NRC Chrono File

Robert E. Denton
Vice President
Nuclear Energy

Baltimore Gas and Electric Company
Calvert Cliffs Nuclear Power Plant
1650 Calvert Cliffs Parkway
Lusby, Maryland 20657
410 586-2200 Ext. 4455 Local
410 260-4455 Baltimore

BGE

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U. S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Document Control Desk

SUBJECT: Calvert Cliffs Nuclear Power Plant
Unit Nos. 1 & 2; Docket Nos. 50-317 & 50-318
Use of NUREG-0800 Standard Review Plan Guidance in Evaluating the Need for Tornado-Generated Missile Barriers

Baltimore Gas and Electric Company hereby proposes a change to the methodology used to evaluate the need for tornado missile protection for Calvert Cliffs Nuclear Power Plant (CCNPP), Units 1 and 2. The proposed methodology change will allow the use of Probabilistic Risk Assessment (PRA) techniques, consistent with NUREG-0800, Standard Review Plan (SRP), to evaluate the need for structural barriers to protect against tornado-generated missiles. NRC approval of this proposed change is requested.

DESCRIPTION OF CHANGE

The Updated Final Safety Analysis Report (UFSAR) will be changed to allow the use of PRA techniques in evaluating the need for tornado-generated missile barriers. Probability of exposures in excess of 10 CFR Part 100 guidelines of less than 10^{-6} per year per unit due to postulated tornado-generated missile strikes will be used as a conservative threshold for evaluating our compliance with draft General Design Criteria (GDC) 2. Existing plant conditions, as well as future changes to the facility, may be evaluated using this revised methodology, and determined acceptable if the total probability of exposures in excess of 10 CFR Part 100 guidelines due to postulated tornado-generated missile strikes is less than 10^{-6} per year per unit. The UFSAR will be updated on the normal cycle with a list of affected plant areas which are not designed, fabricated or erected to withstand the additional forces imposed by tornado-generated missile strikes. The list will be a subset of those systems, structures and components (SSCs) identified as "essential" in response to GDC 2. The total probability from all listed SSCs will be maintained below the 10^{-6} per year per unit threshold. The only known SSCs for inclusion in the next update will be the existing Emergency Diesel Generator (EDG) engines' intake air filter, exhaust piping and mufflers.

AI370001

BACKGROUND

As stated in our Final Safety Evaluation Report submittal (1971), the plant design and construction proceeded based upon the intent of the 1967 draft GDC. Draft GDC 2 states,

> "Those systems and components of reactor facilities which are essential to the prevention of accidents which could affect the public health and safety or to mitigation of their consequences shall be designed, fabricated, and erected to performance standards that will enable the facility to withstand, without loss of the capability to protect the public, the additional forces that might be imposed by natural phenomena such as earthquakes, tornadoes, flooding conditions, winds, ice, and other local site effects. The design bases so established shall reflect: (a) appropriate consideration of the most severe of these natural phenomena that have been recorded for the site and surrounding area, and (b) an appropriate margin for withstanding forces greater than those recorded to reflect uncertainties about the historical data and their suitability as a basis for design."

The Calvert Cliffs Final Safety Analysis Report, Appendix 1A, provided a list of SSCs essential to incident prevention and mitigation of incident consequences. The list of essential systems includes "electrical power sources."

The original CCNPP licensing basis assumed a tornado-generated missile strike to exposed essential components. Accordingly, barriers to protect certain critical components against these postulated missiles were designed and constructed. While conducting a review in support of construction efforts associated with our new EDGs, we identified components of equipment subsystems required to mitigate the consequences of accidents which are not protected from tornado-generated missiles. The specific components identified are the existing EDG engines' intake air filter and exhaust piping and muffler. The unprotected components are located on the roof of the seismic Class I Auxiliary Building.

Our EDGs are defined as systems which mitigate the consequences of an accident. The Calvert Cliffs site currently has three EDGs. Normally, No. 11 EDG is dedicated to Unit 1, No. 21 EDG is dedicated to Unit 2, and No. 12 EDG is able to swing to either Unit. Each EDG is enclosed in a separate room in the Auxiliary Building. The Auxiliary Building is a Class I structure, one of whose functions is to protect the EDGs and their support systems from severe weather effects. The only EDG components which are exposed to outside weather effects are the engine intake air filter and exhaust piping and muffler. They extend through the roof of the Auxiliary Building. The top of the intake air filter is approximately 9' above the roof elevation, while the exhaust piping extends to an elevation of approximately 26' above the roof elevation. Most of the intake air filter and a portion of the exhaust piping, including the entire muffler, is located behind a 7'-6" high parapet wall along the west side of the roof; however, this parapet does not provide complete protection from all postulated tornado missiles.

