3.10 SEISMIC QUALIFICATIONS OF SEISMIC CATEGORY 1 INSTRUMENTATION AND ELECTRICAL EQUIPMENT

3.10.1 SEISMIC QUALIFICATION CRITERIA

The seismic qualification of seismic Category 1 instrumentation and electrical equipment demonstrates the ability of the equipment to perform its safety-related function and/or maintain its structural integrity during and after the postulated safe shutdown earthquake. The demonstration is accomplished by either of the following two methods (or combination thereof):

a) Analysis

The equipment performance is predicted by mathematical analysis techniques. Analysis without testing is acceptable when structural integrity alone can assure the intended functions.

b) Testing

The equipment performance is determined by testing under simulated seismic conditions as specified in the equipment specifications and accompanied by sufficient mathematical analysis to extract the needed information from the test results.

The choice of method is based on the practicality of the method for the type, size, shape, and complexity of the equipment and the reliability of the conclusions. A list of all seismic Category 1 instrumentation, electrical equipment and supports can be found in References 1 and 2.

The safe shutdown earthquake (SSE) and the operating basis earthquake (OBE) horizontal and vertical floor response spectra, reflecting in-structure floor accelerations, are provided to the vendor for each given instrumentation or electrical equipment location. The vendor then determines the appropriate acceleration levels for qualification from these spectra.

In designing the equipment, the vendor combines the effects of gravity loads, normal operating loads, operating temperature loads, other loads that may be included in the specification, and the appropriate SSE and OBE seismic loads.

The adequacy of the seismic qualification program is demonstrated in documentation requirements that the vendor fulfills for each equipment type. The documentation demonstrates that the equipment meets its performance requirements when subjected to the loads for which it was qualified.

Appendix 3.10A, Criteria for Seismic Qualification of Non-NSSS Seismic Category 1 Instrument and Electrical Equipment and Their Supports, is the information provided to manufacturers which presents the criteria or applicable requirements thereof for seismic qualification of Ebasco supplied seismic Category 1 equipment for Waterford 3.

3.10.2 METHODS AND PROCEDURES FOR QUALIFYING ELECTRICAL EQUIPMENT AND INSTRUMENTATION

3.10.2.1 NSSS Equipment

Reference 1 provides a description of the seismic qualification program for CE supplied Class 1E instrumentation and electrical equipment.

3.10.2.2 Non-NSSS Equipment

Non-NSSS seismic Category 1 instrumentation and electrical equipment and supports are qualified either by analysis, by testing, or by a combination of testing and analysis as indicated in References 1 and 2, in conformance with IEEE Standard 344-1971, IEEE Guide for Seismic Qualification of Class 1 Electrical Equipment for Nuclear Power Generating Stations. In some cases, equipment was qualified in accordance with IEEE 344-1975.

→ (DRN 99-2098)

The seismic design criteria discussed in Subsection 3.10.1 form a part of all specifications for seismic Category 1 instrument and electrical equipment. Floor response spectra applicable to the designated equipment locations are included in the specification. The values indicated in these spectra are used for seismic qualification of the equipment.

← (DRN 99-2098)

Certification is obtained from each manufacturer of Class 1E equipment to ensure that his equipment will perform without loss of function resulting from the stipulated seismic loading conditions of the SSE. Non-Class 1E equipment will retain its structural integrity.

For seismic qualification by analysis, the supporting data and design calculations show that the equipment satisfies the specifications. Data and calculations are required to be submitted with a certification of compliance to substantiate that the equipment will not malfunction or lose its structural integrity during or after a seismic loading due to the SSE.

3.10.3 METHODS AND PROCEDURES OF ANALYSIS OR TESTING OF SUPPORTS OF ELECTRICAL EQUIPMENT AND INSTRUMENTATION

Reference 1 provides a description of the seismic analysis and testing performed on NSSS instrumentation and electrical supports and racks.

For non-NSSS equipment, analyses are performed for all supports of electrical equipment and instrumentation such as battery racks, instrument racks, control consoles, cabinets, panels and cable trays to ensure their structural capability to withstand seismic excitation.

The following bases are used in the seismic design and analysis of seismic Category 1 cable tray supports:

a) The maximum cable tray span and physical properties are selected.

b) All cable tray supports are qualified by analysis, using the response spectrum method.

→ (DRN 99-2098)

1) For rigid supports with fundamental frequency greater than 16Hz. for supports attached to concrete and greater than 20 Hz. for supports attached to flexible steel floor framing, the corresponding g values are to be obtained from the response spectrum curve. These g values are then used in the static stress analysis of the support.

2) For non-rigid supports which have frequencies less than that described above, a system frequency is selected such that 1.5 times the corresponding response g is within the system capacity. The support frequency is then calculated. A simplified three dimensional mathematical model is constructed with the desired support frequency and cable trays. This system is dynamically analyzed and responses obtained. The responses averaged g values are then used in the static stress anlaysis of the support.

← (DRN 99-2098)

c) The stresses due to the three earthquakes can be summed up by the square-root-of-the-sum-of-the-squares method.

d) Maximum stress during a SSE is limited to 90 percent of the yield capacity (with full regard to elastic stability) and to allowable working stress limits during an OBE.

