Enclosure 2
Staff Responses to Public Comments on Draft Regulatory Guide DG-1157
(Proposed Revision 1 of Regulatory Guide 1.61)
(Public comments have been edited for clarity)

Comments			**NRC Comment Resolution**
Originator	**DG-1157 Section**	**Specific Comment**	**NRC Staff Response**
Paul Hirschberg (PH)	general	ASME Code Section III, Appendix N contains the ASME-recommended guidance on damping of piping systems. The appendix recommends 5% damping for both OBE and SSE, for all frequencies and pipe sizes. The recommendations are based on the work of the ASME Special Working Group on Damping, which cited testing done by Bechtel. Linear regression analysis of the test data resulted in damping values that range between 5.0 and 8.0 percent for Service Level D, and 4.0% to 7.0% for Service Level B, depending on the pipe size. 5% was selected as a conservative average. 5% damping was the basis for the reduction of the EPRI/GE test data used in formulating the new seismic analysis criteria first published in the 1995 edition of the ASME Code. The draft regulatory guide, as written, specifies 4% damping for SSE and 3% for OBE. The annulled Code Case N-411 damping is allowed as an alternative for SSE only. If these damping levels are used, it will result in the OBE case limiting the design of the piping, requiring more snubbers and pipe whip restraints. In developing the revised seismic rules of NB-3656, the allowable stress levels were determined by fitting the test data assuming 5% damping. If lower damping is now required, the resulting safety margins of the piping system design will be higher than the safety margins agreed upon by the NRC and ASME. In order to have seismic design criteria consistent with the agreed upon safety margins, the Service Level D stress allowables need to be increased, and/or the B_2' stress indices decreased.	The staff does not endorse the American Society of Mechanical Engineers (ASME) Code Section III, Appendix N recommendations. The use of an average or mean value of damping without restriction on the analysis methodology does not assure that there will be a sufficient level of conservatism for the design of piping systems. Studies that compare actual piping system dynamic tests, using simulated seismic excitations, with analysis results have shown that time history analysis or response spectra analysis can underpredict the actual measured response, especially support loads. NUREG/CR-5757, "Verification of Piping Response Calculations of SMACS Code w/Data from Seismic Testing of an In-plant Piping System," and Electric Power Research Institute (EPRI) NP-6153, "Seismic Analysis of Multiply Supported Piping Systems" provide the results of such comparisons for relatively high seismic excitation levels. Even though evaluation of the EPRI/General Electric (GE) test data suggests that sufficient margin may exist in the piping to support the use of higher damping, the test data does not address support loads. Based on a review of the actual test data reported in the referenced reports above, the staff concludes that using the average damping values from the Bechtel linear regression analysis in seismic analyses may likely underestimate support loads. The staff endorsed the use of the annulled Code Case N-411 damping values with enveloped response spectra

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			analysis, in part, based on an assessment by Lawrence Livermore National Laboratory documented in NUREG/CR-3526, "Impact of Changes in Damping and Spectra Peak Broadening on the Seismic Response of Piping Systems." The Livermore assessment found that the use of the annulled Code Case N-411 damping values with enveloped response spectra analysis yielded conservative results when compared to multisupport time history using the then current Regulatory Guide (RG) 1.61 damping values. The staff agrees that the annulled Code Case N-411 damping values were allowed for both the OBE and the SSE. The staff will revise the regulatory guide to allow use of the annulled Code Case N-411 damping values for both the OBE and SSE, consistent with its past practice. The seismic criteria published in the 1995 edition of the ASME Code were initially based on an evaluation of the EPRI/GE test data using a 5% damping value. The Code also required the use of response spectra analysis. However, subsequent data evaluations used for the current ASME Code criteria relied on the ultimate measured moment, which is independent of damping. Therefore, ASME Code criteria specified in NB-3656 are no longer a function of damping values or analysis methods. The RG will be changed to allow the use of the annulled Code Case N-411 damping values, with restrictions, for both the operating-basis earthquake (OBE) and the safe-shutdown earthquake (SSE).

