



REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

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SERVICE LIMITS AND LOADING COMBINATIONS FOR CLASS 1 LINEAR-TYPE 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 Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50) 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 and piping could jeopardize the ability of the supported component or piping 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 linear-type component and piping supports, as defined in Subsection NF of Section III of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code. This guide applies to light-water-cooled reactors.

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B. DISCUSSION

Background

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

To provide uniform requirements for construction, component and piping supports should, as a minimum, have the same ASME Code classification as that of the supported components and piping. This guide delineates levels of service limits and loading combinations, in addition to supplementary criteria, for ASME Class 1 linear-type component and piping supports, as defined by NF-1213 of Section III. This guide does not address snubbers.

Subsection NF of Section III permits the use of four methods for the design of Class 1 linear-type component and piping supports: (1) linear elastic analysis, (2) load rating, (3) experimental stress analysis, and (4) limit analysis. For each method, the ASME Code delineates allowable stress or loading limits for various code levels of service 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. Because the ASME Code does not specify loading combinations, guidance is required to provide a consistent basis for the design of supports.

Component and piping supports considered in this guide are located within seismic Category I structures and, therefore, are assumed to be protected against loadings from natural phenomena or manmade 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. Loadings caused by any natural phenomena other than seismic events should be considered on a case-by-case basis.

1. Design by Linear Elastic Analysis

a. *S_y and S_u at Temperature*

Tables U and Y-1 in Subpart 1 of Part D of Section II and Tables 3, 4, and 5 in the latest accepted versions¹ of ASME Code Cases N-71 and N-249 give the relevant material properties when the linear elastic analysis method is used to design Class 1 linear-type component and piping supports. These tables list values for the minimum yield strength S_y and the ultimate tensile strength S_u . At room temperature, S_y varies from 62 percent to 93 percent of S_u for support materials.

¹ Regulatory Guide 1.84, "Design, Fabrication, and Materials Code Case Acceptability, ASME Section III," provides guidance for the acceptability of ASME Code, Section III code cases and their revisions, including ASME Code Cases N-71 and N-249. Code cases identified as "Conditionally Acceptable Section III Code Cases" are acceptable, provided that they are used with the identified limitations or modifications.

Levels of service limits that are derived from either material property alone might be insufficient to provide a consistent safety margin. Section III recognizes this issue in NF-3322.1(a), which defines the allowable stress in tension on a net section as the lesser of two values, $0.6S_y$ or $0.5S_u$.

Although NF-3322.1(a) specifies allowable tensile stress in terms of both S_y and S_u , the rest of NF-3320 notes other allowable service limits in terms of S_y only. This does not maintain a consistent design margin for those service limits related only to material properties. Modifications similar to NF-3322.1(a) should be employed for all those service limits.

b. *Allowable Increase of Service Limits*

Although NF-3321.1(a) and F-1334 of Section III of the ASME Code permit the increase of allowable stresses under various loading conditions, NF-3321.1(b) limits the increase to less than or equal to two-thirds of the critical buckling stress for compression and compression flange members. NF-3322.1(c) of Section III derives critical buckling stresses with normal design margins. Because buckling prevents “shakedown” in the load-bearing member, NF-3322.1(c) must be controlling. Also, buckling is the result of the interaction of the geometry 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 use the values of E and S_y of the support material at temperature.

Tensile and shear stress limits and their nonlinear interaction are used to derive allowable service limits for bolted connections, which also change with the size of the bolt. For this reason, the increases permitted by NF-3321.1(a) and F-1334 of Section III do not directly apply to allowable tensile stresses and allowable shear stresses for bolts and bolted connections. As specified in F-1335 of Section III, the allowable increase in tensile stress for bolts should not exceed the lesser value of $0.70 S_u$ or S_y , at temperature, and the allowable increase in shear stress for bolts should not exceed the lesser value of $0.42 S_u$ or $0.6 S_y$, at temperature.