TECHNICAL JUSTIFICATION

A PRA was conducted to determine the risks associated with postulated tornado-generated missile strikes on exposed EDG engine air intake and exhaust piping and components. The PRA determined that the probability of potential exposures in excess of 10 CFR Part 100 guidelines occurring as a result of tornado-generated missile strikes on the subject components is approximately 10^{-8} per year (Attachment 1).

The PRA results were evaluated in light of SRP Section 3.5.1.4, Missiles Generated by Natural Phenomena, using the acceptance criteria specified in SRP Section 2.2.3, Evaluation of Potential Accidents. Table 1 provides a comparison of the SRP and the proposed licensing basis for CCNPP.

Table 1

SRP and CCNPP Proposed Licensing Basis
Acceptance Criteria Comparison

SRP Section 3.5.1.4, Revision 2, Missiles Generated by Natural Phenomena	The methodology of identification of appropriate design basis missiles generated by natural phenomena shall be consistent with the acceptance criteria defined for the evaluation of potential accidents from external sources in SRP Section 2.2.3.
SRP Section 2.2.3, Revision 2, Evaluation of Potential Accidents	The expected rate of occurrence of potential exposures in excess of 10 CFR Part 100 guidelines of approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower.
CCNPP Unit Nos. 1 & 2 Proposed Licensing Basis	Tornado-generated missile protection is not required for systems designed to meet the performance standards of draft GDC 2 if the resultant aggregate probability of exposures in excess of 10 CFR Part 100 guidelines is less than 10^{-6} per year.

NUREG-0800, SRP Section 3.5.1.4, Revision 2, and Section 2.2.3, Revision 2 provides a conservatively acceptable threshold for safety due to damage caused by postulated missile strikes. We have chosen to implement the acceptance criteria of these SRP sections to evaluate the necessity of providing tornado missile protection for systems designed to meet the performance standards of draft GDC 2. The attached PRA evaluation for the EDG air intake and exhaust components identifies conservative assumptions which indicate that the actual probability is substantially lower.

The acceptance threshold of 10^{-6} per year for exposures in excess of 10 CFR Part 100 guidelines due to a postulated missile strike is negligible when compared to the overall probability for core damage for CCNPP Units 1 and 2. The magnitude of the acceptance criteria is so small that this methodology change will not involve an increase in the probability or consequences of an accident or malfunction of equipment. Therefore, this methodology change does not adversely impact plant safety. This methodology is consistent with the work being performed for the Individual Plant Examination of External Events.

SCHEDULE

This methodology change is requested to be approved and issued by March 15, 1995. However, issuance of this change is not currently identified as having an impact on outage completion or continued plant operation.

Should you have any questions regarding this matter, we will be pleased to discuss them with you.

Very truly yours,

RED/NH/dlm

Attachment: Probabilistic Risk Assessment Evaluation of Tornado-Generated Missile Impact on the Calvert Cliffs Nuclear Power Plant Emergency Diesel Generator Engine Air Intake and Exhaust

cc: D. A. Brune, Esquire
J. E. Silberg, Esquire
M. J. Case, NRC
D. G. McDonald, Jr., NRC
T. T. Martin, NRC
P. R. Wilson, NRC
R. I. McLean, DNR
J. H. Walter, PSC

bcc: G. C. Creel
L. B. Russell/J. R. Lemons
W. R. Corcoran/M. J. Miernicki
P. E. Katz/P. G. Chabot
J. G. Keppler
D. A. Ward
R. P. Heibel/T. N. Pritchett
C. P. Johnson/A. R. Thornton
R. B. Pond, Jr./S. R. Buxbaum, Jr.
W. A. Thornton
C. H. Cruse/K. J. Nietmann/J. E. Rivera
A. B. Anuje
G. L. Detter
S. B. Haggerty
B. S. Montgomery
K. R. Neddenien
R. C. L. Olson
P. A. Pieringer
L. O. Wenger
N. Haggerty
B. B. Mrowca/L. B. Shanley
T. M. Delaney/S. J. Loeper
C. J. Ludlow/J. F. Szivos
M. J. Gahan
File 18.02
File 25.07
File 28.04
NRC Chrono File

RED/NH/nh/dlm

NRC 94-052

ATTACHMENT (1)

PROBABILISTIC RISK ASSESSMENT EVALUATION

OF

TORNADO-GENERATED MISSILE IMPACT ON THE CALVERT CLIFFS NUCLEAR POWER PLANT EMERGENCY DIESEL GENERATOR ENGINE AIR INTAKE AND EXHAUST

TABLE OF CONTENTS

ATTACHMENT (1)

PROBABILISTIC RISK ASSESSMENT EVALUATION OF TORNADO-GENERATED MISSILE IMPACT ON THE CALVERT CLIFFS NUCLEAR POWER PLANT EMERGENCY DIESEL GENERATOR ENGINE AIR INTAKE AND EXHAUST

1.0 INTRODUCTION

1.1 PURPOSE

To determine the risk significance of tornado-induced missiles causing a failure of the Calvert Cliffs Nuclear Power Plant (CCNPP) Emergency Diesel Generators (EDGs).

