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

ENCLOSURE

SAFETY EVALUATION

H. B. ROBINSON UNIT NO. 2

THE EFFECTS OF TORNADOES ON THE AVAILABILITY OF THE AUXILIARY FEEDWATER AND SERVICE WATER SYSTEM

1.0 INTRODUCTION

The safety evaluation report (SER) related to Amendment No. 74 to the facility operating license for H. B. Robinson Unit No. 2 (HBR2) regarding the TMI Action Plan (NUREG-0737), Item II.E.1.1, Auxiliary Feedwater System (AFWS) upgrades issued on January 6, 1983 required the licensee to provide supporting information to demonstrate that there is acceptable tornado missile protection for the AFWS. The SER additionally identified a concern regarding potential loss of the service water system (SWS) resulting from possible damage to the SWS pump motors due to a tornado strike in the area where these pump motors are located. The staff was particularly concerned with this potential loss since the SWS not only provides a backup water supply to the AFWS but also serves as an integral portion of the ultimate heat sink for the plant by performing the essential cooling function for normal and accident conditions. In response to the above concerns, by letter dated August 29, 1983, the licensee submitted a report, NUS-4396, wherein they provided a tornado missile probabilistic risk assessment (PRA) to demonstrate the availability of the AFWS. Additionally, the report discussed the effect of tornadic and non-tornadic extreme winds on the SWS. By letter dated May 29, 1984, the licensee provided additional clarification relating to the questions raised by the staff on the above submittal.

Based on review of the above information, the National Bureau of Standards, our consultant regarding tornado missile PRA, developed the enclosed technical evaluation report which is a part of this SER. Because the TER estimate of

1.3×10^{-5}/year for the probability of failure of the AFWS at HBR2 due to tornadic and non-tornadic extreme winds exceeded our guideline, by letter dated March 14, 1985, we requested the licensee to either 1) perform an additional probabilistic analysis to demonstrate that failure of the AFWS at HBR2 due to the effects of tornadic and non-tornadic extreme winds is within our guideline value (10^{-6}/year), or 2) provide positive tornado missile protection to the SWS to assure its function as a backup AFWS water supply and UHS. In response to the above request, by letter dated June 13, 1985, the licensee provided a reanalysis wherein they demonstrated that the failure probability for the AFW system due to tornadic and non-tornadic extreme winds is within our acceptable limit. Our evaluation relating to protection of the AFWS against the effects of tornadic and non-tornadic extreme winds is provided below. Our evaluation additionally addresses the concern relating to the SWS UHS function.

2.0 EVALUATION

2.1 Effects of Tornadic and Non-tornadic Extreme Winds on the Availability of the AFWS

As stated above, the TER estimated a total failure probability of about 1.3×10^{-5} per year for the AFWS due to tornadic and non-tornadic winds at the site. This value, however, did not include credit for manual realignment by the operators within 30 minutes to permit lube oil cooling to the turbine driven AFWS pump powered by the pump flow itself. Additionally, the above value did not include credit for the newly installed dedicated diesel which has been provided by the licensee to ensure an adequate power source to achieve safe shutdown as part of compliance with 10 CFR 50 Appendix R requirements. The dedicated diesel generator is cooled by a separate self contained cooling unit while the two emergency diesel generators are cooled by the SWS. In their submittal dated June 13, 1985, the licensee assigned failure probabilities of 5.1×10^{-2}/year and 2.5×10^{-2}year respectively for failure to complete the above manual realignment and for the non-availability of the dedicated diesel due to electrical and mechanical failures unrelated to the occurrence of extreme winds. The licensee indicated that the failure rate assigned to the dedicated diesel was determined using the guidelines of NUREG/CR-2989, "Reliability of Emergency AC Power Systems at Nuclear Power Plants." Using these failure rates in conjunction with the initial probabilities of failure for the AFWS, the licensee calculated a total failure probability of 9.6 x 10^{-7}/year for the AFWS due to tornadic and non-tornadic extreme winds. This value satisfies our criterion of 10^{-6}/year for acceptable tornado missile damage probability.

Based on our review of the above information, we conclude that the AFWS at HBR2 meets our guidelines regarding failure probability due to tornado missile, and, therefore, we find the AFWS to be acceptable.