A simplified method of seismic analysis for instrument tubing consists of locating supports such that the period of the first mode of vibration for the tubing will not exceed the preset value of 70 percent of the second mode of the structure. The period for the tubing will not exceed 0.2 seconds. This method involves the use of appropriate and comprehensive charts and tabulations developed by Ebasco computer code PIPESPAN 2226 that include correction factors for the effects of the concentrated loads, branch connections, changes in tube size, changes of direction, offsets and various combinations of these effects. The tubing is studied for loading effects in each of the three coordinate directions to assure that it is adequately restrained in all directions. An additional analysis is performed to evaluate the thermal effects of the supports on the system. This is done by means of charts that define the minimum distance required for placing restraints adjacent to any expanding leg in order to stay within ASME allowable stress limits.

Detailed procedures are used when installing instrument tubing supports in the field.

3.10.4 OPERATING LICENSE REVIEW

3.10.4.1 Seismic Qualification Review Team (SQRT) Submittal

As requested in NRC Questions 270.1 through 270.6 a SQRT submittal has been made in References 1, 2 and 3.

3.10.4.2 NSSS Equipment

Reference 1 describes tests and analysis performed to demonstrate adequate seismic qualification of NSSS instrumentation and electrical equipment. The manufacturer is required to substantiate design adequacy by analysis or testing.

3.10.4.3 Non-NSSS Equipment

The seismic Category 1 equipment is designed and qualified to perform its safety-related function and/or maintain its structural integrity during and after the SSE. The results of typical tests and analyses of non-NSSS equipment are in References 1 and 2.

Section 3.10 REFERENCES

1. LP&L Letter W3P81-1793, to RL Tedesco from LV Maurin, dated August 5, 1981, and attachments.

2. LP&L Letter W3P81-1830, to RL Tedesco from DL Aswell dated August 11, 1981, and attachments.

3. LP&L Letter W3P82-1918, to RL Tedesco from LV Maurin, dated July 16, 1982, and attachments.

APPENDIX 3.10A

CRITERIA FOR SEISMIC QUALIFICATION OF NON-NSSS SEISMIC CATEGORY 1 INSTRUMENT AND ELECTRICAL EQUIPMENT AND THEIR SUPPORTS

This appendix defines the seismic considerations for seismic Category 1 instrumentation and electrical equipment and their supports which are included with the specifications of all the non-NSSS supplied Seismic Category 1 instrument and electrical items.

a) Seismic Considerations

The following seismic considerations are applicable to all instrument and electrical equipment included in each specification, that are subject to seismic Category 1 requirements.

1) For seismic Category 1 equipment and supports, the seller must demonstrate the equipment's ability to perform its required function during and after the time that it is subjected to the forces resulting from the seismic conditions specified. This can be accomplished in various ways. Two methods commonly used are to:

   (a) predict the equipment's performance by mathematical analysis and/or

   (b) test the equipment under simulated seismic conditions.

   If properly justified, other methods may be used. The documentation provided for the equipment must clearly justify the choice of the analysis method.

2) The seller shall establish a test and/or analysis procedure and submit it for review by the purchaser prior to proceeding with the procedure.

3) The seller shall determine the resonance frequency of the equipment including all components by conducting a resonance frequency search (by analysis or test) in the frequency range of 1-30 cps. Should a resonance frequency be located in this range, then the seller shall determine the corresponding "g" values for the north-south, east-west, and vertical directions from the floor response spectrum. Test or analysis shall be performed to assure that the equipment will perform satisfactorily during and after application of input accelerations equal in magnitude to those determined as above at the resonance frequency. Should a resonance frequency not occur in the frequency range 1--30 cps, then a test or analysis shall be performed for at least three different frequencies and the corresponding "g" values in the three mutually perpendicular directions, as selected by the seller and approved by the purchaser from the floor response spectrum.. One of the selected frequency points shall correspond to the peak value on the respective response curve.

(4) Supports shall be designed to prevent displacement of equipment assuming that friction does not exist. Internal elements shall be designed and supported to assure that no interferences and undue deflections will result from seismic loads.

The primary unit stresses induced by earthquake loads shall be added directly to the unit stresses from all other loadings.

The allowable unit stresses shall not be exceeded due to the addition of the OBE seismic load. The allowable unit stresses may be increased due to the addition of the SSE seismic load to a limiting value that will cause no loss of function.

The combined stresses may reach the yield point of the material but excessive strain shall not occur.

(5) Construction of the equipment shall preclude amplification factors that could result in failure of equipment mounted therein. No major structural resonance below 10 cps shall occur with all equipment mounted.

(6) Full compliance with the guidelines of IEEE-344, Guide for Seismic Qualification of Class 1 Electrical Equipment for Nuclear Power Generating Stations, (minimum 1971 revision) is required.

b) Mathematical Analysis Method

This method should be used for equipment which can be modeled to predict its response.

The analysis method should consist of the following:

1) Model the equipment and supports with sufficient degrees of freedom to ensure adequate representation.

2) Determine the natural frequencies and mode shapes of the equipment and supports as it will be mounted in service.

