Attachment 1

SAIC-91/6670

TECHNICAL EVALUATION REPORT
DUANE ARNOLD ENERGY CENTER
STATION BLACKOUT EVALUATION

TAC No. M68541

Science Applications International Corporation
An Employee-Owned Company

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1.0 8ACKGROUND

On July 21, 1988, the Nuclear Regulatory Commission (NRC) amended its regulations in 10 CFR Part 50 by adding a new section, 50.63, "Loss of All Alternating Current Power" (1). The objective of this requirement is to assure that all nuclear power plants are capable of withstanding a station blackout (SBO) and maintaining adequate reactor core cooling and appropriate containment integrity for a required duration. This requirement is based on information developed under the commission study of Unresolved Safety Issue A-44, "Station Blackout" (2-6).

The staff issued Regulatory Guide (RG) 1.155, "Station Blackout," to provide guidance for meeting the requirements of 10 CFR 50.63 (7). Concurrent with the development of this regulatory guide, the Nuclear Utility Management and Resource Council (NUMARC) developed a document entitled, "Guidelines and Technical Basis for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," NUMARC 87-00 (8). This document provides detailed guidelines and procedures on how to assess each plant's capabilities to comply with the SBO rule. The NRC staff reviewed the guidelines and analysis methodology in NUMARC 87-00 and concluded that the NUMARC document provides an acceptable guidance for addressing the 10 CFR 50.63 requirements. The application of this method results in selecting a minimum acceptable SBO duration capability from two to sixteen hours depending on the plant's characteristics and vulnerabilities to the risk from station blackout. The plant's characteristics affecting the required coping capability are: the redundancy of the onsite emergency AC power sources, the reliability of onsite emergency power sources, the frequency of loss of offsite power (LOOP), and the probable time to restore offsite power.

In order to achieve a consistent systematic response from licensees to the SBO rule and to expedite the staff review process, NUMARC developed two generic response documents. These documents were reviewed and endorsed (9) by the NRC staff for the purposes of plant specific submittals. The documents are titled:

1. "Generic Response to Station Blackout Rule for Plants Using Alternate AC Power," and

2. "Generic Response to Station Blackout Rule for Plants Using AC Independent Station Blackout Response Power."

A plant-specific submittal, using one of the above generic formats, provides only a summary of results of the analysis of the plant's station blackout coping capability. Licensees are expected to ensure that the baseline assumptions used in NUMARC 87-00 are applicable to their plants and to verify the accuracy of the stated results. Compliance with the SBO rule requirements is verified by review and evaluation of the licensee's submittal and audit review of the supporting documents as necessary. Follow up NRC inspections assure that the licensee has implemented the necessary changes as required to meet the SBO rule.

In 1989, a joint NRC/SAIC team headed by an NRC staff member performed audit reviews of the methodology and documentation that support the licensees' submittals for several plants. These audits revealed several deficiencies which were not apparent from the review of the licensees' submittals using the agreed upon generic response format. These deficiencies raised a generic question regarding the degree of the licensees' conformance to the requirements of the SBO rule. To resolve this question, on January 4, 1990, NUMARC issued additional guidance as NUMARC 87-00 Supplemental Questions and Answers (10) addressing the NRC's concerns regarding the deficiencies. NUMARC requested that the licensees send their supplemental responses to the NRC addressing these concerns by March 30, 1990.

2.0 REVIEW PROCESS

The review of the licensee's submittal is focused on the following areas consistent with the positions of RG 1.155:

A. Minimum acceptable SBO duration (Section 3.1),

8. SBO coping capability (Section 3.2),

C. Procedures and training for SBO (Section 3.4),

D. Proposed modifications (Section 3.3), and

E. Quality assurance and technical specifications for SBO equipment (Section 3.5).

For the determination of the proposed minimum acceptable SBO duration, the following factors in the licensee's submittal are reviewed: a) offsite power design characteristics, b) emergency ac power system configuration, c) determination of the emergency diesel generator (EDG) reliability consistent with NSAC-108 criteria (11), and d) determination of the accepted EDG target reliability. Once these factors are known, Table 3-8 of NUMARC 87-00 or Table 2 of Regulatory Guide 1.155 provides a matrix for determining the required coping duration.

For the SBO coping capability, the licensee's submittal is reviewed to assess the availability, adequacy and capability of the plant systems and components needed to achieve and maintain a safe shutdown condition and recover from an SBO of acceptable duration which is determined above. The review process follows the guidelines given in RG 1.155, Section 3.2, to assure:

a. availability of sufficient condensate inventory for decay heat removal,

b. adequacy of the class 1E battery capacity to support safe shutdown,

c. availability of adequate compressed air for air-operated valves necessary for safe shutdown,

d. adequacy of the ventilation systems in the vital and/or dominant areas that include equipment necessary for safe shutdown of the plant,

e. ability to provide appropriate containment integrity, and

f. ability of the plant to maintain adequate reactor coolant system inventory to ensure core cooling for the required coping duration.

The licensee's submittal is reviewed to verify that required procedures (i.e., revised existing and new) for coping with SBO are identified and that appropriate operator training will be provided.