2.2 Effects of Tornadic and Non-tornadic Extreme Winds on the Availability of the SWS

With regard to protection for the SWS against the effects of tornadic winds, we concur with the licensee that because of the design of the system, only the exposed SWS pump motors need be considered for possible damage due to tornado strike in the area of concern. The pump motors are situated in a sheet metal casing on top of the plant intake structure and are vulnerable to damage from either the direct effect of high winds or from tornado induced missiles.

Damage to the SWS pump motors due to tornado missiles is not of primary concern. This is because the circulating water pump motors located on the western side of the SWS pump motors will effectively shield the SWS pump motors from missiles generated by tornadoes traveling in the predominant direction, WSW to ENE. Further, our consultant notes in the TER, missiles are more likely to be hurled from HBR Unit 1 in the direction of the intake structure by only relatively wide tornadoes or tornadoes traveling in the less likely East or ESE direction. Therefore, the TER has assumed that damage to all four SWS pump motors from tornado induced missiles is unlikely or at any rate of secondary importance in comparison with damage due to the wind load itself. We concur with the TER finding in this regard.

As for damage to the SWS pump motors due to the direct effect of tornadic wind load, the TER estimates the probability of failure of the SWS pump motors due to high winds in the area (concurrent with loss of offsite power) to be about 10^{-5}/year. We concur with the TER findings in this regard. However, we note the following additional conservatisms in the probabilistic analyses upon which this value is based:

1. Due to lack of details on the structural capability of the SW pump motors (i.e., lack of fragility curve for the pump motors showing different probabilities of failures at different wind speeds), the TER has assumed that the pump motors will fail if and only if subjected to winds corresponding to the F3 Fujita Scale or stronger (i.e., winds in excess of 158 mph) at the pump motor site. We note that there is some probability that the pump motor will withstand F3 scale winds without loss of function because of the limited body of available data on damage associated with tornadoes of this magnitude.

2. In their earlier submittals, the licensee utilized a different but reasonable calculational technique to demonstrate that the failure probability of the SWS pump motors due to wind loading was somewhat lower (as low as 1.55×10^{-6}/year) than the 10^{-5} value indicated in the TER. Thus, there is uncertainty in the failure probability that would tend to indicate some conservatism in the TER.

   Current staff acceptance criterion (10^{-6}/year) is expressly written to govern probability of tornado missile damage, not damage due solely to wind loading. No numerical probability guideline has been established for wind load alone.

In their June 13, 1985 submittal and a subsequent telephone conversation with us on June 28, 1985, the licensee also stated that in its operating history for 14 years, HBR2 has never experienced tornadic or non-tornadic extreme wind related failure of the SW pump motors or total loss of offsite power. The highest one-minute average wind speed experienced in the vicinity of HBR2 was 60 mph, which is significantly less than the 158 mph wind assumed to cause failure of the SWS pump motors and less than the 73 mph wind assumed to cause loss of offsite power. This experience is supported by the high wind probabilities used in the PRA analyses.

From our review, it is our judgment that providing additional protection to the SWS pump motors against potential damage due to the direct effect of high winds is not cost beneficial because of the low estimated failure probability of 1 x 10^{-5}/year. Additionally, as previously pointed out in the SER, the auxiliary feedwater system will be available for decay heat removal during hot shutdown following a tornado strike at the site.

Based on the above, we conclude that the probability of loss of the SWS pump motors due to tornado wind loads and tornado missiles is acceptably low to assure the essential cooling function for the plant for a safe shutdown. We, therefore, conclude that the current design of the SWS at HBR2 meets the requirements of General Design Criteria 2 and 4 with regard to protection against the effects of tornadoes and tornado missiles, and is, therefore, acceptable.

Principle Contributor:

T. Chandrosekaran

Technical Evaluation of Report NUS - 4396 "The Effects of Tornadoes on the Availability of the Auxiliary Feedwater System at H. B. Robinson Unit 2" (Second Revision, August 1983).

Emil Simiu

1. INTRODUCTION

The objective of this evaluation is to assess the validity and the degree of conservatism of the assumptions, data, and mathematical approach used in the Report NUS - 4396[a] to estimate the effect of extreme winds on the availability of the Auxiliary Feedwater System at H. B. Robinson Unit 2.

