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Subject: **Response to NRC Request for Additional Information Letter No. 12 and Partial Response to RAI Letter No. 22 for the ESBWR Design Certification Application – Missile Protection – RAI Numbers 3.5-1 through 3.5-14 and 3.5-15**

Enclosure 1 contains GE responses to the subject NRC RAI Number 12 transmitted via Reference 1. Also provided is a response to related RAI 3.5-15, included with NRC RAI Letter Number 22, as transmitted by Reference 2.

In addition to the responses, markups of the related sections of the DCD Tier 2 are provided.

If you have any questions about the information provided here, please let me know.

Sincerely,

David H. Hinds
Manager, ESBWR

D068

Reference:

1) MFN 06-091, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 12 Related to ESBWR Design Certification Application,* March 22, 2006

2) Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 22 Related to ESBWR Design Certification Application,* April 19, 2006

Enclosure:

1. MFN 06-110 – Response to NRC Request for Additional Information Letter No. 12 and Partial Response to RAI Letter No. 22 for the ESBWR Design Certification Application – Missile Protection – RAI Numbers 3.5-1 through 3.5-15

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ENCLOSURE 1

MFN 06-110

Response to NRC Request for Additional Information Letter No. 12 and Partial Response to RAI Letter No. 22 for the ESBWR Design Certification Application Missile Protection – RAI Numbers 3.5-1 through 3.5-15

NRC RAI 3.5-1

DCD Section 3.5.1 describes the criteria for missile protection inside the reactor building and lists systems requiring missile protection. However, the information provided is not sufficient for the staff to determine their acceptability. Please

(1) Provide information on missile protection for the systems classified under regulatory treatment of non-safety systems (RTNSS), such as fuel and auxiliary pool cooling system,

(2) Explain why the reactor water cleanup system (RWCU) is not listed as requiring missile protection for its reactor coolant pressure boundary and shutdown cooling functions, and

(3) Confirm that a single active failure concurrent with postulated internally generated missiles has been properly assumed in the selections.

GE Response

(1) and (2) Regulatory Treatment of Non-Safety Systems (RTNSS) is discussed in DCD Section 19.6 and Appendix 1D. In accordance with the discussion in these DCD sections, the Fuel and Auxiliary Pool Cooling System (FAPCS) and Reactor Water Cleanup and Shutdown Cooling system (RWCU/SDC) are not identified as candidates for RTNSS after application of the selection criteria, and in particular they are not relied on to meet the safety goal in the focused PRA. Specifically Table 1D-1 of DCD Appendix 1D does not include these systems as RTNSS candidates. Therefore no specific missile protection has been required for these systems.

This notwithstanding, the design implemented for these systems provides effective protective measures for these types of hazards via separation of redundant components outside of containment in different rooms with strong resistance to expected missiles.

Table 1D-1 of DCD Appendix 1D includes "Systems and Components that Qualify for RTNSS." Included are portions of the Fire Protection System (FPS) to provide water to the PCC and IC pools to maintain passive cooling beyond 24 hours, in case multiple failures prevent opening of the valves connecting the equipment pool and reactor cavity to both PCC/IC buffer pools. Establishing a connection to just one of the two buffer pools is sufficient to replenish the water using FPS and FAPCS and ensure cooling after 24 hours.

Permanently installed piping is included in the FAPCS, which is connected directly with the site FPS as shown in FAPCS schematic diagram (DCD Figure 9.1-1). This connection enables the PCC, IC and Fuel pools to be filled with water from the FPS to continue decay heat removal almost indefinitely. The FPS

has access to enough water on-site to provide makeup water to extend the cooling period from 72 hours through 7 days.

In addition, the FAPCS also includes permanent piping with connections outside the Reactor and Fuel Buildings, which allow readily available alternate water sources to be used to fill the pools, as shown in FAPCS schematic diagram (DCD Figure 9.1-1).

Table 1D-1 of DCD Appendix 1D Rev. 1 also identifies the Basemat-Internal Melt Arrest Coolability (BIMAC) as "Systems and Components that qualify for RTNSS". The BIMAC is designed to ensure that the primary containment maintains its functionality in the event of a severe accident. The BIMAC system is located within and at the base of the reactor pedestal. The system is inherently missile resistant due to its material configuration and is designed such that any missiles that could be generated within the under vessel area would not cause the system to lose functionality.

