Entergy

Entergy Operations, Inc.
1448 S.R. 333
Russellville, AR 72802
Tel 501 858 5000

0CAN070302

July 3, 2003

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: Arkansas Nuclear One - Units 1 and 2
Docket Nos. 50-313 and 50-368
License Nos. DPR-51 and NPF-6
NRC Triennial Fire Protection Inspection Report 01-06; EA-03-016
Significance Determination Process Report

Dear Sir or Madam:

Attached is the subject Significance Determination Process Report that was performed for the apparent violation described in a March 25, 2003, letter from Mr. Dwight D. Chamberlain to Mr. Craig Anderson at Arkansas Nuclear One. The attached information will be discussed at the July 10, 2003, Regulatory Conference at Arlington, Texas. Should you have questions or comments, please call Mr. Glenn Ashley at 479-858-4617.

There are no new commitments contained in this submittal.

Sincerely,

Sherrie R. Cotton

Sherrie R. Cotton
Director, Nuclear Safety Assurance

SRC/RMC
Attachment

BB-12

[redacted]

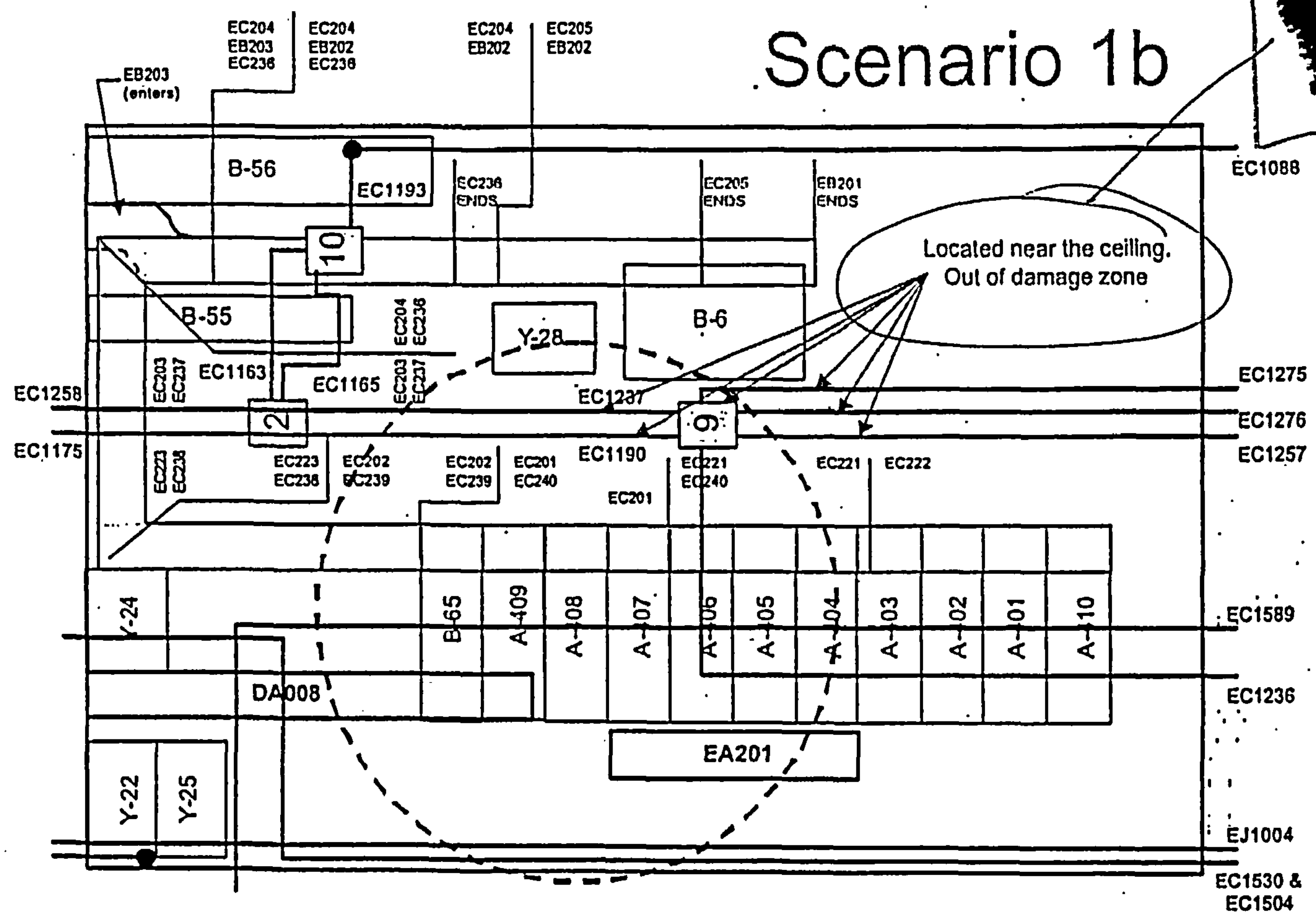

Figure 4: Pictorial Representation of the Zone-of-Influence of a High-Energy Fire in the 4KV Switchgear A4

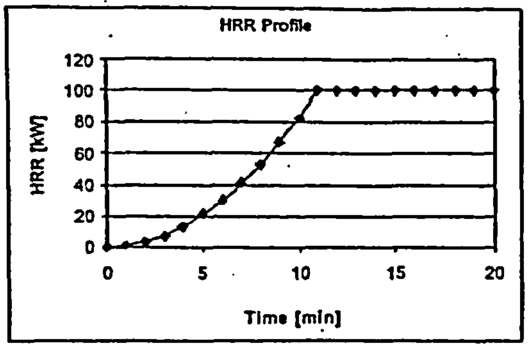

Figure 10: Selected heat release rate profile for cabinet fires in switchgear room 99M.

EPRI's Fire PRA Implementation Guide [Ref. 1] recommends a HRR value of 65 kW for electrical cabinet fires in which the fire would be limited to a single cable bundle. The 65 kW value is the highest value of the fire experiments described in NUREG 4527, [Ref. 2] in control cabinets with IEEE-383 qualified cable and open or closed doors. In these experiments, the fire was limited to one cable bundle. Switchgear cabinets are distinctly different from control panels in that:

1) they have significantly lower combustible loading,

2) the combustibles are confined/separated into sheet-metal walled cubicles (control, breaker and busbar cubicles), and

3) the wires in the cubicle with the most of the heat load, namely the control cubicle are low voltage (120VAC or DC) wires with lower combustible mass.

