3.5 MISSILE PROTECTION

This section describes the missile protection design bases for safety related and seismic Category I structures, systems, and components. Missiles considered are those that could result from plant related operating, shutdown, and accident conditions, including failures within and outside the containment, environmentally generated missiles, and site proximity missiles. Included herein are descriptions of structures, shields, and barriers that are designed to withstand missile attacks, the possible missile loading, and the procedures by which each barrier is designed to resist missile impact. Pipe whip, jet blowdown forces, and other dynamic effects associated with postulated rupture of piping are discussed in Section 3.6.

3.5.1 DESIGN BASES

Missile protection criteria conform to 10CFR50, Appendix A General Design Criterion 4. Protection against postulated missiles is provided to fulfill the following design bases:

a) Missiles shall not penetrate the primary containment.

b) Missiles shall not penetrate the control room envelope boundary.

c) Missiles shall not cause a loss of integrity to the reactor coolant pressure boundary.

d) Missiles shall not damage the fuel stored in the spent fuel pool.

e) Missiles shall not prevent safe shutdown of the plant assuming single failure coincident with a loss of offsite power.

→(DRN 05-127, R14)

f) Missiles shall not damage systems, components, or structures whose failure could result in a release of radioactivity exceeding values specified in 10CFR50.67.

←(DRN 05-127, R14)

3.5.1.1 Internally Generated Missiles (Outside Containment)

Internally generated missiles outside containment are selected as follows:

a) Missiles generated by the high energy systems (A high energy system is defined according to the NRC branch technical position, APCSB3-1):

   1) Temperature detectors installed in piping if failure of a single circumferential weld would cause their ejection.

   2) Valve stems are considered postulated missiles unless at least one feature in addition to the stem threads is included in their design to prevent ejection. Valves with back seats, and motor or air operated valves are considered to have sufficient restraints, so that the valve stem will not become a missile.

   3) Valves two in. and smaller (ASME Section Section III valves of ANSI 900 psig rating and above) are bonnetless valves. Valves larger than two in. have a

pressure seal bonnet design, where the valve bonnet is prevented from becoming a missile by a retaining ring.

Most valves of ANSI rating 600 psig and below have bolted bonnets. Valve bonnets are prevented from becoming missiles by limiting stresses in the bonnet-to-body bolting materials by rules set forth in ASME Code, Section III. Even if bolt failure were to occur, the likelihood of all bolts experiencing a simultaneous complete severance failure is very remote.

Accordingly, bonnets have not been considered as credible missiles.

4) Safety Relief Valves: Main steam safety relief valves are dual outlet valves and are prevented from becoming missiles by limiting stresses in bolting material by rules set forth in the ASME Code, Section III. Accordingly, main steam safety relief valves have not been considered as credible missiles.

The safety relief valves associated with charging pumps are located in separate rooms separated from other safety related equipment.

There are no other safety relief valves in high energy systems located adjacent to the safety related equipment.

5) Nuts, bolts and nut and stud combinations have a small amount of stored energy and thus were not considered as potential missiles.

6) High energy systems located in the Turbine Building are located a sufficient distance from safety related components and have not been analyzed.

→

7) Compressed air or gas bottles in the RAB are seismically restrained, capped when not connected, and are capped when being transported in accordance with plant procedures to ensure they do not become potential missiles.

←

Table 3.5-1 lists the missiles generated by high energy systems considered outside containment.

b) Missiles Generated by Overspeed of Rotating Components

Rotating equipment which has been designed and manufactured to the safety class 3 standards (emergency feedwater pump turbine and diesel generators) have been designed to prevent overspeed assuming angle failure criteria. In addition, such equipment is not normally operating.

Motor operated pumps and fans have induction motors which by their design will not allow operation above synchronous speed. All fans, located adjacent to the safety related equipment, have either a casing or a combined casing and cabinet thickness exceeding the thickness required to stop the self generated missiles at synchronous speeds. The internal energy of the self generated missiles by the pumps is considered to be insufficient to penetrate the pump casings.

Analysis of overspeed protection is listed in Table 3.5-2.

Missile protection analyses for the safety related systems, components and structures located outside the containment are tabulated in Tables 3.5-3 and 3.5-3a.

3.5.1.2 Internally Generated Missiles (Inside Containment)

Internal missiles which would be generated from pressure containing components that are part of the Reactor Coolant System or other high energy systems are considered in the design of the Reactor Building. The entire Reactor Coolant System and parts of the Main Steam System are surrounded by the secondary shield wall, and their components arranged so that a missile generated from one component will not damage its counterparts. The secondary shield wall protects the containment vessel from missiles generated within the secondary shield. Other shields include primary shield walls, which surround the reactor vessel, and the top shield which is located above the control element drive mechanisms.

A tabulation of all safety related structures, systems and components inside the containment and their seismic category is given in Table 3.2-1. General arrangement and section detail drawing showing the location of safety related structures and components are located in Section 1.2.

Missiles generated from pressurized components inside containment are listed in Table 3.5-4. This table also describes the kinetic energy and weight of each missile, and identifies the respective structure, shield, or barrier provided to contain missiles and thus prevent missile damage to the safety related components required for safe shutdown. For a discussion on protection against dynamic effects associated with the postulated rupture of piping inside the containment see Section 3.6.

3.5.1.3 Turbine Missiles

Failures that could occur in the large steam turbines of the main turbine-generator sets have the potential for producing large high-energy missiles. The kinetic energy of ejected missiles can be sufficient to damage even substantial reinforced concrete slabs and panels. The potential for damage to safety-related structures, systems and components due to such turbine failure has been evaluated to determine whether additional protection, beyond that inherently provided by existing structural shielding, is required to further reduce the damage probability.

3.5.1.3.1 Description of Turbine Elements, Placement and Orientation

The placement and orientation of the turbine-generator over the rest of the plant is shown on Figures 3.5-1, 3.5-2, 3.5-3 and 3.5-4. General Arrangement drawings of the turbine itself are shown on Figures 1.2-5 and 1.2-6.

High Pressure Turbine

The HP element is a double flow design and consists of a forged single-piece double flow rotor, a cast steel outer cylinder, and four cast steel blade rings supported inside the outer cylinder. Steam from four control valves enters nozzle chambers at the center of the turbine element through four inlet pipes (two in the cylinder base and two in the cylinder cover). In these chambers, the steam is distributed equally to both halves of the rotor and flows axially through the blading to the exhaust chambers at each end of the HP cylinder.

The HP cylinder cover and base are held together at the horizontal joint by studs and stud-bolts having lengths ranging from 28 to 59 inches and diameters ranging from 2.50 to 3.50 inches.

Low Pressure Turbine

The LP turbines are of a double flow design. Each element consists of a double flow rotor assembly, an outer cylinder, two inner cylinders, and blade rings. The rotor assembly consists of a shaft with 10 shrunk-on discs, numbered consecutively from the center of the rotor outward, made of low alloy steel and two shrunk-on couplings. Steam enters at the top of each outer cylinder where it flows to the inlet chamber of the inner cylinders. In the inlet chamber, the steam is distributed equally to both halves of the rotor and flows through the blading to the condenser. LP turbines are numbered from the high pressure element to the generator, with the lowest numbered LP element (LP1) located next to the HP element, and the highest numbered LP element (LP3) located next to the generator. (See Figure 3.5-6.)

3.5.1.3.2 Turbine Generated Missile Identification and Characteristics

Missiles are generated due to structural failure of turbine discs. Following such a failure, the high rotational energy of the turbine can cause the disc and cylinder fragments to penetrate the turbine casing and become airborne missiles. The large mass and high velocity of these missiles requires that they be evaluated for possible damaging effects. The turbine failures are classified into two general types and are referred to as design overspeed failures and destructive overspeed failures.

3.5.1.3.2.1 High Pressure Turbine Generated Missiles

Calculations show that all fragments generated by a postulated failure of the HP turbine rotor at design overspeed (120 percent of rated speed) would be contained by the HP turbine blade rings and casing. The probability of HP turbine rotor failure at destructive overspeed (193 percent of rated speed) is practically zero due to the very large margin between the high pressure rotor busting speed and the maximum speed at which the steam can drive the unit with all the admission valves fully open. Therefore, no missiles are expected to be generated during HP turbine design and destructive overspeed failure.

3.5.1.3.2.2 Low Pressure Turbine Generated Missiles

It is considered that any shrunk-on wheel on the low pressure rotor could be a source of missiles; the missiles being large sectors of the wheel released by multiple radial fractures. In evaluating the capability of LP structures to contain these fragments, it is assumed that the fragments are 90, 120, and 180 degree segments. Because of kinematic considerations, a 180 degree segment will have a lower initial translational energy and more of the energy will be absorbed by the internal structures. As a result, the likelihood of generating missiles is less than for the other segments, and exit energies will be lower. Therefore, only 90 and 120 degree segment missiles are considered in the analysis.

→(DRN 00-1032)

Calculation shows that 120 degree and 90 degree fragments are very similar in their consequences. A 120 degree fragment might eject from the turbine casing with slightly higher energy than a 90 degree fragment but has a lesser capacity to penetrate other structures by reason of its greater volume. It was assumed therefore, that a wheel fractures into four segments of 90 degrees included angle. The geometries and weights of fragments so defined are given on Figure 3.5-5. The arrangement and identification of LP turbine disc is shown on Figure 3.5-6.

←(DRN 00-1032)

3.5.1.3.2.3 Dissipation of Energy Within the Low Pressure Turbine Cylinders

The total kinetic energy of a released fragment is reduced in collision with the surrounding casing structures. The following is a brief description of the method used.

Rotational kinetic energy was assumed to dissipate in friction and melting. Losses in translational kinetic energy were calculated using the following criteria. If the kinetic energy loss in an inelastic collision (i.e., a disc fragment with the stationary cylinder parts surrounding the fragment) exceeds the deformation energy required to shear and compress the cylinder material in the area of impact the cylinder is perforated. In this case, not only is there energy loss in shearing and compressing the material at the impact area but also there is energy loss in accelerating the effective mass of material lying outside the impact area. Additional energy is lost as a result of an inelastic collision between the disc and the material in the impact area. The disc then carries forward the parts sheared out.

Alternatively, if the inelastic collision energy loss is less than the shear and compression energy, the cylinder is stretched by a tensile mode of deformation.

The disc is contained if the system's kinetic energy, i.e., the initial translational kinetic energy less the energy loss of an inelastic collision, is less than the energy of deformation of the structure. If the system kinetic energy exceeds the energy of deformation, the disc tears through the cylinder part with a residual kinetic energy. No secondary missiles are produced by the failure. The system energy is now equal to the initial kinetic energy less the energy loss of the inelastic collision and the energy loss of deformation. To find the disc energy, the system must now be separated into energy of the disc and the energy of the effective mass of the structure.

Between initial fragment release and final escape from the outer casing several separated collisions can occur, involving the separate barriers encountered. For cast iron diaphragm inner and outer rings, no shear, compression, or stretching work is calculated. The energy lost on impact with these components is only the inelastic collision loss for a collision involving the minimum appropriate fractions of their masses.

A typical low pressure turbine cylinder is shown on Figure 3.5-7.
Westinghouse performed an extensive series of model tests to better understand the process of penetration or containment of disc fragments. The results of the test series were used to develop a method for analytically predicting the effect of a disc or rotor burst. Complete description of the test series, analysis and conclusions is given in Reference 1.

