TORNADO MISSILE RISK EVALUATION

FOR THE

NUCLEAR SERVICE COOLING WATER SYSTEM FANS

AT

VOGTLE ELECTRIC GENERATING PLANT UNITS 1 AND 2

prepared for
GEORGIA POWER COMPANY

by
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PLANT VOGTLE TORNADO MISSILE EVALUATION REPORT

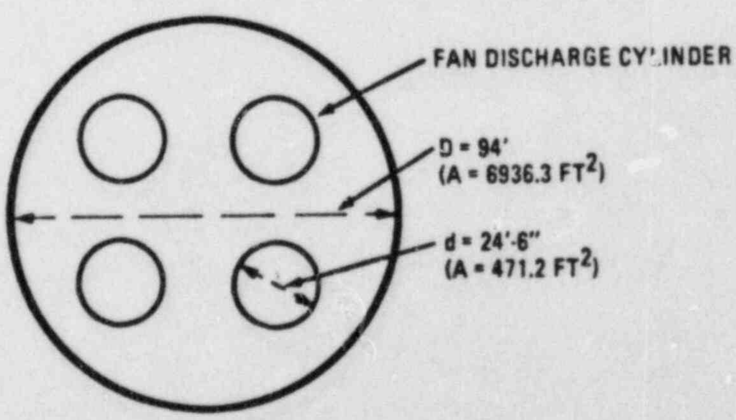
I. INTRODUCTION AND SUMMARY

Tornado-generated missiles are one of the potential hazards to the safe operation of nuclear power plants. This report evaluates the probability of damage to the Nuclear Service Cooling Water (NSCW) system cooling tower fans at Vogtle Electric Generating Plant (VEGP) Units 1 and 2 from tornado-generated missiles. The analysis demonstrates that the median annual probability of tornado-generated missiles striking and damaging one or more NSCW cooling tower fans is extremely small and well below the NRC staff objective of 10^{-7} per year for postulated accidents causing potential exposures in excess of 10 CFR Part 100 guidelines. On that basis, it is concluded that protection of NSCW system cooling tower fans against postulated tornado missile damage is not required.

II. SYSTEM DESCRIPTION

The ultimate heat sinks for Vogtle Electric Generating Plant Unit 1 and Unit 2 are contained in the Nuclear Service Cooling Water (NSCW) systems. Each unit has two independent, redundant NSCW trains consisting of one cooling tower in each NSCW train. The height of each cooling tower is 44'9". The area of the top of each cooling tower is 6936.3 ft^2. Near the top of each cooling tower are four motor-driven fans discharging air through four 471.2 ft^2 openings.

TOP VIEW OF A NSCW COOLING TOWER



During a tornado, offsite power is presumed lost and the reactor automatically trips. Under these conditions, a minimum of three of the four fans in one NSCW cooling tower per unit are required to provide adequate heat rejection. Thus, total NSCW system failure occurs if two or more fans in each of the two redundant NSCW cooling towers per unit become inoperable.

III. ACCEPTANCE CRITERIA

The NRC's acceptance criteria are contained in the "General Design Criteria (GDC) for Nuclear Plants" [1]. Specifically, GDC 2 and 4 apply to this evaluation and are summarized below:

A. GDC 2 requires that "Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as - tornadoes - without loss of capability to perform their safety functions. . ."

B. GDC 4 requires that ". . . structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, . . . from events and conditions outside the nuclear power unit."

The Standard Review Plan (SRP) [2] Section 3.5.1.4 and NRC Regulatory Guide 1.76 [3] provide further guidance in meeting GDC 2 and 4 requirements. Specifically, SRP Section 3.5.1.4 refers to the acceptance criteria of SRP Section 2.2.3 which states "... design basis events include each postulated type of accident for which the expected rate of occurrence of potential exposures in excess of the 10 CFR Part 100 guidelines is estimated to exceed the NRC staff objective of approximately 10^{-7} per year . . . (The) expected rate of occurrence of potential exposures in excess of the 10 CFR 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. . ."

