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July 5, 1983

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Operating Reactors Branch No 5
Nuclear Reactor Regulation
US Nuclear Regulatory Commission
Washington, DC 20555

DOCKET 50-155 - LICENSE DPR-6 -
BIG ROCK POINT PLANT -
SEP TOPICS III-2 "WIND AND TORNADO LOADINGS" AND
III-4.A "TORNADO MISSILES" - PRA EVALUATIONS

The NRC, by letters dated November 29, 1982 and December 9, 1982, transmitted Safety Evaluation Reports on SEP Topics III-4.A "Tornado Missiles" and III-2 "Wind and Tornado Loadings," respectively, for the Big Rock Point Plant. Consumers Power Company February 28, 1983 letter entitled "Systematic Evaluation Program - Consumers Power Company Position Regarding the Resolution of Open Topics" documented our commitment to perform probabilistic risk assessment (PRA) evaluations for these topics. Consumers Power Company letter dated June 1, 1983 entitled "Integrated Assessment of Open Issues and Schedules for Issue Resolutions (Including Environmental Equipment Qualification and Generic Letter 82-33 Issues)" indicated that the PRA evaluations would be submitted to the NRC by January 9, 1984. The attached report fulfills our commitments.

The PRA was used to determine: 1) the affect on core damage probability of various wind loadings, tornado loadings and missiles; 2) the maximum wind speed at which minimum systems and structures may be available to safely shutdown the plant; and 3) the cost-effectiveness of a proposed modification. The proposed modification evaluated by the PRA calls for installing portable pumps to provide another source of makeup water to the emergency condenser through portions of the Fire Protection System thereby reducing core damage frequency and containment failure probability. It was found that the cost-benefit ratio for this modification is slightly less than the $1000/man-rem guideline.

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Consumers Power Company plans to assess the need to implement the proposed modification during the next quarterly TRG meeting. Resolution of SEP Topics III-2 and III-4.A will be incorporated into the living schedule and submitted to the NRC as part of our next status update of the schedule.

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Attachment

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ATTACHMENT

Consumers Power Company
Big Rock Point Plant
Docket 50-155

SEP Topic III-2 "Wind and Tornado Loadings"
SEP Topic III-4.A "Tornado Missiles"
PRA Evaluations

July 5, 1983

49 pages

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SAFETY EVALUATION REPORT

Review of
SEP Topic III-2, Wind and Tornado Loadings
SEP Topic III-4.A, Tornado Missiles

Big Rock Point Nuclear Plant
Docket Number 50-155

1.0 INTRODUCTION

THE NRC's criteria for the evaluation of wind and tornado loadings at the Big Rock Point site resulted in a maximum expected wind speed of 272 mph at a 10^{-7} per year probability level. The purpose of this evaluation is to determine the effect on core damage frequency and societal risk of various intensities of wind and tornado loadings, assessing both potential damage from the wind and tornado loadings and damage as the result of any tornado missiles which may be generated.

2.0 REVIEW CRITERIA

A. Standard Review Plan, Section 3.5.1.4, states: "At the operating license stage, applicants who were not required at the construction-permit stage to design to one of the above missile spectra and the corresponding velocity set, should show the capability of the existing structures and components to withstand at least Missiles 'C' and 'F'."

Missiles "C" and "F" are as specified below:

1. Steel rod: 1 inch in diameter by 3 feet long; weight 8 pounds; horizontal velocity of 0.6 times total tornado velocity.

2. Utility pole: 13-1/2 inches in diameter by 35 feet long; weight 1,490 pounds; horizontal velocity of 0.4 times total tornado velocity.

B. The currently accepted design criteria for wind and tornado loadings are outlined in the Standard Review Plan, Sections 3.3.1, 3.3.2 and 3.8, and in Regulatory Guides 1.76 and 1.117.

3.0 RESPONSE TO SEP TOPICS

A review of SEP Topics III-2 and III-4.A revealed that these issues cannot be treated independently. For each safety system, a threshold wind velocity exists above which it is no longer necessary to consider the effects of tornado missiles.

Table 1 presents the maximum wind velocities which most of the critical structures at the Big Rock Point site can sustain before significant damage occurs as a result of the wind loadings. This table only considers the superficial structure and not the limits of the equipment which is housed in these structures. This evaluation will make assumptions to the effect that equipment located in structures or housing that is damaged will also be damaged. Below the wind velocity limits of Table 1, the effect of tornado missiles on that structure must be evaluated.

The areas of the plant site which are most critical to the operation of the plant are: (1) the screenwell/pump house, (2) the emergency diesel generator room, (3) the turbine building, (4) the cable penetration room, (5) the ventilation stack, (6) the reactor building, and (7) service building. Wind or tornado loadings of a magnitude which results in damage to the above structures would also cause a loss of offsite power. This evaluation will assume that prior to damage occurring to other plant structures, offsite power to the site will be lost.

The consequences of high winds or tornadoes are dependent upon the delay time between the loss of offsite power and the damage which is done to plant structure. The main steam isolation valve and the emergency condenser outlet valves close/open automatically on a loss of offsite power. This requires any structural damage which could disable these valves to occur coincidentally with the loss of offsite power. Below the threshold velocity of 138 mph, from Table 1, a sensitivity study to determine the effects of the immediate failure of the emergency condenser outlet valves and the MSIV on core damage frequency will be performed for tornado missile damage to the cable penetration room. Above this threshold, it will be assumed that the valves fail coincidentally with the loss of offsite power.

Both the main steam isolation valve and the emergency condenser outlet valves are powered from the 125 V dc power supply. The power cables to these valves are routed through the penetration room; an area which has been identified as being vulnerable at wind speeds above 138 mph. At this velocity, the metal siding is torn from the supporting steel structure. This does not imply that the cable trays within the penetration area will also fail at this velocity. Because of the nature of the remaining walls and ceiling which form this enclosure, it can be assumed that a protective enclave will still exist after the metal siding has failed which provides sufficent protection to allow the main steam isolation valve to close and the emergency condenser valves to open. The assumption will be made that the cable penetration area fails at wind velocities in excess of 150 mph. The effect of tornado missiles at wind velocities below 150 mph will also be evaluated.

The loss of offsite power event tree from the Big Rock Point PRA is shown in Figure 1. From the event headings, the critical areas of the plant which could affect the successful mitigation of the loss of offsite power transient can be identified. In addition to the penetration room, which has already been identified, the critical areas are: (1) the emergency diesel generator room, (2) the screenwell/pump house which houses the diesel and electric fire pumps, (3) the station power room, (4) the demineralized water system, and (5) the control room. The most logical method of determining the effects of wind loadings and tornado missiles is to evaluate wind loading intervals which are defined by the survivability of plant structures.

3.1 EFFECT OF WINDS IN THE INTERVAL (80 TO 150 MPH)

From Table 1, damage from wind loadings to plant structures which house equipment needed to mitigate the effects of a loss of power transient begins at 152 mph when damage to the screenwell/pump house occurs. The lower limit of the wind speed interval, 80 mph, corresponds to the original design criteria at which no damage from tornado missiles is postulated to occur. In this interval only, the effects of tornado missiles will be considered.

In Consumers' June 16, 1982 response to the NRC on SEP Topic III-4.A, the following areas were found vulnerable to tornado missiles:

A. The screenwell/pump house

B. The turbine building

C. The emergency diesel generator building

D. The cable penetration room

The probability that a tornado-generated missile strikes a vulnerable area of the Big Rock Point Nuclear Plant is calculated from the work performed under EPRI Project 616 and reported in EPRI NP-768 and 769.

The impact and damage probabilities calculated for a single-unit plant will be used to evaluate the potential for tornado missile damage at Big Rock Point. To determine the damage probabilities from tornado missiles at Big Rock Point, the tornado missile damage probabilities given in EPRI NP-768 must be adjusted for the tornado-occurrence frequency at the Big Rock Point site, the site-specific target area and the number of tornado-generated missiles.

The impact probabilities in EPRI NP-768 were calculated for modified wind-speed ranges. The impact frequencies must be adjusted by the ratio of the frequency of tornadoes at the Big Rock Point site to the frequency of tornadoes at the reference plant site. The tornado wind-speed intervals and their associated probabilities are shown in Table 2.

For the wind-speed interval of 80 to 150 mph, the probability of occurrence at the Big Rock Point site is 3.06×10^{-5} (the sum of the probabilities for F-scale ranges 2 and 3. For the reference plant site, the probability is 1.31×10^{-3} (the sum of the F-scale ranges 2, 3 and 4). The ratio is .023, which reflects the fact that the Big Rock Point Plant site is in a zone of a low tornado frequency.

Another adjustment which must be made is for the plant area. The layout and structure descriptions of the reference plant is shown in Figure 2.

The total plant structure area which is exposed to tornado missiles is 360,000 $feet^2$. The corresponding surface area at Big Rock Point is 100,000 $feet^2$. Assuming the same missile density as the reference site, the impact probabilities would be divided by the Big Rock Point structural surface area.

In calculating the impact frequency, both single and multiple missiles were considered. The impact frequency for multiple missiles was calculated assuming 6,000 potential missiles were available. However, there are fewer potential missiles at the Big Rock Point site. Using the results of a survey presented in EPRI NP-769, Table 6-2, in which Plant 5 and 6 are both operating (with Plant 5 comprised of three units) the average number of potential missiles available at the operating plant site is approximately 3,000. This is the value which will be used to compute the effects of multiple missiles. While the effects of multiple missiles are not linear, a conservative approximation of missile impact probability can be calculated by multiplying the single impact probability by the number of potential missiles.

The single impact probabilities for each F-scale range is given in Table 3. The probability of any target being damaged by a tornado missile is:

$$P = P_I \times R_W \times A_T \times F_S \times N$$

Where:

P_I = Target Impact or Damage Probability (yr^{-1} ft^{-2})

R_W = Ratio of the Wind-Speed Interval Probabilities

A_T = Target Area

F_S = Shielding Factor or the Portion of the Target Not Protected by Missile Shields

N = Number of Potential Missiles

Some of the potential targets at Big Rock Point are protected by 10- to 12-inch-thick concrete walls. The reference analysis performed damage probability calculations for six-inch walls and for nominal thickness walls; ie, the walls' normal-design thickness. Because none of the walls analyzed in the reference study had nominal thickness of less than 12 inches, the results of the 6-inch wall thickness calculation will be used to analyze the Big Rock Point concrete walls.