(3) A concurrent single active failure is assumed in safety-related components used to respond to the consequences of the postulated missile and achieve safe shutdown.

NRC RAI 3.5-2

DCD Section 3.5.1.1.2.2 analyzed the remaining pressurized components considered to be potentially capable of producing missiles. However, the information is not sufficient to determine their acceptability. Please

(1) Provide information on how the various pipe fittings were screened to determine those that could credibly become missile.

GE Response

The following general criteria have been adopted to define potential missiles considered in the analysis.

- Catastrophic failure of safety-related rotating equipment leading to the generation of missiles is not considered credible. Pumps, fans and the like are AC powered. Their speed is governed by the frequency of the AC power supply. Because the AC power supply frequency variation is limited to a narrow range, they cannot attain an overspeed condition. At rated speed, if a component piece, such as a fan blade, breaks off, it would not penetrate the casing. These components are designed to preclude having sufficient energy to move the masses of their rotating parts through the housing in which they are contained.
- Catastrophic failure of non-safety-related rotating equipment leading to the generation of missiles is not considered credible in situations where measures similar to those described for safety-related rotating equipment are applied to them. Protection from non-safety related equipment normally will be provided by separation.
- Valves that are constructed in accordance with the ASME Code, Section III are pressure-seal bonnet-type valves. Valve bonnets are prevented from becoming missiles by limiting stresses in the bolting to those defined by the ASME Code and by designing flanges in accordance with applicable code requirements. Safety factors involved against failure of these types of bonnets are sufficiently high that these pressure seal-type valves are not considered to be a potential missile source.
- Valves that are constructed in accordance with ASME Code, Section III are valves with bolted bonnets. These types of valves were analyzed for the safety factors against failure and, coupled with the low historical incidents of complete severance failure, were determined to not be a potential missile source. The bolted bonnets are prevented from becoming missiles by limiting stresses in the bonnet-to-body bolting material according to ASME Code, Section III requirements.
- The isolation valves installed in the reactor coolant systems have stems with back seats, which eliminate the possibility of ejecting valve stems even if the stem threads fail. A double failure of highly reliable components would be required to produce a valve stem missile, so the overall probability of occurrence is less than 10^{-7} per year. Hence, valve stems cannot become a source of missiles.

- Thermowells and similar fittings attached to piping on pressurized equipment that are attached by welding are not considered to be credible missiles. The complete joint has greater design strength than the parent metal. Threaded connections in high energy systems are not used.
- Nuts, bolts, nut and bolt combinations, and nut and stud combinations have only a small amount of stored energy and are thus of no concern as potential missiles.
- Instrumentation such as pressure, level and flow transmitters and associated piping and tubing are not considered as credible missiles. The amount of high-energy fluid in these instruments is limited and will not result in the generation of missiles.
- The pneumatic system air bottles and components are designed for 17.2 MPag (2500 psig); the EBAS are designed for 11.0 MPag (1600 psig) and the SLC accumulator tank is designed for 17.1 MPa (2500 psia) to ASME Code, Section III requirements. These bottles are not considered a credible source of missiles for the following qualitative analysis:
  - The bottles are fabricated from heavy-wall rolled steel
  - The operating orientation is vertical with the ends facing concrete slabs. The bottles are topped with steel covers thick enough to preclude penetration by a missile.
  - The fill connection and critical parts are protected by a permanent steel collar.
  - The bottles are strapped in a rack to prevent them from toppling over. The racks seismically designed to the ASME Code, Section III, Subsection are NF requirements.

NRC RAI 3.5-3

DCD Section 3.5.1.1.2.2 states that piping failures do not form missiles because the whipping section remains attached to the remainder of the pipe. However, a guillotine break of a high-energy line could cause the pipe attachments to become a missile source. DCD Section 3.6 discusses the dynamic effects related to jet impingement forces and pipe whipping, but missile generation was not considered. Discuss the potential for a guillotine break of a high-energy line outside containment to become a missile source.

GE Response

High energy piping systems outside containment are designed so that consideration does not have to be given to circumferential breaks after applying the break postulation exclusion criteria defined in accordance with Branch Technical Position (BTP) EMEB 3-1, as described in DCD Section 3.6.