The licensee's submittal for any proposed modifications to emergency AC sources, battery capacity, condensate capacity, compressed air capacity, ventilation system for equipment operability, containment isolation integrity and primary coolant make-up capability is reviewed. Technical Specifications and quality assurance requirements set forth by the licensee to ensure high reliability of the equipment, specifically added or assigned to meet the requirements of the SBO rule, are assessed for their adequacy.

This SBO evaluation is based on a review of the licensee's submittals dated April 17, 1989 (12), March 30, 1990 (13), the information available in the plant Updated Final Safety Analysis Report (UFSAR) (14), a telephone conversation between NRC/SAIC and the licensee on February 12, 1991, and the licensee's response (15) to the questions raised during the telephone conversation; it does not include a concurrent site audit review of the supporting documentation. Such an audit may be warranted as an additional confirmatory action. This determination will be made and the audit may be scheduled and performed by the NRC staff at some later date.

3.0 EVALUATION

3.1 Proposed Station Blackout Duration

Licensee's Submittal

The licensee, the Iowa Electric Light and Power Corporation, calculated (12 and 13) a minimum acceptable SBO duration of four hours for the Duane Arnold Energy Center (DAEC). The licensee stated that no modifications are necessary to attain this proposed coping duration.

The plant factors used to estimate the proposed SBO duration are as follows:

1. **Offsite Power Design Characteristics**

   The plant AC power design characteristic group is "P1" based on:

   a. Independence of offsite power group of "I1/2,"

   b. Estimated frequency of LOOPs due to severe weather (SW) which places the plant in SW group "2,"

   c. Estimated frequency of LOOPs due to extremely severe weather (ESW) which places the plant in ESW Group "2," and

   d. Expected frequency of grid-related LOOPs of less than once per 20 years.

2. **Emergency AC (EAC) Power Configuration Group**

   The EAC power configuration of the plant is "C." The DAEC plant is equipped with two emergency diesel generators which are normally available to the plant's safe shutdown equipment. One emergency AC power supply is sufficient to operate the safe shutdown equipment following a loss of offsite power.

3. **Target Emergency Diesel Generator (EDG) Reliability**

The licensee has selected a target EDG reliability of 0.95 based on having a nuclear unit average EDG reliability of greater than 0.95 for the last 100 demands consistent with the NUMARC 87-00 criteria.

Review of Licensee's Submittal

Factors which affect the estimation of the SBO coping duration are: the independence of offsite power system grouping, the estimated frequency of LOOPs caused by grid-related failures, the estimated frequency of LOOPs caused by severe weather (SW) and extremely severe weather (ESW) conditions, the classification of EAC, and the selection of EDG target reliability.

The licensee stated (13 and 15) that 31 years of tabulated weather observations (between 1950 and 1980), recorded at the airport of Cedar Rapids, Iowa, (approximately 15 miles from DAEC), were used with the NUMARC 87-00 methodology for determining the ESW and SW groups. The licensee's estimate (15) of ESW-caused LOOP frequency is consistent with the information provided in NUMARC 87-00, Table 3-2.

The SW-caused LOOP frequency is based on the amount of annual snowfall, the frequency of tornadoes and storms with wind velocities between 75 and 124 mph, and the number of rights-of-way on which offsite power transmission lines traverses. The DAEC switchyard consists of 345 kV and 161 kV sections that are normally connected by an autotransformer. The switchyard is fed from two different directions on two rights-of-way: one 161 kV power line comes from the east, and the rest of the 161 kV and the 345 kV power lines comes from the west and southwest on one right-of-way. Therefore, a multiple rights-of-way coefficient can be used when calculating the SW group using the expression provided in NUMARC 87-00. The licensee's estimates of the amount of annual snowfall and the frequency of tornadoes for the DAEC site are consistent with the numbers given in NUMARC 87-00. However, the licensee stated (16) that the expected frequency of storms at the site is 0.1068 per year based on NUREG/CR-4492 (22) methodology. This estimate [0.1068] is less than one-half of that [0.25] given in NUMARC 87-00. Based on these estimates, the licensee calculated an SW frequency of 0.0098 and classified the site as SW group "2." Using the guidance and data provided in Section 3.2.1 of NUMARC 87-00, we calculated the frequency of SW-caused LOOPs to be 1.05E-2 per year, which places the plant in SW group "3." Our review of the annual extreme wind speed provided by the licensee indicates that the wind speed exceeded 75 mph in 4-out-of-30 data points. This results in a frequency of storms of 0.13 per year. If the licensee were to use this number, the site would be classified as SW group "3."

The licensee performed an analysis, apparently consistent with the NUREG/CR-4492, and modeled the expected annual extreme wind as a Tippet-Fisher Type-I extreme distribution to estimate the frequency of storms with the wind speed between 75 and 125 mph. For the estimation of the distribution parameters, (i.e. location and scale), the licensee matched the mean and the standard deviation of the annual extreme wind data points to that of the distribution. However, the licensee failed to perform a statistical evaluation showing the goodness of fit of the matched distribution to the data points. The resultant distribution predicts that a wind speed of greater than 75 mph occurs at the site at a frequency of 0.1076 per year. This estimate is almost 21% less than the actual frequency of storms with wind speed of greater than 75 mph which occurred at the site. Since the licensee used a limited weather data (1950 to 1980; and no recent data was used), calculated an SW frequency (0.0098) which is very close, or essentially equal, to the frequency (0.01) which changes the SW grouping categorization, and failed to perform the goodness of fit test, we categorize the site in SW group "3" instead of "2" as indicated by the licensee.

