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DESIGN LIMITS AND LOADING COMBINATIONS FOR CLASS 1 PLATE-AND-SHELL-TYPE COMPONENT SUPPORTS

A. INTRODUCTION

General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that the design bases for structures, systems, and components important to safety reflect appropriate combinations of the effects of normal and accident conditions with the effects of natural phenomena such as earthquakes. The failure of members designed to support safety-related components could jeopardize the ability of the supported component to perform its safety function.

This guide delineates acceptable design limits and appropriate combinations of loadings associated with normal operation, postulated accidents, and specified seismic events for the design of Class 1 plate-and-shell-type component supports as defined in Subsection NF of Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code.[1] This guide applies to light-water-cooled reactors.

B. DISCUSSION

Load-bearing members classified as component supports are essential to the safety of nuclear power plants because they retain components in place during loadings associated with normal and upset plant conditions under the stress of specified seismic events, thereby permitting system components to function properly. They also prevent excessive component movement during the loadings associated with emergency and faulted plant conditions combined with a specified seismic event or other natural phenomena, thereby helping to mitigate system damage. Component supports are deformation-sensitive because large deformations in component supports may significantly change the stress distribution in the support system and its components.

NF-1122 and NA-2134 of Section III of the ASME Boiler and Pressure Vessel Code imply that the classification of component supports should, as a minimum, be the same as that of the supported components. This should be considered as a requirement. This guide delineates design limits and loading combinations, in addition to supplementary criteria, for Class 1 plate-and-shell-type component supports as defined by NF-1212 of Section III. Snubbers installed for protection against seismic or dynamic loadings of other origins are not addressed in this guide.

Subsection NF of Section III permits the use of three methods for the design of Class 1 plate-and-shell-type component supports: (1) linear elastic analysis, (2) load rating, and (3) experimental stress analysis. For each method, the ASME Code delineates allowable stress or loading limits for various Code service level limits, as defined by NF-3113 of Section III, so that these limits can be used in conjunction with the resultant loadings or stresses from the appropriate plant conditions. Since the Code does not specify loading combinations, guidance is needed to provide a consistent basis for the design of component supports.

[1] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Division 1, 1974 Edition, including the 1974 Winter Addenda thereto. Copies of the Code may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

Most of the component supports considered in this guide are located within containment. They are therefore assumed to be protected against loadings from natural phenomena or man-made hazards other than the specified seismic events for ordinary nuclear power plants and the wave motion for floating nuclear power plants. Thus only the appropriate loadings from natural phenomena and the specified seismic events or wave motions need to be considered in combination with the loadings associated with plant conditions to develop appropriate loading combinations.

1. Design by Linear Elastic Analysis

When the linear-elastic-analysis method is used to design Class 1 plate-and-shell-type component supports, material properties are given by Table I-11.1 of Appendix I to Section III and Table I of Code Case 1644.5. These tables list values for the design stress intensity S_m at various temperatures. Yet faulted condition category design limits are determined by S_m, S_y, and S_u. The load-rating method also requires the use of S_u.

The minimum yield strength S_y at various temperatures could be found in Table I-13.1 of Appendix I to Section III and Table 3 of Code Case 1644.5 for the design of Class 1 plate-and-shell-type component supports, but values for the ultimate tensile strength S_u above room temperature are not listed in Section III. An interim method should therefore be used to obtain values of S_u at temperature in order to provide a safe design margin.

While NF-3224 and F-1323.1(a) of Section III permit the increase of allowable stresses under various loading conditions, F-1370(c) limits the increase to two-thirds of the critical buckling strength of the component support at temperature. Since buckling prevents "shake-down" in a load-bearing member, it must be regarded as controlling for the level A service limits and F-1370(c) must be regarded as controlling for the level D service limits. Also, buckling is the result of the interaction of the configuration at the load-bearing member and its material properties (i.e., elastic modulus E and minimum yield strength S_y). Because both of these material properties change with temperature, the critical buckling stresses should be calculated with the values of E and S_y of the component support material at temperature.

Allowable design limits for bolted connections are derived on a different basis that varies with the size of the bolt. For this reason, the increases permitted by NF-3224 and F-1323.1(a) of Section III are not directly applicable to bolts and bolted connections.

2. Design by Load Rating

When load-rating methods are used, Subsection NF and Appendix F of Section III do not provide a faulted condition load rating. This deficiency should be provided for by the interim method described in this guide.

3. Design by Experimental Stress Analysis

While the collapse load for the experimental-stress-analysis method is defined by II-1430 in Appendix II to Section III, the design limits for the experimental-stress-analysis method for various operating condition categories are not delineated. This deficiency can be remedied by the interim method described in this guide.

