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RECIP.NAME RECIPIENT AFFILIATION
NOVAK,T.H. Assistant Director for Licensing

SUBJECT: Forwards responses to Auxiliary Sys Branch 820929 request for addl info re probabilistic risk assessment of tornado missile damage to UHS.

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ARIZONA PUBLIC SERVICE COMPANY

STA. ________ P.O. BOX 21666 - PHOENIX, ARIZONA 85036

October 15, 1982
ANPP-22033 - WFQ/KEJ

Mr. T. H. Novak
Assistant Director for Licensing
Division of Licensing
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Subject: Palo Verde Nuclear Generating Station
(PVNGS) Units 1, 2 and 3
Docket Nos. STN-50-528/529/530
File: 82-056-026; G.1.01.10

Reference: Letter from J. Kerigan, NRC, to E. E. Van Brunt, Jr., APS, dated September 29, 1982

Dear Mr. Novak:

Attached are the responses to the referenced letter requesting additional information concerning the PRA of Tornado Missile Damage to the Station Ultimate Heat Sink.

If you have any questions concerning this matter, please contact me.

Very truly yours,

E. E. Van Brunt

E. E. Van Brunt, Jr.
APS Vice President,
Nuclear Projects
ANPP Project Director

EEVBJr/KEJ/sp
Attachment

cc: E. Licitra (w/a)
J. Wermiel (w/a)
L. Bernabei (w/a)
P. Hourihan (w/a)
A. C. Gehr (w/a)

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PDR ADOCK 05000528
A PDR

STATE OF ARIZONA)
) ss.
COUNTY OF MARICOPA)

I, Edwin E. Van Brunt, Jr., represent that I am Vice President Nuclear Projects of Arizona Public Service Company, that the foregoing document has been signed by me on behalf of Arizona Public Service Company with full authority so to do, that I have read such document and know its contents, and that to the best of my knowledge and belief, the statements made therein are true.

Edwin E. Van Brunt

Edwin E. Van Brunt, Jr.

Sworn to before me this 15th day of October, 1982.

Notary Public

My Commission expires:

My Commission Expires May 19, 1986

PALO VERDE NUCLEAR GENERATING STATION
REQUEST FOR ADDITIONAL INFORMATION
AUXILIARY SYSTEMS BRANCH

1. Provide further justification for the assumption in the PRA study that automobiles can be excluded from consideration in the tornado missile analysis.

   Response:

   One of the assumptions listed in Section 1.4 of the PRA study indicated that:

   "...Class G missiles (auto) are excluded from consideration because the parking area and roads are far from the spray pond and a tornado of credible intensity cannot transport them such a distance nor to the elevation of the spray nozzles (12 ft)."

   This assumption is more accurately stated as follows:

   "...Class G missiles (auto) are excluded from explicit consideration..." The probability of the auto becoming airborne is one order of magnitude less than the "standard" missile. In addition, a survey of seven plants [1] indicates that autos constitute about 1% of the total number of potential tornado missiles. These two factors suggest that the number of "standard" missiles should be increased by 0.1% to account for the Class G missiles. This factor is insignificant when compared to the factor of 10 conservatism used in the number of "standard" missiles.

2. The PRA study as currently presented may not provide sufficient evaluation of the effects of existing site features on the installed spray pond. This analysis is required in order to assure that a complete assessment of potential tornado missile damage to the spray pond has been performed. Therefore, provide the following additional information.

   a) It appears that only the SRP Section 3.5.1.4 missile spectrum was considered in determining the "standard" missile used in the PRA study. As the study is an evaluation of an existing structure, it must be shown that the standard missile bounds all potential missile impacts against unprotected spray pond components. Therefore, provide justification and any necessary supporting calculations for excluding potential site missiles of less mass than the "standard" missile traveling at lesser velocity from the PRA evaluation.

   b) A response to part a) above is not required if it can be demonstrated that the actual design wind loading and impulse load due to tornado missiles for which the spray riser piping and nozzles have been designed is adequate to assure that unacceptable damage does not occur as a result of impact from the realistic potential site missiles to be addressed in a. above.

Response:

a) The concept of the "standard" missile was developed from the spectrum in SRP Section 3.5.1.4. However, analysis of surveys at seven nuclear plants [1] shows that potential site missiles have aerodynamic characteristic that are essentially the same as the "standard" missile, except for the automobile. Since the number of potential site missiles varies from time to time, it is not reasonable to base an analysis on one plant survey. The present study uses a conservative distribution of number and type of missiles based on the seven surveyed plants. The "standard" missile bounds all potential missiles.