The licensee selected an independence of offsite power system grouping of "I 1/2." A review of the plant UFSAR and the licensee's response (15) to the questions raised during the telephone conversation indicates that:

1. all offsite power sources are connected to the plant through a single switchyard,

2. the safe shutdown loads are normally powered from off-site power via the 161 kV section of the switchyard through the start-up transformer,

3. upon failure of normal power to the safe shutdown buses, the power feed of the safe shutdown buses is automatically transferred to the standby transformer, which draws power from a tertiary winding of the 345 kV to 161 kV autotransformer, and

4. Both start-up and stand-by transformers are adequately sized. The licensee has performed a LOCA load testing using these transformers and concluded that each has sufficient capacity.

Based on the above and the criteria stated in Table 5 of RG 1.155, the independence of the plant offsite power grouping is "I2."

Establishment of the proper Emergency AC (EAC) Configuration Group is based on the number of available EAC sources and the number of EAC sources required to operate safe shutdown equipment following a LOOP. DAEC has two dedicated EAC sources with one required after a LOOP, placing the plant in EAC Group "C" (RG 1.155, Table 3) as the licensee correctly identified.

The final characteristic needed to establish the duration of DAEC's required coping capability is the target EDG reliability. The licensee stated (12) that the assignment of the EDG target reliability of 0.95 is based on having a unit average EDG reliability of greater than 0.95 for the last 100 demands. During the telephone conversation of February 12, 1991, the licensee stated that EDG 16-21 had experienced one failure in the last 100 demands and EDG 16-31 had experienced no failures in the last 100 demands. We were unable, however, to verify the demonstrated start and load-run reliability of the plant EDGs. This information is only available onsite as part of the submittal's supporting documents. A review of the information in NSAC-108 indicates that EDGs 16-21 and 16-31 at DAEC have an average of 36 and 42 valid demands per calendar year and had a unit average reliability level of 0.99 per EDG per year during the calendar year of 19B3 through 19B5. Therefore, based on the licensee's statement and the NSAC-108 data, we agree that the licensee can choose a reliability goal of 0.95 or 0.975.

In response to the requirement for an EDG reliability program the licensee stated, during the telephone conversation on February 12, 1991, that a reliability program consistent with the guidance provided in RG 1.155 and NUMARC 87-00 is being developed. This was not documented in the licensee's submittals; however, the licensee understands (13) that the targeted EDG reliability needs to be maintained.

With regard to the expected frequency of grid-related LOOPs at the site, we can not confirm the stated results. The available information in NUREG/CR-3992 (3), which gives a compendium of information on the loss of offsite power at nuclear power plants in the U.S., indicates that DAEC did not have any symptomatic grid-related LOOP prior to the calendar year 1984. In the absence of any adverse information we agree with the licensee's statement.

Based on an SW group "3," ESW group "2," and an independence of offsite power group "I1/2," the AC power design characteristics of DAEC is "P2." With this determination, in conjunction with EAC group "C" and a required coping duration of four hours, the licensee needs to increase the EDG target reliability goal to 0.975. Otherwise, the licensee needs to change the coping duration to eight hours and revise the plant coping capability accordingly.

3.2 Station Blackout Coping Capability

The plant coping capability with an SBO event for the required duration of four hours is assessed based on the following results:

1. **Condensate Inventory for Decay Heat Removal**

Licensee's submittal

The licensee stated (12 and 13) that by design condensate storage tank (CST) maintains a minimum level of 75,000 gallons. The licensee during telephone conversation on February 12, 1991 stated that the DAEC Technical Specifications also requires a minimum level of 75,000 gallons be maintained in the CST for HPCI operability. The licensee added that procedures direct the operators to depressurize the reactor vessel to between 200 and 400 psia within one hour of the onset of an SBO event. In its original submittal (12), the licensee stated that 36,675 gallons of water are required for decay heat removal for the required coping duration of four hours. In its revised submittal (13), the licensee stated that 63,390 gallons of condensate are required for the same coping duration. In a plant-specific analysis provided as part of supporting documentation (18), the licensee estimated that 62,800 gallons of condensate would be required for a four hour coping duration. The licensee stated that no modifications or procedural changes are necessary to use the CST water source.

Review of Licensee's Submittal

For calculating the condensate inventory requirement for DAEC during an SBO one has to consider the following:

1. Decay Heat -- Using NUMARC 87-00, Section 7.2.1 and the maximum power level of 1691 MWt, or 102% of nominal power, the plant would require 37,405 gallons of condensate to remove decay heat during four hours.

2. Reactor Coolant Leakage -- The assumed leak rate of 61 gpm, (a seal leak rate of 18 gpm per recirculation pump, and an additional 25 gpm for the maximum technical specification-allowed leakage), results in a total leakage of 14,640 gallons of condensate during four hours.

3. Cool down and Depressurization -- Based on the assumption that the reactor will be depressurized to 200 psia, one has to evaluate the condensate required to replenish the level shrink and that required to remove sensible heat from the reactor vessel, vessel internal, and connected piping. The available data only allows the estimation of the condensate required to replenish the reactor vessel level shrink. We have estimated that ~7450 gallon of condensate would be needed for level shrink.

