dbb

Attachment: 90-day Responses to Request for Additional Information – ANO-1 Transition to NFPA-805

REFERENCES:

1. Entergy letter dated January 29, 2014, *License Amendment Request to Adopt NFPA-805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)* (1CAN011401) (ML14029A438)

2. NRC letter dated May 5, 2015, *Arkansas Nuclear One, Unit 1 – Request for Additional Information Regarding License Amendment Request to Adopt National Fire Protection Association Standard 805* (TAC No. MF3419) (1CNA051501) (ML15091A431)

3. Entergy letter dated May 19, 2015, *Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (1CAN051501) (ML15139A196)

4. Entergy letter dated June 16, 2015, *60-Day Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (1CAN061501) (ML15167A503)

cc: Mr. Marc L. Dapas
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Attachment 1 to

1CAN071501

90-day Responses to Request for Additional Information
ANO-1 Transition to NFPA-805

90-DAY RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
ANO-1 Transition to NFPA-805

By letter dated May 5, 2015 (Reference 2), the NRC requested additional information associated with the Entergy Operations, Inc. (Entergy) request (Reference 1) to transition the Arkansas Nuclear One, Unit 1 (ANO-1), fire protection licensing basis to National Fire Protection Association (NFPA) Standard NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)*. Included below are Entergy responses to all questions requiring a 90-day response with respect to the *request for additional information* (RAI) (Reference 2) which have not been previously submitted.

Fire Protection Engineering (FPE)

Note: Responses to FPE RAIs 02, 03, 05, and 08 were provided in Entergy's 30-day letter (Reference 3). Responses to FPE RAIs 01, 04, and 06 were provided in Entergy's 60-day letter (Reference 4).

FPE RAI 07

The regulations at 10 CFR 50.48(c)(2)(vii) state, in part, that licensees who wish to use performance-based methods for fire protection program (FPP) elements and minimum design requirements of NFPA 805 Chapter 3, shall submit a request that: (a) Satisfies the performance goals, performance objectives, and performance criteria specified in NFPA 805 related to nuclear safety and radiological release; (b) Maintains safety margins; and (c) Maintains fire protection defense-in-depth (DID) (fire prevention, fire detection, fire suppression, mitigation, and post-fire safe shutdown capability). Attachment L of the LAR contains Entergy's requests for approval of performance-based methods utilized to satisfy certain requirements in NFPA 805 Chapter 3.

a) For all the LAR Attachment L performance-based method approval requests, the licensee described the three echelons of DID as: 1) to prevent fires from starting (combustible/hot work controls), 2) rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans), and 3) provide adequate levels of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire-rated cable, success path remains free of fire damage, recovery actions). Please discuss how DID is maintained with respect to the items described for each echelon.

b) In LAR Attachment L, pages L-1 through L-5, the licensee requested approval for deviation from the prescriptive requirements of NFPA 805, Section 3.2.3(1) to use the performance-based method contained in Electric Power Research Institute (EPRI) Technical Report TR-1006756, Fire Protection Surveillance Optimization and Maintenance Guide, Final Report, July 2003, to establish inspection, testing, and maintenance frequencies for fire protection systems and features required by NFPA 805 for ANO-1. Please clarify the scope of the approval request to identify the specific fire protection systems and features that are applicable (e.g., existing fire protection systems, components, and features such as fire detection systems, gaseous fire

suppression systems, water-based fire suppression systems, fire pumps, water supply tanks and fire water distribution systems, fire walls, fire extinguishers, etc.) and indicate whether the application of the approval request will apply to any new fire protection systems, components, or features not yet constructed or installed.

c) In LAR Attachment L, pages L-8 to L-9, the licensee requested the approval for deviation from the requirement of NFPA 805, Section 3.3.5.1, that "Where installed, electrical wiring shall be listed for plenum use, routed in armored cable, routed in metallic conduit, or routed in cable trays with solid metal top and bottom covers." ANO-1 has installed electrical wiring above suspended ceilings which is not listed for plenum use, routed in armored cable, routed in metallic conduit, or routed in cable trays with solid metal top and bottom covers. In the basis for request, please describe any fire protection features (e.g., barriers, detection and suppression systems) available above the suspended ceiling and clarify that the existing administrative controls will ensure that the requirements of NFPA 805, Section 3.3.5.1 are met for future installations above suspended ceilings.

d) In LAR Attachment L, pages L-11 to L-12, the licensee requested the approval for deviation from the requirement of NFPA 805, Section 3.3.5.2, which states that "only metal tray and metal conduits shall be used for electrical raceways." The licensee stated that by procedure, "Underground concrete encased conduits, sizes three (3) inches and larger shall be of an approved heavywall ABS or Schedule 40 PVC [polyvinyl chloride]," and that "Slab and wall embedded conduits three (3) inches and larger shall be Schedule 40 PVC or rigid steel..." Please clarify that this approval request is limited to the existing PVC conduits that are currently installed and that administrative controls will ensure that the requirements of NFPA 805, Section 3.3.5.2 will be met for future installations.

e) In LAR Attachment L, pages L-16 to L-20, the licensee requested the approval for deviation from the requirement of NFPA 805, Section 3.5.3 to allow the use of 4160 Volts alternating current (VAC) electric fire pump motor and 4160 VAC electric fire pump controller (Fire Pump P-6A), which are not Underwriters Laboratories, Inc. (UL) listed for fire protection. The licensee also requested the approval for the diesel engine fire pump (Fire Pump P-68), which does not list or identify a certification for the batteries and the battery charger discharge rate of the lead acid batteries. Please provide the following information:

   i. Pump P-68, describe what "certified by the vendor for fire pump services" (page L-18 of the LAR) for Pump P-68 controller sub-component means with respect to: (a) assuring that the sub-component will perform its intended functions; (b) any impact of using unlisted sub-component on achieving automatic sequenced start functions of the fire pump; and (c) any impact of the unlisted sub-component(s) on the performance of the fire pump to start in the event of failure of the lead pump or that the sub-component will not prevent subsequent pump from starting.

   ii. For Pump P-6A, describe the significance of using non-UL listed pump controllers or components on the reliability and availability of intended sequence start/stop sequence, including the indication of local and remote pump conditions and describe whether the non-UL listed controller presents any challenges to the compliance with NFPA 805, Sections 3.5.6 and 3.5.9 (e.g., start/stop requirements between lead and subsequent fire pumps and indication of operations).

f) In LAR Attachment L, pages L-21 to L-23, the licensee requested the approval for deviation from the requirement of NFPA 805, Section 3.5.16 for the use of the ANO-1 fire protection water supply system for purposes other than fire protection water supply. Exception No. 1 to NFPA 805 Section 3.5.16 states that fire protection water supply systems shall be permitted to be used to provide backup to nuclear safety systems, provided the fire protection water supply systems are designed and maintained to deliver the combined fire and nuclear safety flow demands for the duration specified by the applicable analysis. NFPA 805, Section 3.5.10, states that an underground yard fire main loop, designed and installed in accordance with NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, shall be installed to furnish anticipated water requirements, which domestic service (non-fire protection) use is prohibited.

   i. Please clarify if the approval request should also include a deviation from the requirements of NFPA 805 Section 3.5.10, which states that the underground yard fire main loop is designed and installed in accordance with NFPA 24.

   ii. Please describe the design and licensing bases to demonstrate that the configuration and system interfaces of using the temporary pump will not degrade or impact reliability and availability of the fire water supply system for fire protection, including the following:

      1. Please describe the temporary pump design capacity (e.g., rated flow and pressure - 2000 gallons per minute (gpm) at 125 pounds per square inch (psi)), required flow and pressure for auxiliary cooling, any system operating limits (i.e., maximum operating pump pressure), and anticipated maximum duration for using the temporary pump;

      2. Please describe how the combined fire and auxiliary cooling demand, flow and pressure, are within the performance of the fire pumps P-6A and P-68;

      3. Please describe how the temporary pump design, performance, and system configuration will affect the intended performance of fire pumps P-6A and P-68, including whether the fire pumps will automatically start upon actuation of a water-based fire suppression system(s);

      4. Please clarify whether the temporary pump (not listed for fire protection), when in-use, will serve as the primary pump for the fire water supply system to meet the fire protection supply requirements because fire flows and pressures of the water-base fire suppression systems could be met by temporary pump in lieu of the fire pumps.

   iii. Please discuss how the use of the temporary pump, which is not listed for fire protection use, will affect compliance with other sections of NFPA 805 Chapter 3, which require the use of a listed fire pump (for example, in LAR Attachment A, Section 3.5.2, the licensee stated that fire water is supplied by two fire pumps located in the intake structure), and determine if other deviations from NFPA 805 Chapter 3 will be needed when this temporary pump is in-use.

Response

a) *NFPA 805 Section 3.2.3(1) – EPRI TR-1006756*

DID Echelons

1) Prevent fires from starting (combustible/hotwork controls)

   Maintenance and testing frequency changes to fire protection features do not impact the likelihood of a fire starting. Administrative fire protection controls will remain unchanged when utilizing performance-based methods to establish the appropriate inspection, testing, and maintenance frequencies for fire protection systems and features. EN-DC-161, "Control of Combustibles," and EN-DC-127, "Control of Hot Work and Ignition Sources," are used to help prevent fires from starting. Therefore, DID Echelon 1 is maintained.

2) Rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans)

   Use of performance-based methods established in accordance with EPRI TR-1006756 combined with the monitoring program specified in NFPA 805, Section 2.6, will ensure the availability and reliability of the fire protection systems and features credited for detecting, controlling, and extinguishing fires. Therefore, DID Echelon 2 is maintained.

3) Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire rated cable, success path remains free of fire damage, recovery actions).

   Use of performance-based methods established in accordance with EPRI TR-1006756 will not alter the design of the fire protection systems and features credited for providing an adequate level of fire protection for systems and structures. Therefore, DID Echelon 3 is maintained.

NFPA 805 Section 3.3.3 – Epoxy floor coating

DID Echelons

1) Prevent fires from starting (combustible/hotwork controls)

   The epoxy floor coating is considered a slight contributor to combustible loading in its finished state as a hardened floor covering. EN-DC-161, "Control of Combustibles," and EN-DC-127, "Control of Hot Work and Ignition Sources," are used to help prevent fires from occurring in all areas of the plant, including those with epoxy floor coverings. Therefore, DID Echelon 1 is maintained.

2) Rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans)

   The epoxy floor covering does not physically interact with systems or equipment required to detect, control and extinguish fires. The epoxy floor coatings of the type utilized at ANO do not present a primary fire hazard, will not propagate fire from one fire area to another, and will not exacerbate the severity of a compartment fire. Therefore, the fire detection, suppression, and response is unaffected and DID Echelon 2 is maintained.

3) Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire rated cable, success path remains free of fire damage, recovery actions).

   The epoxy floor coating does not degrade or otherwise affect fire protection for systems and structures. Current fire barriers, fire rated cable, success paths, and recovery actions are unaffected. Therefore, DID Echelon 3 is maintained.

NFPA 805 Section 3.3.5.1 – Plenum wiring

DID Echelons

1) Prevent fires from starting (combustible / hot work controls)

   The non-listed video/communication/data cables that are routed above suspended ceilings are considered in-situ fire loading for purposes of combustible loading evaluations. The cables are low energy and not susceptible to hot shorts. EN-DC-161, "Control of Combustibles," and EN-DC-127, "Control of Hot Work and Ignition Sources," are used when working in the plant including the areas with cables installed above ceilings. Therefore, DID Echelon 1 is maintained.

2) Rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans)

   The non-listed cables that are routed above suspended ceilings do not physically or electrically interact with systems or equipment required to detect, control, and extinguish fires. Therefore, DID Echelon 2 is maintained.

3) Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire rated cable, success path remains free of fire damage, recovery actions).

   The non-listed cables that are routed above suspended ceilings do not degrade or otherwise affect fire protection for systems and structures. Current fire barriers, fire rated cable, success paths, and recovery actions are unaffected. Therefore, DID Echelon 3 is maintained.

NFPA 805 Section 3.3.5.2 – PVC conduit

DID Echelons

1) Prevent fires from starting (combustible / hot work controls)

   The PVC conduit installed at ANO is embedded in concrete within the power block or within underground duct banks that consist of a grouping of PVC conduits surrounded by concrete. The PVC conduit is not subject to flame or heat impingement from an external source which would result in structural failure, contribution to fire load, or damage to circuits based on configuration (i.e., not exposed). EN-DC-161,"Control of Combustibles," and EN-DC-127, "Control of Hot Work and Ignition Sources," are used when working in areas with PVC conduits if the PVC is susceptible to flame or heat impingement. Therefore, DID Echelon 1 is maintained.

2) Rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans)

   The PVC conduits embedded in concrete or located in duct banks do not physically interact with systems or equipment required to detect, control, and extinguish fires. Therefore, DID Echelon 2 is maintained.

3) Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire rated cable, success path remains free of fire damage, recovery actions).

   The PVC conduits embedded in concrete or located in duct banks do not degrade or otherwise affect fire protection for systems and structures. Current fire barriers, fire rated cable, success paths, and recovery actions are unaffected. Therefore, DID Echelon 3 is maintained.

NFPA 805 Section 3.3.12(1) – RCP oil collection system

DID Echelons

1) Prevent fires from starting (combustible / hot work controls)

   The control of hot work (procedure EN-DC-127) activities ensures that any hot work in the Reactor Coolant Pump (RCP) areas will include a hot work fire watch and necessary controls for preventing fires (i.e., inspection of hot work area). The oil historically released as misting does not account for an appreciable heat release rate, or accumulation near potential ignition sources or non-insulated reactor coolant piping. Therefore, DID Echelon 1 is maintained.

2) Rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans)

   The ability to detect and suppress a fire in the Reactor Building cavities is unchanged by potential oil misting or the configuration of the RCP oil collection system. The type of fire anticipated in the Reactor Building cavities is unchanged given the existing lube

oil quantities within the RCP motor reservoirs. The manual hose stations are located outside the Reactor Building cavities and are unaffected by the RCP oil collection system. Fire extinguishers are installed in the Reactor Building during refueling outages to provide extra fire suppression capabilities during work activities. Therefore, DID Echelon 2 is maintained.

3) Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire rated cable, success path remains free of fire damage, recovery actions).

   The RCP oil collection system does not result in degradation of the level of fire protection for systems or structures. The Reactor Building outer wall is the 3-hour rated fire barrier for the Reactor Building. RCP oil misting does not affect fire barriers given the oil mist will not come into contact with the Reactor Building fire barrier. The Reactor Building has two analysis areas separated north to south by the primary shield wall. Ignition of RCP oil in either cavity will not result in the spread of fire from one cavity to the other cavity. The RCP oil mist will not degrade fire rated cable or affect any success paths. There are no recovery actions in the area of the RCPs. The location of the RCPs and the location of the oil mist do not affect the function of equipment credited to meet any of the nuclear safety performance criteria. Therefore, DID Echelon 3 is maintained.

NFPA 805 Section 3.5.3 – Fire pumps

DID Echelons

1) Prevent fires from starting (combustible / hot work controls)

   The function of the fire pumps/motors is not to prevent fires from starting. From a combustible loading perspective the fire pumps/motors and associated controls are considered in-situ combustibles. The exposed part of the fire pumps/motors are standard construction which are mostly non-combustible. The lack of transient combustibles limits the possibility of a fire from starting. EN-DC-127, Control of Hot Work and Ignition Sources, is utilized when working in areas with the fire pumps/motors. Therefore, DID Echelon 1 is maintained.

2) Rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans)

   The fire pumps/motors physically interact with systems or equipment required to control and extinguish fires. The fire pumps/motors do not physically interact with systems or equipment required to detect fires. The fire pumps, controllers, and motors are part of the configuration of the firewater supply system. Historical evidence and procedural testing requirements have shown that the 4160 VAC electric motor, electric fire pump, and electric fire pump controller configuration used at ANO, while not in explicit agreement with the code requirement for a UL Listing, meets the intent of electrically driven fire pump design size, type, and function. No issues have been identified in association with past diesel fire pump tests, specifically with battery problems related to the rectifiers or battery discharge that would prevent the engine from starting. The vendor manual for the diesel engine fire pump controller states that

this equipment is UL Listed and FM Approved for fire service. The diesel fire pump meets the demands for the fire protection water supply system. As such the code deviation has no adverse impact on the control and extinguishing aspects of DID. Therefore, DID Echelon 2 is maintained.

3) Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire rated cable, success path remains free of fire damage, recovery actions).

   The code deviation for fire pumps, controllers, and motors does not degrade or otherwise affect fire protection for systems and structures. Current fire barriers, fire-rated cable, success paths, and recovery actions are unaffected. Therefore, DID Echelon 3 is maintained.

NFPA 805 Section 3.5.16 – Fire supply system for non-fire use

DID Echelons

1) Prevent fires from starting (combustible / hot work controls)

   The use of the fire water supply system for non-fire use may require the installation of temporary hoses from the selected connection point on the fire header to the equipment that is to be connected. The temporary combustibles are subject to the transient combustible limits stated in EN-DC-161, “Control of Combustibles.” EN-DC-161,”Control of Combustibles,” and EN-DC-127, “Control of Hot Work and Ignition Sources,” are utilized when working in areas with the non-fire water temporary connections. Therefore, DID Echelon 1 is maintained.

2) Rapidly detect, control and extinguish fires that do occur thereby limiting damage (fire detection systems, automatic fire suppression, manual fire suppression, pre-fire plans)

   The fire water piping system physically interacts with systems or equipment required to control and extinguish fires. The fire water piping system does not physically interact with systems or equipment required to detect fires. The use of the temporary pump will maintain the fire water system pressurized in the event the fire water system is needed to extinguish a fire. The main fire pumps are available and will start if the fire water system pressure parameters are met (i.e., low pressure auto-start). The temporary loads are manually isolated in the event of a confirmed fire. The temporary pump maintains pressure and a higher flow than the installed jockey pump on the firewater supply system and as such does not have an adverse impact on the control and extinguish aspects of DID. Therefore, DID Echelon 2 is maintained.

3) Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed (fire barriers, fire rated cable, success path remains free of fire damage, recovery actions).

   The temporary configuration that utilizes the fire water system for non-fire use does not degrade or otherwise affect fire protection for systems and structures. Current fire barriers, fire rated cable, success paths, and recovery actions are unaffected. Therefore, DID Echelon 3 is maintained.

b) EPRI Technical Report TR-1006756 may be used to establish inspection, testing, and maintenance frequencies for the following fire protection systems and features:

- Detection and Alarm Systems
- Fire Suppression Systems
- Water Supply, Hydrants and Valves
- Fire Pumps
- Standpipes, Hose Stations and Hoses
- Fire Barriers
- Portable Fire Extinguishers

The application of the approval request will apply to any new fire protection systems, components, or features not yet constructed or installed as well as existing systems.

c) The ANO-1 Main Control Room (MCR) utilizes a Halon suppression system in the suspended ceiling. The Halon system consists of two separate fire extinguishing units that discharge Halon to the MCR ceiling and the Auxiliary Control Room ceiling upon automatic actuation of smoke detectors or manual actuation. When two smoke detectors (one in each string) in the system actuate, a solenoid valve is energized that releases nitrogen to the pilot header. This nitrogen actuation pressure triggers the pilot Halon cylinder. Halon is released to the discharge header and discharged through nozzles to the fire area. Local manual actuation may be accomplished by releasing the manual actuator on the pilot cylinder. Remote manual actuation may be accomplished by using the appropriate zone module's manual actuation switch on the C-463 panels in the MCR. This action energizes the solenoid valve on the nitrogen bottle. Automatic or manual actuation is annunciated on C-26.

The remaining office areas with suspended ceilings contain smoke detectors, with the exception of the Decon (decontamination) Room. Manual fire extinguishers and/or hose reels are available in the Decon Room.

The administrative controls for controlling the types of cables installed in ceilings are contained in OP-6030.109, "Installation of Electrical Cable and Wire." This procedure has been revised to include requirements specific to NFPA 805 regarding cables installed in plenum areas (false ceilings).

d) The approval request for NFPA 805, Section 3.3.5.2, is for currently installed PVC conduits in the applicable areas. Procedure OP-6030.112, "Installation of Raceway Systems," will be revised as part of NFPA 805 implementation (reference LAR Table S-2, Item S2-6) to define which areas are applicable for only using rigid steel conduit.

e)i(a) The P-6B fire pump controller subcomponents (battery charger, relays, etc.) are certified by the vendor for fire pump services. The ability that the subcomponent will perform its intended function is proven by historical evidence and procedural testing. See table below.

Monthly tests that demonstrate functionality of the diesel (P-6B) fire pump, along with quarterly vibration tests, are performed in accordance with procedure OP-1104.032, "Fire Protection Systems," Supplement 2. The following tests are performed for both fire pumps every 18 months in accordance with OP-1104.032, Supplement 8:

- Functional and Capacity
- Shutoff Head
- 100% Capacity and Valve Setpoint
- 150% Capacity
- Controls and Alarms
- Full Actuation

The following routine maintenance activities are performed at the designated frequency:

Maintenance Activity	**Test Procedure**	**Frequency**
P-6B engine and gear oil check	OP-1107.001 Supplement 7	Bi-Weekly
P-6B Inspection	OP-1306.027	Semi-Annually Annually
P-6B engine surveillance	OP-1307.004	Biannually
P-6A & P-6B Disassembly, Inspection and Reassembly	OP-1402.062	Corrective Maintenance – No Frequency
P-6B engine batteries (D08 and D09) and battery charger maintenance	OP-1307.001 Supplement 1 Supplement 2 Supplement 3	Weekly Quarterly 18 Month

e)i(b) In review of ANO documents, no issues were identified in association with past diesel fire pump tests, specifically with battery problems related to the rectifiers or battery discharge that would prevent the engine from starting. Although the pump controller and battery configuration does not meet NFPA 20 (1969), Section 626d.e2 and 626d.e5 requirements, the vendor manual (reference TDK131 0020) for the diesel engine fire pump controller states that this equipment is UL Listed and FM Approved for fire service. The diesel fire pump meets the demands for the fire protection water supply system.

e)i(c) The diesel fire pump start circuitry does not interface with the electric fire pump start circuitry. The diesel fire pump starts automatically if system pressure drops to 90 psig or if AC power is lost to the control cabinet. The ability of the diesel fire pump to start with the unlisted sub-components has been discussed in sub-sections (a) and (b) above. There is no impact on pump motor performance based on unlisted sub-components.

e)ii. The electric fire pump controls and components are composed of standard electric components. The functionality of the control circuits are routinely tested (see below) which illustrate that the non-UL listed pump controllers or components do not affect the reliability or availability of the electric fire pump. The electric fire pump is configured with automatic start / manual stop, and the operating status of the pump is located on the local panel and in the MCR. The functionality of the electric fire pump is verified using routine tests and maintenance activities.

Monthly tests that demonstrate functionality of the electrical (P-6A) fire pump, along with quarterly vibration tests, are performed in accordance with procedure OP-1104.032, Supplement 1. The following tests are performed for both fire pumps every 18 months in accordance with OP-1104.032, Supplement 8:

- Functional and Capacity
- Shutoff Head
- 100% Capacity and Valve Setpoint
- 150% Capacity
- Controls and Alarms
- Full Actuation

Based on the functionality testing and maintenance activities it is concluded that the use of non-UL listed pump controllers and components has an insignificant effect on the reliability and availability of pump start/stop sequence and associated indications.

f)i. NFPA 805, Section 3.5.10, states that an underground yard fire main loop, designed and installed in accordance with NFPA 24, “Standard for the Installation of Private Fire Service Mains and Their Appurtenances,” shall be installed to furnish anticipated water requirements. The ANO fire protection underground fire main loop meets the requirement of NFPA 805, Section 3.5.10, without any deviation associated with the use of domestic water. The prohibition of domestic service is associated with the use of hydrants and hose for purposes other than fire-related services. A deviation from NFPA 805, Section 3.5.10, is therefore not required.

f)ii.1. The temporary pump is rated for 2000 gpm at 120 psi (reference ER-ANO-1999-1909-008). The normal auxiliary flow is for the ANO-1 Control Room chillers. The required flow is 270 gpm (reference drawing M-221, Sheet 1) and the normal flow outlet is to the discharge flume (reference drawing M-211, Sheet 1). The maximum operating temporary pump pressure is 154 psig (reference EC-27142). The anticipated maximum duration for using the temporary pump can be conservatively assumed to be equal to the length of the associated outage. A typical outage without any major equipment maintenance/replacement is approximately 30 to 45 days.

f)ii.2. The fire water system has been hydraulically modeled (reference EC-20945) to verify design pressure (65 psig) and flow (100 gpm) from P-6A or P-6B for various configurations. The model has the capability to set demands for flow rates at hydrants and hose reels throughout the model. The model has been utilized to evaluate various water loads requested by temporary modifications during outage when the normal cooling source (i.e., auxiliary cooling water) is out of service. The calculation of the

impact of non-fire loads combined two larger temporary loads to create a worst case scenario. The worst case scenario used a total of 700 gpm for temporary cooling load and three hose reels discharging rated flows of 100 gpm. The lowest calculated pressure at a hose reel was 95.67 psig, which bounds the design requirement of 65 psig. The fire pumps (P-6A and/or P-6B) easily maintain design parameters for the fire system with temporary loads connected.

f)ii.3. The valve lineup for P-6A and P-6B to the fire water headers is normally open per procedure OP-1104.032. This lineup will allow the main fire water pumps to supply water to the fire water headers when required. This valve lineup is maintained open during the operation of the temporary pump except for isolation of either pump to support maintenance. The temporary pump has a dedicated electrical panel that is utilized to manually start and stop the pump motor. The controls for the temporary pump do not electrically interface with the fire water system low pressure auto-start circuitry associated with the main fire water pumps. Therefore, it is concluded the main fire water pump(s) will start if system conditions meet the pump start criteria (i.e., low pressure). The temporary pump is rated for 2000 gpm at 120 psig, which will be capable of providing water to lower demand suppression systems.

f)ii.4. The Technical Requirements Manual (TRM) has a requirement to 'Establish a backup fire suppression water supply' within 24 hours if both main fire water pumps are non-functional and neither main fire water pump can be restored to functional status within 24 hours. Procedure OP-1104.032 states "The Temp Fire Pump has not been evaluated in, and is not authorized to fulfill the role of the backup fire suppression water supply (reference Unit 1 TRM 3.7.8 Required Action B.2.1 and Unit 2 TRM 3.7.1 Action b.1)." Therefore, it is understood that the temporary pump cannot be used as a primary pump even if both main fire water pumps are out of service.

