5.3 EXTERNAL MISSILES, SNUBBERS, AND WATERTIGHT DOORS

5.3.1 EXTERNAL MISSILES

5.3.1.1 Containment Structure Design Missiles

Turbine Generator Produced Missiles

Both of the turbine generator suppliers made a study of failure of rotating elements of steam turbines and generators. The postulated types of failures are: (a) failure of rotating components operating at or near normal operating speed and, (b) failure of components that control admission of steam to the turbine resulting in destructive shaft rotational speed.

Failure at or Near Operating Speed

All of the known turbine and generator rotor failures at or near rated speed resulted from the combination of severe strain concentrations in relatively brittle materials. New alloys and processes have been developed and adopted to minimize the probability of brittle fracture in rotors, wheels, and shafts. Careful control of chemistry and detailed heat treating cycles have greatly improved the mechanical properties of all of these components. Transition temperatures [the temperature at which the character of the fracture in the steel changes from brittle to ductile, often identified as nil-ductility transition temperature (NDTT)] have been reduced on the low temperature wheel and rotor applications for nuclear units to well below startup temperatures. Improved steel mill practices in vacuum pouring and alloy addition have resulted in forgings which are much more uniform and defect free than ever before. More comprehensive vendor and manufacturer tests involving improved ultrasonic and magnetic particle testing techniques are better able to discover surface and internal defects than in the past. Laboratory investigation has revealed some of the basic relationships between structure strength, material strength, NDTT and defect size, and location, so that the reliability of the rotor as a structure has been significantly improved.

New starting and loading instructions have been developed to reduce the severity of surface and bore thermal stress cycles incurred during service. The new practices include:

- Better temperature sensors;
- Better control devices for acceleration and loading; and
- Better guidance for station operators in the control speed, acceleration, and loading rates to minimize rotor stresses.

New rotor designs have also contributed to the reduced likelihood of a turbine missile. The original Unit 1 low-pressure turbine rotors were conventional rotors with shrunk-on wheels and axial keyways. These built-up rotors were replaced with ones manufactured from monoblock forgings in the 2004 Unit 1 refueling outage. The new Unit 1 rotors are not susceptible to the keyway stress-corrosion cracking mechanism. The result of this is that brittle fracture failure mode (and turbine missile probability) at near-rated speed is essentially eliminated for Unit 1. Therefore, the only credible Unit 1 turbine missile scenario is a ductile failure of the limiting rotor due to a significant over-speed event (greater than 170% of rated speed).

Failure at Destructive Shaft Rotational Speeds

Improvement of rotor quality discussed above, while reducing the chance of failures at operating speed, tend to increase the hazard level associated with

unlimited overspeed because of higher bursting speed. Therefore, turbine overspeed protection systems have been evaluated as follows:

UNIT 1

The Unit 1 main turbine has a GE Speedtronic Mark VI control system. This system is triple modular redundant to ensure a high level of reliability. This system interfaces with the turbine stop valves, control valves, and combined intermediate valves to control the unit.

Overspeed protection is provided at three levels: control, primary, and emergency. Control protection comes through closed loop speed control using the turbine control valves. There are two sets of three magnetic speed pick-ups; one set is for primary protection and the other set is for emergency protection. Primary over-speed protection is provided by a set of three controllers that provide 2-of-3 voting for the turbine trip. The emergency overspeed protection is provided by an independent triple redundant system which also trips the turbine. Three independent speed signals are used permitting speed control with one of the signals failed. The overspeed protection systems will secure steam to the turbine as follows:

a. Main and secondary steam inlets have the following valves in series:

   Stop valves - actuated by the hydraulic fluid trip system via the primary and emergency overspeed protection systems, providing two levels of protection, each of which is triple redundant.

   Control valves - controlled by the speed-load control unit and tripped closed by the primary and emergency overspeed protection systems, providing three levels of redundancy for closure.

