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

ENCLOSURE

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

STATION BLACKOUT RULE

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY UNITS 1, 2, AND 3

DOCKET NOS. 50-259/260/296

1.0 INTRODUCTION

On July 21, 1988, the Code of Federal Regulations, 10 CFR 50, was amended to include a new Section 50.63, entitled, "Loss of All Alternating Current Power," (Station Blackout). The Station Blackout (SBO) rule requires that each light-water-cooled nuclear power plant be able to withstand and recover from an SBO of specified duration, requires licensees to submit information as defined in 10 CFR 50.63, and requires licensees to provide a plan and schedule for conformance to the SBO rule. The SBO rule further requires that the baseline assumptions, analyses, and related information be available for NRC review. Guidance for conformance to the rule is provided by (1) Regulatory Guide (RG) 1.155, Station Blackout, (2) NUMARC 87-00, Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors, and (3) NUMARC 87-00 Supplemental Questions/Answers and Major Assumptions dated December 27, 1989 (issued to the industry by NUMARC* January 4, 1990).

To facilitate the NRC staff's (hereafter referred to as "staff") review of licensee responses to the SBO rule, the staff endorsed two generic response formats. One response format is for use by plants proposing to use an Alternate AC (AAC) power source and the other format is for use by plants proposing an AC independent response. The generic response formats provide the staff with a summary of the results from the licensee's analysis of the plant's SBO coping capability. The licensees are expected to verify the accuracy of the results and maintain documentation that supports the stated results. Compliance to the SBO rule is verified by a review of the licensee's submittal, an audit review of the supporting documentation as deemed necessary, and possible follow-up NRC inspections to ensure that the licensee has implemented the appropriate hardware and/or procedure modifications that will be required to comply with the SBO rule.

The Browns Ferry Station has proposed coping independent of an AAC power source for the SBO coping duration of 4 hours and has submitted its response in the applicable generic response format. The licensee's original response was provided by letters from C. H. Fox, Jr. and E. G. Wallace of the Tennessee Valley Authority (TVA) to the U.S. Nuclear Regulatory Commission (NRC), dated

*Nuclear Management and Resources Council, Inc.

April 18, 1989, April 5, 1990, and May 4, 1990. In addition, the licensee provided a response to the questions raised during a telephone conversation between representatives of the NRC, Science Applications International Corporation (SAIC), and the licensee on October 25, 1990. SAIC, under contract to the NRC, reviewed the licensee's responses. The results of the review are documented by SAIC Technical Evaluation Report (TER), SAIC-91/6659, "Browns Ferry Nuclear Power Station, Units 1, 2, and 3, Station Blackout Evaluation," dated May 31, 1991 (Attachment No. 1).

2.0 EVALUATION

After reviewing the licensee's SBO submittal and the SAIC TER, the staff concurs with the conclusions as identified in the SAIC TER (refer to Attachment 1 for details of the review). Based on this review, the staff findings and recommendations are summarized as follows:

2.1 Station Blackout Duration

The licensee has calculated a minimum acceptable SBO duration of four hours based on a plant AC power design characteristic Group "P1," an emergency AC (EAC) power configuration Group "D," and a target Emergency Diesel Generator (EDG) reliability of 0.975. The "P1" grouping is based on an independence of offsite power classification of Group "I 1/2," a severe weather (SW) classification of Group "2," and an extremely severe weather (ESW) classification of Group "1."

The EAC classification Group "D" is based on eight EDGs at the site, four for Units 1 and 2, and four for Unit 3. There are some cross connections between the Unit 3 EDGs and the Unit 1 and 2 EDGs. These cross connections are not normally used, but could be used to permit the EDGs to support each other if needed for specific scenarios. The licensee has stated that six EDGs are required for safe-shutdown loads following a LOOP, and, therefore, the EAC classification of the site is "D."

After reviewing the available information in the licensee's submittal, RG 1.155, NUMARC 87-00, and SAIC's TER, the staff agrees that the offsite ac power design characteristic group of the Browns Ferry site is "P1" with a minimum required coping duration of four hours.

The licensee's evaluation apparently assumes a simultaneous blackout on all three units. We find this to be acceptable and conservative provided that the 3-unit SBO scenario envelopes the single-unit and double-unit SBO combinations that could occur. Since the station batteries are shared among the units, and load stripping of battery loads is anticipated for the SBO scenario only, the licensee should verify and confirm that the 3-unit SBO scenario envelopes the other possible scenarios, particularly with respect to battery capacity adequacy.