1.2 BACKGROUND

The current design of CCNPP Units 1 and 2 does not provide for tornado missile protection of the EDG exhaust subsystem and air intakes. This risk assessment evaluates the Core Damage Frequency (CDF) due to a tornado damaging these key components coincident with a non-recoverable loss of offsite power (LOOP). As discussed in the cover letter, the acceptance criteria is based upon the probability of exposures in excess of 10 CFR Part 100 guidelines, rather than CDF; however, this evaluation conservatively assumes that CDF results in containment failure, and therefore, equates to exposures in excess of 10 CFR Part 100 guidelines. This assessment will aid in the evaluation of the adequacy of the current plant design with respect to tornado events.

Section 2 of this analysis presents the building blocks required to determine CDF, which is calculated in Section 3. Conclusions are presented in Section 4.

1.3 LIMITATIONS

This analysis considers the effects of tornado missiles on the EDGs only. It does not determine the risk due to wind effects (tornadoes, hurricanes, etc.) or the impact of tornadoes on other plant equipment.

1.4 PLANT MODEL

The Probabilistic Risk Assessment (PRA) plant model used for this analysis is based on the model as of May 18, 1994. This plant model is a refinement of the one documented in the CCNPP Individual Plant Examination Summary Report (Reference 1). The plant model used is based on Unit 1, but has been validated for Unit 2.

2.0 ANALYSIS

2.1 OVERVIEW

In order to determine the risk significance of the postulated events, five key pieces of information must be developed:

Tornado Strike Frequency (P_s'): This is the frequency at which a tornado (as defined in Reference 2, Section 4.1) is expected to come in contact with the "site." Point strike and area strike frequencies are calculated in Section 2.2.

Tornado Missile Impact Parameter (ψ): This is the frequency of impact of a missile on a structure or component, expressed as the frequency of impact per missile per unit target area per tornado (Reference 3, pg. G-35). This value is calculated in Section 2.3.1.

Missile Strike Probability (P_{ms}): This is the probability of a tornado generated missile impacting a target, given a tornado strikes the site. P_{ms} is based on the missile impact parameter (ψ), the target area and the number of missiles available. The value is calculated in Section 2.3.4.

Component Failure Probability (P_F): Given a tornado, a component can fail as a result of being struck by a tornado-generated missile. The probability of this event occurring and causing a failure of the EDG is discussed in Section 2.4

Conditional Core Damage Probability (P_{CCD}): Given a tornado and the failure of the EDG, the likelihood that core damage occurs is calculated. Section 2.5 summarizes the results of this analysis.

The following equation is used to determine the contribution to CDF due to tornado-induced failures of components. The strike frequency (point or area) which results in the higher CDF (which is conservative) is used.

For tornado missiles, $CDF_{TM} = P_s' * P_{ms} * P_F * P_{CCD}$

2.2 TORNADO STRIKE FREQUENCY

The tornado strike frequency is the annual frequency of a tornado striking the site. The estimates for tornado strike frequency are based on data from:

NUREG-4461 (Reference 4), which includes tornado histories from 1954 through 1983 for the 1° box containing Calvert Cliffs. A 1° box is an area enclosed by a rectangle with sides equal to 1° latitude and 1° longitude. Calvert Cliffs is at approximately 38°26' North and 76°27' West (Reference 5, Figure 2.2-5)

National Severe Storms Forecast Center (NSSFC), which includes tornado histories from 1950 through 1984 within 50 nautical miles (NM) of Prince Frederick, Maryland.

Strike frequency is calculated by determining the likelihood that a tornado coincides with a target (in this analysis, the site). Strike frequency calculated using an Area Strike Model is dependent on the area of the target. A Point Strike Model is independent of the target area and can be used for relatively small targets (with respect to the area of the region in which the data is collected).

For the generation of tornado missiles, strike frequencies were calculated using both the Point and Area Strike Models. This is required since the Tornado Missile Impact Parameter (ψ) varies depending on which model is used for the strike frequency (see Section 2.3.1). The area strike calculations were developed with the assumption that a tornado will strike the site from a random direction and at a random orientation to the site. Although tornadoes may preferentially come from certain directions at certain orientations, this information is not available for the CCNPP vicinity. Non-random tornadoes (with respect to direction and orientation) do not affect the results of the area strike frequencies, but can affect the missile impact parameters (ψ - see Section 3.3.3)

2.2.1 Point Strike

The Point Strike Frequency (P_S) is calculated using the methodology described in NUREG-4461; data from both NUREG-4461 and NSSFC is used. A point strike frequency is estimated in this analysis since some of the ψ values used are normalized to point strike frequency. The equations for P_s are:

$P_s = A_t/(A_r * N_y)$ [Reference 4, Eqn. (11)]

A_t = (Number of Tornadoes) * (Average Tornado Area) [Reference 4, pg. 16]

A_r = Area of interest = 4774.3cos(Latitude at middle of box) [Reference 4, Eqn. (14)]

OR

A_r = π (radius of area under consideration)^2 = $\pi\rho^2$

N_y = Number of Years in the period of record [Reference 4, pg. 16]

Values are taken from Reference 4, pages E.1 and E.5 (1° box at 76° Longitude and 38° Latitude) and site-specific data attained from the NSSFC.

