6.0 PLANT IMPROVEMENTS AND UNIQUE SAFETY FEATURES

6.1 UNIQUE SAFETY FEATURES

Certain unique safety features in the design of the North Anna plant help to minimize core damage frequency and related fission product release. Moreover, the design excludes significant "vulnerabilities" that have been identified at other pressurized water reactors.

6.1.1 Core Damage Safety Features

Among the features that assist in the removal of decay heat and thus the prevention of core damage are the following:

- The Main Feedwater pumps are motor driven and therefore not dependent on the availability of Main Steam for the provision of Feedwater.

- The pressurizer power-operated relief valves (PORVs) and charging pumps are sized such that the bleed-and-feed operation can be performed if all secondary heat removal is lost.

- It is possible to cross-connect high-head charging flow and Component Cooling Water from Unit 2 to Unit 1 or vice versa. In the event of the failure of both systems at either unit, reactor coolant pump seal cooling/injection can be maintained from the other unit, thereby minimizing the likelihood of a seal LOCA. Similarly, if there is a station blackout at one unit, seal cooling can still be established from the other unit if a diesel generator is supplying that unit.

- The unit two diesel on the 2J bus can be used to supply power to the 1H bus on Unit 1 in the event of failure of both diesel generators at Unit 1, and successful operation of both diesel generators at Unit 2, following a loss of offsite power.

- AMSAC has been fitted for the initiation of the Auxiliary Feedwater pumps and tripping of the Turbine following an anticipated transient without scram.

- There are two ultimate heat sinks, the Service Water Reservoir and the North Anna reservoir (Lake Anna).

6.1.2 Unique and/or Important Containment Building Safety Features

Those plant features that are most important in inhibiting accident progression, preventing Containment Building failure, and minimizing the source term are as follows:

- The high capacity Containment
- Subatmospheric Containment operation
- Redundancy and diversity of the Recirculation Spray and Containment heat removal systems

Because of the high capacity of the North Anna Containment Building, early Containment failure is highly unlikely. Even if Containment heat removal is not available, Containment over-pressure failure will not occur for at least 1 day.

Operation of the North Anna Containment Building below atmospheric pressure results in a very low probability of loss of Containment isolation. Any sizeable opening in the Containment will be readily detected, since subatmospheric conditions cannot be maintained.

Operation of the Recirculation Spray System makes Containment over-pressure virtually impossible. Neither hydrogen burns nor noncondensible gas generation alone pose a serious threat to Containment integrity. Given the diversity, redundancy, and separation (in inside and outside components) of the Recirculation Spray System, failures of the entire system due to other system failures or the environmental conditions of an accident is highly unlikely.

6.2 PLANT IMPROVEMENTS

The internal events and internal flooding vulnerability analyses discussed in Sections 3.4.2 and 3.3.7 showed that, although no vulnerabilities have been determined, some procedure enhancements and hardware changes were necessary to ensure the core damage frequencies reported in this document. The dominant contributions to the various plant damage states and fission product release are identified in Sections 4.3 and 4.7. Procedural enhancements and hardware modifications are discussed in the following sections.

6.2.1 Internal Event Plant Improvements

The sequences that dominate core damage and fission product release are associated with failure of Emergency Switchgear Room cooling, loss of offsite power, small LOCAs, Steam Generator tube ruptures, and medium LOCAs. Accordingly, any potential plant improvements should focus on the dominant contributors to these sequences.

Table 6-1 summarizes the internal events recommendations. The recommendations are further discussed in the following paragraphs.

Auxiliary Feedwater

The status of the Auxiliary Feedwater full flow recirculation lines were determined to have a risk significant dependence on the internal events core damage frequency. These lines were installed to allow pump testing at various points on the pump head curves. Normally the full flow recirculation lines are isolated during power operation and are typically opened only during periodic pump testing. However, upon restoring the pump to service after testing there is a possibility that the full flow recirculation line isolation valves have been left open.

Because of the risk significance of the Auxiliary Feedwater full flow recirculation line, it is recommended that all procedures which open the Auxiliary Feedwater full flow recirculation valves include independent verification that the valves are closed after testing has been completed. During the IPE process it was found that most tests already included independent verification.