3.5.1.3.2.4 Energy of Escaping Missiles

Table 3.5-5 shows the residual energies of fragments of low pressure disc released at 120 percent of normal speed and at bursting speed, on escape from the outer cylinder. The bursting speed assumed is for a mean tangential stress equal to 85 percent of the minimum specified material ultimate tensile strength.

It is necessary to reach 193 percent of normal speed to achieve a mean tangential stress of 85 percent of ultimate strength. Such a speed is considered extremely unlikely due to the redundancy diversity and reliability of the turbine overspeed protection system (see Subsection 10.2.2).

Also shown in the table are the expected ejection angles and minimum impact areas. These ejection angles are based on test results, and are measured from the vertical radial plane passing through the disc.

When disc fragments are ejected, it is expected that a quantity of the debris from internal collisions would eject simultaneously as well as fragments similar to those of the disc fragment. The angle of ejection of the cylinder fragments are estimated to be approximately the same as those of the disc. The dimensions of these cylinder fragments are given on Figure 3.5-8 and their residual energy is given in Table 3.5-6.

3.5.1.3.3 Turbine Failure Missiles - Probability Analysis

→(DRN 00-1032, R11-A)

The probability of a turbine missile causing damage to a safety-related component or structure in a nuclear power plant is evaluated as a product of three probabilities denoted as P_1, P_2, and P_3. P_1 is the missile generation probability related to the source (type of turbine); P_2 is the strike probability determined by the ballistic flight between source and the target; and P_3 is the damage probability depending on the missile parameters at impact (mass, velocity, direction) and on the target's material and structural properties.

←(DRN 00-1032, R11-A)

→(DRN 06-758, R15)

The following is the analysis submitted to the NRC. Revised analyses [15][18] are described in section 3.5.1.3.7.

←(DRN 06-758, R15)

Turbine missiles may be ejected at any angle of the 360 degree arc about the turbine axis. The ejection path will not always be perfectly normal to the turbine axis, but may vary from the normal for the turbine wheels. The missile ejection angles and directions are illustrated on Figure 3.5-9.

Tests[1] have indicated that deflection angles (θ_2) of turbine generated missiles will be close to zero (+/-5 degrees) for interior discs and 0 to 25 degrees for the end disc. A uniform probability distribution is assumed within this range of angles. To calculate the impact probability it was also assumed that a missile would be ejected with equal probability in the 360 degrees around the rotor axis (θ_1).

A missile having been ejected from a turbine with a given velocity and ejection angle can strike the target either of two ways. Therefore, the strike probability can be thought of as having two components. One is the high trajectory or lob shot strike probability and the other is the low trajectory or direct shot strike probability. A lob shot is one in which

the missile travels in a parabolic path from the point of ejection to the point of impact. A direct shot is one in which the missile travels nearly in a straight line from the point of ejection to the point of impact. In general, for high energy missiles, the closeness of the plant structures to the turbine (relative to the maximum range of the missile) will result in lob shots impacting horizontal surfaces and direct shots impacting vertical surfaces.

3.5.1.3.3.1 Missile Strike Probabilities, P_2

The missile strike probabilities were considered both for high and low trajectory impacts. Classical equations of motion were the basis for determining the maximum and minimum range of missiles. The strike and damage probabilities have been calculated for each piece of safety-related equipment identified on Figures 3.5-1 to 3.5-4.

High Trajectory Probabilities

A relatively simple method for estimating the probability of strikes from high trajectory missiles lies in calculating the overall extent of the region which the missiles can reach. The distances between the missile origin and plant structures are relatively short as compared to the potential range of missiles. Therefore, the high trajectory missiles (HTM) impact on vertical walls would occur only at very steep angles with the horizontal, resulting in impact almost parallel to the surfaces. Such impacts present no hazard and, therefore, HTM impact is limited to horizontal surfaces.

→(DRN 00-1032)

Because of the plant arrangement, the striking of all the vital plant structures with HTM requires that these missiles be ejected at angles bounded by $85 \leq R_1 \leq 90$. Very small R_1 angles cannot result in high trajectory strikes because of the higher elevation of the turbine operating deck. Therefore, the probability of striking any particular target is only related to the plan (horizontal) area of that target, and is given by the ratio of that area to the area of the region which can be struck, by the missile. The latter in turn is conservatively estimated by the area of the half ellipse having a major axis equal to the maximum range of the missile ejected with R_2=0 degrees and a minor axis of the missile ejected with R_1=90 degrees.

←(DRN 00-1032)

$$\text{Probability of strike } P_2 = \frac{\text{Area of Target}}{\text{Area of the half ellipse of the probable missile landing zone}}$$

The maximum range in the +y direction (see Figure 3.5-9) for no air attenuation could result for a missile with R_1 = 45 degrees and R_2 = 0 degrees. The minor axis of the ellipse along $\pm$x direction is equal to the range of the missile with R_1 = 90 degrees and $R_2 = \pm$ a, the maximum possible deflection angle of the particular missile.

Low Trajectory Probabilities

The probability of low trajectory missile (LTM) impact on a critical target is dependent solely on the geometric considerations. The probability, P_2, for LTM is defined as the ratio of the solid angle subtended by the projection of the target area to the total possible solid angle for the ejection of the missile.

the target area to the total possible solid angle for the ejection of the missile.

$$P_i = \frac{(\Omega)}{\Omega i}$$

where:

Ω = solid angle subtended by the projection of the target area within the total possible solid angle

Ωi = total possible solid angle for the i^{th} disc

Pi = probability of impact with the target given the i^{th} missile generation

→(DRN 00-1032)

$$\frac{Pi}{\Omega i} = \frac{\Omega}{\Omega i} = \frac{\int_{min}^{max} d\phi \int_{\alpha\ min}^{\alpha\ max} \cos \propto d \propto}{\int_{\phi i\ min}^{\phi i\ max} d\phi \int_{\propto i\ min}^{\propto i\ max} \cos \propto d \propto}$$

$$= \frac{(\phi\max - \phi\min)}{(\phi i\max - \phi i\min)} \; \frac{(\sin \propto \max - \sin \propto \min)}{(\sin \propto i\max - \sin \propto i\min)}$$

←(DRN 00-1032)

where:

ϕ max = maximum elevation angle of the target

ϕ min = minimum elevation angle of the target

α max = maximum azimuthal angle of the target

α min = minimum azimuthal angle of the target

ϕ imax = maximum possible elevation angle for the i^{th} missile

ϕ imin = minimum possible elevation angle for the i^{th} missile

α imax = maximum possible azimuthal angle for the i^{th} missile

α imin = minimum possible azimuthal angle for the i^{th} missile

Since the missiles considered are 90 degree segments for the disc, the total number of fragments created is four, one in each quadrant of vertical plane. Therefore, for any particular missile (∅imax - ∅imin) will be 90 degrees. For the fragments due to interior discs the maximum possible deflection along the azimuthal direction (αimax - βimin) is 10 degrees whereas for the end discs, it is 25 degrees.

3.5.1.3.3.2 Missile Generator Probability, P_1

→

Turbine missiles may be generated when the steam turbine is driven to an overspeed condition, due to some malfunction in the protection system. At this point one of the discs breaks into several pieces, some of which perforate the turbine casing. Westinghouse has performed tests and analysis to determine the missile generation probabilities, ejection velocities and angles. Results of these test programs and analyses are contained in References 1-3. On the other hand, Bush(4) from his study of historical turbine failure data has projected the probability of turbine failure generating external missiles to be 7×10^{-5}. These probability values based on Westinghouse analysis and review of historical turbine failure data differ by 5 or 6 orders of magnitude. Therefore, the values of the probability of missile generation, P_1, used in our analysis are those recommended by Nuclear Regulatory Commission (Ref 5) based on historical data for design overspeed as 6×10^{-5} and for destructive overspeed as 4×10^{-5} per turbine year. However, due to redundance and periodic testing features of the turbine overspeed protection, and the quality control of the manufacturing processes and materials, the actual probability of missile is considered to be lower than these values.

←

3.5.1.3.3.3. Probability of Missile Strike Damage, P_3

Upon missile impact, failure of a barrier may occur through penetration or loss of structural integrity of the barrier due to the force of impact. Whether or not failure occurs is dependent on the missile velocity (V), impact area, angle of incidence, barrier thickness and material.

The unacceptable strike damage probability, P_3, is considered to have a value of zero (0) when there is no penetration of the final barrier and one (1.0) when penetration on strike is certain. The determination of the ability of turbine missile to penetrate a barrier is discussed in Subsection 3.5.1.3.4.

3.5.1.3.3.4 Impact Area Probability, Pa

The estimates made for penetration capability of the missile are very conservative. It is assumed that the missile impacts normal to the target and does not deform, thereby retaining the original minimum equivalent diameter and orientation that it had prior to the penetration of the first barrier. In reality, the missile may deform or change its orientation, presenting a much larger equivalent diameter for the next barrier. Also since the missile impact is not always normal, the effective thickness of the barrier will be more than the actual thickness.

→

Further a typical turbine missile has six potential, distinct surfaces for target impact. When the fragment impacts a target surface at some angle, the missile rotates about the edge or the point of contact until a stable contact is established between the missile and target. The high trajectory missiles will tumble about its trajectory as it ascends and descends. Therefore, the probability, Pa, that the missile can hit the particular barrier with the area that is capable of damaging it, is approximately given by the ratio of this particular area of the total perimeter surface area of the missile along the exit axis. For example, this area ratio for a disc fragment having an area A_2 that can penetrate a given barrier can be expressed as,

←

→(DRN 00-1032)

$$Pa = \frac{2A_2}{(A_1 + 2A_2 + A_3)}$$ (See Figure 3.5-5)

←(DRN 00-1032)

If the missile were to strike the target with an orientation different from A_2,the barrier could not be penetrated. The damage probability is then the product of P_3 and the impact area probability, Pa.

3.5.1.3.4 Penetration Calculations

Penetration capability of missiles was determined, as recommended by the NRC (Ref 6), using the modified National Defense Research Committee (NDRC) formula and Ballistic Research Laboratory (BRL) formula for concrete and steel barriers respectively. Electric Power Research Institute (EPRI) full scale missile impact tests have shown good correlation between actual penetration depth into reinforced concrete barriers and those predicted by the modified NDRC formula (Ref 7).

a) Concrete Barriers: Modified NDRC formula

One of two formulas for the penetration depth is used depending on the depth to equivalent diameter ratio:

→(DRN 00-1032)

$$X = \left[4KNWd\left(\frac{v}{1000\,d}\right)^{1.8}\right]^{1/2} \quad \text{for} \quad \frac{x}{d} \le 2.0$$

←(DRN 00-1032)

and

$$X = \left[KNW\left(\frac{v}{1000\,d}\right)^{1.8}\right] + d \quad \text{for} \quad X/d \ge 2.0$$

where

v = missile velocity (ft/sec)
N = missile shape factor taken as 1.0
d = missile diameter (inches)
W = missile weight (pounds)

$$K = \frac{180}{\sqrt{fc'}}$$

fc'= concrete compressive strength (psi)
X = concrete wall thickness (inches)

Based on these formulas, the perforation velocity (velocity required for penetration) of the concrete barrier can be expressed as follows:

$$Vp = 1000d \left(\frac{X^2}{4KNWd} \right)^{0.556} \qquad \text{for } \frac{X}{d} \leq 2.0$$

and

→(DRN 00-1032)

$$Vp = 1000\,d \frac{(X - d)^{0.556}}{KNW} \qquad \text{for } \frac{x}{d} \geq 2.0$$

←(DRN 00-1032)

The value of fc', the concrete compressive strength varies according to the type of concrete. A value of fc' = 4000 psi is used for all walls and roofs except the Reactor Building wall and dome. An average compressive strength of 5000 psi is used for the Reactor Building wall and dome. Tests on the concrete compressive strength have been taken. At 28 days, cylinder tests showed an average concrete strength of 4935 psi with a standard deviation of 8 percent. As the concrete cures for one year, approximately a 30 percent increase in the strength of the concrete is expected(8) . Therefore, the compressive strength values used in the penetration calculation of these structures is very conservative.

b) <u>Steel Barriers:</u> BRL Formula

$$X^{3/2} = \frac{0.5MV^2}{17400K^2 d^{3/2}}$$

where

X = steel plate thickness (inches)

M = missile mass $\frac{(lb - sec^2)}{ft}$

V = missile velocity (ft/sec)
K = constant depending on the grade of steel taken as 1.0
d = missile equivalent diameter (inches)

The perforation velocity can be expressed as

→(DRN 00-1032)

$$Vp^2 = \frac{1.12x10^6 (dX)^{3/2}}{W} \qquad (9)$$

The equivalent diameter (d) is calculated for an equivalent circular impact area which would provide the same area as the actual missile impact area.