   Combined intermediate valves in cross-around systems - actuated by the speed load control unit and tripped closed by the primary and emergency overspeed protection systems.

b. Uncontrolled Extraction Lines to Feedwater Heaters

   Positive closing nonreturn valves are provided in extraction lines which have sufficient stored energy to cause a dangerous overspeed condition on a turbine trip. The valves close on a turbine trip via the extraction air relay dump valve which is actuated by the hydraulic fluid trip system. The valves are designed for local or remote manual periodic tests to assure proper operation. The station piping, heater, and check valve systems were reviewed during the design stages to assure that the entrained steam cannot overspeed the unit beyond safe limits.

UNIT 2

a. Main and secondary steam inlets have the following valves in series:

   Governor valves - controlled by the speed governor and tripped closed from an overspeed condition by an electronic overspeed trip through the Turbine Control System (TCS) and a Diverse Overspeed Protection System (DOPS), thus providing three levels of control redundancy.

   Throttle valve – tripped closed from an overspeed condition by an electronic overspeed trip through the TCS and DOPS, thus providing two levels of control redundancy.

Reheat stop and intercept valves in cross-around systems - these are tripped closed from an overspeed condition by an electronic overspeed trip through the TCS and the DOPS.

The speed sensing devices for the governor and the DOPS are separate from each other, thus providing two independent lines of defense.

b. Uncontrolled Extraction Lines to Feedwater Heaters

Positive closing nonreturn valves are provided in extraction lines which have sufficient stored energy to cause an overspeed condition on a turbine trip. These valves are designed for local or remote-manual periodic tests to assure proper operation. The station piping, heater and check valve systems were reviewed to assure that the entrained steam cannot overspeed the unit beyond safe limits.

Special field tests are made of new components to obtain design information and to confirm proper operation. These include the capability of controls to prevent excessive overspeed on loss of load.

Careful analysis of all past failures has led to design, inspection, and testing procedures to substantially eliminate destructive overspeed as a possible cause of failure in modern design units.

Missile Protection

The NRC-preferred method of protecting against turbine missiles is to ensure that turbine missile generation probability, P1, is maintained at a value of less than 10^{-5} per year (Reference 14). While this method has been used for the Unit 2 turbine, it was not a viable method for Unit 1 until the replacement of the low pressure turbine rotors during the 2004 Unit 1 refueling outage.

Maintaining a low value for P1 is accomplished by performing regular, vendor-approved maintenance, and testing of the turbine control and overspeed protection systems. The test intervals have a direct effect on overspeed control system failures and, therefore, turbine missile generator probability, P1.

As mentioned previously, since the new Unit 1 monoblock rotors have no credible failure mode at near-rated speed, the only credible turbine missile scenario for Unit 1 is a significant overspeed event. It follows therefore that the Unit 1 turbine missile probability is essentially the same as the probability of a significant overspeed.

The Unit 1 overspeed probability is stated by General Electric in Reference 16 to be less than $3x10^{-6}$ per year. This is based on the Mark VI turbine control system, monoblock LP turbine rotors, and maintaining the current (extended) valve test intervals. General Electric approved maintenance practices are assumed as well.

MPR Associates performed an analysis on the effect of extending Unit 1 Turbine Overspeed Protection System testing intervals on turbine missile generation in Reference 18. The analysis scales GE Missile Turbine Probability for various components testing frequency extensions. The analysis determined an updated missile generation probability, P1, of $7.85x10^{-6}$. Per Reference 14, maintaining P1 at less than 10^{-5} per year is an acceptable method of managing turbine missile risk. Therefore, the turbine missile risk from Unit 1 is acceptably low for all systems, structures, and components, and no further analysis is required.

For the Westinghouse turbine generator, the guidance in Reference 10 was used. Reference 10 guidance is the same as that used for the General Electric turbine where turbine missile risk can be effectively managed by maintaining the turbine missile generation probability, P1, less than 10^{-5} for unfavorably oriented turbine generators.