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Nuclear Energy Institute (NEI)	Section A (comment 1)	In Section A, "Introduction," footnote 1 refers to Seismic Category I SSCs as defined by RG 1.29. Since Regulatory Guide 1.29 is being considered for revision also (DG-1156), the appropriate draft Regulatory Guide should also be referenced.	The staff agrees. However, no change is necessary in the final version of DG-1157.
NEI	Section B (comment 2)	In Section B, "Discussion," the last sentence of the first paragraph under "Background," states "expected viscous damping resulting from the material of the actual structure." Damping is a function of many more phenomena than the material itself of the SSC. Viscous damping represents the energy dissipation of structural and nonstructural elements, including attached or supported items such as piping insulation, cables in cable trays and conduit, behavior such as large deformations of rod-hung systems, connections, metal cladding, nonstructural partition walls, etc. The current description is too limited.	The staff agrees. The sentence will be modified to discuss structural and nonstructural items that contribute to viscous damping.
NEI	C.1 (comment 3)	On Page 5, under section C.1(2) the draft states in part "attributable to load combinations that include SSE are at least 80% of the applicable code stress limits." The reduction from SSE damping to OBE damping at 80% of the applicable code stress limit is excessively conservative. It will have a substantial effect on computed in-structure-response-spectra (ISRS) for concrete structures on stiff sites where there is limited benefit from SSI effects. Typically, the majority of structural elements will not be stressed to above 80% of the code stress limit under SSE loadings. Thus designers will most often have to use OBE damping for SSE evaluations. As an example, for a reinforced concrete structure, the SSE damping value is 7% while the OBE damping value is 4%. The 7% damping value is appropriate once the concrete has cracked so that energy dissipation occurs due to cracking and	The staff has reviewed and considered the comment. The staff has revised Regulatory Position C.1 to clarify structural damping guidance. See the structural damping attachment on p. 24.

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		relative displacements across cracked surfaces. The 4% damping is more appropriate prior to concrete cracking. This damping value includes the effects of nonstructural energy dissipation due to nonstructural contents spread throughout the structure and is not exclusively due to energy dissipation in a bare concrete structure. Typically, reinforced concrete structural elements begin to crack in shear or flexure at stresses equal to about 50% of code stress limits or slightly higher. In fact, concrete must crack for the reinforcing steel to become effective. Therefore, the transition for reinforced concrete structures from 7% damping to 4% damping typically occurs at about 50% of code stress limits. The 80% stress limit in DG-1157 is excessively conservative, at least for reinforced concrete structures. Similar considerations also apply for other structural elements. Both ASCE/SEI Standard 43-05 and ASCE Standard 4-98 assign Response Level 2 damping when stresses range from about 50% to 100% of code stress limits. Response Level 1 damping is imposed only when stresses are less than 50% of code stress limits. Response Level 2 damping values in these ASCE standards are generally consistent with DG-1157 SSE damping levels. Similarly, ASCE Response Level 1 damping values are generally consistent with DG-1157 OBE damping levels. In summary, the 80% stress limit will result in most SSE evaluations having to use OBE damping levels. No basis exists for the 80% limit. The limits in the ASCE standards should be used.	

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NEI	C.1 (comment 4)	Also on Page 5, under section C.1(2), we recommend adding the following to the end of the paragraph, "When the stresses attributable to load combinations that include SSE are less than 50% of the applicable code limit, the analyst need not reanalyze the structure for SSE using the damping values of Table 2 if it can be judged that the stresses will remain within the code allowables with the lower damping values. This is not applicable for the development of in-structure response spectra." This will relieve the unnecessary burden on the analyst. This recommendation reflects ASCE 4-98 Section 3.1.2.2(b) and (c) and ASCE 43-05 Section 3.4.3 requirements.	See response to NEI Comment 3.
NEI	C.2 (comment 5)	On page 6, Table 3, the damping levels for piping provided with ASME Code Section III, Appendix N of 5% should be specified instead of the Table 3 values within the draft regulatory guide.	See response to PH comment.
NEI	C.2 (comment 5)	On page 6, Section C.2, "Piping Damping," in the last paragraph, the second bullet states that the specified damping values may be used only in those analyses in which the current seismic spectra and procedures have been used. It is not clear what the "current" seismic spectra and procedures are. This should be clarified. However, this bullet and the other bullets in this section that relate to the frequency-dependent damping can be removed from this draft if 5% damping is prescribed for piping, as recommended in ASME Appendix N (see item 5 above).	The staff agrees. The staff will delete the statement "current" seismic spectra. The staff will revise the second bullet to state, "Use is limited to response spectral analyses. The acceptance of the use with other types of dynamic analyses (e.g., time-history analyses or independent support motion method) requires further justification."
NEI	C.5 (comment 6)	On page 9, Section C.5, Table 6 for electrical cabinets, panels, and motor control centers, the damping values specified in the draft might be reasonable for cabinets with all welded connections that are welded to the support structure. However, these values are too low for cabinets with sheet metal screw connections, or cabinets bolted together or bolted to the support	The staff did not have access to and was not presented information to support the suggested damping values during the development of the RG.

