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

A. INTRODUCTION

General Design Criterion 2, "Design Bases for Protec-ion Against Natural Phenomena," of Appendix A, 'General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utiliza-ion Facilities," requires, in part, that the design bases for structures, systems, and components important to afety reflect appropriate combinations of the effects of ormal and accident conditions with the effects of atural phenomena such as earthquakes. The failure of nembers designed to support safety-related components ould jeopardize the ability of the supported component o perform its safety function.

This guide delineates acceptable design limits and ppropriate combinations of loadings associated with ormal operation, postulated accidents, and specified eismic events for the design of Class 1 linear-type omponent supports as defined in Subsection NF of ection III of the American Society of Mechanical ngineers (ASME) Boiler and Pressure Vessel Code. This uide applies to light-water-cooled reactors.

B. DISCUSSION

Load-bearing members classified as component sup-orts are essential to the safety of nuclear power lants since they retain components in place during the adings associated with normal, upset, and emergency lant conditions under the stress of specified seismic vents, thereby permitting system components to func-on properly. They also prevent excessive component ovement during the loadings associated with a faulted lant condition combined with the specified seismic vent, thus helping to mitigate the consequences of stem damage. Component supports are deformation nsitive because large deformations in them may signifi-antly change the stress distribution in the support ystem and its supported 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 ASME Class 1 linear-type component supports as defined by NF-1213 of Section III. Snubbers installed for protection against seismic or dynamic loadings of other origins are not addressed in this guide.

Subsection NF and Appendix XVII of Section III permit the use of four methods for the design of Class 1 linear-type component supports: linear elastic analysis, load rating, experimental stress analysis, and limit analysis. For each method, the ASME Code delineates allowable stress or loading limits for various Code operating condition categories 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. However, the Code's operating condition categories are simply component support design limits; they are not necessarily related to defined plant conditions. Since the Code does not specify loading combinations, guidance is required to provide a consistent basis for the design of component supports.

The component supports considered in this guide are located within containment and are 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.

1. Design by Linear Elastic Analysis

a. *S_u at Temperature.* When the linear elastic analysis method is used to design Class 1 linear-type component supports, material properties are given by Tables I-13.1 and I-13.3 in Appendix I of Section III and Tables 3 and 4 in Code Case 1644-4. These tables list values for the minimum yield strength S_y at various temperatures but only room temperature values for the ultimate tensile strength S_u. At room temperature, S_y varies from 50% to 87% of S_u for component support materials.

Design limits derived from either material property alone may not be sufficient to provide a consistent design margin. This is recognized by Section III, since XVII-2211(a) of Section III defines the allowable stress in tension on a net section as the smaller value of $0.6S_y$ and $0.5S_u$. To alleviate the lack of defined values of S_u at temperatures above room temperature and to provide a safe design margin, an interim method is given in this guide to obtain values of S_u at temperature.

While XVII-2211(a) specifies allowable tensile stress in terms of both S_y and S_u, the rest of XVII-2000 specifies other allowable design limits in terms of S_y only. This does not maintain a consistent design margin for those design limits related only to material properties. Modifications similar to XVII-2211(a) should be employed for all those design limits.

b. *Increase of Design Limits.* While NF-3231.1(a), XVII-2110(a), and F-1370(a) of Section III all permit the increase of allowable stresses under various loading conditions, XVII-2110(b) limits the increase so that two-thirds of the critical buckling stress for compression and compression flange members is not exceeded, and the increase allowed by NF-3231.1(a) is for stress range. Critical buckling stresses with normal design margins are derived in XVII-2200 of Section III. Since buckling prevents "shakedown" in a load-bearing member, XVII-2110(b) must be regarded as controlling. Also, buckling is the result of the interaction of the configuration of 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 from tensile and shear stress limits and their nonlinear interaction; they also change with the size of the bolt. For this reason, the increases permitted by NF-3231.1, XVII-2110(a), and F-1370(a) of Section III are not directly applicable to allowable shear stresses and allowable stresses for bolts and bolted connections.

The range of primary plus secondary stresses should be limited to $2S_y$ but not more than S_u to ensure shakedown. For many allowable stresses above the value of $0.6S_y$, the increase permitted by NF-3231.1(a) will be above the value of $2S_y$ and will thus violate the normal shakedown range. A shakedown analysis is necessary to justify the increase of stress above $2S_y$ or S_u.