The missile generation probability for the Unit 2 (Westinghouse) turbine is calculated by Reference 11. In Reference 11, Westinghouse performed an evaluation of the probability of generating turbine missiles as a direct function of the testing frequency for the turbine governor valves and throttle valves. The report focuses on the probability of turbine missile ejection due to destructive overspeed (runaway speed in excess of approximately 180%). The turbine missile ejection frequencies in Reference 11 were calculated following the same basic methodology as is described in Reference 12. In a supplemental safety evaluation (Reference 13), issued to Westinghouse, the NRC staff accepted the Reference 12 methodology for use in the determination of the probability of turbine missile generation. The turbine generator failure rates used in Reference 11 for turbine governor and throttle valves were based on plant operating experience over a data collection period from 1990 through and including 1995. This time period provided failure rates based on current valve design and maintenance practices while retaining adequate time for rare events to occur. Westinghouse added an allowance to cover any model uncertainties and to account for the probability of missile ejection from design and intermediate overspeed events. The destructive overspeed model was constructed assuming that a loss of load or system separation occurred. The frequency of system separation was calculated to be 0.29 per year; however, a more conservative value of 0.4 per year was used in the Westinghouse analysis. The conditional probability of missile ejection (e.g., the probability of valve failures) was then multiplied by the frequency of system separation to obtain the probability of missile ejection per year from destructive overspeed. The probability of turbine missile ejection due to destructive overspeed was calculated for turbine valve test intervals of one week, one month, three months, six months, and twelve months.

Values for P1 are given in Reference 11 for various valve test intervals and are below 10^{-5}. Maintaining an initial small value of the probability of a turbine failure as discussed above simplifies and improves procedures for evaluation of turbine missile risks and ensures that the public health and safety is maintained. In addition, maintaining P1 at a low value is the NRC preferred method for controlling turbine missile risk per References 10 and 13. By focusing on the missile generation probability, we avoid the numerous modeling approximations that often must be made to incorporate interactions of missiles with obstacles, their trajectories as they deflect off barriers, and the identification and location of safety-related targets.

The analysis for turbine missiles from the Unit 2 turbine is based on the current missile generation probabilities provided by Westinghouse and our current testing interval. The analysis shows that we meet current acceptance criteria. Per Reference 17, the Calvert Cliffs Unit 2 TCS upgrade from the AEH to the Digital AEH-DR (Ovation® platform) is bounded by the present turbine missile generation calculation and resulting valve test frequency.

<u>Tornado Produced Missiles</u>

For an analysis of horizontal missiles created by a tornado having maximum wind speeds of 300 mph, two horizontal missiles were considered. One is a horizontal

missile equivalent to a 12' plank with a 12"x4" cross-section, traveling end-on at 300 mph; the second is a 4000 lb automobile traveling at a speed of 50 mph at no more than 25' above the ground.

For the wood horizontal missile, calculations based on energy principles indicate that, because the impact pressure exceeds the ultimate compressive strength of wood by a factor of about four, the wood would crush due to impact. However, this could cause a secondary source of missiles if the impact force is sufficiently large to cause spalling of the free (inside) face. The compressive shock wave which propagates inward from the impact area generates a tensile pulse which, if it is large enough, will cause spalling of concrete as it moves back from the free (inside) surface. This spalled piece moves off with some velocity due to energy trapped in the material. Successive pieces will spall until a plane is reached where the tensile pulse becomes smaller than the tensile strength of the concrete. From the effects of impact of the wood plank, this plane in a conventionally reinforced concrete section would be located approximately 3" from the free (inside) surface. However, since the Containment Structure is prestressed, there will be residual compression in the free face, as the tensile pulse moves out and spalling will not occur. Calculations indicate that, in the impact area, a 2" or 3"-deep crushing of concrete should be expected as result of excessive bearing stress due to impact.

For the automobile missile, using the same methods as in the original turbine failure analysis, the calculated depth of penetration is 1/4" and, for all practical purposes, the effect of impact on the Containment Structure is negligible.

From the above, it can be seen that the horizontal tornado-generated missiles neither penetrate the Containment Structure wall nor endanger the structural integrity of the Containment Structure or any components of the RCS.

Removable Slabs, Blocks and Partitions

It is improbable that removable blocks which are used only in the waste processing area in the Auxiliary Building would break loose and become missiles, even during a DBE. These blocks are self-locking and contain staggered horizontal and vertical joints. All removable concrete slabs are located in the Auxiliary Building. These slabs are placed over low pressure radwaste equipment, such as filters and demineralizers, and weigh approximately 4000 lbs. It is unlikely that a slab could receive a seismic acceleration in the upward direction sufficient to cause the slab to become a missile.