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<tr><th colspan="3">Comments</th><th>NRC Comment Resolution</th></tr>
<tr><th>Originator</th><th>DG-1157 Section</th><th>Specific Comment</th><th>NRC Staff Response</th></tr>
<tr><td></td><td></td><td>structure. The ASCE/SEI Standard 43-05 damping values of 4% at Response Level 2 and 3% at Response Level 1 are more appropriate for these cabinets. Therefore, the following additions (in underlined font) are recommended to Table 6, row titled, “Electrical Cabinets, Panels, and Motor Control Centers.” Also a footnote should be included (as indicated by the asterisk) in the recommended text (see below, full table shown on p. 19).

<table>
<tr><td>Electrical Cabinets, Panels and Motor Control Centers (MCCs)* (protection, structural support)</td><td></td><td></td></tr>
<tr><td><u>– Welded steel structures and bolted steel structures with friction connections</u></td><td><u>4%</u></td><td><u>3%</u></td></tr>
<tr><td><u>– Bolted steel structures with bearing connections</u></td><td><u>7%</u></td><td><u>5%</u></td></tr>
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<u>* For electrical cabinets/panels assembled as welded or bolted steel structures, the values of Tables 1 and 2 shall apply.”</u></td><td></td></tr>
<tr><td>NEI</td><td>Reference (comment 7)</td><td>The title and date for Reference 11 of DG-1157 is not correct. Correct title and date are, NUREG/CR-6919, “Recommendations for Revision of Seismic Damping Values in Regulatory Guide 1.61,” U.S. Nuclear Regulatory Commission, Washington, DC, November 2006.</td><td>The staff agrees. The staff has corrected the title and date of Reference 11.</td></tr>
<tr><td>John Stevenson and Timothy Adams (JS&TA-1)</td><td>general (comment 1)</td><td>While it is appreciated that the proposed new NRC regulatory position in DG-1157 has increased piping damping values from the values contained in RG 1.61 dated October 1973, they do not appear to fully reflect the large amount of the damping test data gathered and evaluated in the mid-1980s. This data evaluation was supported to a considerable degree by the NRC's Office of Regulatory Research (1, 2, 3, 4, 5, 6, 7, 8, 9; see p. 21) and it formed the basis of the Pressure Vessel Research Committee recommendation to the ASME B&PVC section on pipe damping (9) and should form the basis of any new damping design values selected in the new draft guide.</td><td>See response to PH comment.</td></tr>
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		These data and evaluations are summarized in Reference 10. That data established best-estimate damping values of 6.0% for SSE and 5.0% damping for OBE (>0.33 SSE). The 6.0% damping value for SSE was reduced to 5.0% by the B&PVC when published in Appendix N of the ASME B&PVC, Section III for piping system to simplify the design procedures. Best-estimate (mean) values were purposely used rather than some lower-bound values because of the role damping plays in safe seismic design of piping. Piping failure due to earthquakes were reviewed in NUREG/CR-6239 (11, 12, 13, 14) which surveyed the behavior of approximately 2,000,000 feet of piping in fossil fuel power plants in response to strong motion damaging earthquakes (pga >0.2g) in California from the 1950s to 1980s and the effects of the Alaska 1964 earthquake. The results of these surveys attribute seismic failures of piping to (a) inertial failures of isolated points of weakness in the piping and piping support systems, and (b) excessive deformations due to large header piping, support, or equipment movements, commonly called seismic anchor motions. This latter failure mode (anchor motion effects) was much more problematic than the former failure mode (isolated inertial failures). The use of lower than best-estimate (or mean) damping values in design increases the computed inertia stresses in the pipe which results in pipe lateral supports being placed closer together, thereby increasing the stiffness and rigidity of the piping system. As a result of this increased rigidity of the piping system, any applied seismic anchor, nozzle, or support motion will increase stresses induced in the piping. This increased rigidity (reduced flexibility) also increases the thermal expansion pipe stress and pipe support loads in piping systems normally operating at elevated temperature. Traditionally, the RCS and associated Safety Class 1 piping systems fall into this category. These high thermal stresses can significantly reduce the reliability and fatigue life of these very important systems.	

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		The configurations that contained isolated points of weakness included severely corroded pipe, components constructed of cast iron and brittle materials, threaded fittings, and poorly constructed or defective welds in piping and supports. It was believed these issues could easily be controlled through design and inspection rules and nuclear quality assurance requirements. For these reasons, a best-estimate (mean) value for damping was selected for the ASME B&PVC, Appendix N in an attempt to balance the safe design of piping systems designed to resist all aspect of earthquake-induced inertia and anchor motion loads. Further, it was desired to reduce the effects that low probability of occurrence loads (seismic—10-2 to 10-4/year) would have on high probability (1.0) of service (normal operating thermal expansion) loads. In our opinion, while the DG-1157 damping being less than best-estimate damping values would have minimal effect on the potential for seismic failure of piping due to inertia loads, they would significantly increase the potential for failure due to seismic anchor motion effects. More importantly, the reduction in damping from current ASME Code values will make elevated temperature piping systems more susceptible to reduced reliability and fatigue failure during normal operation. Finally, this reduction in system flexible with the use of the proposed damping values, with its corresponding increase in thermal stress, will result in an increase in Section XI ISI locations. This will increase long-term plant employee radiation exposure and plant operational costs. As a final consideration, if plants were built in high seismic regions, the owner may desire to select an OBE that is greater than SSE/3. In such a case, the OBE would now control design further, resulting in (a) increased supports, (b) increased use of	