←(DRN 00-1032)

c) Moisture Separator Reheater

The moisture separator reheaters (MSR) provide shielding for the Reactor Auxiliary and Reactor Buildings. For all the low trajectory missiles except the fragments from the end discs of group A and F i.e., 5A and 5F, the shielding provided by the MSR is effective. The missiles are either completely stopped or their velocity is sufficiently reduced so that they cannot strike the target. The MSR is composed of a steel cylinder 1.5" thick and internals consisting of a tube bundle. The tube bundle is enclosed on each side by a tube support carbon steel plate 0.25" thick. For a conservative estimate of the energy absorbed to penetrate the MSR, the presence of the tube bundle is neglected. Therefore, to penetrate the MSR, a missile would at least have to penetrate the following barriers in series:

→(DRN 00-1032)

Cylinder 2 x 1.5 = 3.0"

←(DRN 00-1032)

Support Plate 2 x 0.25" = 0.5"

Assuming normal impact, the penetration velocity is calculated from equation (9) as follows:

→(DRN 00-1032)

$$Vp^2 = \frac{1.12 x 10^6 D^{1.5}}{W} = \frac{(2(1.5) + 2(0.25))^{1.5}}{W}$$

$$Vp^2 = \frac{4.395 x 10^6 D^{1.5}}{W}$$

←(DRN 00-1032)

The arrangement and identification of all low pressure discs is shown on Figure 3.5-6. In penetrating the MSR, the missile collides with many barriers and so it is extremely conservative to assume that the missile maintains its original orientation throughout the penetration sequence.

d) Multiple Barriers and Residual Velocity

For multiple barriers in series, the total energy required to penetrate is expressed as follows:

→(DRN 00-1032)

$$E_P = E_1 + E_2 + E_3 + \text{---------} E_n$$

←(DRN 00-1032)

$$V_P^2 = V_1^2 + V_2^2 \text{ --------------} + V_n^2$$

where E_p and V_p are the initial energy and impact velocity required to penetrate all barriers and E_n and V_n are the energy and impact velocity required to penetrate the n_{th} barrier.

The residual velocity (Vr) is calculated from the residual energy which is the difference between the kinetic energy of the missile and the energy required to penetrate the given barrier or multiple barriers.

The residual energy of the missile:

Er = Ei - Ep

The residual velocity

→(DRN 00-1032)

$$Vr = \left(Vi^2 - V_p^2\right)^{1/2}$$

←(DRN 00-1032)

where Vr = residual velocity of missile after perforation of the given barrier (ft/sec)

Vi = impact velocity of the missile normal to the target surface (ft/sec)

Vp = perforation velocity for the barrier (ft/sec).

This equation neglects the mass of the plug which may be punched out of the target. For concrete barriers, the concrete would fracture and not act in conjunction with the missile mass. It provides a conservative estimate for the residual velocity and is in accordance with Regulatory Guide 1.115 (Revision 1).

3.5.1.3.5 Targets and Barriers Associated with Low Trajectory Turbine Missiles

The Reactor Auxiliary Building, Reactor Building and the Fuel Handling Building are within the low trajectory missile strike zone. However, since the Fuel Handling Building is in the shadow of the Reactor Building, there are no missiles that can strike it. The safety-related components located in the Reactor Building are shielded from LTM impact by the MSR. That is, to strike the Reactor Building wall a missile would have to, at least, penetrate 3.5" of carbon steel plate.

The failure of the MSR shell and its support structure due to plastic hinge deformation are low probability events. The MSR and its support structure is a low frequency system and therefore, the period of vibration is substantially higher than an impact time. Hence, the assumption that the missile will penetrate without deflection through the MSR shell is reasonable.

Due to the relative elevation of the turbine deck, for an LTM to strike the Reactor Building, the missiles must first hit and penetrate the MSR shell. Therefore, after strike and penetrating MSR the missiles, even from the destructive overspeed failure, will have substantially reduced velocities and will not be capable of penetrating the containment wall.

→(DRN 00-1032)

For direct strikes on the Reactor Auxiliary Building below the turbine deck elevation, the turbine pedestal beam acts as barrier preventing any missiles from going any further. For strikes above the turbine deck elevation, the MSR acts as barrier as previously described. However, the horizontal and vertical separation of the pedestal beam and MSR produce a gap of 2.2 degrees at the turbine axis which is not covered. Geometric analysis indicates that a missile must be less than eleven (11) inches to penetrate this gap. Therefore, any missile larger cannot strike the RAB wall. A cylinder fragment due to disc #2 failure is

←(DRN 00-1032)

the only missile that can go through this gap and only if oriented properly. Further only the fragment generated due to destructive overspeed failure event is subsequently capable of penetrating the RAB wall.

For the fragments from turbine discs 5A and 5F, however, the MSR does not act as barrier. The pedestal beam and the girder (18" x 3" flange and 54" x 15"/16 web) below the MSR act as barriers for the missiles coming from disc #5A up to 11° and disc #5F up to 9° in θ_2 direction. For disc 5A, the potential targets are located on the westside of the RAB. Since the roof thickness under the mainsteam and feedwater lines is 3 ft, the fragments cannot penetrate the roof. Further the mainsteam and feedwater lines are in the shadow of the pedestal beam. The other safety-related targets are in the shadow of the girder. Therefore, there are no safety-related targets for direct strike for missiles coming from disc #5A. The safety-related targets located in the strike zones of disc numbers 2, groups A, B, E and F and disc number 5 group F are considered for direct shot probability calculations.

→

3.5.1.3.6 Turbine Missile Analysis Results

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The missiles generated by a hypothetical turbine at design (120 percent) and destructive (193 percent) overspeed failure events are characterized by unique size, geometry and ejection velocity. Using the method of analysis described in earlier sections. The value of P_2 x P_3 was calculated for each safety-related equipment located in the strike zone for both low and high trajectory impacts for the missile data provided in Tables 3.5-5 and 3.5-6.

→

The specific safety-related targets are identified and are shown relative to the turbine axis on Figures 3.5-1 to 3.5-4. The targets and the corresponding barriers for both low and high trajectory impacts are given in Tables 3.5-7 to 3.5-9f. The probabilities of strike P_2 and unacceptable damage, P_3, for each target due to each missile have been calculated on the basis of these parameters. As discussed in Subsection 3.5.1.3.3.4, the unacceptable damage probability, P_3, includes the appropriate impact area probability Pa for low trajectory strike targets. However, Pa for high trajectory strike targets is .conservatively assumed to be unity. Tables 3.5-9g and 3.5-9h present the combined strike and barrier failure probabilities (P_2 x P_3) for safety-related targets located in each building for design and destructive overspeed failure events respectively. Also included in the tables is the probability of damage potential for the total plant due to each event.

←

The ejection velocities of the turbine missiles were predicted to have a range of 139 ft/sec to 753 ft/sec. At these velocities and the possible ejection angles, the range of HTM can extend at least 500 ft in all directions. The overall strike and damage probability for the entire plant due to HTM impact is 4.4×10^{-4} for the design overspeed failure event and
8 5 x 10^{-4} for the destructive overspeed failure event.

The strike and damage probability due to LTM impacts for missiles generated by various discs for both design and destructive overspeed failure events are evaluated separately. Since the missiles due to the design overspeed failure event, that can strike the RAB wall, do not have enough energy to penetrate a 2 foot concrete wall the overall damage probability is zero. But for the missiles due to destructive overspeed failure event, the overall strike damage probability is 8.4×10^{-4}.

These estimates for probabilities are very conservative due to the assumptions involved in these calculations. The penetration capability of the missile calculations assume that the impact velocity is the same as ejection velocity. It is also considered that the missile impacts normal to the barrier surface and does not deform, thereby retaining the original minimum equivalent diameter that it had prior to the penetration of the first barrier. In reality the missile impact velocity will be less than the ejection velocity due to air attenuation and relative elevation of impact location. The missile rarely impacts normal to the barrier and so the effective thickness of the barrier is always more than the actual thickness. Also, the missile will deform and thus, present a larger equivalent diameter for the next barrier.

The NRC in Regulatory Guide 1.115 assumes a missile generation probability, based on historical failure data for the turbine, of 10^{-4} per turbine year and, therefore, suggests that the strike and damage probability for the plant should be within 10^{-3} per turbine year. However, due to redundancy and periodic testing features of the turbine overspeed protection and the quality control of the manufacturing processes and materials, the actual probability of missile generation is expected to be significantly lower than the NRC suggested values(5) for missile generation probability, P_1.

The overall plant unacceptable strike damage probability ($P_1 \times P_2 \times P_3$) for this plant from the design overspeed failure event due to low trajectory strike is almost zero and that due to high trajectory strike is 2.6×10^{-8} per turbine year using the NRC(5) Value of P_1,as 6×10^{-5}.

The overall plant unacceptable strike and damage probability ($P_1 \times P_2 \times P_3$) from destructive overspeed failure event due to low trajectory strike is 3.4×10^{-8} per turbine year and that due to high trajectory impacts is 3.4×10^{-8} per turbine year assuming the NRC(5) value of P_1 as 4×10^{-5}.

The combined probability of strike and damage for the total plant due to high and low trajectory impacts is 2.6×10^{-8} per turbine year for the design overspeed failure event and 6.8×10^{-8} for the destructive overspeed failure event.

3.5.1.3.7 Turbine Manufacturer Probability Analysis

→(DRN 00-1032, R11-A)

In 1994 the turbine manufacturer performed a revised calculation of P_1 using newer values of valve failure rates. This analysis (15) uses an NRC assumed value of 1×10^{-2} for $P_2 \times P_3$. The results show that for a quarterly turbine speed control valve test interval, the combined probability of strike damange is 6.5×10^{-9} for the design overspeed case and 4.58×10^{-8} for the destructive overspeed case.

←(DRN 00-1032, R11-A)

→(DRN 06-758, R15)

In 2006, the turbine manufacturer performed an updated calculation of P_1 using the more extensive historical data for valve and disc failure rates. This analysis(18) also used the NRC assumed value of 1×10^{-2} for $P_2 \times P_3$. The analysis was performed for both quarterly and semi-annual turbine speed control valve test intervals, and included normally running and design, intermediate, and destructive overspeed cases. The normally running case is a new turbine missile scenario added for this analysis. Intermediate overspeed is assumed to occur when there is a system separation and one or more alignments of reheat stop valve and reheat interceptor valve failure to close. The results show that for the semi-annual turbine valve test and 90 month "heavy" LP disc inspection interval, the combined probability of strike damage is 7.27×10^{-8} for the normally running case, 7.22×10^{-10} for the design overspeed case, 1.26×10^{-11} for the intermediate overspeed case, and 1.39×10^{-9} for the destructive overspeed case, or a total probability of strike damage of 7.48×10^{-8} per year.