Recommendation for Units 1, 2 and 3: The licensee should verify and confirm that an SBO on all 3-units envelopes (particularly with respect to station battery capacity adequacy) each single and double unit SBO combination (assuming a loss of offsite power on all three units).

2.2 Station Blackout Coping Capability

The characteristics of the following plant systems and components were reviewed to assure that the systems have the availability, adequacy, capability to achieve and maintain safe shutdown and recover from an SBO for a 4-hour coping duration.

2.2.1 Condensate Inventory for Decay Heat Removal

The licensee's initial submittal states that 72,842 gallons of water per unit are required to provide decay heat removal for a 4-hour SBO duration. The minimum permissible condensate storage tank (CST) inventory provides 135,000 gallons of water per unit which exceeds the required capacity for coping with a 4-hour SBO event. The licensee initially assumed a maximum of 25 gpm of reactor coolant system leakage in the calculations. Later, the licensee modified the leak rate from 25 gpm to 36 gpm (18 gpm per pump) and determined that 81,482 gallons of water will be required to cope with a 4-hour SBO event.

Based on NUMARC 87-00, the water required for removing decay heat during the 4-hour SBO has been calculated in the attached TER as 74,300 gallons. In addition, condensate leakage of 61 gpm (18 gpm per pump and an allowed Technical Specifications (TS) leakage of 25 gpm) has to be provided. Therefore, a total condensate inventory of 89,000 gallons is needed to remove decay heat and to replenish the losses due to leakages, assuming no cool-down. The CST provides 135,000 gallons of water per unit. The staff, therefore, concludes that there is sufficient condensate water to cope with an SBO of 4 hours.

2.2.2 Class IE Battery Capacity

There are four 250V dc batteries which are shared between the units. Three of the four batteries are Class 1E and the fourth is a non-Class 1E station battery. The licensee has stated that the Class 1E batteries are currently inadequate to meet the connected loads for four hours without load shedding. The licensee modified procedure O-AOI-57-2 to include battery load shedding in order to provide the necessary 4-hour capacity for SBO loads. This procedure requires the operator to commence load shedding at 30 minutes into the event. The operator is required to load shed each battery until a current of 180 amps (A) is reached. The procedure mandates that this be accomplished within 60 minutes after the onset of the SBO event. The licensee also stated that the non-Class 1E station battery No. 4 is not adequate to supply its connected loads for a 4-hour coping duration. This necessitates the need for manual transferring of the switchyard breaker loads to the No. 2 unit battery so that the offsite power can be restored to the safety buses following the SBO event. This action can be accomplished from the main control room.

The licensee provided an analysis of the Class 1E battery calculation which considers only Unit 2 being in operation. The licensee acknowledged that the return of Units 1 and 3 to service will require additional calculations and modifications. If the loads on Units 1 and/or 3 should change by modification beyond that specified in the present calculation, the licensee's commitment to comply with the SBO rule would automatically necessitate revision of calculations to ensure conformance of the plant dc system design with regulatory requirements.

The staff's review indicates that although the licensee's analysis is non-conservative, the available site battery capacity is sufficient for Unit 2 operation because three Class 1E batteries and one non-Class 1E battery shared between the Units 1, 2, and 3 will supply dc power for Unit 2. However, in order for two or three units to conform to the SBO rule, the licensee should provide additional information and resolve the following concerns:

1) The licensee has taken an exception to the IEEE Standard 485 cell-sizing method in its calculations by breaking the time step size into smaller than one-minute intervals. This results in a smaller net average current and, therefore, is non-conservative;

2) The licensee assumed that only two circuit breakers would be closed at the end of the SBO event and that 5 A would be required to close each breaker. A review of the plant electrical distribution drawings indicates that more than two circuit breakers are required to connect the emergency buses to the offsite power source;

3) The licensee has not provided any information regarding the loading of non-Class 1E Battery No. 4. In particular, the licensee's submittals did not indicate how the turbine emergency bearing oil pump and the generator emergency seal oil pump loads are powered during an SBO.

4) The licensee has not provided any analysis for the 125V dc EDG batteries to demonstrate that control and field flashing of the EDGs will be available for recovery from an SBO.

Recommendation for Unit 2 only: The licensee should verify the adequacy of the dc power supply for the turbine emergency bearing oil pump, the generator emergency seal oil pump, and for the control and field flashing of the EDGs during an SBO.