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		snubbers, and (c) the resulting reduction in piping flexibility and reliability. Further, there would be increased inspection costs and radiation exposure due to the snubber and Section XI ISI. These issues would essentially preclude any owner from selecting an OBE >SSE/3, even if it is in the best interest of safety to do so.	
JS&TA-1	general (comment 2)	In the resolution of USI A-46, the USNRC permitted use of the SQUG-GIP. Table I (see p. 20) compares the SSE damping values of the proposed regulatory guideline updated to those used in the resolution of USI A-46. As can be seen, the proposed values are significantly lower than those accepted in the program for resolution of USI A-46. If these higher values were acceptable for evaluation of the equipment in the current operating plants that had much less rigor in seismic design, it appears inconsistent to apply lower damping values to modern equipment that is subject to much more rigorous seismic design and analysis. The recent changes in Section QR and QR-A of the QME-1 standard implemented 5% damping across the board for experienced and smilianly SSE qualification of mechanical equipment. A similar change was recently made in IEEE-344-2004. The regulatory agency did not express any concerns with the use of 5% damping for equipment qualification during the consensus process that brought about the changes to these standards. As a result of the above discussion, we strongly urge the NRC to reconsider its DG-1157 position on piping damping and accept the current ASME B&PVC Section III, Div. 1, Appendix N values as a means to provide balance in overall seismic and operational safety of piping systems. Also, the agency should	The use of 5% damping if qualified by test is acceptable. However, for analysis, the staff did not have access to and was not presented information to support the use of 5% damping during the development of the guide. For Unresolved Safety Issue (USI) A-46, the staff considered the Generic Implementation Procedure, Revision 2 (GIP-2), dated February 14, 1992, of the Seismic Qualification Utility Group (SQUG) to be an acceptable method for verifying the seismic adequacy of existing equipment as well as seismic qualification for new and replacement equipment in USI A-46 plants. As stated in the comment, the damping values used in the GIP-2 are, in general, higher than those provided in the current version of RG 1.61and DG-1157. The staff accepted the use of higher damping values for qualification of new and replacement equipment in USI A-46 plants for the purpose of consistency in the qualification methodology. The staff also notes that the damping values provided in the current version of RG 1.61 and DG-1157 are consistent with those in Appendix N to Section III of the ASME Code and ASME QME-1. Finally, at this time, the staff has begun the review of ASME, “Qualification of Active Mechanical Equipment Used

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		accept higher equipment damping values consistent with those implemented in ASME QME-1 and IEEE-344.	in Nuclear Power Plant," (QME-1) (to be published by ASME) and IEEE Standard 344-2004, "Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," for revising RG 1.100, "Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants," Revision 2, issued June 1988. The staff plans to publish a draft guide once a final version of ASME QME-1 is published. No change is necessary in the final version of DG-1157.
Gerry Slagis (GS)	general	The DG specifies damping values for piping systems of 4% for SSE and 3% for OBE as *applicable for time-history, response spectra, and equivalent static analysis procedures for structural qualification*. These values are inconsistent with ASME Section III, Appendix N specified values of 5% for both OBE and SSE (Table N-1230-1). The DG should be revised to be consistent with Appendix N. The Appendix N values have been in the Code for a number of years, and represent the best data that the nuclear industry has on damping values for use in the design of piping systems. The Appendix N values were developed through the code committee consensus process, and NRC staff code committee members were actively involved in that process. The stated basis for the DG damping values is: ...*Regulatory Position 2 in Section C of this revised guide provides the piping damping values that resulted from the staff's experience with ASME Code Case N–411 and application reviews of new reactor designs.* From my perspective, this is not an appropriate basis for establishing damping values. The DG should be based on the best technical data that are available rather than previous licensing positions. Appendix N represents	See response to PH comment.