The sum of the above three, excluding that which is required to remove sensible heat from primary system metal and water, is 59,495 gallons of condensate. The licensee's provided plant-specific analysis (1B), which was performed to determine the condensate requirement and the conditions of the suppression pool, and drywell during an SBO event, indicates that the plant would need 62,800 gallons of condensate for decay heat removal and cooldown during a 4-hour SBO event. The calculation was performed by General Electric company using a GE proprietary computer program. Our review of this report indicates that the assumptions and input parameters are consistent with the condition expected during an SBO, therefore, we agree with the licensee that the site has sufficient condensate inventory to cope with an SBO event.

2. Class 1E Battery Capacity

Licensee's Submittal

The licensee stated (12 and 13) that a battery capacity calculation has been performed in accordance with NUMARC 87-00, Section 7.2.2 to verify that the Class 1E batteries have sufficient capacity to meet SBO loads for four hours. In response to the questions raised during the telephone conversation on February 12, 1991, the licensee stated (15) that the battery sizing calculations were revised in 1987 following the replacement of class 1E batteries. These calculations were performed using the guidance from IEEE-Std 450 and 485. In these calculations, maximum permissible loads which are greater than the actual loads were used for a standard cell size, thereby, providing a margin for load growth in the future. The licensee added the main turbine emergency oil pump, and the two recirculation pump MG set auxiliary oil pumps will be shed when the associated equipment has stopped rolling. This action will take place within 30 minutes.

Review of Licensee's Submittal

The DAEC DC power supply system consists of two 125 V batteries and one 250 V battery. The plant UFSAR, Section 8.3.2.1.2, states that the batteries are sized to supply, without recharging, the control and essential instrumentation power for a minimum of four hours and the emergency motor loads for their required length of time.

Our review of the load profile and cell sizing calculations provided (17) by the licensee reveals several deviations from the IEEE-Std 485 which puts in question the accuracy of the battery calculations. These are:

1. <u>250-VDC Battery Sizing Calculation</u> -- The 250-VDC battery sizing worksheet indicates that the licensee has used a maximum uncorrected section sizing of 4.04 positive plates instead of 5.05. This error in conjunction with using a cell correction of 0.9662, which incidently its purpose and use have not been defined by the licensee, made the licensee to conclude that this battery has sufficient capacity with potential growth in future. If the licensee were to use the correct maximum uncorrected section sizing of 5.05 and ignore the cell correction factor, a minimum of 10 (instead of the existing 8) positive plates per cell would be required. This miscalculation invalidates the adequacy of the 250-VDC battery with the consideration of 1.25 for aging correction factor.

2. <u>Adequacy of the Battery terminal Voltage for the Designated Loads</u> -- The licensee stated that nameplate current rating has been used for motors and pumps. Should the nameplate current rating be based on the rated voltage, then the actual required current at the calculated minimum voltage will be under estimated. The licensee needs to verify that this is not true. In addition, the load profiles provided by the licensee show a minimum battery terminal voltage of 215.2-VDC and 105-VDC for the 250-V and 125-V batteries, respectively. The licensee needs to ensure that the expected minimum battery terminal voltage exceeds the minimum voltage required for the operation of the equipment (i.e. inverters) supported by these batteries.

3. <u>Minimum Segment Interval</u> -- IEEE 485 recommends that although momentary loads may exist for only a fraction of second, each is considered to last for a full minute because the instantaneous battery voltage drop for a given momentary load is essentially the same as the voltage drop after one minute. When several momentary loads occur within one

minute period and no discrete sequence can be established, the sum of all momentary loads needs to be assumed to occur in that minute. However, if a discrete sequence can be established, the load for the one minute shall be assumed to be the maximum current at any instant during the one minute period. The licensee, however, did not follow this recommendation and has selected periods as low as a 0.5 second segment.

4. Design Margin Correction Factor -- IEEE-Std 485 recommends that a design margin of 10% to 15% be considered in the battery sizing calculation to compensate for less than optimum operating conditions, recent discharge or ambient temperature less than expected. The licensee did not consider any design margin in its battery sizing calculations.

5. Quality Assurance -- This battery calculation does not seem to have been verified.

6. Temperature Correction Factor -- The licensee used an initial electrolyte temperature of 72°F in its calculations. The licensee needs to verify that under no circumstances the battery room temperature will be less than this temperature, or reconsider a lower temperature consistent with the one expected. In addition, according to the IEEE-Std 450 the temperature correction factor for 72°F is 1.029 not 1.028.

Based on the above, we can not conclude that the battery capacity is adequate. The licensee needs to re-evaluate the battery capacity while considering the above concerns. The licensee also needs to ensure that the battery load profile models the number of HPCI/RCIC operations as used in the plant specific analysis in support of condensate, containment temperature, and reactor coolant inventory calculations.

3. Compressed Air

Licensee's Submittal

The licensee stated (12 and 13) that air operated valves relied upon to cope with an SBO for four hours can either be operated manually or have sufficient backup sources independent of the preferred and blackout unit's Class-1E power supply. Valves requiring manual operation or that need back-up sources for operation will be identified in plant procedures.