Figure 10 shows the configuration of the combustibles in the control cubicles of the 4KV switchgear A4. Based onthe small amount of combustible loading in comparison to the Sandia test, a peak value of a 100 kW fire is a reasonable assumption. This nominal value is higher than the 65 kW recommended by the EPRI Fire PRA Guide. Furthermore, this fire intensity is expected to produce flames capable easily reaching cable trays above the cabinet.

Another parameter in characterizing a fire is its location. The location of an electrical cabinet fire could be significant as assuming a fire on the top of the panel versus one at the location of the vents could mean the difference between ignition or no ignition of the overhead cabling with fire intensities in the 100KW or less range. Also, in a closed-top or mechanically-sealed-top cabinet an assumed fire at the top of the cabinet could mean no-flame heating where the flames are likely to be at the location of the vents or warped panel doors.

IN 2002-27

has the following input parameters: A_o- the cable tray burning area (m^2), and q_{bs}- the experimental bench scale heat release rate value (kW). A_o is assumed to be the width of the cable tray (24") times the characteristic length of the fire, which is assumed to be the length of the cabinet. Due to the uncertainty in the cable type, a value of 400 kW/m^2 is selected for q_{bs}. Notice that this is the highest value that can be selected from the bench scale experiments used for developing the correlation. This selection will result in a conservative estimate of the heat release rate.

The model described in EPRI TR-105928 [Ref. 1] for cable tray propagation in a stack is used for estimating heat release rates from the two and three tray stacks currently present in the room. The model assumes the characteristic length of the fire below the first tray in the stack times the tray width as the burning area in the lowest tray. The fire then propagates to trays above in a 35° angle to each side of the trays. A five-minute delay between cable tray ignitions is recommended based on experimental observations. Figure 11 provides a pictorial representation of the model.