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		the best data that the industry has at this time. Code Case N-411 was superceded by Appendix N. I know of no technical basis for saying that the Appendix N damping values are not valid for piping system design. NUREG/CR-6919 briefly discusses Appendix N damping as follows: *ASME has annulled Code Case N411-1, because Non-Mandatory Appendix N to Section III currently recommends 5% damping at all frequencies, for both OBE and SSE (Ref. 4). The staff had previously accepted 5% SSE damping for AP1000, for uniform support motion, response spectrum analysis of piping systems (Ref. 16). The staff invoked restrictions on its use, consistent with the qualifications formerly in Regulatory Guide 1.84 for Code Case N411-1.* *The staff continues to accept former Code Case N411-1 damping subject to the restrictions identified in Regulatory Guide 1.84. The staff considers acceptance of 5% damping for AP1000 to be a case-specific determination.* NRC has accepted Appendix N damping for AP1000. There is no valid technical reason to object to using Appendix N for new construction. Appendix N damping values should be used without restrictions for elastic analysis of piping systems for seismic response and for other dynamic loads such as building filtered loads and water hammer. The appropriate approach to specifying piping damping values for new construction in RG 1.61 is to simply refer to Appendix N, Table N-1230-1 rather than list specific values. With this approach, NRC is not required to update the RG every time Appendix N changes. NRC staff personnel on the Section III code committee are involved in changes to Appendix N. If there	

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		is a significant technical concern on a revised Appendix N damping value that NRC is not able to resolve with the code committee to its satisfaction, the NRC could take exception to that edition of the code. One minor comment—the use of OBE >SSE/3 rather than just OBE in Table 3 is confusing. The >SSE/3 should be deleted. The damping values apply for the OBE regardless of the intensity relative to SSE. With the expected resurgence of nuclear power in the United States, I would hope that NRC would take a different approach on regulatory guides for seismic design. It is my position that the seismic regulatory guides result in unrealistically high seismic loads (amplified floor response spectra) for design of piping systems. I believe there is one basic cause—too much reliance on conservatism. There are many steps in the seismic design process, and past NRC practice has been to specify conservative parameters for each step of the process rather than most probable parameters. The accumulation of conservatism causes unrealistically high seismic loads (amplified floor response spectra) for design of piping systems. I recommend that NRC consider getting out of the seismic design requirements business and relying on ASCE, ASME, and other industry standards. Back in the early days of nuclear plant construction, the leadership of NRC on seismic issues was necessary and beneficial to the industry. But now, NRC staff does not have the required collective technical expertise to establish seismic design standards. That expertise is in the industry code committees.	
AREVA NP, Inc. (AREVA)	general (comment 1)	<u>Structural Damping</u> DG-1157 proposes a significant deviation from the historical	See response to NEI Comment 3.

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		relationship between stress levels and damping for the selection of damping values for generation of the structural loads and instructure response spectra (IRS) for the safe-shutdown earthquake (SSE). The change imposes a much more restrictive limit on the stress levels for which SSE-level damping can be used than does Regulatory Guide (RG) 1.61 RO (1973), American Society of Civil Engineers (ASCE) 4-98 (in Table 3.1-1), or ASCE 43-05 (in Tables 3-3 and 3-4). A common thread in RG 1.61 RO, ASCE 4-98, and ASCE 43-05 is specification that SSE-level damping is applicable to development of structural loads and generation of IRS if the stress ratios are at least 50% of code allowable limits. DG-1157 is a significant departure from that guidance by restricting the stress range for applicability of the nominal SSE-level damping values in Table 1 to stress ranges at 80% or higher of code allowable limits. For stress levels below 80% of allowable, the use of OBE-level damping (for OBE >1/3 SSE) of Table 2 is specified if justification for alternative values is not provided. The DG is silent regarding applicable damping values for low stress levels for designs with the OBE = 1/3 SSE. DG-1157 contains the following statement on page 3 regarding the study of structural damping values: Structural Damping In 1993, the NRC completed an investigation of the adequacy of the original Regulatory Guide 1.61 structure damping values and other recommendations, and reported the results in NUREG/CR-6011 (Ref. 2). Data were analyzed to identify the parameters that significantly influenced structure damping. Based on that study, the NRC determined that the original Regulatory Guide 1.61 damping values for structure design were adequate but required one significant revision. Specifically, Regulatory Guide 1.61 should distinguish between	

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		"friction-bolted" and "bearing-bolted" connections for steel structures. Regulatory Position 1 in Section **C** of this revised guide provides the updated structural damping values (emphasis added). Contrary to this statement, a second change (i.e., the stress level change discussed above) is introduced. The source for the recommendation that the stress range for use of SSE-level damping values in IRS generation should be made more restrictive is not provided in the supporting regulatory analysis or in NUREG/CR-6919. Further research by AREVA NP indicates that NUREG/CR-6011 appears to be the source for this change. Our concern is that the recommendations in NUREG/CR-6011 appear to be developed without full appreciation for the practical impact on the analysis and design process. To illustrate the potential impact, consider that the seismic analysis of a reinforced concrete Seismic Category I structure prior to issue of DG-1157 would assume 7% damping in both the generation of structural loads for designing the structure and in the generation of IRS. However, under DG-1157 requirements, both the structural evaluation and generation of IRS would be based on 4% damping (from Table 2) if the stress levels were much less than 80% of allowable limits. This situation creates the potential for an iterative and inefficient design process since it cannot always be demonstrated in advance that appropriate stress levels for Seismic Category I structures exceed 80% of code allowable limits. In fact, the answer will not be known until detailed design using final loads and load combinations. The potential inefficiency imposed on the design process is magnified for designs utilizing a nuclear island concept with a seismic model comprising multiple sticks on a common	