The areas of interest, as already stated, are the screenwell/pump house (or more specifically, the electric and diesel fire pumps) the diesel generator room, the station power room, the demineralized water system, the control room, and the cable penetration area. The diesel generator room has three outside walls of ten-inch reinforced concrete and shares one wall with the screenwell/pump house. The roof consists of metal decking supported by structural steel. No missile shielding is assumed. The dimensions of the diesel generator room are 13 feet x 30 feet x 15 feet. A missile hit anywhere on an exposed wall or the roof will be assumed to fail the diesel generator. Hits on the concrete walls will use the damage probabilities of Table 4 and hits on the roof, which is a metal deck supported by structural steel, will use the impact probabilities of Table 3. The impact probability (P_I) for the wind-speed interval of interest is 5.06×10^{-8}/yr. The damage probability is 3.79×10^{-9}/yr. The failure probability of the diesel generator due to tornado-generated missiles is:

$$PQ = (5.06 \times 10^{-13}/\text{yr ft}^2 \times .023 \times 390 \text{ ft}^2 \times 1.0 \times 3000) + (3.79 \times 10^{-14}/\text{yr ft}^2 \times .023 \times 840 \text{ ft}^2 \times 1.0 \times 3000)$$

$$PQ = 1.58 \times 10^{-8}$$

The event tree for the loss of offsite power with failure of the diesel generator is shown in Figure 4. The failure of the diesel generator in coincidence with the loss of offsite power limits the makeup to the emergency condenser to the capability of the operator to open VEC-1 and the performance of the diesel fire pump. In the event that RDS/CS is required, delivery to the reactor vessel will be through one set of core spray valves, which are dc powered, and from the diesel fire pump. The core damage frequencies for both the expected value and the 95% limit are given in Table 5.

The screenwell/pump house has three completely exposed walls and one partially exposed wall of ten-inch reinforced concrete. The roof consists of metal deck supported by structural steel. The impact area for failure of the fire pumps will be less than the exposed area of the protective structure. However, an extremely conservative assumption will be made that an impact on the screenwell/pump house fails both the diesel and electric fire pump. The probability is:

$$PC = (5.06 \times 10^{-13}/\text{yr ft}^2 \times .023 \times 2013 \text{ ft}^2 \times 1.0 \times 3000) + (3.79 \times 10^{-14}/\text{yr ft}^2 \times .023 \times 2355 \text{ ft}^2 \times 1.0 \times 3000)$$

$$PC = 7.64 \times 10^{-8}$$

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The event tree for the loss of offsite power with failure of the fire pumps is shown in Figure 5. In this event tree, no branches which contain RDS/CS are permissible due to the unavailability of the fire pumps. Long-term cooling (given successful transfer of the demineralized water and an air compressor to the 2B bus) is accomplished by the continued delivery of makeup to the emergency condenser from the demineralized water pump. The core damage frequencies for both the expected value and the 95% limit are given in Table 6.

The cable penetration area is vulnerable to tornado missiles through the 4.5-inch reinforced concrete roof and through the east wall. It will be assumed that any impact on these areas will result in the complete disruption of all power and control cable which pass through this area. The probability is:

$$PC^1 = (5.06 \times 10^{-13}/\text{yr ft}^2 \times .023 \times 897 \times 1.0 \times 3000) + (3.79 \times 10^{-14}/\text{yr ft}^2 \times .023 \times 798 \times 1.0 \times 3000)$$

$$PC^1 = 3.34 \times 10^{-8}$$

The event tree for the loss of offsite power with the failure of the cable penetration room is shown in Figure 6. This event tree assumes that the emergency condenser valves and the MSIV (which automatically change position on loss of offsite power) have achieved their required state prior to damage to the cable penetration area. In the event of damage to the cable penetration area, signals to CV-4028 (the valve which controls delivery to the emergency condenser from the demineralized water system) and to VEC-1 (which allows flow from the fire protection system) will be inhibited. This will require the operator to manually open VEC-1 to provide flow from the fire protection system. Also, with the failure of the cable penetration area, the RDS/CS will be disabled due to the interruption of the power and control signals to the RDS valves. The core damage frequencies for both the expected and the 95% limits are given in Table 7.

If the cable penetration room should be disabled before the emergency condenser valves open and the MSIV closes, the probability of core damage will be equal to the probability of cable penetration room damage. With the emergency condenser valves closed, no decay heat can be removed from the emergency condenser and the means of delivering makeup flow becomes immaterial. With the disabling of the RDS/CS, Nothing is available to prevent core damage. The core damage frequency, given the failure of the emergency condenser outlet valves and the MSIV, is given in Table 8.

The demineralized water system can fail from either a direct hit upon the demineralized water tank or one upon the demineralized water pump room in the turbine building. The demineralized water tank is assumed to be completely exposed to tornado missiles, while the demineralized pump room is exposed on the north and south walls. The east and west walls of this room are protected by the thick concrete walls of the pipe tunnel and the radwaste rooms, respectively. The probability that a missile will strike the demineralized water tank is:

P (Tank) = (5.06E-13) (.023) (267) (3000)

P (Tank) = 9.32E-9

The failure probability of the south wall will be calculated using the impact probability and the failure probability of the north wall will be calculated using the damage probability. The probability of a hit upon the demineralized water pump room is:

P (Room) = (5.06E-13) (.023) (552) (3000)
+ (3.79E-14) (.023) (552) (3000)

P (Room) = 2.07E-8

The total probability of disabling the demineralized water system with a tornado missile is:

PD = P (Tank) + P (Room)

PD = 9.32E-9 + 2.07E-8 = 3.00E-8

The sequence core damage probability for loss of offsite power with failure of the demineralized water system is given in Table 9.

The station power room is vulnerable to tornado missiles from both the east and south. The west is protected by the thick concrete walls of the pipe tunnel and the north by the four-foot, six-inch concrete wall which shields the control room. In the event of a hit upon the station power room, it is assumed that all ac and dc power will be lost to the plant's components. This assumption is made because of the location of the 2B bus and the station batteries. The only source of decay heat removal in this situation would be for the operator to manually open VEC-1 and to supply makeup to the emergency condenser with the diesel fire pump. Without ac and dc power, the core spray valves cannot be opened. However, the RDS will still be able to actuate should reactor water level reach the low-level set point. The probability of a missile impact on the station power room is:

Psp = (5.06E-13) (.023) (2047) (3000)

Psp = (7.14E-8)

The sequence core damage frequencies for a loss of offsite power with damage to the station power room are given in Table 10.

As is the case with the cable penetration room, if the station power room is disabled coincident with the loss of offsite power (ie, prior to opening of emergency condenser valves and closure of the MSIV), the probability of core damage will be equal to the probability of a tornado missile damaging the station power room. The core damage frequency under this circumstance is given in Table 11.

A tornado missile can impact the control room from the south and east walls. The south wall consists of 0.5-inch-thick steel plating over partition which contains two windows and a door. The east wall is one-foot-thick concrete. In the event of an impact upon the control room, all failure probabilities for event tree headings which contain operator action are increased to unity. This affects the event headings Em, the makeup to the emergency condenser, and Y, the use of the control rod drive pumps to maintain reactor vessel inventory.

The probability of a tornado missile damaging the control room was calculated using the impact probabilities for the south wall and the damage probability for the east wall. The probability is:

$$P_{cr} = (5.06E\text{-}13)\ (.023)\ (410)\ (3000) + (3.79E\text{-}14)\ (.023)\ (250)\ (3000)$$

$$P_{cr} = 1.49E\text{-}8$$

An impact upon the control room not only is assumed to fail event headings which involve operator action, but is also assumed to fail the RDS/CS since the actuation cabinets for this system are located within this room. Without makeup to the emergency condenser, which is completely operator-dependent upon the loss of offsite power or the RDS/CS, there are no success paths. However, some of these functions may be performed at the alternate shutdown panel. If that is the situation, then the core damage probability can be reduced by factoring in those operator actions which can performed from this panel.

The sequence core damage frequencies for a loss of offsite power with damage to the main control room are given in Table 12.

Another situation would be the simultaneous failure of multiple components. Of particular interest is the simultaneous failure of the diesel generator and the fire pumps. The probability of damaging two components which cannot be damaged by the same missile (ie, they are mutually exclusive events) is evaluated by the expression:

$$P^N[(A|Ij) \cap (B|Ij)] = 1 - [1 - P(A|Ij)]^N - [1 - P(B|Ij)]^N + [1 - P(A|Ij) - P(B|Ij)]^N$$

Using this expression, the probability that both the emergency diesel generator and the fire pumps would fail simultaneously due to tornado missiles is less than 10^{-10}.

The sequences which are created by tornado missiles in the wind-speed interval from the loss of the diesel generator and the loss of the fire pump are shown in Figures 4 and 5. It is assumed that short-term and long-term recovery of offsite power is not possible within 24 hours. Because offsite power cannot be restored, the definition of long-term cooling will change. These sequences will be handled on a case-by-case basis. The sequence quantification is shown in Tables 5 and 6. The sequences are grouped by containment state at the time of core damage. This will be valuable in performing a cost/benefit analysis.

The effect of a tornado missile impacting the cable penetration area should also be evaluated. All power and control signals to in-containment equipment must pass through this area. The failure probability of the cable penetration area due to tornado missiles has been computed above. Table 7 presents the results of the sequence quantification. The effect of the loss of the cable penetration area on the loss of offsite power sequences is shown in Figure 6. The random failure of the diesel generator (Q) is still included because long-term cooling can be accomplished by using the electric or diesel fire pumps to provide secondary makeup water to the emergency condenser.

3.2 EFFECT OF WIND SPEEDS IN THE INTERVAL (150 TO 200 MPH)

At tornado wind speeds above 150 mph, the damage caused by the wind loadings begins to dominate. In the case of the emergency diesel generator room and the screenwell/pump house, the concrete walls collapse at 212 mph and 152 mph, respectively. Figure 9, which is taken from the NRC's evaluation of this topic for Big Rock Point, shows the probability of exceeding threshold wind speeds. At 152 mph, the probability is approximately 8×10^{-6}/year; and for 212 mph, it is approximately 1.6×10^{-6}/year.

The 95% confidence limits for these wind speeds are 6×10^{-5}/year and 2×10^{-5}/year, respectively. Using the information from Table 1, it can be determined that the maximum wind velocities which are of concern in this evaluation occur at 150 mph and 200 mph. Figure 9 presents the probability of exceeding these wind velocities. Since the damage caused by a 150-mph wind is different from the damage which would be caused by a 200-mph wind, the effects of these two wind velocities must be evaluated separately.

Because the probabilities of Figure 9 are cumulative, the probability of wind speeds in the interval 150 mph to 200 mph must be determined. Mathematically, this is represented as.

$$P(150\text{-}200 \text{ mph}) = \int_{150}^{\infty} h(x)dx - \int_{200}^{\infty} h(x)dx;$$

or simply the probability of exceeding a 150 mph-wind less the probability of exceeding a 200-mph wind. From Figure 9, the probability of wind velocities in the interval 150 mph to 200 mph is:

$$P(>150) - P(>200) = 8 \times 10^{-6} - 1.6 \times 10^{-6} = 6.4 \times 10^{-6}$$

Using the 95% confidence limit of Figure 9, the probability of wind speeds occurring in the interval from 150 to 200 mph becomes:

$$P(>150) - P(>200) = 6.0 \times 10^{-5} - 1.4 \times 10^{-5} = 4.6 \times 10^{-5}$$

Winds in excess of 150 mph will result in the failure of the concrete walls of the screenwell/pump house and possibly the failure of the cable penetration area. The diesel and electric fire pumps are assumed to fail when the screenwell/pump house fails. However, if the cable penetration room fails (as it is assumed to for the purposes of this analysis) the sum of core damage frequencies for wind loadings in the 150 to 200 mph interval is equal to the initiator frequency; namely, 6.4×10^{-6} for the expected value and 4.6×10^{-5} for the 95% confidence limit (see Table 13). Failure of the cable penetration room, with the assumption of failure of the emergency condenser valves to open and the MSIV to close, is sufficient to result in core damage without the failure of the screenwell/pump house.