←(DRN 06-758, R15)

3.5.1.4 Missiles Generated by Natural Phenomena

The postulated missiles generated by natural phenomena are the tornado missiles. The plant is designed for multiple tornado missiles and the design bases of Subsection 3.5.1.

The design tornado missiles are listed in Table 3.5-10.

→(DRN 00-1172)

3.5.1.4.1 System/Component Not Requiring Unique Tornado Missile Protection

The safety related systems and structures and their protection from tornado missiles are tabulated in Tables 3.2-1, 3.5-3, 3.5-3a.

A limited amount of safety related systems and components located on RAB roof at +69' elevation, at +46' elevation and in the cooling tower areas are evaluated as not requiring unique tornado missile protection barriers.

Safety-related systems and components are generally protected from tornado generated missiles. The limited amount of unprotected portions of safety-related systems and components will be analyzed using probabilistic missile strike analysis as permitted in Standard Review Plan 3.5.1.4 "Missiles Generated By Natural Phenomena". This analysis is conducted to establish the total (cumulative) probability per year of missiles striking safety-related structures, systems and components due to postulated tornadoes. This information will be then used to determine the specific design provisions that must be provided to maintain the estimate of strike probability below an acceptable level.

→(DRN 05-127, R14)

The acceptable level established for the protection of such systems and components at Waterford 3 is consistent with the acceptance criteria in Standard Review Plan 2.2.3 "Evaluation of Potential Accidents", i.e., that a probability of occurrence of initiating events (those that could lead to potential consequences in excess of the 10CFR50.67 Guidelines) of "approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower. The Waterford 3 specific acceptance criteria is that the total probability of tornado missiles striking a safety-related system or component must be shown by analysis to be less than 1×10^{-6} per year.

←(DRN 05-127, R14)

This acceptance criteria contains the following conservatism:

- There are no tornado generated missiles that can directly impact on irradiated fuel, even on the spent fuel stored in the Fuel Handling Building (FHB). Any missiles postulated to enter the fuel storage area would be stopped by concrete walls and roof barriers.

- It is assumed that a safety-related system or component simply being struck by a tornado missile will result in damage sufficient to preclude it from performing its intended safety function, although this is not realistic for all cases since missile barrier protection is afforded to majority of the systems and certain plant SSC are located below grade and protected by concrete walls and sub-compartments.

The analysis uses an NRC(16) approved methodology developed by the Electric Power Research Institute (EPRI)(17). The methodology is implemented using the computer program TORMIS, which is further described in section 3.5.1.4.2.

Should the Waterford 3 evaluations using the TORMIS methodology provide results indicating that the plant configuration exceed W3's 10^{-6} acceptance criteria, then missile protective barrier will be utilized to reduce the total cumulative probability value to below the acceptance criteria value of 10^{-6}.

3.5.1.4.2 TORMIS Description

TORMIS implements a methodology developed by the Electric Power Research Institute(17). TORMIS determines the probability of striking walls and roofs of buildings on which exposed portions of the safety-related systems and components are located. The probability is calculated by simulating a large number of tornado strike events at the site for each tornado wind speed intensity scale. After the probability of striking the walls or the roof is calculated, the exposed surface areas of the components are factored in to compute the probability of striking a particular target.

←(DRN 00-1172)

→ (DRN 00-1172)
The TORMIS analysis for W3 is in accordance with the TORMIS program, as described in Reference 17, using site-specific parameters described below:

1. The probability of a tornado strike at WF3 is based upon local region values.

2. The Fujita Scale (F-Scale) wind speeds were used in lieu of the TORMIS wind speeds (F'-Scale) for the F_0 through F_5 intensities. In addition, a wind speed range from 300 to 360 mph was used for the F_6 intensity to correspond to the tornado wind speed described in Section 3.3.2.1 "Applicable Design parameters".

3. A more conservative near-ground profile was used than the base case in TORMIS, resulting in a higher tornado ground wind speed to ~246 mph giving a ratio of V_0N_{33} equal to 0.82. NRC has accepted this value for other nuclear sites submittal using TORMIS analysis.

4. A site-specific walkdown was performed to include the contents of the warehouses, office buildings, sheds, trailers, parking lots, and switch yards. Based on the walkdown, a total of 71,800 missiles were postulated in 9 missile zones. This number is considered conservative on the basis of the example problem in Ref. 17 where a total of 65,550 missiles were postulated for one unit plant site.

← (DRN 00-1172)

→ (LBDCR 15-001, R309)
The TORMIS analysis demonstrated that due to the low probability of tornado missile damage, the following identified plant features that are unprotected are not required to have additional protective tornado missile barriers.

- Dry cooling tower fans and motors and associated conduits and electrical boxes
- Component cooling water piping, accumulators, and cabinets
- Main steam header supply to the emergency feedwater (EFW) pump turbine piping and EFW pump discharge piping to the isolation valve
- Plant Stack
- Terry turbine exhaust stack
- Emergency diesel generator stacks
- Emergency diesel generator fuel oil storage tank vents
- Emergency diesel generator fuel oil storage tank fill lines
- Emergency diesel generator day tank vents
- Containment escape hatch and doors D051, D266, and D270
- Control room differential pressure sensing lines (2)
- Sump pump motor and floor drain for sump number 2
- Control room breathing air system storage tank
- Main steam line relief valves' vent stacks (east and west)
- Waste management piping
- Main steam dump valve vent to atmosphere
- Reactor building roof drains

← (LBDCR 15-001, R309)

3.5.1.5 Missiles Generated by Events Near the Site

Railroad facilities, main roadways, Mississippi River shipping channel, industrial facilities, pipelines, and military installations are located a sufficient distance from the safety related portions of the plant so that the missiles from the design basis explosive events do not reach or damage safety related portions of the plant. (Refer to Subsection 2.2.3).

3.5.1.6 Aircraft Hazards

Aircraft impact is not considered as a design basis event for the Waterford 3 safety-related structures. Section 2.2 contains a discussion on aircraft hazards.

3.5.2 SYSTEMS TO BE PROTECTED

→ (DRN 00-1172)

Systems and structures to be protected from internally-generated missiles outside containment are listed in Table 3.5-3. System protection from internally-generated missiles inside the containment is described in Subsection 3.5.1.2 and Table 3.5-4. System protection from tornado missiles is listed in Tables 3.2-1, 3.5-3 and 3.5-3a.

←(DRN 00-1172)

3.5.3 BARRIER DESIGN PROCEDURES

The procedures employed in the design of structures and barriers to withstand the missiles are described in the following subsections. Waterford 3 design of structural barriers for tornado missiles does not depend on the composite resistances of steel and concrete. Only concrete barriers or steel barriers have been utilized.

3.5.3.1 <u>Local Damage Prediction</u>

3.5.3.1.1 Concrete Barriers

→ (DRN 00-1172)

Concrete barriers are designed to prevent missile perforation of the barrier. For local damage prediction of missile impact on concrete barrier structures, the following formula suggested by Amirikian[(10)], known as the Modified Petry, Formulas, are given below:

← (DRN 00-1172)

a) Where slab thickness is greater than three times the penetration depth:

$$D = KA_pV' \qquad (10)$$

where:

D = penetration of missile, ft.

→ (DRN 00-1172)

$$V' = \text{velocity factor} = \log_{10}\left(1+\frac{V^2}{215{,}000}\right)$$

← (DRN 00-1172)

V = missile impact velocity, ft/sec

A_p = W/A_c = sectional pressure, lb/ft^2

A_c = missile contact area, ft^2

→ (DRN 00-1172)

W = missile weight, lbs.

K = material constant = 4.76×10^{-3} (Note: For steel rod missile, K = 2.75×10^{-3} in accordance with Reference 7)

← (DRN 00-1172)

b) Where slab thickness is less than three times the penetration depth but greater than two times the penetration depth:

$$D' = D\left[1 + \exp\left(-4(a - 2)\right)\right] \qquad (11)$$

where:

D' = revised missile penetration, ft.

a = T/D

T = slab thickness, ft.

D = penetration of missile from above, ft.

In no case is the slab or wall thickness less than 2D. Table 3.5-4 shows results of missile penetration and the available minimum thickness of concrete for the selected missiles discussed in Subsection 3.5.1.

3.5.3.1.2 Steel Barriers

Steel gratings are designed to prevent perforation of the barrier. For local damage prediction of missile impact, the following formulas are used:

Stanford Research Formula

$$\frac{E}{D} = \frac{S}{46{,}000}\left(16{,}000\,T^2 + 1500\,\frac{W}{W_s}\,T\right)$$

where: T = steel thickness to be penetrated (in.)
E = critical kinetic energy required for penetration (ft-lb)
W = length of a square side between rigid supports (in.)
W_S = length of a standard width (4 in.)
D = missile diameter (in.)
S = ultimate tensile strength of the target steel plate (psi)

This formula is good for 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< V_C <400

where L is the missile length (in) and the missile is assumed to be cylindrical, and V_C is the missile velocity (fps).

→ (DRN 00-1172)

Rewritten the Stanford formula becomes,

$$T = \sqrt{\frac{2.91E}{DS} + 0.0022f^2 - 0.047f} \qquad (13)$$

← (DRN 00-1172)

where f = window factor, and f = W/D is used in lieu of W/W_S

The Stanford formula is further modified for the steel grating with the following correction factors:

α = Correction factor for reduced contact area

⟶ (DRN 00-1172)

β = Correction factor for Poisson's effect

⟵ (DRN 00-1172)

The modified Stanford formula becomes,

⟶ (DRN 00-1172; 00-1032, R11-A)

$$T = \sqrt{\frac{2.91E \propto}{D\beta S} + 0.0022\ f^2 - 0.047\ f} \qquad (14)$$

⟵ (DRN 00-1172; 00-1032, R11-A)

where α (for 2" x 4" plank) = 5.33

α (for 3" diameter pipe) = 3.67

α (for 4000 lb auto) = 3.67

α (for 1" diameter rod) = 2.91

α (for 13.5" diameter pole) = 3.74

$\beta = 1-\nu^2 = 0.91$

To ensure conservatism for (W/D) ratios greater than 8, or (W/T) ratios greater than 100, use

$f = W/D \leq 8$

or

$f \leq 100\ (T/D)$, whichever is lower

<u>Ballistic Research Laboratory formula:</u>

$$T^{3/2} = \frac{0.5MV^2}{17400K^2D^{3/2}} \qquad (15)$$

where T = thickness to be penetrated (in.)

⟶(DRN 00-1172)

M = mass of missile $\frac{(wt)}{g}\ \frac{lb-sec^2}{ft}$

⟵ (DRN 00-1172)

V = velocity of missiles (fps)

D = diameter of missile (in.)

K = constant depending on the grade of steel and is usually about one.

The modified Ballistic Research Laboratory formula is also modified for the steel grating with the same correction factors α and β as shown for the modified Stanford formula,

$$T^{3/2} = \frac{0.5MV^2\alpha}{17400(K\beta)^2 D^{3/2}} \quad (16)$$

Table 3.5-13 shows results of missile penetration from both formulas. This reveals that the thickness of the steel grating (7") is much greater than the recommended 1.25 T, where T is the depth of penetration.