	1° box	50 NM radius
No. of tornadoes	15	51
Avg. tornado area	0.105	0.137
N_y	30	35

NUREG-4461 (1° box) Data

A_t = (Number of Tornadoes) * (Average Tornado Area)
= 15 * 0.105 = 1.575

A_r = 4774.3cos(Latitude at middle of box)
= 4774.3cos(38.5) = 3736.4 mi^2

N_y = 30

Therefore,

P_s = 1.575/(3736.4 * 30) = 1.41x10^{-5}/yr

P_s must be corrected to account for large bodies of water in the region, since only tornadoes which occur over land are captured in the databases. To determine the percentage of land in the 1° box, a trace of a map was made. A grid was made on the map and, based on grid squares, the estimated percentage of land is 62%.

P_s' is the corrected Point Strike Frequency, accounting for the percentage of land versus water.

P_s' = P_s * (Total Area of the region / Land Area) (Reference 4, pg. 17)
= 1.41x10^{-5} *(1.0/0.62) = 2.27x10^{-5}/yr

NSSFC (50 NM radius) Data

$A_t = 51 * 0.137 = 6.987$

$A_r = \pi\rho^2$ (including NM to statute mile conversion of 1.151) = 10405 mi^2

$N_y = 35$

Therefore,

$P_s = 6.987/(10405 * 35) = 1.92x10^{-5}/yr$

To determine the percentage of land within 50 NM of Prince Frederick, a trace of a map was made. A grid was made on the map and, based on grid squares, the estimated percentage of land is 75%. Therefore,

$P_s' = 1.92x10^{-5} *(1.0/0.75) = 2.56x10^{-5}/yr$

Results

Since the Point Strike Frequencies calculated using both sets of data are very similar, the conservative value (2.56x10^{-5}/yr from the NSSFC data) will be used in this analysis.

2.2.2 Area Strike

A method for determining Area Strike Frequency was developed. The frequency for a tornado striking the site, characterized by a given radius, is calculated by multiplying the probability of a tornado striking the site by the frequency of tornadoes in the sample area. Given the average tornado strike path and site dimensions, the probability of a tornado striking the site is determined using trigonometric and probabilistic relationships.

The data required to calculate the Area Strike Frequency is developed below.

Short Length (Tornado Width [x]) and Long Length (Tornado Length [y])

The NSSFC data gives a true average length and width. No length or width data is provided for 1° boxes in NUREG-4461. In the NSSFC data, the product of length times width (0.101 sq. mi.) is less than the true average area provided (0.137 sq. mi.). In order to be conservative (since the larger the tornado, the higher the area strike frequency), new lengths and widths are calculated.

It is assumed that the average tornado has a length to width ratio equal to 37.5 (from NSSFC data, true average length = 1.95 mi. and true average width = 0.052 mi.). By solving two equations, x and y can be determined:

$y/x = 37.5$ and $x*y$ = true average area.

Therefore, using the average tornado areas from Section 2.2.1 as the true average area:

1° box:	x = 0.053 mi. = 279.84 ft.	y = 1.99 mi. = 10507.2 ft.
50 NM circle:	x = 0.060 mi. = 316.8 ft.	y = 2.25 mi. = 11880.0 ft.

Site Radius (r)

Two values of the site radius (2000 feet and 1 mile) are chosen to agree with the ψ values described in Section 2.3.1.

Area of Sample

The land area within the sample area is calculated from the data in Section 2.2.1. For the 1° box, the area is equal to:

$$3736.4*0.62 = 2316.6 \text{ square miles}$$

For the 50 NM radius circle, the area is:

$$10405*0.75 = 7803.75 \text{ square miles}$$

Frequency of Tornado Strike in Sample Area

This value is equal to the number of tornadoes divided by the number of years in the sample. From the data in Section 2.2.1:

1° box:	15/30 = 0.5 tornadoes/year
50 NM circle:	51/35 = 1.46 tornadoes/year

Results

Based on the above values, four area strike frequencies are calculated, one for each radius (2000 feet and 1 mile) using both sets of data (1° box and 50 NM radius). The results are presented below (in tornado strikes per year).