The temporary pump, however, may serve as the water supply pump for fire suppression systems provided the required suppression flow does not lower the fire water system pressure below the starting value for the main fire water pumps. If the temporary pump fails to operate or system pressure is lowered below main fire water pump auto-start value, the main fire water pumps will provide needed flow to the affected suppression systems.

f)iii. The temporary pump is not utilized as a fire pump for compliance with any of the NFPA 805, Chapter 3, sections, except Section 3.5.16 for which the exemption has been requested. The temporary pump is used for fire water system pressure maintenance while having flow capacity to provide water for auxiliary applications. The applicable sections that discuss fire water supply systems are not affected by the use of the temporary pump and do not require deviations from NFPA 805, Chapter 3. The normal fire water supply pumps are available if system flow and pressure requirements demand increased fire water flow.

Safe Shutdown Analysis (SSA)

Note: Responses to 30-day SSA RAIs 01, 03, 04, 05 and 60-day SSA RAI 02 were submitted in Entergy letter dated May 19, 2015 (Reference 3). Responses to SSA RAI 06 and 08 were provided in Entergy's 60-day letter (Reference 4). SSA RAI 11 is expected to be addressed in the 120-day RAI response.

<u>SSA RAI 07</u>

NFPA 805 Section 2.2.4 requires, in part, that the NSPC be evaluated on a fire area basis, and NFPA 805 Section 2.7.1.2 requires, in part, that the NSCA be documented on a fire area basis. LAR Attachment C includes a summary of the NSCA for each fire area; LAR Table 4-3 includes a summary of the required fire protection systems and features; and LAR Attachment W, Table W-2 includes a summary of the fire area risks for each fire area. There are several fire area designations in these attachments and tables that are different. Please provide the following clarifications:

a) LAR Attachment C includes the NSCA summary for Fire Area ADMIN - Administration Building, and although LAR Attachment C includes a summary table for required fire protection systems and features, there is no corresponding entry in LAR Table 4-3 and LAR Attachment W, Table W-2 does not include this fire area in the Fire Area Risk Summary. Please clarify the reason for the difference between the LAR Attachment C, Table 4-3, and LAR Attachment W.

b) LAR Attachment W, Table W-2 includes the risk summary for Fire Area AAC, "SBOD [Station Blackout Diesel] Alternate Diesel Building," but there are no results for the NSCA for this fire area in LAR Attachment C. Please clarify the reason for the difference between the LAR Attachments C and W. If an NSCA was performed for this fire area, please provide the NSCA results for this fire area in an updated LAR Attachment C.

Response

a) The Technical Support Center (TSC) located within the Administration Building is used to monitor plant conditions using the Safety Parameter Display System (SPDS) and coordinate activities when necessary to abandon the Main Control Room (MCR) as the result of a fire in the MCR (Fire Zone 129-F) or Cable Spreading room (Fire Zone 97-R). The Administration Building is important to the ANO fire protection program as it contains cables and equipment required for monitoring and, therefore, is included in Attachment C, but is not part of the Power Block as defined within Attachment I of the ANO-1 LAR. Since the Administration Building is not part of the Power Block and does not contribute to overall plant risk, it is not included in Attachment W. The Administration Building (ADMIN) is included at the end of Table 4-3 on page 75 of the LAR.

b) The SBOD is documented in Attachment C of the ANO-2 LAR as it is physically located on the ANO-2 side of the site, interfaces directly with, and is controlled from ANO-2. These facts combined with the SBOD not being credited in the ANO-1 deterministic analysis make it unnecessary to be included in Attachment C. The SBOD is included in Attachment W due to its risk importance in the Fire PRA (FPRA) for ANO-1. The FPRA, developed using the guidance of NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities," performs a quantitative assessment of risk which contains elements that are not considerations within the deterministic safe shutdown analysis.

<u>SSA RAI 09</u>

RG 1.205 Section 2.4, states, in part, that:

> NFPA 805, Section 4.2.3.1, identifies recovery actions for which the additional risk must be evaluated, as required by NFPA 805, Section 4.2.4. These "success path" recovery actions are operator actions that, if not successful, would lead to the fire-induced failure of the "one success path of required cables and equipment to achieve and maintain the nuclear safety performance criteria." Other operator actions that do not involve the success path may be credited in plant procedures or the fire PRA [probabilistic risk assessment] to overcome a combination of fire-induced and random failures may also be recovery actions, but licensees do not need to evaluate the additional risk of their use.

LAR Attachment G identified a number of "Defense-in-Depth Recovery Actions." Please provide additional information to clarify how these recovery actions are evaluated in the NSCA. Specifically, provide the following information:

a) Describe the methodology for identifying DID recovery actions and how they were credited, if at all, in the risk determination for the fire area.

b) Clarify if the NFPA 805 nuclear safety and radioactive release performance goals, objectives and criteria, including the risk acceptance guidelines, are met without these actions and provide the bases for this conclusion.

c) In LAR Attachments C and G, DID recovery actions are credited in Fire Area G to resolve VFDRs that involve spurious operation of valves, such as CV-1227, CV-1228, CV-1408, CV-1274, and CV-3807, that may be affected by hot short issues described in Information Notice (IN) 92-18, "Potential for Loss of Remote Shutdown Capability During a Control Room Fire," dated February 28, 1992 (ADAMS Accession No. ML031200481). In LAR Attachment G, Step 4, the licensee stated that the recovery actions are evaluated against the feasibility criteria of NEI 04-02; FAQ 07-0030, Revision 5; and RG 1.205. Please discuss how the feasibility of performing these specific DID recovery actions for spuriously operated valves are met if its' respective circuit(s) are damaged as described in IN 92-18.

Response

a) The response to PRA RAI 16, included in this letter, provides an overview of the qualitative methodology used for identifying where recovery actions are desirable for Defense in Depth (DID). DID actions are not quantitatively assessed for risk within the Fire Risk Evaluations (FREs) performed for those fire areas where the performance-based approach of NFPA 805, Section 4.2.4, is applied.

b) In accordance with NFPA 805, the nuclear safety performance goal is to provide reasonable assurance that a fire during any operational mode and plant configuration will not prevent the plant from achieving and maintaining the fuel in a safe and stable condition. The nuclear safety performance criteria require that in the event of a fire, fire protection features shall be capable of providing reasonable assurance that the plant is not placed in an unrecoverable condition. As stated in NFPA 805, Section 4.2.2, the use of a performance-based approach satisfies the nuclear safety performance criteria for those fire

areas not in deterministic compliance. Since the use of DID recoveries has no impact on the quantified risk (CDF and LERF) in any performance-based fire area, there is no additional risk in their use to demonstrate the availability of a success path for any performance goal listed in Attachment C of the ANO-1 NFPA 805 LAR. No defense-in-depth recovery actions are needed to ensure the nuclear safety goal or performance criteria are met.

The NFPA 805 Radioactive Release Goal is to provide reasonable assurance that a fire will not result in a radiological release that adversely affects the public, plant personnel, or the environment. The Radioactive Release Performance Criteria states that radiation release to any unrestricted area due to the direction effects of fire suppression activities (but not involving fuel damage) shall be as low as reasonably achievable and shall not exceed applicable 10 CFR 20 limits. The ANO-1 evaluation of radioactive release included a review of areas in which radiological hazards existed or might exist. Many of these areas have engineering controls (i.e., ventilation systems or monitored drain paths). The DID recovery actions are not needed to support any of these systems. For those areas where there are no engineering controls, radiation protection and chemistry personnel would be summoned by the Main Control Room (MCR) to monitor gaseous releases and contain pooling suppression water. There are no DID actions related to these areas.

c) Fire scenarios within the ANO-1 MCR (Fire Area G) quantified for risk in the FRE include a base scenario for a room exposure fire and individual scenarios for fixed locations inclusive of control panels. The qualitatively selected DID recoveries listed in LAR Attachment G are for the base MCR scenario. Fire scenario report PRA-A1-05-004 assumes that MCR electrical panel fires will be contained and controlled within the panel by operations personnel response to the fire.

If the fire ignites and is contained within MCR panel C16 (motor operated valves (MOVs) CV-1227, CV-1228, CV-1408, and CV-1274) or panel C19 (MOV CV-3807), the low conditional core damage probabilities (CCDPs) in the E-04 range and corresponding low CDFs do not warrant DID recoveries to maintain balance of DID echelons.

If MCR abandonment were required due to the base scenario, then the fire would have occurred outside of these panels. The frequency of MCR abandonment shown in the fire scenario report is in the E-05 range per reactor year, which is of low likelihood. MCR abandonment is based upon habitability concerns from criterion contained within NUREG/CR 6850 and considered to have occurred when the temperature at a point greater than 6′ above the floor exceeds 200 °F or a smoke layer descends below 6’ causing visual impairment of the operators. Abandonment performed at or before this threshold temperature allows time to perform ex-MCR actions prior to reaching the thermoset cable damage threshold of 330 °C (625 °F) listed in Appendix H of NUREG/CR 6850. Cable fire testing summarized in EPRI TR-1003326, “Characterization of Fire-Induced Circuit Faults,” Section 12.2.5.2, shows the shortest time to spurious actuation of thermoset cable was 14 minutes and only one out of 28 spurious actuations occurred within 20 minutes. The average time to spurious operation of thermoset cable was 46.3 minutes. This provides indication that there will be time, assuming a fire is of sufficient size to cause damage, to take actions before spurious operation could occur. The circuits associated with the subject MOVs are not routed overhead or within the zone of influence for other fire scenarios within the MCR. Control switches for these MOVs are installed on the panels at or below 6’ and the associated wires and cables descend through penetrations in the floor.

The control panel also provides additional protection from the radiant heat of the fire. Therefore, these valves may be appropriately aligned from the MCR panel in the event of a MCR fire. To further ensure the valves remain in the desired position, a DID action is performed to locally de-energize load center B-6. This is not a complex action and will remove power from the downstream Motor Control Centers that control the subject MOVs. Once this action is performed, there is no longer motive power to allow spurious operation. Based upon these qualitative arguments for qualitatively selected DID actions, there will be sufficient time once the MCR is abandoned to remove power and thereby prevent spurious actuation caused from fire induced damage.

SSA RAI 10

NFPA 805 Section 4.2.1 states that one success path necessary to achieve and maintain the nuclear safety performance criteria shall be maintained free of fire damage by a single fire. NFPA 805 Section 4.2.3.1 states that use of recovery actions to demonstrate availability of a success path for the nuclear safety performance criteria automatically shall imply use of the performance-based approach as outlined in Section 4.2.4. NFPA 805 Section 4.2.4 states that when the use of recovery actions has resulted in the use of [the performance-based] approach, the additional risk presented by their use shall be evaluated. NFPA 805 Section 1.6.52 defines a recovery action as activities to achieve the nuclear safety performance criteria that take place outside of the main control room (MCR) or outside the primary control station(s) for the equipment being operated, including the replacement or modification of components.

In LAR Attachment C, for a fire in Fire Area G, "Control Room," and associated fire zones, the licensee stated in the "Method of Accomplishment" for the process monitoring performance goal that instrumentation is available in the TSC (Technical Support Center) to monitor neutron flux, pressurizer level, reactor coolant system (RCS) pressure, RCS temperature, and credited steam generator (SG) level and pressure using Safety Parameter Display System (SPDS). This activity is performed outside the MCR and is a recovery action as defined in NFPA 805 Section 1.6.52. LAR Attachment G, Table G-1 identifies the recovery actions and activities credited in the nuclear safety capability assessment (NSCA), and the recovery action to monitor instrumentation at the TSC is not identified.

a) Please clarify that the process monitoring function performed at the SPDS is maintained free of fire damage by a fire in Fire Area G, as required by Section 4.2.1, including the power source and instrumentation input data to the SPDS.

b) In LAR Attachment G, Step 4, the licensee stated that the recovery actions are evaluated against the feasibility criteria of NEI 04-02, FAQ 07-0030, Revision 5, and RG 1 .205. Please discuss how each of the feasibility criteria of FAQ 07-0030 will be met for performing the process monitoring function at the SPDS, including the method of communications between operators at the SPDS and other operators performing recovery actions in other areas of the plant.

c) Please confirm that all recovery actions that are credited in the NSCA are described in LAR Attachment G, such as monitoring instruments at the SPDS and breaker actions to de-energize a valve prior to locally operating a valve, are evaluated for risk as required by NFPA 805 Section 4.2.4.

Response

a) The SPDS is a computer system designed to monitor and display a concise set of parameters from which the safety status of the plant can be readily and reliably determined. The system provides plant status information to the ANO-1 and ANO-2 MCRs, the technical support center (TSC), and the emergency operating facility (EOF). The central processing units (CPUs), input/output cabinets, and routers for SPDS are physically located in ANO-2 and powered from inverter 2Y26, which is fed from an ANO-2 safety-related emergency diesel generator or a station battery. Each CPU receives input from critical sensors and the instrument loops for these sensors have isolation from Fire Area G where required to support MCR abandonment. The power for the instrument loops are from ANO-1 sources available for a Fire Area G fire scenario. The centralized SPDS computer equipment interfaces to displays (personal computers) at the TSC, EOF, and MCRs via fiber optic cables. Displays at the TSC, along with TSC communications, are on the security power distribution system that is backed by the security diesel and inverter.

   The instruments, equipment, and plant cabling described above needed by SPDS to provide the necessary monitoring capability of critical parameters in the TSC are included in the ANO cable and raceway database (plant data management system or PDMS). The data residing in PDMS was used by CALC-85-E-0086-01, "Safe Shutdown Capability Assessment," and confirms that SPDS is maintained free of fire damage by a fire in Fire Area G.

b) In a MCR abandonment scenario the Shift Manager and Shift Technical Advisor (STA) are directed by the alternate shutdown procedure (OP-1203.002) to transition to the TSC (located in the administration building). Cognitive supporting tasks within the TSC are an implicit part of recovery actions, limited to the monitoring of plant parameters displayed by SPDS and procedural coordination with operators within the power block using the available communication system. These cognitive tasks at the TSC are equivalent to non-abandonment MCR tasks that support execution of recovery actions in the current safe shutdown analysis. The eleven feasibility criteria listed in FAQ 07-0030 as applied to cognitive tasks performed in the TSC are:

   1. Demonstrations

      ANO directive COPD-016, "Operations Procedure Review/Training Program," includes a review of the alternate shutdown procedure for technical accuracy and field walk downs.

   2. Systems and Indications

      The TSC is equipped with SPDS display equipment. See the response to part (a) of this RAI for additional discussion.

   3. Communications

      The TSC is equipped with radio equipment and all operators obtain radios staged in the Alternate Shutdown Locker as directed by OP-1203.002, "Alternate Shutdown."

4. Emergency Lighting

   Fixed or portable emergency lighting is provided for the path from the MCR to the TSC.

5. Tools-Equipment

   No special tools or equipment are required for personnel in the TSC.

6. Procedures

   OP-1203.002, "Alternate Shutdown," is used. Controlled hard copies of emergency and abnormal operating procedures are maintained at the TSC.

7. Staffing

   The Shift Manager and STA report to the TSC. Operators are dispatched from the MCR to specified plant locations for performance of recovery actions.

8. Actions in the Fire Area

   The TSC is not in the fire-affected area.

9. Time

   The Shift Manager transitions to the TSC within 8 minutes following the decision to abandon the MCR. Prescriptive actions to secure plant equipment can be performed during this time.

10. Training

   Lesson Plan A1LP-RO-ALTSD, "Alternate Shutdown Abnormal Operating Procedure," addresses OP-1203.002, "Alternate Shutdown."

11. Drills

   ANO-1 LAR Item S2-6 involves a broad range of changes inclusive of changes in the training program. Internal tracking Item LAR-2014-00248, CA 50, has been previously issued to ensure the specific requirements of FAQ 07-0030, Criterion 11, are incorporated in the training program.

c) The Human Error Probability (HEP) used in the ANO-1 FPRA was developed in PRA-A1-05-007, "Fire Probabilistic Risk Assessment Human Reliability Analysis (HRA) Notebook." The probability of failure for a recovery action encompasses two contributions:

   - The cognitive portion, which accounts for errors in detection, diagnosis, or decision-making, and
   - The execution portion, in which possible errors in carrying out a decision can be made.

The recovery actions of equipment in Attachment G, exclusive of the new common feedwater pump (CFW), are prescriptive actions for risk mitigation that require no instrumentation cues for performance. These actions will close isolation valves to ensure the integrity of the Reactor Coolant System (RCS) (CV-1221 and PSV-1000), secure Reactor Coolant Pumps for prevention of a seal loss-of-coolant accident, and secure High Pressure Injection pumps to prevent over pressurization of the RCS. The risk analysis for these recovery actions appropriately includes cognitive error for additional stress and procedure usage. The execution error includes actions to open the breaker and locally operate the valve where required.

The recovery action and its associated risk for the future new CFW pump are based upon MCR abandonment and local operation at a dedicated control panel for the pump and valves. While starting the pump and establishing flow to the Steam Generators is a prescriptive action, this recovery will require monitoring of instrumentation. The availability of the instrumentation is considered part of the human failure event for this scenario and is not an independent recovery action.

Fire Modeling (FM)

Note: Response to FM RAI 05 and one 90-day response (FM RAI 03) were provided in Entergy's 60-day letter (Reference 4).

FM RAI 01

NFPA 805 Section 2.4.3.3, states that:

> The PSA [probabilistic safety assessment] approach, methods, and data shall be acceptable to the AHJ [authority having jurisdiction] ....

The NRC staff noted that the ANO-1 fire modeling comprised the following:

- The Consolidated Fire Growth and Smoke Transport (CFAST) model was used to calculate MCR abandonment times and to evaluate development and timing of hot gas layer conditions in selected fire zones.
- The Generic Fire Modeling Treatments (GFMTs) approach was used to determine the zone of influence (ZOI) in all fire areas throughout the plant.
- FLASH-CAT was used for calculating fire propagation in stacks of more than two horizontal cable trays.
- HEATING 7.3 was used in the assessment of the fire resistance of conduit embedded in concrete.
- As described in NUREG-1805, "Fire Dynamics Tools (FDTS): Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program," December 2004 (ADAMS Accession No. ML043290075), the Point Source Model and the Solid Flame Model were used to determine whether there is adequate separation between the Administration Building and the ANO-1 Turbine Building.

LAR Section 4.5.1.2, "Fire PRA," states that fire modeling was performed as part of the Fire PRA development (NFPA 805 Section 4.2.4.2). Reference is made to LAR Attachment J, "Fire Modeling V&V [verification and validation]," for a discussion of the acceptability of the fire models that were used to develop the FPRA.

Regarding the acceptability of the PRA approach, methods, and data, please provide the following information:

a) Please identify any applications of fire modeling tools and methods used in the development of the LAR that are not discussed in LAR Attachment J.

b) Please describe how non-cable secondary combustibles were identified and accounted for in the fire modeling analyses and the fire risk evaluations.

c) Regarding fire propagation in cable trays:

   (i) Please explain how the expansion of the ZOI of an ignition source due to the heat release rate (HRR) of secondary combustibles (cable trays) was accounted for.

   (ii) In any fire area, please explain how cable tray covers, fire-resistant coatings, and fire wraps were credited in terms of delaying or preventing ignition and subsequent flame spread of cables. In addition, explain how holes in cable tray covers were treated in regard to the fire modeling damage criteria.

d) Regarding high energy arcing fault (HEAF) generated fires, please describe the criteria used to decide whether a cable tray in the vicinity of an electrical cabinet will ignite following a HEAF event in the cabinet. Explain how the ignited area was determined and subsequent fire propagation was calculated. If applicable, describe and justify the effect of tray covers and fire-resistant wraps on HEAF-induced cable tray ignition and subsequent fire propagation.

e) Provide justification for the assumed fire areas and elevations that were used in the transient fire modeling analyses. Explain how the model assumptions in terms of location and HRR of transient combustibles in a fire area or zone will not be violated during and post-transition.

Regarding the acceptability of the GFMTs approach, please provide the following information:

f) Explain how the modification to the critical heat flux for a target that is immersed in a thermal plume was used in the ZOI determination.

g) Explain how wall and corner effects were accounted for in the ZOI calculations for transient fires.

h) Describe how transient combustibles in an actual plant setting are characterized in terms of the three fuel package groupings in Supplement 3, "Transient Ignition Source Strength," of the GFMT. Identify areas, if any, where the NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Volume 1: Summary and Overview," September 2005 (ADAMS Accession No. ML052580075), transient combustible HRR characterization (probability distribution and test data) may not encompass typical plant configurations. Finally, explain how any administrative action will be used to control the type of transient combustibles in a fire area.

Regarding the development and timing of the Hot Gas Layer (HGL) calculations, please provide the following information:

i) Explain when and how wall and corner effects were accounted for in the HGL timing calculations. Describe the process for selecting alternate scenarios that have characteristics that are consistent with the "image" method adjustments, as described at the end of the first paragraph on page J-4 of the LAR Attachment J.

j) Explain how the time to ignition of the lowest tray was determined in the FLASH-CAT cable tray fire propagation calculations.

Regarding the acceptability of CFAST for the MCR abandonment time calculations, please provide the following information:

k) During the onsite regulatory audit from April 20-23, 2015, the NRC staff noted that the licensee has completely revised the MCR abandonment calculations. Please explain the differences between the original and the revised analyses, and, in particular, provide an explanation regarding the assumptions that were made and the scenarios that were modeled. In addition, please provide technical justification for substantive, potentially non-conservative changes that were made in the assumptions for the calculations (e.g., increase of the effective volume of the MCR in CFAST, reduction of the peak HRR of the workstation fire, etc.).

l) Please provide the basis for the assumption that the fire brigade is expected to arrive within 15 minutes. In addition, describe the uncertainty associated with this assumption, discuss possible adverse effects of not meeting this assumption on the results of the FPRA, and explain how possible adverse effects will be mitigated.

m) LAR Attachment H, Table H-1, "NFPA 805 Frequently Asked Question Summary Table," credits FAQ 08-0052, "Transient Fires - Growth Rates and Control Room Non-Suppression," dated August 4, 2009 (ADAMS Accession No. ML092120501). Please provide justification for using the transient fire growth rates that differ from those specified in FAQ 08-0052, and discuss the effect of these deviations on the risk results (i.e., core damage frequency (CDF), large early release frequency (LERF), ΔCDF, and ΔLERF).

n) Please provide the technical justification for the assumption that fire spreads to adjacent cabinets in 15 minutes, and not in 10 minutes as recommended in Appendix S of NUREG/CR-6850 for the case when cables in the adjacent cabinet are in direct contact with the separating wall.

o) During a plant walkdown as part of the onsite regulatory audit held from April 20-23, 2015, the NRC staff noted that several electrical cabinets in the electrical equipment area have plexiglass doors, and observed plastic cases with self-contained breathing apparatus and a partially covered vertical cable tray in the southwest corner of the electrical equipment area. Please provide technical justification for not explicitly considering fire scenarios that involve these combustibles in the MCR abandonment time calculations.

p) Regarding the sensitivity analysis:

(i) A baseline fire scenario is considered insensitive if the change in the total probability of control room abandonment remains less than 15 percent. Please provide technical justification for the 15 percent criterion.

(ii) The sensitivity analysis appears to indicate that raising the fire base to 1.2 m or 2.4 m significantly reduces the abandonment times for scenarios without operating HVAC. Please explain why the baseline scenarios were not updated to include the higher fire elevations.

Response

a) The V&V basis for all known fire modeling tools or methods that support the Fire PRA (FPRA), directly or indirectly, have been described in LAR Attachment J. An interpolation of the cable damage times described in Appendix H of NUREG/CR-6850, “EPPI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology,” is used in the ANO-1 FPRA; however, this interpolation is not considered to be a fire modeling tool or method and is thus not included in the LAR Attachment J discussion.