3.5.3.2 Overall Damage Prediction

3.5.3.2.1 Concrete Barriers

The overall structural capacity is determined to preclude structural collapse under missile impact concurrent with tornado wind and tornado differential pressure loadings (Subsection 3.3.2.2).

→ (DRN 00-1172)

For all reinforced concrete structural elements subjected to impactive loads (i.e., tornado-generated missiles), the structural response is determined by using impulse, momentum, and energy balance techniques of Williamson and Alvy (9). For concrete barriers, strain energy capacity is limited by the ductility criteria specified in Table 3.5-12.

← (DRN 00-1172)

The force-time function is considered as a simplified pulse type function and the actual structure is idealized as an equivalent single-degree-of-freedom system. For the equivalent structure system, the load, mass, load mass factors, and the parameters involving the maximum resistance, spring constant, and dynamic reactions of the systems under various loading conditions are determined. (13), (14).

The ultimate load capacity of concrete barriers is based on the yield line theory of reinforced concrete slabs. The resistance and yield displacement values are calculated in accordance with the boundary conditions and long/short sides ratio of the two-way slab. The ductility factors are shown in Table 3.5-12.

The procedure used to determine the force-time function, deformation criteria, and the methods of analysis are discussed below.

a) For soft missiles characterized by significant local deformation of the missile during impact (wood plank and utility pole, excluding automobile), the peak of the impactive force is determined by the formula:

$$F\ crushing = \sigma\ crushing \times A_{net} \quad (17)$$

where: σ crushing = 3750 psi for wood missiles

A_{net} = net cross sectional area of the missile

Assuming a rectangular impulse for the force function the duration of the impulse, t_d is determined by the formula:

$$td = \frac{mV_m}{F\ crushing} \quad (18)$$

td - Time duration of impact

where: m = mass of missile

V_m = striking velocity of the missile

b) For an automobile, a forcing function for frontal impact striking a rigid barrier is:

→ (DRN 00-1032, R11-A)

$F(t) = 0.625\ V_S W \sin 20\ t$ $\quad 0 \leq t \leq 0.0785$ sec (19)

← (DRN 00-1032, R11-A)

$F(t) = 0$ $\quad t > 0.0785$ sec (20)

where:

F (t) = amplitude of the force

V_S = striking velocity of the automobile

W = weight of the automobile

t = time after impact (seconds)

→ (DRN 00-1172)

20t = (20 radians/sec) (t)

← (DRN 00-1172)

Based on the above formula, the forcing function for the automobile is approximated as a rectangular shape of magnitude:

$$F = 0.625\ V_s W \qquad (21)$$

and total time duration, t_d, of

$$t_d = \frac{MV_s}{F} \qquad (22)$$

where M is the mass of the automobile.

c) For rigid missiles characterized by significant local penetration during impact,(solid steel rod and steel pipe), the following equations are used to determine F and t_d for a rectangular pulse:

→ (DRN 00-1172; 00-1032, R11-A)

$$F = \frac{mV_m^{\ 2}}{2D} = \frac{WV_m}{2gD} \qquad (23)$$

$$t_d = 2D/V_m \qquad (24)$$

← (DRN 00-1032, R11-A)

where:

D = penetration depth calculated from the Modified Petry formula as described in Subsection 3.5.3.1.

→ (DRN 00-1172)

3.5.3.2.2 Steel Barriers

For steel barriers, the equivalent static load concentrated on the impact area is determined by Williamson & Alvy's methods (9) (10).

→ (DRN 00-1032, R11-A)

Impact with penetration

← (DRN 00-1032, R11-A)

$$Fi = \frac{WV^2}{gx} \qquad (25)$$

→ (DRN 00-1172)

$$t_1 = \frac{2x}{v} \qquad (26)$$

←DRN 00-1172)
→(DRN 00-1172)

$$F = F_i \Bigg/ \left[\frac{(2\mu - 1)^{1/2} T}{\pi t_1} + \frac{1 - \frac{1}{2\mu}}{1 + \frac{0.7T}{t_1}} \right] \qquad (27)$$

←(DRN 00-1172)

where: F_i = peak force of impact (lb)
W = weight of missile (lb)
V = velocity of missile (ft/sec)
g = gravitational force (32. ft/sec^2)

→ (DRN 00-1172)

X = penetration depth (ft)

← (DRN 00-1172)

t_1 = duration of impact (sec)
F = equivalent static load (lb)
T = natural period of system (sec)

→ (DRN 00-1032, R11-A)

μ = ductility ratio = 26 (for flexure design)
= 10 (for shear design)

←(DRN 00-1032, R11-A)

Impact without penetration

→ (DRN 00-1172)

$$q_y = \frac{\mu W}{(2\mu - 1)} \left[1 + \left[1 + \frac{(2\mu - 1)}{\mu^2} \frac{(2\pi V)^2}{(gT)^2} \right]^{1/2} \right] \qquad (28)$$

←(DRN 00-1172)

where: q_y = equivalent static load (lb)

→ (EC-40242, R308)

The equations (25) and (26) set up the characteristics of impulse force, and equation (27) or (28) expresses the equivalent static load. The capability of the grating panel to resist the impulse force is a function of its natural period, yielding strength, ductility and time duration of impulse. Table 3.5-13 shows the calculated equivalent static loads which are all smaller than the resistance capability of the grating panel Rm (equals to 546.2 kips).

← (EC-40242, R308)

→ (DRN 00-1032, R11-A)

Gratings are made of a series of bearing plates (7"x 3/8") and cross bars (1 1/4" X 1/4"). Impact forces are mainly taken by the bearing plates, local punching shear was calculated. In addition, the shear stress of the cross bars was also calculated; this further assures that the cross bars are able to transfer any impact force to the bearing plates, and the structural integrity of the grating panel can thus be assured. The results are also shown in Table 3.5-13, they are all within the allowable stress limit (equal to 21.6 ksi).

← (DRN 00-1032, R11-A)

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→(DRN 00-1172)

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←(DRN 00-1172)

→(DRN 06-758, R15)

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←(DRN 06-758, R15)

TABLE 3.5-1

MISSILES OUTSIDE CONTAINMENT

GENERATED BY HIGH ENERGY SYSTEMS

SYSTEM	THERMOWELLS	VALVE STEMS
Main Steam	TE-MS-0301A, 0301B installed on top of piping, ejection assumed 15° max. from vertical, does not impinge on safety related equipment.	All manually operated valves have backseats
Main Feedwater	None located in RAB	All manually operated valves have backseats
Chemical and Volume Control (Charging)	TE-CH 0212 is located away from safety-related equipment	All manually operated valves have backseats
Chemical and Volume Control (Letdown)	TIC-223 & 224 are located in letdown heat exchanger room. Letdown heat exchanger is not required for safe shutdown.	All manually operated valves have backseats
Steam Generator Blowdown (up-stream blowdown tank)	None located in RAB	All manually operated valves have backseats

TABLE 3.5-2 Revision 9 (12/97)

MISSILES OUTSIDE CONTAINMENT

FROM FAILURE OF OVERSPEED PROTECTION

COMPONENT	SAFETY CLASSIFICATION	OVERSPEED PROTECTION	REMARKS
→ Emergency FW Pump Turbine ←	3	Mechanical trip and Electrical trip	Turbine is designed to withstand 125% overspeed, and is not normally operating.
Diesel Generators	3	Mechanical trip - set at 125% overspeed Electrical trip - set	D - G is designed to withstand 125% overspeed, and is not normally operating.
Main FW Pump Turbines	Non-safety	Mechanical and Electrical trips	Located in the ground floor of the Turbine Building. Separated from safety related equipment by RAB wall.
Main Turbine	Non-Safety	Mechanical trip - set at 111% overspeed Electrical trip - set at 111.5% overspeed	Analysis of T-G failure is described in Subsection 3.5.1.3. Overspeed protection is described in Subsection 10.2.2.

TABLE 3.5-3 (Sheet 1 of 4) Revision 10 (10/99)

MISSILE PROTECTION - OUTSIDE CONTAINMENT
TABULATION OF SAFETY RELATED STRUCTURES AND SYSTEMS

System or Structure	Location (Figure)	Description Section	FSAR Figure	Missile Protection
→ Main Control Room	Dwg. G134	6.4, 9.4	9.4-1 6.4-1, 2 & 3	Concrete walls of the main control room are designed to withstand tornado missiles. Main steam and feedwater lines do not contain components in the vicinity of the main control room which could be postulated as missiles, which would possibly penetrate the main control room walls.
Diesel Generators	Dwg. G135	9.5.4 thru 9.5.8 and 8.3	N/A	Diesel generators, including piping, are located in separate rooms. Exhaust silencers are also located in separate rooms. Air intake pipe is protected from tornado missiles by grating Diesel oil feed tanks are located in separate rooms. Main diesel oil tanks and pumps are in separate rooms. Diesel oil piping is routed from high energy piping.
Essential Services System	Dwg. G134	9.2.9	9.2.8 (for Fig. 9.2.-8, Sht.3, refer to Dwg. G853, Sht. 5,	Equipment room where chillers are Chilled Water located is provided with missile doors and protection from external missiles.
Spent Fuel Storage Pool	1.2-15	9.1.2	N/A	Spent fuel pool is located inside of the Fuel Handling Building. There are no high energy lines in the Fuel Handling Building. ←

TABLE 3.5-3 (Sheet 2 of 4) Revision 11 (05/01)

MISSILE PROTECTION - OUTSIDE CONTAINMENT
TABULATION OF SAFETY RELATED STRUCTURES AND SYSTEMS

System or Structure	Location (Figure)	Description Section	FSAR Figure	Missile Protection
→ (DRN 00-1172) Main Steam and Feedwater	Dwg. G134 & 1.2-17	10.3 & 10.4.7	10.2-4 and 10.4-2 (for Fig. 10.4-2 Sht. 1, refer to Dwg. G153, Sht. 1)	Main steam and feedwater isolation Systems and valves and their components are protected from tornado missiles by grating. There are no components in the vicinity of these valves which could be postulated as missiles. The probability of a damaging missile striking the exposed piping is less than 10^{-8} per year.
← (DRN 00-1172) Electrical Equipment (4.16, 480V, and 125 V	Dwg. G135	8.3.1	N/A	All electrical switching equipment is located in the RAB. There is no high energy piping located in the switchgear room. The high energy compressed air bottles in the switchgear “B” room are seismically restrained, capped when not connected, and are capped when being transported in accordance with plant procedures to ensure they do not become potential missiles.
Containment Spray System and Safety	1.2-11	6.2 & 6.3	Dwg. G163 & 6.3-1 (for Fig. 6.3-1, Sht.1, refer to Dwg. G167 Sht.1)	There are two separate rooms housing the HPSI, LPSI and containment spray pumps and the related Injection System instrumentation. In one room are located pumps and instrumentation associated with Channel A, and in the other room, channel B. The

TABLE 3.5-3 (Sheet 3 of 4) Revision 11 (05/01)

MISSILE PROTECTION - OUTSIDE CONTAINMENT
TABULATION OF SAFETY RELATED STRUCTURES AND SYSTEMS

System or Structure	Location (Figure)	Description Section	FSAR Figure	Missile Protection
				third HPSI pump is a spare pump that can be powered either from the electrical bus A or B, and is located in the same room with A pumps.**
→ (DRN 00-1172)				
Emergency Feedwater System	1.2-11	10.4.9	10.4-2 (for Fig. 10.4-2, Sht. 1, refer to Dwg. G153, Sht. 1)	Each motor driven emergency feedwater pump is located in its own room, and turbine driven pump is separated from high energy systems. Piping is routed away from components which are postulated as missiles. The probability of damaging missile striking the exposed EFW line to SG No. 2 is less than 10^{-8} per year. Emergency feedwater isolation valves and main steam supply valves to the emergency feedwater pump turbine are protected from tornado missiles by grating.
Component Cooling Water System & Ultimate Heat Sink	Dwg. G135, 1.2-24 & 1.2-25	9.2.2 & 9.2.5	9.2-1 (for 9.2-1, Sht. 4, refer to Dwg. G160, Sht.4, & for 9.2-1, Sht. 6, refer to Dwg. G160, Sht.6	Each component cooling water pump and each component cooling water heat exchanger is located in separate rooms. Protection of components outside the RAB from tornado missiles is described in Subsection 9.2.5.3.3 and protected from tornado generated missile as mentioned in section 3.5.1.4.1. Piping is routed away high energy lines.