NRC RAI 3.5-4

DCD Section 3.5.1.1.1.3 discusses other missile analyses. However, gravitational missiles are not addressed in this section. Provide an assessment of potential gravitational missiles generated outside containment and explain plant design features that could prevent the impact of a falling object on safety-related equipment necessary to achieve a safe shutdown.

GE Response

In accordance with the Seismic Category II definition criterion, this category is assigned to components that do not perform safety functions, but whose interaction or structural failure may impair the actuation of Seismic Category I components. Safety-related components are located on certain floors of the Nuclear Island, surrounded by walls and floors of Seismic Category I structures that provide them with physical protection against gravitational missiles located outside these areas. The potential missile loads that could be generated by non-seismic components located within these areas are prevented from becoming missiles by seismic anchorage of the non-seismic components in the vicinity of safety-related components and physical separation, so as to avoid any potential damage.

NRC RAI 3.5-5

DCD Section 3.5.1.1.2.2.6 states that blowout panels are hinged to prevent them from becoming missiles. Explain how protection from external missiles is provided for safety-related components located near the openings of the swing-type blowout panels.

GE Response

The hinged blowout panels, which are designed to prevent them from becoming a missile, are located near the roof of the reactor building. However, no safety-related components are near this area, so there is no concern.

NRC RAI 3.5-6

Squib valves are seldom used in operating nuclear plants such that the reliability of the valve is not traceable through plant operating experience. Discuss how the failure of explosive squib valves were evaluated, both an initiating event and at time of actuation demand, to verify that potential missiles could not damage surrounding safety-related components such that a safety function would not be threatened. If used as a basis for the evaluation, provide design information to show that this type of valve will not become a credible missile source.

GE Response

Explosive squib valves have been used in the past in BWR SLC systems. Other systems also employ explosive squib valves in the ESBWR design, namely the GDCS and DPV. These valves have been specified to be integrally designed and built, manufactured and tested such that no missile actuation could be generated in the event of squib actuation.

Find attached sketches (Figures 2&3) showing relevant features for Depressurization Valve and explosive squib valves.

NRC RAI 3.5-7

Safety-relief valves (SRVs) used in ESBWR design function as safety valves and open to prevent nuclear system over-pressurization and are self-actuating by inlet steam pressure. Discuss the possibility of the safety-relief valves becoming internally generated missiles, and provide basis to determine that these components will not credibly affect safety-related equipment needed for safe shutdown.

GE Response

Design characteristics of the SRVs provide the basis to exclude the possibility of internally generated missiles, as is discussed in DCD 3.5.1.1.2.2. They are used in all existing operating BWR and are designed and manufactured so that they do not produce potential missiles upon failure. Note that the retaining components that act as guides will prevent the larger diameter components in the shaft from becoming missiles.

Find attached sketch (Figure 1) showing relevant features for SRV valves.

NRC RAI 3.5-8

DCD Section 3.5.1.4 states that the design basis tornado and tornado missile spectrum are defined in DCD Sections 2.3.1, 2.3.2, and Table 2.0-1 in the design of Seismic Category I buildings. In considering tornado-generated missile threat to plant safety-related SSCs, explain whether the missile threat is considered concurrent with a loss-of-offsite-power.

GE Response

The Seismic Category I buildings for ESBWR are designed to remain intact and to protect any safety-related structures, systems and components (SSCs) located within them from damage due to the design basis tornado and tornado missile spectrum. There are two events analyzed in the DCD that assume a loss-of-offsite power and only take credit for safety-related SSCs located in Seismic Category I structures.

The ESBWR is designed to handle design basis LOCA events with a concurrent loss-of-offsite power. LOCA events only take credit for safety-related SSCs located in Seismic Category I structures. A design basis tornado and tornado missile spectrum would not disable any equipment credited for use in responding to a design basis LOCA. Therefore, the response of the ESBWR to a design basis tornado and tornado missile spectrum concurrent with a loss-of-offsite power is bounded by the LOCA analysis results contained in DCD Tier 2 Subsections 6.2.1 (containment response) and 6.3.3 (RPV response).