	Strike Area	
Tornado Data	2000 ft.	1 Mile
1° box	4.38×10^{-4}	1.54×10^{-3}
50 NM radius	4.20×10^{-4}	1.43×10^{-3}

The highest value considering a 2000 foot radius strike area (i.e., 4.38×10^{-4}/yr) will be used in calculations which use area strike frequency. The one-mile radius strike frequencies are not used, except for sensitivity calculations. See Sections 2.3.1 and 3.3.1 for discussions of the strike areas.

2.3 MISSILE STRIKE PROBABILITY

There are several variables which must be determined to assess the Missile Strike Probability (P_{ms}). They are:

> ψ, the missile impact parameter. It is defined as the probability of impact/missile/unit target area/tornado strike frequency (Reference 3, pg. G-35)
>
> A, the area of the target(s) in question (in ft^2)
>
> N_m, the number of candidate missiles

The equation for determining the probability of a missile impacting a target, *given a tornado* (i.e., probability per tornado) is derived from unit analysis:

$$P_{ms} = AN_m \psi$$

2.3.1 Missile Impact Parameter (ψ)

Ideally, the Missile Strike Probability (P_{ms}) should be calculated based on plant specific configuration using a computer simulation (e.g., the TORMIS methodology, as used in the Seabrook study [Reference 12, pg. I-1]). However, several PRAs have derived ψ-values based on models developed for other sites, due to the complexity of the analyses and the somewhat generic applicability of the data (i.e., based on the tornado experience in NRC Tornado Region I [per Reference 8, Figure 1, CCNPP is in

Tornado Region I]). Due to the unavailability of a plant specific reference, conservative values are chosen from these derived ψ values.

The PRAs researched are described in Section 2.3.1.1. The ψ-values chosen for the analysis of CCNPP are provided in Section 2.3.1.2.

2.3.1.1 ψ-Values Used in Other PRAs

Oconee PRA (NSAC-60)

The Oconee study (Reference 9, pg. K-10) considers two values for the missile strike parameter, based on an *area* strike frequency. One value is derived from EPRI NP-0768 and 0769 (References 6 and 7) which is based on assuming all missiles within 2000 feet of the plant. The second is from a SAIC study and is based on assuming missiles from within one mile of the plant. The value derived from the EPRI study is higher than the one from SAIC, since it is more likely that a missile generated close to a target will strike it. However, fewer missiles are included in the missile population of the EPRI study.

The mean displacement range of missiles considered in the EPRI study was less than 350 feet. In 250 simulations of each type of missile, no missiles traveled more than 2000 feet (Reference 7, pg. 2-22). The comparison of missile strike probabilities between the EPRI and SAIC studies in the Oconee PRA shows that missile strikes are dominated by close-in missiles. However, the SAIC study did find that some missiles were transported from as far away as 4000 feet (Reference 9, pg. K-11).

The values for ψ are: EPRI NP-0768

EPRI Study (2000 ft. radius) 3.3×10^{-11}/missile/ft^2 of target area/tornado strike frequency

SAIC Study (1 mile radius) 4.52×10^{-12}/missile/ft^2 of target area/tornado strike frequency

St. Lucie and Turkey Point Shutdown Decay Heat Removal Studies (NUREG-4710 & 4762)

ψ_n: NORMALIZED TO POINT STRIKE FREQ

In NUREGs-4710 and -4762 (Reference 3, Appendix G, Section 4.1 and Reference 10, Appendix G, Section 4.1), several mean values of ψ are derived from EPRI NP-0769 (Reference 7) and a TORMIS study of the Seabrook site (Reference 12). The values derived in NUREGs-4710 and -4762 are normalized to point strike frequency and will be designated ψ_n.

One value is given for large structures (i.e., buildings, tanks, etc.) in NRC Regions I and II; the large structure ψ_n is derived from EPRI NP-0769 (see Reference 3, pg. G-35 and G-36). Since this ψ is normalized to point strike frequency, it is higher than the Oconee PRA value (3.3×10^{-11}), because point strike probability is less than area strike probability.

Three values of ψ_n are derived for small targets (approximately 100 to 1000 ft^2). They are from the Seabrook study and are subdivided into high, medium and low exposure areas. These subcategories are based on judgment and consider where the targets are located relative to the concentration of missiles and the shielding effects of other buildings. Note that the site area considered for the Seabrook analysis missile origination is estimated to be 4.8 million ft^2, which is equivalent to a circle with a radius of about 1200 feet. The mean values from NUREG-4710, Table 4-1b are:

"High exposure" 2.42×10^{-9}/missile/ft^2 of target area/tornado point strike frequency

"Medium exposure" 8.64×10^{-11}/missile/ft^2 of target area/tornado point strike frequency

"Low exposure" 1.54×10^{-11}/missile/ft^2 of target area/tornado point strike frequency