← (DRN 00-1172)

** The Containment Spray and Safety Injection Systems are moderate energy systems and missiles from these systems are not postulated. Piping from the Containment Spray and Safety Injection Systems are not routed in the vicinity of the high pressure.

TABLE 3.5-3 (Sheet 4 of 4) Revision 11 (05/01)

MISSILE PROTECTION - OUTSIDE CONTAINMENT
TABULATION OF SAFETY RELATED STRUCTURES AND SYSTEMS

System or Structure	Location (Figure)	Description Section	FSAR Figure	Missile Protection
Containment Isolation	N/A	6.2.4	N/A	All containment isolation valves are located away or protected from missiles.
Containment	1.2-17 to 1.2-22	3.8.2	N/A	Concrete Shield Building is designed to withstand tornado missiles.
Containment Cooling System	1.2-18 & 1.2-19	6.2.2	9.4-7	Containment fan coolers are located in separate quadrants of the containment. Ductwork is routed away from high energy systems.
→ (DRN 00-1172)				
Station Service Transformers 480V MCC	1.2-24	N/A	N/A	To be protected from tornado missiles by grating. Safety related conduits/cables that are not required for plant shutdown following a design bases tornado event (e.g. Wet cooling tower fan motors, Area radiation monitors for fuel handling building (FHB), emergency filtration units in FHB, some dry cooling tower fan motors, etc.) are not protected from potential missiles. See section 3.5.1.4.1.
← (DRN 00-1172)				

TABLE 3.5-3a Revision 10 (10/99)

TABLE OF PROTECTED SAFETY RELATED HVAC
AIR INTAKES & EXHAUSTS

SYSTEM NAME	BUILDING	OPENING TYPE	LOUVER/ DAMPER NO	GENERAL ARRGT. DRAWING NO	LOCATION BY COLUMNS	CENTER LINE ELEV. FT. MSL	MISSILE PROTECTION
➔							
CONTROL	REACTOR	OUTSIDE					
ROOM	AUXILIARY	AIR INTAKE	L-23	Dwg. G134	L AND 12A	+ 73.35 FT	YES MPL-4
HVAC	BUILDING	EXHAUST	L-13	1.2-17	L AND 11A	+ 59.5	YES ROOF GRATING
RAB CABLE	REACTOR	QA INTAKE	L-29	Dwg. G134	J AND 12A	+ 62.48 FT	YES MPL-2
VAULT &	AUXILIARY	EXHAUST	L-10	Dwg. G134	L AND 11A	+ 76.75 FT	YES MPL-5
SWITCHGEAR	BUILDING		L-27	Dwg. G134	G AND 12A	+ 63.98 FT	YES MPL-3
AREAS HVAC			L-30	Dwg. G134	L AND 11A	+ 72.00 FT	YES MPL-5
	REACTOR	SMOKE	LD-41	1.2-18	M AND 12A	+ 35.00 FT	YES MPL-20
	AUXILIARY	VENT	LD-42	1.2-18	L AND 12A	+ 35.00 FT	YES MPL-20
	BUILDING		LD-43	1.2-17	L AND 9A	+ 56.75 FT	YES ROOF GRATING
DIESEL	REACTOR	QA INTAKE	LD-2	Dwg. G135	J AND 1A	+ 36.00 FT	YES MPL
GENERATOR	AUXILIARY	EXHAUST	L-4	Dwg. G134	J AND 3A	+ 82.00 FT	YES MPL-12
A	BUILDING	EXHAUST	L-4	Dwg. G134	J AND 3A	+ 82.00 FT	YES MPL-13
DIESEL	REACTOR	QA INTAKE	L-7	Dwg. G134	J AND 6A	+ 55.5 FT	YES MPL-7
GENERATOR	AUXILIARY	QA INTAKE	L-7	Dwg. G134	J AND 7A	+ 55.5 FT	YES MPL-8
B	BUILDING	EXHAUST	L-6	Dwg. G134	J AND 5A	+ 82.00 FT	YES MPL-9
	EXHAUST		L-6	Dwg. G134	J AND 6A	+ 82.00 FT	YES MPL-11
RAB H. & V.	REACTOR	QA INTAKE	LD-1	Dwg. G134	J AND 1A	+ 63.06 FT	YES MPL-18
EQUIPMENT	AUXILIARY	QA INTAKE	LD-1	Dwg. G134	J AND 2A	+ 63.06 FT	YES MPL-19
ROOM	BUILDING	EXHAUST	L-22	Dwg. G134	L AND 7A	+ 79.00 FT	YES MPL-6
	EXHAUST		L-22	Dwg. G134	L AND 8A	+ 79.00 FT	YES MPL-10
←							
CONTAINMENT	REACTOR	CONTAINMENT	2HV-B150B		N AND 10A	+ 52.5 FT	YES ROOF GRATING
PURGE	AUXILIARY	PURGE VALVE	& LD-39	1.2-17			
MAKE-UP	BUILDING						
SYSTEM							
REACTOR	QA INTAKE		L-1	1.2-14	J AND 1A	+ 75.00 FT	YES MPL-16
AUXILIARY	QA INTAKE		L-1	1.2-14	J AND 1A	+ 75.00 FT	YES MPL-17
BUILDING	QA INTAKE		L-2	1.2-14	J AND 1A	+ 96.5 FT	YES MPL-14
	QA INTAKE		L-2	1.2-14	J AND 1A	+ 96.5 FT	YES MPL-15

MPL - Missile Protected Louvre

TABLE 3.5-4 (1 of 2)

POTENTIAL MISSILES INSIDE CONTAINMENT

	Item	Kinetic Energy ((ft -lb)	Weight (lb)	Impact Section	Structure/Shield/Barrier	Penetration Depth (in.)	Available Min. Concrete Thickness (in.)
I.	Reactor Vessel						
	A. Closure Heat Nut	1706	100	Annular ring: OD=10-2/16" ID = 6.9"	Missile shield on reactor vessel	0.042	36
	B. Closure Head Nut	5226	577	Solid circle6-3/4" diameter	Missile shield on reactor vessel	0.159	36
	C. Instrumentation Assembly	101,615	321	Solid disk 11' diameter	Missile shield on reactor vessel	1.091	36
	D. Instrumentation From Flange Up	114,000	165	Solid disk 6-1/2" diameter and 3" thick	Missile shield on reactor vessel	3.341	36
	E. Instrument Flange Stud	14.3	6-1/2	Solid circle 1-1/2" diameter	Missile shield on reactor vessel	0.009	36
II.	Steam Generator						
	A. Primary Manway Stud & Nut	71	4-1/4	Solid Circle 1-1/2" diameter	Low energy	0.043	48
	B. Secondary Handhold Stud & Nut	7	1.15	Solid circle 3/4" diameter	Low energy	0.017	48
	C. Secondary Manway Stud & Nut	7	3.36	Solid circle 1-1/4" diameter	Low energy	0.007	48
III.	Pressurizer						
	A. Safety Valve with Flange	89,200	550	Solid circle 2" diameter	Pressurizer enclosure	10.932 (included penetration through 2" thick steel plate)	24 (included 2" thick steel plate)
	B. Safety Valve Flange Bolt	15	3.7	Solid circle 1-1/4" diameter	Pressurizer enclosure	0.012	24
	C. Lower Temperature Element	288	3	Edge of solid disk 2-3/4" diameter and 1/2" thick	Pressurizer enclosure	0.051	24
	D. Manway Stud & Nut	712	4-1/4	Solid circle 1-1/2" diameter	Pressurizer enclosure	0.043	24

TABLE 3.5-4 (2 of 2) Revision 307 (07/13)

POTENTIAL MISSILES INSIDE CONTAINMENT

Item		Kinetic Energy ((ft -lb)	Weight (lb)	Impact Section	Structure/Shield/Barrier	Penetration Depth (in.)	Available Min. Concrete Thickness (in.)
➔(EC-2800, R307)							
IVa.	Control Rod Drive Assembly (Mag Jack) (CEDM)	65,400	1250	Solid circle 1.88" diameter	Missile shield on reactor vessel	8.71	36
IVb.	Control Rod Drive Assembly (Mag Jack) (CEDM)	65,400	1250	Solid circle 10" diameter	Missile shield on reactor vessel	3.67	36
🡐(EC-2800, R307)							
V.	Main Coolant Piping Temperature Nozzle with RTD	1095	8	Edge of solid disk 2-3/4" diameter and 1/2" thick	Secondary shield wall	0.193	48
VI.	Surge and Spray Piping Thermal Wells With RTD Assembly	277	1-3/4 2-3/4"	Edge of solid disk diameter and 1/2" thick	Secondary shield wall	0.048	48
VII.	Reactor Coolant Pump Thermal Well with RTD	1095	8	Edge of solid disk 2-3/4" diameter and 1/2" thick	Secondary shield wall	0.193	48

TABLE 3.5-5

PARAMETERS OF LOW PRESSURE WHEEL FRAGMENTS

Wheel Fragment(1)	1	2	3	4	5
Design Overspeed	120%	120%	120%	120%	120%
Ejection Angle, Measured from Plane of rotation	±5°	±5°	±5°	±5°	±5°*
Escape Translational Energy (10^6 ft-lb_f)	1.1	5.2	9.0	3.1	2.3
Escape Velocity (fps)	139	305	434	258	222
Weight (lbs)	3521	3611	3069	3018	3017
Impact area considered in Pen-etration Calculations (ft^2)	2.78	2.55	2.08	1.86	2.29
Destructive Speed	193%	193%	193%	193%	193%
Ejection Angle, Measured from Plane of Rotation	±5°	±5°	±5°	±5°	±5°*
Escape Translational Energy (10^6 ft-lb_f)	4.2	17.6	27.0	6.3	15.0
Escape Velocity (fps)	277	560	753	400	601
Weight (lbs)	3521	3611	3069	2539	2674
Impact Area (ft^2)	2.78	2.55	2.08	1.86	2.29

* Positive when measured towards the adjacent coupling on the rotor shaft.

(1) See Figure 3.5-6.

TABLE 3.5-6

PARAMETERS OF LOW PRESSURE TURBINE CYLINDER FRAGMENTS

Cylinder Fragment(1)	1	2	3	4	5
Disc to which Cylinder Fragment is Associated	1	1	1	2	4
Design Overspeed	120%	120%	120%	120%	120%
Ejection Angle, Measured from Plane of Rotation	±5°	±5°	±5°	±5°	±5°
Escape Translational Energy (10^6 ft-lb_f)	0.9	0.1	0.4	1.5	0.3
Escape Velocity (fps)	139	139	139	305	258
Weight (lbs)	2854	366	1199	1057	305
Impact area (ft^2)	0.8875	0.1146	0.3778	0.333	0.1056
Destructive Speed	193%	193%	193%	193%	193%
Ejection Angle, Measured Plane of Rotation	±5°	±5°	±5°	±5°	±5°
Escape Translational Energy (10^6 ft-lb_f)	3.4	0.4	1.4	5.2	0.8
Escape Velocity (fps)	277	277	277	560	400
Weight (lbs)	2854	366	1199	1057	305
Impact area (ft^2)	0.8875	0.1146	0.3778	0.333	0.1056

* Positive when measured towards the adjacent coupling on the rotor shaft

(1) See Figure 3.5-6.

