3.10 Seismic and Dynamic Qualification of Seismic Category I Mechanical and Electrical Equipment

Safety-related equipment and selected portions of post-accident monitoring equipment are classified as seismic Category I, as discussed in Subsection 3.2.1.1. This section addresses the seismic and dynamic qualification of this equipment other than piping and includes the following types:

- Safety-related instrumentation and electrical equipment and certain monitoring equipment.
- Safety-related active mechanical equipment that performs a mechanical motion while accomplishing a system safety-related function. These devices include the control rod drive mechanisms; HVAC and fluid system valves.
- Safety-related, nonactive mechanical equipment whose mechanical motion is not required while accomplishing a system safety-related function, but whose structural integrity must be maintained in order to fulfill its design safety-related function.

This section presents or references information to demonstrate that mechanical equipment, electrical equipment, instrumentation, and, where applicable, their supports classified as seismic Category I are capable of performing their designated safety-related functions under the full range of normal and accident (including seismic) loadings. This equipment includes devices associated with systems essential to safe shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing significant release of radioactive material to the environment or in mitigating the consequences of accidents. The information presented or referenced includes:

- Identification of the seismic Category I instrumentation, electrical equipment, and appropriate mechanical equipment
- Qualification criteria employed for each type of equipment
- Designated safety-related functional requirements
- Definition of the applicable seismic environment
- Definition of other normal and accident loadings
- Documentation of the qualification process employed to demonstrate the required structural integrity and operability of mechanical and electrical equipment and instrumentation in the event of a safe shutdown earthquake (SSE) after a number of postulated occurrences of an earthquake smaller than a safe shutdown earthquake in combination with other relevant dynamic and static loads.

The AP1000 plant is based on the Certified Seismic Design Response Spectra (CSDRS) defined in Subsection 3.7.1.1. The CSDRS are based on Regulatory Guide 1.60 design response spectra with an increase in the 25 hertz region. The Ground Motion Response Spectra (GMRS) for some

Central and Eastern United States rock sites show higher amplitude at high frequency than the CSDRS. Evaluations for high frequency exceedance at AP1000 plant rock sites have been performed as described in Appendix 3I. It is the conclusion of these evaluations that AP1000 plant systems, structures, and components are qualified for the high frequency seismic response based on the CSDRS with the exception of potential high frequency sensitive components (APP-GW-GLN-144, Reference 5). Specific models of components are not identified as part of the AP1000 certified design and are evaluated for high frequency sensitivity as part of the equipment qualification. Appendix 3I provides the criteria for addressing potential high frequency sensitive components for plant locations where there is CSDRS exceedance in the high frequency region.

3.10.1 Seismic and Dynamic Qualification Criteria

3.10.1.1 Qualification Standards

The methods of meeting the general requirements for the seismic and dynamic qualification of seismic Category I mechanical and electrical equipment and instrumentation as described by General Design Criteria (GDC) 1, 2, 4, 14, 23, and 30 are described in Section 3.1. The general methods of implementing the requirements of Appendix B to 10CFR50 are described in Chapter 17.

The Nuclear Regulatory Commission (NRC) recommendations concerning the methods employed for seismic qualification of mechanical and electrical equipment are contained in Regulatory Guide 1.100, which endorses IEEE 344-1987 (Reference 1).

[*AP1000 meets IEEE 344-1987, as modified by Regulatory Guide 1.100, by either type testing or analysis or by an appropriate combination of these methods*]* employing the methodology described in Appendix 3D.

The guidance provided in the ASME Code, Section III, is followed in the design of seismic Category I mechanical equipment to achieve the structural integrity of pressure boundary components. In addition, the AP1000 implements an operability program for active valves following Regulatory Guide 1.148, as addressed in Subsection 1.9.1 and in Section 3.9.

3.10.1.2 Performance Requirements for Seismic Qualification

An equipment qualification data package (EQDP) is developed for the instrumentation and electrical equipment classified as seismic Category I. Table 3.11-1 of Section 3.11 identifies the seismic Category I electrical equipment and instrumentation supplied for the AP1000. Each equipment qualification data package contains a section entitled “Performance Requirements.” This section establishes the safety-related functional requirements of the equipment to be demonstrated during and after a seismic event. The required response spectra employed by the AP1000 for generic seismic qualification are also identified in the section.