3.3 EFFECTS OF WIND SPEEDS IN THE INTERVAL (200-250 MPH)

The next interval of tornado wind velocities to be evaluated are those in the interval 200 to 250 mph.

At this velocity, the walls of the emergency diesel generator room collapse and the ventilation stack fails in addition to the damage to the screenwell/pump room and the turbine building, which has already been described. The probability of winds in this interval is:

$$P(200\text{-}250 \text{ mph}) = \int_{200}^{\infty} h(x)dx - \int_{250}^{\infty} h(x)dx;$$

or simply the probability of exceeding a 200 mph-wind minus the probability of exceeding a 250 mph-wind. From Figure 9, the probability of winds in the interval 200 mph to 250 mph is:

$$P(>200) - P(>250) = 1.6 \times 10^{-6} - 3 \times 10^{-7} = 1.3 \times 10^{-6}$$

Damage from wind loadings in this interval would increase the failure probability of the emergency diesel generator (Q) heading to unity. The assumption of failure to restore offsite power in the short term (F_S) and the long term (F_ℓ) would also apply in this situation. With the loss of offsite power, the failure of the EDG and the failure of the screenwell/pump house, long-term makeup to the emergency condenser is impossible. However, failure of the cable penetration area precludes operation of the emergency condenser and is sufficent to result in core damage without the failure of either the screenwell/pump house or the diesel generator room.

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The collapse of the chimney is not assumed to contribute to an increase in core damage frequency; however, the collapse of the chimney could result in a breach of containment integrity. This is not significant since the containment is not isolated due to the failure of the MSIV to close. The probability of wind velocities in the interval 200 to 250 mph using the 95% confidence limits of Figure 9 is:

$$P(>200) - P(>250) = 1.4 \times 10^{-5} - 3.0 \times 10^{-6} = 1.1 \times 10^{-5}$$

The core damage frequencies for both the expected probability and the 95% confidence limit are shown in Table 14.

In the event that the containment can be isolated, the containment failure probability from the collapse of the ventilation stack can be calculated. It is assumed that the stack is equally likely to fall in any direction and that any collapse of the stack which impacts the reactor building will result in a breach. The probability of the stack falling on the reactor enclosure is equal to the ratio of an arc about the reactor enclosure to the circumference of a circle whose diamater is equal to the height of the stack. This is shown pictorially in Figure 10 and the probability is .28.

3.4 EFFECTS OF WIND SPEEDS IN THE INTERVAL (250 TO 272 MPH)

For the last tornado wind loading interval 250 to 272 mph, the failures are the same as those described for the 200 to 250 mph interval. No damage to the reactor building was calculated up to 250 mph. For this evaluation, it will be assumed that the reactor building fails at wind speeds above 250 mph. This assumption has no effect on this evaluation because of the assumption of MSIV failure coincident with the loss of offsite power. The expected core damage frequency for the tornado wind loading interval 250 to 272 mph is given in Table 15. The probability of winds in this interval is:

$$P(>250) - P(>272) = 3.0 \times 10^{-7} - 1.0 \times 10^{-7} = 2.0 \times 10^{-7}$$

At the 95% confidence limit, the interval extends from 250 mph to 360 mph and the probability, taken from Figure 9, is:

$$P(>250) - P(>360) = 3.0 \times 10^{-6} - 1.0 \times 10^{-7} = 2.9 \times 10^{-6}$$

The core damage frequency for the 95% limit is given in Table 15.

4.0 CALCULATED EFFECTS ON SOCIETAL RISK

The effect of tornado wind loadings on plant risk is equal to the core damage frequency multiplied by the containment failure probability. The core damage frequencies have already been determined in the previous sections and the containment failure probability will be dependent upon the wind velocity interval.

It will be assumed that missile damage to the cable penetration room and station power room occurs prior to, or simultaneous with, a loss of off-site power 50 percent of the time. As such, their contribution to the containment release frequency will be taken as one-half of the values provided in Table 7 plus one-half of the value provided in Table 8 for the case of missile damage to the cable penetration room and one-half of the values listed in Table 10 plus one-half of the value listed in Table 11 for the case of missile damage to the station power room.

For the wind velocity interval 80 to 150 mph, the containment failure probabilities are the same as those considered in the PRA. The sequences presented in Tables 5 through 15 would be contributors to Release Category BRP-3. (A description of release categories can be found in Section 5, Appendix V of the Big Rock Point PRA.) The containment failure probabilities are .064 for sequences which are isolated and 1.0 for those which are not isolated. Table 16 presents the sequence release category frequencies for the expected values.

At wind-loading speeds above 150 mph, the containment failure probability is assumed to be unity. The sum of the sequence release probabilities for the four wind-speed intervals using expected values is 7.96×10^{-6}. This represents less than 3.0 percent of the total release category frequency for BRP-3.

Table 17 provides the release category frequencies at the 95 percent limits.

5.0 COST-BENEFIT ANALYSIS

A modification which has been proposed to reduce the probability of core damage and containment release due to tornadoes and tornado-generated missiles is the locating on site of portable pumps. In the event that the Big Rock Plant incurs tornado-related damage, the pumps would provide a source of makeup water to the emergency condenser through the fire system piping thus reducing the probability of core damage. A cost-benefit analysis will be undertaken to determine the cost-effectiveness of such a modification. The analysis will be performed with the assumption that an alternate shutdown panel is in place in the core spray pump room. In the event that tornado damage is such that the normal means of opening the emergency condenser outlet valves and closing the MSIV is not available, this panel will provide an alternate path through which these actions can be performed.

Sequence core damage frequencies have been presented in Tables 5 through 15. The values provided in these tables will be recalculated to account for the availability of the alternate shutdown panel and the portable pumps.

TABLE 5 - Tornado Missile Damage to the Diesel Generator, Wind Speed Interval 80 to 150 mph.

The proability of a failure of long-term cooling (L) is taken to be the probability that the diesel fire pump will fail to run for 24 hours. Because it is already assumed that the emergency condenser outlet valves have opened and the MSIV has closed, the value of L (4.8×10^{-4}) is not affected by the availability of the alternate shutdown panel. The presence of portable pumps will reduce the value of L by providing an additional means of makeup to the emergency condenser. The value of L now becomes the product of diesel pump unavailability and portable pump unavailability:

L = (Failure of diesel fire pump) (Failure of portable pumps)
  = (Failure of diesel fire pump) (Pump fails to run + operator fails to put pumps into service)

$$= (4.8 \times 10^{-4})\ (1.0 \times 10^{-2} + 2.0 \times 10^{-3})$$

$$= 5.76 \times 10^{-6}$$

The probability of portable pump failure was obtained from failure data provided in Appendix III of the BRP PRA. The probability of operator error was taken from NUREG/CR-1278; the Handbook of Human Reliability Analysis.

E_m is the probability of a failure to makeup to the emergency condenser. The value of E_m is reduced somewhat by the availability of portable pumps:

E_m = (VEC-1 fails to open) + [Diesel fire pump fails to start + pump out of service + no fuel for pump] (portable pumps fail)

$$= (8 \times 10^{-3}) + (3.06 \times 10^{-3} + 1.33 \times 10^{-4} + 1 \times 10^{-3})\ (1.2 \times 10^{-2})$$

$$= 8.05 \times 10^{-3}$$

The values of E_v, Emergency Condenser failure due to failure of the outlet and/or inlet valves to open; I, failure to isolate the primary system; and C, failure of the RDS/core spray are not affected by the addition of the alternate shutdown panel or the portable pumps.

TABLE 6 - Tornado Missile Damage to the Fire Pumps, Wind Speed Interval 80 to 150 mph.

The value of L is dominated by the failure of the diesel generator to run for 24 hours (the diesel generator is used to power the demineralized water pump). The addition of the alternate shutdown panel will have no effect on long-term cooling availability. The installation of portable pumps will reduce L by a factor equal to the pumps' unavailability.

L = (Demineralized pump unavailability) (Portable pump unavailability)
= (Demineralized pump unavailability) (Makeup valve VEC-1 fails to open + portable pumps fail)

$= (.48)\ (8 \times 10^{-3} + 1.2 \times 10^{-2})$

$= 9.6 \times 10^{-3}$

E_m is affected in the same way as L. That is, its value remains unchanged with the addition of the alternate shutdown panel but is reduced by a factor of 2.0×10^{-2} if the portable pumps are assumed to be in place:

$$E_m = (.25)\ (2 \times 10^{-2})$$
$$= 5 \times 10^{-3}$$

The values of E_v; I; Q (failure to provide emergency power); and Y (failure to provide primary system makeup) remain unchanged.

TABLE 7 - Tornado Missile Damage to the Cable Penetration Room, Wind Speed Interval 80 to 150 mph.

TABLE 8 - Same as Table 7, Except Damage to Cable Penetration Room Assumed to Occur Coincident With Loss of Offsite Power.

The presence of the alternate shutdown panel will allow opening of the emergency condenser outlet valves and closure of the MSIV. This, in effect, eliminates Table 8. With the alternate shutdown panel in place, the value of L, E_v, Q and I remain the same as those given in Table 7. The value of E_m listed in Table 7 is dominated by the failure of an operator to manually open VEC-1. With the alternate shutdown panel operable, VEC-1 can be opened remotely and E_m becomes equal to:

(VEC-1 fails to open) + (Diesel pump fails) (Electric pump fails)

= (VEC-1 fails to open) + [(Diesel pump out for maintenance) + (pump fails to start) + (Pump fails to run)] [(Electric pump out for maintenance) + (Pump fails to start) + (Pump fails to run) + (Diesel generator fails to run)]

$= (8 \times 10^{-3}) + [(1.33 \times 10^{-4}) + (3.1 \times 10^{-3}) + 4\ (2 \times 10^{-5})]\ [(8.03 \times 10^{-4}) + (5.6 \times 10^{-3}) + 4\ (4 \times 10^{-6}) + 4\ (2 \times 10^{-2})]$

$= 8.3 \times 10^{-3}$

The pump failure data was obtained from Appendix III of the BRP PRA. An operating time of four hours was assumed.

With portable pumps installed, the value of E_m is:

(VEC-1 FTO) + (Diesel fire pump fails) (Electric fire pump fails) (Portable pumps fail)

$= (8 \times 10^{-3}) + (3.31 \times 10^{-3})\ (8.64 \times 10^{-2})\ (1.2 \times 10^{-2})$

$= 8.00 \times 10^{-3}$

The value of L will also be reduced by a factor equal to the portable pump failure probability.