5.3.1.2 Other Structures Design Missiles

Unit 1 Turbine Missile Analysis

The Unit 1 turbine (General Electric) has a missile generation probability (P1) of less than 10^{-5} per year. Therefore, per Reference 14, as long as P1 is maintained less than 10^{-5} per year, the Unit 1 turbine presents an acceptably low risk and no further analysis of missile risk from the Unit 1 turbine is necessary. This also applies to the turbine missile risk for all equipment, including the safety-related Diesel Generator Building.

Unit 2 Turbine Missile Analysis

The Unit 2 turbine (Westinghouse) has a missile generation probability (P1) of less than 10^{-5} per year. Therefore, per Reference 10, as long as P1 is maintained less than 10^{-5} per year, the Unit 2 turbine presents an acceptably low risk and no further detailed analysis of missile risk from the Unit 2 turbine is necessary.

Conclusion

Based on the above discussion, both Units' turbine generators have an acceptably low probability of generating a missile, and Units 1 and 2 are adequately protected against turbine missiles.

5.3.2 SNUBBERS

All safety-related snubbers must be capable of performing their specified function to ensure that the structural integrity of the Reactor Coolant System and all other safety-related systems is maintained during and following a seismic or other event initiating dynamic loads. Snubbers excluded from this program are those installed on non-safety-related systems and then only if their failure or failure of the system on which they are installed would have no adverse effect on any safety-related system.

The visual inspection frequency is based on maintenance of a constant level of snubber protection to systems. Therefore, inspection intervals vary inversely with the observed snubber failures. These intervals are determined by the number of inoperable snubbers found during the previous inspection, the total population or category size, and the previous inspection interval.

Snubbers may be categorized, based upon their accessibility during power operation, as accessible or inaccessible. These categories may be examined separately or jointly. However, that decision must be made and documented before any inspection. The decision shall be used in determining the next inspection interval for that category. Inspections performed before an interval has elapsed may be used as new reference points in determining the next interval. However, the results of such early inspections (nominal time less 25%) may not be used to lengthen the required inspection interval. Any inspection whose results require a shorter inspection interval will override the previous schedule.

When the cause of snubber rejection is clearly established, remedied and verified by inservice functional testing, that snubber and any other snubbers that may be generically susceptible, may be exempted from being counted as inoperable. Generically susceptible snubbers are those that are: (1) of a specific make or model; (2) of the same design; and (3) similarly located or exposed to the same environmental conditions such as temperature, radiation, and vibration. These snubber installation characteristics shall be evaluated to determine if further functional testing of similar snubber installations is warranted.

A snubber is considered inoperable if it fails to satisfy the acceptance criteria of the visual inspection. When a snubber is found inoperable, a determination of the snubber mode of failure is made. In addition, an engineering evaluation is performed to determine if the supported component or system, or any safety-related component or system has been adversely affected by the inoperability of the snubber. Operation may continue indefinitely if an engineering review and evaluation can document within 12 or 72 hours, depending on applicability of Technical Specification LCO 3.0.8, that the equipment to which the snubber is connected can perform its required safety functions with the snubber inoperable. If the review and evaluation cannot justify that the supported equipment will perform its required functions, the system must be declared inoperable and the applicable action requirements met.

The inspection program allows inspection intervals to be compatible with a 24-month fuel cycle, up to and including an increase to every other refueling outage. To provide assurance of snubber functional reliability, a representative sample (10%) of the installed snubbers of each type [e.g., small bore (< 8") and large bore (> 8")] will be functionally tested during plant shutdowns or at refueling intervals. Observed failures of these sample

snubbers shall require functional testing of additional units (5% for each failure or until every snubber has been functionally tested).