Review of Licensee's Submittal

The licensee is planning to depressurize the reactor using the pressure relief valves and provide reactor coolant make-up using the HPCI or RCIC system. The pressure relief valves are air-operated, and each is backed-up by a 200-gallon nitrogen accumulator which provides five valve actuations as required per NUREG-0737, item II.K.3.28 (Reference 13, Section 6.3.2.2.2.) Neither HPCI nor RCIC depend on compressed air for their operation. Therefore, we agree with the licensee's statement that the plant has sufficient compressed air for the operation of the needed valves during an SBO event.

4. Effects of Loss of Ventilation

Licensee's Submittal

The licensee stated (12 and 13) that the effects of loss of ventilation in the control room and in each of the dominant areas of concern were determined using a plant-specific thermal transient analysis in lieu of the NUMARC 87-00 method. The licensee reported the following results:

AREA (Initial Temp.)	TEMPERATURE (Ref. 10)	TEMPERATURE (Ref. 11)
HPCI Room (120°F; Ref. 20)	151°F	150°F (Peak) 139°F (following operator action to open HPCI Room doors after 30 minutes.
RCIC Room (104°f; Ref. 20)	128°F	129°F (with proposed insulation of RCIC turbine)
Steam Tunnel (190°F; Ref. 20)	240°F	240°F
Essential Switch-gear Room (83°F; Ref. 20)	115°F	115°F

Additionally, the licensee stated that the control room will not exceed 120°F and, therefore, it is not a dominant area of concern.

The licensee stated that reasonable assurance of equipment operability has been assessed using Appendix F to NUMARC 87-00, the Topical Report, NUREG/CR-4942 (23), and the DAEC Equipment Qualification (EQ) Program. The licensee provided the control room heat-up calculation (19) and the assessment of SBO equipment operability (20) in response to the questions raised during the telephone conversation of February 12, 1991.

Review of Licensee's Submittal

We reviewed the licensee's provided information on the control room heat-up calculation, the equipment operability assessment, and the containment response to an SBO event (18 - 20). These reviews reveal the following general assumptions which were used in the plant heat-up calculations:

1. the control room and the cable spreading room initial temperatures are at 75°F,

2. the turbine and reactor buildings are at a nominal temperature of 85°F, and

3. the outside ambient temperature is at 90°F, maximum temperature during tornado and hail conditions.

We neither received nor reviewed the heat-up calculations for HPCI room, RCIC room, essential switchgear room, and steam tunnel area. For these areas we accept the licensee's statements pending future audit/verification.

o **Control Room**

The licensee calculated the transient temperature response during a four-hour SBO event for the control room and the adjacent instrument and relay cabinet room, using NUTECH's HVAC computer code, and found a final temperature of 101° and I10°F for these rooms, respectively. The HVAC code models a single homogeneous volume with heat slabs, heat sources, and other associated HVAC equipment using a forward finite difference technique to solve the appropriate energy equations. The licensee's calculation provides an explanation of the HVAC code input and a listing of the code input as well as plots of the code's output. Calculations, along with some plant drawings, are provided for the heat slab parameters and heat loads in each room. Review of these calculations have resulted in a number of significant comments, delineated below, which would appreciably increase the calculated room temperatures.

1. The assumed initial control room temperature of 76°F is non-conservative unless the licensee has appropriate technical specifications and/or administrative controls that would require plant shut down if this temperature is exceeded. Since a degraded HVAC is conceivable, especially during a very hot day, a higher initial room temperature, which is consistent with the conditions expected, needs to be considered. In the absence of a technical specification limit and a maximum historical temperature, the licensee can use an initial temperature of 90°F which is the midway between 104° and 76°F.

2. The assumed initial temperature of 85°F for the turbine, reactor, and administration buildings is non-conservative, and it is inconsistent with the NUMARC guidance which states that for areas without air conditioning use of an initial temperature other than 104°F needs to be justified.

3. The assumed outside ambient air temperature of 90°F is non-conservative for this location. Based on NUREG/CR-1390 (24), the extreme annual maximum temperature for the 99% probability level (one in 100 years) for the site is 112°F. The extreme temperature for the 50% probability level (once every two years) is 98°F.

4. The licensee partitioned the control room complex into three areas: the operating area, relay and instrument cabinet area, and the support area. No heat-up calculation was performed for the support area, and the licensee assumed that the temperature in this area will remain at 76°F. The operating and the relay and instrument cabinet areas are separated mainly by the control room panels in the middle, and some metal studs with gypsum boards at the extremities. The licensee assumed that there is no heat transfer between these two areas, a hypothetical adiabatic partition. In

the calculation of the temperature rise in the relay and instrument cabinet area the licensee assumed the temperature down-stream of the floor area to be at 76°F. We find the 76°F temperature assumption to be non-conservative. In addition, the assumption of the adiabatic partition is reasonable only when the temperature difference between these areas is negligible. The temperature results show that this is not the case.

5. The concrete thermal properties used in the calculation are not in agreement with values in common references and represent a non-conservative difference. The licensee used a thermal conductivity, specific heat, density, and associated thermal diffusivity (in standard British Units), of 0.85, 0.18, 130., and 0.0363, respectively. A more appropriate, generally used in containment analysis, and conservative set of values would be 0.7, 0.2, 140., and 0.025 respectively. The difference represents a 30% reduction in thermal diffusivity which will directly impact the concrete heat transfer capability and the four hour room temperature.