For the linear elastic analysis method, F-1334 permits an increase of tension limits for the level D service limits by a variable factor that is the lesser of 2 or $1.167S_u/S_y$ if $S_u > 1.2S_y$, or 1.4 if $S_u \leq 1.2S_y$. 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 lesser value of $0.45S_y$ or $0.375S_u$ (as recommended by this guide for a net section of pinholes, for example) or the lesser value of $0.6S_y$ or $0.5S_u$ (for a net section without pinholes, for example).

2. Design by Load Rating

NF-3380 of Section III specifies the qualification of linear-type component and piping supports to service level A, B, and C limits, using load-rating criteria. F-1334.8 specifies the qualification of linear-type supports to service level D limits using load rating criteria. This guide provides additional guidance for the determination of the service level D load rating.

3. Design by Experimental Stress Analysis

Although II-1430 in Appendix II to Section III defines the test collapse load for the experimental stress analysis method, the various levels of service limits for experimental stress analysis are not delineated. The method described in this guide remedies this deficiency.

4. Large Deformation

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

When component and piping supports are designed for loadings associated with the faulted plant conditions, Appendix F to Section III of the ASME Code permits the use of plastic analysis methods in certain acceptable combinations for all three elements. The selection of these acceptable combinations assumes that 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 and piping). Because large deformations always affect the stress distribution, care should be exercised even when using the plastic analysis method in the methodology combination approved in Appendix F. This is especially important for identifying buckling or instability problems when the change of geometry should be considered to avoid erroneous results.

5. Function of Supported System

In selecting the level of service limits for different loading combinations, the decision must take into account the function of the supported system. To ensure that systems will operate properly regardless of plant condition if their normal function is to prevent or mitigate the consequences of events associated with an emergency or faulted plant condition [e.g., the function of the emergency core cooling system (ECCS) during faulted plant conditions], it is appropriate to use the level A or B service limits specified in Subsection NF of the ASME Code Section III (or other justifiable limits provided by the code).

Because NF-3320 derived all equations from American Institute of Steel Construction (AISC) rules and many AISC compression equations have built-in constants based on mechanical properties of steel at room temperature, it would be imprudent to use these equations indiscriminately for all NF sections and the latest accepted version of ASME Code Cases N-71 and N-249 involving materials at all temperatures. 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

Because component and piping supports are deformation-sensitive load-bearing elements, satisfying the service limits of Section III will not automatically ensure their proper function. If specified by the code design specification, deformation limits might be the controlling criterion. However, if a particular plant condition does not require the function of a support, the stresses or loads resulting from the loading combinations under that plant condition do not need to satisfy the design limits for the plant condition.

7. Definitions

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

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

Normal Plant Conditions. Those operating conditions that occur in the course of system startup, operation, hot standby, refueling, and shutdown, with the exception of upset, emergency, or faulted plant conditions.

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

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

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

Service Limits. Stress limits for the design of component and piping supports, defined by Subsection NF of Section III of the ASME Boiler and Pressure Vessel Code.

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

Operating-Basis Earthquake (OBE). Seismic event defined in Appendix A to 10 CFR Part 100, “Reactor Site Criteria.

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

Specified Seismic Events. Operating-Basis Earthquake (OBE) and Safe-Shutdown Earthquake (SSE), defined above.

System Mechanical Loadings. The static and dynamic loadings developed by the system operating parameters — including deadweight, pressure, and other external loadings — and effects resulting from constraints of free-end movements, but excluding effects resulting from thermal and peak stresses generated within the component or piping support.