NUREG-4710, pg. G-37 uses weights of 0.1 for high, 0.4 for medium and 0.5 for low exposures. This results in a ψ_n for small targets of:

$$\psi_n = 0.1*(2.42e^{-9}) + 0.4*(8.64e^{-11}) + 0.5*(1.54e^{-11}) = 2.85\times10^{-10}$$

NUREG-4762, pg. G-40 uses weights of 0.1 for high, 0.8 for medium and 0.1 for low exposures. This results in a ψ_n for small targets of:

$$\psi_n = 0.1*(2.42e^{-9}) + 0.8*(8.64e^{-11}) + 0.1*(1.54e^{-11}) = 3.13\times10^{-10}$$

2.3.1.2 ψ-Values Used for CCNPP Analysis

Area Strike Model

For area strike frequency calculations at CCNPP, 2000 feet is chosen based on the findings of the EPRI study, discussed above. Additionally, a significant portion of the area between 2000 feet and 1 mile from the center of the site is water (the Chesapeake Bay) and does not contain any appreciable missiles. See Section 3.3.1 for more discussion of the assumption to use 2000 feet.

Therefore, for area strike models, the EPRI value derived in the Oconee PRA (3.3×10^{-11}/missile/ft^2 of target area/tornado strike frequency) will be used.

Point Strike Model

For point strike models, the mean values for ψ_n (for high, medium and low exposures) derived in NUREG-4710 and 4762 will be used. The weighting factors associated with high, medium and low exposures are chosen based on examination of the layout of the EDG rooftop components.

For the EDGs, the weighting of exposures chosen in NUREG-4710 (0.1, 0.4 and 0.5) seems reasonable given the protection provided by the buildings, structures and the parapet wall. Most of the EDG components on the roof are shielded by the parapet wall, the Auxiliary Building, Containment and the Refueling Water Tank. Therefore, the ψ_n for the EDGs is 2.85×10^{-10}.

2.3.2 Target Area (A)

The target area is the exposed area of the components of concern. Target areas are calculated for one EDG (all three EDGs have the same target area). The calculations are simple area calculations for an open ended cylinder, given a certain length and diameter. The area of the intake filter is a cylinder with one end closed.

Two areas are shown, one for the total area and one for 75% of the area. 75% of the area is considered a reasonable estimate of the area actually exposed to a tornado missile. Since the exhaust piping and silencer generally run along the roof or a wall, 25% of the area is assumed to be shielded from a missile strike. The reduction in area due to this shielding was not accounted for in the intake filter and two portions of the exhaust piping, since they are not shielded as such.

The results are summarized below. All EDGs have approximately the same dimensions.

Component	Total Area	75% Area
EDG intake filter:	158.4 ft^2	158.4 ft^2 (same as 100% area)
EDG exhaust silencer:	247.3 ft^2	185.5 ft^2
EDG exhaust piping:	229.4 ft^2	188.6 ft^2
TOTAL Area (per EDG)	635.0 ft^2	532.4 ft^2

2.3.3 Number of Candidate Missiles (N_m)

The number of candidate missiles (those missiles which could cause damage to the components of interest) is typically determined by a detailed survey and walk down of the area surrounding the site. Although a detailed survey of the site has not been performed, an examination of the area revealed that the number of missiles present at CCNPP seems comparable to the number at other sites described below. The number of missiles chosen for this analysis is calculated in Section 2.3.3.2, based on the data in Section 2.3.3.1.

2.3.3.1 Data from other PRAs

The Oconee PRA (Reference 9, Section K3.2) mentions three values:

6000 missiles (within 2000 feet) from the EPRI study (Reference 6, pg. 3-24)
75,000 missiles (within 1 mile) used in the SAIC study (Reference 9, pg. K-11)
69,000 missiles (within 1 mile) used in the Oconee study (Reference 9, pp. K-8 & K-11)

NUREG-4710, (Reference 3, page G-37) uses a distribution of missiles as described below (no area was given):

Probability Weight	Number of Missiles
0.2	5,000
0.6	25,000
0.2	60,000

Therefore, the weighted average = (0.2*5000)+(0.6*25000)+(0.2*60000) = 28,000

The preliminary values to be used in the Turkey Point IPEEE are 100,000 missiles within approximately one mile. An earlier study of Turkey Point by Sandia (Reference 10, pp. G-40) used a distribution of missiles (no area given):

Probability Weight	Number of Missiles
0.2	10,000
0.6	40,000
0.2	70,000

Therefore, the weighted average = (0.2*10000)+(0.6*40000)+(0.2*70000) = 40,000

The preliminary values to be used in the Fort Calhoun Station IPEEE are 30,000 missiles, which is based on the mean value used in the St. Lucie study.

The Seabrook study (Reference 12, Table IV-10) uses 66,796 missiles within approximately 1200 feet (area from Section 2.3.1.2).