The Station Blackout event described in DCD tier 2 Subsection 15.5.5 begins with a loss of all AC power and also takes credit only for safety-related SSCs located in Seismic Category I structures. Therefore, the response to a design basis tornado and tornado missile spectrum concurrent with a loss-of-offsite power is also bounded by the Station Blackout event response.

NRC RAI 3.5-9

DCD Section 3.5.1.4 states, "because tornado missiles are used in the design basis, it is not necessary to consider missile generated from other natural phenomena." This statement may not be true. Wind driven missiles generated by other site-specific extreme winds should be considered on a case-by-case basis if they are considered credible. Please address the potential for other extreme winds more fully.

GE Response

A DOE study, conducted by the University of Texas at Lubbock, concludes that extreme winds are less intense than tornado winds and do not have the strong vertical component that produces airborne missiles in tornados. Therefore wind driven missiles are not considered in the design.

Reference: "Rationale for Wind-borne Missile Criteria for DOE Facilities", James R. McDonald, PhD, PE, Sept. 1999 UCRL-CR-135687 S/C B 505188

NRC RAI 3.5-10

In DCD Section 3.5.1.1.1.2, it is stated that the COL holder shall submit for NRC approval, within three years of obtaining an operating license, a turbine system maintenance program including probability calculations of turbine missile generation based on the NRC-approved methodology such as Reference 3.5-1, or volumetrically inspect all low pressure turbine rotors at the second refueling outage and every other (alternate) refueling outage thereafter until a maintenance program is approved by the staff. (A) The staff requests that the COL applicant include the turbine system maintenance program for NRC approval as part of the COL application. Turbine integrity plays an important role in ensuring public health and safety. Therefore, the staff needs to review and approve the turbine system maintenance program to confirm that the turbine will be adequately maintained under the program before the operating license is granted. (B) The "COL holder" implies that the utility company has obtained the operating license whereas the "COL applicant" implies that the utility company has not obtained the operating licensee. Therefore, in the context of the turbine maintenance program submittal, the COL "holder" in DCD Section 3.5.1.1.1.2 should be changed to the COL "applicant".

GE Response

The COL applicant will provide a turbine maintenance program at COL. A maintenance program will be incorporated into the turbine documentation prior to the turbine delivery. Refer to subsection 10.2.5.3 for additional information and to subsection 3.5.4.4 for COL licensing.

NRC RAI 3.5-11

Provide the technical basis for volumetrically inspecting all low pressure turbine rotors at the second refueling outage and every other refueling outage, and not at every refueling outage.

GE Response

The technical basis for the steam turbine maintenance program will be based on forged rotors with integral turbine disks, and any required inspections and frequency will be provided in the COLA. Refer to subsection 3.5.4.4 for COL licensing information.

NRC RAI 3.5-12

DCD Section 3.5.4.4 requires that "The COL holder shall provide a turbine system maintenance program to the NRC or alternative volumetric inspection as described in Subsection 3.5.1.1." Depending on resolution of RAI 3.5-10, the commitment in Section 3.5.4.4 may need to be revised. As written, DCD Section 3.5.4.4 is inadequate because it does not require the COL holder to submit, for staff review, the probability of turbine missile generation, which is a commitment in DCD Section 3.5.1.1.1.2.

GE Response

See marked up DCD Section 3.5.1.1.1.2 and new subsection 3.5.4.5 for COL licensing information. Based on recent experience it is expected that the probability figures will be in the range of 10^{-8}. The turbine generator, relative to the ESBWR reactor building, provides a favorable orientation with respect to low trajectory missiles (see Fig. 3.5-2) and ESBWR uses modern manufacturing technology that includes forged turbine rotor geometry, with integral turbine disks. They do not utilize shrunk-on disks as in older technology. Therefore, rotor stresses are very low. Additionally, the shrunk-on disk key way that was cause for stress corrosion cracking failure was eliminated in forged turbine rotor with integral turbine disks. A complete failure of the control system is required to achieve the maximum attainable overspeed for the unit. These newer units are referred to as "forged monoblock" rotors.