6. It is considered, although it is not explicitly stated by the licensee, that the HVAC computer code has been subjected to the proper QA activities and that the appropriate selection of time step size and heat slab nodes has been made.

7. It appears that after the first 90 minutes into the event the control room complex will only be lit by wall pack emergency lights. In the first 90 minutes the control room lighting is supported by 72 fluorescent battery backed fixtures. The licensee deducted the heat generated by these lighting from the overall control room heat load. The licensee did not indicate how long the emergency lights will

last and whether the lighting is sufficient to perform the needed functions inside the control room. In addition, since the licensee is proposing to improve the control room lighting, therefore, the control room heat load should be adjusted for the additional heat generation from the proposed lightings.

Based on the above comments, the licensee needs to perform a re-analysis of the control and relay rooms with revised input parameters to the HVAC computer code.

o Drywell (Containment)

The licensee performed a plant-specific analysis to evaluate the containment (drywell, wetwell, and torus) response under SBO conditions. The analysis gives the assumptions, initial conditions, and the final results of the containment temperature and pressure rise during an SBO. Based on this analysis the licensee will depressurize the reactor within the first hour of the event to limit the drywell temperature to less than 300°F. The final temperature after four hours with the depressurization was estimated to be 293°F which exceeds the containment design temperature of 281°F. The licensee stated that a list of equipment located within the containment has been complied and their operabilities at this temperature have been verified. We reviewed the assumptions and the initial conditions used in this analysis, and found them to be consistent with the SBO conditions. Since no equipment listing and associated operability assessment were provided by the licensee for review, no review can be performed. However, we agree with the licensee that the equipment located within the containment are generally qualified for higher temperatures than calculated in this analysis.

o Reasonable Assurance of Operability

The licensee stated (19) that HPCI and RCIC equipment is specified to operate satisfactorily under accident conditions at 148 °F. The licensee concluded that since the HPCI room exceeds this temperature very briefly and the RCIC room remains well below this temperature that there is reasonable assurance of equipment operability in these rooms during an SBO with a duration of four hours. We agree that as long as the licensee opens the HPCI room doors within 30 minutes of the onset of an SBO there is reasonable assurance of equipment operability in these rooms.

The licensee provided a list of all equipment in the steam tunnel, and identified those that are required to mitigate or recover from an SBO. The licensee stated the identified equipment is either environmentally qualified or is similar to a qualified model. The licensee stated that a rigorous evaluation of all equipment in the switchgear room is not required since the maximum temperature of the room (115°F) is not significantly above the normal operating temperature of 104°F. We disagree with the licensee's conclusion based on the following:

1. The final temperature calculation is based on an assumption that the initial room temperature is 83°F, therefore, a higher temperature may result if a higher initial temperature is used. (Note that we did not review this calculation.)

2. When the switchgear room temperature is 115°F, the temperature of the operating equipment inside the cabinet is 125 to 135°F, or 10 to 20 degrees higher than the average bulk ambient temperature.

Therefore, the licensee needs to re-evaluate the switchgear room temperature rise, or state why the assumed initial temperature is justified, and assess the equipment operability inside the cabinets.

5. Containment Isolation

Licensee's Submittal

The licensee stated (12 and 13) that containment isolation valves that must be capable of being closed or that must be operated (cycled) under SBO conditions can be positioned (with indication) independent of the preferred and blacked-out unit's Class 1E power supplies. No actions and/or procedure changes were required to provide appropriate containment integrity during an SBO event.

In response to the questions raised during the telephone conversation on February 12, 1991, the licensee stated (15) that in addition to the five exclusion criteria given in NUMARC 87-00 and RG 1.155 two other exclusion criteria were used. The licensee identified the additional exclusion criteria as (21):

1. Isolation valves of a redundant pair, one of which may be positioned independent of any AC, and

2. Valves that are normally open and should remain open to mitigate the SBO event.

The licensee also provided the list of the CIVs along with criteria used to exclude the valve, or penetration. The licensee added that all isolation valves, except for check and manual valves, are monitored by the containment isolation monitoring system (CIMS). The CIMS meets the requirements of RG 1.97, Rev. 2 Category I instruments and provides continuous indication of CIVs in the control room during an SBO event.

Review of Licensee's Submittal

Our review of the containment penetrations and the associated CIVs provided by the licensee indicates (21) that there are several valves which are excluded using the additional criteria. These valves, which are AC operated, are either normally open or closed and fail as is upon loss of power. The licensee needs to confirm that the valve position indications for all AC-operated valves are available in the control room during an SBO event for CIMS to be effective. If not, the licensee needs to provide assurance that the valves excluded by the additional criteria are either fully closed or can be closed, if needed. The assurance needs to be provided by listing these valves in an appropriate procedure and identify actions which are needed to confirm that these valves are closed, if needed. The valve closure needs to be confirmed by position indication, (local, remote, mechanical, process information, etc.).

