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SAFETY AND DESIGN IMPACT OF HURRICANE ANDREW

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ABSTRACT

Turkey Point completed the IPE in June of 1991. Hurricane Andrew landed at Turkey Point on August 24, 1992. Although the safety related systems, components and structures were not damaged by the Hurricane Andrew, certain nonsafety related components and the neighboring fossil plant sustained noticeable damage. Among the major components that were nonsafety related but would affect the PRA of the plant included the service water pumps and the high tower.

This paper discusses the safety and design impact of Hurricane Andrew on Turkey Point Nuclear Power Plant. The risk of hurricanes on the interim and evolving plant configurations are briefly described. The risk of the plant from internal events as a result of damage incurred during Hurricane Andrew are discussed. The design change as the result of Hurricane Andrew and its impact on the PRA are presented.

IMPACT OF HURRICANE ANDREW ON EXTERNAL EVENT RISK

Hurricane associated risk stems from wind, storm surge, wind-generated missiles, and precipitation. The risk from these different components associated with hurricanes consists of the hazard (certain magnitude and corresponding likelihood of these components of hurricane at the site) and the consequence (the impact and the challenges on the systems required to safely removing the decay heat).

The Turkey Point Hurricane PRA identified that the storm surge for a Category V hurricane poses the largest risk for two reasons: the hazard is very uncertain (storm surge > 19 ft may be as high as 1.0E-4/Yr) and the consequence is very severe (e.g. several crucial equipment including 4kV switchgears may be flooded and unavailable to function). The frequency of a storm surge exceeding 19 ft is conservatively taken to be 1.0E-4/Yr. Because there was no recovery procedures or plans to cope with the flooding concerns due to the surge, the core damage frequency was taken as 1.0E-4/yr. A specific recommendation was made to enhance the existing hurricane procedure to identify and prepare plant for potential recovery actions.

Although the wind hazard is higher than the storm surge hazard, the Category I structures is designed for wind velocity of 225 mph and reviewed not to lose function up to the wind velocity of 337 mph. The major contributor to the wind risk of hurricanes comes from the falling of Unit 2 chimney (stack) at 165 mph. Sandia A-45 Decay Heat Removal Study quantified the risk from the stack on the order of 2.4E-5/Yr. In the Turkey Point Hurricane PRA, two additional EDGs installed in 1991 were considered. It was estimated that loss of all A.C. power due to the falling of the stack was below 1.0E-7/Yr. The contributions of the wind-generated missiles and the precipitation are negligible compared with that from the storm surge and the wind.

During the rampage of Hurricane Andrew, the fossil unit 1 chimney was damaged significantly and had to be demolished to avoid potential collapse. Unit 2 chimney related risk on Units 3 and 4 was reassessed. The conditions of the plant during the hurricane is assumed to be at hot shutdown or cold shutdown (i.e. modes 4 or 5). Based on the insights gained as a result of reviewing the LOCA and seal LOCA sections of References 1, 3, and 4, these initiators are generally less likely (up to a factor of 20 lower) during modes 4, 5, and 6 operations than during full power operation. These initiators occurring within 24 hours of the hurricane-induced offsite power loss are either orders of magnitude lower (LOCAs) or highly unlikely (seal LOCA at low power and low pressure conditions). Thus this calculation only focuses on non-LOCA type plant safety function requirements, i.e. secondary heat removal capability.

The frequency of the hurricane exceeding the capacity of the Unit 2 stack is estimated to be 1.0E-3/yr. This is based on the Reference 2 with some degree of conservatism to account for the uncertainties and variations of the various hurricane hazard models.

The probability of the Unit 2 stack falling (approximately 200-ft in length of the failed piece) on the Unit 4 EDG building is conservatively estimated to be 0.113. This is based on a simple geometric scoping calculation based on the following rough distances extrapolated from an aerial photo of the Turkey Point Plant taken on August 27, 1992.

To more realistically estimate the risk of the falling stack, the adjustment factors to address the mission time and the recovery of EDG hardware are developed as follows:

1. The mission time of the EDG for maintaining decay heat removal capability for 24 hours can be accomplished by either EDG. In addition, there is some probability of repair depending on the available time to repair. Reference 5 provides a list of non-recovery probability for various periods of time available to repair and restoration from test and maintenance.

2. The mission time of the first EDG is 24 hours; but the mission time for the second EDG can vary from 0 to 24 hours depending on when the first EDG fails. A reasonable approximation for the probability of both EDGs failing to provide AC power for 24 hours is obtained by multiplying an adjustment factor of 0.5 to that based on the mission time of 24 hours.

3. The nonrecovery factor for EDG hardware failures for 12 hours is 0.5; the nonrecovery probability for common cause failures of EDGs to start for 2 to 4 hours is 0.7, while that for failure to run for 6 to 8 hours is 0.5; the nonrecovery probability for EDG test or maintenance for 2 to 4 hours is 0.8.

The probability of the failure of the AFW system is estimated to be 1.64E-2, dominated by common cause failure of Unit 3 EDGs, combinations of one EDG in test or maintenance with the other EDG failure to start and common cause failure of AFW flow control valves.

The Unit 4 core damage frequency due to the stack falling on Unit 4 EDG is :

1.0E-3/yr * 0.113 * 1.64E-2 = 1.9E-6/yr.