The study conservatively assumes that any missile strike on the spray arm completely destroys all four spray arms in that set. thus, the missile mass and velocity are immaterial.

b) Although the spray pond system is designed to withstand tornado wind loads up to 300 MPH, it is not specifically designed to withstand impulse loads associated with missile strike. As mentioned above, the study conservatively assumes spray system damage from any missile impact.

3. Identify the upper and lower bounds selected for each of the conditional probabilities in the PRA study and justify the actual bounds selected.

Response:

Equation 4.1 in the study identifies two conditional probability terms. The first is the conditional probability of hitting a target given the tornado occurrence (P_H). The second is the conditional probability of target damage given the missile hit (P_D). The latter term was conservatively assigned the maximum value of unity. Thus, the upper and lower bounds of the conditional probability P_H is the matter for consideration. (In the study consideration was given to multiple missile strikes, however, this response will be limited to discussion of one strike.)

The conditional probability of hitting a single target given the tornado is dependent on five factors, as follows:

$$P_H = n_p A \sum_{F=0}^{6} \Phi(F/a)\, \eta(F)\, \psi(z,F)$$

where:

n_p = local density of potential missiles near the spray ponds (ft^2),

A = effective target area of one nozzle set (ft^2),

$\Phi(F/a)$ = relative frequency of tornado with severity equal to F on the Fujita scale given path area (a) of tornado,

$\eta(F)$ = Probability that a potential missile becomes airborne (probability of missile injection) for tornado of F-scale,

$\psi(z,F)$ = height distribution of airborne missiles.

The local density of potential missiles near the spray ponds is determined from the nuclear plant surveys. The upper and lower bounds are $3.6x10^{-4}$ and $2.0x10^{-4}$, respectively. These values are conservative in that they are five to nine times greater than data developed by Twisdale [1] based on the same surveys.

The probability of hitting the effective area A by a point missile has to be the same as the probability of hitting the real target by a real missile of length ℓ. Therefore, the effective area A depends on the real geometry of the target and the spectrum of missile lengths. A Monte Carlo simulation was applied to estimate the effective area of a nozzle set as a function of missile length. Instead of a real spectrum of missile lengths based on survey data a more conservative spectrum was used, assuming that 20% of the potential missiles are utility poles with length ℓ = 35 ft and 80% of the missiles have length ℓ = 20 ft each. The effective area for this spectrum is 2.5 times greater than the spectrum based on the survey data.

The summation of the three terms in the above equation is the conditional probability that a tornado missile becomes airborne and is transported to a target at elevation z, given the tornado occurrence. The first term, relative frequency Φ (F/a) of tornado with severity equal to F on the Fujita scale given path area a, is based on historical data consisting of about 20,000 tornado occurrences. The relative frequency Φ (F/a) for typical values of path area a and tornado intensity F are given in Table 3-1. This distribution conservatively over estimates the higher intensity tornadoes. The second term, η(F) is the probability that a potential missile becomes airborne for a given intensity tornado.

The upper and lower limits are provided in Table 3-2. The upper limit corresponds to the case when the restraining force for horizontal injection is zero friction and for vertical injection is gravity. The lower limit is based on a restraining force equal to five times gravity. The third term ψ(Z,F) is the height distribution of airborne missiles. The height distribution for the spray nozzles, located at elevation z = 12′, is given in Table 3-2. This distribution is based on a theoretical model. The model has been found to be in good agreement with Twisdale′s [1] Monte Carlo simulation.

TABLE 3-1

RELATIVE FREQUENCY OF TORNADO $\Phi(F/a)$ WITH SEVERITY F ON THE FUJITA SCALE GIVEN PATH AREA a

F \ a	Lower Path Area 0.012 mi^2	Median Path Area 0.345 mi^2	Upper Path Area 10.150 mi^2
0	.6417	.1293	.0004
1	.3344	.5516	.1514
2	.0173	.2737	.4238
3	.0066	.0416	.3037
4	.0000	.0036	.0993
5	.0000	.0002	.0185
6	.0000	.0000	.0029

TABLE 3-2

PROBABILITY $\eta(F)$ THAT A POTENTIAL MISSILE BECOMES AIRBORNE AND PROBABILITY $\psi(Z,F)$ THAT AN AIRBORNE MISSILE IS ELEVATED TO A HEIGHT Z = 12 FT