6. Reactor Coolant Inventory

Licensee's Submittal

The licensee stated (10 and 11) that the ability to maintain adequate reactor coolant inventory was assessed in a plant-specific analysis (18). The analysis shows that expected rates of reactor coolant inventory loss under SBO conditions do no result in more than a momentary core uncovery for an SBO of four hours. Therefore, the licensee concluded that makeup systems in addition to those currently available under SBO conditions are not required.

Review of Licensee's Submittal

The licensee's analysis (18), which was performed using a GE computer program (SHEX-04) to calculate the plant response under the conditions of an SBO was reviewed. The analysis considered a scenario in which reactor pressure vessel safety relief valves lift early in the scenario, followed shortly by initiation of HPCI and RCIC. HPCI and RCIC subsequently stop due to high reactor pressure vessel (RPV) level. After approximately 5 to 10 minutes the operators prevent subsequent injections of HPCI and continue to operate HPCI in the recirculation mode to and from the CST. Water level is maintained with the RCIC system. About 30 minutes after the onset of an SBO, the operator initiates a controlled RPV depressurization at less than 100°F. At about 110 minutes the RPV is maintained at about 200 psig, using HPCI and RCIC as necessary. At the end of an SBO, the maximum suppression pool temperature is estimated to reach 175°F.

Our review indicates that the analysis approach, assumptions and methodology to be consistent with the guidance of NUMARC 87-00. Both HPCI and RCIC pump have sufficient capacity to provide the necessary reactor vessel inventory make-up. Therefore, we agree with the licensee's statement that no additional make-up capabilities are necessary to cope with an SBO with a duration of four hours.

NOTE:

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

3.3 Proposed Procedures and Training

Licensee's Submittal

The licensee stated that plant procedures have been reviewed and will be modified to meet the guidelines in NUMARC 87-00, Section 4 in the following areas:

1. Station Blackout Response,
2. AC power restoration, and
3. Severe Weather.

The licensee listed the procedures that will be used to cope with a loss of AC power in its submittals (12 and 13). The licensee added that as part of a plant-specific analysis it was determined that the equipment operability concerns inside the containment can be alleviated by depressurizing the reactor vessel to between 200 and 400 psia within 30 minutes. Therefore, depressurization of the reactor vessel will be directed by plant procedures as appropriate.

Review of Licensee's Submittal

We neither received nor reviewed the affected procedures or training. These procedures are plant specific actions concerning the required activities to cope with an SBO. It is the licensee's responsibility to revise and implement these procedures, as needed, to mitigate an SBO event and to assure that these procedures are complete and correct in their contents and that the associated training needs are carried out accordingly.

3.4 Proposed Modifications

Licensee's Submittal

The licensee stated (12) that no modifications would be required to cope with an SBO with a duration of four hours. However, in its revised submittal (13) the licensee stated that insulation will be installed around the RCIC turbine to reduce RCIC room temperature rise during an SBO. Additionally, the licensee stated that control room lighting conditions will be improved to support operations during an SBO.

Review of Licensee's Submittal

The licensee stated that the modifications will be implemented in accordance with the applicable design and licensing requirements to comply with the guidance of RG 1.155 and NUMARC 87-00. If properly implemented, the modifications to the RCIC system will reduce the RC1C room temperature during an SBO. The modification to the control room lighting will improve the operations in the control room.

3.5 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.

4.0 CONCLUSIONS

Based on our review of the licensee's submittals, a telephone conversation between NRC/SAIC and the licensee, and the information available in the UFSAR for the Duane Arnold Energy Center, we find the submittal conforms with the requirements of the SBO rule and the guidance of RG 1.155 with the following exceptions:

1. **Emergency Diesel Generator Reliability Program**

   The licensee's submittals do not document the conformance of the plant's EDG reliability program with the guidance of the RG 1.155, Section 1.2, and NUMARC 87-00, Appendix D.

2. **Proposed Station Blackout Duration**

a. <u>Severe Weather Group/Offsite Power Design Characteristic</u>

   The licensee used different data set to classify the site SW grouping. The main difference between the licensee's results and that given in NUMARC is the estimated expected frequency of storms at the site. The licensee estimated the expected frequency of storms at the site to be 0.1068 per year, which is less than one-half of the 0.25 value given in NUMARC 87-00. The licensee's calculation resulted in an overall frequency of 0.0098 compared to 0.0105 using NUMARC data. Our review of the licensee's storm frequency calculation indicates that the method used under-estimates the actual occurrence at the site, (see the text). Since the licensee's calculated SW frequency (0.0098) is very close to the frequency (0.01) which changes the SW grouping categorization and the licensee failed to perform the goodness of fit test to justify the underestimation, we categorize the site in SW group "3" instead of "2" as indicated by the licensee. This classification puts the site in a "P2" offsite power characteristic group.

b. SBO Coping Duration and EDG Target Reliability

Based on the above, the licensee can commit to an EDG reliability target of 0.975 and a required coping duration of four hours, or to an EDG reliability target of 0.95 and a required coping duration of eight hours. The licensee's analysis and our review are based on an four hour coping durations, a revised submittal and a new review would be required for an eight hour coping duration.

3. Class 1E Battery Capacity

Our review of the load profile and cell sizing calculations provided by the licensee indicates several deviations from IEEE-Std 485 which puts in question the adequacy of the battery calculations, see item 2 in Section 3.2 for more detail. The licensee needs to respond to the concerns raised in the text.