2.3.3.2 Missile Population for CCNPP

Based on data from the studies cited above, a representative value is calculated for CCNPP. It is believed that the EPRI value of 6000 missiles is too low, based on significantly higher values used at other plants and a general survey of the site. Additionally, since Fort Calhoun used NUREG-4710 as a source, the value from Fort Calhoun is not considered, to avoid double counting the data sources. The NUREG-4762 data will not be used since there is a more recent estimate (100,000). Although some of the other studies used a one mile radius from the plant site as the area for the missile population, those values will be considered, since they should be conservative.

An average of the data from NUREG-4710 and the Oconee, Seabrook and Turkey Point analyses was used to calculate the value for CCNPP.

$N_m = (75{,}000 + 69{,}000 + 28{,}000 + 66{,}796 + 100{,}000)/5 = 67{,}760$ (approximately)

This value may be high due to the inclusion of data from sites that used missile populations within one mile and the fact that approximately 20% of the area within 2000 feet of the center of the site is water. However, it does not seem *overly* conservative considering the number of trees, laydown areas and temporary structures in the vicinity of the plant.

2.3.4 Calculation of Missile Strike Probability (P_{ms})

Missile strike probabilities for individual component strikes are calculated based on the values for A, N_m and ψ developed above. Using the equation from Section 2.3, the missile strike probabilities for individual components (one using the point strike and one using the area strike model) are calculated below. Both point and area missile strike probabilities will be used in Section 3.2 with the point and area tornado strike frequencies for calculating CDF.

$P_{ms} = AN_m\,\psi$

Where,

$N_m = 67{,}760$	(Section 2.3.3.2)
$\psi_n = 2.85\times10^{-10}$	(Point strike -Section 2.3.1.2)
$\psi = 3.3\times10^{-11}$	(Area strike - Section 2.3.1.2)
$A = 532.4\ ft^2$	(Section 2.3.2.1)

Therefore,

$P_{ms}(EDG) = 1.03\times10^{-2}$/tornado *point* strike
$P_{ms}(EDG) = 1.19\times10^{-3}$/tornado *area* strike

2.4 COMPONENT DAMAGE PROBABILITY

This section discusses the likelihood of component failure, given a tornado missile strike on that component.

The conservative assumption made in this analysis is that if a missile strikes any part of an EDG, it is assumed to fail. More likely, the failure probability is less than 10%. With respect to the wind speeds experienced in the area (i.e., no tornadoes greater than F-3 intensity or 206 mph (Reference 4, pp. C.35 and D.85 and NSSFC data) and the damage which must be incurred on the EDG components to actually fail the EDG (e.g., crush the exhaust piping enough to greatly restrict flow), a value of 0.1 is likely conservative. However, given that this value would be strictly based on engineering judgment and significant engineering judgment is already used in this analysis, a more conservative value of 1.0 is used.

2.5 CONDITIONAL CORE DAMAGE PROBABILITY (CCDP)

The CCDP was estimated based on sequence examination and probabilistic analysis of the most recent plant model results. The failure of one or more EDGs was analyzed, considering a non-recoverable LOOP.

A CCDP of approximately 0.02 is used based on loss of one or more EDGs. However, there is a possibility that the damage to the EDG exhaust or intake components, due to a tornado, is recoverable. This recovery is not taken into account.

3.0 RESULTS (CORE DAMAGE FREQUENCY)

The core damage contribution due to the vulnerability of the exposed EDG components during a tornado is evaluated. For core damage to occur, a tornado must strike the site and damage the EDGs. A tornado striking the site is assumed to cause an unrecoverable LOOP. This is similar to the assumption taken in NUREG-4710 (Reference 3, pp G-40 and G-49).

For tornado missiles, CDF will be calculated using point strike and area strike models; the choice of model affects the tornado strike frequency (P_S') and the probability of missile strike (P_{MS}). The risk associated with tornado missiles will be based on the highest CDF from these calculations. Core Damage Frequency due to tornado missile impacts is given by:

WHY?, ?
Bounding?

$$CDF_{TM} = P_s' * P_{ms} * P_F * P_{CCD}$$

The likelihood that multiple EDGs are struck by missiles is less than a single missile strike. Also, the CCDP used in this analysis is the same regardless of the number of EDGs struck. Therefore, the CDF calculated here is for a single EDG failure, which is bounding.