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

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

C. REGULATORY POSITION

The construction of ASME Code² Class 1 linear-type component and piping supports excluding snubbers, which this guide does not address, should follow the rules of Subsection NF of Section III, as supplemented by the stipulations below.³

1. The classification of component and piping supports should, as a minimum, be the same as that of the supported components and piping.
2. The ASME Code level A and B service limits for component and piping supports designed by linear elastic analysis, which are related to S_y , should meet the appropriate stress limits of Subsection NF 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 Regulatory Positions 2a, 2b, and 2c:
 - a. The tensile stress limit F_t for a net section, as specified in NF-3322.1(a)(1) of Section III, should be the lesser of two values, $0.6S_y$ or $0.5S_u$, at temperature. For net sections at pinholes in eyebars, pin-connected plates, or built-up structural members, F_t as specified in NF-3322.1(a)(2) should be the lesser of two values, $0.45S_y$ or $0.375S_u$, at temperature.
 - b. The shear stress limit F_v for a gross section as specified in NF-3322.1(b)(1) of Section III, should be the lesser of two values, $0.4S_y$ or $0.33S_u$, at temperature.
 - c. The bending stress limit F_b resulting from tension and bending in structural members as specified in NF-3320, should be (1) the lesser value of $0.66 S_y$ or $0.55 S_u$, at temperature, for compact sections, (2) the lesser value of $0.75 S_y$ or $0.63 S_u$, at temperature, for doubly symmetrical members with bending about the minor axis, and (3) the lesser value of $0.6 S_y$ or $0.5 S_u$, at temperature, for box-type flexural members and miscellaneous members.

Many of the limits and equations for compression strength specified in NF-3320 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 re-derived with the appropriate Young's Modulus unless the conservatism of using these constants as specified is demonstrated.

3. Component and piping supports designed by linear elastic analysis may increase their level A or B service limits according to the provisions of NF-3321.1(a) of Section III of the ASME Code. F-1334 permits an increase of level A or B service limits for level D service limits by the lesser factor of 2 or $1.167S_u/S_y$ if $S_u > 1.2S_y$, or 1.4 if $S_u \leq 1.2S_y$, where S_y and S_u are support material properties at temperature.

However, all increases (i.e., those allowed by NF-3321.1(a) and F-1334) should always be subject to the limits in NF-3321.1(b). Material properties at temperature should be used to calculate the critical buckling strengths defined by NF-3321.1(b). As specified in F-1335, the allowable increase in tensile stress for bolts should not exceed the lesser value of $0.70 S_u$ or S_y , at temperature, and the allowable increase in shear stress for bolts should not exceed the lesser value of $0.42 S_u$ or $0.6 S_y$, at temperature.

² ASME Boiler and Pressure Vessel Code, Section III, Division I, 2001 Edition through the 2003 Addenda.

³ If the function of a component or piping support is not required during a plant condition, satisfaction of the design limits of the support for that plant condition is not needed, provided excessive deflection or failure of the support will not result in the loss of function of any other safety-related system.

If the increased service limit for stress range by NF-3321.1(a) is more than $2S_y$ or S_u , its limit should be the lesser of two values, $2S_y$ or S_u , unless a shakedown analysis justifies it.

4. The limits in Regulatory Positions 4a through 4d should apply to the design of component and piping supports subjected to the combined loadings of system mechanical loadings⁴ associated with (1) either the ASME Code design condition or the normal or upset plant conditions and (2) the vibratory motion of the OBE.^{5,6}

a. Supports designed by the linear elastic analysis method should not exceed the stress limits of NF-3320 of Section III and Regulatory Position 2 of this guide.

b. Supports designed by using the load-rating method should not exceed the service level A or service level B load rating of NF-3382 of Section III.

c. The lower bound test collapse load determined by NF-3340 and adjusted according to the provision of NF-3341.1(a) of Section III should not be less than that required to support a factored load equal to 1.7 times those of the service level A and B limits for supports designed by the limit analysis method.

d. Supports designed by using the experimental stress analysis method should not exceed the test collapse load determined by II-1400 of Section III divided by 1.7.