3) The following damping factors should be used in the seismic analysis:

	Percent Critical Damping	
	OBE	SSE
Welded Steel Plate Assemblies	1	1
Welded Steel Framed Structures	2	2
Bolted or Riveted Steel Framed Structures	2.5	2.5
Reinforced Concrete Equipment Supports	2	5

4) If the equipment and supports are capable of being lumped into a single mass, and if the natural period is certified to be less than 0.03 seconds, it may be analyzed statically, and the equipment shall bee designed to safely withstand the following loading conditions:

   (a) The OBE seismic load shall consist of the most severe combination of a horizontal seismic load coefficient of 0.50g, which can act in either of the two major horizontal directions, acting simultaneously with a vertical seismic load coefficient of 0.34g, which can act upward or downward.

   (b) The SSE seismic load shall consist of the most severe combination of a horizontal seismic load assuming a coefficient of 1.00g, and a vertical seismic load assuming a coefficient of 0.67g, acting as above.

   All seismic loads may be assumed to act at the center of gravity of the equipment.

   (c) The unit stresses induced from the earthquake seismic loads shall be combined in accordance with the applicable equipment codes. If the codes are not specific, the seismic loads shall be added directly to the unit stresses from other applicable loading. The allowable unit stresses shall not be increased due to the addition of the OBE seismic load. The allowable unit stresses may be increased due to the addition of the SSE seismic load to a limiting value that will cause no loss of function.

5) If the equipment model is a multidegree of freedom model, and the natural periods of the equipment (including its supports) are less than 0.03 seconds, it may be analyzed statically. In this static analysis, the seismic forces on each component of the equipment are obtained by concentrating its mass at its center of gravity and designing to the loading conditions in (3) above.

6) If the natural period of the equipment and supports is not less than 0.03 seconds, then the seller shall perform a dynamic analysis using the response spectrum model analysis technique (floor response spectra to be supplied by purchaser, if required) or a time history modal analysis (time history input to be supplied by purchaser, if required). Other methods of analysis may be used if properly justified. The seller shall perform a stress analysis using the inertia forces or the equivalent static loads obtained from the dynamic analysis for each mode.

   The square root of the sum of the squares method should normally be used to combine the modal responses when the response spectrum modal analysis technique is employed. In those cases, however, where modal frequencies are closely spaced, the responses of the closely spaced modes should be combined by the sum of the absolute values method and, in turn, combined with the responses of the remaining significant modes by the square root of the sum of the squares method.

If the time history modal analysis is used, the maximum responses should be determined by obtaining the greatest sum of the responses of all significant modes at a particular time.

IN each of the preceding analyses, each of the two major horizontal directions should be considered separately, but simultaneously with the vertical direction in the most conservative manner.

7) The analysis should include evaluation of the effects of the calculated stresses on mechanical strength, alignment, electrical performance, and non-interruption of function as related to the functional requirements of the equipment during a SSE.

c) Testing

The seller shall perform seismic tests by subjecting the purchaser's equipment to vibratory motion which conservatively simulates that to be seen at the equipment mounting during a SSE. The equipment to be tested should be mounted on the vibration generator in a manner that simulates the intended service mounting. The vibration motion should be applied to each of the three major perpendicular axes independently by unless symmetry justifies less. The equipment being tested must demonstrate its ability to perform its intended function and sufficient monitoring equipment should be used to evaluate performance before, during and following the test.

The seller shall submit his detailed testing procedures for the purchaser's approval. Actual testing shall generally involve the following procedures:

1) Perform a low amplitude frequency search to determine potential resonance regions.

2) Test the equipment at these resonance frequencies with amplitude and test duration equivalent to that produced by the floor time history motions (to be supplied by the purchaser). The sine beat test is the preferred method of testing; however, other methods of testing are permitted if properly justified.

3) Sufficient monitoring equipment, such as strain gauges, shall be used to evaluate the performance of the equipment before, during and after the test. In addition, enough vibration monitoring equipment shall be used to allow determination of the applied vibration levels. The location of the monitoring sensors shall be documented.

The seller shall subject his equipment to the seismic response indicated above and submit to the purchaser evidence (test data) which substantiates that the equipment and accessories will not suffer loss of function due to these seismic considerations.

d) Documentation

The seller shall provide documentation explaining his methods of seismic analysis or testing, and the results for each piece of equipment supplied.

Proof shall be furnished by the seller demonstrating the ability of the equipment covered by the specification to operate properly during and after each specified disturbance. Analysis (mathematical computations), type testing or actual testing will be considered adequate proof.

The seller shall furnish the purchaser with certification that the subject equipment has satisfied seismic criteria. Certification shall identify equipment by serial number or other unique means of identification and shall include the seismic loading for which the equipment is being certified.

If the natural period of the equipment was mathematically determined or tested and found to be greater than 0.03 seconds, the seller must provide the modeling method used, as well as the mass point locations, spring constants and section moduli to facilitate the overall seismic analysis by the purchaser. In any case, the seller must supply support loadings (static and dynamic at the equipment bases), and anchor bolt sizes and locations to meet the above seismic considerations.