2. NOTATIONS

The following notations are used:

Events

W	Occurrence of winds in excess of 73 mph
O	Loss of Offsite Power due to wind
E	Failure of Emergency Power Sources due to mechanical and electrical failure unrelated to occurrence of extreme winds
A	Failure of Auxiliary Feedwater Sources due to mechanical failure unrelated to occurrence of extreme winds

[a] Hereinafter referred to as the Report

8504020422

C	Failure of Condensate Storage Tank due to extreme winds or wind-borne missiles
M	Failure of operators to realign valves manually in less than 30 minutes to direct suction from Condensate Storage Tank to Service Water System
S	Failure of Service Water Pumps due to extreme winds or wind-borne missiles
F_3	Occurrence of winds corresponding to the F_3 Fujita Scale or stronger (i.e., winds in excess of 158 mph)

Probabilities

P(J)	Probability of event J
P(J,K)	Probability of events J and K

3. ASSUMPTIONS USED IN THE REPORT

The following assumptions are listed in the Report:

1. The occurrence of winds in excess of 73 mph (event W) at the plant site will cause the loss of offsite power (event O) and, therefore, the failure of the deep well sources since no emergency power is supplied to the well pumps. Thus, P(O) = P(W).

2. Offsite power is not recoverable in the short term (less than a few hours).

3. The Condensate Storage Tank will fail owing to direct wind or to missile effects if and only if subjected to winds corresponding to the F3 Fujita scale or stronger (i.e., winds in excess of 158 mph) at the location of the tank, so that P(C) = $P(F_3)$.

4. The probability of the failure of operators to manually realign valves to direct suction from the Condensate Storage Tank to the Service Water System in less than 30 minutes is about 10^{-2}, i.e., P(M) = 10^{-2}.

5. The probability that both emergency power sources will not function owing to mechanical or electrical failures unrelated to the occurrence of extreme winds is 10^{-3} per demand, i.e., P(E) = 10^{-3}.

6. The probability that the Auxiliary Feedwater Sources will not function owing to mechanical failures unrelated to the occurrence of extreme winds is 10^{-4} per demand, i.e., P(A) = 10^{-4}.

7. In the absence of any details on the capacity of the service water pump motors, it is assumed that the pump motors will fail (i.e., event S will occur) if and only if subjected to winds corresponding to the F3 Fujita scale or stronger (i.e., winds in excess of 158 mph) at the pump site.

8. Because (a) Service Water Pumps are likely to be shielded by the circulating water pumps, and (b) it would appear that missiles would be hurled from Unit 1 in the direction of the intake structures only by relatively wide tornadoes or tornadoes traveling in an E or ESE direction, it is assumed in the Report that damage from missiles to all four Service Water Pumps is unlikely.

9. The probability of failure due to high winds of the Service Water Pumps is numerically the same as the probability of failure of the Condensate Storage Tank, i.e., P(S) = P(C) (see assumptions 3 and 7). Note that the numerical equivalence does not imply the simultaneity of events C and S since the same tornado does not necessarily cause both events).

10. The probability of simultaneous failure due to high winds of both the Condensate Storage Tank and the Service Water Pumps is about one sixth of the probability of failure of either the Condensate Storage Tank or of the Service Water Pumps alone, i.e., P(C,S) = (1/6) x P(C).

11. Events O, E, and A are mutually independent.

12. Events C and M are independent.

4. DATA USED IN THE REPORT

The Report uses data on tornadoes obtained from the National Severe Storms Forecast Center (NSSFC), and on the NSSFC classification of these tornadoes in terms of the Fujita scale. Data on non-tornadic extreme winds are not used in the Report.

5. PROBABILISTIC ANALYSIS OF WIND EFFECTS ON THE AVAILABILITY OF THE AUXILIARY FEEDWATER SYSTEM (AFWS)

It is stated in the Report that the Auxiliary Feedwater System may become unavailable in one of three ways, described in subsections 5.1, 5.2, and 5.3, respectively.

5.1 FAILURE DUE TO EVENTS O AND E

The following relation holds (see assumption 11, Sect. 3):

$$P(O,E) = P(O)\ P(E) \tag{1}$$

According to assumption 1, Sect. 3, P(O) = P(W). According to the Report, P(W) = 1.9×10^{-4} per year (due only to tornadoes). However, according to memorandum Docket No. 50-261 from William P. Gamill to Olan D. Parr, dated June 12, 1982 on Tornado and Extreme Wind Frequencies for H. B. Robinson Plant (TAC # 49223), winds in excess of 73 mph due to non-tornadic phenomena are more likely than those due to tornadoes, so that P(W) ≈ $3\text{x}10^{-3}$ per year (see Fig. 1). Since, according to assumption 5, Sect. 3, P(E) = 10^{-3}, it follows from Eq. 1 that

$$P(O,E) \approx 3\text{x}10^{-3} \times 10^{-3} = 3\text{x}10^{-6} \text{ per year} \tag{1a}$$