The service life of a snubber is determined by reviewing manufacturer information, snubber service conditions, and associated installation and maintenance records (newly installed snubber, seal replaced, in high radiation area, in high temperature area, etc.) The requirement to monitor snubber service life ensures the snubbers periodically undergo a performance evaluation in view of their age and operating conditions. The service life program is designed to uniquely reflect the conditions at Calvert Cliffs. The criteria for evaluating service life is be determined, and documented, by the licensee. Records provide statistical bases for future determination of snubber service life. The requirements for the maintenance of records and the snubber service life review are not intended to affect plant operation.

Snubber Inspection Program

a. *Visual Inspections*

Visual inspections shall be performed in accordance with the schedule determined by Table 5.4. Snubbers are categorized as inaccessible or accessible during reactor operation. Each of these categories (inaccessible and accessible) may be inspected independently or jointly according to the schedule determined by Table 5.4. The visual inspection interval for each population or category of snubbers shall be determined based upon the criteria provided in Table 5.4.

b. Visual Inspection Acceptance Criteria

Visual inspections shall verify (1) that there are no visible indications of damage or impaired operability, and (2) that the snubber installation exhibits no visual indications of detachment from foundations or supporting structures. Snubbers that appear inoperable as a result of visual inspections may be determined operable for the purpose of establishing the next visual inspection interval, provided that: (1) the cause of the rejection is clearly established, remedied and functionally tested for that particular snubber and for other snubbers that may be generically susceptible; or (2) the affected snubber is functionally tested in the as found condition and determined operable per the Hydraulic Snubbers Functional Test Acceptance Criteria, as applicable. When the fluid port of a hydraulic snubber is found to be uncovered, the snubber shall be determined inoperable unless it can be determined operable via functional testing for the purpose of establishing the next visual inspection interval.

For the snubber(s) found inoperable, an engineering evaluation shall be performed on the component(s) that are supported by the snubber(s). The scope of this engineering evaluation shall be consistent with the licensee's engineering judgment and may be limited to a visual inspection of the supported component(s). The purpose of this engineering evaluation shall be to determine if the component(s) supported by the snubber(s) were adversely affected by the inoperability of the snubber(s) in order to ensure that the supported component remains capable of meeting the designed service.

c. Functional Tests

At least once per 24 months, a representative sample of 10% of each type of snubbers in use in the plant shall be functionally tested either in-place or in a bench test. For each snubber that does not meet the functional test acceptance criteria of the Hydraulic Snubbers Functional Test Acceptance Criteria, an additional 5% of that type snubber shall be functionally tested until no more failures are found or until all snubbers of that type have been functionally tested.

Snubbers identified as “Especially Difficult to Remove” or in “High Exposure Zones” shall also be included in the representative sample (permanent or other exemptions from functional testing for individual snubbers in these categories may be granted by the NRC only if a justifiable basis for exemption is presented and/or snubber life destructive testing was performed to qualify snubber operability for all design conditions at either the completion of their fabrication or at a subsequent date).

In addition to the regular sample, snubbers that failed the previous functional test shall be retested during the next test period. If a spare snubber has been installed in place of a failed snubber, then both the failed snubber (if it is repaired and installed in another position) and the spare snubber shall be retested during the next test period. Failure of these snubbers shall not entail functional testing of additional snubbers.

If any snubber selected for functional testing either fails to lock up or fails to move, i.e., frozen in place, the cause will be evaluated and if caused by manufacturer or design deficiency all generically susceptible snubbers of the same design subject to the same defect shall be functionally tested. This testing requirement shall be independent of the requirements stated above for snubbers not meeting the functional test acceptance criteria.

For the snubber(s) found inoperable, an engineering evaluation shall be performed on the component(s) that are supported by the snubber(s). The scope of this engineering evaluation shall be consistent with the licensee's engineering judgment and may be limited to a visual inspection of the supported component(s). The purpose of this engineering evaluation shall be to determine if the component(s) supported by the snubber(s) were adversely affected by the inoperability of the snubber(s) in order to ensure that the supported component remains capable of meeting the designed service.

d. Hydraulic Snubbers Functional Test Acceptance Criteria

The hydraulic snubber functional test shall verify that:

1. Activation (restraining action) is achieved within the specified range of velocity or acceleration in both tension and compression.
2. Snubber bleed, or release rate, where required, is within the specified range in compression or tension. For snubbers specifically required to not displace under continuous load, the ability of the snubber to withstand load without displacement shall be verified.

e. Snubber Service Life Monitoring

A record of the service life of each snubber, the date at which the designated service life commences and the installation and maintenance records on which the designated service life is based shall be maintained.