Note that new ZOI and hot gas layer (HGL) tables were developed for ANO-2 that are applicable to ANO-1 in Reports PRA-A2-05-017, Rev. 0, “Combined Ignition Source – Cable Tray Fire Scenario ZOIs for Arkansas Nuclear One Unit 2 Applications,” and PRA-A2-05-018, Rev. 0, “Evaluation of the Development and Timing of Hot Gas Layer Conditions in Generic ANO-2 Fire Compartments with Secondary Combustibles.” These evaluations use the same approach described in Report PRA-A1-05-011, Rev. 0, “Evaluation of Development and Timing of Hot Gas Layer Conditions in Selected ANO Fire Zones,” and Report 1SPH02902.030, “Generic Fire Modeling Treatments,” both of which are described in LAR Attachment J.

b) Additional walkdowns will be performed for ANO-1, similar to walkdowns completed for ANO-2, to identify non-cable secondary combustibles within the ZOI of a fixed ignition source. The results of these walkdowns will be incorporated into the FPRA analysis where the combustibles are to remain in place and may impact the FPRA analysis. Combustible storage areas will be assessed with respect to potential transient ignition of these combustibles. Criteria for negligible quantities of non-cable secondary combustibles will be applied to focus the evaluation on areas containing combustibles of sufficient quantity to alter the FPRA results. The results will be provided with the FPRA updates associated with PRA RAI 03.

c)(i) The expansion of the ZOI for scenarios in which cable trays are ignited by a fixed or transient ignition source is described in detail in Report PRA-A2-05-017, Rev. 0. The ZOI dimensions increase with time and are tabulated in PRA-A2-05-017, Rev. 0, at ten minute increments from the time the ignition source ignites to sixty minutes after the ignition source ignites. There are three mechanisms that contribute to an expanding ZOI when one or more cable trays are involved:

- Vertical fire propagation through a stack of cable trays. This causes the fire base in the cable trays to shift and causes additional fuel to become involved.

- Horizontal propagation along a cable tray. This causes the physical position of the burning regions, and thus the fire, to expand laterally. In addition, the propagation involves additional fuel, which leads to an increased heat release rate.
- Increased overall heat release rate. The increased heat release rate causes the ZOI to expand via increased heat fluxes (parallel and perpendicular to the cable trays) and elevated thermal plume temperatures.

The increased heat release rate is calculated using the FLASH-CAT method (NUREG/CR-7010, Volume 1, "Cable Heat Release, Ignition, and Spread in Tray Installations During Fire (CHRISTIFIRE) Phase 1: Horizontal Trays"). The vertical and horizontal effects of the increased heat release rate on the ZOI dimensions are evaluated using the methods described in the GFMT report (1SPH02902.030, Rev. 0) as described in Report PRA-A2-05-017, Rev. 0.

c)(ii) Fire-resistant coatings and fire wraps were not credited in any fire area in the fire modeling evaluations. Solid cable tray covers were credited to isolate cables from contributing to the scenario heat release rates only. As such, there is no ignition or flame spread on covered cable trays. However, cables protected with cable tray covers were considered to be damaged when within a fire scenario ZOI. The presence of holes in the covers would not affect the assumed damage criteria for the cables in the trays.

d) The approach for HEAF fire propagation is similar to that used for non-HEAF panel fires with the peak HRR for the HEAF fire assumed to occur at the initiation of the fire. The basis for initial HEAF damage is described in Attachment B of PRA-A1-05-004, Rev. 0, "ANO-1 Fire Scenarios Report," in accordance with the guidance of NUREG/CR-6850, Appendix M. If multiple heat release rate profiles are possible, the ignition source component with the greatest ZOI is used to determine the affected targets for the scenario. Subsequent fire propagation is based on the same methodology used for non-HEAF fires with the fire propagation assumed to occur 12 minutes earlier to account for the elimination of the 12-minute time to maximum heat release rate for the HEAF fire. No credit for mitigation effects is applied for cable tray covers or fire-resistant wraps when provided.

e) The basis for the assumed fire areas for transient fuel packages are described in Report PRA-ES-05-006, Rev. 0, "Supplemental Generic Fire Modeling Treatments: Transient Fuel Package Ignition Source Characteristics." The assumed area for the 98th percentile transient fuel package is determined using data provided in the test references cited in Table G-7 of NUREG/CR-6850, Volume 2, Appendix G. Based on this data, it was determined that the heat release rate per unit area for the unconfined transient material is about 360 kW/m^2 (31.7 Btu/s-ft^2), resulting in a fire area of 0.88 m^2 (9.5 ft^2). The assumed area for other percentile transient fuel packages is determined using a range of heat release rate per unit area values applicable to other configurations and fuel package sizes as described in PRA-ES-05-006, Rev. 0. The results are based on the most adverse fire area, and accordingly, there is no specific assumed fire area.

The assumed transient fire elevation is 0.0 m (0.0 ft) in all generic ZOI and HGL calculations for maximum portability. Vertical offsets for elevated transient fuel packages may be provided, as applicable, based on the walkdown observations. In the case of a ZOI application, any vertical offset would simply be added to the vertical ZOI dimension. In the case of a HGL timing estimate, the vertical offset would be implemented by subtracting the

room volume below the fire base from the total room volume. The plant-wide practice at ANO-1 is to store transient combustibles in approved containers in accordance with EN-DC-161, "Control of Combustibles." As such, the default transient base location for FPRA scenarios is the floor, or 0.0 m (0.0 ft), to represent miscellaneous loose material. In addition, transient combustible loading is prohibited in Level 1, or fire sensitive, areas without strict controls. Note that larger quantities of transient material may be stored in designated combustible storage zones, which will be assessed individually for their potential impact on risk significant targets.

Note that the transient fire base height in the room specific HGL calculations (Report PRA-A1-05-011, Rev. 0) is 0.61 m (2.0 ft). This base elevation represents additional conservatism and does not consider the plant specific practice to store combustibles in closed metal containers.

f) The modified critical heat flux was implemented using either a two or a three point treatment in the FPRA. Most plant areas use the two point treatment of the modified critical heat flux. The first point corresponds to temperature conditions between ambient and 80 °C (176 °F) and represents the temperature interval in which the ZOIs, such as those documented in the GMFT report are applicable. The second point corresponds to temperature conditions greater than 80 °C (176 °F) and is conservatively characterized in the FPRA as a full-room burnout. This applies to both targets located in the thermal plume region and to targets that are located outside the thermal plume region. Several plant areas use a three point treatment for greater resolution on the risk characterization. The first point corresponds to temperature conditions between ambient and 80 °C (176 °F), and represents the temperature interval in which the ZOIs for thermoset cable targets are applicable. The second point corresponds to temperature conditions greater than 80 °C (176 °F), but less than 220 °C (428 °F), and represents the region where the HGL can produce a heat flux up to 5.7 kW/m^2 (0.5 Btu/s-ft^2). The ZOIs for thermoplastic cables are applicable in this temperature range when used to identify thermoset cable targets because the total heat flux at the ZOI boundary is 11.4 kW/m^2 (1.0 Btu/s-ft^2), the generic threshold for thermoset cables per NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology." The third point corresponds to temperature conditions greater than 220 °C (428 °F) and is conservatively characterized in the FPRA as a full-room burnout. This applies to both targets located in the thermal plume region and to targets that are located outside the thermal plume region.

g) Wall and corner effects are assessed directly in PRA-ES-05-006, Rev. 0, PRA-A1-05-011, Rev. 0, PRA-A2-05-017, Rev. 0, and PRA-A2-05-018, Rev. 0, for transient fire scenarios using a location factor or 'Image' method approach as described in NIST-GCR-90-580, "Development of an Instructional Program for Practicing Engineers Hazard I Users." The 'Image' method is a simple means of incorporating wall and corner effects by taking advantage of the proportionality between the fire perimeter and the plume air entrainment by changing the fire area. When determining the ZOI, the fire area and heat release rate are increased by a factor of two for fires in wall locations and a factor of four for fires in a corner location. When determining the HGL temperature in an enclosure with CFAST for a fire in a wall location, the fire heat release rate, enclosure width (i.e., volume), and ventilation area are increased by a factor of two. Likewise, when determining the HGL temperature in an enclosure with CFAST for a fire in a corner location, the fire heat release rate and ventilation area is increased by a factor of four, and the enclosure width and length are each increased by a factor of two, resulting in a volume increase factor of four.

The ZOI dimensions and HGL temperature timing provided in Report 1SPH02902.030, Rev. 0 do not directly incorporate wall and corner location factors, but the data may be applied to such configurations by selecting the data for a fire size that is two or four times the actual fire size.

h) The transient fuel packages are assumed to be miscellaneous materials (trash configurations) that do not contain acetone or other combustible liquids. Combustible or flammable liquids are stored in approved non-combustible containers per EN-DC-161, “Control of Combustibles,” and are thus not considered to contribute to the overall heat release rate. This corresponds to the Group 3 and Group 4 transient fuel packages described in report PRA-ES-05-006, Rev. 0. The 98th percentile transient fuel packages are considered a special case of the Group 3 and Group 4 transient fuel packages with a specific heat release rate per unit area as described in report PRA-ES-05-006, Rev. 0.

The transient fire heat release rate conditional probability distribution specified in NUREG/CR-6850, “EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology,” with a 317 kW (300 Btu/s) 98th percentile peak heat release rate fire, is considered to be generically applicable to nuclear power plants. ANO-1 does not differ in any significant manner with respect to its transient combustible controls to warrant a significant increase or decrease in the applicable heat release rate profile or heat release rate conditional probability distribution as specified in NUREG/CR-6850. However, for areas that have been designated as "no transient combustible areas," to address the potential for violation of these controls, a 69 kW (65 Btu/s) 98th percentile peak heat release rate fire is applied. This heat release rate is considered appropriate given the unlikely event that transients are stored in these areas contrary to the controls imposed. The 69 kW (65 Btu/s) peak heat release rate was defined based on the heat release rate specified in NUREG/CR-6850 for a motor fire given that the most likely transient fire in a zone with limited transients would be associated with temporary cabling since this configuration would provide both the ignition source (energized temporary cabling) and combustible (cable insulation). The motor configuration would resemble such a transient fire.

The control of combustibles is ensured by procedure EN-DC-161, which limits the accumulation and composition of materials using a graded approach (Level 1 [highest risk] through Level 4 [lowest risk]). The procedure provides the framework for the introduction of combustibles into each hazard level area and the required conditions that apply when combustibles are introduced. Combustibles that do not meet the specified requirements for each hazard level require a Transient Combustible Evaluation (TCE) to be performed or specified compensatory measures to be implemented. High hazard areas (Level 1) require a TCE or compensatory measures when any transient combustible material is introduced, whereas lower hazard areas require a TCE or compensatory measures only when the exempt quantity is exceeded. The use of the combustible control procedure will limit the combustible configurations in high hazard areas to configurations that are bound by the analysis provided in report PRA-ES-05-006, Rev. 0, or, where impractical, to provide for the necessary compensatory measures via the TCE.

It is noted that there is one case considered in the updated Main Control Room (MCR) abandonment calculation (CALC-ANO1-FP-09-0011, Rev. 1, “Evaluation of Unit 1 Control Room Abandonment Times at ANO Facility”) in which a transient fuel package fire scenario is characterized using a heat release rate profile that is more adverse than the standard

NUREG/CR-6850, Volume 2, Appendix E, Case 8, transient fuel package fire scenario. Specifically, an office type fuel arrangement is postulated and characterized using a heat release rate profile applicable to such fuel packages. This configuration is unique to the MCR area among risk significant plant areas.

i) The HGL timing for both ignition source fire scenarios and combination ignition source – cable tray fire scenarios in the ANO-1 FPRA will be determined using Reports PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, in the updated FPRA. The HGL effects for wall and corner fire locations are directly accounted for in Reports PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, using the 'Image' method as described in the response to Part g) of this RAI response.

The HGL effects for wall and corner location fire scenarios in the original FPRA were determined using Report PRA-A1-05-011, Rev. 0, for specific compartments when determining the potential for a HGL to affect multiple compartments. As noted, wall and corner effects are directly accounted for in this report. The HGL effects within an enclosure were originally determined using the GFMT report and PRA-ES-05-007, Rev. 0. In both cases, wall and corner effects were not directly modeled. In order to assess the effects of a wall or corner fire scenario, the heat release rate of the ignition source and the enclosure volume was increased by a factor of two or four and the corresponding results applied. This heat release rate and volume increase represents the 'alternate' scenario as described in LAR Attachment J. This procedure will be replaced through the use of HGL data contained in Report PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, for wall or corner location fire scenarios as applicable in the updated FPRA. The results will be provided with the FPRA updates associated with PRA RAI 03.

j) The lowest cable tray is assumed to ignite one minute after the ignition source ignites in the FLASH-CAT cable tray fire propagations in reports PRA-A1-05-011, Rev. 0, PRA-A2-05-017, Rev. 0, and PRA-A2-05-018, Rev. 0. The cable tray ignition time of one minute is based on the minimum ignition time for thermoset cables listed in Tables H-5 and H-7 of NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology." The ignition time for the lowest cable tray is assumed to be five minutes in PRA-ES-05-007, Rev. 0; however, the information in this report will be replaced by the tables provided in PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, in the updated FPRA. The results will be provided with the FPRA updates associated with PRA RAI 03.

k) The updated MCR abandonment analysis (CALC-ANO1-FP-09-0011, Rev. 1, "Evaluation of Control Room Abandonment Times at Arkansas Nuclear One, Unit 1") includes several differences from the version submitted with the LAR (CALC-ANO1-FP-09-00011, Rev. 0). A number of these changes were made in advance of the audit, and further changes have been made based on responses to the RAIs. The following list summarizes the major changes made to the report:

- Room Volumes have been updated based on the design input from calculation CALC-91-E-0117-04, Rev. 1, "ANO-1 and ANO-2 Control Room Free Air Volume." The original volumes were scaled from drawings that had mixed scales and were thus inappropriate when using a single scale. The updated MCR abandonment calculation volumes and dimensions are correct and are obtained directly from field data documented in the design input calculations.

- Model input parameter sensitivity analysis has been expanded and updated to incorporate input parameter uncertainty directly into the model baseline evaluations. This process is considered to be conservative based on the response to FM RAI 01 p)(i), below.
- New model baseline scenarios have been added to the analysis, including wall/corner configuration transients, fires in ANO-2 that impact ANO-1, and breakage of the glass barrier between ANO-1 and ANO-2. Several of these configurations were added to the analysis in response to RAIs from the ANO-2 LAR audit.
- The transient fire scenarios have been revised from a variable t-squared growth parameter to the recommended growth rates from NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology." Both confined and unconfined transient growth rates are considered in the sensitivity analysis, and the baseline input assumption is selected as appropriate to maintain conservatism.
- The delay in fire propagation between electrical cabinets has been revised to ten minutes from fifteen minutes in the original analysis in order to conservatively bound the configurations described in NUREG/CR-6850.
- The workstation fire scenario was revised from a four panel workstation with a peak heat release rate of 4,000 kW (3,791 Btu/s) to a two panel workstation with a peak heat release rate of 1,800 kW (1,706 Btu/s). The two scenarios specify identical fire growth rates. The analysis was revised to the smaller workstation due to observations of the ANO-1 MCR, which noted that the space considered is not large enough to accommodate the more conservative four panel workstation. The abandonment times predicted for these scenarios characteristically occur within the growth phase of the fire (less than three minutes predicted time to abandonment), so that this change has no impact on the analysis.
- The model verification and validation descriptions have been updated and expanded based on guidance in NUREG-1934, "Nuclear Power Plant Fire Modeling Analysis Guidelines (NPP FIRE MAG)."
- The model uncertainty has been quantified and incorporated into the analysis as necessary based on guidance in NUREG-1934. The model uncertainty analysis demonstrates that the reported abandonment times are conservative with only a 2.7 percent likelihood that a more conservative prediction might occur due to model uncertainty.
- The model abandonment criteria was revised from 50 °C (122 °F) occupant immersion in the original analysis to the NUREG/CR-6850 recommended value 93 °C (200 °F) upper layer temperature based on limiting the radiant heat flux exposure to an occupant of 1.0 kW/m^2 (0.08 $Btu/s\text{-}ft^2$) or less. This is a non-conservative change; however, the original analysis used an optional performance criteria that is not required for MCR abandonment evaluations nor is it recommended in any guidance documentation for this purpose.

The noted revisions to the MCR Abandonment analysis are considered appropriate because either a conservative bias is generated in the reported results, or the revisions are justified by industry guidance.

l) The ANO-1 fire brigade response time of fifteen minutes is based on what is considered a reasonably conservative bounding response time and is consistent with response times assumed or noted at other plants within the Entergy fleet as well as at other utilities. A review of fire brigade drill reports for fire brigade drills conducted in 2011 and 2012 indicates that the fire brigade response time for fires in the general area of the MCR would be approximately 9 – 10 minutes (FBDRL-2011-28, "Fire Drill Scenario Unit 1 Turbine Building 386' el." and FBDRL-2012-02, "Fire Drill Scenario Unit 2 Turbine Generator"). The fire brigade drill conducted on December 1, 2011, was an announced fire drill for a hydrogen leak at the ANO-1 Turbine Generator and had a response time of 9 minutes (FBDRL-2011-28). The fire brigade drill conducted on February 23, 2012, was also an announced drill for a hydrogen leak at the ANO-2 Turbine Generator and had a response time of 10 minutes (FBDRL-2012-02). The ANO-1 and ANO-2 Turbine Generators are on the same elevation as the ANO-1 MCR and similar response times are thus expected.

   The fire brigade response time is incorporated into the updated MCR abandonment calculation (CALC-ANO1-FP-009-00011, Rev. 1) via a change in the status of the boundary doors (closed to open), though credit for manual suppression is independent of this assumption and the fire heat release rates in the CFAST models are not reduced at the brigade arrival time. Because the MCR boundary doors may open for reasons other than fire brigade arrival, such as operator actions or occupant egress, a value of fifteen minutes was selected as an intermediate value within the time interval considered in the calculation. Note that the FPRA uses the natural ventilation configuration that produces the minimum abandonment time when applied to all ignition sources, which is the closed door configuration. Because the most adverse abandonment time is used for the range of natural ventilation conditions, the uncertainty in the door open time is bounded by the use of the data provided in the MCR abandonment calculation.

   For completeness, the MCR abandonment calculation has been updated to include a sensitivity assessment of the model results to the time the boundary doors are assumed to open (see Section B.3.8 of CALC-ANO1-FP-009-00011, Rev. 1). The sensitivity assessment considers the effect of opening the boundary door to the MCR between ten and twenty minutes on both the calculated abandonment times and the total probability of MCR abandonment. It is shown that opening the doors at ten minutes generally reduces the total probability of abandonment, though several scenarios show a non-significant increase. It is also shown that opening the door at twenty minutes either does not affect the total probability of abandonment relative to the assumed fifteen-minute baseline time for opening a door or causes a decrease in the total probability of abandonment. Note that given that the maximum time at which abandonment can affect the non-suppression probability is 20.9 minutes, the scenarios for which the door opens at twenty minutes are nearly the same scenarios as the closed door baseline scenarios.

   Based on the actual response times of the fire brigade, the use of the abandonment times in the FPRA, and the sensitivity of the abandonment times to uncertainty in the fire brigade arrival time, there are no known adverse effects associated with not meeting this assumption.

m) The characterization of the transient fire scenarios has been revised in the updated MCR abandonment calculation (CALC-ANO1-FP-09-00011, Rev. 1) such that the scenarios are consistent with the guidance provided in NUREG/CR-6850, Supplement 1, "Fire Probabilistic Risk Assessment Methods Enhancements." Further, the sensitivity analysis

contained in Appendix B has been restructured and is used to provide a basis for the baseline scenario assumptions, including the time to reach a peak heat release rate for the transient fire scenarios. It is shown in Section B.3.4 of CALC-ANO1-FP-09-00011, Rev. 1, that a two-minute growth rate, which corresponds to a base height of 0.0 m (0.0 ft), provides a conservative result for transient fire scenarios located in the MCR area.

Because the revised transient growth rates are consistent with current NUREG guidance, it is not necessary to compute the impact on fire risk results (i.e., CDF, LERF, ΔCDF and ΔLERF) for this RAI response.

n) The original MCR abandonment calculation (CALC-ANO1-FP-09-00011, Rev. 0) postulated a fifteen-minute propagation between adjacent panels assuming that the conditions specified in Appendix S of NUREG/CR-6850, “EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology,” for fifteen-minute propagation would generally exist. However, in order to demonstrate that this is technically justified, detailed walkdowns are required to document the internal panel configuration. In lieu of performing these walkdowns to justify the propagation time for each specific panel configuration, the conservative generic value of ten minutes per Appendix S of NUREG/CR-6850 has been used in the updated MCR abandonment calculation (see Section 5.1.3 of CALC-ANO1-FP-09-00011, Rev. 1) in place of the fifteen minutes used in the original calculation.

o) The parameter sensitivity analysis in the updated MCR abandonment calculation (CALC-ANO1-FP-09-00011, Rev. 1) includes an assessment of the impact of the plastic doors on the total probability of MCR abandonment (see Section B.3.12). The plastic doors are conservatively treated as an additional combustible and pyrolizing fuel mass analogous to a cable tray secondary combustible. The heat release rate contribution is determined from the HELEN-FIRE test data, Tests 8, 9, 10, 40, and 41 (NUREG/CR-7197, “Heat Release Rates of Electrical Enclosure Fires, draft”), which all included a plastic door. These are the only fire tests identified that evaluate an electrical cabinet with a plastic panel door. While the HELEN-FIRE report is currently in draft, the experimental results will not change, and the observations of the fire behavior are valid. Tests 8, 9, 10, and 40 all resulted in non-sustained ignition of the contents, and the observed heat release rate was nominally equivalent to the ignitor. Test 41 produced an observable impact due to the plastic panel door. In this case, the fire grew normally for approximately eight minutes, resulting in a nominal steady heat release rate of 150 kW (142 Btu/s). At eleven minutes, the plastic panel door was observed to burn through, resulting in fire growth to a peak of 250 kW (237 Btu/s). Therefore, it is assumed that the effect of a plastic panel door can increase the peak heat release rate of the electrical cabinet by approximately 100 kW (95 Btu/s).

The additional 100 kW (95 Btu/s) heat release rate is added to the peak electrical panel heat release rate profile in the sensitivity scenarios, while the growth parameter is maintained as the baseline assumption in the MCR abandonment calculation (see Section B.3.12 of CALC-ANO1-FP-09-00011, Rev. 1). It is shown that the electrical panels with plastic doors located in the Electrical Equipment Area may be treated in the FPRA using the abandonment times for an electrical panel fire in the Operating Area of the MCR. Table B-12 of CALC-ANO1-FP-09-00011 shows that an Operating Area fire location is a conservative surrogate and introduces up to 89 percent conservative bias in the total probability of MCR abandonment. Based on recent testing documented in

NUREG/CR-7197, the heat release rate contribution from plastic doors on electrical panels is highly uncertain, though the most conservative observed effect is applied uniformly in the analysis. Accordingly, the treatment of the plastic doors in Section B.3.12 of CALC- ANO1-FP-09-00011, Rev. 1, is considered conservative.

The parameter sensitivity analysis in the updated MCR abandonment calculation also includes an assessment of the polyethylene Self-Contained Breathing Apparatus (SCBA) containers and the partially covered vertical cable trays on the probability of MCR abandonment (see Section B.3.13 of CALC-ANO1-FP-09-00011, Rev. 1). It is shown that the baseline corner configuration Bin 15 transient fire scenario in the MCR (578 kW (548 Btu/s)) is representative of the effects generated by the SCBA and vertical cable tray fuel packages in the Electrical Equipment Room. The SCBA fuel package produces abandonment in 1.4 minutes, relative to a corner Bin 15 transient in the MCR fire in 1.4 minutes. Both of these scenarios produce rapid abandonment due to their large peak heat release rate and relatively fast fire growth.

p)(i) The selection of fifteen percent criterion for model sensitivity to input parameter uncertainty is justified based on several considerations of the MCR abandonment application. The first consideration is that the process used to incorporate the parameter sensitivity into the baseline assumptions is conservative. This can be demonstrated by describing the process in more detail. The second consideration is that the fire modeling results of MCR abandonment are simply used as an input in a larger PRA model that includes various parameters with accepted levels of uncertainty. Given that the PRA model contains a significant amount of uncertainty, it can be shown that the additional uncertainty contributed by the assumed 15 percent threshold is insignificant. These factors taken together justify the selection of 15 percent model sensitivity to input parameter uncertainty.

Description of the Parameter Sensitivity Evaluation Process

The overall process for evaluating input parameter sensitivity and baseline parameter selection is performed prior to the development of the final report on MCR abandonment. Initially, a set of baseline input parameters is selected by the analyst based on knowledge of model V&V requirements, observations of the MCR, and engineering judgment based on results of prior analyses. This initial set of inputs is evaluated using the model, and compared against the sensitivity variations provided in Appendix B of the MCR Abandonment Report. The outputs are then placed into one of the following three categories:

- The parameter does not significantly affect the analysis results over the potential range of values that could be assigned to the parameter (Sensitivity Group 1). This corresponds to a parameter sensitivity within the range of 0 to +15 percent in terms of the potential risk contribution.
- The parameter does affect the analysis results, but the value selected for the baseline case is conservative (Sensitivity Group 2). This corresponds to a parameter sensitivity that is a negative percent in terms of the potential risk contribution. There is no specific constraint on the degree to which a parameter sensitivity may introduce a negative percent in potential risk and thus may introduce significant conservatism relative to an average or typical value.