L (With both fire pumps available + portable pumps)
$= (2.3 \times 10^{-4})\ (1.2 \times 10^{-2}) = 2.76 \times 10^{-6}$

L (With diesel fire pump only + portable pumps)
$= (4.8 \times 10^{-4})\ (1.2 \times 10^{-2}) = 5.76 \times 10^{-6}$

TABLE 9 - Tornado Missile Damage to the Demineralized Water Tank and Pump Wind Speed Interval 80 to 150 mph.

The values of the accident sequences listed in Table 9 are not affected by the installation of the alternate shutdown panel. The availability of portable pumps will reduce L by a factor equal to the probability of portable pump failure: 1.2×10^{-2}. The value of E_m will become equal to 8.05×10^{-3} when the availability of the portable pumps is considered. Having portable pumps onsite will not affect the values of C, E_v, Q, I and Y.

TABLE 10 - Tornado Missile Damage to the Station Power Room, Wind Speed Interval 80 to 150 mph.

TABLE 11 - Same as Table 10 but Damage to Station Power Room is Assumed to Occur Coincident With Loss of Offsite Power.

As was the case with Tables 7 and 8, operability of the alternate shutdown panel will allow opening of the emergency condenser outlet valves and closure of the MSIV thereby eliminating the need to consider Table 11. With the shutdown panel in place, the values of L, E_v, E_m, Q and I are the same as given in Table 10. If installation of the portable pumps is considered, the value of L is reduced by a factor of 1.2×10^{-2}; the probability of portable pump failure. The value of E_m now becomes 8.05×10^{-3}. (The derivation of this probability is provided above.)

TABLE 12 - Tornado Missile Damage to the Control Room, Wind Speed Interval 80 to 150 mph.

The alternate shutdown panel will allow the plant to be shut down even though the control room may be severely damaged. Rather than assuming that damage to the control room directly results in core damage as was done in Table 12, the accident sequences now considered are $P_{cr}L$, $P_{cr}E_m$, $P_{cr}E_v$, $P_{cr}QE_m$, $P_{cr}QE_v$, $P_{cr}QL$, $P_{cr}IY$ and $P_{cr}QI$. The failure probabilities used for each of the events comprising the accident sequences have been previously derived; their values are:

L (With both the diesel and electric fire pumps available)
$= 2.3 \times 10^{-4}$

L (With diesel pump only available) $= 4.8 \times 10^{-4}$

$E_m = 8.3 \times 10^{-3}$

$E_v = 2.8 \times 10^{-3}$

Q = .018
I = .038
Y = .1

With the portable pumps on site, the value of L is reduced by a factor equal to the probability of portable pump failure: 1.2×10^{-2}. The value of E_m would now equal 8.00×10^{-3}.

TABLE 13 - Tornado Damage to Screenwell/Pump House and Cable Penetration Room, Wind Speed Interval 150 to 200 mph.

Tornadoes with wind speeds of 150 to 200 mph are assumed to directly result in damage to the core. The alternate shutdown panel will be of no benefit in this situation because while it will be possible to open the emergency condenser outlet valves and close the MSIV, no means will be available to make up to the emergency condenser. The availability of portable pumps will, however, serve to reduce core damage probability. Because a source of makeup water to the emergency condenser will be available, the tornado itself will no longer directly result in core damage. Instead, the following accident sequences must be considered: P1L, $P1E_v$, $P1E_m$, $P1QE_v$, $P1QE_m$, P1QL and P1I. The failure rates assigned to the events are:

$L = 1.2 \times 10^{-2}$

$E_v = 2.8 \times 10^{-3}$

$E_m = 2.0 \times 10^{-2}$

$Q = .018$

$I = .038$

TABLE 14 - Tornado Damage to Screenwell/Pump House, Emergency Diesel Generator, and Cable Penetration Room, Wind Speed Interval 200 to 250 mph.

As was the case with tornado wind speeds of 150 to 200 mph, tornadoes in the 200 to 250 mph range are assumed in themselves to result in core damage. In this case, the alternate shutdown panel will be of no benefit. With portable pumps on site, a source of makeup to the emergency condenser will be available and the core damage frequency will be reduced. Under these circumstances, the accident sequences to be considered are PZL, PZE_v, PZE_m and PZI, where:

$L = 1.2 \times 10^{-2}$, $E_v = 2.8 \times 10^{-3}$, $E_m = 2.0 \times 10^{-2}$ $I = .038$

TABLE 15 - Tornado Damage Due To Wind Speeds of 250 to 272 mph (250 to 360 mph for 95% limit).

At the wind speeds considered here, it is assumed that damage to the plant will be so extensive that neither the alternate shutdown panel nor the portable pumps will be of any benefit in reducing the core damage probability. The core damage frequency is taken to be the probability of occurrence of a tornado with wind speeds of 250 to 272 mph (250 to 360 mph for the 95% limit).

Table 18 lists all accident sequences considered in this evaluation and their expected frequency of occurrence with the assumption that the alternate shutdown panel is operable and the portable pumps are on site. The table also indicates core damage frequency and containment release frequency.

In determining the cost-benefit of a modification, it is necessary to evaluate the reduction in exposure resulting from that modification. Reduction in exposure is calculated using the relationship:

Man-rem Reduction = (ΔCRF) (LF) (MR/LF) (T),
where ΔCRF = change in containment
release frequency resulting from a modification
LF = Latent fatalities resulting from a core melt accident (59.4)
MR/LF = Manrems/latent fatality (10000)

T = Expected remaining life of plant (18 years)

Man-rem Reduction = $(7.9 \times 10^{-6} - 5.12 \times 10^{-7})$ (59.4) (10000) (18) = 79

It has been estimated that the cost of placing portable pumps onsite would be \$75,000. This amount includes the cost of the pumps themselves, the cost of constructing a concrete bunker in which to house the pumps and miscellaneous expenses such as the costs associated with engineering work and procedural revisions.

The cost-benefit ratio of this modification is, therefore, 75000/79 or \$950/man-rem.

6.0 CONCLUSIONS

This analysis was conducted using analyses performed by Consumers Power Company as a basis, while making some conservative assumptions where analysis was lacking. Consumers Power Company had analyzed the effects of wind loadings up to a maximum of 250 mph on plant structures. When these structures reached their failure point, the equipment housed within these structures was assumed to fail such as the equipment in the screenwell/pump house and the emergency diesel generator room.

Other assumptions made were: (1) the collapse of the ventilation stack resulted in the loss of containment integrity and (2) failure of the containment boundary occurred at wind velocities in excess of 250 mph.

Using the wind velocity interval probabilities provided by the NRC, the analyses of Consumers Power Company, the EPRI tornado missile study, and the assumptions described above, a cost-benefit analysis was performed on the effects of tornado wind loadings and missiles. This analysis demonstrated that for the expected values of tornado wind velocities, the cost of the proposed modification (ie, the installation of portable pumps) is \$950/man-rem. This is very close to the NRC's proposed limit of \$1000/man-rem which is used to evaluate cost-effectiveness.

Table 1

Structure	Element	Maximum Pressure (psi)	Maximum Wind Velocity (mph)
Reactor Building	Steel Spherical Shell	1.35	250
Screen House/ Discharge structure	Roof Decking	0.41	182
	Concrete Walls	1.35	152
Emergency Diesel Generator Room	Roof Decking	0.46	193
	Concrete Walls	1.35	212
240-foot Stack	Concrete Stack	NA	200
	Foundation	NA	200
Condensate Water Storage Tank	Tank	1.35	250
Demineralized Water Storage Tank	Tank	1.35	250
Solid Radwaste Storage Vaults	Superstructure	0.17	100
	Original "low level" Vault	1.04	250
	Original "high level" Vault	1.35	250
	New Vault	1.35	250
Turbine Building	South Wall Intermediate Columns	0.17	110
	Crane Columns and Roof Truss	0.21	121
	North and South Wall Bracing	NA	121
	Wall Intermediate Columns	0.22	125
	Metal Siding	0.24	138
Turbine Building	Roof Bracing	NA	140
	East and West Wall Bracing	NA	148
	Roof Decking	0.49	198
	Roof Purlins	0.82	>250
Service Building	Safety-Related Block Walls	0.03-.16	NA
	Wall Bracing Column J	NA	123
	Exterior Column	0.23	126
	Metal Siding	0.24	138
	Girts	0.28	140
	Control Room South Wall	0.57	NA
	Roof Decking	0.81	233
	Boiler Stack	NA	>250

Table 1 (Continued)

Structure	Element	Maximum Pressure (psi)	Maximum Wind Velocity (mph)
Turbine Building	Metal Siding	0.24	138
Passageway	East and West Wall Column	0.36	159
	"Blowout" Panel	0.50	NA
Fuel Cask Loading Dock/Core Spray Equipment Room	Superstructure	NA	>250
	Block Wall	0.03	NA

Table 2

WIND SPEED RANGE PROBABILITIES

F-Scale	Wind Speed Range[1] (McDonald)	Probability	Wind Speed Range[2] (Twisdale)	Probability
1	40-72	4.87×10^{-5}	40-73	9.32×10^{-4}
2	72-112	2.09×10^{-5}	73-103	8.17×10^{-4}
3	112-157	9.77×10^{-6}	103-135	3.77×10^{-4}
4	157-206	3.03×10^{-6}	135-168	1.18×10^{-4}
5	206-260	6.85×10^{-7}	168-209	3.86×10^{-5}
6	260-318	1.08×10^{-7}	209-277	8.78×10^{-6}

(1) From NRC wind-speed study for Big Rock Point

(2) Used in EPRI tornado study

Table 3

TARGET IMPACT PROBABILITIES

F-Scale	Expected Value	95% Limit
2	1.62×10^{-8}	2.84×10^{-8}
3	2.53×10^{-8}	4.23×10^{-8}
4	9.12×10^{-9}	1.37×10^{-8}
5	1.14×10^{-8}	1.93×10^{-8}
6	3.99×10^{-9}	7.11×10^{-9}
All	6.60×10^{-8}	8.72×10^{-8}

Table 4

TARGET DAMAGE PROBABILITIES

(ASSUMING 6-INCH THICK CONCRETE WALLS)

F-Scale	Expected Value	95% Limit
2	4.64×10^{-11}	9.79×10^{-11}
3	2.92×10^{-9}	8.00×10^{-9}
4	8.29×10^{-10}	1.38×10^{-9}
5	2.50×10^{-9}	4.38×10^{-9}
6	1.11×10^{-9}	1.89×10^{-9}
All	7.41×10^{-9}	1.22×10^{-8}

TABLE 5
Sequence Core Damage Frequencies for Tornado Missiles

Loss of Offsite Power With Failure of the Diesel Generator
Wind Speed Interval (80 to 150 MPH)

Containment Isolated

Sequence	Expected Value		95% Limit
PQL[1]	(1.58E-8) (4.8E-4) =	*	*
PQEv	(1.58E-8) (2.8E-3) =	*	*
PQEmC[2]	(1.58E-8) (.0122) (.037) =	*	*
		*	*

Containment Unisolated

PQIC	(1.58E-8) (.038) (.037) =	*	*

(1)Long-term cooling (L) given success of EM is calculated to be the probability that the diesel fire pump will continue to run for 24 hours.