5. The limits in Regulatory Positions 5a through 5d should apply to the design of component and piping supports subjected to the system mechanical loadings associated with the emergency plant condition, except when the normal function of the supported system is to prevent or mitigate the consequences of events associated with the emergency plant condition (Regulatory Position 7 then applies).^{5,6}

a. Supports designed by using the linear elastic analysis method should not exceed the stress limits of NF-3320 and Regulatory Positions 2 and 3, increased according to the provisions of NF-3321.1(a) of Section III and Regulatory Position 3.

b. Supports designed by the load-rating method should not exceed the service level C load rating of NF-3382.2 of Section III.

c. The lower bound test collapse load determined by NF-3340 adjusted according to the provision of NF-3341.1(a) of Section III should not be less than that required to support a factored load equal to 1.3 times that of the service level C limit for supports designed by the limit analysis method.

d. Supports designed by using the experimental stress analysis method should not exceed the test collapse load determined by II-1400 of Section III divided by 1.3.

⁴ System mechanical loadings include all non-self-limiting loadings and the effects resulting from constraints of free-end displacements, but not the effects resulting from thermal or peak stresses generated within the component or piping support.

⁵ Because component and piping 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 Because the design of component and piping supports is an integral part of the design of the system and the component and piping, the designer should make sure that methods used for the analysis of the system, component and piping, and support are compatible. The designer of supports should consider large deformations in the system or components and piping.

6. The limits in Regulatory Positions 6a through 6d should apply to the design of component and piping supports subjected to the combined loadings of (1) the system mechanical loadings associated with the normal plant condition, (2) the vibratory motion of the SSE, and (3) the dynamic system loadings associated with the faulted plant condition, except when the normal function of the supported system is to prevent or mitigate the consequences of events associated with the faulted plant condition (Regulatory Position 7 then applies).

a. Supports designed by using the linear elastic analysis method should not exceed the stress limits of NF-3320 of Section III and Regulatory Position 2 of this guide, increased according to the provisions of F-1334 of Section III and Regulatory Position 3.

b. Supports designed by using the load-rating method should not exceed the lesser value of $TL \times 2F_{all}/S_u^*$ or $TL \times 0.7 S_u/S_u^*$, where TL , S_u , and S_u^* are defined in F-1332.7 of Section III and F_{all} is the allowable stress value defined in NF-3382.1.

c. Supports designed by the limit analysis method should not exceed the lower bound test collapse load determined by NF-3340, adjusted according to the provision of F-1334.6(a).

d. Supports designed by using the experimental stress analysis method should not exceed the test collapse load determined by II-1400, adjusted according to the provision of F-1334.6(c).

7. The limits in Regulatory Position 4 or other justifiable limits provided by the ASME Code should apply to the design of component and piping supports in systems whose normal function is to prevent or mitigate the consequences of events associated with an emergency or faulted plant condition. The design specification should define these limits, which are typically stated in the preliminary and final safety analysis reports (PSAR, FSAR), so that the function of the supported system will be maintained when it is subjected to the loading combinations described in Regulatory Positions 5 and 6.

D. IMPLEMENTATION

The purpose of this section is to provide information to licensees regarding the NRC staff's plans for using this regulatory guide. No backfitting is intended or approved in connection with the issuance of this guide.

Except in those cases in which a licensee proposes or has previously established an acceptable alternative method for complying with specified portions of the NRC's regulations, the NRC staff will use the methods described in this guide to evaluate (1) submittals in connection with applications for construction permits, standard plant design certifications, operating licenses, early site permits, and combined licenses; and (2) submittals from operating reactor licensees who voluntarily propose to initiate system modifications that have a clear nexus with the subject for which guidance is provided herein.

REGULATORY ANALYSIS / BACKFIT ANALYSIS

The regulatory analysis and backfit analysis for this regulatory guide are available in Draft Regulatory Guide DG-1168, "Service Limits and Loading Combinations for Class 1 Linear-Type Component Supports."⁷ The NRC issued DG-1168 in October 2006 to solicit public comment on the draft of this Revision 2 of Regulatory Guide 1.124.

⁷ Draft Regulatory Guide DG-1168 is available electronically under Accession #ML063000449 in the NRC's Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4209, by fax at (301) 415-3548, and by email to PDR@nrc.gov.