F-Scale	$\eta(F)$			$\psi(Z,F)$ (Z = 12 ft)
	Lower Limit	Median	Upper Limit	
0	0.00	0.01	0.18	0.224
1	0.00	0.03	0.43	0.273
2	0.00	0.04	0.65	0.349
3	0.01	0.09	0.77	0.430
4	0.08	0.25	0.82	0.588
5	0.22	0.43	0.86	0.701
6	0.35	0.56	0.89	0.779

4. The probability of the tornado as derived and used in Appendix A of the PRA study does not appear to be a total conditional probability, but a conditional probability of tornado severity occurrence given a path area. Justify the acceptability of this approach.

Response:

The probability $P_o(a)$ considered in Appendix A is the conditional probability of tornado occurrence with path area (a). The so-called "total" probability P_o of tornado occurrence is simply the expectation of tornado strike and can be expressed through $P_o(a)$ by:

$$P_o = \int_0^\infty P_o(a) \; f(a) \, da = \frac{\nu \bar{a}}{S}$$

where f(a) is distribution of striking tornado by path area a, and $\bar{a}$ is an average tornado path area given by the equation:

$$\bar{a} = \int_0^\infty a \; f(a) \, da$$

The expected value P_o is not used directly for two reasons. First, the PRA Study used distributions for the probability of events of interest, and not a point estimate (e.g. mean value). Second, the probability of hitting a target depends on the path area. The expected value P_o is of limited usefulness even in the case of a point estimate because of strong correlation between path area and Fujita intensity. If the correlation between path area and Fujita intensity is taken into account (i.e. the joint distribution function $f(a,F) = f(a) \, \Phi(F/a)$ is used), the result is significantly greater. This approach was used in the PRA Study.

5. Identify and justify all assumptions and assumed conditions utilized in determining the conditional probabilities associated with Appendices B, C, D and E. The justification shall discuss the significance of each assumption and its effect (the sensitivity) on the final answer.

Response:

All significant assumptions and conditions that effect the conditional probabilities associated with Appendices B, C, D and E were considered in the response to question 3. It was shown that the effective area is overestimated by a factor of 2.5. The tornado path area is overestimated by a factor of 5 and the upper bound number of potential missiles was increased by a factor of 10 over Twisdale's [1]. The total conservatism incorporated in the upper limit of probability is 125 (5x10x2.5).

6. In Appendix A of the PRA study, an assumption is made of a constant tornado frequency per unit area to account for a nonuniform geographic distribution of tornado characteristics. Justify the approach of adjusting the tornado frequency per county based on population distribution and neglecting the meteorological and/or geographic variabilities of the site area.

Response:

Appendix A of the PRA study examined a thirty year record of tornado occurrences for each county in the state of Arizona. A regression analysis indicated that the low number of recorded tornadoes for some counties could be attributed to their low population density. It was further found that the tornado record for Maricopa County had the highest occurrence rate and did not require adjustment for population density.

The regression analysis did show a mild correlation between county area and the number of tornado occurrences. This correlation may be due to meteorological or geographic variables. However, any adjustments for these effects would result in a reduced frequency of tornado occurrence rate at the plant site compared to the Maricopa County data. Since this adjustment could not be justified and may be nonconservative, it was not used. Since the plant is located in Maricopa County and it reports the highest frequency of tornado occurrences, the actual record was used in the PRA analysis.

7. In Appendix B of the PRA study, it is stated that $P_o(a)$ is the probability of any tornado striking per year. However, this quantity is actually the probability of tornados of path area a. Explain the effects on the results for smaller path area tornados as appears to often be the case with tornadoes near the site area.

Response:

The quantity $P_o(a)$ is the conditional probability of tornado occurrence with path area a striking the plant site. The words "with path area (a)" was omitted because the argument "a" in the notation $P_o(a)$ is implicit. As indicated in response 4, the PRA study considered a distribution of tornadoes by path area. The final results are for tornadoes included in the distribution.

The contribution of any tornado size depends on frequency of occurrence according to Thom distribution. Tornadoes with small path area are less likely to strike a given target; however, tornadoes with small path area generally mean more frequent occurrences. The net effect is that tornadoes with small path areas are more likely to strike the plant. These factors have been included in the PRA Study.

References

1. Twisdale, L.A., Dunn, W.L. Clue, J. "Tornado Missile Risk Analysis," EPRI NP-768, May 1978.