Certain preparations and special effort to reduce the unavailability of the AFW due to loss of all AC power are considered in a sensitivity study. These include the elimination of the following cutsets from the AFW system results: (1). failure to start (common cause or independent failure of EDGs (2). EDG unavailable due to test or maintenance. One means of accomplishing the above reduction of AFW unavailability would be to place both EDGs in a running condition shortly (to avoid an increase in probability of failure to run) prior to the loss of offsite power. The AFW system unavailability is reduced from 1.64E-2 to 7.22E-3, and the core damage frequency is 8.16E-7/yr. This value is below the screening value of 1.0E-6/yr as stipulated in NUREG-1407 (Reference 6) and is considered not risk significant.

The Unit 3 core damage frequency due to the stack falling on Unit 4 EDG is expected to be slightly smaller than that of Unit 4. Although Unit 3 seems to have the benefit of having Unit 3 EDGs when Unit 4 EDG building is assumed failed by the falling stack, the dominant failure of EDGs will make both RHR and AFW unavailable. The only advantage for Unit 3 compared with Unit 4 would be the additional capability of RHR if common cause failures of AFW occur. For Unit 4, the blackout conditions make AFW the only available mitigating system.

Results indicate that the loss of Unit 4 EDGs and D switchgears affects the AFW system unavailability significantly. In addition, the RHR system of Unit 4 is lost due to the loss of all AC power. With the elimination of start failure or test/maintenance unavailability, the AFW system unavailability is reduced by approximately a factor of 2.

The effect of the loss of Unit 3 EDGs, which is considered beyond the reach of the falling stack (190 ft in length), is addressed in the Turkey Point IPE Submittal (Reference 2) and the calculated core damage frequency is less than 1.0E-7/yr. Other effects of stack falling such as loss of ICW or RWST (assuming 400 ft of falling piece) have also been addressed in the Turkey Point IPE Submittal and the calculated core damage frequency is less than 1.0E-7/yr.

Table 1 summarizes the core damage frequency for the various cases analyzed.

IMPACT OF HURRICANE ANDREW ON INTERNAL EVENT RISK

From the internal event standpoint, the main effect of Hurricane Andrew on the Turkey Point PRA was the collapse of the high tower due to excessive wind. The high tower provides cooling water for charging pumps during loss of AC power scenarios to prevent a seal LOCA. Before Hurricane Andrew destroyed the high tower, the service water system included one service water pump, 3 raw water booster pumps (A, B and C) and the high tower. The service water failure is dominated by operator failure to connect the hose(s) for charging pump cooling. The new design eliminates the high tower and the service water pump. Instead of using the gravity feed from the high tower, an additional diesel-driven raw water pump is used.

The failure probability of the high tower to provide service water cooling was considered negligible because of the passive failure mechanism. The failure probability to provide service water cooling to the charging pumps is dominated by operator failure to use the hose connection to the charging pumps.

The revised core damage frequency for the case of eliminating the high tower and replacing with an additional diesel driven raw water tank is calculated to change from 9.35E-5/yr to 9.55E-5/yr, representing approximately 2% change.

IV. Conclusions

The major effects of Hurricane Andrew on the Turkey Point Hurricane PRA can be understood from the hazard and the consequence standpoint. The hazard is generally developed based on historical occurrences. Since hurricanes with such magnitudes as Hurricane Andrew are very rare, and there are quite many unpredictable factors affecting the magnitude, the range and the course of travel of a hurricane, one cannot confidently estimate the occurrence frequency of damaging hurricanes. The Turkey Point Hurricane PRA study observed the above point vividly and is reinforced by Hurricane Hugo and Hurricane Andrew. From the consequence standpoint, Hurricane Andrew seems to reveal that several assumptions commonly taken for credit may be reconsidered. These include: the duration of loss of offsite power (typically within a day or so the probability is assumed negligible), the mission time of interest (typically 24 hours) and the outside support (typically assumed in the PRA to be available within 24 hours and that's why the mission time of 24 hours is assumed). The diesel generator failure probability to run seems to be overestimated due to the lack of diesel run time limitations.

A conservative estimate for replacing the high tower with a dedicated diesel driven service water pump gives an increase in core damage frequency from 9.35E-5/yr to 9.55E-5/yr represents approximately 2% change. With a more detailed recovery analysis (e.g. time dependent offsite power recovery) to remove the conservatism, the core damage may be even lower than that is calculated.

V. REFERENCES

1. Seabrook Station Probabilistic Safety Study, Shutdown (Modes 4, 5 and 6), May 1988
2. Turkey Point IPE Submittal, June 1991
3. NUREG/CR-4077, "Reactor Coolant Pump Shaft Seal Behavior During Station Blackout," Charles A. Kittmer, et., al., April, 1985
4. WCAP-10541, Revision 2, "Reactor Coolant Pump Seal Performance Following A Loss of All AC Power", C. H. Campen and W. D. Tauche, November 1986
5. NUREG/CR-4550, Vol. 1, Rev. 1, "Analysis of Core Damage Frequency: Internal Events Methodology", January 1990
6. NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities", June 1991

TABLE 1 A COMPARISON OF HURRICANE ANALYSIS RESULTS		
Cases	AFW Failure Probability	Core Damage Frequency from Hurricane
1. IPE Submittal	8.15E-4; Dominated by Common Case Failure of AFW Components	< 1.0E-7/YR
2. This study without EDGs running prior to Loss of Offsite Power	1.64E-2; Dominated by EDG Failures	1.9E-6/YR
3. This study with EDGs running prior to Loss of Offsite Power	7.22E-3; Dominated by EDG Failures	8.2E-7/YR