3.5 Missile Protection

According to 10 CFR 50, Appendix A, GDC 2 and 4 (Reference 1), essential structures, systems, and components (SSCs) important to safety are required to be protected from internal and external missiles.

Missile protection is provided for safety-related equipment and components so that internal and external missiles do not cause the release of significant amounts of radioactivity or prevent the safe and orderly shutdown of the reactor.

The protection of safety-related SSCs is accomplished by one or more of the following:

a. Minimizing the sources of missiles by equipment design features that prevent missile generation

b. Orienting or physically separating potential missile sources away from safety-related equipment and components

c. Containing the potential missiles through the use of protective shields or barriers near the missile source or safety-related facility and equipment

d. Hardening of safety-related equipment and components to withstand missile impact when such impacts cannot be reasonably avoided by the methods listed above

Table 3.2-1 is the list of applicable SSCs and major SSCs to be protected from missiles are provided in Table 3.5-1. General arrangement drawings showing locations of the SSCs are given in Section 1.2.

3.5.1 Missile Selection and Description

For equipment with energy sources capable of generating a missile, the selection is based on the application of a single failure criterion to the retention features of the component. Where sufficient retention redundancy is provided in the event of a failure, no missile is postulated.

The types of missiles considered in the design of safety-related SSCs are categorized as follows, based on their origin:

a. Internally generated missiles (outside the containment)

b. Internally generated missiles (inside the containment)

c. Turbine missiles

d. Natural phenomena missiles

e. Site proximity missiles (except aircraft)

f. Aircraft hazards

The criteria for each type of missiles are described below. An evaluation is performed to verify that missiles do not adversely affect the safety functions of safety-related SSCs.

3.5.1.1 Internally Generated Missiles (Outside the Containment)

The criteria used for missile protection of internally generated outside the containment are generally consistent with the NRC guidelines in Standard Review Plan (SRP) 3.5.1.1 (Reference 2).

Barriers or retention features in structures other than containment are designed in accordance with the design procedure described in Subsection 3.5.3. The following procedures are used to achieve compliance with design criteria for protection against missiles that are generated by the failure of pressurized or rotating components outside the containment.

a. Classifying missiles based on their source

b. Classifying equipment and components that require protection from missiles, based on the design criteria described in Section 3.5

c. Following the procedures listed below to protect equipment and components from failure

   1) Identifying features of missiles generated by the failure of rotating components (e.g., motor-driven pumps, fans), pressurized components (e.g., reactor vessel closure head stud and nut), or gravitational missiles (e.g., falling objects resulting from a nonseismically designed SSC during a seismic event)

   2) Determining the effects of the identified missiles on equipment and components (design structures between the missiles and protected equipment to withstand the missile impact if the structures are in the trajectory path)

   3) Relocating equipment and missile generation source in relation to postulated missile trajectories to protect equipment from being impacted by a missile

   4) Installing barriers or retention features, to protect equipment and components from impact by a missile.

Internally generated missiles can be generated from two types of equipment: rotating components and pressurized components. Rotating components include turbine wheels, fans, and pumps. Pressurized components include valve stems, valve bonnets, bolted connections on pressure vessels, and instrument wells.

Missiles generated by postulated failures of rotating components are selected and evaluated based on the following conditions:

a. All rotating components that are operated during normal operating plant conditions are capable of generating missiles.

b. The energy of potential missiles generated from rotating components is based on a 120 percent overspeed condition as a minimum.

c. The missile is postulated to occur only if the energy of the missile is sufficient to perforate the equipment's protective housing.

Missiles generated by postulated failures of pressurized components are selected and evaluated based on the following conditions:

a. Pressurized components in the systems whose maximum operating pressure exceeds 19.3 kgf/cm^2 (275 psig) are assumed to be missile generation sources.

b. Connecting portions installed on piping or components are assumed to be missile generation sources. Connecting portions include thermowells, pressure gauges, and lines for vents, drains, and testing.

c. A connecting portion may be eliminated as a missile generation source if it is welded and its design strength is stronger than that of the basement.

d. Valves constructed in accordance with regulation and valves designed to prevent ejection are not considered credible missile generation sources.

e. Non-ASME pressurized vessels with an operating pressure greater than 19.3 kgf/cm^2 (275 psig) are considered missile generation sources. ASME vessels are not considered missile generation sources because of their controlled design and fabrication.

f. Non-ASME valves in piping systems with an operating pressure greater than 19.3 kgf/cm^2 (275 psig) are considered missile generation sources.

g. An industrial pressure bottle containing highly pressurized gas is considered a missile generation source except when the bottle is designed with overpressure protection and is located in a separate room to control the effect of an explosion.