Recommendations for Units 1 and 3: In order for the plant to conform to the SBO rule for Units 1 and 3, the licensee should describe the modifications that will be required to the dc power supply systems and/or the dc connected loads to assure adequate battery capacity for a 4-hour SBO event. The licensee should repeat the battery calculations (if necessary) using conservative assumptions, and confirm that the battery capacity is adequate for an SBO event of 4 hours. The licensee should verify the adequacy of the dc power supply for the turbine emergency bearing oil pump, the generator emergency seal oil pump, and for the control and field flashing of the EDGs during an SBO.

2.2.3 Compressed Air

The licensee has stated that the air-operated valves needed to cope with an SBO have sufficient backup sources independent of ac power for a 4-hour coping duration. There are no valves that require manual operation. The licensee stated that the only valves which are required to be operable during an SBO event are the main steam relief valves (MSRVs).

Each MSRV has an accumulator and each accumulator has sufficient capacity to cycle the valve at least five times which is sufficient to cope with a 4-hour SBO event.

Based on its review, the staff concludes that the compressed air of Browns Ferry Units 1, 2, and 3 will have sufficient capacity to cope with a 4-hour SBO event and is, therefore, acceptable.

2.2.4 Effects of Loss of Ventilation

During an SBO event, the Browns Ferry Nuclear (BFN) plant will be without heating, ventilation, and air conditioning (HVAC) systems. Consequently, the licensee has performed area heat-up calculations, which are based on the methodology outlined in NUMARC 87-00, and provided the results for the control rooms, the main steam tunnel, and the High Pressure Coolant Injection (HPCI) and Reactor Core Isolation Cooling (RCIC) rooms in the submittal.

The licensee also provided drywell heat-up calculations during an SBO event. The analysis followed, with a few exceptions, the method used by Oak Ridge National Laboratory (ORNL) as part of the NRC-sponsored accident sequence analysis (ASA) program for the BFN Unit 1 SBO event, NUREG/CR-2182. The licensee stated that the calculation was performed to include changes in the revised emergency procedures, to use more applicable data, and to verify and document the validity of the ORNL report. The licensee concluded that the ORNL results are correct and consistent with results produced by this calculation. The licensee noted that, if heat loads and heat sinks are more realistically modeled, the drywell temperature without depressurization of the reactor would be 299°F at the end of four hours. This result differs from that of the ORNL study which predicts a drywell temperature in excess of 320°F after three hours into an SBO event (without depressurization). The licensee plans to depressurize the reactor after 10 minutes at a rate of 100°F/hr. A similar sequence was evaluated in the ORNL report which indicated that the drywell temperature would exceed the design temperature of 281°F for a short period of time (less than 10 minutes), and would then decrease below this limit. The licensee stated that the TVA case will be similar to or will be bounded by the ORNL case.

After reviewing the supporting documentation and SAIC's TER, the staff finds that the initial temperatures used by the licensee to perform the heat-up calculations for the control rooms and HPCI and RCIC rooms do not represent the maximum historical temperatures experienced in these areas and are, therefore, non-conservative. Also, the staff finds that the heat loads used by the licensee for the control room are significantly lower than those used in similar plants. However, the licensee has not provided enough detailed information for the staff to review what these heat loads include. In addition, the licensee did not assess the equipment operability in HPCI and RCIC rooms to ascertain if the equipment is capable of withstanding a temperature of at least 135°F. With regard to the main steam tunnel, the licensee stated that it is not a concern due to the fact that no equipment is required to be operable in the main steam tunnel after the closure of main steam isolation valves (MSIVs). Based on its review of the licensee's rationale, the staff concurs with the licensee that this area shall not be a concern. Also, the final drywell temperature analysis in the ORNL report is based on the assumption of a leak rate of 4 gpm as compared to a leak rate of 61 gpm (as recommended by NUMARC 87-00). Therefore, the TVA case may not be bounded by the ORNL case.

Recommendations for Unit 2 only: The licensee should use a higher initial temperature in areas like the HPCI and RCIC rooms and assess the equipment operability in these rooms to ascertain if they are capable of withstanding a temperature of at least 135°F. The licensee should consider a more conservative initial control room temperature for the heat-up calculation based on a value representing the maximum temperature experienced in the control room (with proper documentation). If the maximum experienced temperature is not known, an initial temperature of an average value between the maximum control room HVAC system design temperature and 104°F, assumed initial temperature for non-HVAC areas, is considered by the staff to be conservative enough for a control room heat-up evaluation. The licensee should also use a higher heat generation rate which is approximately 240 watts (W) per person, as recommended by the American Society of Heating, Refrigerating, and Air Conditioning Engineering (ASHRAE) handbook, for the control room occupant in temperature calculations. In addition, the licensee should reevaluate the drywell heat-up with an assumed leak rate of 61 gpm (as recommended by NUMARC 87-00) and verify that containment integrity will not be jeopardized.