At least once per 24 months, the installation and maintenance records for each safety-related snubber shall be reviewed to verify that the indicated service life has not been exceeded or will not be exceeded prior to the next scheduled snubber service life review (including the 1.25 times extension). If the indicated service life will be exceeded prior to the next scheduled snubber service life review, the snubber service life shall be reevaluated or the snubber shall be replaced or reconditioned so as to extend its service life beyond the date of the next scheduled service life review. This reevaluation, replacement or reconditioning shall be indicated in the records.

5.3.3 WATERTIGHT DOORS

Watertight doors are provided in various locations to ensure the protection of safety-related equipment from the effects of water or steam escaping from ruptured pipes or components in adjoining rooms. While the plant is in operating Modes 1 through 4, the following watertight doors are determined to be closed at least once per 12 hours, except when the door is being used for normal entry and exit:

a. ECCS Pump Room Doors (4),

b. Service Water Pump Room to Heater Bay Doors (2),

c. Auxiliary Feed Pump Room to Heater Bay Doors (2),

d. Emergency Escape Hatch, Service Water Pump Room from Penetration Room,

e. Main Steam Piping Area from Piping Penetration Room Door,

f. Passage to Main Steam Piping Area Door,

g. Warehouse to Intake Structure Door, (Elevation 12'), and

h. Intake Structure Door from Outside.

5.3.4 REFERENCES

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13. Letter from NRC to the Chairman of the Turbine Valve Test Frequency Evaluation Subgroup, Mr. D. M. Musolf, Manager, Nuclear Support Services, Northern States Power Company, dated November 2, 1989
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17. Impact to Missile Probability and Valve Testing, Calvert Cliffs Unit 2, Turbine Control System Upgrade, WNA-AR-00659-CCAL2, Revision 0, December 2016

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TABLE 5.4

SNUBBER VISUAL INSPECTION INTERVAL

	NUMBER OF INOPERABLE SNUBBERS		
Population or Category (Notes 1 and 2)	Column A Extend Interval (Notes 3 and 6)	Column B Repeat Interval (Notes 4 and 6)	Column C Reduce Interval (Notes 5 and 6)
1	0	0	1
80	0	0	2
100	0	1	4
150	0	3	8
200	2	5	13
300	5	12	25
400	8	18	36
500	12	24	48
750	20	40	78
1000 or greater	29	56	109

Note 1: The next visual inspection interval for a snubber population or category size shall be determined based upon the previous inspection interval and the number of inoperable snubbers found during that interval. Snubbers may be categorized, based upon their accessibility during power operation, as accessible or inaccessible. These categories may be examined separately or jointly. However, the licensee must make and document that decision before any inspection and shall use that decision as the basis upon which to determine the next inspection interval for that category.

Note 2: Interpolation between population or category sizes and the number of inoperable snubbers is permissible. Use next lower integer for the value of the limit for Columns A, B, or C if that integer includes a fractional value of inoperable snubbers as determined by interpolation.

Note 3: If the number of inoperable snubbers is equal to or less than the number in Column A, the next inspection interval may be twice the previous interval but not greater than 48 months.

Note 4: If the number of inoperable snubbers is equal to or less than the number in Column B but greater than the number in Column A, the next inspection interval shall be the same as the previous interval.

Note 5: If the number of inoperable snubbers is equal to or greater than the number in Column C, the next inspection interval shall be two-thirds of the previous interval. However, if the number of inoperable snubbers is less than the number in Column C but greater than the number in Column B, the next interval shall be reduced proportionally by interpolation, that is, the previous interval shall be reduced by a factor that is one-third of the ratio of the difference between the number of inoperable snubbers found during the previous interval and the number in Column B to the difference in the numbers in Columns B and C.

Note 6: An extension of 1.25 times the inspection interval is applicable for all inspection intervals up to and including 48 months.