(2)Failure of emergency condenser makeup (EM) is the probability that VEC-1 fails to be opened (8E-3) plus the probability that the diesel fire pump fails to start (3.06E-3) plus the probability that the diesel fire pump is out of service (1.33E-4) plus the probability that no fuel is available for the pump (1.0E-3).

*Sequence Probability < 10^{-10}

TABLE 6
Sequence Core Damage Frequencies for Tornado Missiles

Loss of Offsite Power With Fire Pump Failure
Wind Speed Interval (80 to 150 MPH)

Containment Isolated

Sequence	Expected Value		95% Limit
PCL[1]	(7.64E-8) (.48) (1-.25)	= 2.75E-8	4.75E-8
PCEv	(7.64E-8) (2.8E-3)	= 2.14E-10	3.69E-10
PCEm	(7.64E-8) (.25)	= 1.91E-8	3.30E-8
PCQ	(7.64E-8) (.018)	= 1.37E-9	2.37E-9
		4.82E-8	8.32E-8

Containment Unisolated

PCYI	(7.64E-8) (.1) (.038)	= 2.90E-10	5.01E-10
PCQI	(7.64E-8) (.018) (.038)	= *	8.57E-9
		2.9E-10	9.07E-9

(1)The failure probability for long-term cooling is equal to the failure probability of the demineralized water pump to run for 24 hours given that the operator has loaded it onto the emergency diesel generator. Demineralized water pump unavailability is dominated by the probability that the emergency diesel generator will fail to run for 24 hours (24 hours x 1.97E-2/hour).

*Sequence Probability < 10^{-10}

TABLE 7

Sequence Core Damage Frequencies for Tornado Missiles

Loss of Offsite Power With Failure of the Cable Penetration Room
Wind Speed Interval (80 to 150 MPH)

Containment Isolated

Sequence	Expected Value		95% Limit
PC'L[1]	(3.34E-8) (2.3E-4) (1-.31)	= *	*
$PC'E_v$	(3.34E-8) (2.8E-3)	= *	1.61E-10
$PC'E_m$	(3.34E-8) (.31)	= 1.03E-8	1.78E-8
PC'QL	(3.34E-8) (.018) (4.8E-4) (1-.31)	= *	*
$PC'QE_v$	(3.34E-8) (.018) (2.8E-3)	= *	*
$PC'QE_m$	(3.34E-8) (.018) (.31)	= 1.86E-10	3.20E-10
		1.05E-8	1.83E-8

Containment Unisolated

Sequence	Expected Value		95% Limit
PC'I	(3.34E-8) (.038)	= 1.27E-9	2.18E-9
PC'QI	(3.34E-8) (.018) (.038)	= *	*
		1.27E-9	2.18E-9

(1)The failure probability is equal to the probability that both the diesel fire pump and the electric fire pump fail to supply makeup to the emergency condenser secondary given that the operator has manually opened VEC-1: L = (failure of diesel fire pump) (failure of electric fire pump + failure of emergency diesel generator to run for 24 hours).

*Sequence Probability < 10^{-10}

TABLE 8
Sequence Core Damage Frequency for Tornado Missiles

Failure of the Cable Penetration Room
Coincident With Loss of Offsite Power
Wind Speed Interval (80 to 150 MPH)

Containment Unisolated

Sequence	Expected Value	95% Limit
PC'	3.34E-8	5.74E-8

TABLE 9
Sequence Core Damage Frequencies for Tornado Missiles

Loss of Offsite Power With Failure of the Demineralized Water Tank and the Demineralized Water Pump Room
Wind Speed Interval (80 to 150 MPH)

Containment Isolated

Sequence	Expected Value		95% Limit
PDL	(3.0E-8) (2.3 x 10-4)	= *	*
PDC^1	(3.0E-8) (8.6E-3)	= 2.58E-10	4.39E-10
PDE_v	(3.0E-8) (2.8E-3)	= *	1.44E-10
PDQL	(3.0E-8) (.018) (4.8E-4)	= *	*
$PDQE_mC^2$	(3.0E-8) (.018) (.0122) (.037)	= *	*
$PDQE_v$	(3.0E-8) (.018) (2.8E-3)	= *	*
		2.58E-10	5.83E-10

Containment Unisolated

PDIYC	(3.0E-8) (.038) (.1) (8.6E-3)	= *	*
PDQIC	(3.0E-8) (.018) (.038) (.037)	= *	*
		*	*

(1)The failure probability of the core spray is the probability of the failure of RDS/CS given the loss of offsite power.

(2)The failure probability of the core spray is the probability of the failure of the RDS/CS given the loss of all ac power.

*Sequence Probability < 10^{-10}

TABLE 10
Sequence Core Damage Frequencies for Tornado Missiles

Loss of Offsite Power With Damage to the Station Power Room
Wind Speed Interval (80 to 150 MPH)

Containment Isolated

Sequence	Expected Value		95% Limit
PspL	(7.14E-8) (4.8E-4)	= *	*
PspEv	(7.14E-8) (2.8E-3)	= 2.0E-10	3.33E-10
PspEm	(7.14E-8) (.0122)	= 8.71E-10	1.45E-9
		1.07E-9	1.78E-9

Containment Unisolated

PQI	(7.14E-8) (.018) (.038) =	*	*

*Sequence Probability < 10^{-10}

TABLE 11
Sequence Core Damage Frequency for Tornado Missiles

Failure of the Station Power Room
Coincident With Loss of Offsite Power
Wind Speed Interval (80 to 150 MPH)

Containment Unisolated

Sequence	Expected Value	95% Limit
Psp	7.14E-8	1.19E-7

TABLE 12

Sequence Core Damage Frequencies for Tornado Missiles

Loss of Offsite Power With Control Room Damage
Wind Speed Interval (80 to 150 MPH)

Containment Isolated

Sequence	Expected Value	95% Limit
Pcr	(1.49E-8) (.962) = 1.43E-8	2.45E-8

Containment Unisolated

PcrI	(1.49E-8) (.038) = 5.66E-10	9.69E-10

(1)Failure of the control room is assumed to increase the failure probability of all headings which involve operator action to unity. This includes placing the demineralized water pump or the control rod drive pump on the 2B bus and opening VEC-1. In addition, damage may occur to the RDS actuation cabinets located in the control room which will also prevent automatic RDS/CS. Some of these functions may be accomplished from the alternate shutdown panel.

TABLE 13

Sequence Core Damage Frequencies for Tornado Wind Loadings

Loss of Offsite Power With Screenwell/Pump House
and Cable Penetration Failure
Wind Speed Interval (150 to 200 MPH)

Containment Unisolated

Sequence	Expected Value	95% Limit
P1	6.4E-6	4.6E-5

TABLE 14
Sequence Core Damage Frequencies for Tornado Wind Loadings

Loss of Offsite Power With Failure of the Screenwell/Pump House, the Emergency Diesel Generator Room and the Cable Penetration Room
Wind Speed Interval (200 to 250 MPH)

Containment Unisolated

Sequence	Expected Value	95% Limit
P2	1.30E-6	1.10E-5

TABLE 15
Sequence Core Damage Frequencies for Tornado Wind Loadings

Loss of Offsite Power With Failure of the
Cable Penetration Room
Wind Speed Interval (250 to 272 MPH) - Expected Value
Wind Speed Interval (250 to 360 MPH) - 95% Limit

Containment Unisolated

Sequence	Expected Value	95% Limit
P3	2.00E-7	2.90E-6

TABLE 16
Release Category Frequencies

Expected Values

Tornado Missile Wind Speed Interval (80 to 150 MPH)

Containment Isolated

6.85E-8 x .064	= 4.4E-9

Containment Unisolated

5.4E-8 x 1.0	= 5.4E-8

Tornado Wind Loading Interval (150 to 200 MPH)

Containment Unisolated

6.40E-6 x 1.0	= 6.40E-6

Tornado Wind Loading Interval (200 to 250 MPH)

Containment Unisolated

1.30E-6 x 1.0	= 1.30E-6

Tornado Wind Loading Interval (250 to 272 MPH)

2.00E-7 x 1.0	= 2.00E-7
	7.96E-6

TABLE 17
Release Category Frequencies

95% Limits

Tornado Missile Wind Speed Interval (80 to 150 MPH)

Containment Isolated

1.18E-8 x .064	= 7.58E-9

Containment Unisolated

8.44E-8 x 1.0	= 8.44E-8

Tornado Wind Loading Interval (150 to 200 MPH)

Containment Unisolated

4.60E-5 x 1.0	= 4.60E-5

Tornado Wind Loading Interval (200 to 250 MPH)

Containment Unisolated

1.10E-5 x 1.0	= 1.10E-5

Tornado Wind Loading Interval (250 to 272 MPH)

2.90E-6 x 1.0	= 2.90E-6
	6.00E-5

TABLE 18
Sequence Core Damage Frequencies for Tornado Wind Loadings, Alternate Shutdown Panel Installed and Portable Pumps Onsite

Sequence	(A) Alternate Shutdown Panel Operable	(B) Alternate Shutdown Panel Operable and Portable Pumps Onsite
(Tornado Missile Damage to Diesel Generator)		
PQL	$< 10^{-10}$	$< 10^{-10}$
PQE_v	$< 10^{-10}$	$< 10^{-10}$
PQE_mC	$< 10^{-10}$	$< 10^{-10}$
PQIC	$< 10^{-10}$	$< 10^{-10}$
(Tornado Missile Damage to Fire Pumps)		
PCL	2.75E-8	5.5E-10
PCE_v	2.14E-10	2.14E-10
PCE_m	1.91E-8	3.82E-10
PCQ	1.37E-9	1.37E-9
PCYI	2.9E-10	2.9E-10
PCQI	$< 10^{-10}$	$< 10^{-10}$
Tornado Missile Damage to Cable Penetration Room)		
PC'L	$< 10^{-10}$	$< 10^{-10}$
$PC'E_v$	$< 10^{-10}$	$< 10^{-10}$
$PC'E_m$	2.87E-10	2.67E-10
PC'QL	$< 10^{-10}$	$< 10^{-10}$
$PC'QE_v$	$< 10^{-10}$	$< 10^{-10}$
$PC'QE_m$	$< 10^{-10}$	$< 10^{-10}$
PC'I	1.27E-9	1.27E-9
PC'QI	$< 10^{-10}$	$< 10^{-10}$