Assuming the fire in the switchgear cabinet A4 will have a characteristic length of 3' (A conservative assumption due to the limited openings in the top of the switch gear.), the first tray will have a burning area of 6 ft^2, and a heat release rate of 100 kW. The second tray in the stack will have a burning area of 7.1 ft^2, and a heat release rate of 120 kW.

Assuming the fire in the MCC cabinet B55 will have a characteristic length of 3', the first tray will have a burning area of 6 ft^2, and a heat release rate of 100 kW. The second tray in the stack will have a burning area of 8.4 ft^2, and a heat release rate of 140 kW. Finally, the third and last tray in the stack will have a burning area of 9.7 ft^2, and a heat release rate of 160 kW.

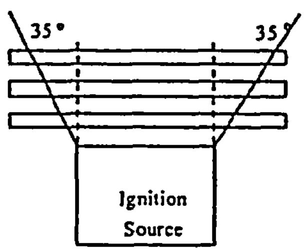

Figure 12: Cable tray stack fire propagation model

II.1.3.4 Localized Damage to Targets

Localized damage to targets can occur to cable trays and conduits located inside the flames, in the fire plume, or subjected to flame radiation. Targets are considered damaged or ignited when their surface temperature reach 700 °F. It is assumed that only cable trays (not metal conduits) will ignite and contribute to room heat up. Cables inside metal conduits assumed damaged at the

Summary

Several parameters contribute to the extent and timing of fire damage in fire zone 99-M. These include:

- Size and profile of the initial fire, i.e., how fast the fire grows to its peak and how long it takes before it begins to decay
- The cable damage temperature. ANO verified through review of the original and current plant design and installation documents that the cables installed throughout the plant are predominantly thermoset. Thermoplastic cables are, however, used on a very limited basis. A review by the ANO staff identified no thermoplastic cables in the 3 fire zones in unit 1 where this issues was examined for risk, namely, 99-M, 100N and 104S. Therefore our assessment assumed damage and ignition temperature of 700°F for cables in these fire zones.
- Size and location of any cable fire that may be initiated by the initial fire.

The following is a summary of the insights from the fire modeling:

- The maximum expected fire scenario in the room is an energetic arcing fire in the 4KV switchgear. This is for two reasons. First, this event is capable of the largest set of immediate circuit/equipment damage and, second, the event is capable of initiating secondary cable fires that can cause additional time-phased circuit/equipment failures.
- A credible fire scenario cannot be postulated in this zone which would result in an immediate damaging 700°F hot gas layer. A large ~2MW fire is needed to produce a damaging 700°F HGL in this fire zone. Only cable fires in the room are capable of generating such intensity if enough cables are burning. Even if such a large cable fire can be sustained (unlimited oxygen) it will take about 2 hours for the cable fire to propagate to this size.
- Large elevated cable fires that continue to grow unabated can not be sustained due to oxygen limitation:

    1) Cable fires can only burn inside the hot gas layer. Assuming no manual intervention, with either closed or open doors, the cable trays will be immersed in smoke because the height of the door is not high enough to allow for smoke movement from the top section of the room, and no automatic extraction system is in place. The fire eventually would be oxygen controlled if it keeps growing in such an environment.. CFAST results are consistent with this argument.

    2) If the simulation is run with open doors, AND the fire is assumed at the elevation lower than the steady state position of the hot gas layer, the fire will have enough oxygen to burn at the stipulated intensity. Therefore, assuming open doors, and a cable fire located about 1 m high growing up to 2 MW in 1.5 hours can generate a hot gas layer of 700 °F. All cable trays in fire zone 99-M are located above the steady state position of the hot gas layer, i.e., 6 ft. With closed doors, the smoke layer would reach the floor, and eventually the fire will be oxygen controlled.

Communications between the control room and all others involved in the simulation were of a high volume, but the self powered radio phones permitted each person to hear the others communication. The communications were provided on a multiple channel self powered radio system, which is independent of the fire effect in any zone and loud speakers for plant communications from the control room (e.g., site emergency). The volume of communication was high, but each person focused on only the important communications during the initial stages of the event, which involved verification of the instruction, and verification of the action completion.

II.2.2.5 Special tools for executing a local action

Most of the actions could be performed without any special tools.