5.2 FAILURE DUE TO EVENTS O AND A

The following relation holds (see assumption 11, Sect. 3):

$$P(O,A) = P(O)\ P(A) \tag{2}$$

From assumptions 1 and 6, Sect. 3, and Fig. 1, it then follows

$$P(O,A) \approx 3\text{x}10^{-3} \times 10^{-4} = 3\text{x}10^{-7} \text{ per year} \tag{2a}$$

5.3 FAILURE DUE TO LOSS OF OFFSITE POWER AND UNAVAILABILITY OF AUXILIARY FEEDWATER SOURCES CAUSED BY EXTREME WINDS

Three possible scenarios are considered in the Report with regard to the unavailability of auxiliary feedwater sources. These are described in subsections 5.3.1, 5.3.2 and 5.3.3.

5.3.1 FAILURE DUE TO EVENTS O AND C AND M

The following relation holds:

$$P(O,C,M) = P(C,M) \tag{3a}$$

$$= P(C)P(M) \tag{3b}$$

$$= P(F_3)P(M) \tag{3c}$$

Equation 3a holds because the occurrence of the extreme winds that result in the failure of the Condensate Storage Tank also causes the loss of offsite power. Equation 3b and 3c follow from assumptions 12 and 3, Sect. 3, respectively. According to the Report, $P(F_3) = 1.55 \times 10^{-6}$ per year. However, according to Fig. 1, $P(F_3) \approx 10^{-5}$ per year. From Eq. 3c and assumption 4 it then follows that

$$P(O,C,M) \approx 10^{-5} \times 10^{-2} = 10^{-7} \text{ per year} \tag{3d}$$

5.3.2 FAILURE DUE TO EVENTS O AND S

The following relation holds:

$$P(O,S) = P(S) \tag{4a}$$

$$= P(F_3) \tag{4b}$$

Equation 4b follows from assumptions 9 and 3, Sect. 2. From fig. 1 it then follows:

$$P(O,S) \approx 10^{-5} \text{ per year}$$

Note that, according to the Report, $P(O,S) \approx 1.55 \times 10^{-6}$ per year.

5.3.3 FAILURE DUE TO EVENTS O, AND C, AND S

The following relation holds:

$$P(O,C,S) = P(C,S) \tag{5a}$$

$$= 1/6\ P(C) \tag{5b}$$

$$= 1/6\ P(F_3) \tag{5c}$$

Equations 5b and 5c follow from assumptions 10 and 3, respectively. From Eq. 5c and Fig. 1

$$P(O,C,S) = 1/6 \times 10^{-5}$$

Denoting the complement of event S by $\overline{S}$, it follows that

$$P(O,C,\overline{S}) = P(C,\overline{S})$$

$$= 5/6 \times 10^{-5}$$

Note also that $P(O,C,\overline{S},M) = P(O,C,\overline{S})\ P(M)$.

6. DISCUSSION AND SUMMARY

It is stated in the Report (last paragraph of p. 4-6) that "the Service Water provides cooling for the Auxiliary Feedwater Pumps (Motor and Steam driven)", and that failure of the Service Water Pump Motors would result in "failure of the Auxiliary Feedwater System even if the Condensate Storage Tank were available". It is further stated (p. 4-7 of Report) that "It is possible to realign the system so that the lube oil cooler can be cooled by Auxiliary Feedwater pump flow but this would need to be done within 30 minutes. Conservatively, no credit was taken for this action".

The assumptions listed in the Report (see Sect. 3 of this evaluation) are acceptable from the point of view of their conservatism, as is the assumption that failure of the Service Water System Motors entails failure of the Auxiliary Feedwater System even if the Condensate Storage Tank were available. The mathematical approach is also acceptable. However, the reviewer feels that the data are incomplete in that nontornadic wind speed information is not included. Indeed, probabilities P(O) and P(W) are determined by the occurrence of nontornadic winds (see Fig. 1).