- The parameter does affect the analysis results significantly and the value selected for the baseline case is not conservative (Sensitivity Group 3). This corresponds to a parameter sensitivity that is greater than +15 percent in terms of the potential risk contribution.

All quantities that fall into Sensitivity Group 1 or Group 2 are accepted as viable baseline input parameters. Quantities that fall into Sensitivity Group 3 trigger a revision in the baseline input parameters or some other conservative treatment that can explicitly account for the parameter, such as an additional limit of applicability. Group 3 results are not generally accepted for use in the baseline unless it is found through repeated iterations of the sensitivity analysis that the result cannot be corrected directly with parameter selection. This process is repeated several times until a final set of baseline parameters can be established that almost entirely results in Group 1 or Group 2 sensitivity. Since Group 2 is a conservative outcome, this process is considered to be conservative for evaluating the risk of MCR abandonment.

Quantification of Uncertainty in the Overall PRA Model

The MCR abandonment timing is used as an input to a larger PRA model. This PRA model calculation has multiple input parameters, several of which have a known and quantifiable uncertainty. The following analysis will attempt to compare the parameter uncertainty introduced by the MCR abandonment time predictions to the uncertainty that currently exists in the other PRA model inputs. If the contribution to the uncertainty associated with the abandonment time is significantly lower than the total uncertainty in the other parameters, then the selection of fifteen percent can be justified.

One of the primary risk calculations is the CDF. The CDF is a summation of several individual events evaluated by their frequency and their consequence. The typical expression used for CDF of an individual event (i) is provided in NUREG/CR-6850, “EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology,” Appendix M:”

$$CDF_i = \lambda_g \cdot W_L \cdot W_{is} \cdot SF_i \cdot P_{ns} \cdot CCDP_i$$

Where λ_g is the generic frequency of the event (NUREG/CR-6850, Supplement 1, Section 10.2.1, “Fire Probabilistic Risk Assessment Methods Enhancements Supplement 1 to NUREG/CR-6850 and EPRI 1011989”), W_L is the location weighting factor, W_{iS} is the ignition source weighting factor, SF_i is the severity factor for the scenario, P_{ns} is the probability of no suppression, and $CCDP_i$ is the conditional core damage probability for the scenario. The probability of no suppression is evaluated using the expression:

$$P_{ns} = MAX(0.001, \exp(-\lambda t))$$

where λ is the rate of manual suppression (1/minute) (NUREG/CR-6850, Volume 2, Table P-2), and t is the timing of the event. In this case, t is the time predicted for MCR abandonment. The terms λ_g and λ have quantified uncertainties, and each term is statistically represented by a gamma distribution or exponential distribution respectively.

The gamma distribution for λ_g is provided in NUREG/CR-6850, Supplement 1, Section 10.2.1, with Bin Number 4 corresponding to fires inside the MCR. The mean is specified as 8.24E-04, and the variance of this form of the gamma distribution is $(Alpha/Beta)^2 = (1/1212.9)^2 = 6.79E\text{-}07$, while the standard deviation is Alpha/Beta = 8.24E-04 (equal to the mean since Alpha = 1.0). The exponential distribution for λ is provided in NUREG/CR-6850, Volume 2, Table P-2, and NUREG/CR-6850, Supplement 1, Table 14-2, for fires inside the MCR. The mean is specified as 0.33, and the variance of the exponential distribution is equal to the square of the mean, or $(0.33)^2 = 0.1089$, while the standard deviation is equal to the mean. Note that the exponential distribution is equivalent to the gamma distribution for the special case of Alpha = 1.0. These two parameters are highly variable due to uncertainty since the standard deviation is equal to the mean.

The MCR abandonment timing analysis essentially limits the probability of non-suppression output parameter to have at most fifteen percent uncertainty due to input parameter variations. The only variable input used is the abandonment time, and the rate of manual suppression is assumed constant (0.33/minute). The standard deviation of the time parameter due to this assumption is approximately 0.3, and the variance is correspondingly $(0.3)^2 = 0.09$. The time parameter will be assumed to have a uniform distribution with the specified variance. Note that the time parameter itself must be maintained as a variable quantity in the analysis since the probability of no suppression is a time dependent function.

The total variance of a complex function of uncertain variables can be evaluated using the Method of Moments (Modarres, M. *Risk Analysis in Engineering: Techniques, Tools, and Trends*. CRC Press, 2006. pg. 208). This method uses a Taylor series expansion of the function about the mean input variables to define the total variance. The result can be expressed using the two-term approximation that the co-variances of the variables are negligible:

$$Total\ Variance = S^2 = \sum_{i=1}^{n} S_i^2 = \sum_{i=1}^{n} S(x_i)^2 \left[\frac{\partial CDF}{\partial x_i}\right]^2$$

where S is the standard deviation, S_i^2 is the total variance due to parameter *i*, $S(x_i)^2$ is the variance of parameter i (see above), and $\partial CDF / \partial x_i$ is the partial derivative of the equation for CDF over all its input parameters x_i. This expression can be evaluated analytically considering that only the variance due to λ_g, λ, and t contribute. The math is trivial, and the result is dependent on time due to the partial derivative of CDF with respect to λ_g. The results of this analysis are summarized in Figure 1 where variable S_1 is λ_g, S_2 is λ and S_3 is t respectively, and CDF is the product of the mean values over an interval of 0 – 20 minutes.

Figure 1 – Input parameter variance on the CDF evaluation

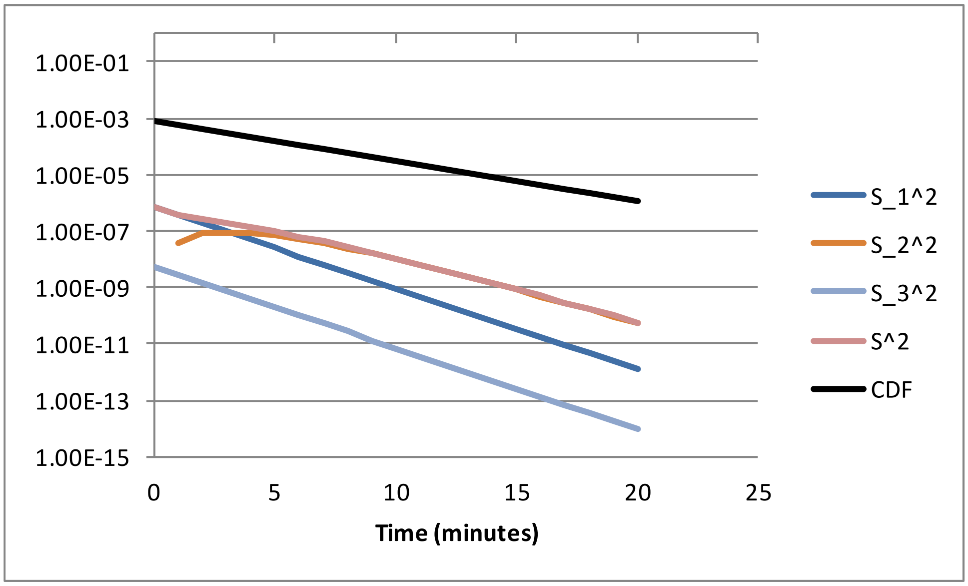

Figure 1 shows that the total variance attributable to the uncertainty in the time to abandonment is approximately two to four orders of magnitude smaller than the total variance. This means that the contribution to uncertainty of CDF is completely dominated by the uncertainty in λ_g and λ and that the assumed uncertainty of fifteen percent in the parameter *t* is negligible by comparison. For example, the assumed uncertainty in the parameter *t* could be ten times greater than what is currently assumed without having an adverse impact on the total uncertainty in the PRA.

Conclusion

The selection of fifteen percent criterion for model sensitivity to input parameter uncertainty is justified based on several considerations of the MCR abandonment application. The process has been designed to incorporate parameter sensitivity in a conservative way. The selection has also been justified by comparing the uncertainty introduced to the PRA model by the time to abandonment with the uncertainty that already exists in other parameters used to define risk. Given that the PRA model contains a significant amount of uncertainty, it was shown that the additional uncertainty contributed by the assumed 15 percent threshold is insignificant. These factors taken together justify the selection of 15 percent model sensitivity to input parameter uncertainty.

p)(ii) The sensitivity analysis has been revised in the updated MCR abandonment calculation (CALC-ANO1-FP-09-00011, Rev. 1) to provide a basis for the baseline parameter selections. The procedure used in the sensitivity analysis is described in the response to Part p)(i) of this RAI. In the case of the assumed fire base elevation of the panel ignition sources, it is shown in Section B.3.4 of CALC-ANO1-FP-09-00011, Rev. 1, that an elevation of 2.4 m (8.0 ft) produces a conservative total probability of MCR abandonment when summed over multiple heat release rate bins. Accordingly, the baseline fire elevation for the electrical panels is set to 2.4 m (8.0 ft) in the updated MCR abandonment calculation.

<u>FM RAI 02</u>

LAR Section 4.5.1 states, in part, that

> In accordance with the guidance in RG 1.205, a Fire PRA (FPRA) model was developed for ANO-1 in compliance with the requirements of Part 4 "Requirements for Fires at Power Probabilistic Risk Assessment Requirements," of the American Society of Mechanical Engineers (ASME) and American Nuclear Society (ANS) combined PRA Standard, ASME/ANS RA-Sa-2009, 'Standard for Level 1 /Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Application,' ... "

ASME/ANS Standard RA-Sa-0009, Part 4, requires damage thresholds be established to support the FPRA. The standard further states that thermal impact(s) must be considered in determining the potential for thermal damage of systems, structures, and components (SSCs) and appropriate temperature and critical heat flux criteria must be used in the analysis.

Please provide the following information:

a) Describe how the installed cabling in the power block was characterized, specifically with regard to the critical damage threshold temperatures and critical heat fluxes for thermoset and thermoplastic cables as described in NUREG/CR-6850.

b) In any fire area, explain how cable tray covers, fire-resistant coatings, and fire wraps were credited in terms of delaying or preventing damage of cables. In addition, explain how holes in cable tray covers were treated in regard to the fire modeling damage criteria.

c) Explain how the damage thresholds for non-cable components (i.e., pumps, valves, electrical cabinets, etc.) were determined. Identify any non-cable components that were assigned damage thresholds different from those for thermoset and thermoplastic cables, and provide a technical justification for these damage thresholds.

d) Describe the damage criteria that were used for exposed temperature-sensitive electronic equipment. Explain how temperature-sensitive equipment inside an enclosure was treated, and provide a technical justification for these damage criteria.

Response

a) All cables at ANO-1 were treated as thermoset, IEEE-383 qualified cables. The damage threshold temperature and critical heat flux applied to the cables was 330 °C (625 °F) and 11 kW/m^2 (1.0 Btu/s-ft^2), respectively. These damage thresholds are as reported in NUREG/CR-6850, Volume 2, Appendix H, Table H-1. The heat release rate distributions applied to electrical panel ignition sources correspond to the NUREG/CR-6850, Volume 2, Appendix E, Table E-1, heat release rate distribution cases for electrical panels containing IEEE-383 qualified cables (vertical cabinets with qualified cable).

b) Fire-resistant coatings and fire wraps were not credited in any fire area in the fire modeling evaluations. Solid cable tray covers were credited to isolate cables from contributing to the scenario heat release rates only. Cables protected with cable tray covers were considered to be damaged if within a fire scenario zone of influence (ZOI).

c) Thermoset, IEEE-383 qualified cable damage temperatures were applied to non-cable components (i.e., pumps, valves, electrical cabinets, etc.) as specified in NUREG/CR-6850, Volume 2, Appendix H, Section H.2.

d) Exposed sensitive electronic equipment was not credited in the FPRA. As such, damage to exposed sensitive electronic equipment was not assessed and exposed sensitive electronic equipment damage threshold are not applicable. Plant walkdowns did not identify such items.

The damage threshold for sensitive electronics located inside cabinets at ANO-1 is 11 kW/m^2 (1.0 Btu/s-ft^2), the same damage threshold applied to thermoset, IEEE-383 qualified cables, per FPRA FAQ-13-0004, "Clarifications on Treatment of Sensitive Electronics." The basis for assuming cable damage thresholds for temperature sensitive equipment located inside cabinets is the protection provided by the enclosures. In general, any component that should be evaluated using the lower damage threshold specified in Section H.2 of NUREG/CR-6850 is likely to be located within a ventilated panel (cabinet) or some other robust enclosure. The presence of that robust enclosure essentially shields the component from direct radiant exposure. Consequently, the actual exposure temperature would be based on the temperature response of the enclosure to the incident heat flux and the thermal response of the air within the enclosure.

A fire modeling analysis was performed using the Fire Dynamics Simulator (FDS) to calculate the heat flux and temperatures within a metal cabinet exposed to a fire in support of FPRA FAQ 13-0004. The objective of the analysis was to determine whether conditions within a panel (cabinet) would remain below the damage threshold specified in Section H.2 of NUREG/CR-6850 for sensitive electronic equipment (3.0 kW/m^2 [0.25 Btu/s-ft^2] and 65 °C [150 °F]) when the exterior surface was subjected to a heat flux equal to or exceeding the generic screening damage threshold for thermoset cables. The specific fire considered assumed a heat release rate of 317 kW (300 Btu/s) and corresponded to the NUREG/CR-6850 98th percentile transient ignition source. The fire was placed such that its centerline was 1.0 m (3.3 ft) from the panel (cabinet) surface. This distance is typical of a horizontal ZOI for thermoset cable targets. The FDS simulations for this analysis found that the heat flux and temperature experienced by components within the enclosure remained below that specified in Section H.2 of NUREG/CR-6850 for sensitive electronic equipment (i.e., 3.0 kW/m^2 [0.25 Btu/s-ft^2] and 65 °C [150 °F]), while the exterior surface heat flux exceeded the generic screening damage threshold for thermoset cables as specified in Table H-1 of NUREG/CR-6850 (i.e., 11 kW/m^2 [1.0 Btu/s-ft^2]). These results support the recommendation that a generic screening heat flux damage threshold for thermoset cables, as observed on the outer surface of the cabinet, can be used as a conservative surrogate for assessing the potential for thermal damage to solid-state and sensitive electronics within an electrical panel (cabinet).

The procedure used at ANO-1 is thus consistent with the findings associated with the FPRA FAQ 13-0004 analysis insofar as the ZOIs for thermoset cable targets are used as surrogates for the damage thresholds for temperature sensitive equipment located inside cabinets.

<u>FM RAI 04</u>

NFPA 805 Section 2.7.3.3, "Limitations of Use," states, in part, that:

> Acceptable engineering methods and numerical models shall only be used for applications to the extent these methods have been subject to verification and validation. These engineering methods shall only be applied within the scope, limitations, and assumptions prescribed for that method.

LAR Section 4.7.3, "Compliance with Quality Requirements in Section 2.7.3 of NFPA 805," states, in part, that:

> Engineering methods and numerical models used in support of compliance with 10 CFR 50.48(c) were used appropriately and will continue to be used as required by Section 2.7.3.3 of NFPA 805.

Regarding the limitations of use, please identify the use, if any, of the GFMTs approach (including the GFMTs supplements), outside the limits of applicability of the method. For those cases, explain how the use of the GFMTs approach was justified.

Response

There are two broad categories of limitations that are applicable to the GFMT approach. These include limitations associated with the implementation of the ZOI and limitations associated with the CFAST fire modeling of the HGL conditions. In addition, limitations apply to the CFAST fire modeling conducted in support of the MCR abandonment calculation, CALC-ANO1-FP-09-00011, Rev. 1, "Evaluation of Control Room Abandonment Times at Arkansas Nuclear One, Unit 1."

1. Generic Fire Modeling Treatments Approach - ZOIs

   The Generic Fire Modeling Treatments approach, as documented in Report 1SPH02902.030, Rev. 0, "Generic Fire Modeling Treatments," is intended to provide conservative ZOI dimensions and HGL temperature estimates for various types of ignition sources when used within the stated limitations. There are five basic limitations that should be considered when applying the original GFMT ZOIs (Report 1SPH02902.030, Rev. 0). The five limitations represent conditions or configurations for which the original GFMT ZOI data may potentially be non-conservative if applied outside the particular limitation:

   - The application of the generic ZOI data in compartments in which the HGL temperature exceeds 80 °C (176 °F),
   - The application of the generic ZOI data to fire scenarios in wall and corner configurations,
   - The application of the generic ZOI data for panel ignition sources with panels having plan dimensions greater than 0.91 x 0.61 x 2.13 m (3.0 x 2.0 x 7.0 ft),
   - The application of the generic ZOI data to scenarios that result in flame impingement to the ceiling, and
   - The application of the ZOI data to configurations in which secondary combustibles (cable trays) are ignited.

Report PRA-ES-05-006, Rev. 0, “Supplemental Generic Fire Modeling Treatments: Transient Fuel Package Ignition Source Characteristics,” was developed to address a number of these limitations under various circumstances that arise at ANO-1. In addition, several method enhancements have been developed to address specific configurations or conditions that have been encountered when applying the GFMT in the field, including the consideration of combination ignition source - secondary combustibles fire scenarios. These method enhancements are documented in PRA-A2-05-017, Rev. 0, “Combined Ignition Source – Cable Tray Fire Scenario ZOIs for Arkansas Nuclear One Unit 2 Applications,” PRA-A1-05-011, Rev. 0, “Evaluation of Development and Timing of Hot Gas Layer Conditions in Selected ANO Fire Zones,” and PRA-A2-05-018, Rev. 0, “Evaluation of the Development and Timing of Hot Gas Layer Conditions in Generic ANO-2 Fire Compartments with Secondary Combustibles.” Note that PRA-A2-05-017, Rev. 0 and PRA-A2-05-018, Rev. 0 were originally developed for ANO-2 fire compartments, but the configurations considered are applicable to compartments in ANO-1.

ZOIs in Elevated Temperature Enclosures

In most situations, ZOIs are not used above 80 °C (176 °F) to determine target failures, which effectively transitions a scenario to a full room burnout. In situations where additional resolution is needed to better quantify the risk, an extended ZOI dimension is used. The expanded ZOI is based on the ZOI dimensions for thermoplastic cables and is applicable in environments where the HGL temperature radiates a heat flux equal to 5.7 kW/m^2 (0.5 Btu/s-ft^2). The total heat flux to a target located on the ZOI boundary under these conditions is 11.4 kW/m^2 (1.0 Btu/s-ft^2), the NUREG/CR-6850, “EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology,” steady-state threshold value for thermoset cables. The applicable limit for the expanded ZOI is 220 °C (428 °F).

ZOIs in Wall and Corner Locations

The application of the generic ZOI data to fires postulated in wall and corner configurations exceeds the original limitations of the Report 1SPH02902.030, Rev. 0. However, the ZOI dimensions for ignition sources in wall and corner configurations are provided in PRA-ES-05-006, Rev. 0, for transient fire scenarios and PRA-A2-05-017, Rev. 0, for transient and electrical panel fire scenarios with and without secondary combustibles.

Wall and corner effects are assessed in PRA-ES-05-006, Rev. 0, for transient fire scenarios and PRA-A2-05-017, Rev. 0, using a location factor or ‘Image’ method approach as described in NIST-GCR-90-580, “Development of an Instructional Program for Practicing Engineers Hazard I Users.” The ‘Image’ method is a simple means of incorporating wall and corner effects by taking advantage of the proportionality between the fire perimeter and the plume air entrainment by changing the fire area. The ZOI dimensions provided in Report 1SPH02902.030, Rev. 0, for open locations may be used to estimate the ZOI for wall and corner locations for ignition sources that do not involve secondary combustibles by selecting the data for a fire size that is two or four times the actual fire size.

Walkdowns will be performed to identify fixed ignition source fire scenarios that should be treated using wall and corner location factors. The updated FPRA will address transient fuel packages in wall and corner configurations using the ZOI data provided in PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev 0. The location for fixed ignition sources such as

electrical panels was generally assumed to be open given that most panel vents are orientated away from wall boundaries. The updated fire scenario results will be provided in the update to Attachment W of the original LAR when all FPRA revisions are complete. The results will be provided with the FPRA updates associated with PRA RAI 03.

ZOIs for Large Dimension Electrical Panels

The original GFMT report and Supplement 2 of the GFMT report ZOI data was derived for panels having plan dimensions up to 0.91 x 0.61 m (3.0 x 2.0 ft) and a height up to 2.13 m (7.0 ft). The dimensions primarily affect the extent of the horizontal component of the ZOI that is below the top of the panel. This ZOI component is calculated from an energy balance at the panel surface, and the target exposure mechanism is a heated radiating vertical plane. Consequently, changes in the panel dimensions affect the dimensions of the radiating plane, which in turn affects the geometry configuration factor between the target and the radiating plane. The lower horizontal ZOI dimension is the limiting horizontal ZOI dimension and is used in the FPRA as the basis for determining the affected target set. An approximate upper limit for the ZOI dimensions based on a 0.91 x 0.61 x 2.13 m (3.0 x 2.0 x 7.0 ft) tall panel may be estimated by comparing against a limiting open panel configuration. In this case, the maximum heat transferred across one boundary would be given through the definition of the emissive power and a radiation area as follows:

$$Q_{b,max} = A_b E \qquad \text{(FM 04–1)}$$

where $Q_{b,max}$ is the maximum heat that can be transferred across a vertical boundary of an electrical panel (kW [Btu/s]), A_b is the area of the boundary (m^2 [ft^2]), and E is the flame emissive power (kW/m^2 [Btu/s-ft^2]). Assuming the maximum average flame emissive power over the panel boundary is 120 kW/m^2 (10.6 Btu/s-ft^2) based on Section 3-10 of the *SFPE Handbook of Fire Protection Engineering*, 4th Edition, “Fire Hazard Calculations for Large, Open Hydrocarbon Fires,” and data provided in *Combustion and Flame*, No. 139, pp. 263-277, “Analysis of the Geometric and Radiative Characteristics of Hydrocarbon Pool Fires,” the maximum heat that could be transferred across a vertical boundary via thermal radiation is about 235 kW (223 Btu/s) if the heat transferred across an open boundary is considered to be an upper limit on the boundary heat losses in any one direction. To link this heat loss to the postulated fire size, the radiant fraction is used, which is reasonably approximated as 0.3 for enclosure fires per Section 3-8 of the *SFPE Handbook of Fire Protection Engineering*, 4th Edition, “Modeling Enclosure Fires Using Computational Fluid Dynamics (CFD).” Dividing the maximum boundary heat loss of 235 kW (223 Btu/s) by the radiant fraction (0.3) results in the largest fire size for which the lateral ZOI dimensions would be conservative, or 783 kW (742 Btu/s). This value exceeds the severe fire heat release rate used to characterize both the multiple bundle (717 kW [680 Btu/s] based on the Bin 8 heat release rate) and single bundle (211 kW [200 Btu/s]) electrical panels. This result is based on a radiant fraction of 0.3; if a value at the upper end of the often cited range 0.3 – 0.4 is assumed per Section 3-8 of the *SFPE Handbook of Fire Protection Engineering*, 4th Edition, the largest fire size for which the lateral ZOI dimensions would be conservative, or 588 kW (557 Btu/s). However, this would be based on all heat losses being directed toward the target. The internal temperature during a fully developed enclosure fire would be greater than 600 °C (1,112 °F), which suggest the heat losses from all boundaries, except the open boundary, would be on the order of 110 kW (104 Btu/s). This means that the maximum total energy that could radiate toward the target via thermal radiation would be about 600 kW (569 Btu/s) × 0.4 or 240 kW (227 Btu/s). This is

comparable to the maximum boundary heat loss via thermal radiation (235 kW [223 Btu/s]), which indicates the conclusion applies over a wider range of radiant fractions when the additional boundary heat losses are included. There are no known applications of the panel fire ZOI dimensions to panels that have a heat release rate greater than 783 kW (742 Btu/s) in an open location and a plan size that exceeds 0.91 x 0.61 m (3.0 x 2.0 ft) within the FPRA. The limiting fire size (and plan dimension for the panels) for wall and corner locations is increased by a factor of two and four due to the symmetry planes assumed in the 'Image' method. This suggests that the panel size constraint is met for electrical panel ignition source fire scenarios. A review of the fixed ignition source (panel) heat release rates was performed as part of the FPRA updates and it was confirmed that there are no panels evaluated in the FPRA with a heat release rate greater than 783 kW (742 Btu/s) in an open location. As such, this limitation is considered to be met for ANO-1.

Flame Height Limitation for ZOIs

The original GFMT report (1SPH02902.030) limits the application of the ZOIs to situations in which the flames remain lower than the ceiling height. Subsequent analysis presented in PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0, indicates that the ZOIs remain conservative provided the ceiling jet temperature at the ZOI boundary remains less severe than the threshold damage temperature for the cable target. The minimum ceiling height above the fire base is listed in PRA-ES-05-006, Rev. 0, for transient ignition sources and in PRA-A2-05-017, Rev. 0, for transient and fixed ignition sources that involve secondary combustibles. The results indicate that a ceiling height of 0.3 – 1.5 m (1.0 – 5.0 ft) above the fire base, depending on ignition source and cable tray configuration, is sufficient to meet the ceiling jet condition whether or not flame impingement occurs. There are no known applications that fall below this range listed in PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0.