NRC RAI 3.5-13

In DCD Section 3.5.1.1.1.2, it is stated that "...the COL holder shall meet the minimum requirement for the probability of turbine missile generation given in Table 3.5-1 at COL..." This commitment is not shown in DCD Section 3.5.4, COL Information. This commitment needs to be added to DCD Section 3.5.4 as follows:

3.5.4.5 Probability of Turbine Missile Generation
The COL applicant shall meet the minimum requirement for the probability of turbine missile generation provided in Table 3.5-1.

GE Response

See attached mark up of DCD Section 3.5.1.1.1.2 and 3.5.4 for clarification requested.

NRC RAI 3.5-14

In DCD Table 3.5-1, it is required that if the probability of missile generation, P1, exceeds 10-4, the COL applicant is required to take action to reduce P1 to less than 10-4 before returning the turbine to service. Discuss how the COL applicant would monitor the turbine system to ensure that the probability of missile generation satisfies the acceptance criteria in DCD Table 3.5-1 during the life of the plant.

GE Response

A detailed turbine monitoring program will be supplied as part of the turbine maintenance program in the COLA. It is based on years of successful operation of similar turbines in this same size range. (See Subsection 3.5.1.1.2.)

NRC RAI 3.5-15

DCD Tier 2, Section 3.5.3.1.1, states that ACI-349, appendix C, Section C.7, "Code Requirements for Nuclear Safety Related Concrete Structures," was used to prevent perforation in the event of missile impact. RG 1.142 provides guidance to licensees and applicants on methods acceptable to the NRC staff for complying with the NRC's regulations in the design, evaluation, and quality assurance of safety-related nuclear concrete structures, excluding concrete reactor vessel and concrete containments. This regulatory guide contains some exceptions to ACI-349 to reflect the existing review practices of the NRC staff. For example, part C.3.7.a of ACI-349 states that a ductility ratio of 1.3 is acceptable for shear carried by concrete alone. In contrast, RG 1.142 part C 10.4.1 states that a ductility ratio of 1.0 is acceptable for the same case. Confirm that all applicable provisions of RG 1.142, including the permissible ductility ration, are complied with in the ESBWR Design. Otherwise, discuss the bases for exceptions taken with respect to RG 1.142.

GE Response

ESBWR complies with the requirements of RG 1.142 including permissible ductility ratio. See Table 1.9-21.