For the linear elastic analysis method, F-1370(a) of Section III permits increase of tension design limits for the faulted operating condition category by a variable factor which is the smaller value of $1.2S_y/F_t$ or $0.7S_u/F_t$. Depending on whether the section considered is a net section at pinholes in eyebars, pin-connected plates, or built-up structural members, F_t may assume the smaller value of $0.45S_y$ or $0.375S_u$ (as recommended by this guide for a net section at pinholes, etc.) or the smaller value of $0.6S_y$ or $0.5S_u$ (for a net section without pinholes, etc.). Thus greater values of the factor may be obtained for sections at pinholes, which does not account for local stress and is not consistent with NF-3231.1 and XVII-2110(a) of Section III. A procedure to correct this factor is provided in this guide.

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 guide provides an interim method for the determination of faulted condition load rating.

3. Design by Experimental Stress Analysis

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

4. Large Deformation

The design of component supports is an integral part of the design of the 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 employed in the design process, large deformations that would result in substantially different stress distributions may occur.

For the evaluation of the faulted operating condition category, Appendix F of 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 the 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 Supported System

In selecting design limits for different loading combinations, the function of the supported system must be taken into account. To ensure that systems whose normal safety-related function occurs during plant conditions other than normal or upset (e.g., the function of ECCS during faulted plant conditions) will operate properly regardless of plant condition, the design limits for the design, normal, and upset plant operating condition categories of Subsection NF (which are identical) should be used.

Since Appendix XVII derived all equations from AISC rules and many AISC compression equations have built-in constants based on mechanical properties of steel at room temperature, to use these equations indiscriminately for all NF and Code Case 1644 materials at all temperatures would not be prudent. For materials other than steel and working temperatures substantially different from room temperature, these equations should be rederived with the appropriate material properties.

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 that plant condition do not need to satisfy the design limits for that plant condition.

7. Definitions

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.

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 deadweight, 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 Conditions. Those deviations from the normal plant condition that have a high probability of occurrence.

C. REGULATORY POSITION

ASME Code[1] Class 1 linear-type component supports excluding snubbers, which are not addressed herein, 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 a temperature t should be estimated by either Method 1 or Method 2 on an interim basis until Section III includes such values.

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.

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[1] American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Division 1, 1974 Edition, including the 1974 Winter Addenda thereto.

[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 deflection or failure of the support will not result in the loss of function of any other safety-related system.

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

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 1644-4

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.

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

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 1644-4

S_y = minimum yield strength at temperature t tabulated in Section III, Appendix I, or Code Case 1644-4

S_{yr} = minimum yield strength at room temperature, tabulated in Section III, Appendix I, or Code Case 1644-4.

3. The design limits for component supports designed by linear elastic analysis for the design condition and the normal or upset operating condition categories,[3] when these limits are related to S_y alone, should meet the appropriate stress limits of Appendix XVII of Section III but should not exceed the limit specified when the value of 5/6 S_u is substituted for S_y. Examples are shown below in a and b. The bearing stress limit specified by XVII-2461.2 should be modified by c (below).

[3]Code operating condition categories only specify design limits. They are not necessarily related to corresponding plant conditions.

a. The tensile stress limit F_t for a net section as specified in XVII-2211(a) of Section III should be the smaller value of $0.6S_y$ or $0.5S_u$ at temperature. For net sections at pinholes in eye-bars, pin-connected plates, or built-up structural members, F_t as specified in XVII-2211(b) should be the smaller value of $0.45S_y$ or $0.375S_u$ at temperature.

b. The shear stress limit F_v for a gross section as specified in XVII-2212 of Section III should be the smaller value of $0.4S_y$ or $0.33S_u$ at temperature.

c. The bearing stress limit F_v on the projected area of bolts in bearing-type connections as specified in XVII-2461.2 of Section III should be the smaller value of $1.35S_y$ or $0.9S_u$ at temperature, where S_y and S_u are material properties of the connected part.

Many limits and equations for compression strength specified in Sections XVII-2214, XVII-2224, XVII-2225, XVII-2240, and XVII-2260 have built-in constants based on Young's Modulus of 29,000 Ksi. For materials with Young's Modulus at working temperatures substantially different from 29,000 Ksi, these constants should be rederived with the appropriate Young's Modulus unless conservatism of using these constants as specified can be demonstrated.