For active seismic Category I mechanical components, the performance requirements are defined in the appropriate design and equipment specifications. Requirements for active valves are discussed in Subsection 3.10.2.2. The equipment qualification data packages are referenced in Subsection 3.10.4. For other seismic Category I mechanical components, the performance requirement is to maintain structural integrity under appropriate loading conditions.

A master list and summary of seismic qualification of safety-related seismic Category I electrical and mechanical equipment are maintained as part of the equipment qualification file.

3.10.1.3 Performance Criteria

Seismic and dynamic loading qualification demonstrates that seismic Category I instrumentation and electrical equipment and active valves are capable of performing their designated safety-related functions under applicable plant loading conditions, including the safe shutdown earthquake. The qualification also demonstrates the structural integrity of seismic Category I nonactive valves, mechanical supports, and structures. Some permanent deformation of supports and structures is acceptable at the safe shutdown earthquake level, provided that the capability to perform the designated safety-related functions is not impaired.

*NRC Staff approval is required prior to implementing a change in this information.

3.10.2 Methods and Procedures for Qualifying Electrical Equipment, Instrumentation, and Mechanical Components

Testing is the preferred method to qualify equipment. Both dynamic and static test approaches are used to demonstrate structural integrity and operability of mechanical and electrical equipment in the event of a safe shutdown earthquake preceded by five earthquakes of a magnitude equal to 50 percent of the calculated safe shutdown earthquake. Test samples are selected according to type, load level, and size, as well as other pertinent factors on a prototype basis.

Analysis using mathematical modeling techniques correlated to tests performed on similar equipment or structures and verified analytical approaches are used to quality equipment. Combined analysis and testing is also used to qualify equipment.

The analytical approach to seismic qualification without testing is used under the following conditions:

- If operability can be demonstrated by analysis alone.
- If only maintaining structural integrity is required for the safety-related function.
- If the equipment is too large or heavy to obtain a representative test input at existing test facilities. (The essential control devices and electrical parts of large equipment are tested separately if required.)
- If the interfaces (for example, interconnecting cables to the cabinet or other complex inputs) cannot be conservatively considered during testing.
- If the response of the equipment is essentially linear or has a simple nonlinear behavior that can be predicted by conservative analytical methods.

A combination of testing and analysis is used when complete testing is not practical.

Equipment that has been previously qualified by means of test and analysis equivalent to those described herein is acceptable provided that proper documentation is submitted.

Seismic qualification of seismic Category I instrumentation and electrical equipment is demonstrated by either type testing or a combination of test and analysis. The qualification method employed by the AP1000 for a particular item of equipment is based upon many factors including practicability, complexity of equipment, economics, and availability of previous seismic qualification. The qualification method employed for a particular item of instrumentation or electrical equipment is identified in the individual equipment qualification data package.

For active valves, the AP1000 uses a combination of tests and analyses to demonstrate the structural integrity and operability of such components. Other seismic Category I mechanical equipment is qualified by analysis to demonstrate structural integrity.

The methods of load combination and methods of combining dynamic responses for mechanical equipment are discussed in Section 3.9. For instrumentation and electrical equipment, the only dynamic loads considered in testing are seismic loads and hydrodynamic and vibratory loads where applicable. Other dynamic loads to which instrumentation and electrical equipment may be subjected are enveloped by this testing or are addressed by analysis.

3.10.2.1 Seismic Qualification of Instrumentation and Electrical Equipment

3.10.2.1.1 Type Testing

For seismic Category I instrumentation and electrical equipment, seismic qualification by test is performed according to IEEE 344-1987. Where testing is used, multifrequency, multiaxis inputs are developed by the general procedures outlined in Appendix 3D. The test results contained in the individual equipment qualification data packages demonstrate that the measured test response spectrum envelops the required response spectrum defined in the equipment qualification data package.

Alternative test methods, such as single-frequency, single-axis inputs for line-mounted equipment, are used in selected cases as permitted by IEEE 344-1987 and Regulatory Guide 1.100. These methods are further described in Appendix 3D.