P_s'	= Tornado Strike Frequency	
	$= 2.56 \times 10^{-5}$/yr	(Point Strike - Section 2.2.1)
	$= 4.38 \times 10^{-4}$/yr	(Area Strike - Section 2.2.2)
P_{ms}	= Probability of Missile Strike	
	$= 1.03 \times 10^{-2}$	(Point Strike - Section 2.3.4.1)
	$= 1.19 \times 10^{-3}$	(Area Strike - Section 2.3.4.1)
P_F	= 1.0	(Section 2.4.1)
P_{CCD}	=0.02	(Section 2.5.1)

Therefore,

CDF_{TM} (Point Strike) = 5.27×10^{-9}/yr
CDF_{TM} (Area Strike) = 1.04×10^{-8}/yr

3.1 SENSITIVE ASSUMPTIONS

3.1.1 Site Area (5280 or 2000 ft radius)

If the area of the site for tornado missile generation is larger (i.e., by using a one mile radius), the tornado strike frequency will increase by approximately a factor of 3.5 (Section 2.2.2). However, the ψ will decrease by approximately a factor of 7 (=$3.3\times10^{-11}/4.52\times10^{-12}$ from Section 2.3.1.1). It is expected that the number of available missiles will increase, but the value chosen for this analysis is already biased with data from studies using 1-mile radius areas. The assumed missile population will have to double to cause an increase in missile strike frequency. However, none of the studies reviewed, even those using 1-mile radii, used greater than 100,000 missiles. Therefore, it is not expected that CDF will increase enough to change the conclusions of this analysis, if CDF increases at all.

3.1.2 Missile Population

If the actual missile population is higher than the value used, there will be a direct impact (i.e., CDF will increase by the ratio of missile populations) on the CDF due to tornado missiles. However, the value is believed to be conservative as discussed above.

3.1.3 ψ Value

The value chosen for ψ has a direct impact on CDF. However, based on a review of the literature and the complexity of performing a site specific analysis, it is believed that the best values were used. The use of the weighting factors for high, medium and low exposures (Section 2.3.1.2) is also believed to be representative based on the orientation and location of components and random tornado orientations and directions. Even if the ψ value is assumed to be totally based on the high exposure (2.42×10^{-9}), the CDF due to tornado missiles will still be below 10^{-7}.

3.1.4 Tornado Strike Frequency

The tornado experience used to determine strike frequencies is based on fairly recent data, specific to the locale of CCNPP. Using a higher tornado occurrence rate, such as EPRI NP-2005, Region C data (Reference 13), would result in a strike frequency of approximately two times the local strike frequency. This would increase the CDF (calculated using the point strike model) by a factor of two, but not change the conclusions of this analysis.

3.1.5 Conditional Core Damage Probability

CCDP is 0.02 for failure of all EDGs. This was conservatively estimated based on sequence examination and probabilistic analysis of the most recent plant model results.

3.2 CONSERVATIVE ASSUMPTIONS

The following assumptions are considered to be conservative and, based on further analysis, could be made more realistic. They are not listed in any specific order.

1. Assumed that a LOOP is not recoverable following a tornado. There is some probability that offsite power can be recovered before the batteries deplete and/or the EDGs are repaired. This has not been quantified, but the impact of power recovery will be to lower the CCDP and thus, the CDF.

2. Did not account for EDG recovery (e.g., repair, cutting away of damaged piping, etc.). Based on the damage incurred by the exposed EDG components, there may be a simple repair which has not been factored into this analysis.

3. EDG failure probability is conservative (assumed guaranteed failure). As discussed in Section 2.4.1, a value of 0.1 could probably be used and still be conservative.

4. ψ values are based on NRC Region I tornado experience, which has a much higher incidence of high F-Scale tornadoes. There have been no tornadoes F-4 or greater recorded in our area (including the 5° box). Calculations of ψ are based on simulations using trials with various tornado intensities. Since NRC Region I encompasses a large area, including the midwest where there are very strong tornadoes, ψ values calculated are believed to be higher since stronger tornadoes produce more, larger and farther-traveling missiles.

5. Assumed that core damage will result in exposures in excess of 10 CFR Part 100 guidelines. This assumption is conservative in that it assumes the containment function is guaranteed to fail, which is not necessarily true.

4.0 CONCLUSIONS

The risk to the public associated with failures of the EDGs resulting from tornado-induced missiles is very low.

The contribution to core damage to each unit due to a tornado missile strike on the EDGs is nearly 100 times less than 10^{-6}/yr, which would screen it from consideration using the criteria in NUREG-1407 (Reference 11). This is classified as having low risk significance, using the Potential Vulnerability Underlying Cause Review Criteria in Table 3.4.2.1-1 of the Individual Plant Examination Summary Report (Reference 1). Based on the conservatisms in this analysis (Section 3.2), this value may be lower.

For the purposes of this evaluation, CDF is assumed to be equal to expected rate of occurrence of potential exposures in excess of 10 CFR Part 100 guidelines; therefore, the calculated value (1.04×10^{-8}/yr) is acceptable using the methodology proposed in the cover letter, and the contribution to CDF and risk to the public due to a tornado-induced failure of one or more EDGs is negligible.

5.0 REFERENCES

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