IV. ANALYSIS

The probability of damage to NSCW system cooling tower fans depends on three factors:

A. The tornado occurrence rate at the Vogtle plant site

B. The conditional probability of one or more tornado missiles being generated and entering the top of a NSCW cooling tower given the tornado occurrence, and

C. The conditional probability of cooling tower fan damage, given that a tornado-generated missile has entered the top of a cooling tower.

The tornado occurrence rate at the VEGP site is estimated using National Weather Service historical records of tornado strikes for the site region between years 1950 through 1982 [4]. Table 1 shows 5th, 50th, and 95th percentile estimates of the annual frequency of tornados in a 10,000 square mile area surrounding the VEGP site, the distribution of tornado path areas, and the resulting 5th, 50th, and 95th percentile estimates of the annual probability of a tornado occurrence at the VEGP site. Values shown for the annual frequency of tornado occurrences in a 10,000 square mile area surrounding the site, and the distribution of tornado path areas are based on historical data for the entire state of Georgia. The statewide data yield higher (i.e., more conservative) estimates of the tornado occurrence probability at the VEGP site than do local occurrence data. To allow comparison of predicted tornado occurrence rates with those derived independently by NRC, Table 1 reports mean values of estimated parameters in addition to the 5th, 50th, and 95th percentile values.

The conditional probability of a tornado missile being generated and entering the top of a NSCW cooling tower, given the tornado occurrence, depends on the following factors:

A. The number of potential missiles near the VEGP site

B. The conditional probability of a potential missile becoming airborne (or injected), given the occurrence of a tornado

C. The conditional probability of missiles being transported from their origin to the target, given that they become airborne, and

D. The target area.

The number of potential missiles assumed in the analysis (Table 2) represents a conservative generic missile distribution (see section V) and is based on data from Electric Power Research Institute (EPRI) surveys at seven nuclear power plant sites [5]. The probability of potential missiles becoming airborne is calculated using a missile model developed at Jet Propulsion Laboratory (JPL) [6]. The conditional probability of missiles being transported from their origin to a target is based on a statistical mechanics model [7], [8]. This approach develops a modified Green's function to quantify the probability of the airborne missile striking a unit target area at some distance and elevation from its origin. This probability is then multiplied by the area of the target to obtain the total probability of strike.

Each of the above factors has uncertainty associated with it. For this reason, a probability distribution is used to represent the uncertainty associated with each factor. These uncertainties are propagated throughout the analysis. Therefore, the final result is not a single value for the probability of damage, but a distribution of values. The 5th percentile, median (50th percentile) and 95th percentile values are reported in Table 3. The median value or "best estimate" [9] is compared to the NRC acceptance criteria given in Section III above.

The conditional probability of cooling tower fans being damaged, given that the tornado-generated missile or missiles have entered the top of the cooling tower, is conservatively taken to be certain and total. That is, the conditional probability is taken as unity.

V. ASSUMPTIONS AND CONSERVATISMS

The following assumptions are used in this study.

A. A tornado missile strike in the open top of any one cooling tower represents total NSCW system failure for that unit (see conservatisms A and D below). This implies that one NSCW train is out of service throughout the tornado event and hence the failure of the redundant train's cooling tower is sufficient to fail the entire NSCW system.

B. The distribution of potential tornado missiles by number and length are based on an EPRI survey of seven nuclear plants [5].

C. One half of all potential missiles are distributed up to 20 feet above grade, with the remainder at grade level.

D. The number of unrestrained missiles postulated for this study is equal to 10 percent of the total number of missiles.

Assumptions B, C, and D are based on engineering judgement and lead to a conservative estimation of the distribution of missiles when compared to previously published literature [5], [8]. The median number of missiles (6000) used in this analysis is greater than the 1000 and 2650 missiles derived in references [5] and [8], respectively.