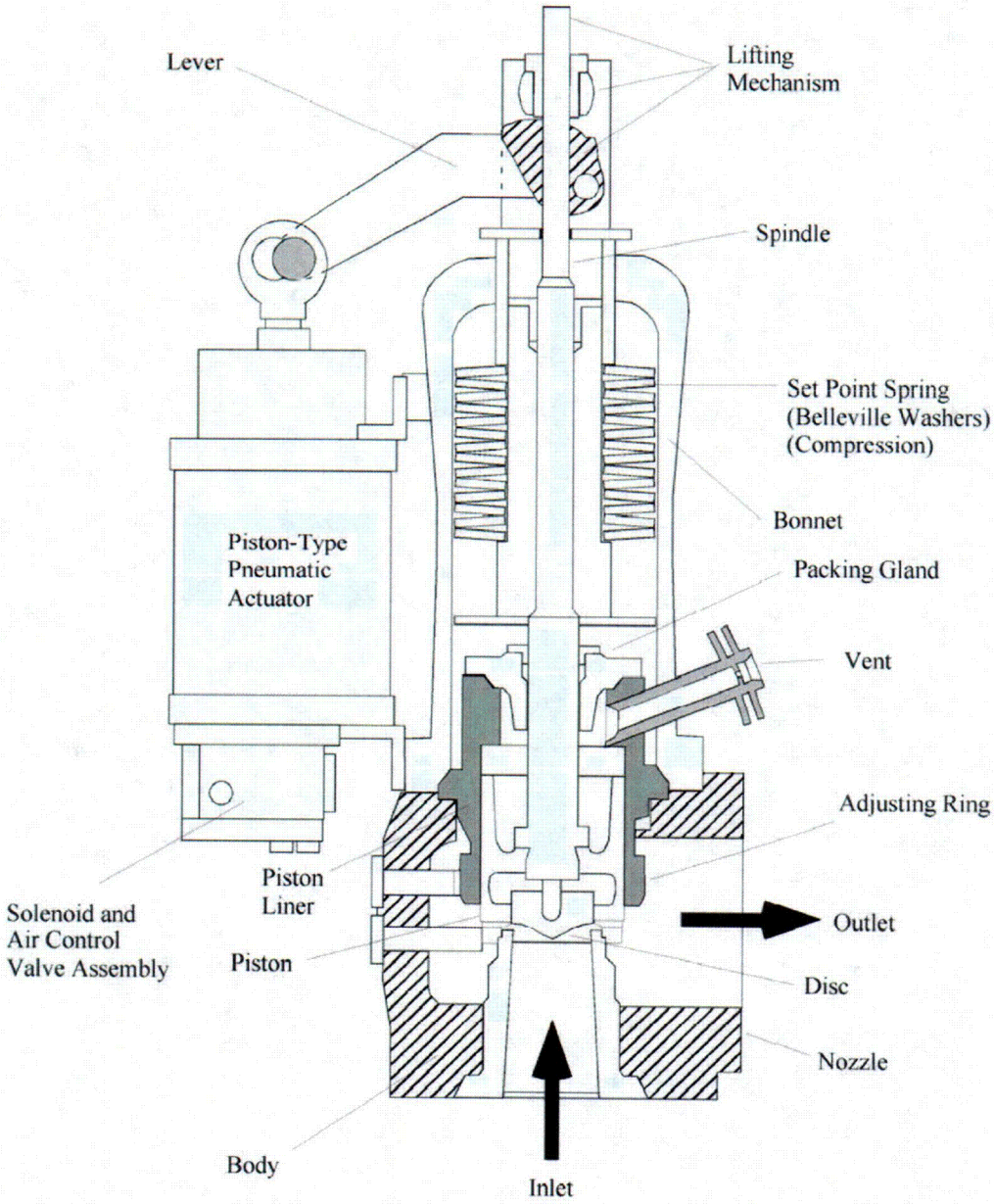

Figure 1 Safety Relief Valve (RAI 3.5-7)