TABLE 3.5-7

SAFETY-RELATED COMPONENTS LOCATED INSIDE REACTOR BUILDING AND BARRIERS

Safety-Related Component		Barriers	
		LTM	HTM
1.	Reactor Vessel		
2.	Steam Generator #1		
3.	Steam Generator #2		
4.	SIT 2A		
5.	SIT 2B		
6.	SIT 1A		
7.	SIT 1B		
8.	HR		
9.	HR		
10.	Pressurizer		
11.	F&W and MS Lines	MSR and Turbine Pedestal Concrete Beam; 3 foot Concrete Wall and 1.9 inch steel Containment Vessel	30 inch Concrete dome and 0.95' inch steel containment vessel
113.	C-2C		
114.	C-2B		
115.	C-3B		
116.	C-2A		
117.	Reg HX		
118.	C-1A		
119.	Pressurizer		
120.	C-1B		
121.	C-1C		
122.	C-1D		
123.	C-3A		
124.	AH-1 (3C)		
125.	AH-1 (3A)		
126.	C-2D		
163.	CAC (3D-SB)		
164.	CAC (3B-SB)		
Total area exposed to missile strike in Reactor Building (Ft^2)		2396	

TABLE 3.5-8

SAFETY-RELATED EQUIPMENT IN RAB WING AREA AND BARRIERS

Safety-Related Component		HTM Barriers
Main Steam Lines ≈ 600 Ft^2		2’ concrete equivalent
Feedwater Lines ≈ 600 Ft^2		2’ concrete equivalent
11.	N_2 VIII	2’ concrete
12.	accu-VII	2’ concrete
13.	mula- VI	2’ concrete
15.	tor V	2’ concrete
19.	Rad Monitors	2’ concrete
150.	DST a	4’ concrete roof at +21
151.	DST b	4’ concrete roof at +21
152.	CAM	4’ concrete roof at +21
165.	H_2 anal Panel 48A	4’ concrete roof at +21
166.	48B	4’ concrete roof at +21
Duct Work		2’ concrete at +69’ and 1’ @ +46’
Cable Trays		2’ concrete at +69 and 1’ @ +46’

TABLE 3.5-9a (1 of 3)

SAFETY-RELATED EQUIPMENT LOCATED IN RAB
AT FL.EL.+46 AND BARRIERS

Safety-Related Component		Barriers LTM	Barriers HTM
14.	AH-25	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
16.	AH A&B	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
17.	EVA	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
18.	H&V-E41	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at El +69’
20.	CVAS, HX A&B	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
21.	H&V E17	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
22.	Fans	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at El +69’
23.	H&V E17	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at El +69’
24.	H&V E41	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
25.	Fan	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
26.	Water Chiller	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
27.	Water Chiller	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69
28.	Pump	Moisture Separator and Reheater, Turbine Pedestal COncrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
29.	Pump	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69
30.	Fan	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
31.	Cabinet	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
32.	DG Oil Tank	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete roof at EL +69’
33.	Cabinet C101B	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete @ +106.5’ 2’ concrete @ +95.50’ and 2’ concrete @ +69’
34.	Water Chiller	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2’ Concrete Wall	2’ concrete @ +106.5’ 2’ concrete @ +95.50’ and 2’ concrete @ +69’

TABLE 3.5-9a (2 of 3)

SAFETY-RELATED EQUIPMENT LOCATED IN RAB
AT FL.EL.+46 AND BARRIERS

Safety-Related Component		Barriers LTM	Barriers HTM
35.	Pump	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete @ +106.5' 2' concrete @ +95.50' and 2' concrete @ +69'
36.	AH-13	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete @ +106.5' 2' concrete @ +95.50' and 2' concrete @ +69'
37.	Cabinet	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete @ +106.5' 2' concrete @ +95.50' and 2' concrete @ +69'
38.	Tanks	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete @ +106.5' 2' concrete @ +95.50' and 2' concrete @ +69'
39.	CCW Surge Tank	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete @ 106.5' 2' concrete @ +95.50' and 2' concrete @ +69'
40-44	Fans	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete @ 69'
	FW&MS Lines	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	
Main Steam Line		Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete equivalent
Feedwater LInes		Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete equivalent
45.	Control Panels #14, 42, 43, 44, 45, 25, 26, 27, 28, 29, 30, 31	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete roof at EL +69'
46.	Control Panels #1, 2, 3, 4, 6, 7, 8, 18, 35, 36	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete roof at EL +69'

TABLE 3.5-9a (3 of 3)

SAFETY-RELATED EQUIPMENT LOCATED IN RAB
AT FL.EL.+46 AND BARRIERS

Safety-Related Component		Barriers LTM	Barriers HTM
47.	Control Panels	Moisture Separator and Reheater, Turbine Pedestal Concrete Beams and 2' Concrete Wall	2' concrete roof at EL +69'
48.	Control Panels #10, 22, 50		2' concrete roof at EL +69'
49.	Control Panels #13, 14, 15, 17, 33		2' concrete roof at EL +69'
113.	Control Panels #11A, B, 12A, 46, 47, 123		2' concrete roof at EL +69'
114.	Control Panels #19, 20		2' concrete roof at EL +69'
115.	Radiation Monitor		2' concrete roof at EL +69'
116.	Computer Panels		2' concrete roof at EL +69'
117.	Computer Units		2' concrete roof at El +69'
118.	Computer Units		2' concrete roof at EL +69'
119.	LPA & LPB		2' concrete roof at EL +69'
120.	Computer Units		2' concrete roof at EL +69'

TABLE 3.5-9b (1 of 5)

SAFETY-RELATED EQUIPMENT IN RAB @ EL.+21 AND BARRIERS

Safety-Related Component		Barriers: LTM	Barriers: HTM
50.	CC HX A	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +106.5, 2’ @ 95.5’, 2’ @ 69’ and 1’ @ 46
51.	CC HX B	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +106.5, 2’ @ 95.5’, 2’ @ 69’ and 1’ @ 46
52.	DG-A Elec Panel	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +106.5, 2’ @ 95.5’, 2’ @ 69’ and 1’ @ 46
53.	AR	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +106..5, 2’ @ 95.5’, 2’ @ 69’ and 1’ @ 46
54.	DG 3A-S	Turbine pedestal concrete beam appxox. 11’ X 10	2’ @ +106.5, 2’ @ 95.5’, 2’ @ 69’ and 1’ @ 46
55.	AI Silencer A	Turbine pedestal concrete beam appprox. 11’ X 10	2’ @ +69’ and 1’ @ 46’
56.	Air Dryer A1 & A2	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
57.	RM	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
58.	N2 accumulator	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
59.	AH10 3A	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
60.	CCW Pump A	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
61.	Rm	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
62.	N2 ACC	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
63.	AH20 3B	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
64.	CCW Pump A/B	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
65.	AH20 3A	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
66.	RM	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’
67	AH10 3B	Turbine pedestal concrete beam approx. 11’ X 10	2’ @ +69’ and 1’ @ 46’

TABLE 3.5-9b (2 of 5)

SAFETY-RELATED EQUIPMENT IN RAB @ EL.+21 AND BARRIERS

Safety-Related Component		Barriers: LTM	Barriers: HTM
68.	CCW Pump B	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
69.	1C C-90B	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
70.	DG-B Elec. Panel	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
71.	Air Receiver	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
72.	DG 3B-S	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
73.	AI Silencer B	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
74.	Air Dryer B1	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
75.	Air Dryer B2	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 1' @ +46'
76.	Holdup Tank	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 3' @ +46'
77.	Holdup Tank	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 3' @ +46'
78.	Holdup Tank	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 3' @ +46'
79.	Holdup Tank	Turbine pedestal concrete beam approx. 11' X 10	2' @ +69' and 3' @ +46'
80.	Trip SWGR	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
81.	Iso Panel IP3MB	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
82.	480V MCC 3B312-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
83.	SUPS 3MB-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'

TABLE 3.5-9b (3 of 5)

SAFETY-RELATED EQUIPMENT IN RAB @ EL.+21 AND BARRIERS

Safety-Related Component		Barriers: LTM	Barriers: HTM
84.	Battery Charger	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
85.	125V dc Panel	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
86.	Battery 3B-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
87.	Battery 3AB-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
88.	Battery 3A-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
89.	Battery 3A-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
90.	Battery Charger	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
91.	E Equipment	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
92.	SWGR 3A31-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
93.	SWGR 3A3-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
94.	MCC 3A313-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
95.	MCC 3A312-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
96.	ARC 3A-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
97.	MCC 3A311-S	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
98.	Battery Charger	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’

TABLE 3.5-9b (4 of 5)

SAFETY-RELATED EQUIPMENT IN RAB @ EL.+21 AND BARRIERS

Safety-Related Component		Barriers LTM	Barriers HTM
99.	MCC 3AB311-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
100.	SWGR 3AB3-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
101.	125DC PNL3AB-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
102.	SWGR 3AB31-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
103.	MCC 3AB312-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
104.	MCC 3B311-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
105.	ARC 3B	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
106.	E Equipment	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
107.	SWGR 3B3-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
108.	SWGR 3B31-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
109.	MCC 3B313-S	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
110.	ACP LCP43	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
111.	Dist. PNL 387A&B	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
112.	Inverter	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'
131.	Aux. Panel 2	Turbine pedestal concrete beam	2' @ +69, 1' @ +46, 1' @ 35'

TABLE 3.5-9b (5 of 5) Revision 9 (12/97)

SAFETY-RELATED EQUIPMENT IN RAB @ EL.+21 AND BARRIERS

Safety-Related Component		Barriers LTM	Barriers HTM
132.	Aux. Panel 1	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
133.	Aux. Panel 3	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
→ 134.	Compressed Air Bottle Station #1	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
135.	Compressed Air Bottle Station #2	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
136.	Compressed Air Bottle Station #3	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’
137.	Compressed Air Bottle Station #4 ←	Turbine pedestal concrete beam	2’ @ +69, 1’ @ +46, 1’ @ 35’

TABLE 3.5-9c Revision 11-B (06/02)

SAFETY-RELATED EQUIPMENT IN RAB AT EL -4.0' AND BARRIERS

Safety-Related Component		Barriers	
		LTM	HTM
153.	VCT	Turbine pedestal concrete beam	2' @ 95.5', 2' @ 69', 3' @ 21'
154.	PIE	Turbine pedestal concrete beam	2' @ 95.5', 2' @ 69', 3' @ 21'
155.	DIE	Turbine pedestal concrete beam	2' @ 95.5', 2' @ 69', 3' @ 21'
156.	PIE	Turbine pedestal concrete beam	2' @ 95.5', 2' @ 69', 3' @ 21'
→(DRN 00-804)			
157.	Flash Tank[1]	Turbine pedestal concrete beam	2' @ 95.5', 2' @ 69', 3' @ 21'
158.	Flash Pumps[1]	Turbine pedestal concrete beam	2' @ 95.5', 2' @ 69', 3' @ 21'
←(DRN 00-804)			
159.	BA Tank A	Turbine pedestal concrete beam	2' @ 69', 1' @ 46', 1' @ 35' and 1' @ 21'
160.	BA Tank B	Turbine pedestal concrete beam	2' @ 69', 1' @ 46', 1' @ 35' and 1' @ 21'
161.	HX	Turbine pedestal concrete beam	2' @ 69', 1' @ 46', 1' @ 35' and 1' @ 21'
162.	HTP	Turbine pedestal concrete beam	2' @ 69', 1' @ 46', 1' @ 35' and 1' @ 21'
171.	AH-30(3A)	Turbine pedestal concrete beam	2' @ 69', 1' @ 46', 1' @ 35' and 1' @ 21'
172.	AH-30(3B)	Turbine pedestal concrete beam	2' @ 69', 1' @ 46', 1' @ 35' and 1' @ 21'

→(DRN 00-804)

[1] The BMS Flash Tank and Flash Tank pumps have been inactive per ER-W3-00-0225-00-00.