In addition to the special tools of gloves, dosimeter, keys, flashlights, etc. some special tools were needed for the A3 breaker operation, because control power to the breakers failed in this event. In particular, a grounding stick, which was available from a nearby location, was needed. The valves all had attached hand wheels for manual operation.

II.2.2.6 Training on local actions and use of procedures

The local auxiliary operators demonstrated good knowledge of the locations and how to operate each equipment type.

For actions called for by the control room crew there was no discernable difference between an experienced operator and a recently licensed operator for finding the location, the equipment, and assessing the condition and implementing requested actions using either generic procedures or verbal requests the requested action. The conclusion from this observation is that the training process for field operators provides the key knowledge for operating any equipment specified by the control room in addition to the guidance provided by procedures for generic operation of the equipment.

II.2.2.7 Accessibility for performing local actions

[redacted]

The plant walk down demonstrated that the location and the equipment for performing each action were accessible. The simulation confirmed that the timing for performing the actions was adequate.

A walk down of the pathways prior to the simulation was undertaken to verify that the possible local actions could be undertaken. While most of the valves and breakers were easily accessible from normal height or by climbing permanently fixed ladders, one valve for steam admission from Steam generator A to the 7A EFW turbine had very difficult access over several pipes and in a cramped area. Its redundant valve from steam generator B to 7A EFW turbine was more easily accessible via a fixed ladder. Hazard warnings or other obvious obstacles did not restrict operators from operating the key safety valves or breakers. The pathway to each location was assessable without going through fire zone 99-M.

II.2.2.8 Procedures for response to a complex fire scenario

The evolution of a fire in zone 99-M is expected to be a very rare event, even so it was demonstrated during the simulation that the current EOPs and new attachment could be used to manage an extensive fire in that zone.

Current EOP/AOP/Pre-Fire Plans

The current ANO1 symptom based EOPs provided adequate guidance for a crew licensed on the ANO1 plant to manage all of the systems needed to protect the core following a fire in 99-M.

This was demonstrated by observation of one crew in the simulator, who successfully cooled the core following the procedures and selecting the necessary floating steps. There was no time required for studying any element of the procedure, as the crew appeared to have in mind all the elements of how to maintain cooling given a continuously eroding man-machine interface. The current procedures were applied in an ***opportunistic*** manner to manage core cooling safety trains during the event. The phasing of the fire permitted some successful automatic alignments early in the sequence; however, the operators did not anticipate protecting the operating equipment from spurious operations by removing power from the valves that were manual positioned.

New fire procedure attachment

The new attachment provides specific guidance for lining up, controlling, and preventing spurious actions from stopping a key safety train given a fire in 99-M.

In simulation of this event the crew did not start the new attachment for about 15 minutes after the fire started. By this time it is expected that the damage to cables and the potential for new spurious actions would be over, even if the temperature of the damaged switch gear was high enough to cause additional self ignition. Fortunately, the new attachment provides a process for moving valves and breakers into their correct positions for core cooling, and then removing the electric control power to prevent a future spurious operation. The fact that the new attachment provides specific valve and breaker identification numbers for communication to the local operators for a fire in 99-M means that the control room is more likely to be operating a ***tactical*** manner for managing core cooling equipment during the event. Since the new attachment had only recently been written, the crew had not practiced on the procedure before the simulation.

II.2.2.9 Verification and validation of local manual actions

Our walk down and simulation exercise provided a verification and validation that the current procedures as well and the new attachment could be performed to protect the core in the event of a fire in 99-M.

The control room identification of the action, the timing of the action, the route to the local stations was clear of the fire zone, and the use of current auxiliary operators in the simulation clearly showed that the such actions can be performed. The only issue remaining is the effect that a real fire might have on the local environment (e.g., smoke, heat and toxic gases). The crew is trained in the use of protective gear including special breathing packs.

Once the actions are shown to be feasible the next step is to determine the reliability of the action considering the details of the elements used in quantifying the error potential for each action as is done in the next section.