C01

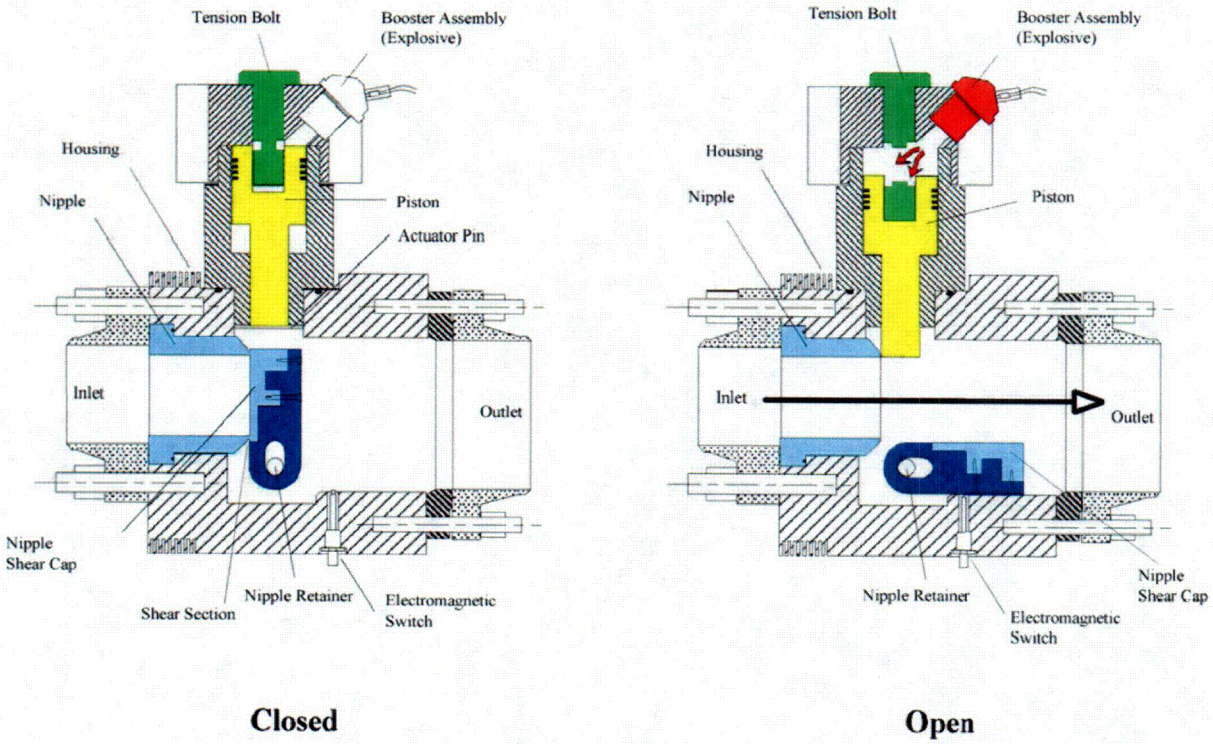

Figure 2 Depressurization Valve (RAI 3.5-6)

C02

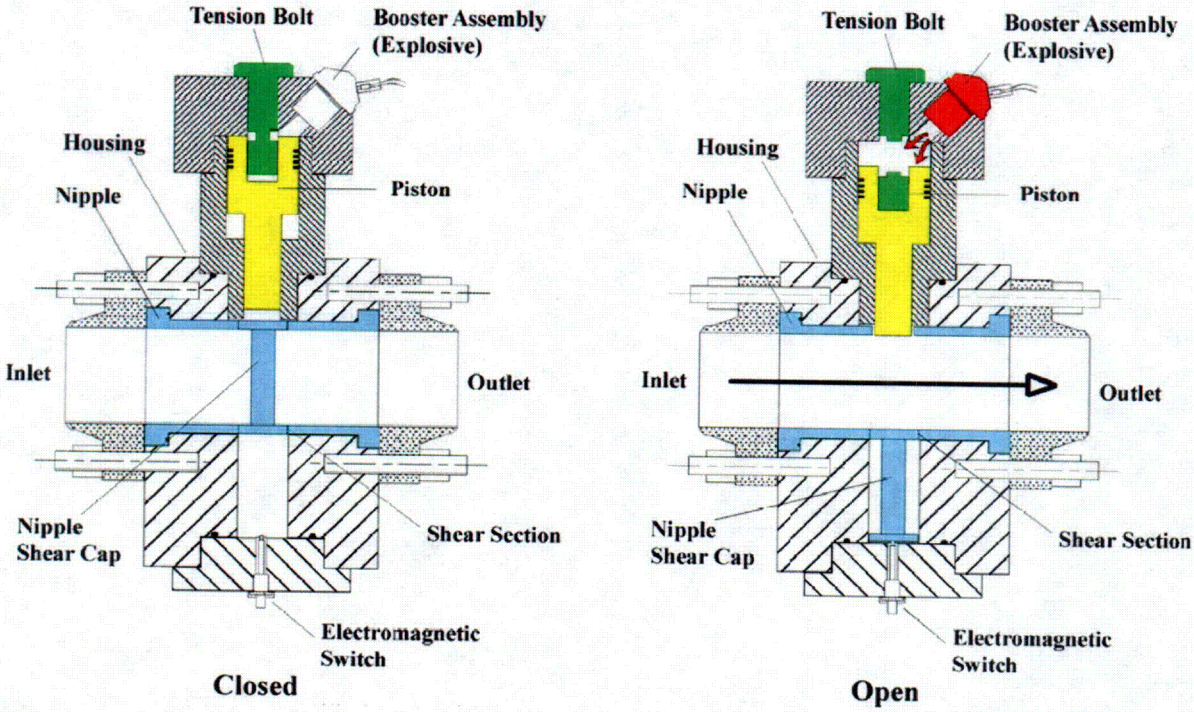

Figure 3 Typical Squib Explosive Valve for GDCS Injection (RAI 3.5-6)

C03

(7) Electrical and control systems and wiring required for operation of items (1) through (6); and

(8) Remote shutdown panel.

The following general criteria are used in the design, manufacture, and inspection of equipment:

- All pressurized equipment and sections of piping that may periodically become isolated under pressure are provided with pressure-relief valves acceptable under ASME Code Section III. The valves ensure that no pressure buildup in equipment or piping sections exceeds the design limits of the materials involved.
- Components and equipment of the various systems are designed and built to the standards established by the ASME Code or other equivalent industrial standard. A stringent quality control program is also enforced during manufacture, testing, and installation.
- Volumetric and ultrasonic testing where required by code, coupled with periodic in-service inspections of materials used in components and equipment, add further assurance that any material flaws that could permit the generation of missiles are detected.