3.10.2.1.2 Analysis

Seismic qualification by the analysis method can be used to demonstrate qualification for equipment where structural integrity or limitations of deformation provide the safety-related function. Seismic analysis is widely used to demonstrate qualification of equipment where testing is impractical, equipment is easily modeled (no secondary structures), and no complex equipment functions are required.

Analysis may complement tests when needed to extrapolate or interpolate experimental data. Analysis may be used to investigate established failure modes related to structural integrity, fatigue, and stress-strain behavior. Two methods of computation are: (1) static equivalent load, which yields conservative results, and (2) dynamic analysis, which takes into account the dynamic response properties of the structure and which can be suitably represented by linear models.

The analysis method is not recommended for complex equipment that cannot be modeled to adequately predict its response.

3.10.2.1.3 Combination of Test and Analysis

The AP1000 uses a combination of test and analysis to qualify seismic Category I instrumentation and electrical equipment. The test methods are similar to those described for type testing. Available test results are employed in combination with the analysis methods described in IEEE 344-1987 to demonstrate seismic qualification. The analytical methods include both static and dynamic techniques, which are described in detail in Appendix 3D.

3.10.2.2 Seismic and Operability Qualification of Active Mechanical Equipment

Active mechanical equipment is qualified for both structural integrity and operability for its intended service conditions by a combination of test and analysis. These methods address the applicable loading conditions, such as thermal transients, significant flow loads, and/or degraded flow conditions. The test and analysis methods utilized in qualification of these components provide adequate confidence of operability under required plant conditions.

Qualification methods used for active valves are described in this subsection. The qualification methods used for control rod drive mechanisms and snubbers are described in Section 3.9. The qualification program for valves that are part of the reactor coolant pressure boundary shall include testing or analysis that demonstrate that these valves will not experience leakage beyond the limits defined in the design specification for each valve when subjected to design loading.

Safety-related active valves, listed in Table 3.11-1, are required to function at the time of an accident. Tests and analyses are conducted to qualify active valves providing confidence that these valves operate during a seismic event.

The safety-related valves are subjected to a series of type tests or actual tests before service and during the plant life. Before installation, the following tests are performed: body hydrostatic test to ASME Code, Section III, requirements, back-seat and main seat leakage tests, disc hydrostatic tests, and operational tests to verify that the valve opens and closes within stroke time requirements. For the qualification of motor operators for environmental conditions, see Section 3.11. After installation, the valves undergo system level hydrostatic tests, construction acceptance tests, and preoperational tests. Where applicable, periodic in-service inspections and operations are performed in-situ to verify the functional capability of the valve. On active valves, an analysis of the extended structure is performed for static equivalent seismic safe shutdown earthquake loads applied at the center of gravity of the extended structure. The maximum stress limits used for active Class 1, 2, and 3 valves are compared to acceptable standards in the ASME Code. Valve discs are evaluated for maximum design line pressure and maximum differential pressure resulting from plant operating, transient, and accident conditions. Feedwater line valve discs are evaluated, using appropriate ASME Code, Section III limits, for the effect of dynamic loads by considering the effect of an equivalent differential pressure. The equivalent differential pressure is developed from a transient analysis based on wave mechanics that includes consideration of system arrangement and valve closing dynamics. Valve operating conditions are included as part of the valve design specification and are used to evaluate the valve disc. Additional information is provided on the controlled-closure, feedwater check valve in Subsection 10.4.7.2.2.

In addition to these tests and analyses, representative valves of each design type having extended structures are subjected to static pull tests and nozzle load tests as appropriate. These tests verify operability of a rigid valve (natural frequency equaling or exceeding 33 hertz) during a simulated plant faulted-condition event by demonstrating operational capabilities within the specified limits. A representative valve of a specific design type is identified for this testing by the specification (for example, globe valve, motor-operated valve) for that particular type of valve. A further subdivision of design is based upon the valve size, pressure rating, type of operator, and previous operability testing to evaluate the need for additional testing of a particular design type. The testing procedures are described in Appendix 3D.