4. Component supports designed by linear elastic analysis may increase their design limits according to the provisions of NF-3231.1(a), XVII-2110(a), and F-1370(a) of Section III. The increase of design limits provided by NF-3231.1(a) is for stress range. The increase of design limits provided by F-1370(a) for the faulted operating condition category should be the smaller factor of 2 or $1.167S_u/S_y$, if $S_u \geq 1.2S_y$ or 1.4 if $S_u \leq 1.2S_y$, where S_y and S_u are component-support material properties at temperature.

However, all increases [i.e., those allowed by NF-3231.1(a), XVII-2110(a), and F-1370(a)] should always be limited by XVII-2110(b) of Section III. The critical buckling strengths defined by XVII-2110(b) of Section III should be calculated using material properties at temperature. This increase of design limits does not apply to design limits for bolted connections and shear stresses. Any increase of design limits for bolted connections and shear stresses should be justified.

If the increased design limit for stress range by NF-3231.1(a) is more than $2S_y$ or S_u, it should be limited to the smaller value of $2S_y$ or S_u unless it can be justified by a shakedown analysis.

5. Component supports subjected to the most adverse combination of the vibratory motion of the OBE

and system mechanical loadings[4] associated with either the Code design condition or the normal or upset plant conditions should be designed within the following limits:[5,6]

a. The stress limits of XVII-2000 of Section III and Regulatory Position 3 of this guide should not be exceeded for component supports designed by the linear elastic analysis method. These stress limits may be increased according to the provisions of NF-3231.1(a) of Section III and Regulatory Position 4 of this guide when effects resulting from constraints of free-end mechanical and seismic displacements are added to the loading combination.

b. The normal condition load rating or the upset condition load rating of NF-3262.3 of Section III should not be exceeded for component supports designed by the load-rating method.

c. The lower bound collapse load determined by XVII-4200 adjusted according to the provision of XVII-4110(a) of Section III should not be exceeded for component supports designed by the limit analysis method.

d. 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.

6. Component supports subjected to the most adverse combination of system mechanical loadings[4] associated with the emergency plant condition should be designed within the following design limits except when their normal function is required during the emergency plant condition (at which time Regulatory Position 8 applies):[5,6]

a. The stress limits of XVII-2000 of Section III and Regulatory Positions 3 and 4, increased according to the provisions of XVII-2110(a) of Section III and Regulatory Position 4 of this guide, should not be exceeded for component supports designed by the linear elastic analysis method.

b. The emergency condition load rating of NF-3262.3 of Section III should not be exceeded for component supports designed by the load-rating method.

c. The lower bound collapse load determined by XVII-4200 adjusted according to the provision of XVII-4110(a) of Section III should not be exceeded for component supports designed by the limit analysis method.

d. The collapse load determined by II-1400 of Section III 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 and system mechanical loadings[4] associated simultaneously with the faulted plant condition and the normal plant condition should be designed within the following design limits except when their normal function is required during the faulted plant condition (at which time Regulatory Position 8 applies):[3,5,6]

a. The stress limits of XVII-2000 of Section III and Regulatory Position 3 of this guide, increased according to the provisions of F-1370(a) of Section III and Regulatory Position 4 of this guide, should not be exceeded for component supports designed by the linear elastic analysis method.

b. The smaller value of T.L. $\times$ $2S/S_u$ or T.L. $\times$ $0.7S_u'/S_u$ should not be exceeded, where T.L., S, and S_u are defined according to NF-3262.1 of Section III, and S_u is the minimum ultimate tensile strength of the material at service temperature for component supports designed by the load-rating method.

c. The lower bound collapse load determined by XVII-4200 adjusted according to the provision of F-1370(b) of Section III should not be exceeded for component supports designed by the limit analysis method.

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

8. Component supports whose normal function is required during an emergency or faulted plant condition and that are subjected to loading combinations described in Regulatory Positions 6 and 7 should be designed within the design limits described in Regulatory Position 5 or other justifiable design limits.

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[4]System mechanical loadings include all non-self-limiting loadings and do not include loadings 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 criteria does not ensure that their functional requirements will be fulfilled. 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 in Appendix F of 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 July 1, 1977. If an applicant wishes to use this regulatory guide in developing submittals for construction permit applications docketed on or before July 1, 1977, the pertinent portions of the application will be evaluated on the basis of this guide.