Quench and Recirculation Spray

Periodic testing of the Quench Spray and Recirculation Spray systems involves realignment of the piping. This realignment includes installation of flanges and pipe elbows which prevent the pumps from delivering water to the spray headers. These tests are performed every 18 months to every 5 years and involve engineers, mechanics and operators. The infrequent test interval and the multiple personnel involved introduces a chance for miscommunication. Also it is typical to test all spray headers simultaneously which allows for the possibility of a common cause failure of all Quench and Recirculation Spray systems. During system operability walkdowns operations personnel ensure that all valves and pumps are properly aligned but do not inspect the test flange and elbow locations.

The risk significance of the Containment spray systems is sufficient enough to justify improving all procedures which realign the Quench Spray or Recirculation Spray systems to include specific guidance for system restoration and independent verification that the piping has been restored to fully operable. Misalignment of the systems has not been identified as a problem in the past. The IPE process only determined this to be a potential human error which has a risk significance.

Alternate Safety Injection Header

The North Anna design basis utilizes a single Safety Injection System header for initial injection into the Reactor Coolant System and two headers during the recirculation phase. This arrangement is adequate for one active component failure during injection, and one active and one passive component failure during the recirculation phase. A PRA approach identifies accident sequences during which multiple component failures prevent safety injection through the normal injection header. A solution to some of these sequences is to revise the emergency operating procedures to allow consideration of the alternate SI header during injection when multiple failures prevent SI flow through the normal injection header.

The IPE process does not allow taking credit for this operator action unless it is specifically proceduralized. The emergency operating procedures are not revised without a detailed analysis beyond the scope of this IPE. It is recommended that the EOP process further evaluate revising the emergency procedures to utilize the alternate SI header if the normal header has failed.

RWST Isolation Valve

The small LOCA initiating event contributes 14.7% of the core damage frequency. The top sequence, S2D1D3, is a small LOCA with loss of high head safety injection and low head safety injection following successful core cooling recovery. The dominant cut set for this sequence contains a plugging failure of the RWST isolation valve (1QSMV--PG-1QS38). In order to reduce the likelihood of valve plugging between demands, the LHSI pump periodic test procedures should be revised to perform the test on each train in a staggered fashion.

Emergency Switchgear Room Cooling

Loss of ESGR cooling was found to contribute to core damage in two ways. As an initiating event, T8, a random failure or maintenance on HV equipment leads to reactor trip. If ESGR cooling is not recovered, core damage can result from a seal LOCA or loss of AFW. T8 sequences contribute 9.8% of the core damage frequency. Loss of ESGR cooling can also occur following another initiating event. In this situation, safety systems are unavailable to mitigate the initiating event. These sequences account for 24.2% of the core damage frequency.

As a result of the importance of these sequences, significant resources were expended to enhance the availability of ESGR room cooling. As a result of this effort, several required

administrative and procedural modifications were identified. These changes are summarized below.

Plant operations modifications should be implemented to decrease the T8 initiator frequency through reduced chiller fail to start or fail to run events, as well as reduced duration of chiller outages. Also, planned outages involving two chillers unavailable at one time should be administratively controlled to either reduce their frequency, or to limit their duration to less than one hour (the PRA model accounts for most unplanned dual chiller outages caused when a chiller or pump etc. experiences a running fault while one chiller is in maintenance). Recovery of chiller faults should be addressed through enhanced trouble-shooting procedures that can be performed by on-site personnel and through operator training to recover simple chiller faults.

6.2.2 Flood Protection Improvements

During the performance of the internal flooding analysis it was discovered that the Auxiliary Building was subject to several flooding scenarios. These flooding scenarios are discussed in some detail in Appendix E. The most significant contributors to the flooding events include failure of the pipe or a component in the Safeguards Building. It was also determined that the charging pump cubicles could flood through the floor drain lines. As a result of these findings several minor modifications were recommended to be incorporated into the station design. The IPE flooding analysis assumes that these modifications have been completed. The modifications are summarized in Table 6-2 and are discussed separately below.