Internally generated missiles (outside the containment) from rotating and pressurized components are not considered credible for the same reasons described above.

Missiles falling from heavy load transfers by crane and missiles from dropped SSCs designed to non-seismic category outside the containment are considered gravity-based missiles. The design complies with SRP 9.1.5 (Reference 3) and NUREG-0612 (Reference 4) for falling heavy loads from equipment or component transfers, and the

design provides reasonable assurance that the effect of heavy load drops during transfers by a crane is eliminated by blocking the path above the systems and components that are necessary to achieve a safe shutdown or accident. The drop of nonseismically designed SSCs outside the containment could affect safety-related systems. Therefore, they are designed to seismic Category II to protect the safety-related systems from the impact of dropped objects.

The COL applicant is to provide the procedure for heavy load transfer to strictly limit the transfer route during plant maintenance and repair periods (COL 3.5(1)).

3.5.1.1.1 Potential Missiles from Rotating Component

3.5.1.1.1.1 NSSS Components

If the probability of missile generation P_1 is maintained less than 10^{-7} per year, the missile is not considered statistically significant. If the probability of occurrence is greater than 10^{-7} per year, the probability of impact on a significant target is determined. If the product of these two probabilities is less than 10^{-7} per year, the missile is not considered statistically significant.

Safety-related NSSS pumps and associated motors are considered rotating missile generation sources outside containment. However, there is no postulated missile because P_1 is less than 10^{-7} per year for the following reasons.

a. Pump motors are an induction type that have relatively slow running speeds and are not prone to overspeed. These motors are pretested at full running speed by the motor vendor prior to installation.

b. The motor stator serves as a natural container of rotor missiles if any are generated.

c. Safety-related pumps have relatively low suction pressures and are not driven to overspeed due to a pipe break in their discharge lines. In addition, the induction motor would act as a brake to prevent pump overspeed.

d. Industry pumps are designed to prevent the penetration of pump casings from impeller pieces.

3.5.1.1.1.2 Balance of Plant Components

All rotating components inside seismic Category I structures outside the containment are considered potential missile generation sources. Rotating parts in these components are therefore designed to be contained by a protective casing or structures.

The turbine building, which contacts with the seismic Category I auxiliary building, is designed as seismic Category II. The turbine building does not contain safety-related systems or components and does not require design for protection from rotating components that become missiles.

The turbine, the object with the largest kinetic energy in the turbine building, is considered a missile generation source. Turbine missiles are described in Subsection 3.5.1.3. The main feedwater pump, the object with the second largest kinetic energy outside containment, is considered in this subsection to be a missile generation source that flies toward the auxiliary building. Even though the main feedwater pump is not a missile source because of its design (i.e., the inside fragment cannot perforate the casing), it is verified whether the auxiliary building is within the influence by assuming penetration of its casing by a fragment. The results provide reasonable assurance that missiles from the main feedwater pump would not perforate the external wall of the auxiliary building. Considering that missiles that are generated from rotating components near the auxiliary building have rotors that are oriented toward the auxiliary building, reasonable assurance of the protection of safety-related systems and components inside the auxiliary building is provided.

3.5.1.1.2 Potential Missiles from Pressurized Components

3.5.1.1.2.1 NSSS Components

If the probability of missile generation P_1 is maintained less than 10^{-7} per year, the missile is not considered statistically significant. If the probability of occurrence is greater than 10^{-7} per year, the probability of impact on a significant target is determined. If the product of these two probabilities is less than 10^{-7} per year, the missile is not considered statistically

significant.

Safety-related NSSS pumps and associated motors are considered rotating missile generation source outside containment. However, no postulated missiles are generated by valves in the NSSS vendor scope, and P_1 is less than 10^{-7} per year for one or more of the following reasons:

a. All valve stems are provided with a backseat or shoulder larger than the valve bonnet opening.

b. Motor-operated and manual valve stems are restrained by stem threads.

c. Operators on motor, hydraulic, and pneumatic operated valves prevent stem ejection.

d. Pneumatic-operated diaphragms and safety valve stems are restrained by the actuator casing.

3.5.1.1.2.2 Balance of Plant Components

Missile protection analysis is performed to provide reasonable assurance that the SSCs required for safe shutdown are located outside the trajectory of postulated missiles, capable of withstanding the impact, or protected from impact by a barrier or wall.