Recommendations for Units 1 and 3: The recommendations described above for Unit 2 apply for Units 1 and 3 as well, and the licensee's subsequent responses for Units 1 and 3 must address these items.

2.2.5 Containment Isolation

The licensee has reviewed the plant list of containment isolation valves (CIVs) and has stated that all valves which must be capable of being closed or operated (cycled) under SBO conditions can be positioned with indication independent of the preferred and blacked out unit's Class 1E power supplies.

The licensee provided a list of CIVs and its exclusion criteria for these valves. Of these criteria, the staff finds that three exclusion criteria utilized by the licensee are not consistent with the exclusion criteria given in RG 1.155. Valves excluded by the licensee using the three criteria should be incorporated into an appropriate procedure. In addition, there are several other valves (containment cooling to drywell, containment cooling to suppression pool, etc.) which do not meet the exclusion criteria outlined in RG 1.155. The licensee did not list the CIVs which are either normally-closed or normally-open, and fail as-is upon loss of AC power, and cannot be excluded by the criteria given in RG 1.155. The licensee is required to confirm that valve closure has position indication.

Recommendation for Unit 2: The licensee should reevaluate the CIVs according to the exclusion criteria given in RG 1.155. The licensee should list in appropriate procedures the CIVs which are either normally-closed and fail as-is upon loss of ac power or are normally-open and fail as-is upon loss of ac power, and cannot be excluded by the criteria given in RG 1.155, and identify the actions necessary to ensure that these valves are fully closed, if necessary. The staff's position is that valve closure needs to be confirmed by position indication (local, mechanical, remote, process information, etc.).

Recommendation for Units 1 and 3: The recommendation described above for Unit 2 applies for Units 1 and 3 as well, and the licensee's subsequent responses for Units 1 and 3 must address this item.

2.2.6 Reactor Coolant Inventory

The licensee stated that a plant-specific analysis was used to assess the ability to maintain adequate reactor coolant system (RCS) inventory to ensure that the core is cooled. The expected rates of RCS inventory loss under SBO conditions do not result in core uncovery during a 4-hour SBO event and, therefore, no make-up systems other than those available under SBO conditions are necessary to maintain adequate RCS inventory. The licensee also stated that the appropriate procedure(s) for loss of all ac power will be revised to ensure adequate RCS inventory and to identify applicable reactor vessel depressurization requirements.

Reactor coolant make-up is necessary to replenish the assumed RCS inventory losses due to the reactor coolant pump seal leakage (18 gpm per pump per NUMARC 87-00 guideline), the Technical Specifications maximum allowable leakage (25 gpm), and the reactor vessel level shrink due to RCS cooldown. The licensee stated that the RCIC pump was modeled to assess its capability to remove decay heat and maintain reactor coolant inventory during an SBO event. The steam-driven RCIC pump has a 600 gallons per minute (gpm) capacity, which is sufficient to provide condensate for decay heat removal, RCS cooldown, and to compensate for RCS inventory losses. Based on the above, we find that there is reasonable assurance that there will be adequate reactor coolant during an SBO event.

The 18 gpm recirculation pump seal leak rate was agreed to between NUMARC and the NRC staff pending resolution of Generic Issue (GI) 23. If the final resolution of GI-23 defines higher recirculation pump seal leak rates than assumed for this evaluation, the licensee should be aware of the potential impact of this resolution on its analyses and actions addressing conformance to the SBO rule.

2.3 Procedures and Training

The licensee has stated that appropriate procedures have been reviewed, and changes necessary to meet NUMARC 87-00 guidelines will be implemented. The proposed procedure modifications indicated above were not reviewed by the staff, but the licensee is expected to maintain and implement these procedures to ensure an appropriate response to an SBO event. Although personnel training requirements for an SBO response were not specifically addressed by the licensee's submittal, the staff expects the licensee to implement appropriate training to assure an effective response to an SBO.

2.4 Proposed Modifications

The licensee indicated that several modifications/changes will be necessary in order for all three units to have sufficient battery capacity to cope with a 4-hour SBO event.

Recommendation for Unit 2 only: No proposed modifications are necessary.

Recommendation for Units 1 and 3: The licensee should confirm and document the necessary modifications required to ensure sufficient class 1E battery capacity for all three units. This documentation should be included with other documentation to be maintained by the licensee in support of the SBO submittals.

2.5 Quality Assurance and Technical Specifications

The licensee's submittals did not provide any information on how the plant complies with the requirements of RG 1.155, Appendices A and B.