4. Effects of Loss of Ventilation

The licensee performed non-NUMARC transient heat-up calculations using a proprietary computer program. Upon the request, the licensee provided the control room heat-up calculation to be reviewed. Our review of the information provided by the licensee has resulted in the following concerns:

a. Control Room

The control room heat-up calculation has resulted in a number of significant concerns, (see item 4 in Section 3.2), which would appreciably increase the final room temperature. The licensee needs to provide a response to the individual concerns delineated in the text.

b. Essential Switchgear Room

The licensee did not perform an assessment of equipment operability for this room since the calculated final temperature (115°F) was less than 120°F. However, for calculating this temperature the licensee uses a non-conservative initial room temperature of 83°F. Therefore, the final temperature will be higher if a more conservative initial temperature is used. In addition, when the average bulk room temperature is 115°F, the operating equipment inside the cabinet will be at 10° or 20°F higher temperature. Based on these, the licensee needs to re-assess the equipment operability in this room and justify why a higher initial room temperature should not be used.

5. Containment Isolation

The licensee used two criteria in addition to those provided in RG 1.155 and NUMARC 87-00. Our review of the containment penetrations and the associated CIVs provided by the licensee indicates that there are several valves which are excluded using these additional criteria. These valves, which are AC operated, are either normally open or closed and fail as is upon loss of power. The licensee needs to confirm that the valve position indications for all AC-operated valves are available in the control room during an SBO event for CIMS to be effective. If not, the licensee needs to provide assurance that the valves excluded by the additional criteria are either fully closed or can be closed, if needed. The assurance needs to be provided by listing these valves in an appropriate procedure and identify actions which are needed to confirm that these valves are closed, if needed. The valve closure needs to be confirmed by position indication, (local, remote, mechanical, process information, etc.).

6. 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.

5.0 REFERENCES

1. The Office of Federal Register, "Code of Federal Regulations Title 10 Part 50.63," 10 CFR 50.63, January 1, 1989.

2. U.S. Nuclear Regulatory Commission, "Evaluation of Station Blackout Accidents at Nuclear Power Plants - Technical Findings Related to Unresolved Safety Issue A-44," NUREG-1032, Baranowsky, P. W., June 1988.

3. U.S. Nuclear Regulatory Commission, "Collection and Evaluation of Complete and Partial Losses of Offsite Power at Nuclear Power Plants," NUREG/CR-3992, February 1985.

4. U.S. Nuclear Regulatory Commission, "Reliability of Emergency AC Power System at Nuclear Power Plants," NUREG/CR-2989, July 1983.

5. U.S. Nuclear Regulatory Commission, "Emergency Diesel Generator Operating Experience, 1981-1983," NUREG/CR-4347, December 1985.

6. U.S. Nuclear Regulatory Commission, "Station Blackout Accident Analyses (Part of NRC Task Action Plan A-44)," NUREG/CR-3226, May 1983.

7. U.S. Nuclear Regulatory Commission Office of Nuclear Regulatory Research, "Regulatory Guide 1.155 Station Blackout," August 198B.

8. Nuclear Management and Resources Council, Inc., "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," NUMARC 87-00, November 1987.

9. Thadani, A. C., Letter to W. H. Rasin of NUMARC, "Approval of NUMARC Documents on Station Blackout (TAC-40577)," dated October 7, 198B.

10. Thadani, A. C., letter to A. Marion of NUMARC, "Publicly Noticed Meeting December 27, 1989," dated January 3, 1990.

11. Nuclear Safety Analysis Center, "The Reliability of Emergency Diesel Generators at U.S. Nuclear Power Plants," NSAC-108, Wyckoff, H., September 1986.

12. Mineck, D. L., letter to U.S. Nuclear Regulatory Commission Document Control Desk, "Duane Arnold Energy Center, Docket No: 50-331, Op. License No: DPR-49, 10 CFR 50.63, Loss of All Alternating Current Power, Information Submittal", NG-89-0923, April 17, 1989.

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14. Duane Arnold Energy Center, Updated Final Safety Analysis Report.

15. Duane Arnold Energy Center, "Responses to NRC Questions Regarding SBO Submittal".

16. Johnson, B. H., "Assessment of the Duration Required of the DAEC to Withstand a Station Blackout", Attachment 1 to Reference 15, March 8, 1990.

17. CAL-IELP-E87-06 Rev 3, "Load Profile and Cell Sizing", Attachment 2 to Reference 15.

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19. Mahini, R. T., "Transient Temperature Evaluation for the Control Room at DAEC during Station Blackout," Nutech Calculation Package File No: IEL004.034, Revision 1, August 4, 1989, Attachment 4 to Reference 15.

20. DAEC, "Assessment of Equipment Environment and Operability during a Station Blackout Event," March 20, 1990, Attachment 5 to Reference 15.

2I. DAEC, "Assessment of Containment Integrity for Station Blackout," March 20, 1990, Attachment 6 to Reference I5.

22. NUREG/CR-4492, "Methodology for Estimating Extreme Winds for Probabilistic Risk Assessments," Ramsdell, J. V., et. al., October 1986.

23. NUREG/CR-4942, "Equipment Operability During Station Blackout Events," Jacobus, M. J., Nicolette, V. F., and Payne, A. C., October 1987.

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