3.5.1.2 Internally Generated Missiles (Inside Containment)

The criteria used for missile protection of internally generated inside the containment are generally consistent with the NRC guidelines in SRP 3.5.1.2 (Reference 5).

Structures inside the containment, including the secondary shield wall, refueling pool wall, structural beams, and floor slabs, serve as missile shields for equipment, including the reactor coolant loop, that must be protected from missiles. These structures and additional protective features protect the reactor coolant pressure boundary (RCPB), containment liner plate, containment penetration, main steam line, main feedwater line, direct vessel injection line, and steam generator, including the instrument connection of steam side, blowdown

line, and drain line from the missile. Engineered safety features, except for some portions of piping for direct vessel injection following a loss-of-coolant accident, are located outside the secondary shield wall to minimize the effects from missiles generated by the RCPB.

The protective shield is installed above the control element drive mechanism to protect the control rod drive mechanism and reactor vessel and SSCs required for safe shutdown from internally generated missiles and a missile from the control element drive mechanism breakaway.

The protective features inside the containment are provided to protect the containment liner plate, isolation system, and the main steam system related to the steam generator from missiles caused by the main steam and main feedwater line breaks, and to prevent the malfunction of other systems or equipment.

The secondary shield wall between the containment wall and refueling pool wall serves as a shield to protect the reactor coolant system, including the steam generator, from missiles generated inside the containment annulus area. The secondary shield wall also serves as a shield to protect safe-shutdown equipment, such as the safety injection tank, from missiles generated by the RCPB.

Missiles falling from heavy load transfers by crane and missiles from dropped SSCs designed to non-seismic category inside the containment are considered gravity-caused missiles. Designs for other lifts comply only with SRP 9.1.5 and NUREG-0612 for falling heavy loads from equipment or component transfers, and the design provides reasonable assurance that the effect of heavy load drops during transfers by crane is eliminated by blocking the path above the systems and components that are necessary to achieve a safe shutdown or protect against an accident. The drop of nonseismically designed SSCs in the containment could affect safety-related systems. Therefore, they are designed to seismic Category II to protect the safety-related systems from the impact of dropped objects.

The COL applicant is to provide the procedure for heavy load transfer to strictly limit the transfer route during plant maintenance and repair period (COL 3.5(1)).

3.5.1.2.1 Potential Missiles from Rotating Components

3.5.1.2.1.1 NSSS Components

If the probability of missile generation P_1 is maintained less than 10^{-7} per year, the missile is not considered statistically significant. If the probability of occurrence is greater than 10^{-7} per year, the probability of impact on a significant target is determined. If the product of these two probabilities is less than 10^{-7} per year, the missile is not considered statistically significant.

The only safety-related NSSS rotating components inside the containment are the reactor coolant pumps. However, there are no postulated missiles generated, and P_1 is less than 10^{-7} per year for the reasons described in Subsection 3.5.1.1.1.1.

3.5.1.2.1.2 Balance of Plant Components

If the probability of missile generation P_1 is maintained less than 10^{-7} per year, the missile is not considered statistically significant. If the probability of occurrence is greater than 10^{-7} per year, the probability of impact on a significant target is determined. If the product of these two probabilities is less than 10^{-7} per year, the missile is not considered statistically significant.

The only safety-related BOP rotating components inside the containment are heating, ventilation and air conditioning (HVAC) equipment, pump impellers, and blades of turbine-driven components. Since the casings of these components are designed to preclude missile ejection, no missiles for HVAC are postulated. Therefore, there is no missile generated and P_1 is less than 10^{-7} per year.

3.5.1.2.2 Potential Missiles from Pressurized Components

3.5.1.2.2.1 NSSS Components

Table 3.5-2 lists the postulated missiles and their weight, shape, dimensions, and impact energy. Major pretensioned studs and nuts, instruments, and the control rod drive

mechanism missiles are included. Items that are excluded because of redundant retention features are valve stems, valve bonnets, and pressurized cover plates.

3.5.1.2.2.2 Balance of Plant Components

Credible missiles resulting from failures of pressurized components in the balance of plant components are selected based on the same conditions as listed in Subsection 3.5.1.1.

As mentioned above, potential missiles from balance of plant pressurized components inside the containment are in the high-energy system range. Most of the valves installed on a high-energy line are designed according to ANSI Class 900 and are excluded as a missile source from pressurized components. Valves installed on auxiliary steam systems are also excluded as a missile source because the operating pressure is below 19.3 kgf/cm^2 (275 psig). Therefore, there is no missile influence from missile generation of balance of plant pressurized components inside the containment.