4. Large Deformations

The design of component supports is an integral part of the design of a system and its components. A complete and consistent design is possible only when system/component/component-support interaction is properly considered. When all three are evaluated on an elastic basis, the interaction is usually valid because individual deformations are small. However, if plastic analysis methods are used in the design process, large deformations that would result in substantially different stress distributions may occur.

For the evaluation of the level D service limits, Appendix F to Section III permits the use of plastic analysis methods in certain acceptable combinations for all three elements. These acceptable combinations are selected on the assumption that component supports are more deformation-sensitive (i.e., their deformation in general will have a large effect on the stress distribution in the system and its components).

Since large deformations always affect stress distribution, care should be exercised even if the plastic analysis method is used in the Appendix-F-approved methodology combination. This is especially important for identifying buckling or instability problems, where the change of geometry should be taken into account to avoid erroneous results.

5. Function of the Supported System

In selecting design limits for different loading combinations, the function of the system and its supports must be taken into account. If a support's service is required by the normal function of the supported system during any plant operating condition, the design limits for the normal-operating-condition category or some other justifiable design limits should be used to evaluate the effect of all loading combinations during that specific plant operating condition. This will ensure the proper functioning of safety-related systems, such as the injection of the

Emergency Core Cooling System (ECCS) under the action of a Loss-of-Coolant Accident (LOCA) and a Safe Shutdown Earthquake (SSE) during the faulted plant condition.

6. Deformation Limits

Since component supports are deformation-sensitive load-bearing elements, satisfying the design limits of Section III will not automatically ensure their proper function. Deformation limits, if specified by the Code Design Specification, may be the controlling criterion. On the other hand, if the function of a component support is not required for a particular plant condition, the stresses or loads resulting from the loading combinations under the particular plant condition do not need to satisfy the design limits for the plant condition.

7. Definitions

Critical Buckling Strength. The strength at which lateral displacements start to develop simultaneously with in-plane or axial deformations.

Emergency Plant Condition. Those operating conditions that have a low probability of occurrence.

Faulted Plant Condition. Those operating conditions associated with postulated events of extremely low probability.

Normal Plant Condition. Those operating conditions in the course of system startup, operation, hot standby, refueling, and shutdown other than upset, emergency, or faulted plant conditions.

Operating Basis Earthquake (OBE). As defined in Appendix A to 10 CFR Part 100.

Operating Condition Categories. Categories of design limits for component supports as defined by NF-3113 of Section III of the ASME Code.

Plant Conditions. Operating conditions of the plant categorized as normal, upset, emergency, and faulted plant conditions.

Safe Shutdown Earthquake (SSE). As defined in Appendix A to 10 CFR Part 100.

Specified Seismic Events. Operating Basis Earthquake and Safe Shutdown Earthquake.

System Mechanical Loadings. The static and dynamic loadings that are developed by the system operating parameters, including dead weight, pressure, and other non-self-limiting loadings, but excluding effects resulting from constraints of free-end movements and thermal and peak stresses.

Ultimate Tensile Strength. Material property based on engineering stress-strain relationship.

Upset Plant Condition. Those deviations from the normal plant condition that have a high probability of occurrence.

C. REGULATORY POSITION

All ASME Code Class 1 plate-and-shell-type component supports except snubbers, which are not addressed in this guide, should be constructed to the rules of Subsection NF of Section III, as supplemented by the following:[2]

1. The classification of component supports should, as a minimum, be the same as that of the supported components.

2. Values of S_u at temperature, when they are not listed in Section III, should be estimated by either Method 1, Method 2, or Method 3, as described below on an interim basis until Section III includes such values. Values of S_y at temperature listed by Tables I-1.1, I-1.2, and I-11.1 of Appendix I and Table 3 of the latest approved version of Code Case 1644 of Section III may be used for the interim calculation.

a. *Method 1.* This method applies to component support materials whose values of ultimate strength S_u at temperature have been tabulated by their manufacturers in catalogs or other publications.

$$S_u = S_{ur} \frac{S'_u}{S'_{ur}} \text{, but not greater than } S_{ur}$$

where

S_u = ultimate tensile strength at temperature t to be used to determine the design limits

S_{ur} = ultimate tensile strength at room temperature tabulated in Section III, Appendix I, or Code Case 1644

S'_u = ultimate tensile strength at temperature t tabulated by manufacturers in their catalogs or other publications

S'_{ur} = ultimate tensile strength at room temperature tabulated by manufacturers in the same publications.