II.2.3 Reliability of Manual Actions (Human Reliability Analysis – HRA)

To evaluate the impact of a fire on the crew actions a human reliability modeling approach was developed using the current human error probability (HEP) values developed from the SAIC TRC model [Ref. 14], which is an integrated single model that considers timing and other factors to produce a single human failure event (HFE) value. The HFE represents an integration of error factors that apply to the scenario, whereas HEP refers to the human error associated with a defined task not yet integrated into the overall scenario. The EPRI HRA calculator was used to supplement the initial assessments with revisions in the P1 and P3 assessments.

II.2.3.1 Current HRA model in the CCDP

The equation for the SAIC TRC is a lognormal distribution of the following form:

$$P(t)=\frac{1}{\sqrt{2\pi}\sigma_R}\int_{-\infty}^{t}\frac{1}{s}exp\left\{-\left[\frac{ln(s/m)}{\sigma_R}\right]^2\right\}ds$$

The HRA analyst accounts for the operational context by adjusting the parameters m and σ_R for rule-based versus knowledge-based behavior, no burden versus burden, and other performance influencing factors.

The HFEs for non-recovery are based on the TRC system, which assigns an error mode category, location, response time, time available, error factors, and other uncertainty factors. Defaults are provided based on the event categorization, and rules of thumb are provided for the application context. This system is useful for single scenario recovery models. The internal events application of the TRC model assumes good control and indication interfaces in the control room and locally, reliable instrumentation and no smoke or flame nearby. It does not explicitly address the cognitive areas of detection, situation assessment, planning, and execution of the task (in the control room or locally).

The CCDP model for zone 99-M was developed by considering the bounding components that could be damaged in a realistic fire as summarized in Appendix B.2. Based on the fire growth model this included all equipment in an A4 breaker cabinet and the two cable trays above it. In the realistic fire the amount of combustible material to feed the fire is not sufficient to form a hot gas layer that damages the remaining equipment in the room[2]. Thus, the fire model used to

[2] In the simulation the realistic fire was expanded to assume a hot gas layer at T=15 min to extend the simulation by damaging all equipment in the room. Even in this case both crews demonstrated that the current and enhanced EOPs were sufficient to

Human reliability analysis

The CCDP evaluations indicate that impact of ΔHEP is measurable but small between the two procedures.

A fire in 99-M is expected to increase the ΔHEP for feasible actions over the initial internal events PRA results.

The EPRI HRA calculator facilitates quantification and documentation.

Change in the HFEs ranges from zero to one depending on the fire scenario context. In most cases the change is less than 0.05.

II.2.4.2 Qualitative Evaluation of Feasibility for Manual Actions

Screening for HRA

Both the control room actions and local manual actions have reasonable likelihood's of success in preventing core damage for the realistic fire and the complete room affected fire when failures occur over a time period using the existing procedures. This was demonstrated in the simulation when the control room operators were exp osed to the type of alarms and control malfunctions expected from a fire in the 99-M zone. The operators also contacted local operators interacting at the local plant sites as they would under fire conditions.

The strategy for using symptom based – emergency procedures requires operators to think beyond the opportunistic approach of responding to the situation to protect against hot shorts and erroneous signals.

The ***current fire emergency procedures*** include warnings about possible hot shorts and unreliable indications, but it is up to the operators to select cooling equipment and identify protective actions. During simulation of the zone 99-M fire using current procedures, the process revealed that the operators are able to "think" how to adapt to dev elop a conceptual approach for dealing with a wide spectrum of fires, especially since there is time to do so when the fire damage is simulated to occur progressively rather than unrealistically assuming all fire damage occurs instantaneously.

The ***revised fire EOP attachment*** includes explicitly identified cooling systems to line up for operation and protective actions such as opening specific breakers to remove power from valves that might spuriously close and inhibit operation of the EFW system. The simulation revealed that the crew needs additional training on the new attachment, and as used it was started about 15 minutes after the trip and by this time the fire damage is expected to have potentially caused spurious events. The procedure supports systematic realignment after spurious closures.