3.5.1.3 Turbine Missiles

Although the auxiliary system associated with the turbine is non-safety-related, missiles generated by turbine failure can adversely affect the integrity of safety-related SSCs. Safety-related SSCs are evaluated to provide reasonable assurance that they are adequately protected from potential turbine missiles.

3.5.1.3.1 Geometry

The turbine generator is composed of one high-pressure and three low-pressure turbines. As shown in Figure 3.5-1, the turbine shaft is placed in a line with the containment and auxiliary building. The figure shows that the turbine generator is placed with favorable orientation so that most of the SSCs are excluded from the low-trajectory turbine missile strike zone and are concentrated in an area bounded by lines inclined at 25 degrees to the turbine wheel planes and passing through the end wheels of the low-pressure stages.

3.5.1.3.2 Evaluation

Missiles generated by turbine failure can result in a failure of safety-related SSCs. Thus, safety-related SSCs are designed to be protected from potential turbine missiles. The design criteria for the protection of safety-related SSCs are described in Section 3.5.

The probability of unacceptable damage resulting from failure of a single turbine (P_4) is calculated by multiplying all items ($P_1 \times P_2 \times P_3$) below.

a. Probability of turbine failure resulting in the ejection of turbine disc (or internal structure) fragments through the turbine casing (P_1)

b. Probability of ejected turbine missile striking safety-related SSCs (P_2)

c. Probability of struck SSCs failing to perform their safety function (P_3)

Thus, the total damage probability per year (P) of each unit resulting from turbine failure in site is calculated as follows.

$$P = P_4 = P_1 \times P_2 \times P_3$$

Where:

P_4 = probability of unacceptable damage to safety-related SSCs in target unit

P_1 = probability of missile generation that can result in failure of safety-related SSCs in the target unit

P_2 = probability of a missile striking safety-related SSCs in the target unit; the target is safety-related SSCs struck by a missile

P_3 = probability of stuck SSCs failing to perform their safety function; value is conservatively assumed to be 1.0

As described in SRP 3.5.1.3 (Reference 6), on the basis of simple estimates for a variety of plant layouts, the strike and damage probability product can be reasonably assumed to fall within a range that depends on the gross features of turbine generator orientation.

For favorably oriented turbine generators, the product of P_2 and P_3 tends to be in the range of 10^{-4} to 10^{-3} per year per plant.

An estimate of 10^{-3} per year for a favorable orientation is conservatively assumed.

The COL applicant is to confirm the probability of turbine missile generation P_1 is less than 1×10^{-4} per year for a favorable orientation to satisfy the probability of unacceptable damage to safety-related SSCs from turbine missile P_4, less than 1×10^{-7} per year (COL 3.5(2)).

3.5.1.4 Missiles Generated by Tornadoes and Extreme Winds

Safety-related SSCs of the APR1400 are protected against the impact generated by tornado or hurricane missiles. The protection measures consist of seismic Category I structures, shields, and barriers to withstand the effects of missile impact generated by a tornado or hurricane. The protection provides reasonable assurance of conformance to 10 CFR 50, Appendix A, GDC 2 and 4 and 10 CFR 52.47(b)(1) (Reference 7).

Procedures are followed to predict local damage of the impacted area and the response of seismic Category I structures, shields and barriers, or portions thereof, to the missile impact generated by a tornado or hurricane. The procedure for determining local damage includes an estimation of the depth of penetration and, in the case of concrete barriers, the potential for generation of secondary missiles by spalling or scabbing.

Procedures for overall response include assumptions on acceptable ductility ratios where elasto-plastic behavior is relied upon and methods for estimation of forces, moments, and shears induced in the barrier by the impact force of the missile.

Design basis missile spectra for tornadoes and their maximum horizontal speeds (vertical speeds are 67 percent of horizontal speeds) are determined based on the Region I spectrum, which is defined in Table 2 of NRC RG 1.76 (Reference 8). Design basis missile spectra for tornadoes and their maximum speeds are determined based on the Region I spectrum, which is defined in Table 2 of NRC RG 1.76. Design basis missile spectra for hurricanes are determined based on Table 1 of NRC RG 1.221 (Reference 9). The design basis missile velocities for hurricanes correspond to the hurricane windspeed of 116 m/s (260

mph) in Table 2 of NRC RG 1.221. The selected missile types are listed below, and the specified dimensions, mass, and velocity of each missile are defined in Table 3.5-2.

a. Pipe – Rigid missile that tests penetration

b. Automobile – Massive high-kinetic-energy missile that deforms on impact

c. Solid steel sphere – Small rigid missile of sufficient size to pass through any opening in protective barriers

Exterior walls and roof slabs of seismic Category I structures are required to function as missile barriers. The design of missile barriers provides reasonable assurance that the structure will not collapse under the missile load and the barrier will not be penetrated.