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		foundation. Confirmation of the final damping values for some or all of the sticks will depend on completion of final detailed design results for all structures in the model. Additional seismic analyses may be necessary to develop revised seismic forces for structural evaluation and to generate revised IRS if the stress levels for just some of the structures (sticks) are less than 80% of code allowable limits. Development of those revised loads and IRS would then necessitate reevaluation and possible redesign of the structure(s), systems, and components (SSCs). In actual practice, applicants may attempt to minimize the uncertainty associated with an iterative design process by making worst-case bounding assumptions about stress levels and damping. Inclusion of the 80% requirement could, therefore, have an unintended and adverse impact on the efficient and economic design of SSCs. Damping values used for loading or stress analyses should be consistent with the code limits without regard to actual stress. The resulting margin to allowable when using the damping consistent with the allowable will be meaningful using this approach. Using lower damping unduly penalizes structures which might be overdesigned and causes analytical iterations which are time-consuming and unnecessary.	
AREVA	general (comment 2)	<u>Bolted Damping (in the structural section)</u> DG-1157 contains the following statement on page 3 regarding the study of structural damping values: <u>Structural Damping</u> In 1993, the NRC completed an investigation of the adequacy of the original Regulatory Guide 1.61 structure damping values and other recommendations, and reported the results in	The staff agrees. The staff will add the following statement to the section entitled, Background, Structural Damping: "Friction-bolted connections are also referred to as 'slip-critical' connections. In these connections, the bolt preload is high enough that friction is not overcome, and the bolt does not experience shear loading."

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		NUREG/CR-6011 (Ref. 2). Data were analyzed to identify the parameters that significantly influenced structure damping. Based on that study, the NRC determined that the original Regulatory Guide 1.61 damping values for structure design were adequate but required one significant revision. Specifically, Regulatory Guide 1.61 should distinguish between "friction-bolted" and "bearing-bolted" connections for steel structures. Regulatory Position 1 in Section C of this revised guide provides the updated structural damping values (emphasis added). The term "friction bolted" is not clear. AREVA NP believes it means a slip-critical bolted joint where bolt preload is so high that friction is never overcome and the bolt never sees load in shear. This should be clarified.	
AREVA	general (comment 3)	<u>Piping Damping</u> The use of 5% damping for envelope uniform support motion is not addressed. Its use has been previously approved in both the AP1000 and System 80+ certified designs. Use of frequency-dependent damping is not an equivalent alternative as that approach results in damping values less than 4% for frequencies greater than 13.3 Hertz (Hz). Damping values used for loading or stress analyses should be consistent with the code limits without regard to actual stress. The resulting margin to allowable when using the damping consistent with the allowable will be meaningful using this approach. Using lower damping unduly penalizes structures which might be overdesigned and causes analytical iterations which are time-consuming and unnecessary. AREVA NP recommends that the NRC consider alternate piping damping methods than the approach proposed in DG-1157, as shown in Table 1 of Attachment 1 (see p. 22).	See response to PH comment.

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		AREVA NP prefers option 1 of Table 1; however, the other options are acceptable and listed in order of preference.	
AREVA	general (comment 4)	Electrical Distribution System Damping AREVA NP expects that the precedent approach for justifying higher damping values for fully loaded cable tray systems, based on test data, that was used for the **AP1000** and ESBWR designs is not precluded by DG-1157.	Cable tray damping higher than that specified in Table 4 of DG-1157 is permissible for flexible support systems, if an adequate technical basis is submitted. No change is necessary in the final version of DG-1157.
AREVA	general (comment 5)	Recommendations for Changes/Requests for Clarification to DG-1 157 1.a. Retain the 50% code allowable limits on the stress levels for which SSE-level damping can be used to generate IRS, consistent with RG 1.61, ASCE 43-05, and ASCE 4-98. 1.b. Damping values used for loading or stress analyses should be consistent with the code limits without regard to actual stress. 2. If the 80% stress-level threshold is retained, clarify expectations for damping values to be used in the SSE analysis for plants for which the OBE is defined as 1/3 SSE (and, hence, OBE design cases are not performed) and stress levels for a given structure are much less than 80% of allowable limits. If the damping values in Table 2 are not to be considered the lower-bound values for the SSE analysis under these conditions, the appropriate values should be provided. 3. Extend the section on piping to address the use of 5% damping for the envelope uniform support motion response spectra analysis, consistent with prior approvals.	See response to NEI Comment 3. See response to NEI Comment 3. See response to PH comment.