←(DRN 00-804)

TABLE 3.5-9d (1 of 3)

SAFETY-RELATED EQUIPMENT IN RAB AT EL -35.0'

Safety-Related Component		Barriers LTM	Barriers HTM
207.	SC HX A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
208.	SC HX B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
209.	AH-3, 3A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
210.	AH-3, 3B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
211.	1C C-27A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
212.	1C C-27B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
213.	1C C-26B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
214.	1C C-40	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
215.	1C C-26A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
216.	AH-2, 3D	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
217.	AH-2, 3A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
218.	LPSI Pump B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
219.	LPSI Pump A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
220.	CS Pump B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
221.	CS Pump A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
222.	AH 3B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
223.	AH 3C	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
224.	HPSI Pump B	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
225.	HPSI Pump A	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'
226.	EDT Pump	Turbine pedestal concrete beam	2' @ +69', 1' @ +46', 1' @ +35', 1' @ 21' and 2' @ -4'

TABLE 3.5-9d (2 of 3)

SAFETY-RELATED EQUIPMENT IN RAB AT EL -35.0’

Safety-Related Component		Barriers LTM	HTM
227.	RDT Pump	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
228.	HPSI Pump A/B	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
229.	AH-21, 3B	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
230.	EFW Pump B	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
231.	EFW Pump A	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
232.	AH-17, 3B	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
233.	AH-17, 3A	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
234.	1C C-35B	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
235.	1C C-35A	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
236.	1C C-39	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
237.	EFW Pump	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
238.	CCW Pump B	Turbine pedestal concrete beam	2’ @ +69’, 1’ @ +46’, 1’ @ +35’, 1’ @ 21’ and 2’ @ -4’
239.	CCW Pump A	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
240.	Gas Surge Tank	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
241.	1C C-38	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
242.	WG Comp. B	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
243.	WG Comp. A	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
244.	Gas Decay Tank C	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
245.	Gas Decay Tank B	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
246.	Gas Decay Tank A	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
247.	Charging Pump B	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
248.	Charging Pump A/B	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
249.	Charging Pump A	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’
250.	AH-18, 3B	Turbine pedestal concrete beam	3’ @ -4’, 3’ @ +21’, 1’ @ +46’, 2’ @ +69’

TABLE 3.5-9d (3 of 3)

SAFETY-RELATED EQUIPMENT IN RAB AT EL -35.0'

Safety-Related Component		Barriers	
		LTM	HTM
251.	AH-22, 3B	Turbine pedestal concrete beam	3' @ -4', 3' @ +21', 1' @ +46', 2' @ +69'
252.	AH-22, 3A	Turbine pedestal concrete beam	3' @ -4', 3' @ +21', 1' @ +46', 2' @ +69'
253.	AH-18, 3A	Turbine pedestal concrete beam	3' @ -4', 3' @ +21', 1' @ +46', 2' @ +69'
254.	BA Pump B	Turbine pedestal concrete beam	3' @ -4', 3' @ +21', 1' @ +46', 2' @ +69'
255.	BA Pump A	Turbine pedestal concrete beam	3' @ -4', 3' @ +21', 1' @ +46', 2' @ +69'

TABLE 3.5-9e

SAFETY-RELATED EQUIPMENT IN RAB - CABLE TRAYS AND HVAC DUCTS

		Area (Ft^2)	Barriers
a)	Floor EL +46’		
	Cable Trays	902	2’ concrete roof @ +69’
	HVAC Ducts	869	
b)	Floor EL +35’		
	Cable Vault and Trays	7268	2’ @ +69’ and 1’ @ +46’
	HVAC Ducts	549	
c)	Floor EL +21’		
	Cable Trays	2200	2’ @ +69’, 1’ @ +46’ and 1’ @ +35’
	HVAC Ducts	719	
d)	Floor EL +7’		
	Cable Trays	824	2’ @ 69’, 1’ @ 46’, 1 @ 35’ and 1’ @ 21’
	HVAC Ducts	894	
e)	Floor EL -4’		
	Cable Trays	786	2’ @ 69’, 1’ @ 46’ and 3’ @ 21’
	HVAC Ducts	60	
f)	Floor EL -35’		
	Cable Trays	1433	2’ @ +69’, 1’ @ 46’, 3’ @ 21’ and 2’ @ -4’
	HVAC Ducts	993	

TABLE 3.5-9f Revision 1 (12/87)

SAFETY-RELATED EQUIPMENT IN FUEL HANDLING BUILDING AND BARRIERS

Safety-Related Component		Barriers
		HTM
167.	Fuel Pool HX	2’ @ 91’, 1’ @ 46’ and 2’ @ +21’
168.	Fans	2’ @ 91’, 1’ @ 46’ and 3.5’ @ 17.5’
169.	Fuel Pool Pumps	2’ @ 91’, 5’ @ +24’
170. →	EFT	2’ @ 91’, 1’ @ 46’, 3.5’ @ +17.5’
171. ←	Backup Fuel Pool	2’ @ 91’, 5’ @ 24’, and 2’ @ +1.00’

TABLE 3.5-9g

RESULTS OF PROBABILITY ANALYSIS FOR DESIGN OVERSPEED TURBINE FAILURE EVENT

Safety-Related Equipment Located in		Strike and Damage Probability (P_2 x P_3) per missile source	
		LTM	HTM
1.	Reactor Building	-	-
2.	Reactor Auxiliary Building Wing Area		2.96 x 10^{-5}
3.	Reactor Auxiliary Building including Control Room	-	4.10 x 10^{-4}
4.	Fuel Handling Building	-	-
	Overall Plant strike and Damage Probability, $\Sigma P_2 P_3$	-	4.4 x 10^{-4}
	Plant unacceptable turbine missile strike and damage probability for design overspeed failure event (ΣP_1 x P_2 x P_3)*	-	2.64 x 10^{-8}

*P_1 = 6.0 x 10^{-5} (Ref 6)

TABLE 3.5-9h

RESULTS OF PROBABILITY ANALYSIS FOR DESTRUCTIVE OVERSPEED FAILURE EVENT

Safety-Related Equipment Located in		Strike and Damage Probability (P_2 x P_3) per missile source	
		LTM	HTM
1.	Reactor Building	-	2.64 X 10^{-5}
2.	Reactor Auxiliary Building Wing Area	-	4.82 X 10^{-5}
3.	Reactor Auxiliary	8.4 x 10^{-4}	7.72 x 10^{-4}
4.	Fuel Handling Building	-	1.01 x 10^{-6}
	Total plant strike and damage probability per missile source	8.4 x 10^{-4}	8.48 x 10^{-4}
	Plant unacceptable turbine missile damage probability for destructive overspeed failure event (P_1xP_2xP_3)*	3.36 x 10^{-8}	3.39 x 10^{-8}

*P_1 = 4.0 x 10^{-5} (Ref 6)

TABLE 3.5-10 Revision 8 (5/96)

POTENTIAL TORNADO MISSILES

Missile	Weight (lbs)	Density (lb/cu. ft.)	Impact Area (sq. ft.)	Maximum Velocity (ft/sec)	Kinetic Energy (ft-lb)	Impact Height	Concrete Penetration Depth (in.)	Minimum Available Concrete Thickness (in.)
1) 2" x 4" x 10' wooden plank traveling at a speed of 300 mph	27.8	50	0.055	440	8.36×10^4	Grade to top of structure	7.972	24
2) 3" dia Schedule 40 pipe 10' long traveling end on at 100 mph	75.8		0.063	147	2.54×10^4	Grade to top of structure	2.859	24
3) Automobile 4000 lb weight traveling at 50 mph	4000		20.0	73.5	3.36×10^5	Grade to 25' above grade	0.123	24
4) 1" diameter steel rod 3' long 8 lb weight traveling at 216 mph	8		0.00545	316.8	1.25×10^4	Grade to top of structure	0.672*	24
5) 13.5" diameter utility pole, 35' long 1490 lb weight traveling at 144 mph	1490		0.994	211.2	1.03×10^6	Grade to 30' above grade	7.008	24

* Note: Penetration for the 1" diameter steel rod is based on use of modified Petry formula with K value of 2.75×10^{-3} in accordance with Reference 7.

TABLE 3.5-11

TORNADO MISSILE CONCRETE BARRIER MINIMUM THICKNESS*

Building	Minimum Thickness (ft)
Reactor Building	
Cylindrical Wall	3
Dome	2-1/2
Reactor Auxiliary Building	
Wall	2
Roof Slab	2
Fuel Handling Building	
Wall	2
Roof Slab	2
Component Cooling Water System Structure	
Wall	2
Roof Slab	2

*The required 28 day design strength for the above structure is 4000 psi (refer to Subsection 3.8.4.6.1.2)

TABLE 3.5-12

ALLOWABLE DUCTILITY RATIOS FOR TORNADO IMPACT LOADS

Elements where flexure governs design	
Reinforced Concrete Beams, Walls and Slabs	$\mu = \frac{0.5}{p - p'} \leq 10$
Structural Steel members	$\mu = 26$
Elements where shear governs design	
Reinforced Concrete Beams, Walls and Slabs	
Shear carried by concrete only	$\mu = 1.0$
Shear carried by concrete and stirrups	$\mu = 1.3$
Shear carried by stirrups completely	$\mu = 3.0$
Structural Steel members	$\mu = 10$

Where μ = Allowable ductility
p = ratio of tension reinforcement
p' = ratio of compression reinforcement

TABLE 3.5-13 Revision 308 (11/14)

STEEL BARRIERS

Missile	Weight (lb)	Traveling Velocity (mph)	Impact Height	Steel Penetration Depth (in) Stanford Formula	Brl Formula	Equivalent Static Load (kips) μ= 26	μ= 10	Maximum Shear Stress (KSI) (μ = 10) Shear Transfer Of Cross Bars	Punching Shear In Bearing Bars
→(EC-40242, R308)									
1) 2" x 4" x 10' Wooden plank	27.8	300	all height	3.04	3.59	10.34	16.92	0.34	3.92
2) 3" dia Sch. 40 pipe, 10' long	75.8	100	all height	1.69	1.58	10.64	17.41	0.35	2.02
3) 4000# automobile (soft missile)	4000	50	at grade	0.85	0.26	211.50	346.49	7.05	2.01
4) 1" dia steel rod, 3' long	8	216	all height	1.37	1.86	3.38	4.08	0.08	0.94
5) 13.5" dia utility pole, 35' long	1490	144	grade to 30' above grade	4.04	3.08	199.00	432.44	8.80	11.14
←(EC-40242, R308)									