The COL applicant is to evaluate site-specific hazards induced by external events that may produce more energetic missiles than tornado or hurricane missiles, and provide reasonable assurance that the seismic Category I structures are designed to withstand these loads (COL 3.5(3)).

3.5.1.5 Site Proximity Missiles (Except Aircraft)

The COL applicant is to evaluate the potential for site proximity explosions and missiles due to train explosions (including rocket effects), truck explosions, ship or barge explosions, industrial facilities, pipeline explosions, or military facilities (COL 3.5(4)). If the total probability of explosion is greater than an order of magnitude of 10^{-7} per year, a missile description, including size, shape, weight, energy, material properties, and trajectory, will be specified. A description of the missile effects on the SSCs will be developed and addressed, if necessary.

3.5.1.6 Aircraft Hazards

The COL applicant is to provide justification for the site-specific aircraft hazard and an aircraft hazard analysis in accordance with the requirements of NRC RG 1.206 (Reference 10) (COL 3.5(5)).

3.5.2 Structures, Systems, and Components to be Protected from Externally Generated Missiles

All safety-related SSCs required to safely shut the reactor down and maintain it in a safe condition are housed in seismic Category I structures. Seismic Category I structures are designed as tornado/hurricane resistant (see Subsection 3.5.1.4) and other external missile resistant.

Structures used to protect safety-related SSCs meet the requirements of NRC RGs 1.13 (Reference 11), 1.27 (Reference 12), 1.115 (Reference 13), and 1.117 (Reference 14).

Major SSCs protected against missile impact are listed in Table 3.5-4.

Openings and penetrations through the exterior walls and roofs of seismic Category I structures and the location of equipment in the vicinity of such openings are arranged so that a missile passing through the opening would not prevent the safe shutdown of the plant and would not result in an offsite release of nuclides exceeding the limits defined in 10 CFR 100 (Reference 15). Otherwise, structural barriers composed of enclosures, missiles-resistant doors and covers, and physical protection features are designed to resist tornado missiles in accordance with the design procedures described in Subsection 3.5.3. Tornado and hurricane missiles are not postulated to strike more than once at a target location. Because of the robustness of the exterior wall, all seismic Category I structures are capable of withstanding the impact of each identified missile.

3.5.3 Barrier Design Procedures

Missile barriers, whether steel or concrete, are designed with sufficient strength and thickness to prevent local damage including perforation, spalling and scabbing, and overall damage. The procedures by which structures and barriers are designed to perform this function are presented in this subsection.

3.5.3.1 Evaluation of Local Structural Effects

The prediction of local damage in the immediate vicinity of an affected area depends on the basic material of construction of the barrier itself. Corresponding procedures are described below.

3.5.3.1.1 Concrete Barriers

Local damage prediction for concrete structures includes the estimation of the depth of missile penetration and an assessment of whether secondary missiles could be generated by spalling. Design criteria for concrete barriers are consistent with the National Defense Research Council (NDRC), "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects" (Reference 16). The modified NDRC formula is used to estimate the missile penetration depth, and barrier thickness to prevent perforation, spalling, and scabbing effects. The design thicknesses of missile barriers are 20 percent greater than the threshold values for the phenomenon being prevented. The design thicknesses also satisfy the minimum acceptable barrier thickness requirements for local damage prediction against tornado-generated missiles as well as hurricane-generated missiles. The minimum barrier thicknesses for local damage due to tornado- and hurricane-generated missiles are provided in Table 3.5-3. The equations used to evaluate local structural effects are described as follows.