1. Installation of backflow prevention devices in the common floor drain lines to prevent the propagation of the floods from the Auxiliary Building to the charging pump cubicles via the drain system. This modification increases the critical flood height in the Auxiliary Building from 24" to 44" which in turn increases the critical flood volume and the time available for isolation of a flood source.

2. Reinforcement of the present fire barrier in the piping penetration between the Auxiliary Building and the Quench Spray Pump House (QSPH) such that it limits the flooding flow rate reaching the Auxiliary Building to less than approximately 300 gpm. This modification keeps a majority of the flood water originating in the Safeguards Building or QSPH from damaging equipment in the Auxiliary Building.

3. Modifications to the Chiller Room/Fan Room door and the Chiller Room/Turbine Building door to redirect flooding

away from the Instrument Rack Room and the Emergency Switchgear Room. The modification to the Chiller Room/Fan Room door is to add a 3'3" high dike. This causes a flood originating in the Chiller Room to fill the room to 3' deep and overflow the existing 3' dike protecting the Chiller Room/Turbine Building door. The Chiller Room/Turbine Building door must be modified to allow a sufficient gap at the bottom to allow the worst case flood to leak under this door, around the missile shield protecting the door and into the Turbine Building. Due to the large area of the Turbine Building and relatively small flood flow rate, there will be no significant hazard to the Turbine Building.

These Chiller Room door modifications allow the redirection of the flood water away from the ESGR. A Chiller Room flood will cause the loss of all ESGR cooling for one unit even with these modifications. Existing station procedures provide adequate operator guidance during a loss of ESGR cooling. This is less severe than allowing the flood to propagate to the ESGR where it will cause the loss of all AC and DC emergency electrical power and all instrumentation for both units.

Procedure Changes

The internal flooding analysis is based on the power station as it is currently operated. In order to keep the flooding analysis valid, it is prudent to ensure the operability of all flooding mitigating equipment included in the analysis. Table 6-3 is a list of all procedure changes which are required to be implemented to keep this internal flooding core damage frequency at 3.6E-6/year. Some of these procedures or administrative controls currently exist. The new procedures are not immediately necessary but should be implemented before the next suggested test interval (typically 18 months).

TABLE 6-1
INTERNAL EVENTS
PROCEDURAL REQUIREMENTS

1. All procedures which open the Auxiliary Feedwater full flow recirculation manual valves should be revised to add independent verification that the valves are closed upon completion of the procedure. Without independent verification of these valves, the CDF increases to 7.2E-5/year. With independent verification of these valves, the North Anna CDF remains at 6.8E-5/year.

2. All procedures which realign the Quench Spray or Recirculation Spray headers for testing should be revised to add independent verification that the headers have been restored to fully operable upon completion of the test. Currently some procedures install blank flanges, elbow or reconfigure the piping between the system's pumps and the spray headers during testing. There are no specific procedural guidance for system restoration. These same procedures do not have any form of independent verification to ensure the piping is fully operable. If some of these test flanges or other piping changes are left installed, the system will not deliver adequate flow to the spray headers. Without independent verification the CDF increases to 7.0E-5/year. If the QS and RS system piping are independently verified to be operable by a qualified operator performing a system walkdown at the end of each refueling outage, then the North Anna IPE CDF remains at 6.8E-5/year.

3. Revise 1-E-0, Reactor Trip or Safety Injection, to add opening 1-SI-MOV-1836 to the RNO of step 14, verify SI flow, or to the RNO of step 16, check Charging Pump alignment. Without procedural guidance to use the alternate SI header the CDF increases to 7.1E-5/year. With procedural improvement to open 1-SI-MOV-1836 if the normal path fails, the North Anna IPE CDF remains at 6.8E-5/year.

4. Administratively ensure that LHSI pump testing is performed in a staggered fashion. Each pump is still tested once per 90 days. The tests are performed approximately 45 days apart to minimize time between discharge check valve operation. The CDF increases to 7.0E-5/year if the tests are not staggered.