Conservatisms incorporated in this study are as follows:

A. Relationships Between Missile Strikes, Damage, and Activity Releases:

1. Missile-inflicted damage is certain and total

2. Damage leads directly to activity releases in excess of 10 CFR 100.

B Missile Characteristics:

1. The angle distributions for all potential tornado-generated missiles are random.

2. All potential tornado-generated missiles are at random orientation. However, in calculating the probability of injection of potential missiles, their maximum cross-sectional areas are assumed to be perpendicular to the wind. This maximizes the probability of potential missiles becoming airborne.

C. Tornado Occurrence Frequency

The tornado occurrence frequency is based on a 33-year historical record. The data are fitted by a lognormal distribution having a larger mean and spread than the empirical distribution.

D. Geometric Factors:

1. Sheltering by other structures is neglected.

2. A missile strike in any cooling tower opening results in failure. No credit is taken for the existence of four 24'6" diameter openings. Instead one 94' diameter opening is assumed.

3. No credit is taken for the fact that multiple strikes are needed to incapacitate at least two fans in each of two NSCW cooling towers per unit.

VI. RESULTS AND CONCLUSIONS

The results of the probabilistic analysis demonstrate that tornado missile damage to the NSCW cooling tower fans has a low probability of occurrence. The lower bound (5th percentile), median (50th percentile) and upper bound (95th percentile) values are reported in Table 3. The median value, 2×10^{-9} per year is substantially smaller than the NRC acceptance criterion of 10^{-7} per year.

Table 1

PROBABILITY OF TORNADO OCCURRENCE AT THE VEGP SITE

	Lower (5th Percentile)	Median (50th Percentile)	Mean (for comparison)	Upper (95th Percentile)
Annual Frequency of Tornado Occurrence in an Area of 10,000 mi^2 Surrounding the VEGP Site	1.39	3.23	3.70	7.52
Tornado Path Area (sq. mile)	$1.10(10^{-3})$	$6.77(10^{-2})$	1.55	4.15
Annual Probability of Tornado Occurrence at the VEGP Site	$3.26(10^{-7})$	$2.18(10^{-5})$	$5.72(10^{-4})$	$1.46(10^{-3})$

Table 2

DISTRIBUTION OF POTENTIAL MISSILES

	Lower	Median	Upper
Local Surface Density of Potential Missiles Near the Cooling Towers (ft^{-2})	$9.40(10^{-5})$	$2.40(10^{-4})$	$6.13(10^{-4})$
Effective Number of Potential Missiles on Site and in Vicinity	2350	6000	15,300

Table 3

PROBABILITY OF DAMAGE TO NSCW COOLING TOWER FANS FROM TORNADO-GENERATED MISSILES PER YEAR*

	Lower (5th Percentile)	Median (50th Percentile)	Upper (95 Percentile)
Probability of Tornado Striking the Plant Site	$3(10^{-7})$	$2(10^{-5})$	$1(10^{-3})$
Conditional Probability of Hitting the Top of the Cooling Tower	$9(10^{-8})$	$1(10^{-4})$	$2(10^{-2})$
Conditional Probability of Incapacitating NSCW System Given a Hit	1	1	1
Total Probability, P_T	$2(10^{-13})$	$2(10^{-9})$	$7(10^{-6})$

*All numbers are rounded to one significant figure. Simulated distributions reported in rows 2 and 4 are not lognormal.

VIII. REFERENCES

1. 10 CFR Part 50, Appendix A, "Design Basis for Protection Against Natural Phenomena."

2. Standard Review Plan, U.S. Nuclear Regulatory Commission, NUREG-75/087.

3. Nuclear Regulatory Commission, "Design Basis Tornado for Nuclear Power Plants," Regulatory Guide 1.76, April 1974.

4. "U.S. Tornado Breakdown by Counties 1950-1982," U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, National Severe Storms Forecast Center, Room 1728, Federal Building, 601 E. 12th Street, Kansas City, Missouri 64106.