3.5.3.1.1.1 Penetration

The depth of missile penetration, x, is calculated using the modified NDRC formulas:

$$x = KNW\left(\frac{V_o}{1{,}000d}\right)^{1.80} + d, \quad for\ \frac{x}{d} > 2.0,$$

$$x = \sqrt{4KNWd\left(\frac{V_o}{1{,}000d}\right)^{1.80}}, \quad for\ \frac{x}{d} \leq 2.0$$

Where:

x = penetration depth (inch)

K = concrete penetrability factor, based on experimental data

= $\frac{180}{\sqrt{f`_c}}$, (with f'$_c$ in psi)

N = missile shape factor and is taken as follows:

= 0.72 for flat-nosed bodies

= 0.84 for blunt-nosed bodies

= 1.00 for spherical end

= 1.14 for very sharp nose

W = missile weight (lb)

V_o = missile impact velocity (ft/sec)

d = effective missile diameter for cylindrical solid missiles, or the outside diameter for hollow pipe missiles. For solid missiles with non-circular cross section, d is the diameter of an equivalent solid cylindrical shaped missile with the same contact surface area as the actual missile (inch)

3.5.3.1.1.2 Perforation

The thickness, t_p, required to prevent perforation is calculated by the modified NDRC formulas:

$$t_p = \left[3.19\left(\frac{x}{d_e}\right) - 0.718\left(\frac{x}{d_e}\right)^2\right]d_e, \quad for\ \frac{x}{d_e} \le 1.35$$

$$t_p = \left[1.32 + 1.24\left(\frac{x}{d_e}\right)\right]d_e, \quad for 1.35 \le \frac{x}{d_e} \le 1.35$$

Where:

t_p = barrier thickness to prevent perforation (inch)

x = penetration depth (inch)

d_e = diameter of a solid bar with the same contact area as the pipe, effective missile diameter for solid missile (inch)

3.5.3.1.1.3 Scabbing

The thickness t_s, required to preclude scabbing is calculated by the modified NDRC formulas:

$$\frac{t_s}{d_e} = \left[7.91 \left(\frac{x}{d_e} \right) - 5.06 \left(\frac{x}{d_e} \right)^2 \right], \quad for \ \frac{x}{d_e} \le 0.65$$

$$\frac{t_s}{d_e} = 2.12 + 1.36 \left(\frac{x}{d_e} \right), \quad for \ 0.65 \le \frac{x}{d_e} \le 11.75$$

Where:

t_s = barrier thickness to prevent scabbing (inch)

χ = penetration depth (inch)

d_e = diameter of a solid bar with the same contact area as the pipe, effective missile diameter for solid missile (inch)

3.5.3.1.2 Steel Barriers

Both of the Ballistic Research Laboratory (BRL) formulas available in "Reactor Safeguards" (Reference 17) and the Stanford Research Institute (SRI) equation are used as the basis for the design and analysis of steel barriers.

BRL Formula

$$T = \frac{(E_k)^{\frac{2}{3}}}{672 D_e}$$

Where:

T = steel plate thickness for which perforation is possible (inch)

D_e = effective diameter of missile (inch)

E_k = missile kinetic energy, $MV^2/2$ (ft-lb)

V = impact velocity (ft/sec)

M = mass of missile (lb-sec^2/ft)

SRI Formula

$$\frac{E}{D} = \frac{S}{46{,}500}\left(16{,}000T^2 + 1{,}500\frac{W}{W_S}T\right)$$

Where:

E = critical kinetic energy required for perforation (ft-lb)

D = effective diameter of missile (in)

S = ultimate tensile strength of the target (steel plate) (lb/in^2)

T = target plate thickness (in)

W = length of a square side between rigid supports (in)

W_s = length of a standard window (4 in)

The SRI formula is applicable within the following ranges:

$0.1 < T/D < 0.8$

$0.002 < T/L < 0.05$

$10 < L/D < 50$

$5 < W/D < 8$

$8 < W/T < 100$

$70 < \nu < 400$

Where:

L = missile length (in)

ν = impact velocity (ft/sec)

3.5.3.2 Overall Damage Prediction

The response of a structure or barrier to missile impact depends largely on the location of impact, the dynamic and deformation properties of the barrier and the missile, and the kinetic energy of the missile itself.

The energy-balanced method is used to evaluate the overall effects when it is permissible to have the target structures undergo inelastic deformation to absorb the energy of a rigid missile impact alone. The energy imparted to the structure by the impact is determined first and then compared with the maximum energy that the structure can safely absorb.

For structures allowed to deform beyond yield, the ductility ratios provided in NRC RG 1.142 (Reference 18) and *[AISC N690]** including Supplement 2 (2004) are followed.

3.5.4 Combined License Information

COL 3.5(1) The COL applicant is to provide the procedure for heavy load transfer to strictly limit the transfer route inside and outside containment during plant maintenance and repair periods.