3.5.1.1 Internally Generated Missiles (Outside Containment)

This subsection addresses structures, systems and components (SSC) provided to support the reactor facility, and that require protection from internally generated missiles (outside containment) to ensure conformance with the requirements of General Design Criterion 4. The design addresses concerns for missiles that could result from in-plant component overspeed failures and high-pressure system ruptures as discussed in SRP 3.5.1.1, when applicable.

3.5.1.1.1 Rotating Equipment

3.5.1.1.1.1 Missile Characterization

Equipment within the general categories of pumps, fans, blowers, diesel generators, compressors, and turbines and, in particular, components in systems normally functioning during power reactor operation have been examined for any possible source of credible and significant missiles.

3.5.1.1.1.2 Main Steam Turbine

Acceptance criterion 1 of SRP Section Turbine Missiles considers a plant with a favorable turbine generator placement and orientation, and adhering to the guidelines of Regulatory Guide 1.115, as adequately protected against turbine missile hazards. Further, this criterion specifies that exclusion of safety-related structures, systems or components from low trajectory turbine missile strike zones constitutes adequate protection against low trajectory turbine missiles. The turbine generator placement and orientation of the ESBWR as shown in Figure 3.5-2 meets the guidelines of Regulatory Guide 1.115. Refer to Subsection 3.5.4.4 and 3.5.4.5 for COL licensing information.

At COL the applicant shall meet the minimum requirements for the probability of turbine missile generation given in Table 3.5-1.

3.5.3.1.2 Steel Structures and Barriers

The Stanford equation (Reference 3.5-6) is applied for steel structures and barriers. Composite barriers are not utilized in ESBWR Standard Plant for missile protection.

3.5.3.2 Overall Damage Prediction

The overall response of a structure or barrier to missile impact depends largely upon the location of impact (e.g., near mid-span or near a support), dynamic properties of the structure/barrier and missile, and on the kinetic energy of the missile. In general, it has been assumed that the momentum of the missile is transferred to the structure or barrier and only a portion of the kinetic energy is absorbed as strain energy within the structure or barrier.

After demonstrating that the missile does not perforate the structure or barrier, an equivalent static load concentrated at the impact area is determined. The structural response to this load, in conjunction with other appropriate design loads, is evaluated using an analysis procedure similar to that in Reference 3.5-7.

3.5.4 COL Information

3.5.4.1 Missiles Generated by Natural Phenomena from Remainder of Plant Structures, Systems, and Components

The COL applicant shall provide an evaluation to show that the remainder of nonsafety-related plant structures, systems and components, during a site-specific tornado, do not generate missiles exceeding the design basis missiles considered in Subsection 3.5.1.4.

3.5.4.2 Site Proximity Missiles and Aircraft Hazards

Analyses or proximity distances to selected points shall be provided to demonstrate that the probability of site proximity missiles (including aircraft) impacting the ESBWR Standard Plant and causing consequences greater than 10 CFR 100 (and 10 CFR 50.34(a)) exposure guidelines is $< 10^{-7}$ per year (Subsection 3.5.1.5 and 3.5.1.6).

3.5.4.3 Impact of Failure of Nonsafety-Related Structures, Systems and Components

An evaluation of all nonsafety-related structures, systems and components (not housed in a tornado structure), whose failure because of a design basis tornado missile that could adversely impact the safety function of a safety-related systems and components, shall be provided to the NRC by the applicant referencing the ESBWR design (Subsection 3.5.1.4).

3.5.4.4 Turbine System Maintenance Program

The COL applicant shall provide a Turbine System Maintenance Program. (Subsection 3.5.1.1)

3.5.4.5 Probability of Turbine Missile Generation

The COL applicant shall provide a calculation of the probability of turbine missile generation using the criteria used for the probability calculation in accordance with the NRC requirements such as in Reference 3.5-1 and NUREG 0933 item A37. (See Subsection 3.5.1.1.1.2.)