The accelerations used for the static valve qualification are equivalent, as justified by analysis, to 6.0g in two orthogonal horizontal directions and 6.0g vertical. For testing, the required input motion (RIM) curve shall be consistent with the profile of Figure 6 of IEEE 382-1996 (Reference 2), with the acceleration magnitude increased to 6.0g. The piping design maintains the operator accelerations to these levels. If the natural frequency of the valve is less than 33 hertz, a dynamic analysis of the valve is performed to determine the equivalent loads to be applied during the static test.

Valves that are safety related but are classified as not having an extended structure, such as check valves and safety valves, are considered separately.

Check valves are characteristically simple in design. Their operation is not affected by seismic accelerations or the maximum applied nozzle loads. These valves are designed so that once the structural integrity of the valve is verified using standard methods, the capability of the valve to operate is demonstrated by its design features. The valve also undergoes in-shop hydrostatic and seat leakage tests, and periodic in situ valve exercising and inspection to verify the functional capability of the valve.

The pressurizer safety valves are qualified by the following procedures (these valves are also subjected to tests and analysis similar to check valves): stress and deformation analyses of critical items that affect operability for faulted condition loads, in-shop hydrostatic and seat leakage tests, and periodic in situ valve inspection. In addition to these tests, a static load equivalent to that applied by the faulted condition is applied at the top of the bonnet, and the fluid pressure is increased until the valve mechanism actuates. Successful actuation within the design requirements of the valve demonstrates its over-pressurization safety capabilities during a seismic event.

Safety-related active valves mounted in HVAC ductwork used to isolate main control room areas during design events are listed in Table 3.11-1. These valves are qualified to operate on demand using air operators.

Using these methods, the safety-related valves are qualified for operability during a faulted event. These methods conservatively simulate the seismic event and demonstrate that the active valves perform their safety-related function when necessary.

3.10.2.3 Valve Operator Qualification

Active valve motor operators, position sensors, and solenoid valves are seismically qualified according to IEEE 382-1996, as discussed in the appropriate equipment qualification data packages.

3.10.2.4 Seismic Qualification of Other Seismic Category I Mechanical Equipment

For seismic Category I mechanical equipment not defined as active, the AP1000 uses analysis to demonstrate structural integrity. The analysis methods are described in Sections 3.7 and 3.9 and in Appendix 3D.

3.10.3 Method and Procedures for Qualifying Supports of Electrical Equipment, Instrumentation, and Mechanical Components

The equipment qualification data packages identify the equipment mounting employed for qualification and establish interface requirements for the equipment to provide confidence that subsequent in-plant installation does not degrade the established qualification. Interface requirements are defined based on the test configuration and other design requirements. Dynamic coupling effects resulting from mounting the component according to these interface criteria are considered in the qualification program.

Information concerning the structural integrity of pressure-retaining components, their supports, and core supports is presented in Section 3.9.

The following bases are used in the design and analysis of cable tray supports and instrument tubing supports:

- The methods used in the seismic analysis of cable tray supports are described in Appendix 3F.

- The seismic Category I instrument tubing systems are supported so that the allowable stresses permitted by ASME Code, Section III, are not exceeded when the tubing is subjected to the loads specified in Section 3.9.

3.10.4 Documentation

The results of tests and analyses verifying that the criteria established in Subsection 3.10.1 are satisfied, employing the qualification methods described in Subsections 3.10.2 and 3.10.3, are included in the individual equipment qualification data packages and test reports. The upkeep of the equipment qualification file is maintained during the equipment selection and procurement phase is discussed in Subsection 3.11.5.

Seismic qualification of equipment is documented in equipment qualification data packages, test reports, analysis reports, and calculation notes. Appendix 3D provides guidance in this area.

3.10.5 Standard Review Plan Evaluation

A summary describing the Standard Review Plan differences in regard to seismic and dynamic qualification of mechanical and electrical equipment is provided Subsection 1.9.2.

3.10.6 Combined License Information Item on Experienced-Based Qualification

Not used.

3.10.7 References

1. IEEE 344-1987, “Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.”

2. IEEE 382-1996, “IEEE Standard for Qualification of Actuators for Power-Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Plants.”

3. APP-GW-GLN-144, “AP1000 Design Control Document High Frequency Seismic Tier 1 Changes,” Westinghouse Electric Company LLC.