b. *Method 2.* This method applies to component support materials whose values of ultimate tensile strength at temperature have not been tabulated by their manufacturers in any catalog or publication.

$$S_u = S_{ur} \frac{S_y}{S_{yr}}$$

[2] If the function of a component support is not required during a plant condition, the design limits of the support for that plant condition need not be satisfied, provided excessive deflections or failure of the support will not result in the loss of function of any other safety-related system.

where

S_u = ultimate tensile strength at temperature t to be used to determine the design limits

S_{ur} = ultimate tensile strength at room temperature tabulated in Section III, Appendix I, or Code Case 1644

S_y = minimum yield strength at temperature t tabulated in Section III, Appendix I, or Code Case 1644

S_{yr} = minimum yield strength at room temperature, tabulated in Section III, Appendix I, or Code Case 1644

c. *Method 3.* Since the listed values of S_m at temperature in Section III will always be less than one-third of the corresponding values of ultimate strength S_u at temperature, S_u at temperature may be replaced by the value of 3 S_m at the same temperature.

3. Design limits for component supports designed by linear elastic analysis should always be limited by the critical buckling strength. The critical buckling strength should be calculated using temperature material properties. A design margin of 2 for flat plates and 3 for shells should be maintained for loadings combined according to Regulatory Positions 4 and 5 of this guide. Design limits related to critical buckling strength should not be increased unless the Code specifically allows such an increase.

4. Component supports subjected to the most adverse combination of the vibratory motion of the OBE or the appropriate wave motion and system mechanical loadings[3] associated with either the Code design condition or the normal or upset plant conditions should be designed with the following limits:[4,5]

a. The stress limits of (1) NF-3221.1 and NF-3221.2 for design condition loadings, (2) NF-3222 for normal and upset operating condition loadings, and (3) Regulatory Position 3 of this guide should not be exceeded for component supports designed by the linear-elastic-analysis method.

b. The normal condition load rating or the upset condition load rating of NF-3262.2 of Section III should not be exceeded for component supports designed by the load-rating method.

c. The collapse load determined by II-1400 of Section III divided by 1.7 should not be exceeded for component supports designed by the experimental-stress-analysis method.

5. The limits in Regulatory Position 4 or some other justifiable design limits should not be exceeded by those component supports whose service is required by the normal function of the supported system during emergency or faulted plant conditions.

6. Component supports subjected to the most adverse combination of system mechanical loadings[3] associated with the emergency plant condition should be designed within the following design limits:[4,5]

a. The stress limits of NF-3224 of Section III and Regulatory Position 3 should not be exceeded for component supports designed by the linear-elastic-analysis method.

b. The emergency condition load rating of NF-3262.2 of Section III should not be exceeded for component supports designed by the load-rating method.

c. The collapse load determined by II-1400 of Section III and divided by 1.3 should not be exceeded for component supports designed by the experimental-stress-analysis method.

7. Component supports subjected to the most adverse combination of the vibratory motion of SSE or the appropriate wave motion and system mechanical loadings[3] associated simultaneously with the faulted plant condition and the upset plant condition should be designed within the following design limits:[4,5]

a. The stress limits of F-1323.1(a) and F-1370(c) of Section III should not be exceeded for component supports designed by the linear-elastic-analysis method.

b. The value of T.L. x $0.7 \frac{S_u'}{S_u}$ should not be exceeded, where T.L. and S_u are defined according to NF-3262.1 of Section III and S_u' is the ultimate tensile strength of the material at service temperature for component supports designed by the load-rating method.

c. The collapse load determined by II-1400 adjusted according to the provisions of F-1370(b) of Section III should not be exceeded for component supports designed by the experimental-stress-analysis method.

[3] System mechanical loadings include all non-self-limiting loadings and do not include effects resulting from constraints of free-end displacements and thermal or peak stresses.

[4] Since component supports are deformation-sensitive in the performance of their service requirements, satisfying these limits does not ensure the fulfilling of their functional requirements. Any deformation limits specified by the design specification may be controlling and should be satisfied.

[5] Since the design of component supports is an integral part of the design of the system and the design of the component, the designer must make sure that methods used for the analysis of the system, component, and component support are compatible (see Table F-1322.2-1 of Appendix F to Section III). Large deformations in the system or components should be considered in the design of component supports.

D. IMPLEMENTATION

The purpose of this section is to provide guidance to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with the specified portions of the Commission's regulations, the method described herein will be used in the evaluation of submittals for construction permit applications docketed after April 1, 1978. If an applicant wishes to use this regulatory guide in developing submittals for construction permit applications docketed on or before April 1, 1978, the pertinent portions of the application will be evaluated on the basis of this guide.