ZOIs for Scenarios with Secondary Combustibles (Cable Trays)

The ZOIs provided in the original GFMT report (1SPH02902.030) postulates a single ignition source fire without secondary combustibles and is thus applicable to configurations that do not involve secondary combustibles, such as cable tray stacks. The original procedures for addressing situations in which cable trays could ignite was to extend the vertical ZOI dimension to the ceiling. This approach has been replaced with ZOIs developed for specific ignition source – cable tray configurations as documented in PRA-A2-05-017, Rev. 0. The ZOIs are provided in tabular format at ten minute time increments, and directly incorporate the vertical flame propagation through the cable trays using NUREG/CR-6850, Volume 2, Appendix R, guidance and the lateral flame spread and overall heat release rate development as recommended in NUREG/CR-7010, "Cable Heat Release, Ignition, and Spread in Tray Installations During Fire (CHRISTIFIRE) Volume 1: Horizontal Trays."

2. Generic Fire Modeling Treatment Approach – Hot Gas Layers

The GFMT approach, as documented in Report 1SPH02902.030, Rev. 0, is intended to provide conservative HGL temperature estimates for various types of ignition sources when used within the stated limitations. The method for determining the potential for HGL effects is based on zone model evaluations using CFAST, Versions 6.0.10 and 6.1.1. The approach involves two basic types of CFAST calculations:

- Generic enclosures that minimize the heat losses to the boundaries (report 1SPH02902.030, Rev. 0, and PRA-A2-05-018, Rev. 0), and
- Specific enclosures that minimize the heat losses to the boundaries (PRA-A1-05-011, Rev. 0).

The key CFAST model limits that apply to the ANO-1 CFAST evaluations as identified in NIST-SP-1026, "CFAST – Consolidated Model of Fire and Smoke Transport (Version 6) Technical Reference Guide," NUREG-1824, Volume 5, "Verification & Validation of Selected Fire Models for Nuclear Power Plant Applications, Volume 5, Consolidated Fire Growth and Transport Model," and report 1SPH02902.030 are as follows:

- Maximum vent size to enclosure volume ratio of 2 m^{-1} (0.61 ft^{-1})
- Secondary combustibles
- Wall and ceiling locations
- Maximum enclosure aspect ratio of five (length to width)

Vent Size

The approach adopted in both the generic and the specific enclosure analysis is to evaluate a range of ventilation fractions, from 0.001 to 10 percent of the enclosure boundary. Given that the width is set equal to the length in both the generic and specific enclosure evaluations, the maximum vent size to enclosure volume ratio is given by the following equation:

$$\frac{W + 2H}{5WH} \qquad \text{(FM 04-2)}$$

where *W* is the enclosure width or length (m [ft]), and *H* is the enclosure height. Based on the definition of the generic volume, the enclosure height is one-half the enclosure width, so that the vent size to enclosure volume ratio can only exceed 2 m^{-1} (0.61 ft^{-1}) if the ceiling height is 0.2 m or less. Because the minimum ceiling height considered is 1.4 m (4.5 ft) in PRA-A2-05-018, Rev. 0, this condition is necessarily met. Based on Equation FM 04-2, for a vent area that is ten percent of the boundary area, the largest ceiling height that yields a vent size to enclosure volume ratio of 2 m^{-1} (0.61 ft^{-1}) is 0.3 m (1.0 ft). All of the specific enclosures evaluated in PRA-A1-05-011, Rev. 0, have ceiling heights significantly larger than 0.3 m (1.0 ft); thus, this limitation is met in all ANO-1 CFAST models.

Hot Gas Layers in Enclosures with Secondary Combustibles

The HGL tables provided in the original GFMT report (1SPH02902.030) postulates a single ignition source fire without secondary combustibles and is thus applicable to configurations that do not involve secondary combustibles, such as cable tray stacks. PRA-ES-05-007, Rev. 0, provides HGL data for a single cable tray configuration having the following characteristics:

- Total cross-sectional length of 0.9 m (3.0 ft) as represented by two 0.45 m (1.5 ft) wide cable trays placed side-by-side that release heat from the top and bottom or two 0.9 m (3.0 ft) wide cable trays that release heat from the top only
- Heat release rate per unit area of 225 kW/m^2 (19.8 Btu/s-ft^2)
- Flame propagate rates of 0.3 mm/s (0.012 in/s) for thermoset/IEEE-383 qualified cables and 0.9 mm/s (0.035 in/s) for thermoplastic/non-IEEE-383 qualified cables
- Fire propagation in two directions
- Fire ignition at a single vertical plane located above the ignition source
- Cable tray(s) having a base height 0.3 m (1.0 ft) above the base of the ignition source
- Heat release rate per unit area reaches a maximum value at the ignition time for any fixed location on the cable trays
- Ignition of the cables at five minutes after the ignition source ignites

The HGL results are considered to be conservative when applied to configurations that meet the aforementioned constraints largely because the heat release rate per unit area is not linearly ramped over a timescale equal to one-sixth the fire duration as suggested in NUREG/CR-7010, Volume 1. Detailed HGL tables for bounding ignition source – cable tray configurations in specific ANO-1 enclosures are provided in PRA-A1-05-011, Rev. 0, and are used to determine the potential for multiple fire area effects. The heat release rates for the cable trays are determined in PRA-A1-05-011, Rev. 0, using the guidance provided in NUREG/CR-6850 and NUREG/CR-7010, Volume 1, including the heat release rate per unit area, the flame spread rate, and the vertical propagation rate. Finally, because there is the potential for non-conservative applications of the HGL tables provided in PRA-ES-05-007, Rev. 0, additional HGL tables have been developed and documented in PRA-A2-5-018, Rev. 0 for fixed and transient ignition sources that involve one through eight cable trays arranged within a single cable tray stack using the guidance provided in NUREG/CR-6850 and NUREG/CR-7010, Volume 1. The HGL tables provided in PRA-A2-05-018, Rev. 0, will replace those documented in PRA-ES-05-007, Rev. 0, in the updated FPRA and the fire scenario results will be provided in the update to Attachment W of the original LAR when all FPRA revisions are complete. The results will be provided with the FPRA updates associated with PRA RAI 03. Note that PRA-A2-05-017, Rev. 0, and PRA-A2-05-018, Rev. 0, were originally developed for ANO-2 fire compartments, but the configurations considered are applicable to compartments in ANO-1.

Hot Gas Layers for Fires in Wall and Corner Locations

The application of the generic HGL data to fires postulated in wall and corner configurations exceeds the original limitations of the Report 1SPH02902.030, Rev. 0. However, the HGL data for ignition sources in wall and corner configurations are provided in PRA-A2-05-018, Rev. 0, for transient and electrical panel fire scenarios with and without secondary combustibles.

As previously noted, wall and corner effects are using a location factor or ‘Image’ method approach as described in NIST-GCR-90-580. The HGL data provided in Report 1SPH02902.030, Rev. 0, for open locations may be used to estimate the HGL timing for wall and corner locations for ignition sources that do not involve secondary combustibles by selecting the data for a fire size that is two or four times the actual fire size.

Walkdowns will be performed to identify fixed ignition source fire scenarios that should be treated using wall and corner location factors. The updated FPRA will address transient fuel packages in wall and corner configurations using the HGL data provided in PRA-A2-05-017, Rev 0. The location for fixed ignition sources such as electrical panels was generally assumed to be open given that most panel vents are orientated away from wall boundaries. The updated fire scenario results will be provided in the update to Attachment W of the original LAR with the FPRA updates associated with PRA RAI 03.

Enclosure Aspect Ratio

A final limitation of the GFMT report (1SPH02902.030, Rev. 0), Report PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, relates to the maximum aspect ratio of an enclosure for which the HGL data is applied. The HGL information is provided for enclosures having an aspect ratio up to five, per Section 3.2 of NUREG-1824, Volume 5. In situations where the model is applied to enclosures having a larger aspect ratio, the behavior transitions to a channel flow typical of a corridor configuration. Localized effects in the vicinity of the fire could be more severe than the average conditions throughout the enclosure length, and thus a non-conservative result could be generated. NUREG-1934, “Nuclear Power Plant Fire Modeling Application Guide,” describes a method to apply a fire model in a conservative manner under these conditions. This method involves the modification of the enclosure dimensions such that the application falls within the model limitation and the HGL temperature results are conservative. This modification is incorporated directly into the specific enclosure analysis for enclosures or enclosure models that have aspect ratios greater than five, thus the limitation does not apply to PRA-A1-05-011, Rev. 0. A review of the enclosure aspect ratios will be performed as part of the FPRA update, and applications in enclosures that exceed the limiting aspect ratio will be adjusted using the method provided in NUREG-1934. The updated fire scenario results will be provided in the update to Attachment W of the original LAR with the FPRA updates associated with PRA RAI 03.

3. Updated Main Control Room Abandonment Calculation

The key CFAST model limits that apply to the updated ANO-1 MCR abandonment calculation (CALC-ANO1-FP-09-00011, Rev. 1) as identified in NIST-SP-1026, “CFAST – Consolidated Model of Fire and Smoke Transport (Version 6) Technical Reference Guide,” and NUREG-1824, Volume 5, are as follows:

- The maximum vent size to enclosure volume ratio should not exceed 2 m^{-1} (0.61 ft^{-1})
- The maximum enclosure aspect ratio as defined by the ratio of the compartment length to compartment width should not exceed five

The maximum vent sizes considered in the MCR abandonment calculation consist of a single open door, a louver, and a damaged glass boundary. The total vent size to enclosure volume ratio for this opening combination remains much less than 2 m^{-1} (0.61 ft^{-1}) and indicates this limitation is met for all CFAST evaluations. There are four primary spaces used to evaluate fires in the MCR: the ANO-1 and ANO-2 MCR areas, and the ANO-1 and ANO-2 electrical equipment areas. The approximate aspect ratio for each of these spaces is as follows (CALC-ANO1-FP-09-00011, Rev. 1):

- ANO-1 MCR area: 1.83
- ANO-2 MCR area: 1.88
- ANO-1 electrical equipment area: 1.15
- ANO-2 electrical equipment area: 1.35

These aspect ratios are less than the CFAST limit of five and indicate this limitation is met for all CFAST evaluations.

FM RAI 06

NFPA 805, Section 2.7.3.5, "Uncertainty Analysis," states, in part, that:

> An uncertainty analysis shall be performed to provide reasonable assurance that the performance criteria have been met.

LAR Section 4.7.3, "Compliance with Quality Requirements in Section 2.7.3 of NFPA 805," states, in part, that:

> Uncertainty analyses were performed as required by Section 2.7.3.5 of NFPA 805 and the results were considered in the context of the application. This is of particular interest in fire modeling and FPRA development.

Regarding the uncertainty analysis for fire modeling, please provide the following information:

a. Describe how the uncertainty associated with the input parameters (compartment geometry, radiative fraction, thermophysical properties, etc.) were addressed and accounted for in the fire modeling analyses.

b. Describe how the "model" and "completeness" uncertainties were accounted for in the fire modeling analyses.

Response

a) Fire model uncertainty associated with the fire model input parameters was not explicitly accounted for in the FPRA development at ANO-1. However, the uncertainty associated with specific fire modeling parameters is addressed through the use of a conservative and bounding analysis and sensitivity studies are provided in the various documents that demonstrate this. There are four primary areas at ANO-1 in which fire modeling parameter uncertainty is applicable:

   - The updated main control room (MCR) abandonment analysis (CALC-ANO1-FP-09-00011, Rev. 1, “Evaluation of Control Room Abandonment Times at Arkansas Nuclear One, Unit 1”)
   - The hot gas layer (HGL) tabulations as contained in 1SPH2902.030, Rev. 0, “Generic Fire Modeling Treatments,” PRA-A1-05-011, Rev. 0, “Evaluation of Development and Timing of Hot Gas Layer Conditions in Selected ANO Fire Zones,”

and PRA-A2-05-018, Rev. 0, "Evaluation of the Development and Timing of Hot Gas Layer Conditions in Generic ANO-2 Fire Compartments with Secondary Combustibles"

- The Zone of Influence (ZOI) tabulations as contained in 1SPH2902.030, Rev. 0, PRA-ES-05-006, Rev. 0, "Supplemental Generic Fire Modeling Treatments: Transient Fuel Package Ignition Source Characteristics," and PRA-A2-05-017, Rev. 0, "Combined Ignition Source – Cable Tray Fire Scenario ZOIs for Arkansas Nuclear One Unit 2 Applications"
- Administration and Turbine Building separation analysis (CALC-ANO1-FP-08-00003, Rev. 0, "Fire Protection Evaluation of Administrative Building Separation from ANO-1 Turbine Building per NFPA 80A Requirements")

Note that the HGL tables provided in PRA-ES-05-007, Rev. 0, "Evaluation of Development and Timing of Hot Gas Layer Conditions in Generic ANO-1 Fire Compartments," have been replaced by the tables provided in PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, in the updated FPRA.

MCR Abandonment Calculation

The updated MCR abandonment calculation CALC-ANO1-FP-09-00011, Rev. 1, is structured to provide a reasonably conservative abandonment time for a given heat release rate input over a range of potential input parameter values. The MCR abandonment calculation provides baseline cases for fifteen forced and natural ventilation combinations and effectively provides a sensitivity assessment on these parameters. Specifically, for a given fire scenario considered in the FPRA, the shortest abandonment time among the various natural ventilation configurations is selected. In order to demonstrate that the analysis results are conservative relative to the uncertainty in other parameters, a fire modeling sensitivity analysis is provided in Appendix B to CALC-ANO1-FP-09-00011, Rev. 1. The sensitivity analysis is used to justify the selection of the input parameter values for the baseline cases using a variation in the total probability of abandonment criterion (fifteen percent non-conservative, no limit for conservative). The total probability of abandonment is defined as a product of the severity factor for a particular heat release rate bin and the probability of non-suppression summed over the applicable number of heat release rate bins. A three bin summation is used in the sensitivity analysis whereas a fifteen bin summation is used when comparing the baseline fire scenarios. The aggregate effect of the parameter uncertainty using this approach is conservatively biased as described in the response to FM RAI 01.p.i.

The sensitivity analysis provided in Appendix B to CALC-ANO1-FP-09-00011, Rev. 1 is performed on various model parameters and demonstrates that the parameter sensitivity may be grouped as follows over the range of parameter uncertainty:

- The parameter does not significantly affect the analysis results over the potential range of values that could be assigned to the parameter (Sensitivity Group 1),
- The parameter does affect the analysis results, but the value selected for the baseline case is conservative (Sensitivity Group 2), and
- The parameter does affect the analysis results and the value selected for the baseline case is not conservative (Sensitivity Group 3).

A significant effect is defined in the parameter sensitivity as a fifteen percent variation in the probability of MCR abandonment as summed over three heat release rate bins (see response to FM RAI 01.p.i). The model parameters are evaluated against baseline fire scenarios that consist of the single and multiple bundle electrical panel ignition sources and transient ignition sources. Except where door parameters and ventilation parameters are assessed, the baseline configuration involves a MCR configuration with normal heating, ventilation, and air conditioning (HVAC) conditions and with all boundary doors closed.

The parameters that fall into Sensitivity Group 1 include the assumed boundary leakage fraction, the assumed fuel heat of combustion, and several other parameters that are specific to some ignition sources or fire locations. The timing of the smoke purge transition would fall into Sensitivity Group 1, if the timing of the transition is between 2.5 minutes and 6.5 minutes.

Parameters that fall into the second group (Sensitivity Group 2) include the assumption that the barrier performance remains intact for fires in ANO-1, the assumed burning regime for transient fires, the assumed radiant fraction, and the assumed fire base height.

One parameter falls into Sensitivity Group 3: the initial ambient temperature. In this case, it is shown that the baseline scenarios are conservative or the effect is not significant for initial ambient temperatures up to about 34 °C (93 °F). The maximum design basis temperature for the MCR is 28.9°C (84°F), so an initial temperature greater than 34 °C (93 °F) would represent an off-normal condition. The results of this analysis should, therefore, not be used, if the postulated scenario would have an initial temperature greater than 34 °C (93 °F) in the MCR.

Based on Appendix B of CALC-ANO1-FP-09-00011, Rev. 1, the baseline results presented in the MCR abandonment calculation are considered conservative with respect to uncertainty in the parameter values.

Hot Gas Layer (HGL) Tabulations

The GFMT report (1SPH02902.030, Rev. 0), PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, provide times at which the HGL in a generic enclosure will exceed specified temperature thresholds. The computations are performed using the zone computer model CFAST, Versions 6.0.10 and Version 6.1.1. The methodology for computing the HGL tables is described in detail in Section 6.3 and Appendix B of the GFMT report. Essentially, CFAST is used to balance energy and mass flow through openings and the time at which the HGL temperature reaches a threshold value is reported regardless of the HGL height. The primary input parameters include the fire size, the enclosure geometry, the fuel properties, the opening characteristics, the boundary material properties, and the initial ambient temperature.

The fire size is a prescribed input per NUREG/CR-6850, “EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology,” or is specified with a particular set of input parameters and subject to the parameter constraints (ignition source - cable tray fire scenarios). The room geometry is selected in such a way as to minimize the heat losses to the boundaries and thus varies from volume to volume. Under this assumption, the height of the enclosure necessarily varies with the volume. However, a sensitivity analysis is conducted on the room enclosure shape (Section B.4.4 of report

1SPH02900.030, Rev. 0) and it is shown that minimizing the enclosure boundary surface area provides a bounding or nearly bounding result for a given enclosure volume when the length to width aspect ratio is varied from 1:1 to 1:5 in the cases considered. As the aspect ratio increases, a significant reduction in the temperature is observed indicating that spaces that deviate from a 1:1 aspect ratio have an increasing safety margin embedded in the HGL temperature results.

The selection of the fuel properties is evaluated in Sections B.4.1 and B.4.2 of the GFMT report. Fuel properties are varied over a large range of potential values and the most adverse combination is selected to represent all fuels. In this case a relatively low soot yield material is used because it reduces the radiant heat losses from the HGL to the enclosure boundaries and maximizes the HGL temperature.

The opening characteristics are described in terms of a boundary fraction and are varied over a range of 0.001 – 10 percent in the baseline cases. The HGL associated with the most adverse ventilation case is selected in the FPRA among the reported ventilation conditions for a given fire size and enclosure volume. The key input parameter that is set is the ventilation geometry (length, width, and base height) given a vent fraction.
Section B.4.5 of the GFMT report provides a sensitivity analysis on the effects of various vent orientations and placements on the predicted temperature. A total of fifty-four vent configurations were examined for the baseline enclosures. It is found that the bounding case can be one of three orientations: one in which the vent width is equal to the enclosure width, located either at the ceiling or at the floor, and one in which the vent height is equal to the enclosure height. All HGL tables reported in the GFMT report, PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, are based on the most adverse HGL condition among the three vent orientations and thus represent the bounding configuration for the vent geometry.

The boundary material properties are defined as concrete having the lowest thermal diffusivity listed among available data as described in Section B.4.3 of the GFMT report. The thermal diffusivity of the selected concrete, defined as the thermal conductivity divided by the heat capacity and density, is 5.9 x 10^{-7} m^2/s (6.3 x 10^{-6} ft^2/s) and is about thirty percent lower than the value of 8.9 x 10^{-7} m^2/s (9.6 x 10^{-6} ft^2/s) recommended in NUREG-1805. This conservatively biases the results for the boundary materials, though it is shown in Section B.4.3 of the GFMT report that the results are not conservative if they are applied to spaces bound with thermal insulation, lightweight concrete, or gypsum wallboard.

The initial ambient temperature is assumed to be 20 °C (68 °F) in the GFMT report, PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0. Although an ambient temperature of 20 °C (68 °F) is not a conservative and bounding assumption, the effect is readily bound by other conservative aspects of the model approach such as the enclosure geometry, ventilation effects, fuel properties, and HGL position.

Finally, a significant conservatism embedded in the CFAST model results is the specification of an adiabatic floor. Radiant heat losses from both the fire and the HGL to the floor are not credited with reducing the HGL temperature. This assumption is expected to conservatively bias the temperature predictions.

Based on the overall conservative bias associated with the CFAST model parameters (collectively), the HGL tables reported in the GFMT report, PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, are considered conservative with respect to uncertainty in the parameter values.

ZOI Calculations

The GFMT report, PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0, provide ZOI dimensions for various ignition sources and combination ignition sources – cable tray configurations for which FPRA fire scenarios are developed. The tabulated ZOI dimensions are all based on the methodologies described in GFMT report, except the ZOI dimensions for the ignition source – secondary combustible configurations include the physical offset associated with both the cable tray arrangement and the fire spread in the cable trays. The ZOI dimensions essentially consist of a vertical component derived from a plume exposure correlation and one or more horizontal components, each derived from a radiant heat flux calculation.

The vertical plume calculation uses an empirical model that requires as inputs the fire size, the ambient temperature, and fire diameter. The fire size is an input parameter specified by NUREG/CR-6850. The fire diameter and ambient temperature are the primary parameters subject to uncertainty. In this case, the fire diameter in the GFMT report provides ZOI dimensions assuming a variable diameter (as characterized using the heat release rate and heat release rate per unit area). A heat release rate per unit area range between 200 kW/m^2 (17.6 $Btu/s\text{-}ft^2$) and 1,000 kW/m^2 (88.1 $Btu/s\text{-}ft^2$) is used for transient combustible materials and range up to 3,000 kW/m^2 (264 $Btu/s\text{-}ft^2$) for electronic panels. The baseline ambient temperature assumed in the GFMT report is 20 °C (68 °F) with a maximum application limit of 80 °C (176 °F). The baseline ambient temperature selection in PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0, is varied from 20 °C (68 °F) to 80 °C (176 °F) and is thus not subject to assumption or uncertainty, at least within the temperature limits of applicability.

The maximum effect of an elevated initial ambient temperature on the ZOI dimensions for transient fuel package fires is provided in PRA-ES-05-006, Rev. 0, and in PRA-A2-05-017, Rev. 0, for various ignition source – cable tray configurations. The ZOI dimension may change by about two to five percent when the ambient temperature is 40 °C (104 °F) and ten to twenty percent if the ambient temperature is 80 °C (176 °F) ,based on various ignition sources and cable tray configurations evaluated in open, wall, and corner locations. This differential is expected to be readily bound by the conservatisms that are embedded in the ZOI development. These conservatisms relative to a transient fuel package fire include the use of steady-state target damage thresholds, a fire diameter that maximizes the ZOI dimension, the use of a ZOI box rather than a cone, and the selection of the most adverse result among a range of methods. PRA-A2-05-017, Rev. 0, also provides an assessment of the calculation results to uncertainty in the assumed fire diameter and it is shown that the variation is less than the ZOI resolution implemented in the field.

An additional offsetting conservative factor for the panel fires relative to an elevated ambient temperature environment is the assumed heat release rate per unit area for the electronic panel fires for the vertical ZOI dimension, which is effectively 3,000 kW/m^2 (264 $Btu/s\text{-}ft^2$). This means that the characteristic fire dimension for the 98^{th} percentile panel fires is on the order of 0.26 – 0.48 m (0.9 – 1.6 ft). The characteristic dimension for

the electronic panels as evaluated using the NUREG/CR-6850 guidance would be based on the panel top surface area and will typically be on the order of 0.6 – 1.2 m (2.0 – 4.0 ft). This indicates a significant bias is introduced by assuming the fire plan area can occupy only a fraction of the panel top. An additional conservative bias is introduced in setting the base location of the vertical ZOI dimension. Per NUREG/CR-6850, Supplement 1, "Fire Probabilistic Risk Assessment Method Enhancements," the fire base height may be set 0.3 m (1.0 ft) below the panel top (if the panel does not have significant openings in the top). The vertical ZOI dimensions for the electronic panels reported in the GFMT report use the panel top as the base height reference for the vertical ZOI dimension. This introduces a uniform 0.3 m (1.0 ft) bias in all vertical ZOI dimensions for the electronic panels. As such, the vertical ZOI dimension is calculated using bounding input parameters when viewed collectively.

In the case of the horizontal ZOI dimension, the maximum distance as obtained using the more severe prediction among both a solid flame model and the Point Source Model (PSM). The ZOI dimensions for the ignition source – cable tray configurations are obtained in a similar manner, but include heat flux calculations for using the total heat release rate of all heat sources and the heat flux calculations using the sum of the ignition source and cable trays contributions. The PSM requires as input the fire size and the fire radiant fraction, which is assumed to be 0.4. The fire size is a prescribed input per NUREG/CR-6850. Based on the *SFPE Handbook of Fire Protection Engineering*, Section 3–10, "Fire Hazard Calculations for Large, Open Hydrocarbon Fires," the effective radiant fraction for conservative (but not bounding) results is 0.21. A bounding result is obtained when a safety factor of two is used. By assuming a radiant fraction of 0.4, an effectively bounding result is thus obtained. The solid flame heat flux model requires the fire size and fire diameter as input parameters. The fire size is a prescribed input per NUREG/CR-6850. The fire diameter is varied via the heat release rate per unit area parameter. In this case, the most adverse fire diameter is intermediate with a heat release rate per unit area of about 350 – 400 kW/m^2 (30.8 – 35.2 $Btu/s\text{-}ft^2$), depending on the specific case. The value that yields the maximum ZOI dimension is the value used in the analysis.

