Revision 1
October 1978

U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

Regulatory Guide 1.130

* SERVICE 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, "Domestic 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 levels of service 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.

The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

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.

In order to provide a consistent level of safety, the ASME Boiler and Pressure Vessel Code classification for component supports should, as a minimum, be the same as that of the supported components. This guide delineates levels of service limits and loading combinations, as well as supplementary criteria, for Class 1 plate-and-shell-type component supports as defined by NF-1212 of Section III of the Code. Snubbers 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 levels, as defined by NF-3113 and NCA-2142.2(b) 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.

Component supports considered in this guide are located within Seismic Category I structures and are

* Lines indicate substantive changes from previous issue.

[1] American Society of Mechanical Engineers Boiler and Pressure Vessel Codes Section III, Division 1, 1977 Edition, including the 1977 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.

therefore assumed to be protected against loadings from natural phenomena or man-made hazards other than the specified seismic events. Thus only the specified seismic events need to be considered in combination with the loadings associated with plant conditions to develop appropriate loading combinations. When loadings caused by natural phenomena other than seismic events, such as the subsidence of the land surface as a result of large-scale groundwater withdrawals exist, they should be specified in the Design Specification, and the loading combinations reflecting the inclusion of these loadings should be reviewed.

1. Design by Linear Elastic Analysis

When the linear-elastic-analysis method is used to design Class I plate-and-shell-type component supports, material properties are given by Tables I-1.1, I-1.2, and I-11.1 of Appendix I to Section III and Table 1 of the latest accepted version[2] of Code Case 1644. These tables list values for the design stress intensity S_m at various temperatures. Yet level D service 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 Tables I-2.1, I-2.2, and I-13.3 of Appendix I to Section III and Table 3 of the latest accepted version[2] of Code Case 1644 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. The interim methods proposed by this guide should therefore be used to obtain values of S_u at temperature in order to provide a safe design margin.

While NF-3222.3 and F-1323.1(a) of Section III permit the increase of allowable service limits under various loading conditions, F-1370(c) limits the increase to two-thirds of the critical buckling strength of the component support at temperature. However, NF 3211(d) and NB 3220 do not specify the percentage of critical buckling strength for level A service limits. 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 service 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-3222.3 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 level D load rating. This guide provides an interim method for the determination of the load rating for level D limits.

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 the level of service limits for different loading combinations, the designer must take into account the function of the supported system. To ensure that systems whose normal function is to prevent or mitigate consequences of events associated with an emergency or faulted plant condition (e.g., the func-

[2] Regulatory Guide 1.85, "Code Case Acceptability-ASME Section III Materials," provides guidance for the acceptability of ASME Section III Code Cases and their revisions, including Code Case 1644. Supplementary provisions for the use of specified code cases and their revisions may also be provided and should be considered when applicable.

tion of ECCS during faulted plant conditions) will operate properly regardless of plant condition, the Code level A or B service limits of Subsection NF (which are identical) or other justifiable limits provided by the Code should be used.

6. Deformation Limits

Since component supports are deformation-sensitive load-bearing elements, satisfying the service 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.

Design Condition. The loading condition defined by NF-3112 of Section III of the ASME Boiler and Pressure Vessel Code.

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.

Levels of Service Limits. Four levels (A, B, C, and D) of service limits defined by Section III of the Code for the design of loadings associated with different plant conditions for components and component supports in nuclear power plants.

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 "Seismic and Geologic Siting Criteria for Nuclear Power Plants," to 10 CFR Part 100, "Reactor Site Criteria."

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.

Service Limits. Stress limits for the design of component supports as defined by Subsection NF of Section III.

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 external 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

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 of the Code, as supplemented by the following:[3]

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 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-2.1, I-2.2, and I-13.1 of Appendix I and Table 3 of the latest accepted version[1] 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 tensile strength at temperature have not been tabulated by their manufacturers or are not available.

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

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 the latest accpeted version[2] of Code Case 1644

[3] 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.

S_y = minimum yield strength at temperature t tabulated in Section III, Appendix I, or the latest accepted version[2] of Code Case 1644

S_{yr} = minimum yield strength at room temperature, tabulated in Section III, Appendix I, or the latest accepted version[2] of Code Case 1644.

b. *Method 2*. 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 approximated by the value of $3S_m$ at the same temperature.

c. *Method 3*. This method applies to component support materials whose values of ultimate strength S_u at temperature are available as tabulated by their manufacturers.

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

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 the latest accepted version[2] of 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.

3. Service 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 material at temperature properties. A design margin of 2 for flat plates and 3 for shells should be maintained for loadings combined according to Regulatory Position 4 of this guide. Service limits related to critical buckling strength should not be increased unless the Code specifically allows such an increase.

4. Component supports subjected to the combined loadings of (a) the vibratory motion of the OBE and (b) system mechanical loadings[4] associated with either (a) the Code design condition or (b) normal or upset plant conditions should be designed as follows.[5-6]

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

b. The load rating for level A limits or level B limits 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. Component supports subjected to the system mechanical loadings[4] associated with the emergency plant condition should be designed within the following design limits except when the normal function of the supported system is to prevent or mitigate the consequences of events associated with the emergency plant condition (at which time Regulatory Position 7 applies):[5-6]

a. The service 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 load rating for level C limits 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.

6. Component supports subjected to the combined loadings of (a) the vibratory motion of SSE and (b) the system mechanical loadings[4] associated with the normal plant condition and (c) the dynamic system loadings associated with the faulted plant condition should be designed within the following design limits except when the normal function of the supported system is to prevent or mitigate the consequences of events associated with the faulted plant condition (at which time Regulatory Position 7 applies):[5-6]

a. The service limits of F-1323.1(a) and F-1370(c) of Section III should not be exceeded for

[4]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.

[5]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.

[6]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.

component supports designed by the linear-elastic-analysis method.

b. The value of T.L. $\times\ 0.7\ \frac{S'_u}{S_u}$ 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 and divided by 1.1 should not be exceeded for component supports designed by the experimental-stress-analysis method.

d. If plastic methods are used for the design of component supports, the combined loadings of Regulatory Position 6 should include all loads such as thermal loads and constraints of free displacements, which contribute to expansion stress intensities, and the service limits of F–1324 and F–1370(c) of Section III should not be exceeded.

7. Component supports in systems whose normal function is to prevent or mitigate the consequences of events associated with an emergency or faulted plant condition should be designed within the limits described in Regulatory Position 4 or other justifiable limits such as the level C or level D service limits provided by the Code. These limits should be defined by the design specification so that the function of the supported system will be maintained when the supports are subjected to the loading combinations described in Regulatory Positions 5 and 6.

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 October 31, 1978. If an applicant wishes to use this regulatory guide in developing submittals for construction permit applications docketed on or before October 31, 1978, the pertinent portions of the application will be evaluated on the basis of this guide.