Regulatory Guide Number:	**1.92, Revision 3**
Title:	**Combining Modal Responses and Spatial Components in Seismic Response Analysis**
Office/division/branch:	**RES/DE/SGSEB**
Technical Lead:	**Jinsuo Nie**
Staff Action Decided:	**Reviewed with issues identified for future consideration**

1. What are the known technical or regulatory issues with the current version of the Regulatory Guide (RG)?

RG 1.92 Revision 3, published in October 2012, provides guidance on methods that the NRC staff considers acceptable for combining modal responses and spatial components in seismic response analysis of nuclear power plant structures, systems and components important to safety (SSCs). The changes from Revision 2 were editorial with no substantive change in the Staff Regulatory Positions. RG 1.92 Revision 2 was issued in 2006 and implemented recommendations provided in NUREG/CR-6645, "Reevaluation of Regulatory Guidance on Combination Methods for Seismic Response Spectrum Analysis," published in December 1999.

One issue to be addressed is clarifying the regulatory position related to Section 1.1.1 on closely spaced modes to reflect the staff experience gained in licensing reviews of new reactor designs. Specifically, Revision 3 considers that the modal combination methods described in Revision 1 remain acceptable. These methods rely on a 10% frequency window criterion to define closely spaced modes regardless of damping ratios. However, the Revision 1 criterion differs from the current criterion in Section 1.1.1 of Revision 3, which is damping dependent and the 10% criterion is only applicable when the critical damping ratio is ≤ 2%. This apparent confusion needs to be addressed in a future revision of the RG. It should be noted that the general methods explicitly provisioned in Regulatory Position 1.1 of Revision 3 remain acceptable.

Based on recent licensing experience, staff also identified three other technical issues that need further confirmatory research to address issues potentially affecting RG 1.92. They are:

(A) The first issue involves the spatial combination of the effects of the three directional (3D) components of an earthquake motion. RG 1.92 Revision 3 provides guidance for the spatial combination of the 3D effects for individual response parameters but does not explicitly include guidance for multiple response parameters, such as column axial force and moment that occur in the same interacting design equations. The lack of such guidance is not an issue when the square-root-sum-of-the-squares (SRSS) method is used for spatial combination. However, it has been an issue in the past licensing reviews when the 100-40-40 rule was used. There are relevant criteria to address this in American Society of Civil Engineers Standard ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," published in 1999, which is referenced in RG 1.92 since Revision 2. ASCE 4-16 was published in 2017 and is an extensive update of ASCE 4-98, but it remains about the same in the area

of spatial combination. However, some believe that one of the ASCE 4 methods that has been widely used for spatial combination is overly conservative and an alternative implementation of the 100-40-40 rule may be acceptable. Therefore, there is a need for confirmatory research to compare the results of the 100-40-40 rule with time history analyses using multiple time histories and develop an explicit regulatory positon in RG 1.92 on spatial combination of multiple interacting response parameters.

(B) The current seismic response spectrum analysis (RSA) methods in RG 1.92 Revision 3 were established based on the typical RG 1.60 spectral shape, which is characterized by several structural response regions: periodic, transition from periodic to rigid, transition from rigid to max acceleration, and max acceleration. Different combination rules were developed to combine periodic modes and rigid modes. In other words, the methods in RG 1.92 Revision 3 rely on the existence of a zero-period-acceleration (ZPA) frequency in the input response spectrum to identify in-phase modes. However, the hard-rock high frequency (HRHF) response spectra evaluated in recent license applications often do not exhibit a clear ZPA frequency. Therefore, whether this structural response characterization can be extended to the HRHF spectral shapes should be investigated by benchmarking RSA against time history analyses using the HRHF input, in order to develop appropriate technical positions.

(C) There is a need for a more robust benchmark of the RSA methods than that documented in NUREG/CR-6645. Based on the random vibration theory, the RSA methods produce the average peak responses of a structure subjected to an input response spectrum, which is a key representation of the stochastic input motion. NUREG/CR-6645 compared the RSA methods to the time history methods using only one input time history. One time history is only one realization of the underlying stochastic process, and does not always provide sufficient information on the effects of the stochastic process. Therefore, a more rigorous benchmark of the RSA methods is needed to use multiple input time histories and to consider varied fundamental frequencies of the structure relative to the input response spectrum. This will require confirmatory research to address the issue. The resultant insights from this benchmark will inform the need to update certain aspects of the regulatory positions in RG 1.92.

2. What is the impact on internal and external stakeholders of <u>not</u> updating the RG for the known issues, in terms of anticipated numbers of licensing and inspection activities over the next several years?

RG 1.92 is used when a licensing activity involves a seismic response analysis of an SSC that requires the combination of modal responses or spatial components. It applies to any new application or review of plant modifications requiring a RSA. However, this RG is considered mostly applicable in new reactor applications. Since none is anticipated in the next several years (2 to 5 years), updating this RG is not critical at this time. For small modular reactors the NuScale design certification is almost complete and the existing guidance was deemed acceptable for a design certification.

3. What is an estimate of the level of effort needed to address identified issues in terms of full-time equivalent (FTE) and contractor resources?

NRC staff requires approximately 2.5 FTEs to complete the proposed rigorous benchmarks of the RSA methods and the 100-40-40 rule, and identification or development of approaches to consider HRHF response spectra, as described above inIssues (A) through (C). This level of effort also includes documenting the results in a report, developing the revised RG, and discussing the analytical results and any resultant changes/additions to the regulatory guidance with staff in the NRC program offices. Based on the results of these activities, contractor support may be required for a consensus review by an external expert panel.

4. Based on the answers to the questions above, what is the staff action for this guide (Reviewed with no issues identified, Reviewed with issues identified for future consideration, Revise, or Withdraw)?

Reviewed with issues identified for future consideration.

5. Provide a conceptual plan and timeframe to address the issues identified during the review.

The NRC staff plans to conduct analyses and developments as indicated in the answer to Question 1, review licensing documents (safety evaluation reports and requests for additional information), review relevant sections of the ASCE 4 standard, conduct panel review of the results as needed, and revise RG 1.92 accordingly. This activity would start in FY2019 or FY2020 depending on funding limitations and staff priorities, and would be completed in approximately 3 years.

NOTE: This review was conducted in May 2018 and reflects the staff's plans as of that date. These plans are tentative and are subject to change.