The electronic panel ignition source ZOIs have additional conservative margins by including an additional calculation that is more conservative than the approach suggested in NUREG/CR-6850, Supplement 1. Per NUREG/CR-6850, Supplement 1, the fire base is located 0.3 m (1.0 ft) below the top of the panel and is typically modeled assuming the panel boundaries do not exist (open fire). The horizontal ZOI dimensions developed in the GFMT report include an upper horizontal ZOI dimension that is computed in this manner and a lower ZOI dimension that assumes internal flame impingement on the panel boundary. This flame impingement imposes a 120 kW/m^2 (10.6 $Btu/s\text{-}ft^2$) heat flux on any internal boundary that radiates outward from a single side. The lower horizontal ZOI dimension is significantly larger than the upper fire plume base horizontal dimension, typically by a factor of two (compare Tables 5-16 and 5-17 in the GFMT report, for example). The FPRA selects the most adverse horizontal ZOI dimension and thus incorporates this bias directly.

Based on the overall conservative bias associated with the input parameter, both the horizontal and vertical ZOI dimensions reported in the GFMT report, PRA-ES-05-006, Rev. 0, and PRA-A2-05-017, Rev. 0, are considered conservative with respect to parameter uncertainty.

Building Separation Calculation

The building separation calculation, CALC-ANO1-FP-08-00003, Rev. 0, essentially computes the radiant heat flux from an open, 1,687 kW (1,500 Btu/s) fire to a point 3.4 m (11 ft) away from edge of a fire emanating from a wall opening. Both the point source model and the solid flame model as contained in the NUREG-1805, "Fire Dynamics Tools (FDT^S) Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program," are used to determine the most adverse heat flux at the target location. The maximum predicted heat flux is 1.34 kW/m^2 (0.12 $Btu/s\text{-}ft^2$) whereas the critical heat flux is 12.5 kW/m^2 (1.1 $Btu/s\text{-}ft^2$) based on guidance provided in NFPA 80A, "Recommended Practice for Protection of Buildings from Exterior Fire Exposures." This represents a safety margin on the order of ten and indicates that the results and conclusions are highly conservative.

Excluding the physical dimensions associated with the fire and the target and the assigned fire size, there are two model parameters selected in the analysis:

- Assumed radiant fraction (point source model)
- The empirical fire diameter constant, $k\beta$ (solid flame model)

The fire area and target separation inputs are based on the physical dimensions of the exposure and target position and the burning rate and heat of combustion represent an alternate means of specifying the fire heat release rate.

The assumed radiant fraction in the point source model is 0.3, consistent with the recommended value in NUREG-1805. Data provided in Section 3-4 of the *SFPE Handbook of Fire Protection Engineering*, "Generation of Heat and Gaseous, Liquid, and Solid Products in Fires," suggests that the radiant fraction may be as high as 0.6 or certain fuels burning under enriched oxygen environments. Because the target heat flux is a linear function of the radiant fraction, the most adverse target heat flux would thus be $0.6/0.3 \times 1.34$ or 2.68 kW/m^2 (0.24 $Btu/s\text{-}ft^2$). This is lower than the target threshold by a factor of five and indicates that the results are not sensitive to uncertainty in this model parameter.

The empirical diameter constant, $k\beta$, is used in the solid flame model to adjust the burning rate, and thus the heat release rate, for small diameter fires. The value assumed in CALC-ANO1-FP-08-00003, Rev. 0 is 100 m^{-1} (30.5 ft^{-1}), which effectively eliminates the diameter dependence and forces the full heat release rate to be used. A selection of a lower value would result in a lower model heat release rate and thus a lower predicted heat flux. A selection of a higher value would have no effect because the full heat release rate is assumed. As such, the parameter selection is conservative and bounds the uncertainty that could arise from different parameter value selections.

b) Fire modeling "model" and "completeness" uncertainty was not explicitly accounted for in all fire modeling evaluations or incorporated into the FPRA at ANO-1. However, the uncertainty associated with fire modeling "model" and "completeness" uncertainty is addressed through the use of a conservative and bounding analysis. There are four primary areas at ANO-1 in which fire modeling "model" and "completeness" uncertainty is applicable:

- The updated MCR abandonment analysis (CALC-ANO1-FP-09-00011, Rev. 1)
- The HGL tabulations as contained in 1SPH2902.030, Rev. 0, PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0
- The ZOI tabulations as contained in 1SPH2902.030, Rev. 0, PRA-ES-05-006, Rev. 0; and PRA-A2-05-017, Rev. 0
- Administration and Turbine Building separation analysis (CALC-ANO1-FP-08-00003, Rev. 0)

Note that the HGL tables provided in PRA-ES-05-007, Rev. 0, have been replaced by the tables provided in PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0, in the updated FPRA.

MCR Abandonment Calculation

The MCR abandonment calculation (CALC-ANO1-FP-09-00011, Rev. 1) provides an assessment of the model uncertainty in Section B.4 of Appendix B using the methods described in NUREG-1934, "Nuclear Power Plant Fire Modeling Analysis Guidelines (NPP FIRE MAG)." The uncertainty is assessed for a range of heat release rate bins associated with the primary baseline fire scenario ignition sources in MCR area. Table B-16 of CALC-ANO1-FP-09-00011, Rev. 1, shows that the maximum probability the actual abandonment time would be fifteen percent, or more, lower than the predicted value is less than 3.5 percent for transient and electronic panel fire scenarios in the MCR (see response to FM RAI 01.p.i for a discussion of the basis for using a fifteen percent threshold). Based on the sensitivity analysis presented in Section B.3 of CALC-ANO1-FP-09-00011, Rev. 1, it may be concluded that the "model" and "completeness" uncertainties are bound by the conservative bias introduced by the parameter selection.

Hot Gas Layer Tabulations

The HGL tables are computed using the zone computer model CFAST, Versions 6.0.10 and 6.1.1 in the GFMT report and in the detailed evaluations of secondary combustible configurations (PRA-A1-05-011, Rev. 0, and PRA-A2-05-018, Rev. 0). As described in the response to FM RAI 06.a, there are a significant number of parameters that are conservatively biased in the model, including the fuel properties, the combustion properties, the boundary properties, the adiabatic floor surface, and the enclosure geometry. In addition, for a given CFAST geometry, the FPRA selects the most adverse scenario among a ventilation range between 0.001 and 10 percent of the enclosure boundary area. The approximate effect of each of these parameters (except for the adiabatic floor surface) on the temperature results are provided in Appendix B of the GFMT report. For example, Figures B4-7a through B4-7c and B4-8a through B4-8b in the GFMT report demonstrate that the effect of changing the thermal diffusivity of the boundary materials on the steady state temperature is roughly proportional to the change in the thermal diffusivity at least when centered on a value of 5.9×10^{-7} m^2/s (6.3×10^{-6} ft^2/s). Given that this value is about thirty percent lower than the thermal diffusivity recommended in NUREG-1805 for normal weight concrete, a comparable test case would have a temperature reduction of about 93 °C (167 °F). This sensitivity alone is comparable to the temperature change necessary to reduce the "model" and "completeness" uncertainty to less than two percent as

determined using the methods described in NUREG-1934 (i.e., the probability of exceeding the critical value due to model uncertainty is less than two percent when the HGL temperature is about 93 °C (167 °F) lower than the critical value). When all conservatively biased input parameters are considered together, it is expected that the collective effect on the predicted temperature will result in a low probability of exceeding a threshold value at a tabulated time.

Consequently, it is concluded that fire model “model” uncertainty would not contribute significantly to the risk uncertainty because it is sufficiently bound by the conservatisms in the CFAST HGL analyses.

ZOI Calculations

The ZOI computations provided in the GFMT report and in the analysis of secondary combustible configurations (PRA-A2-05-017, Rev. 0) rely on a plume centerline temperature, an open source fire radiant heat flux computation, and a radiant heat flux computation from a heated panel or burning array of cables. The plume centerline temperature computation is shown in NUREG-1934 and NUREG-1824 “Verification & Validation of Selected Fire Models for Nuclear Power Plant Applications Volume 3: Fire Dynamics Tools (FDT^S),” to have a non-conservative bias and a relatively large standard deviation. However, the application considered did not explicitly account for the HGL temperature changes, which are the expected source of the bias and variation. Similar plume correlations used by CFAST and MAGIC show a conservative bias and smaller variation. The application of the plume correlations is limited in the GFMT report and PRA-A2-05-017, Rev. 0, to 80 °C (176 °F) or less through the use of the modified critical heat flux, which is intended to adapt the models for elevated internal temperatures. Further, as discussed in the response to FM RAI 06.a, the vertical plume ZOI dimension may have as much as a 0.3 m (1.0 ft) conservative bias embedded based on the assumed diameters and the base elevations relative to NUREG/CR-6850 and NUREG/CR-6850, Supplement 1, guidelines.

The horizontal ZOI dimensions are computed using a radiant heat flux model with the radiant fraction set to about two times the value recommended in the *SFPE Handbook of Fire Protection Engineering*, Section 3-10. Effectively, the radiant heat flux has a bias of two explicitly embedded in the calculation. The probability that the heat flux at a fixed location would exceed the IEEE-383 qualified/thermoset cable limit of 11.4 kW/m^2 (1.0 Btu/s-ft^2) given a prediction of 5.70 kW/m^2 (0.50 Btu/s-ft^2) (i.e., removed conservative bias) may be computed using the methods described in NUREG-1934 with the bias and normalized variance for the radiant heat flux models, which are 2.02 and 0.59. The resulting probability is nearly zero. In the case of the electronic panel fires, an additional margin is provided through the use of a conservative model beyond that required in NUREG/CR-6850 and NUREG/CR-6850, Supplement 1, for portions of the ZOI below the panel. Because the FPRA uses the most adverse horizontal ZOI dimension above or below the panel, this additional model introduces a second conservative factor.

Consequently, it is concluded that fire model “model” and “completeness” uncertainty either would not contribute to the risk uncertainty or are bound by the conservatisms in the analysis, depending on the ZOI dimension considered.

Building Separation Calculation

The effect of fire modeling "model" and "completeness" uncertainty associated with the heat flux calculation provided in CALC-ANO1-FP-08-00003, Rev. 0, may be estimated using the methods described in NUREG-1934. Specifically, the probability that the true calculated value will be greater than a critical value is given by the following equation:

$$\boldsymbol{P(x > x_c) = \frac{1}{2}\mathbf{erfc}\left(\frac{x_c-\mu}{\sigma\sqrt{2}}\right)} \qquad \text{(FM 06-1)}$$

where $\boldsymbol{P}$ is the probability, $\boldsymbol{x}$ is a parameter value, $\boldsymbol{x_c}$ is a threshold parameter value, $\boldsymbol{\mu}$ is the mean 'true' predicted value of the parameter, $\boldsymbol{\sigma}$ is the standard deviation of the model prediction for the parameter of interest. The mean value is determined from the model bias as follows:

$$\boldsymbol{\mu = M/\delta} \qquad \text{(FM 06–2)}$$

where $\boldsymbol{M}$ is the model prediction and $\boldsymbol{\delta}$ is the model bias. The standard deviation is computed from the normalized standard deviation as follows:

$$\boldsymbol{\sigma = \widetilde{\sigma}_M(M/\delta)} \qquad \text{(FM 06–3)}$$

where $\boldsymbol{\widetilde{\sigma}_M}$ is the normalized standard deviation.

The model bias and normalized standard deviation for the Fire Dynamics Tools (FDT^S) heat flux calculation is 2.02 and 0.59, respectively, per NUREG-1934. The critical heat flux is 12.5 kW/m^2 (1.1 $Btu/s\text{-}ft^2$) and the maximum predicted heat flux is 1.34 kW/m^2 (0.11 $Btu/s\text{-}ft^2$). Per Equation FM 06-1, the probability that the true heat flux at the target is greater than 12.5 kW/m^2 (1.1 $Btu/s\text{-}ft^2$) is nearly zero. Consequently, it is concluded that fire modeling "model" and "completeness" is not significant relative to the calculation results and recommendations.

Probabilistic Risk Assessment (PRA)

Note: Responses to PRA RAIs 01.a, 01.b, 01.c, 01.d, 01.g, 01.h, 01.i, 02.b, 04, 06, 12, and 14, and one 90-day response (PRA RAI 02.c) were provided in Entergy's 60-day letter (Reference 4). PRA RAIs 03 (without quantitative results), 10, 11, 13, 15, 17 (without quantitative results), and 18 are expected to be addressed in the 120-day RAI response.

<u>PRA RAI 01</u> – Fire PRA Facts and Observations (F&Os)

Section 2.4.3.3 of NFPA 805 states that the probabilistic safety assessment (PSA) (PSA is also referred to as PRA) approach, methods, and data shall be acceptable to the AHJ, which is the NRC. RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a FPRA and endorses, with exceptions and clarifications, NEI 04-02 Revision 2, "Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program Under 10 CFR 50.48(c)," April 2008. (ADAMS Accession No. ML081130188), as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. RG 1.200, Revision 2, "An Approach for Determining the Technical Adequacy of Probabilistic Risk

Assessment Results for Risk-informed Activities," March 2009 (ADAMS Accession No. ML090410014), describes a peer review process utilizing an associated ASME/ANS standard (ASME/ANS-RA-Sa-2009) as one acceptable approach for determining the technical adequacy of the PRA once acceptable consensus approaches or models have been established for evaluations that could influence the regulatory decision. The primary result of a peer review are the Facts and Observations (F&Os) recorded by the peer review team and the subsequent resolution of these F&Os.

Please clarify the following dispositions to the ANO-1 FPRA F&Os and Supporting Requirements (SRs) assessment identified in LAR Attachment V that have the potential to impact the Fire PRA results and do not appear to be fully resolved:

e) <u>CF-A1-01</u> (Updated guidance on circuit failure mode likelihood analysis in NUREG/CR-7150)

New guidance on using conditional probabilities of spurious operation for control circuits is contained in a letter dated April 23, 2014, from Joseph Giitter, NRC, to Michael Tschiltz, NEI, "Supplemental Interim Technical Guidance on Fire-Induced Circuit Failure Mode Likelihood Analysis" (ADAMS Package Accession No. ML14111A366), and in Section 7 of NUREG/CR-7150, "Joint Assessment of Cable Damage and Quantification of Effects from Fire (JACQUE-FIRE)," Volume 2: Expert Elicitation Exercise for Nuclear Power Plant Fire-Induced Electrical Circuit Failure, Final Report, May 2014 (ADAMS Accession No. ML14141A129). This guidance includes: a) replacement of the conditional hot short probability tables in NUREG/CR-6850 for Option #1 (including removal of credit for CPTs and conduit) with new circuit failure probabilities for single-break and double-break control circuits (Option #2 in NUREG/CR-6850 is no longer an adequate method and should not be used); b) replacement of the probability of spurious operation duration figure in FAQ 08-0051 (NUREG/CR-6850 Supplement 1) for alternating current (AC) control circuits and additional guidance to address duration for direct current (DC) control circuits; c) a method for incorporation of the uncertainty values for the circuit failure probabilities and spurious operation duration in the state-of-knowledge correlation (SOKC) for developing the mean CDF/LERF; and, d) recommendations on the hot short probabilities to use for other cable configurations, including panel wiring, trunk cables, and instrument cables.

Please provide an assessment of the assumptions used in the FPRA relative to the updated guidance in NUREG/CR-7150, Volume 2, specifically addressing each of the items a) through d) above. If the FPRA assumptions are not bounded by the new guidance, please provide a justification for each difference or provide updated risk results as part of the integrated analysis requested in PRA RAI 03, utilizing the guidance in NUREG/CR-7150, Volume 2.

Response

The hot short probabilities credited in the ANO-1 NFPA 805 LAR submittal eliminated credit for control power transformer reductions in hot short probabilities specified in Chapter 10 of NUREG/CR-6850 (see Att. W of LAR submittal). The hot short probabilities credited are considered to be bounding with respect to the guidelines of NUREG/CR-7150, Volume 2. A review of the hot short probabilities currently used in the FPRA will be performed to ensure consistency with the guidance of NUREG/CR-7150, Volume 2. The updated FPRA results to be submitted in conjunction with PRA RAI 03 will incorporate these hot short probabilities and will no longer use the NUREG/CR-6850 specified values.

Based on the above, the specific items identified in this RAI are dispositioned as follows:

a) The new circuit failure probabilities used are reviewed against the NUREG/CR-7510, Volume 2, guidance and have been confirmed to be equal to or greater than the values specified in the guidance. Credit for additional circuit failure probabilities will be consistent with NUREG/CR-7150, Volume 2.

b) Spurious operation duration probabilities to be used are based on NUREG/CR-7150, Volume 2, guidance. The analysis supporting the LAR did not credit spurious operation duration probabilities from FAQ 08-0051.

c) The SOKC for hot short probabilities and hot short duration probabilities based on NUREG/CR-7150, Volume 2, are being incorporated into the uncertainty analysis update.

d) The guidance from NUREG/CR-7150 regarding ‘other cable configurations’ recommends the use of the aggregate spurious operation conditional probabilities for in-panel wiring and trunk cables. For instrument circuits, no spurious operation conditional probability will be credited. The guidance on ‘other cable configurations’ will be incorporated into the ANO-1 FPRA in support of the integrated risk assessment PRA RAI 03.

f) HRA-A3-01 and ES-C2-01 (Undesirable operator actions caused by spurious actuations)

F&Os HRA-A3-01 and ES-C2-01 questioned how spurious indications that could result in undesirable operator actions were evaluated. The disposition to the F&Os discusses instrument failures but does not clarify how operator actions resulting from spurious indications are addressed by the analysis.

Given that fire can create spurious indications, please clarify how spurious instrument indications were treated in the FPRA. Please include explanation of how scenario specific spurious indications were either modeled in the FPRA, or discounted as not impacting the fire scenario.

Response

The ANO-1 post-fire shutdown procedure (OP-1203.049, “Fires in Areas Affecting Safe Shutdown”) provides guidance for the operators, on a fire zone basis, identifying the list of instrumentation that has been confirmed to be unaffected by fire and should be relied upon for post-fire shutdown. This guidance allows the operators to rely on available instruments and/or to confirm other instruments with the reliable instruments prior to taking action based on the associated plant process parameter. This information will preclude the impact of spurious indication of fire impacted instruments on operator actions during the post fire shutdown. Below is an example of the type of information available to the operator for each fire zone from OP-1203.049.

Fire Area B1@170-Z
(Penthouse)

Available Appendix R Instrumentation

RCS Loop B Temperature		
TE-1040, RPS-C Loop B RC Temperature		T1040
TE-1041, RPS-D Loop B RC Temperature		T1041
TE-1139, RC Loop B Hot Leg	TR-1139	T1139
TE-1144, RC Loop B PPA Cold Leg		T1144
TE-1148, RC Loop B PPB Cold Leg	TI-1147	T1147
Steam Generator B Level and Pressure		
LT-2667, SG B Low Range Level Channel A (uncompensated)		L2667
LT-2669, SG B High Range Level Channel A (uncompensated)		L2669
PT-2667A , SG B Main Steam Pressure Channel A	PR-2667A	P2667A
LT-2667 / PT-2667A, SG B High Range Level Channel A (compensated)	LI-2667	L2667C, LSGB1R
LT-2669 / PT-2667A, SG B High Range Level Channel A (compensated)	LI-2669	L2669C, LSGB1R
LT-2671, SG B Low Range Level Channel A (uncompensated)		L2671
LT-2673, SG B Upper Range Level Channel A (uncompensated)		L2673
PT-2667B , SG B Main Steam Pressure	PI-2667B	P2667B
LT-2671 / PT-2667B, SG B High Range Level Channel B (compensated)	LI-2671	L2671C, LSGB1G
LT-2673 / PT-2667B, SG B High Range Level Channel A (compensated)	LI-2673	L2673C, LSGB1G
CST Level		
LT-4204, EFW CST T41B Level	LRS-4204	L4204
LT-4205, EFW CST T41B Level	LIS-4205	L4205
Local		
• LI-4292, CST T-41 Level • PI-3812A, Reactor Building Coolers VCC-2A/2B Inlet Pressure • PI-3813A, Reactor Building Coolers VCC-2C/2D Inlet Pressure		

<u>PRA RAI 02</u> – Internal Events PRA F&Os

Section 2.4.3.3 of NFPA 805 states that the PRA approach, methods, and data shall be acceptable to the NRC. RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a Fire PRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. RG 1.200 describes a peer review process utilizing an associated ASME/ANS standard (currently ASME/ANS-RA-Sa-2009) as one acceptable approach for determining the technical adequacy of the PRA once acceptable consensus approaches or models have been established. The primary results of a peer review are the F&Os recorded by the peer review and the subsequent resolution of these F&Os.

Please clarify the following dispositions to Internal Events F&Os and SRs assessment identified in the LAR Attachment U that have the potential to impact the Fire PRA results and do not appear to be fully resolved:

a) <u>SY-B14, SY-A22, and AS-B3</u> (Phenomenological conditions associated with each accident sequence)

SR SY-B14 stipulates that SSCs that need to operate in conditions beyond their environmental qualifications should be identified. SR SY-A22 states that credit for component operability can be taken only if analysis exists to demonstrate rated design capabilities are not exceeded. Though the disposition states that this F&O is only a documentation issue, it is not clear how it can be concluded that not meeting these F&Os has no impact on the FPRA. The NRC staff reviewed the Internal Events PRA notebooks and could not determine whether such assessment had been performed.

i. Please explain whether phenomenological conditions associated with each accident sequence were assessed to determine impact on the successful credited function of SSCs.

ii. If this assessment was not performed or if the results were not applied to the FPRA, please address these impacts in the integrated analysis provided in response to PRA RAI 03.

Response

SR AS-B3 states:

> For each accident sequence, IDENTIFY the phenomenological conditions created by the accident progression. Phenomenological impacts include generation of harsh environments affecting temperature, pressure, debris, water levels, humidity, etc. that could impact the success of the system or function under consideration [e.g., loss of pump net positive suction head (NPSH), clogging of flow paths]. INCLUDE the impact of the accident progression phenomena, either in the accident sequence models or in the system models.

A report by the Pressurized Water Reactor (PWR) Owners Group, WCAP-16679-P, “Accident Sequence Phenomena Considerations,” Rev. 0 (November 2006), provides guidance for addressing issues associated with the impact of phenomenological conditions, created as a result of an accident sequence, on the reliability and/or availability of equipment used to mitigate

the consequences of that accident sequence. The guidance includes a list of phenomenological conditions that should be addressed in the Level 1 and for Level 2 PRA for PWRs. The list of phenomena was identified from the ASME PRA Standard, from phenomena currently addressed in plant specific PRAs, from phenomena identified by the NRC, and finally from phenomena identified from operating experience. This report was prepared specifically to address SR AS-B3, as well as the Level 2 phenomena described in SRs LE-C8 and LE-C9.

Although the WCAP does not explicitly refer to ASME Standard SRs SY-A22 and SY-B14, which are related to various accident sequence phenomena in the WCAP, these SRs are addressed in several of the WCAP sections. SY-A22 states:

> TAKE CREDIT for system or component operability only if an analysis exists to demonstrate that rated or design capabilities are not exceeded.

SY-B14 states:

> IDENTIFY SSCs that may be required to operate in conditions beyond their environmental qualifications. INCLUDE dependent failures of multiple SSCs that result from operation in these adverse conditions.

The ANO-1 "PRA Peer Review Report Using ASME PRA Standard Requirements," (PWR Owners Group, August 2009) clarifies the issue with regard to SY-A22. The peer review evaluation for SY-A22 references F&O 1-13 with the basis:

> "The System Notebooks do not discuss if any components are operated beyond rated or design capabilities. It should be determined if any equipment is exceeding the design or qualification in a harsh environment following a transient."

WCAP-16679 addresses the question of whether "any equipment is exceeding the design or qualification in a harsh environment" in Subsection 2.1 (Equipment Operation in Beyond Design Basis Conditions), 2.5 (Loss of Cooling to Critical Equipment), 2.6 (Sufficient NPSH for Emergency Core Cooling Recirculation), and 2.17 (Containment Water Level).

The peer review evaluation for SY-B14 also references F&O 1-13, with the basis statement:

> "The System Notebooks do not discuss if any components are operated beyond environmental qualification requirements. It should be documented if any equipment are exceeding the qualification in a harsh environment following a transient."

ASME Standard SR SY-B14 lists examples of degraded environments to be considered. The listed items, with the WCAP subsections that address them, are:

(a) Loss of coolant accident (LOCA) inside containment with failure of containment heat removal (2.1)

(b) safety relief valve operability (small LOCA, drywell spray, severe accident) (for BWRs) (N/A)

(c) steam line breaks outside containment (2.1)

(d) debris that could plug screens/filters (both internal and external to the plant) (2.2, 2.3, 2.4)

(e) heating of the water supply (e.g., BWR suppression pool, PWR containment sump) that could affect pump operability (2.1)

(f) loss of NPSH for pumps (2.6)

(g) steam binding of pumps (2.15)

ASME Standard item (c), steam line breaks outside containment, is considered in WCAP Subsection 2.1, Discussion section, specifically "…high energy line breaks outside containment…"

Evaluation of Accident Sequence Phenomena

The WCAP-16679-P guidance was used to evaluate the ANO-1 Level 1 PRA for its treatment of accident sequence phenomena; and as discussed above, this addresses SRs AS-B3, SY-A22, and SY-B14. The evaluation of the WCAP accident sequence phenomena found only one issue regarding Pressure-Induced Steam Generator tube rupture (PI-SGTR) not being included in the Level 1 model. This impact for the internal events model is small, but the impact for the FPRA is uncertain; therefore, this phenomenon will be included in the Integrated Analysis performed in response to PRA RAI 03. Discussion of each of the phenomena identified in the WCAP and how it is addressed in the ANO-1 PRA follows.