TABLE 18
continued

Sequence	(A) Alternate Shutdown Panel Operable	(B) Alternate Shutdown Panel Operable and Portable Pumps Onsite
(Tornado Missile Damage to Demineralized Water Tank and Pump)		
PDL	$< 10^{-10}$	$< 10^{-10}$
PDC	2.58E-10	2.58E-10
PDE_v	$< 10^{-10}$	$< 10^{-10}$
PDQL	$< 10^{-10}$	$< 10^{-10}$
$PDQE_mC$	$< 10^{-10}$	$< 10^{-10}$
$PDQE_v$	$< 10^{-10}$	$< 10^{-10}$
PDIYC	$< 10^{-10}$	$< 10^{-10}$
PDQIC	$< 10^{-10}$	$< 10^{-10}$
(Tornado Missile Damage to Station Power Room)		
$P_{sp}L$	$< 10^{-10}$	$< 10^{-10}$
$P_{sp}Ev$	2.0E-10	2.0E-10
$P_{sp}Em$	8.71E-10	5.75E-10
$P_{sp}QI$	$< 10^{-10}$	$< 10^{-10}$
(Tornado Missile Damage to Control Room)		
$P_{cr}L$	$< 10^{-10}$	$< 10^{-10}$
$P_{cr}Em$	1.23E-10	1.15×10^{-10}
$P_{cr}Ev$	$< 10^{-10}$	$< 10^{-10}$
$P_{cr}QL$	$< 10^{-10}$	$< 10^{-10}$
$P_{cr}QEv$	$< 10^{-10}$	$< 10^{-10}$
$P_{cr}QEm$	$< 10^{-10}$	$< 10^{-10}$
$P_{cr}IY$	$< 10^{-10}$	$< 10^{-10}$
$P_{cr}QI$	$< 10^{-10}$	$< 10^{-10}$

TABLE 18
continued

Sequence	(A) Alternate Shutdown Panel Operable	(B) Alternate Shutdown Panel Operable and Portable Pumps Onsite
(Screenwell/Pump House and Cable Penetration Room Failure Due to 150 to 200 MPH Tornado)		
P1L		7.68E-8
$P1E_v$		1.79E-8
$P1E_m$		1.28E-7
P1QL		1.38E-9
$P1QE_v$		3.23E-10
$P1QE_m$		2.3E-10
P1	6.4E-6	
P1I		2.43E-7
Screenhouse, Emergency Diesel Generator and Cable Penetration Room Failure (Due to 200 to 250 MPH Tornado)		
P2L		1.56E-8
$P2E_v$		3.64E-9
$P2E_m$		2.6E-8
P2	1.3E-6	
P2I		4.94E-8
(Extensive Damage to Plant Due to 250 to 272 MPH Tornado)		
P3	2.0E-7	2.0E-7

CORE DAMAGE FREQUENCY

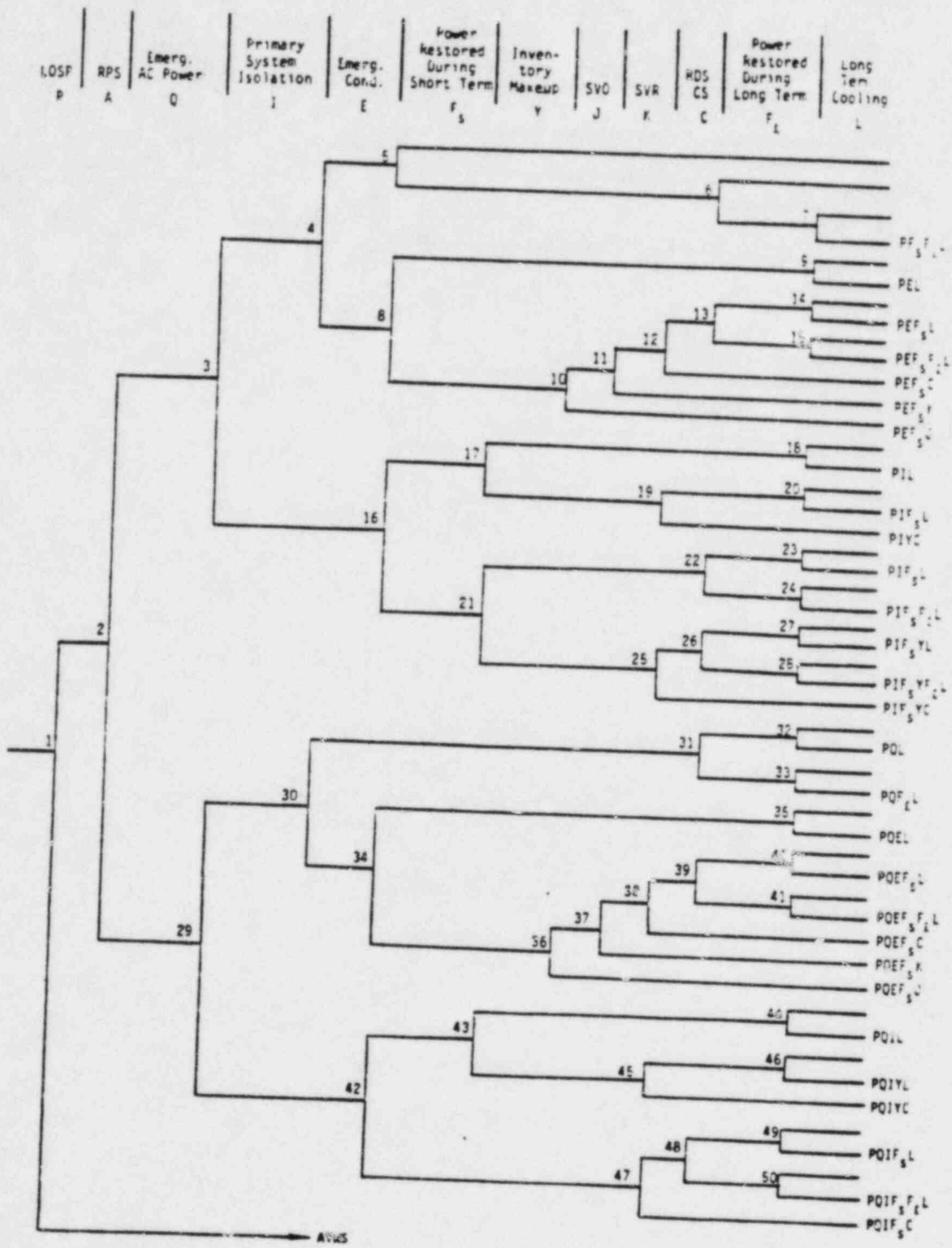
Alternate Shutdown Panel, Containment Isolated - 5.03E-8
Alternate Shutdown Panel, Containment Unisolated - 7.9E-6
Alternate Shutdown Panel and Portable Pumps, Containment Isolated - 2.76E-7
Alternate Shutdown Panel and Portable Pumps, Containment Unisolated - 4.94E-7

CONTAINMENT RELEASE FREQUENCY

Alternate Shutdown Panel - (5.03E-8) (.064) + (7.9E-6) (1.0) = 7.9E-6
Alternate Shutdown Panel and Portable Pumps - (2.76E-7) (.064) + (4.94E-7) (1.0) = 5.12E-7

FIGURE (1)

LOSS OF OFFSITE POWER EVENT TREE



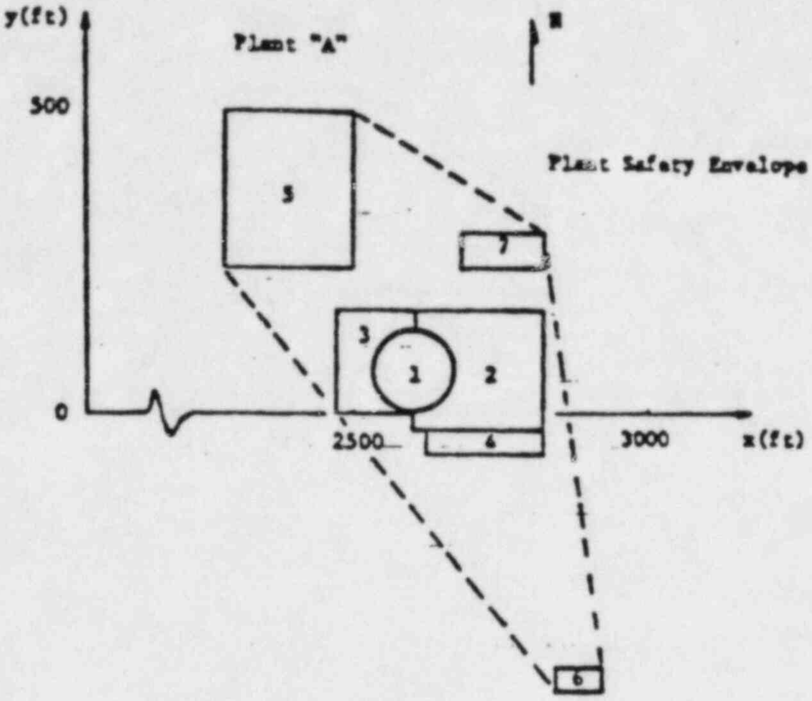


Figure 3-1. Plan View of Safety Related Structures

Table 3-1. Plant "A" Structures Description

Target Number	Description	Dimensions (ft) Length	Width	Height (ft)	Barrier Thickness (in)
1	Containment	140 Diameter		230	24 Dome, 36 Cylinder
2	Auxiliary Bldg.	220	200	80	18
3	Fuel Handling Bldg.	170	130	60	18
4	Diesel Generator Bldg.	200	40	50	18
5	Waste Processing Bldg.	260	220	40	18
6	Service Water Intake Str.	80	40	20	12
7	Tanks Enclosure	140	60	40	12

FIGURE 2: LAYOUT AND STRUCTURAL DIMENSIONS
OF THE EPRI STUDY REFERENCE PLANT

FIGURE (3)
BIG ROCK POINT SITE PLAN

LOSP W/ EDG FAILURE	RPS	PRI SYS ISO	EMERG. COND. VALVES	EMERG. COND. MAKEUP	RDS/ CS	LONG TERM COOL	SEQUENCE
PQ	A	I	Ev	Em	C	L	