Application of inspection criteria

The NRC inspection criteria for fire protection manual actions [Ref. 13] were also used as a measure of the qualitative identification of feasibility for performing operator actions. Table 6

Table 7: Basis for feasibility of local action used to protect the core during a 99-M fire

Feasibility criteria	Met	Plant Walkdown	Simulation Preparation	Training Simulation MCR Events	In-Plant Local Simulation	Post Simulation Discussion
Instrumentation for diagnosis	Yes		X	X		
Environmental considerations	Yes	X				X
Staffing	Yes			X	X	
Communications	Yes			X	X	X
Special tools	Yes	X			X	
Training	Yes			X	X	X
Accessibility	Yes	X			X	
Procedures	Yes		X	X		
Verification and validation	Yes	X		X	X	X

II.2.4.3 Quantitative HRA

In developing the CCDP there is a need to address special fire specific manual actions that are identified in the fire procedures and to recover key components needed to ensure safe shutdown of the reactor core under the fire scenario conditions. The manual action for closing a 4160-volt breaker to start 7B is parallel to the actions for 7A for opening the steam admission valves to supply power to the turbine.

The fire in 99-M is expected to increase the ΔHEP for typical feasible actions over the initial internal events PRA results from zero to a value in the range of 3E-3 to 4E-2 for various scenarios and conditions. If the action is not feasible, then the HEP assessment is set at 1.0.

Ex5

[redacted]

There is actually a very small difference in the impact of the current procedures versus the new attachment on the likelihood of core damage, however, the EOP new attachment helps the crew move from an opportunistic approach to control (where the probability of action failure is in the range of .5 to 1E-2) to a more tactical control process (where the probability of action failure is in the range of 0.1 to 1E-3) [Ref. 18]. Figure 23 illustrates the impact of the fire on the estimate of the ΔHEPs for the current EOPs and the new EOP attachment for a fire in zone 99-M. It shows a slight decrease for some of the HEPs. The basic inputs to this figure are derived from the inputs to Table 4. When the ΔHEPs are combined with the current HFE assessments as provided in Table 4 it is interesting to compare the impact of the fire on the HFEs ordered from smallest to largest in Figure 24. The impact for most of the actions considered is very small in terms of change in overall frequency.

Enough of physical separation of critical cables and circuits to limit fire progression in some cases and provide the needed time for the fire brigade to control and extinguish the fire,

Feasible and reliable means of safe shutdown (including manual actions) to safely shutdown the plant after the postulated fire scenarios.

Quantitatively, this element was estimated to provide at least 1.5 orders of magnitude (fire scenario CCDPs range from 4E-5 to 3E-02) for most fire scenarios in this area.

II.4.2.2 Safety Margin

A critical aspect of risk-informed decision-making is recognition of inherent uncertainties in the estimates and consideration of these uncertainties in the decision-making. Determination and use of margin is one way to ensure appropriateness of the decision in the face of these uncertainties. The following discussion is a qualitative assessment of the safety margin.

We used the concept of limiting fire scenario described in the NFPA 805 (sections 1.6.36 and C.3.3) to ensure confidence in our estimate of fire consequences. The NFPA 805 define a limiting fire scenario as," "Fire scenario(s) in which one or more of the inputs to the fire modeling calculation (e.g., heat release rate, initiation location or ventilation rate) are varied to the point that the performance criterion is not met. The intent of this scenario(s) is to determine that there is a resale margin between the expected fire scenario conditions and the point of failure."

Having already included a high-energy fire in the 4KV switchgear where considerable failures occur in virtually no time followed by additional time-phased failures (if suppression is failed), we defined the creation of a hot gas layer (leading to failure of all circuits in the room) as the "point of failure." We determined the following conditions required to reach this hypothetic "point of failure."

Cable damage temperatures of 400-500°F and a 500KW fire that ramps in 12 minutes can reach the "point of failure". The cables at ANO were investigated and confirmed to be thermoset with 700°F damage/ignition temperature

The only credible means of generating a 700°F HGL is through a large cable fire (over 24 linear ft of 24" cable trays). Even though such a cable fire can theoretically be developed if the cable fire continues for nearly 2 hours unchecked, there are realistic considerations that make such occurrence non-credible. Foremost, a cable fire of such magnitude requires considerable volume of oxygen to sustain. These cable fires are expected to be in the smoke layer once the smoke layer reaches the top of the door. Once in the smoke layer, intensity of the cable fire will be controlled by the oxygen availability. With an elevated cable fire that grows at a rate of 10 linear ft/hr as input;

- The oxygen depletion occurs very quickly, regardless of open or closed door
- The cable fire does not grow beyond the initial 12 ft and

IV CONCLUSIONS

[redacted]

In response to the issu e of adequacy of the manual actions at the ANO power station, a fire significance determination process (SDP) examination was performed. Following are the conclusions of this examination..