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Originator	DG-1157 Section	Specific Comment	NRC Staff Response
		4. AREVA NP recommends that NRC revise piping damping methods as shown in option 1 of Table 1 (see p. 22). 5. Clarify definition of a “friction bolted” connection consistently with AREVA NP understanding (slip-critical bolted joints).	See response to PH comment. See response to AREVA Comment 2.

NEI-7 (Table 6)

Electrical Cabinets, Panels and Motor Control Centers (MCCs)* (protection, structural support)		
– Welded steel structures and bolted steel structures with friction connections	4%	3%
– Bolted steel structures with bearing connections	7%	5%

* For electrical cabinets/panels assembled as welded or bolted steel structures, the values of Tables 1 and 2 shall apply.”

JS&TA-2 (Table 1)

Equipment Class Number and Name		USI A46 Damping	DG-1157 Damping (SSE)
#1	Motor Control Centers	5% Damping	3%
#2	Low Voltage Switchers	5% Damping	3%
#3	Medium Voltage Switcher	5% Damping	3%
#4	Transformers	5% Damping	3%
#5	Horizontal Pumps with Motors	5% Damping	3%
#6	Vertical Pumps with Motors a. Vertical Immersion	3% Damping	3%
	b. Centrifugal	5% Damping	3%
	c. Deep-Well	3% Damping	3%
#12	Air Compressors	5% Damping	3%
#13	Motor-Generators	5% Damping	3%
#15	Batteries on Racks	5% Damping	3%
#16	Battery Chargers and Inverters	5% Damping	3%
#17	Engine-Generators	5% Damping	3%
#18	Instrument Racks	3% Damping	3%
#14 & #20	Generic Equipment Cabinets	5% Damping	3%
#14 & #20	Walk-Through Control Panels	5% Damping	3%

JS&TA—References

(1) Ware, A.G., 1981, “A Survey of Experimentally Determined Damping Values in Nuclear Power Plant Piping Systems,” NUREG/CR-2406.

(2) Ware, A.G., 1982, “Parameters that Influence Damping in Nuclear Power Plant Piping Systems,” NUREG/CR-3022.

(3) Ware, A.G., and Thinnes, G.L., 1984, “Damping Results for Straight Sections of 3-in. and 8-in. Unpressurized Pipes,” NUREG/CR-3722.

(4) Ware, A.G., 1985, “An Assessment of Frequency-Dependent Damping Using the Nuclear Piping System Damping Data Base,” *ASME Journal of Pressure Vessel Technology*, Vol. 107, pp. 361–365.

(5) Ware, A.G., 1986a, “Statistical Evaluation of Light Water Reactor Piping Damping Data Representative of Seismic and Hydrodynamic Events,” EGG-EA-7260.

(6) Ware, A.G., 1986b, “Pipe Damping-Results of Vibration Tests in the 33 to 100 Hertz Frequency Range,” NUREG/CR-4562.

(7) Ware, A.G., and Arendts, J.G., 1986, “Pipe Damping—Experimental Results from Laboratory Tests in the Seismic Frequency Range,” NUREG/CR-4529.

(8) Ware, A.G., 1989, "The Effect of Plastic Behavior on Damping in Piping Systems," *10th International Conference on Structural Mechanics in Reactor Technology (SMiRT)*, Anaheim, California., Vol. F, pp. 105–110.

(9) Ware, A.G., “The History of Allowable Damping Values for U.S. Nuclear Plant Piping,” *Transaction of the ASME 294*, Vol. 113, May 1991.

(10) Welding Research Council, 1984a, WRC Bulletin 300, “Technical Position on Criteria Establishment, Technical Position on Damping Values for Piping—Interim Summary Report, Technical Position on Response Spectra Broadening, Technical Position on Industry Practices.”

(11) Stevenson, J.D., “Survey of Strong Motion Earthquake Effects on Thermal Power Plants in California with Emphasis on Piping Systems—Main Report,” NUREG/CR-6239, Vol. 1 November 1995.

(12) Stevenson, J.D., “Survey of Strong Motion Earthquake Effects on Thermal Power Plants in California with Emphasis on Piping Systems—Main Report,” Appendices, NUREG/CR-6239, Vol. 2, November 1995.