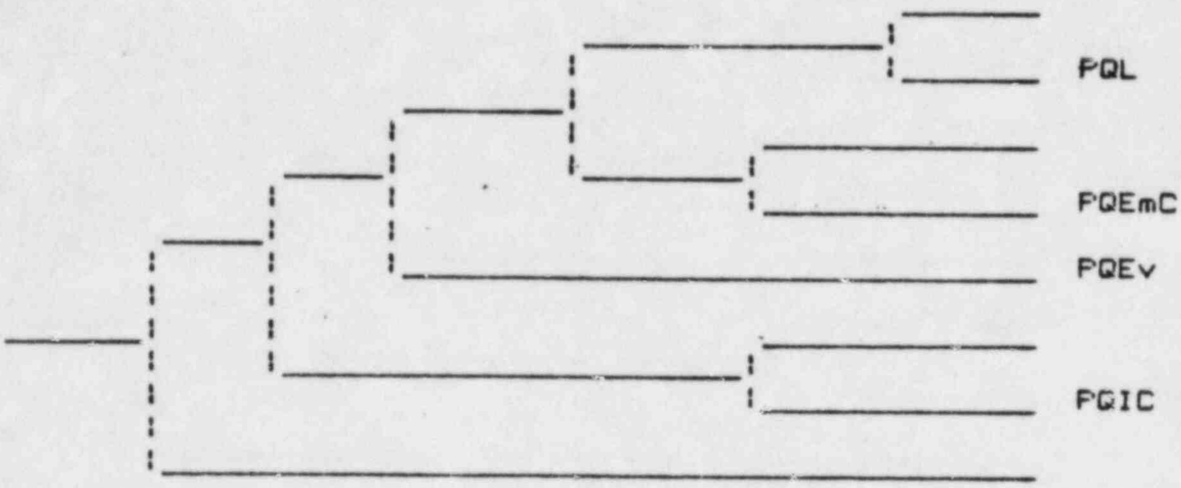


FIGURE 4

LOSS OF OFFSITE POWER WITH FAILURE OF THE DIESEL GENERATOR DUE TO TORNADO MISSILES

(80-150) MPH

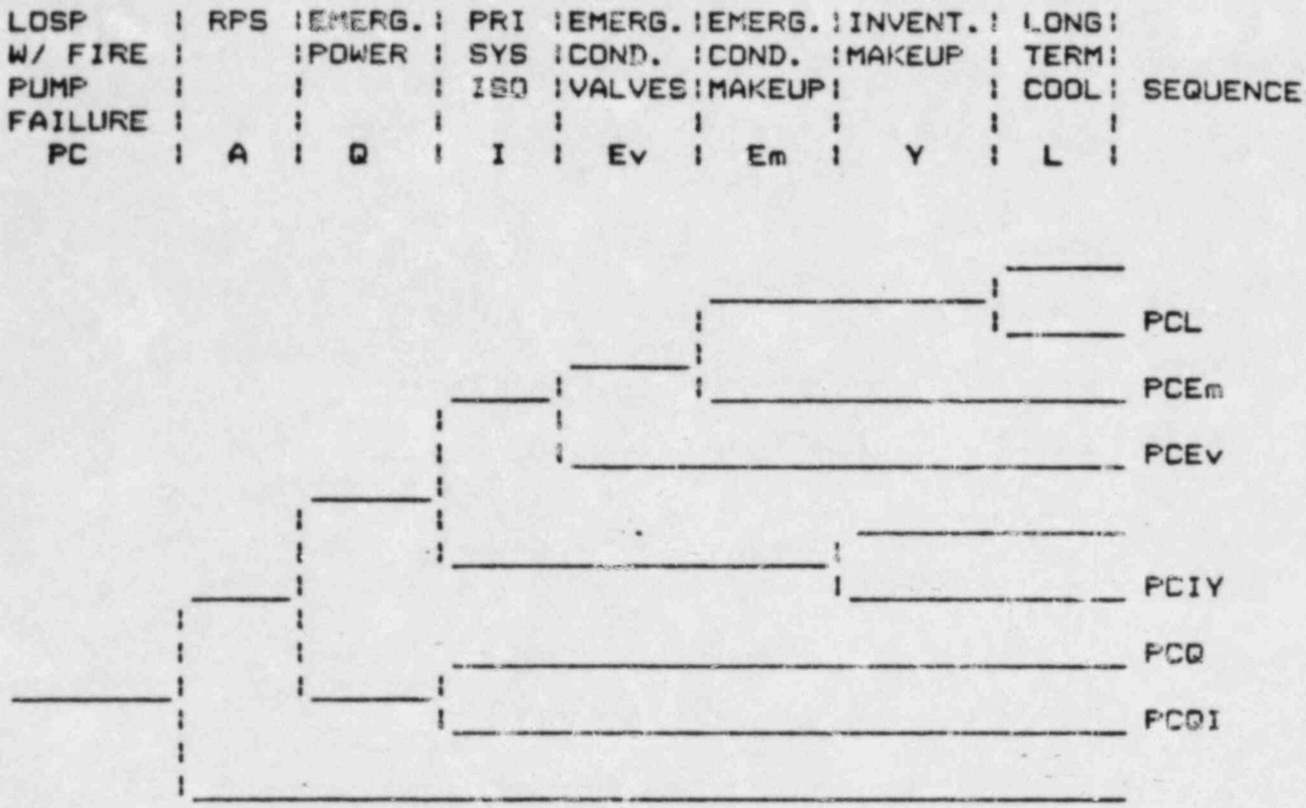


Figure 5

LOSS OF OFFSITE POWER WITH FAILURE OF THE FIRE PUMPS DUE TO TORNADO MISSILES

(80-150) MPH

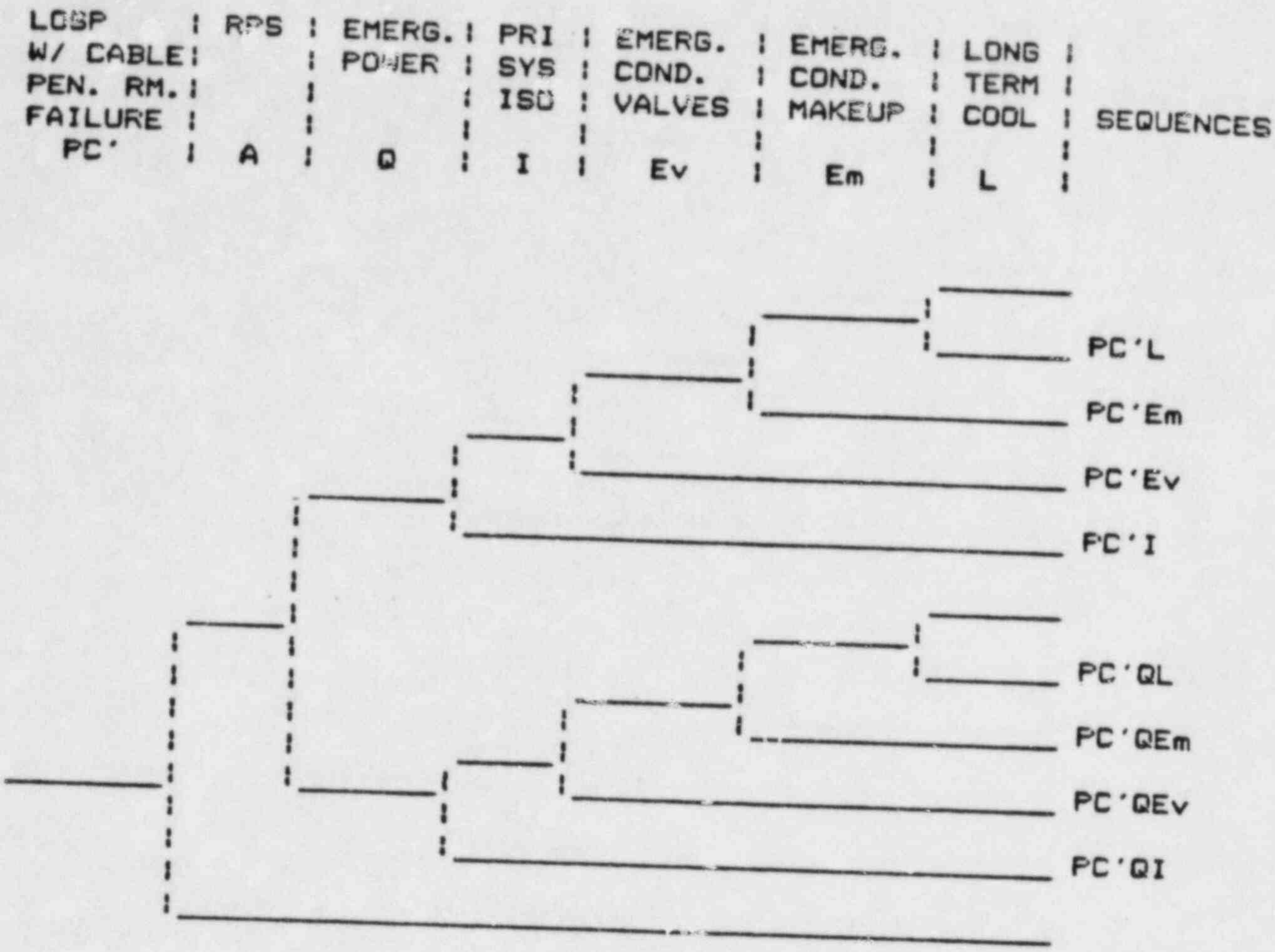


Figure 6

LOSS OF OFFSITE POWER WITH FAILURE OF THE CABLE PENETRATION ROOM DUE TO TORNADO MISSILES

(80-150) MPH

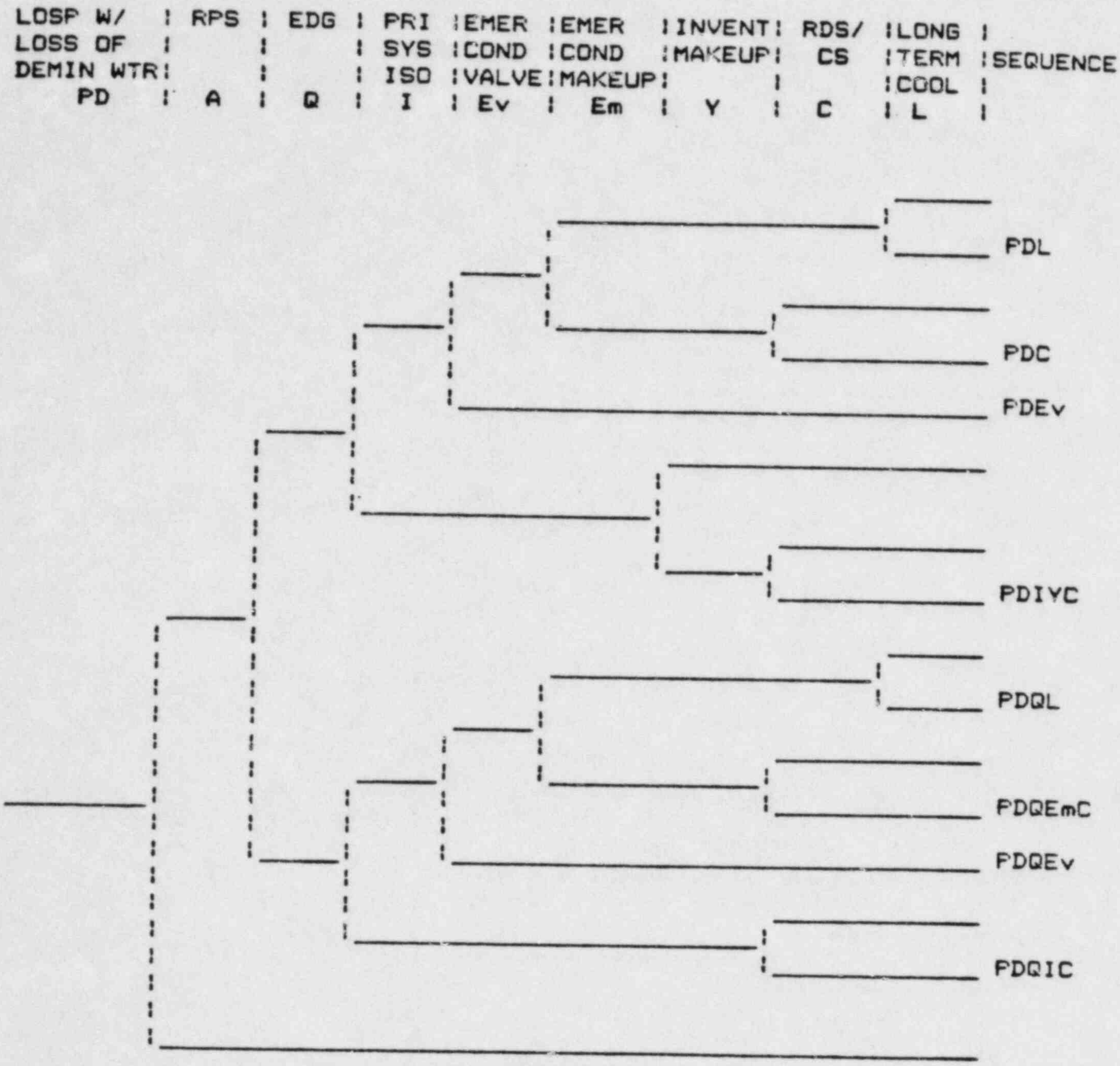


Figure 7