COL 3.5(2) The COL applicant is to confirm the probability of turbine missile generation P_1 is less than 1×10^{-4} per year for a favorable orientation to safety, and the probability of unacceptable damage to safety-related SSCs from turbine missile P_4 is less than 1×10^{-7} per year.

COL 3.5(3) The COL applicant is to evaluate site-specific hazards induced by external events that may produce more energetic missiles than tornado or hurricane missiles, and provide reasonable assurance that seismic Category I and II structures are designed to withstand these loads.

COL 3.5(4) The COL applicant is to evaluate the potential for site proximity explosions and missiles due to train explosions (including rocket effects), truck explosions, ship or barge explosions, industrial facilities, pipeline explosions, or military facilities.

COL 3.5(5) The COL applicant is to provide justification for the site-specific aircraft hazard and an aircraft hazard analysis in accordance with the requirements of NRC RG 1.206.

3.5.5 References

1. 10 Code of Federal Regulations Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission.

2. Standard Review Plan 3.5.1.1, "Internally Generated Missiles (Outside Containment)," Rev.3, U.S. Nuclear Regulatory Commission, March 2007.

3. Standard Review Plan 9.1.5, "Overhead Heavy Load Handling Systems," Rev. 1, NUREG-0800, U.S.Nuclear Regulatory Commission, March 2007.

4. NUREG-0612, "Control of Heavy load at Nuclear Power Plant: Resolution of Generic Technical Activity A-36," July 2007.

5. Standard Review Plan 3.5.1.2 "Internally Generated Missiles (Inside Containment)," Rev.3, U.S. Nuclear Regulatory Commission, March 2007.

6. Standard Review Plan 3.5.1.3, "Turbine Missiles," Rev.3, U.S. Nuclear Regulatory Commission, March 2007.

7. 10 Code of Federal Regulations Part 52 "License, Certifications, and Approvals for Nuclear Power Plant," U.S. Nuclear Regulatory Commission

8. NRC RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," Rev.3, U.S. Nuclear Regulatory Commission, February 2007.

9. NRC RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, October 2011.

10. NRC RG 1.206, “Combined License Applications for Nuclear Power Plants,” Rev. 0, U.S. Nuclear Regulatory Commission, June 2007.

11. NRC RG 1.13, “Spent Fuel Storage Facility Design Basis,” Rev. 2, U.S. Nuclear Regulatory Commission, March 2007.

12. NRC RG 1.27, “Ultimate Heat Sink,” Rev. 2, U.S. Nuclear Regulatory Commission, January 1976.

13. NRC RG 1.115, “Protection Against Low-Trajectory Turbine Missiles,” Rev. 2, U.S. Nuclear Regulatory Commission, January 2012.

14. NRC RG 1.117, “Tornado Design Classification,” Rev. 1, U.S. Nuclear Regulatory Commission, April 1978.

15. 10 Code of Federal Regulations Part 100 “Reactor Site Criteria,” U.S. Nuclear Regulatory Commission.

16. R. P. Kennedy, “A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects,” Nuclear Engineering and Design, Volume 37, Number 2. 183-203, 1976.

17. Russell, C.R., “Reactor Safeguards,” MacMillan, 1962.

18. NRC RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments),” Rev. 2, U.S. Nuclear Regulatory Commission, November 2011.

Table 3.5-1 (1 of 2)

Kinetic Energy of Potential Missiles[1]

Security-Related Information – Withheld Under 10 CFR 2.390

Table 3.5-1 (2 of 2)

Security-Related Information – Withheld Under 10 CFR 2.390

Table 3.5-2

Design Basis Missiles

Wind	Missile Type	Dimensions	Mass kg (lb)	Max. Horizontal Strike Velocity m/sec (ft/s)
Design Basis Tornado [(1)]	Schedule 40 Pipe	Φ 0.168 m × 4.58 m long (Φ 6.625 in × 15 ft long)	130 (287)	41 (135)
	Automobile	5 m × 2 m × 1.3 m (16.4 ft × 6.6 ft × 4.3ft)	1,810 (4,000)	41 (135)
	Solid Steel Sphere	Φ 2.54 cm (Φ 1 in)	0.0669 (0.147)	8 (26)
Design Basis Hurricane [(2)]	Schedule 40 Pipe	Φ 0.168 m × 4.58 m long (Φ 6.625 in × 15 ft long)	130 (287)	64.5 (212)
	Automobile	5 m × 2 m × 1.3 m (16.4 ft × 6.6 ft × 4.3 ft)	1,810 (4,000)	80.2 (263)
	Solid Steel Sphere	Φ 2.54 cm (Φ 1 in)	0.0669 (0.147)	57.3 (188)

(1) The missile velocities in vertical direction are 67 percent of horizontal missile velocities. The automobile missile is considered to impact at all altitudes less than 10.06 m (33 ft) above all grade levels within 0.8 km (0.5 mi) of the plant structures.