5. Administratively eliminate preplanned dual outages for the MCR/ESGR chiller train equipment. The CDF will increase to 7.1E-5/year if dual chiller outages continue at the same frequency as in the past.

TABLE 6-1 (Continued)
INTERNAL EVENTS
PROCEDURAL REQUIREMENTS

6. Improve maintenance practices to limit the mean time to repair (MTTR) MCR/ESGR chiller train equipment to less than 60 hours when one chiller is inoperable, and to less than 36 hours when two chillers are inoperable. The CDF will increase to 8.0E-5/year if the mean time to repair is not improved.

7. Modify station procedures to provide troubleshooting and repair of the MCR/ESGR chiller protection circuitry and reduce refrigerant related chiller failures. Use historical data to identify sensors/equipment susceptible to failure. This supports both a reduced MTTR and recovery functions. The CDF increases to 7.3E-5/year without procedure improvements.

TABLE 6-2
INTERNAL FLOODING
HARDWARE MODIFICATIONS

1. Install back flow prevention devices in Charging Pump Cubicle floor drains.

2. Improve the piping penetration fire barrier between the Quench Spray Pump House and Auxiliary Building to limit the flooding flow rate.

3. Add a 3'3" dike to protect the Chiller Room/Fan Room doors (both units) and trim the bottom of the Chiller Room/Turbine Building doors (both units) to have a gap large enough to pass 1000 gpm.

TABLE 6-3
INTERNAL FLOODING
PROCEDURE REQUIREMENTS

1. Inspect the Charging Pump Cubicle drain back flow prevention devices every 18 months and replace if necessary.

2. Administrative control and periodic inspection of all flood dikes and barriers. Verify in place once every 18 months. Administrative control and inspection should include the following devices:

   - Flood barrier installed at the piping penetration between the Quench Spray Pump House and the Auxiliary Building.
   - The flood barrier protecting the pipe tunnel between the Quench Spray Pump House and the Turbine Building.
   - The flood barrier protecting the pipe tunnel between the Quench Spray Pump House and the Auxiliary Feedwater Pump House.
   - The 3' flood dike protecting the Turbine Building/ESGR door.
   - The 3' flood dike protecting the Turbine Building/Auxiliary Building pipe tunnel.
   - The 9" flood dike protecting the ESGR/Cable Vault doors (both units).
   - The flood barrier pipe in a pipe surrounding the SW lines in the Fan Rooms (four pipes on each unit) should be periodically inspected to ensure integrity of the outer pipe.
   - The gap under the Chiller Room/Turbine Building door is large enough to allow 1000 gpm (with 3'0" head) to pass through. No obstructions of this gap. The missile door may be closed. It does not hinder flow by itself.
   - There are no penetrations in the Chiller Room/Fan Room wall or in the Chiller Room/Instrument Rack Room wall below 3'3".
   - The fire protection lines in the Emergency Switchgear Room are isolated and dry.

TABLE 6-3 (Continued)
INTERNAL FLOODING
PROCEDURE REQUIREMENTS

- The grating above the Turbine Building condenser outlet valve pit must have at least a 50 ft^2 area clear at all times. The remaining grating may be covered in plastic or other items which limit flow of water from the basement into these pits. This is applicable at all times, including maintenance outages.

3. Periodic testing of alarms and all automatic equipment actuations for the following flooding level switches.

   - 1-CW-LS-107A/107B and 2-CW-LS-207A/207B in the Turbine Building condenser outlet valve pit.
   - 1-CW-LS-106A-1/2/3, 1-CW-LS-106B-1/2/3, 2-CW-LS-206A-1/2/3 and 2-CW-LS-206B-1/2/3 in the Turbine Building basement (254').
   - 1-DA-LSH-114 in the Auxiliary Building SW pit.
   - 1-DA-LS-105,111A/B in Auxiliary Building sump.
   - 1-DA-LS-101-1/2 in the Safeguards Building sump.

4. 0-AP-39.2 "Auxiliary Building Flooding" abnormal procedure should be modified to include steps to identify and isolate remotely isolatable floods and RWST floods.

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