Equipment Operation in Beyond Design Basis Conditions

For accident sequences assessed in the PRA, certain equipment may be credited for operation in conditions that are beyond their design basis pressures, temperatures and /or radiation. This may present a challenge to the ability of the equipment to complete its mission assumed in the PRA. For the Level 1 PRA, the concerns are containment fan coolers (specifically, the switch to low speed) and isolation valves credited in the interfacing-system loss of coolant accident (ISLOCA).

Since the ANO-1 Reactor Building (RB) cooling units use single speed axial fans, there is no switch to low speed and the containment fan cooler issue is not applicable.

In the ANO-1 PRA, the ISLOCA initiators were conservatively and simplistically treated to lead directly to a core damage condition. Therefore, there is no issue concerning operation of an isolation valve in a high temperature steam environment.

Use of Raw Water Systems as Backup Water Supplies

In some instances, the PRA model assumes that raw water systems can be used as a back up to a primary system that normally uses high quality water. In this case, there is the potential for equipment failures in portions of the primary system that are still in use due to effects of the poor water quality of the raw water source. The potential impact of biological or other debris on the reliability of equipment that is normally supplied by raw water systems would be addressed in the failure data analysis for that equipment and no further assessment is required. However, when the PRA models use of raw water systems as a backup for systems normally exposed to only high quality water, the PRA analyst should assure that the PRA model addresses the potential for failure due to the low quality water. The recommended assessment process is:

- Determine if the raw water system is subject to biological or other debris failures based on the applicable raw water system failure modes.
- Assess whether the primary system could be subject to failures due to the use of the raw water by a comparison of restrictions in the primary system flow path compared to restrictions in the raw water system. The most likely restrictions that could be subject to plugging are flow control valves and orifices.
- If any restrictions are identified as having a potential for plugging, assess whether the plugging is likely within the mission time assumed in the PRA for that function.

With respect to the first assessment step, the Service Water (SW) system is potentially subject to biological and other plugging. With respect to the second assessment step, the Emergency Feedwater (EFW) system has line sizes similar to or larger than the SW loop line sizes supplying various loads. Since the EFW lines are similar to or larger in size than important equipment supply lines in the SW system, by the guidance in WCAP-16679-P described above, plugging of the EFW system when supplied by SW is not a concern.

Service Water Screen Clogging

If the screens that filter the intake SW from the source (e.g., river, lake, etc.) become clogged, there will be a decreased ability to provide cooling water to essential functions required for bringing the plant to a safe stable condition. The ANO-1 PRA model includes failure of SW screens due to debris clogging. This is included in the loss of all SW initiating event fault tree (%T8) and in a mission time common cause SW plugging event, as well as basic events for individual sluice gate and pump strainers. There is some question as to whether the plant-specific experience with debris plugging is correctly captured in the model; this will be evaluated. Nevertheless, the FPRA is not affected by SW debris initiating events (since the initiator is a fire), and the model includes mission time clogging of the traveling screens.

Containment Sump Debris

For Reactor Coolant System (RCS) pipe breaks inside containment, the PRA model should consider the potential for the loss of emergency core cooling recirculation due to blockages on the containment sump screens in the recirculation cooling flow path (including the fuel assemblies) due to the debris generated by the accident, or from subsequent chemical reactions between the sump water and the debris.

The potential for loss of long-term core cooling due to debris plugging of the RB sump is included in ANO-1 PRA model. Sump plugging basic events are included in the logic for low pressure recirculation (low pressure injection (LPI) operation with pump suction from the RB sump) and, via operation in "piggy-back mode," high pressure recirculation for smaller LOCAs. The recommended sump plugging probabilities from WCAP-16882-NP, "PRA Modeling of Debris-Induced Failure of Long Term Core Cooling via Recirculation Sumps," Rev. 0 (PWR Owners Group, October 2009) are used, with probabilities applied for various size LOCAs and non-LOCA conditions, as recommended. These WCAP probabilities include both plugging of the sump screens themselves, as well as other plugging phenomena such as chemical precipitation and downstream effects. No recovery from sump plugging is credited.

Loss of Cooling to Critical Equipment

Certain equipment modeled in the PRA requires some form of cooling for continued operation to complete its mission. WCAP-16679-P recommended that the PRA analyst verify that equipment cooling assessments have been completed for all critical equipment modeled in the PRA. Equipment cooling assessments for critical equipment in the ANO-1 PRA model are complete. These equipment room cooling calculations are typically actually room “heatup” calculations, since they estimate room temperature response with equipment operating and no room cooling. If acceptable room temperatures result with no room cooling, it is concluded that room cooling is not required and a room cooling dependency is not included in the PRA model.

A decay heat removal (DHR)/LPI pump room cooling calculation supports the modeling assumption that room cooling is needed for these rooms for operation in recirc mode. The ANO-1 PRA model thus includes room cooling for the LPR (LPI recirculation mode) and DHR modes in the LPI system logic. Ventilation is also assumed to be required, and is modeled, for the Emergency Diesel Generator (EDG) rooms.

Other major equipment rooms for which room heatup calculations show that room cooling is not required, and thus is not modeled, are: high pressure injection (HPI) pumps, EFW pumps, SW pumps, and 4160 V Switchgear rooms. Control Room cooling is addressed in a separate section.

Sufficient NPSH for Emergency Core Cooling Recirculation

The operability of the emergency core cooling recirculation pumps depends on the available NPSH in the RB sump being at least equal to the required NPSH. For PRA accident scenarios with an unisolated RB, the WCAP recommends that this phenomenon only needs to be considered for large LOCA initiating events with the loss of all containment heat removal.

Failure of containment isolation is not included in ANO-1 Level 1 PRA, but the model does include a large LOCA scenario with loss of all containment heat removal as a core damage scenario. Whether containment isolation succeeds or fails, a large LOCA with failure of all containment heat removal is modeled as causing core damage; therefore, the recommended scenario is included in the ANO-1 PRA.

Control Room Habitability

The WCAP recommendation is that consideration of control room habitability and operator reliability should not be an issue with respect to either temperatures or radiation for accident sequences involving the loss of control room ventilation and cooling in either the Level 1 or the Level 2 PRA. Consistent with the WCAP recommendation, loss of control room heating, ventilation, and air conditioning (HVAC) is not considered an issue in the ANO-1 PRA. The response to NRC questions on the ANO-1 Individual Plant Examination (IPE) (Ref. Entergy letter dated May 9, 1996, TAC No. M74376, 1CAN059602) describes the basis for not including control room HVAC. This basis includes a conservative calculation of control room temperature following loss of all normal and emergency room cooling, which was determined not to exceed 115 °F.

Operator Actions in Harsh Environments

The ability of operators to perform local actions credited in the PRA could be impacted by environmental conditions (high temperatures or flooding) created by pipe breaks such as high energy line breaks (HELBs) or interfacing system LOCAs. The WCAP recommends checking whether harsh conditions could impact the following operator actions:

(1) for ISLOCA, the steam environment in the vicinity of the break could impact the ability to complete local operator actions to close isolation valves;

(2) for HELB, the ability to complete local operator actions to close isolation valves may also be affected by the environment (steam, temperatures and/or flooding) created by the HELB;

(3) for station blackout (SBO), the ability of operators to locally control the turbine driven EFW pump following the loss of DC power during a prolonged SBO event may be impacted by the loss of room cooling in that plant area.

For ISLOCA and HELB, no recovery actions to isolate the rupture are included in the ANO-1 PRA such that the harsh conditions associated with the rupture have no impact on the model. For SBO, a GOTHIC calculation of the EFW pump room temperature with no HVAC and with the turbine-driven EFW pump running shows that the temperature will be less than 115 °F at 24 hours, with a peak of 122 °F at 30 days; this shows that the environment for the operator action to manually control the EFW pump turbine after battery depletion is feasible. The human reliability analysis (HRA) for this action (human failure event QHF1RUNSBO) includes consideration of the elevated temperature in the execution phase: "Since the action is performed in a hot and dark environment, the stress level is *extreme* and recovery by self-review and other crew members is *not credited*."

Loss of Instrument Air – AOVs

Following an event that results in the loss of air supply, including SBO, air operated valves (AOVs) and instrumentation modeled in the PRA may have a decreased ability to perform their intended functions. The WCAP recommends that the PRA analyst identify the AOVs that are modeled in the PRA for SBO sequences and the AOVs inside the RB that are modeled for all other initiating events. For any AOVs credited for these conditions, the PRA analyst should verify that consideration was given to the capability of the valves for their assumed mission time.

The AOVs in the ANO-1 model associated with SBO and located inside the RB were reviewed to determine whether there were any problems with respect to the valve capability for the PRA mission time. For SBO, none of the AOVs are required, since only the turbine-driven EFW pump would be available for decay heat removal and all other support system (e.g., SW) would be de-energized. Valves required for the turbine-driven EFW pump, both in the suction or discharge, and including the steam supply to the EFW turbine, are motor-operated, check, or manual valves. For containment isolation valves inside the RB, the only AOVs inside the RB that are in the ANO-1 PRA model are the RB purge valves, and these valves fail safe (closed-isolated) on loss of instrument air.

Depressurized Steam Generators – Turbine Driven Emergency Feedwater Pumps

The PRA model for operation of the turbine driven EFW pumps to maintain Steam Generator (SG) levels may be challenged by depressurization of the SGs. If a SG atmospheric relief valve sticks open on one of the two SGs supplying steam to the EFW pump turbine, then the turbine driven EFW pump inlet pressure may fall below the minimum required for continued operation.

The potential for failure of SG relief valves (Main Steam Safety Valves (MSSVs)) failing open was not explicitly considered in the ANO-1 PRA in assessing the unavailability of the turbine-driven EFW pump (P-7A). This phenomenon is not a significant contributor to EFW turbine-driven pump unavailability based on the following. Each steam supply line to the EFW pump turbine has a check valve (MS-272 from SG-A and MS-271 from SG-B). If an MSSV failed open on one SG, causing depressurization of that SG, the check valve in the associated steam supply line to the EFW pump turbine would prevent depressurization of the other SG steam supply line; thus, the turbine-driven EFW pump would not be failed by a single SG depressurizing. In order for the steam supply to the turbine-driven EFW pump to be lost due to SG depressurization resulting from a stuck open MSSV, both SG would have to be depressurized. This would require that an MSSV in each steam line be failed open; the probability of which is much lower than the failure probability (unavailability) of the P-7A pump. Therefore, this issue is not significant for the ANO-1 PRA model (note that this phenomenon is included in the Rev. 5 model).

Overfilled Steam Generators – Emergency Feedwater Availability

The PRA for SBO models the operation of the turbine driven EFW pump to maintain SG level and thus provide a means of removing decay heat from the core. If the SG is overfilled, the turbine driven EFW pump would fail due to excess water in the extraction steam. The SBO emergency operating procedures direct the operators to maintain SG level using the turbine driven EFW capability. However, the station batteries have a finite life. If AC power is not recovered by the time the batteries are depleted, SG level indication will be lost and the operators must implement a strategy for operation of the turbine driven EFW pumps.

The failure of the turbine-driven EFW pump in an SBO due to SG overfill after loss of DC power is modeled in the ANO-1 PRA. Battery discharge is included as a failure of the turbine-driven pump (P-7A), under an AND gate with operator action to manually control the pump. This operator action models the operators manually operating the turbine-driven EFW pump during an SBO, as directed by the SBO procedure, OP-1202.008. This procedure directs the operator to take manual control of pump P-7A using the EFW operating procedure, OP-1106.006. Without this manual control of the turbine-driven EFW pump in which the operators can use the EFW turbine throttle valve (CV-6601A) to control SG level, the ANO-1 PRA assumes that the EFW turbine-driven pump will be failed by the loss of DC power.

Depressurized Steam Generators – Steam Generator Tube Integrity

The PRA models the use of the SG relief valves in a cycling mode to maintain SG pressure. SG depressurization as a result of either stuck open or leaking SG relief or safety valves would result in an increased challenge to tube integrity, possibly leading to a PI-SGTR (thermally-induced SGTR does not apply to Level 1 PRA accident sequences, since it is the hot gases from a badly damaged core that cause SG tube failure, but is included in the ANO-1 LERF model).

The ANO-1 Level 1 PRA model does not include Level 1 PI-SGTR events as a possible contribution to SGTR events (PI-SGTR is included in the LERF model). An evaluation of this issue using the ANO-1 PRA model estimated that the PI-SGTR event initiator frequency is about 10% of the random SGTR initiator frequency. Thus, the PI-SGTR is potentially significant, but not dominant. Note that this event has essentially the same effects as the random SGTR which is in the model, thus this induced SGTR represents an addition to the %RA/B SGTR initiators in the current model. Since the impact of PI-SGTR in a fire scenario is more difficult to evaluate, the assessment of the impact of PI-SGTR in the FPRA will be included in the Integrated Analysis performed in response to PRA RAI 03.

Pressurizer PORVS after Core Uncovery

The PRA model may include the use of the pressurizer power-operated relief valve (PORV) to depressurize the RCS following the onset of core damage. In this case, pressurizer PORVs would be passing superheated steam, which could result in failure of the PORV in either the closed position or in a stuck open position. The WCAP recommends that no failures of the pressurizer PORV due to thermal effects be modeled in the PRA for the base model (i.e., assume that the competing factors result in an even trade-off). However, pressurizer PORV survivability should be identified as a key assumption in the Level 2 analysis and consideration should be given to including a sensitivity analysis for thermally induced pressurizer PORV failures.

For ANO-1, the Electromatic Relief Valve (ERV) provides the same function as the PORV for RCS depressurization in these conditions and is modeled in the Level 2 LERF analysis as recommended above. Therefore, this modeling of ERV failure is identified as a key assumption in the LERF Notebook and the identified sensitivity analysis for thermally induced Emergency Core Cooling System (ECCS) vent valve failures is considered there.

Valves Closing Against Large Pressure Differentials

PRA models may credit the isolation of breaks or re-alignment of system functions by closing (or opening) valves that may be subject to high pressure differentials. The WCAP recommends that the PRA analyst verify that consideration was given to the differential pressures for valves that are modeled in the PRA for ISLOCA isolation. The WCAP additionally recommends verifying the assumptions in the PRA model for the anticipated transients without scram (ATWS) event concerning RCS overpressure. For those cases in which RCS overpressure is not assumed to lead directly to core damage, it is recommended verifying that consideration was given to the potential for check valves sticking closed after an ATWS event.

In the ANO-1 PRA, ISLOCA initiators were conservatively and simplistically treated to lead directly to a core damage condition. No credit is taken for potential operator actions to close valves in order to isolate an ISLOCA, so closure against a large differential pressure is not a concern. For ATWS, failure of RCS integrity due to primary overpressurization is assumed to result in core damage. Since ATWS overpressure is assumed to lead directly to core damage, this issue is not applicable.

Air / Steam Binding

The PRA model typically does not consider that design errors and/or maintenance errors could result in conditions wherein air or steam binding could occur in pumps assumed to operate in the PRA model. WCAP-16679-P recommends that no failures of systems due to air and steam binding need to be modeled in the PRA for the base model. It does recommend, however, that air binding should be identified as an uncertainty in the PRA models.

The Rev. 4 ANO-1 PRA documentation does not identify air and steam binding as an uncertainty. The documentation of this uncertainty will be considered for addition to future model documentation. However, this issue has no effect on the PRA model, as indicated by the WCAP recommendation in the previous paragraph "that no failures of systems due to air and steam binding need to be modeled in the PRA for the base model."

Backup Systems for Multi-Units

Backup functions from an unaffected unit on the same site are sometimes credited in the PRA. For events that impact both units, assurance needs to be provided that the backup function can be performed simultaneously for the affected unit as well as support the primary function for the unaffected unit. In the ANO-1 model, the only backup systems that are shared between the units are the shared Instrument Air (IA) System, the common Alternate AC Diesel Generator (AACDG) system, and the Emergency Cooling Pond (ECP).

ANO-1 shares IA with ANO-2. The ANO-1 PRA model includes three loss of IA initiators: %T17A ("Loss of IA Affecting Both Units"), %T17B ("LOSS OF Unit 1 Instrument Air"), and %T17C ("Loss of Unit 2 Instrument Air Initiator"). In the model, any one of these initiators will cause a loss of ANO-1 IA (it is conservatively assumed that there will be no isolation of the cross connection in the case of an ANO- 2 loss of IA, which is why an ANO-2 loss of IA is modeled to fail ANO-1 IA). This modeling ensures that the effect of a loss of IA initiators is captured. In addition, ANO calculations show that the ANO-2 IA system has sufficient capacity to supply both ANO-1 and ANO-2 air loads.

The AACDG is an independent, stand-alone power source composed of a diesel-generator and auxiliaries with a requirement to provide the load of one of the four safety buses at ANO in the event of a SBO. The ACCDG has a continuous rating of 4400 kW at 4160 volts. According to the AACDG operating procedure (OP-2104.037), any combination of ANO-1 and ANO-2 vital and non-vital buses may be energized as long as total load remains < 4400 kW. Potential ANO-1 and ANO-2 loads are listed in the procedure. During a SBO, the HPI/HPSI, LPI/LPSI, and Spray pumps would not be needed (since the SBO is not a LOCA scenario), such that those loads would need not be powered. If those loads are excluded, the ANO-1 load would be 1583 kW and the ANO-2 load would be 1370 kW, for a total of 2953 kW. This is well below the 4400 KW limit, showing that the ACC DG could provide emergency AC power to both units in the unlikely case of an SBO in both units.

Startup transformer #2 (SU2) can provide 4160 V and 6900 V power to non-safety and safety buses on either or both ANO units. Procedures give guidance to the operators of both units to ensure that the power available from SU2 is safely apportioned between the units. For ANO-1, procedure OP-1107.001 provides this guidance. Attachment E of this procedure includes SU2 loading restrictions. SU2 can power safety buses from either or both units, allowing both units to be safely shut down.

The ECP serves as a back-up heat sink for the SW system. Water is supplied from the pond by gravity flow to the SW pump compartments in the Intake Structure. This water from the ECP is circulated through the SW system and is then returned to the ECP, where natural cooling occurs. The ECP is designed to support shutdown of both units for 30 days, including design-basis accident loads for one unit. Therefore, the ECP has the capability to support both units simultaneously.

Containment Water Level (Non-bypass sequences with RWST refill)

Some PRA models credit refueling water storage tank (RWST) refill as a success path for continued core cooling. For accident sequences except for bypass sequences (e.g., SGTRs and ISLOCAs), the extra water would be delivered to the RB and could submerge critical equipment and instrumentation relied upon to control the accident. This issue is not applicable to ANO-1 since the PRA does not credit the borated water storage tank (ANO-1 equivalent of RWST) refill for non-bypass sequences.

Mini-Recirculation

If the RCS pressure does not drop below the shutoff head of the ECCS pumps, the pumps will dead-head and may not be available to inject once the RCS pressure drops below the shutoff head of the pumps. The WCAP recommends that the PRA analyst should verify that ECCS pump operation in a dead-headed mode is considered in the PRA model, with special attention paid to ATWS initiating events. ECCS pump operation in a dead-headed mode is considered in the ANO-1 PRA model.

The HPI system is a high head system, with shutoff head well above normal RCS pressure. Therefore, the pump cannot dead-head even with the mini-flow recirculation lines closed. In fact, the system is designed for the mini-flow recirculation valves (CV-1300 and CV-1301), which are normally open to ensure adequate cooling while the operating HPI pump provides normal RCS makeup, to close on an Engineered Safeguards Actuation Signal (ESAS) to maximize ECCS flow.

The DHR/LPI pumps do not have mini-flow recirculation lines, so this issue is not applicable. The system does have recirculation lines, but are only used for surveillance testing and to recirculate and sample the BWST utilizing the Spent Fuel Pool purification system.

Pump dead-heading is generally not an issue for ATWS because the ATWS initiator itself does not cause an ESAS. ATWS results in high RCS pressure, which will not cause an ESAS to occur. Note that since ATWS is not a fire-initiated sequence (NUREG/CR-6850, Table 2-1), the issue of pump dead-heading in an ATWS is not applicable to the FPRA.

d) DA-C10 (Data - counting operational demands)

Based on the NRC staff's review of the F&O disposition for DA-C10, it appears that surveillance tests were not fully evaluated to adjust the demand count of component failures based on what failure modes are evaluated in the tests. Given that the potential impact from this evaluation is unknown and several component failure rates could be affected, it is not apparent how it can be concluded that resolution of this finding would have only a "very small impact" on the FPRA results.

Please provide further justification for not fully evaluating surveillance tests and adjusting the failure rates used in the FPRA for post-transition change evaluation (i.e., when the PRA results are compared against the self-approval guidance for post transition change evaluation).

Response

The ANO-1 plant-specific data analysis calculated demand failure probabilities for certain components in the internal events PRA. Since the internal events PRA provides the base model for the FPRA, these plant-specific failure probabilities were thus incorporated into the FPRA. For these demand failures, the data analysis used actual demand counts for components for which adequate demand data was available. The components for which demand data was used are of various types: 1) Reactor Building Cooling (RBC) fan units, 2) High Pressure Injection (HPI), Low Pressure Injection (LPI), and Emergency Feedwater (EFW) pumps, 3) LPI room coolers, 4) Emergency Diesel Generators (EDGs), EDG Fuel Transfer Pumps, and EDG Sequencers, 5) RCS and Main Steam Safety Valves (MSSVs), 6) Alternate AC Diesel Generator (AACDG), 7) Boric Acid (BA) pumps, 8) Service Water (SW), Condensate, Circulating Water, and Intermediate Cooling Water (ICW) pumps, 9) Instrument Air and Service Air compressors, and 10) 480 V to 120 V transformers. Of these component groups, only the first seven have surveillance procedures. The seventh component group (BA) is only a part of the PRA modeling for ATWS, which is not a fire-initiated sequence and thus does not affect the FPRA; therefore, BA was not evaluated further. The surveillance procedures associated with the first six component groups were reviewed to ensure that there are not "portions of the tests or sub-elements [that] have additional successes that should or should not be counted when estimating operational demands" (reference LAR Attachment U entry for SR DA-C10, to which this RAI refers).

The RBC fan units are tested using OP-1104.033, "Reactor Building Ventilation" (note that the procedure revisions used in the reviews described in the RAI response are the revisions in effect at the end of the PRA plant-specific data window; these describe the surveillance testing upon which the demand counting was based). The testing is simple and involves starting the fan units and verifying proper operation. The testing has no sub-elements that have additional successes that should or should not be counted. The testing aligns with the way the components are modeled in the PRA. The plant-specific demand failure event in the PRA model corresponds to just the RBC fan unit, consistent with the demand data.

The HPI, LPI, and EFW pumps are tested using OP-1104.002, "Makeup & Purification System Operation," OP-1104.004, "Decay Heat Removal Operating Procedure," and OP-1106.006, "Emergency Feedwater Pump Operation," respectively. As was the case for RBC, the testing for these pumps is simple and involves starting the pumps and verifying proper operation. The testing has no sub-elements that have additional successes that should or should not be counted. The testing aligns with the way the components are modeled in the PRA. The plant-specific demand failure event in the PRA model corresponds to just the pump, consistent with the demand data.

The LPI room coolers start automatically when the associated LPI pump starts. The room coolers are tested at the same time as the LPI pumps, using the same procedure. When the pump is started, the LPI procedure directs the operators to also check that the room coolers start and operate. The room coolers have specific demand failure events that use the actual

demand counts. The testing has no sub-elements that have additional successes that should or should not be counted. The testing aligns with the way the components are modeled in the PRA. The plant-specific demand failure event in the PRA model corresponds to just the fan cooler, consistent with the demand data.

The engineered safeguards system components described above are included in procedure OP-1305.006, “Integrated ES System Test.” This procedure tests actuation of components in response to an ESAS. Since the PRA plant-specific data are developed for individual components, the Integrated ES test represents an additional simple demand that is appropriately counted. There are no sub-elements that need to be counted separately, since the components are modeled separately.

The EDGs and EDG fuel transfer pumps are tested using OP-1104.036, “Emergency Diesel Generator Operation.” In addition, the EDGs and sequencers are testing using OP-1305.006, “Integrated ES System Test.” It is important to note that the ANO-1 PRA explicitly models the EDGs, fuel transfer pumps, and sequencers separately. Demand counting is done for each of these component types (EDG, transfer pump, sequencer) separately and a separate demand failure rate was calculated for each type. Since separate demands counts were made for these three component types, the example given in SR DA-C10 for Category II of sub-elements of surveillance tests that might complicate the demand counting (EDG and sequencer included together in one component boundary in the PRA model, but testing at different frequencies) does not apply to the ANO-1 plant-specific data analysis. The surveillance testing for the EDGs and sequences do have sub-elements that have additional successes that should be counted (i.e., the EDGs are tested more frequently than the sequences), and these additional successes are in fact counted. The EDG demand data counts the actual EDG demands, and the sequence demand data counts the actual sequencer demands. In the case of the transfer pumps, there is a specific surveillance test for these pumps and a specific PRA failure event which includes the transfer pump demand counts. Therefore, the testing aligns with the way the components are modeled in the PRA.