The TS for SBO equipment are currently being considered generically by the NRC in the context of the Technical Specification Improvement Program and remains an open item at this time. However, the staff would expect that plant procedures will reflect appropriate testing and surveillance requirements necessary to ensure the operability of SBO equipment. If the staff later determines that a TS regarding SBO equipment is warranted, the licensee will be notified of the implementation requirements.

Recommendation for Unit 2: The licensee should verify that SBO equipment is covered by an appropriate QA program consistent with the guidance of RG 1.155.

Recommendation for Units 1 and 3: The recommendations described above for Unit 2 apply for Units 1 and 3, as well and the licensee's subsequent responses for Units 1 and 3 must address this item.

2.6 EDG Reliability Program

The licensee's submittal on SBO did not specifically address a commitment to implement an EDG reliability program to conform to the guidance of RG 1.155, Position 1.2 and NUMARC 87-00, Appendix D.

Recommendation for Unit 2: The licensee should implement an EDG reliability program which meets the guidance of RG 1.155, Section 1.2. If an EDG reliability program currently exists, the program should be evaluated and adjusted in accordance with RG 1.155. Confirmation that such a program is in place or will be implemented should be included in the documentation supporting the SBO submittals that is to be maintained by the licensee.

Recommendation for Units 1 and 3: The recommendation described above for Unit 2 applies for Units 1 and 3 as well, and the licensee's subsequent responses for Units 1 and 3 must address this item.

2.7 Scope of Staff Review

The SBO rule (10 CFR 50.63) requires licensees to submit a response containing specifically defined information. It also requires utilities to have baseline assumptions, analyses, and related information used in their coping evaluation available to the NRC. The staff and its contractor (SAIC) did not perform a detailed review of the proposed equipment or procedure modifications which are scheduled for later implementation. However, based on our review of the licensee SBO submittals and FSAR, we have identified the following areas for focus in any follow-up inspection or assessment that may be undertaken by the NRC to further verify conformance with the SBO rule:

a. Hardware and procedural modifications;

b. SBO procedures in accordance with RG 1.155, Position 3.4, and NUMARC 87-00, Section 4;

c. Operator staffing and training to follow the identified actions in the SBO procedures;

d. EDG reliability program meets, as a minimum, the guidelines of RG 1.155;

e. Equipment and components required to cope with an SBO are incorporated in a QA program that meets guidance of RG 1.155, Appendix A; and

f. Actions taken pertaining to the specific recommendations noted above in this SE.

Additional areas may be identified following staff review of licensee's revised response to the SBO rule.

3.0 SUMMARY AND CONCLUSIONS

The staff has reviewed the licensee's responses to the SBO rule (10 CFR 50.63) and the TER prepared by the staff's consultant, SAIC. Based on our review, we find that Browns Ferry Units 1 and 3 are not in conformance with the SBO rule and that a revised response must be submitted. The specific item of non-conformance is the inadequate capacity of the batteries to power the safe shutdown loads for all of the operating units during an SBO. As a result, we cannot find that all 3 units of Browns Ferry conform to the SBO rule until the battery capacity issue is resolved.

We find that the present battery capacity is adequate for the single-unit operation of Browns Ferry Unit 2. We therefore find that Browns Ferry Unit 2 conforms with the SBO rule contingent on the satisfactory resolution of the recommendations presented in this SE. These recommendations include the resolution of the various assumptions used in the calculation of battery capacity to power the safe shutdown loads during an SBO event; implementation of an EDG reliability program consistent with RG 1.155; ventilation evaluations for the control room, HPCI, RCIC and drywell areas; reevaluation of the CIVs according to the exclusion criteria described in RG 1.155; and verification that SBO equipment is covered by an appropriate QA program. The licensee is expected to ensure that the baseline assumptions of NUMARC 87-00 are applicable to the Browns Ferry Power Station. Also, the licensee should maintain all analyses and related information in the documentation supporting their SBO submittals for further inspection and assessment as may be undertaken by the NRC to audit conformance with the SBO rule.

Based on our review, the staff finds that Browns Ferry Units 1 and 3 are not in conformance with the SBO rule and that a revised response must be submitted. Browns Ferry Unit 2 conforms with the SBO rule and the guidance of

RG 1.155 contingent upon receipt of confirmation from the licensee (within 30 days) that the recommendations identified within this SE will be implemented. The schedule for implementation should also be provided in accordance with 10 CFR 50.63(c)(4).

Dated: July 11, 1991

Principal Contributor: N. K. Trehan

Attachment: Technical Evaluation Report (SAIC-91/6659)