5. Twisdale, L. A., et al., "Tornado Missile Risk Analysis," EPRI NP-768, May 1978, EPRI NP-769, May 1978.

6. Redmann, G. M., et al., "Wind Field and Trajectory Models for Tornado-Propelled Objects," EPRI 308, Technical Report 1, February 1976.

7. Goodman, J. and Koch, J. E., "Conditional Probability of the Tornado Missile Impact Given a Tornado Occurrence," Proceedings of the International ANS/ENS Topical Meeting on Probabilistic Risk Assessment, Port Chester, New York, September 20-24, 1981, pp. 419-424.

8. Goodman, J. and Koch, J. E., "The Probability of a Tornado Missile Hitting a Target," Nuclear Engineering and Design 75 (1982), pp. 125-155.

9. Apostolakis, G., et al., "Data Specialization for Plant Specific Risk Studies," Nuclear Engineering and Design 56 (1980), pp. 321-329.

BNL COMMENTS ON THE VOGTLE AFWS RELIABILITY ANALYSIS

The following is a list of comments from Brookhaven National Laboratory (BNL) on the VEGP Auxiliary Feedwater System Reliability Analysis. The comments were drawn from the Technical Evaluation Report (TER) entitled "Review of the Vogtle Units 1 and 2 Auxiliary Feedwater System Reliability Analysis", which was prepared by BNL. This TER was attached to a January 10, 1985, letter from Elinor G. Adensam to Donald O. Foster.

Comments:

(1) pp. 8, 29 - Pump testing procedure requires further discussion by the applicant. does the test of automatic signals (18 mo) actually stroke valves + start pump unavailability during this test is most severe in cold S/D valve position after test needs double verification (TMI II.E.1.1) Staggered Tests [illegible]

(2) pp. 10, 20 - No preaccident operator errors were assumed for the manual valves in the applicant's report. This omission has a significant impact on the quantitative results.

(3) p. 10 - Applicant assumed that the probability of a motor-operated valve failing is 5.0E-3/demand. BNL assumed a 0.2 recovery factor resulting in a motor-operated valve failure rate of 1.0E-3/demand.

(4) pp. 11, 23 - Westinghouse Technical Specifications allow for two inoperable AFWS pumps. However, BNL and the applicant assumed that only one AFWS train can be in maintenance at a time.

(5) p. 12 - Applicant did not assume maintenance of the diesel generators.

(6) p. 12 - Table on p. 12 shows discrepancies between applicant's data and BNL data.

(7) p. 16 - The check valves on the pump suctions have had their flappers removed. This could present operational problems.

(8) p. 17 - Emergency procedures for transferring AFWS suction from one CST to the other CST have not been provided by the applicant.

(9) p. 17 - Possible common mode failures are discussed in section 9.1.6.

(10) p. 18 - Emergency procedures for operation of the AFWS must be provided by the applicant.

(11) p. 19 - Applicant states that unavailability due to testing and common cause human error during testing and maintenance were considered in the fault tree. However, BNL was unable to find these aspects in the fault tree.

(12) p. 19 - The fault trees do not usefully model maintenance acts excluded by the technical specifications (i.e. simultaneous maintenance of AFWS trains).

(13) p. 20 - Applicant has maintenance data for DC power, but no data for failure on demand. Further, there is no event for DC power maintenance in the fault tree, but there is an event for random DC power failure.

(14) pp. 22-23 - In order to perform their own assessment, BNL modified the applicant's fault trees. One modification included modeling the possibility of maintenance on the steam generator intake check valves and stop check valves (Note: This appears to disagree with BNL statement on p. 12 that maintenance was not assumed for valves other than motor-operated valves). Another modification models the operator failing to close the recirculation valve in the condensate system return line. There were also other minor modifications to the fault tree.

February 14, 1985

MEETING SUMMARY DISTRIBUTION

Docket No(s): 50-424/425
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