LOSS OF OFFSITE POWER WITH FAILURE OF THE DEMINERALIZED WATER SYSTEM

(80-150) MPH

LOSP W/STAT. PWR RM FAILURE	RPS	PRI SYS ISO	EMER. COND. VALVE	EMER. COND. MAKEUP	LONG TERM COOL	SEQUENCE
Psp	A	I	Ev	Em	L	

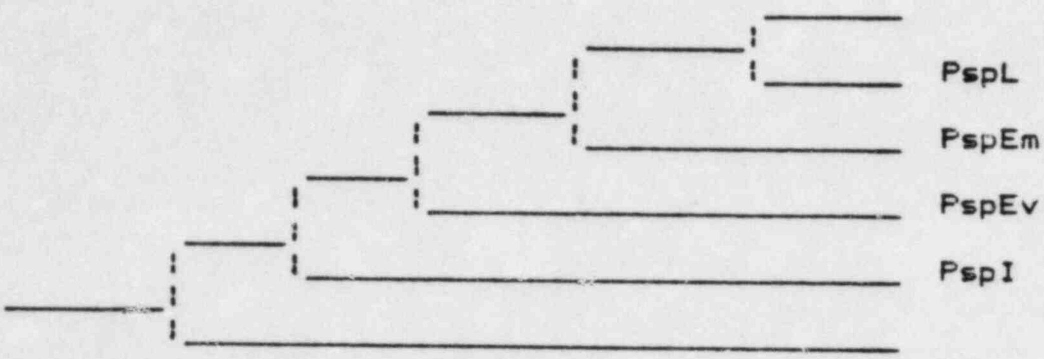


Figure 8

LOSS OF OFFSITE POWER WITH FAILURE OF THE STATION POWER ROOM DUE TO TORNADO MISSILES

(80-150) MPH

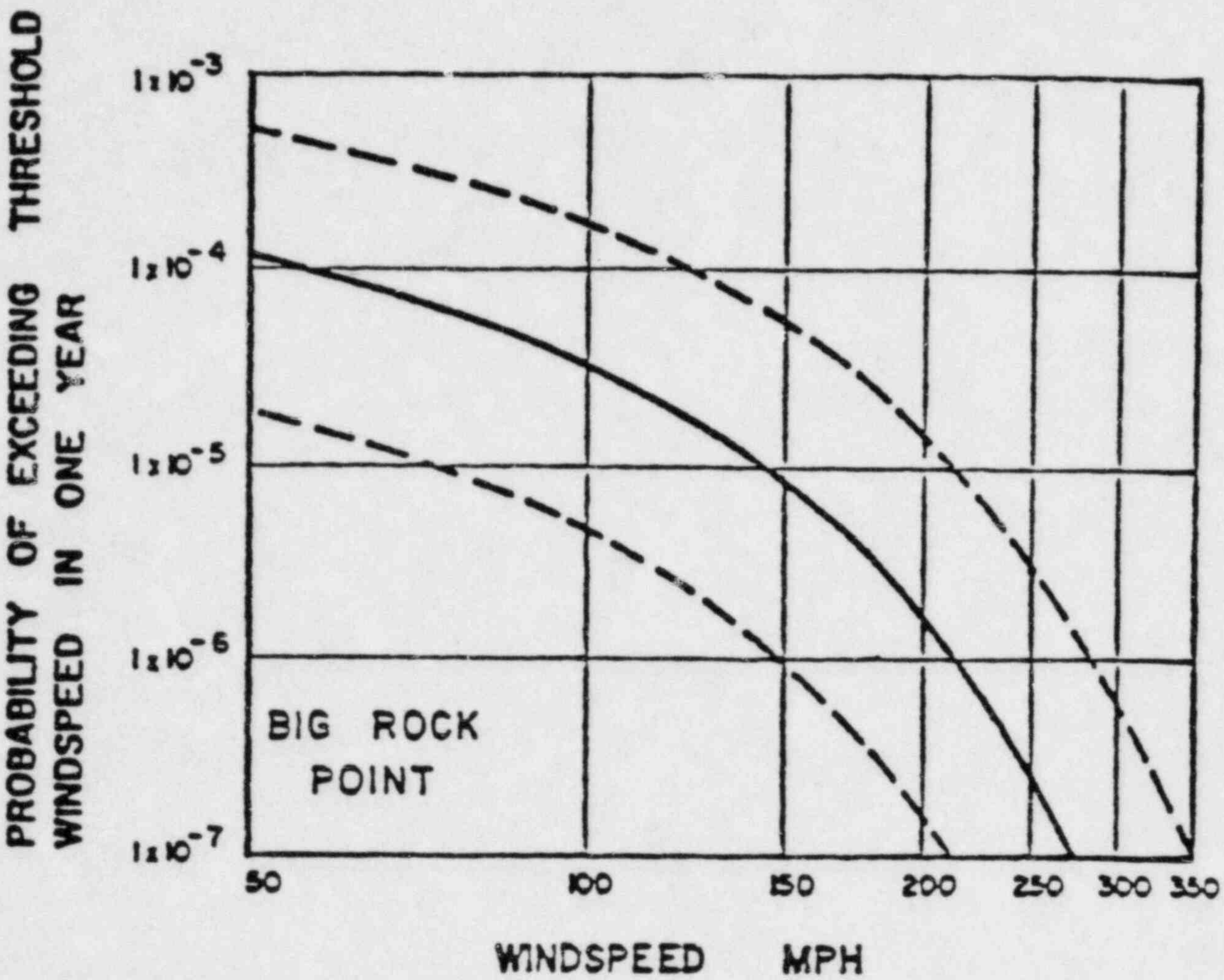


FIGURE 9: TORNADO HAZARD PROBABILITY MODEL WITH 95 PERCENT CONFIDENCE LIMITS

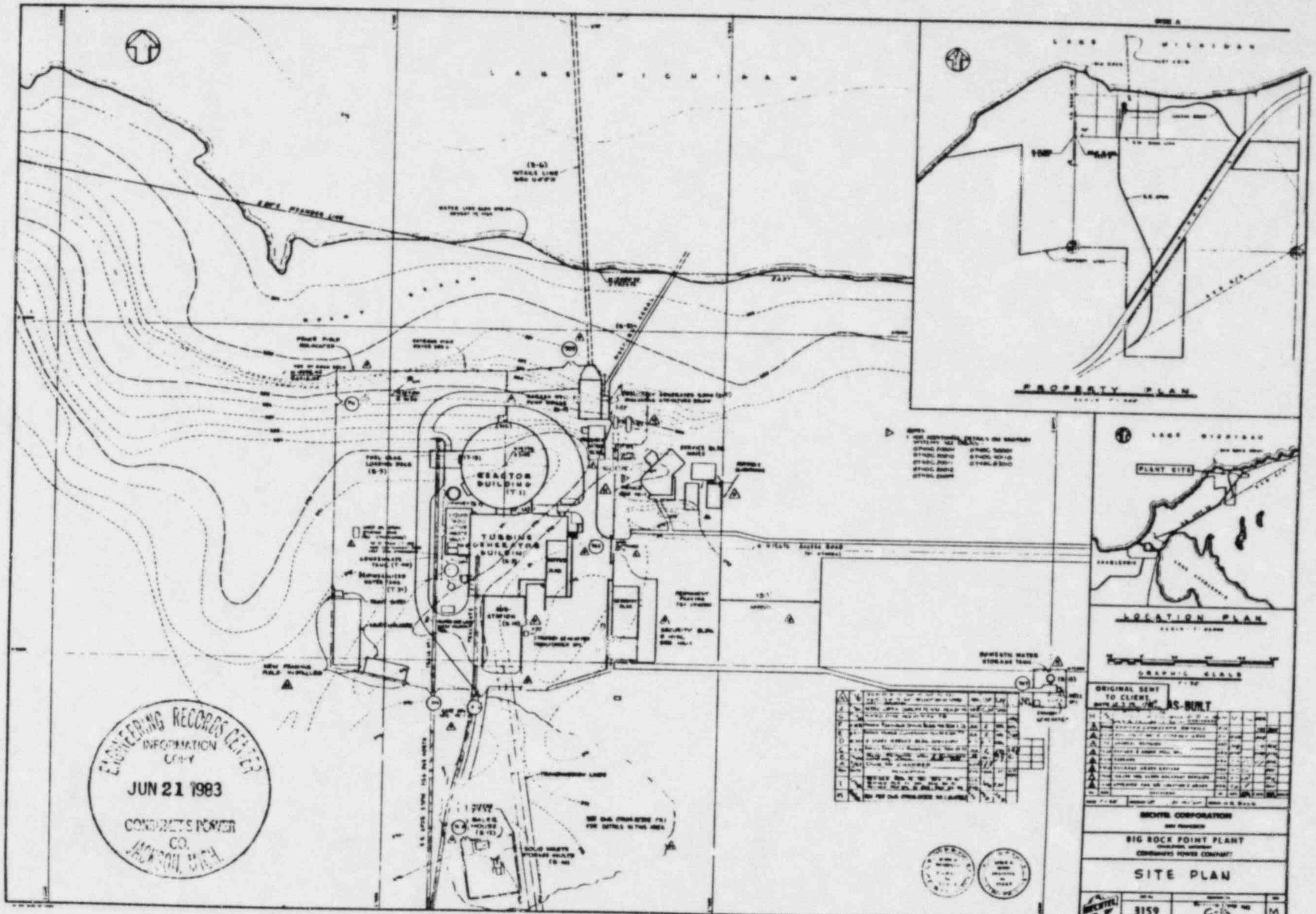


FIGURE (10)
BIG ROCK POINT SITE PLAN