(2) Missiles are based on the maximum wind velocity at elevation 10.06 m (33 ft) above ground. The design-basis vertical missile velocity for all missiles is 26 m/s (58 mph).

Table 3.5-3

Minimum Acceptable Barrier Thickness Requirements for Local Damage Prediction against Missiles Generated by Natural Phenomena

Concrete Strength kg/cm^2 (psi)	Wall Thickness cm (in)	Roof Thickness cm (in)
350 (5,000)	51.1 (20.2)	43.7 (12.7)
420 (6,000)	50.3 (19.4)	42.5 (12.4)

Table 3.5-4 (1 of 3)

Major Systems and Components To Be Protected from Externally Generated Missiles

Protected Components	Missile Barrier
All Valves of Containment Isolation System	Reactor Containment Building
Auxiliary Feedwater System Auxiliary Feedwater Turbine and Steam Inlet/Outlet Auxiliary Feedwater Storage Tank Safety-related Pipes and Valves	Auxiliary Building
Component Cooling Water System Component Cooling Water Heat Exchanger Component Cooling Water Pump Component Cooling Water Makeup Pump Safety-related Pipes and Valves	Component Cooling Water Heat Exchanger Building
Containment Spray System Containment Spray Pump Containment Spray Heat Exchanger Containment Spray Mini-Flow Heat Exchanger Safety-related Pipes and Valves	Reactor Containment and Auxiliary Buildings
Chemical and Volume Control System Regenerative Heat Exchanger Letdown Heat Exchanger Charging Pump Mini-Flow Heat Exchanger Control Volume Tank Charging Pump (Auxiliary Charging Pump) Boric Acid Storage Tank Safety-related Pipes and Valves	Reactor Containment and Auxiliary Buildings

Table 3.5-4 (2 of 3)

Protected Components	Missile Barrier
Direct Transmission System Condenser, charger, and distribution panel	Auxiliary Building
Emergency Diesel Generator System Engine, Generator and Vent System Diesel Oil Storage Tank Diesel Oil Transfer Pump Diesel Oil Day Tank Safety-related Pipes and Valves	Auxiliary Building
Engineering Safety Features System	Reactor Containment and Auxiliary Buildings
Spent Fuel Pool Cooling Cleanup System Spent Fuel Pool Heat Exchanger Spent Fuel Pool Clean Up Pump Safety-related Pipes and Valves	Auxiliary Building
Fuel Handling and Transfer System New fuel rack Spent fuel rack	Auxiliary Building
Main Feedwater System Pipe and valves from SG to MSV house penetration anchor	Reactor Containment and Auxiliary Buildings
In-Core Monitoring System In-Core Instrument	Reactor Containment Building
In-containment Refueling Water Storage System In-containment Refueling Water Storage tank	Reactor Containment Building

Table 3.5-4 (3 of 3)

Protected Components	Missile Barrier
Main Steam System Pipe and Valves from S/G to MSIV Room Penetration Anchor	Reactor Containment and Auxiliary Buildings
Reactor Coolant System (including SDVS) Reactor Vessel, Control rod assembly Steam Generator, Pressurizer, Reactor Coolant Pump, Component inside Containment	Reactor Containment Building
Shutdown Cooling System Shutdown Cooling Pump and Heat Exchanger RCPB Pipes and Valves	Reactor Containment and Auxiliary Buildings
S/G Blowdown System Pipe and Valves from S/G to MSV House Penetration Anchor	Reactor Containment and Auxiliary Buildings
Safety Injection System Safety Injection Pump and Tank RCPB Pipes and Valves	Reactor Containment and Auxiliary Buildings
Essential Service Water System Essential Service Water Pump Safety-related Pipes and Valves	Intake Structure
Control Room HVAC System AHU, ACU Control, Isolate and Smoke Damper	Auxiliary Building

Security-Related Information – Withheld Under 10 CFR 2.390

Figure 3.5-1 Turbine missile strike zone