The RCS and MSSVs are tested with surveillance procedures OP-1306.011, “Unit 1 Pressurizer Code Safety Valve Test,” and OP-1306.017, “Unit 1 Main Steam Safety Valve Test,” respectively. The tests produce simple demands on individual valves that are appropriately counted. There are no sub-elements that need to be counted separately.

The AACDG is tested with surveillance procedure OP-2104.037, “Alternate AC Diesel Generator Operations.” This procedure performs a simple start and run of the AACDG. There are also some optional steps to feed the ANO-1 4160 V A-1 bus or ANO-2 4160 V 2A-1 bus, but the PRA model does not include plant-specific data calculations, and associated demands, for these buses; therefore, this section of the surveillance test is not applicable to the data analysis. Only the AACDG start is modeled in the PRA using demand data, and the surveillance procedure produces simple demands that are appropriately counted.

In conclusion, the surveillance tests associated with components in the ANO-1 PRA for which plant-specific demand data was developed were reviewed. The testing has no sub-elements that have additional successes which have not been counted. The testing aligns with the way the components are modeled in the PRA. Therefore, no adjustment in the demand failure counts is necessary.

e) DA-C4, DA-E2 (Data - counting failures)

Based on the NRC staff's review of the F&O disposition for DA-C4/DA-E2, it appears that consideration of plant-specific component data for the FPRA was limited to the data in the Maintenance Rule Database. Given that the potential impact from evaluating these additional failures from data sources outside the Maintenance Rule Database is unknown and that a number of failure rates could be affected, it is not clear how it can be concluded that resolution of this finding would have only a "very small impact" on the FPRA results.

Please provide further justification for not considering plant-specific component failure data beyond the data in the Maintenance Rule Database in the FPRA for post-transition change evaluation (i.e., when the PRA results are compared against the self-approval guidance for post-transition change evaluation).

Response

The Arkansas Nuclear One Unit 1, "PRA Peer Review Report Using ASME PRA Standard Requirements," PWR Owners Group, August 2009, states that the requirements of SR DA-C4 and DA-E2 are met for all three Capability Categories. The F&Os associated with these SRs suggest enhancements to the data analysis. In order to ensure that the ANO-1 PRA plant-specific data analysis did not overlook significant failures, the Maintenance Rule (MR) program (reference CALC-96-R-0003-01, Rev. 1, CALC-96-R-0003-01, Rev. 3, and EN-DC-204, Rev. 0) was reviewed, focusing on MR functions and functional failure (FF) determinations. This review confirmed that use of the MR FF data ANO-1 data analysis is appropriate and that significant failures are not missing.

The ANO-1 plant-specific data analysis used MR FF data for components for which the MR database had adequate FF data. EN-DC-204, Rev. 0, "Maintenance Rule Scope and Basis," which provides the guidance for scoping and FF determination, requires that risk significant systems have specific performance criteria tied to the PRA. FFs are counted when a system experiences a failure affecting a MR system function.

The MR risk significant systems and components in the ANO-1 plant specific data analysis are:

MR System	PRA Components
A,B	4.16 KV and 480 V Transformers
AAC	Alternate AC Diesel Generator
ABHV	Low Pressure Injection (LPI) Room Coolers
D	Battery Chargers
EDG	Diesel Generators, Sequencers, Ventilation Fans
EFW	Turbine-Driven Emergency Feedwater Pump
HPI	High Pressure Injection Pumps
LPI	LPI Pumps (a Decay Heat Removal system operating mode)
MS	Main Steam Safety Valves (MSSVs)
RBHV	Reactor Building Coolers
SW	Service Water Pumps
XFMR	Startup Transformers #1 and #2

The MR database was reviewed to ensure that the MR functions for the risk significant systems included the PRA functions. Because the MR functions, against which FFs are counted, include the PRA functions, the ANO-1 plant-specific data analysis did not miss any PRA-relevant failures.

MR non-risk significant systems generally don't have MR system functions that align with the PRA (because they are non-risk significant). The MR non-risk significant systems in the ANO-1 plant specific data analysis are:

MR System	PRA Components
CA	Boric Acid Pumps
CS	Condensate Pumps, Condenser Vacuum Pumps
IA	Compressors, Filters, Dryers
ICW	ICW Pumps
RCP	Reactor Coolant Pumps
SA	Compressors, Filters

Because these systems are non-risk significant, the failure rates for these components by definition do not have a significant effect on the PRA model results, and thus will not affect the FPRA. In particular, since the risk significance determination (reference CALC-93-E-0042-01, Rev. 1) includes Risk Achievement Worth (RAW) > 2 and Fussel-Vesely (FV) > 0.005, non-risk significance means that the CDF is not sensitive to large changes in component failure rate (RAW measures the CDF change for setting a basic event failure probability to 1.0 and FV is related to Risk Reduction Worth, which measures the CDF change for setting a basic event failure probability to 0.0). Since, for these non-risk significant systems, the CDF is not sensitive to significant changes in failure rate, any differences in failure rate that might be calculated using other data bases will not be significant.

<u>PRA RAI 05</u> – Sensitive Electronics

Section 2.4.3.3 of NFPA 805 states that the PRA approach, methods, and data shall be acceptable to the NRC. RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a fire PRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. By letter to NEI dated July 12, 2006, the NRC established the ongoing FAQ process where official agency positions regarding acceptable methods can be documented until they can be included in revisions to RG 1.205 or NEI 04-02. Methods that have not been determined to be acceptable by the NRC staff or acceptable methods that appear to have been applied differently than described require additional justification to allow the NRC staff to complete its review of the proposed method.

The fire scenario analysis appears to indicate that consideration of the impact of sensitive electronics is only considered for cabinets "touching or nearly touching" and was not considered "in areas such as the MCR where the fire would be expected to be extinguished quickly."

Neither of these assumptions is consistent with the most recent guidance for performing assessment of sensitive electronics (i.e., FAQ 13-0004, "Clarifications on Treatment of Sensitive Electronics," dated December 3, 2013 (ADAMS Accession No. ML13322A085)).

Please describe the treatment of sensitive electronics for the FPRA and explain whether it is consistent with the guidance in FAQ 13-0004, including the caveats about configurations that can invalidate the approach (i.e., sensitive electronic mounted on the surface of cabinets and the presence of louver or vents). If the approach is not consistent with FAQ 13-0004, justify the approach or replace the current approach with an acceptable approach into the integrated analysis performed in response to PRA RAI 3.

Response

Walkdowns to verify sensitive electronics locations with respect to fire ignitions sources have been initiated. The walkdowns are being performed in accordance with the guidance of FAQ 13-0004. The results of these walkdowns will be reviewed, in accordance with the FAQ 13-0004 guidance, and the impact of potential sensitive electronics fire scenario targets will be incorporated into the list of fire impacts for the corresponding fire scenarios. Based on a similar review of the walkdowns performed for ANO-2 (in which no sensitive electronics impacts were identified), it is expected that the review of the ANO-1 walkdowns will have no impact on the FPRA results. However, any impact identified will be incorporated into the analysis results provided in response to PRA RAI 03.

<u>PRA RAI 07</u> – Fire Propagation from Electrical Cabinets

Section 2.4.3.3 of NFPA 805 states that the PRA approach, methods, and data shall be acceptable to the NRC. RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a fire PRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. By letter to NEI July 12, 2006, the NRC established the ongoing FAQ process where official agency positions regarding acceptable methods can be documented until they can be included in revisions to RG 1.205 or NEI 04-02. Methods that have not been determined to be acceptable by the NRC staff require additional justification to allow the NRC staff to complete its review of the proposed method.

The fire scenario analysis indicates that the contribution of "sealed panels" was excluded from fire modeling. It is not clear from the analysis how "sealed panels" are defined or how fire propagation from "sealed panels" versus "unsealed" panels were modeled. Nor is it clear from the ignition frequency assessment how "sealed panels" were counted. Please provide the following information:

a) Per Section 6.5.6 of NUREG/CR-6850, fires originating from within "well-sealed electrical cabinets that have robustly secured doors (and/or access panels) and that house only circuits below 440V," do not meet the definition of potentially challenging fires and, therefore, should be excluded from the counting process for Bin 15. By counting these cabinets as ignition sources within Bin 15, the frequencies applied to other cabinets may be inappropriately reduced.

Please discuss how many Bin 15 cabinets are identified and how many of these are well-sealed less than 440 Volt (V) cabinets and the impact of this deviation from NUREG/CR-6850 on the transition and post-transition risk estimates.

b) Please clarify if the criteria used to evaluate whether electrical cabinets below 440 V are "well sealed" is consistent with guidance in Chapter 8 of Supplement 1 of NUREG/CR-6850. If not, please explain how the current approach is an acceptable approach in accordance with the integrated analysis performed in response to PRA RAI 03.

c) All cabinets having circuits of 440 V or greater should be counted for purposes of Bin 15 frequency apportionment based on the guidance in Section 6.5.6 of NUREG/CR-6850.

   Please clarify that this guidance is being applied. If not, please explain how the current approach is an acceptable approach in accordance with the integrated analysis performed in response to PRA RAI 03.

d) For those cabinets that house circuits of 440 V or greater, propagation of fire outside the ignition source should be evaluated based on guidance in Chapter 6 of NUREG/CR-6850, which states that "an arcing fault could compromise panel integrity (an arcing fault could burn through the panel sides, but this should not be confused with the high energy arcing fault type fires)."

   Please describe how fire propagation outside of well-sealed cabinets greater than 440 V is evaluated. If propagation is not evaluated, please explain how the current approach is an acceptable approach in accordance with the integrated analysis performed in response to PRA RAI 03.

Response

a) A review of the “well-sealed” panels that house circuits below 440 V is in progress. The “well-sealed” panels represent a small percentage of the total Bin 15 count and will be removed from the Bin 15 frequency allocation. The removal of these panels is not expected to significantly increase the individual panel frequency and the impact of this change will be incorporated into the integrated FPRA analysis that will be provided in conjunction with PRA RAI 03.

b) ANO utilized the criteria for non-propagating cabinet fires consistent with Chapter 8 of NUREG/CR-6850, Supplement 1. A well-sealed, non-ventilated, electrical cabinet with panel doors that are anchored with multiple points of contact were considered not to propagate. All remaining Bin 15 counted cabinets assumed the potential to propagate outside the panel walls.

c) All cabinets having circuits of 440 V or greater are included in the Bin 15 frequency counting process in accordance with the guidance of NUREG/CR-6850.

d) “Well sealed” electrical cabinets that are 440 V or greater were not evaluated as propagating fires. The ANO-1 FPRA is being updated to reflect the guidance issued in FAQ 14-0009 (Treatment of Well-Sealed Electrical Panels Greater than 440 V) to generate a severity factor for fire propagation to thermoplastic target sets outside the cabinet. The

zone of influence and hot gas layer will be treated similarly to ventilated electrical cabinets. This revision will be incorporated into the integrated FPRA analysis that will be provided in conjunction with PRA RAI 03.

PRA RAI 08 – Transient Frequency Adjustment Factor

Section 2.4.3.3 of NFPA 805 states that the PRA approach, methods, and data shall be acceptable to the NRC. RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a fire PRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. By letter to NEI dated July 12, 2006, the NRC established the ongoing FAQ process where official agency positions regarding acceptable methods can be documented until they can be included in revisions to RG 1.205 or NEI 04-02. Methods that have not been determined to be acceptable by the NRC staff require additional justification to allow the NRC staff to complete its review of the proposed method.

The fire scenario PRA analysis appears to indicate that a "Transient Frequency Adjustment Factor" of 0.1 was used to represent the fraction of time transient combustibles are allowed in the Cable Spreading Room. Section 6.5.7.2 of NUREG/CR-6850 states: "It is assumed that transient fires may occur at all areas of a plant unless precluded by design and/or operation, such as inside a BWR [boiling-water reactor] drywell or torus during power operation. Administrative controls significantly impact the characteristics and likelihood of transient fires, but do not preclude their occurrence, since there is industry evidence of failure to follow administrative control procedures."

Please remove credit for use of the Transient Frequency Adjustment Factor in the integrated analysis provided in response to PRA RAI 03, or replace it with an acceptable credit such as use of influencing factors per guidance in FAQ 12-0064, "Hot Work/Transient Fire Frequency - Influence Factors."

Response

Transient Frequency Adjustment Factor of 0.1 is being removed from the analysis and replaced with a frequency adjustment that is consistent with FAQ 12-0064. The apportioning of the transient weighting factors will be reviewed and will take into account the relative electro-mechanical maintenance, hot work, occupancy, and storage for each transient bin. Areas such as the cable spreading room that lack physical equipment or areas that contain personnel access controls support will be considered when apportioning the transient frequency.

The impact of this change on the FPRA quantification will be addressed via the updated quantification results to be provided in conjunction with the response to PRA RAI 03.

PRA RAI 09 – Modeling of Fire Propagation in the MCR

Section 2.4.3.3 of NFPA 805 states that the PRA approach, methods, and data shall be acceptable to the NRC. RG 1.205 identifies NUREG/CR-6850 as documenting a methodology for conducting a fire PRA and endorses, with exceptions and clarifications, NEI 04-02, Revision 2, as providing methods acceptable to the NRC staff for adopting a fire protection

program consistent with NFPA-805. By letter to NEI dated July 12, 2006, the NRC established the ongoing FAQ process where official agency positions regarding acceptable methods can be documented until they can be included in revisions to RG 1.205 or NEI 04-02. Methods that have not been determined to be acceptable by the NRC staff require additional justification to allow the NRC staff to complete its review of the proposed method.

The fire scenario analysis states "[f]or electrical panel fires inside the control room the fire is expected to be contained within the panel due to early fire detection and suppression by operations personnel." This statement appears to be inconsistent with guidance for addressing the potential for fire propagation between adjacent electrical panels/cabinets in NUREG/CR-6850. It is not clear from the analysis how the potential for fire propagation between adjacent electrical panels/cabinets in the MCR was addressed.

a) Please describe the approach used to model fire propagation between adjacent Bin 15 electrical panels in the MCR and between segments of the Bin 4 Main Control Board.

b) If the potential for fire propagation between adjacent electrical panels/cabinets has not been evaluated or is not consistent with NRC guidance, please justify the approach or use an acceptable approach in the integrated analysis provided in response to PRA RAI 3.

Response

a) Propagation of an electrical cabinet fire to an adjacent electrical cabinet was modeled in the ANO-1 FPRA as follows:

   For most of the non-abandonment Main Control Room (MCR) scenarios, fire propagation was limited to the cabling within the enclosure boundaries of the source cabinet. The cabinet is considered an adjacent cabinet if the cabinet is separated from the source cabinet. Each cabinet was modeled as its own scenario without propagation to the adjacent cabinets since the cabinets are separated by double walls and an air gap. The Control Room cabinets are not open and cannot expose an adjacent cabinet to the source heat flux without first penetrating through the source cabinet walls and the adjacent cabinet walls.

   This treatment is consistent with the criteria specified in Appendix S of NUREG/CR-6850 which states, “Fire spread to an adjacent cabinet was prevented if the cabinets were separated by a double wall with an air gap.” Therefore, the guidance provided in Chapter 11 of NUREG/CR-6850, Page 11-39, is applicable: “For cabinets with a double wall separated by an air gap and back covers, as suggested in Appendix S, it can be assumed that the fire would not propagate between the cabinets.”

   In addition to the guidance listed in Appendix S and Chapter 11 of NUREG/CR-6850, which is applicable to panels in any location in the plant, the MCR is constantly manned, resulting in a high likelihood of early detection. This allows quick and appropriate response to any fire scenario within the MCR area and further limits the ability of a fire to propagate to an adjacent cabinet.

In limited cases, MCR panel fires were conservatively assumed to spread to adjacent panels. Four scenarios were identified where a fire could spread to an adjacent panel due to the lack of separation (double panel wall with an air gap) between the panels. The scenarios are:

- C23, C27
- RS-1, RS-3
- RS-2, RS-4
- C01, C02, C03, C04, C09, C100

Except in limited cases as specified above, the definitions for each single MCR fire scenario include the cable targets within the cabinet outer boundaries. Using the guidance in Appendix S and Chapter 11 of NUREG/CR-6850, it is assumed that MCR panel fires would not propagate to adjacent cabinets.

b) The modeling of fire propagation between adjacent panels in the MCR was performed in accordance with the guidance of NUREG/CR-6850. However, during the audit walk-downs it was identified that one of the cabinet scenarios did not have a full partition wall and was open to the adjacent cabinets. As a result, the MCR panels will be walked down and visually verified to ensure all MCR cabinet scenarios are consistent with part a) of this response. Any changes resulting from the walk-downs will be incorporated into the ANO-1 FPRA in support of the integrated risk assessment PRA RAI 03.

<u>PRA RAI 16</u> – Defense in Depth and Safety Margin

Section 2.4.3.3 of NFPA 805 states that the PRA approach, methods, and data shall be acceptable to the NRC. Section 2.4.4.1 of NFPA-805 further states that the change in public health risk arising from transition from the current fire protection program to an NFPA-805 based program, and all future plant changes to the program, shall be acceptable to the NRC. RG 1.174 provides quantitative guidelines on CDF and LERF, and identifies acceptable changes to these frequencies that result from proposed changes to the plant's licensing basis and describes a general framework to determine the acceptability of risk-informed changes. The NRC staff review of the information in the LAR has identified the following information that is required to fully characterize the risk estimates.

LAR Section 4.5.2.2 provides a high-level description of how transition to NFPA 805 impacts DID and safety margin.

a) Please provide further explanation of the method used to determine when a substantial imbalance between DID echelons existed in the Fire Risk Evaluations (FREs), and identify the types of plant improvements made in response to this assessment.

b) Please provide further discussion of the approach in applying the NEI 04-02, Revision 2 criteria for assessing safety margin in the FREs.

Response

a) The method used in the ANO-1 Fire Risk Evaluations (FREs) to determine when a substantial imbalance between defense-in-depth (DID) echelons existed was based on the guidance in NEI 04-02, Revision 2. Each fire area was evaluated for the adequacy of DID by consideration of the VFDRs, associated fire area risk (CDF), and scenario consequences (CCDP) to identify DID echelon imbalances. The following table is utilized in each FRE to aid in the consistency of the review for DID, with the exception of the discussion section which supports this response.

Defense-in-Depth Impact Review	
Method of Providing DID	Discussion
Echelon 1: Prevent fires from starting	
• Combustible Control • Hot Work Control	Combustible and hot work controls are fundamental elements of DID and as such are always in place. The issue considered in the FREs is whether this element needed strengthening to offset a weakness in another echelon thereby providing a reasonable balance. Considerations include: • Creating a new Transient Combustible Free Area • Modifying an existing Transient Combustible Free Area • Creating or modifying restrictions on Hot Work The fire scenarios involved in the FRE quantitative calculation are reviewed to determine if additional controls should be added. The remaining elements of DID were reviewed to ensure an over-reliance was not placed on programmatic activities to compensate for weaknesses on plant design.

Defense-in-Depth Impact Review	
Method of Providing DID	Discussion
Echelon 2: Rapidly detect, control and extinguish promptly those fires that do occur thereby limiting fire damage	
• Detection System • Automatic Fire Suppression • Portable Fire Extinguisher • Hose stations and hydrants located in the area(s) • Pre-Fire Plan	Automatic suppression and detection may or may not exist in the fire area of concern. The issue considered by the FRE is whether installed suppression or detection is required for DID or whether additional suppression or detection is needed to offset a weakness in another echelon thereby providing a reasonable balance. Considerations include: • If a Fire Area contains both suppression and detection and firefighting activities would be challenging, both detection and suppression may be required • If a Fire Area contains both suppression and detection and firefighting activities would not be challenging, detection and manual firefighting may be required • If a Fire Area contains detection and a recovery action is required, the detection system may be required. If a Fire Area contains neither suppression nor detection and a recovery action is required, consider adding detection or suppression. The fire scenarios involved in the FRE quantitative calculation were reviewed to determine the types of fires and reliance on suppression should be evaluated in the area to best determine options for this element of DID.

<table>
<tr><th colspan="2">Defense-in-Depth Impact Review</th></tr>
<tr><th>Method of Providing DID</th><th>Discussion</th></tr>
<tr><td colspan="2">Echelon 3: Provide adequate level of fire protection for systems and structures so that a fire will not prevent essential safety functions from being performed</td></tr>
<tr><td>Walls, floors ceilings and structural elements are rated or have been evaluated as adequate for the hazard.
Openings in the fire barrier are rated or have been evaluated as adequate for the hazard.
Supplemental barriers (e.g., ERFBS, cable tray covers, etc.)
Guidance provided to operations personnel detailing the credited success path(s) including recovery actions to achieve nuclear safety performance criteria.</td><td>If fires are not rapidly detected and promptly extinguished, the third echelon of DID would be relied upon. The issue considered in the FREs is whether existing separation is adequate or whether additional measures (e.g., supplemental barriers, fire rated cable, or recovery actions) are required to offset a weakness in another echelon thereby providing a reasonable balance.
Considerations include:
If the VFDR is never affected in the same fire scenario, internal Fire Area separation may be adequate and no additional reliance on recovery actions is necessary.
If the VFDR is affected in the same fire scenario, internal Fire Area separation may not be adequate and reliance on a recovery action may be necessary.
If the consequence associated with existing VFDRs were considered high (e.g., CCDP>1E-01 or by qualitative Safe Shutdown (SSD) assessment), regardless of whether it is in a risk significant fire scenario, a recovery action, supplemental barriers, or other modification was considered.
There are known modeling differences between a Fire PRA and nuclear safety capability assessment (NSCA) due to different success criteria, end states, etc. Although a VFDR may be associated with a function not considered as a significant contribution to CDF, the VFDR may be considered important enough to the NSCA to retain as a recovery action.
The fire scenarios involved in the FRE quantitative calculation were reviewed to understand the fires evaluated and the consequence in the area so that the options DID could be determined.</td></tr>
</table>

b) In accordance with NEI 04-02, Revision 2, the maintenance of adequate safety margin was assessed by the consideration of categories of analyses used by the ANO-1 FREs. Safety margins were considered to be maintained if:

- Codes and standards or their alternatives accepted for use by the NRC are met, and,
- Safety analysis acceptance criteria in the licensing basis (e.g., UFSAR, supporting analyses, etc.) are met, or provide sufficient margin to account for analysis and data uncertainty.

The requirements related to safety margins for the FREs were evaluated for each specific analysis type. These analyses can be grouped into four categories. These categories and a description of how they are maintained for ANO-1 are as follows:

1. Fire Modeling

   Fire modeling was performed within the FPRA utilizing codes and standards developed by industry and NRC staff to provide realistic yet conservative results. Specifically, the heat release rates utilized in the transition analysis are based upon NUREG/CR-6850, Task 8, Scoping Fire Modeling. These heat release rates are conservative and represent values used to screen out fixed ignition sources that do not pose a threat to the targets within specific fire compartments and to assign severity factors to unscreened fixed ignition sources.

2. Plant System Performance

   Plant system performance parameters were not modified as a result of a fire risk evaluation. These performance parameters were originally established to support nuclear performance criteria contained in the plant specific accident analyses. These analyses established component and system performance criteria necessary to establish safe and stable plant operation, as well as, safe shutdown of the unit in the event of a fire. These performance parameters were not modified as a result of this fire risk evaluation.

3. PRA Logic Model

   The ANO-1 FPRA was developed in accordance with NUREG/CR-6850, which was developed jointly between the NRC and EPRI. The specific codes and standards used in the FPRA application and development were 10 CFR 50.48(c), NFPA 805, 2001 edition, NRC Regulatory Guide (RG) 1.205, Revision 1, and NUREG/CR-6850. In addition, ANS RASa-2009, Addenda A to ASME/ANS RA-S-2008 Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, ASME, and the American Nuclear Society, December 2008 was used in the development of the FPRA. The NRC endorsed this Standard in Revision 2 of RG 1.200 in March 2009. An industry peer review was also conducted as part of the process and any significant findings were resolved to meet the standard.

   These codes and standards were applied in a manner which would provide FPRA results which contain and complement safety margin. The bases for the application of these FPRA codes and standards were not altered in support of the fire risk evaluation.

4. Success Path Confirmation

   In accordance with the requirements of 10 CFR 50.48(c)(iii), the ANO-1 FPRA results, including the sequences for the scenarios of concern, have been reviewed. It was verified that the results do not rely solely on feed and bleed as the fire-protected safe shutdown path for maintaining reactor coolant inventory, pressure control, and decay heat removal capability for the fire areas considered.

REFERENCES

1. Entergy letter dated January 29, 2014, *License Amendment Request to Adopt NFPA-805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)* (1CAN011401) (ML14029A438)

2. NRC letter dated May 5, 2015, *Arkansas Nuclear One, Unit 1 – Request for Additional Information Regarding License Amendment Request to Adopt National Fire Protection Association Standard 805* (TAC No. MF3419) (1CNA051501) (ML15091A431)

3. Entergy letter dated May 19, 2015, *Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (1CAN051501) (ML15139A196)

4. Entergy letter dated June 16, 2015, *60-Day Response to Request for Additional Information – Adoption of National Fire Protection Association Standard NFPA-805* (1CAN061501) (ML15167A503)