(13) The Seismic Design Task Group and Stevenson and Associates, Inc., “Report of the U.S. Nuclear Regulatory Commission Piping Review Committee, Summary and Evaluation of Historical Strong-Motion Earthquake Seismic Response and Damage to Above Ground Industrial Piping,” NUREG-1061, Vol. 2 Addendum, U.S. Nuclear Regulatory Commission, April 1985.

(14) Stevenson, J.D., Trip Report—In Transit Storage and Port Office Building (Old Railroad Building), Whittier, Alaska, September 1992.

AREVA (Attachment 1)

Table 1 – Alternatives for Piping Damping Values in Order of Preference

Option	OBE	SSE	Reference
1 for all seismic analysis	5%	6%	Ware, A. G., The History of Allowable Damping Values for U.S. Nuclear Plant, Piping Transactions of the ASME/Journal of Pressure Vessel Technology, May 1991
2 for all seismic analysis	5%	5%	ASME Appendix N 2001 or later
3 for all seismic analysis	0 to 10 Hz - 5% 10 to 20 Hz - 5% to 3% > 20 Hz – 3%	0 to 10 Hz - 5% 10 to 20 Hz - 5% to 4% > 20 Hz - 4%	Modified N-411 modified to be consistent with the non ASME Code Case N-411 damping for high frequencies
4 for seismic analysis using envelope spectra	0 to 10 Hz - 5% 10 to 20 Hz - 5% to 3% > 20 Hz – 3%	0 to 10 Hz - 5% 10 to 20 Hz - 5% to 4% > 20 Hz - 4%	Modified N-411 modified to be consistent with the non ASME Code Case N-411 damping for high frequencies
for seismic analysis using time history or multi-support spectra	3%	4%	Non-ASME Code Case N-411 damping

Attachment

1. Structural Damping

1.1 Acceptable Structural Damping Values for Containment Structures, Containment Internal Structures, and Other Seismic Category I Structures

Safe-Shutdown Earthquake (SSE)

For the SSE analysis, Table 1 provides the applicable damping values:

TABLE 1 SSE Damping Values

Structural Material	**Damping (% of Critical Damping)**
Reinforced Concrete	7%
Reinforced Masonry	7%
Prestressed Concrete	5%
Welded Steel or Bolted Steel with Friction Connections	4%
Bolted Steel with Bearing Connections	7%
Note: For steel structures with a combination of different connection types, use the lowest specified damping value, or as an alternative, use a "weighted average" damping value based on the number of each type present in the structure.	

<u>Operating-Basis Earthquake (OBE)</u>

If the design-basis OBE ground acceleration selected is to be less than or equal to one-third of the design-basis SSE ground acceleration, then a separate OBE analysis is not required. However, if the design-basis OBE ground acceleration selected is to be greater than one-third of the design-basis SSE ground acceleration, then a separate OBE analysis should be conducted. For the OBE analysis, Table 2 provides the applicable damping values:

TABLE 2 OBE Damping Values

<u>Structural Material</u>	**<u>Damping</u> (% of Critical Damping)**
Reinforced Concrete	4%
Reinforced Masonry	4%
Prestressed Concrete	3%
Welded Steel or Bolted Steel with Friction Connections	3%
Bolted Steel with Bearing Connections	5%

1.2 Special Consideration for In-Structure Response Spectra Generation

The SSE damping values specified in Table 1, for linear dynamic analysis of structures, have been selected based on the expectation that the structural response resulting from load combinations that include SSE will be close to applicable code stress limits, as defined in Section 3.8 of NUREG-0800 (Ref. 14).

However, there may be cases in which the predicted structural response to load combinations that include SSE is significantly below the applicable code stress limits. Because equivalent viscous damping ratios have been shown to be dependent on the structural response level, it is necessary to consider that the SSE damping values specified in Table 1 may be inconsistent with the predicted structural response level.

For structural evaluation this is not a concern because the damping-compatible structural response will still be less than the applicable code stress limits, as defined in Section 3.8 of NUREG-0800.

However, for in-structure response spectra generation, it is necessary to use the damping-compatible structural response. Consequently, the following additional guidance is provided for analyses used to determine in-structure response spectra:

(a) Use the OBE damping values specified in Table 2, which are acceptable to the staff without further review.

(b) Submit a plant-specific technical basis for use of damping values higher than the OBE damping values specified in Table 2, but not greater than the SSE damping values specified in Table 1 (e.g., see NUREG/CR-6919, Section 3.2.3), subject to staff review on a case-by-case basis.

In general, for certified standard plant designs where the design-basis in-structure response spectra represent the envelope of the in-structure responses obtained from multiple analyses conducted to consider a range of expected site soil conditions, it is not necessary for combined license applicants to address this issue. However, if plant-specific seismic analyses are conducted for Category I structures and/or structures not included as part of the standard plant, then the applicant (or licensee) is expected to address this issue accordingly.