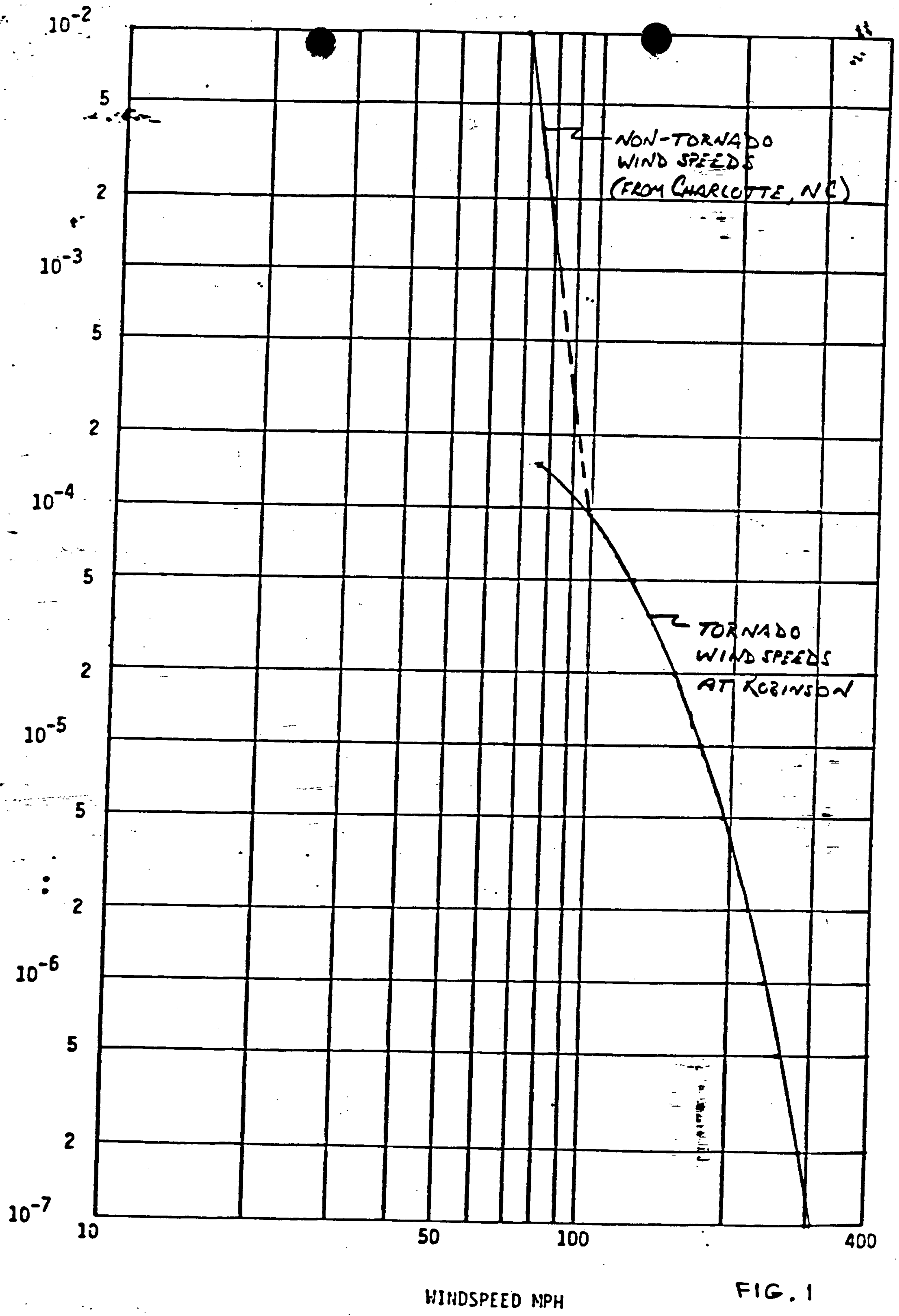
From the assumptions listed in the Report (see Sect. 3 herein), the information on wind speeds provided by NRC (see Fig. 1 herein), and the description in the Report of the ways in which the Auxiliary Feedwater System may become unavailable (see Sect. 5 herein), it follows that the probability of failure of the Auxiliary Feedwater System can be estimated as follows:

$$P_f \approx P(O,E) + P(O,A) + P(O,C,\overline{S},M) + P(O,S)$$

$$\approx 3 \times 10^{-6} + 3 \times 10^{-7} + \frac{5}{6} 10^{-7} + 10^{-5}$$

$$\approx 1.34 \times 10^{-5} \text{ per year}$$

This is about one order of magnitude higher than the probability of failure estimated in the Report.



NON-TORNADO WIND SPEEDS (FROM CHARLOTTE, NC)
TORNADO WIND SPEEDS AT ROBINSON
PROBABILITY YR^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10
50
100
400
WINDSPEED MPH

FIG. 1