Reliability of the Manual Actions – The manual actions identified during the simulation and from the ANO unit 1 PRA were evaluated. The plant walk down and simulator exercise showed the equipment was accessible and the operators had enough knowledge to use their procedures to perform each of the actions necessary. Our assessment of the manual action using generally accepted human reliability methods show that the manual actions, using both the old and the new procedures are reasonable and reliable. Detailed simulation of the maximum expected fire scenarios were done with two independent crews to obtain data for the development of the human reliability estimates. Following are a few insights:

Previous procedures use an opportunistic approach to control where crews respond to cues and symptoms by selecting the appropriate procedure for that condition

New AOP attachment assists crew to respond using a more tactical control process

Identifying symptom or cue will generate appropriate response for either procedure

Ability to recover from spurious actuations is enhanced in new AOP's

Risk-Significance of the Current Symptomatic Procedures – Our assessment of the risk-significance of the current procedures used to reach safe shutdown for a fire in fire zone 99-M shows that the ? CDF to zone specific procedures is less than 1E-06/yr, i.e., a Green finding. An examination of elements of defense-in-depth (DiD) and safety margin shows that an adequate balance in the DiD elements is maintained with adequate margin in the determination of the consequences of the fire.

The following are some of the key observations and important factors in our examination of the issue, particularly as it relates to the fire zone 99-M;

The bounding fire results from a high-energy arcing fault in the 4KV switchgear and the ensuing fire. This fire starts with and immediate set of failures followed by time-phased secondary failures caused by the ignition of the intervening combustibles. Time-phased failures are critical in the effectiveness of the operators.

A 700°F damaging hot gas layer in the fire zone 99-M is not credible due to the configuration of the combustibles in the room. A zone-wide damage scenario through a large cable fire is not possible due to the location of the cable tray, i.e., in the smoke layer above the door opening. Even if such scenario was assumed its timing to reach damaging hot gas layer will reach 2 hours due to slow growth (10 ft/hr) cable fire.

APPENDIX B.1 SIMULATOR OBSERVATIONS

The simulation of a fire in zone 99-M integrated the efforts of eight activities. The activities are:

1. Identification of the equipment failures as a function of timing from the fire growth model,
2. Testing the simulation to identify unusual or unexpected behaviors,
3. Providing communications that would be expected (fire brigade, manual actions, and external communications),
4. Modeling crew organization for fire,
5. Observing the control room crew actions and communications during the simulation, and
6. Verifying the local manual actions called for by the crew.
7. Summarizing the results so that the feasibility can be demonstrated (Feasibility section)
8. Support the evaluation of human reliability for the actions. (Appendix A)

B.1.1 Fire Damage to Plant Equipment

The fire growth model was converted into a fire damage effects by identifying the equipment in the breaker cabinet and the components serviced by the cables in the two trays above the cabinet. The effect of the fire damage and possible failure modes of the associated equipment was evaluated by the engineering team and the failures were then introduced in the simulator programming. The failures modeled addresses loss of signals, false alarms, and spurious actions. The equipment failures and timing are shown in Appendix B.2.

B.1.2 Initial Scenario Testing

The initial mockup was tested to understand the interactive effects of the failures on the simulator model. A surprise was identified – when time phasing the failures, and if the operators opt for an early trip the EFW valve alignments are automatically positioned to the shutdown core-cooling mode. This along with continuation of the main feedwater pumps results in a steam generator overfill condition. Steam generators dry out results if all equipment is assumed to fail at the same time. Thus, the course of the scenario is highly dependent on the previous actions of the crew, as well as the hardware failures and their timing introduced into the simulation.

The simulator fidelity was very good. No indications of differences in the control room and simulator were noted except the fire indication panel is not modeled in the simulator. In this scenario the fire alarm panel power supply is lost on the A4 bus trip with only the fire panel trouble alarm activated (K12D1), but this alarm was not used by either crew to detect the fire.