Article HAA-3000
Responsibilities and Duties

HAA-3200

HAA-3250 Provision of Design Specifications

HAA-3252 Contents of Design Specifications

(a) The Design Specifications shall contain sufficient detail to provide a complete basis for Division 5 construction. Such requirements shall not result in construction that fails to conform with the rules of this Division. All Design Specifications shall include (1) through (8).

(1) the functions and boundaries of the items covered (NCA-3254)

(2) the design requirements (HAA-2100 and NCA-2140), including all required overpressure protection requirements (NCA-3220(m))

(3) the environmental conditions, including radiation (see Section III Appendices, Nonmandatory Appendix W for further insights and guidance)

(4) the Code classification of the items covered (Article HAA-2000)

(5) material requirements, including impact test requirements

(6) additional fracture mechanics data for base metal, weld metal, and heat-affected zone required to use Section III Appendices, Nonmandatory Appendix G, Figure G-2210-1 in accordance with Section III Appendices, Nonmandatory Appendix G, G-2110(b), when the methods of Section III Appendices, Nonmandatory Appendix G are used to provide protection against nonductile fracture for materials that have specified minimum yield strengths greater than 50.0 ksi (345 MPa) but not exceeding 90.0 ksi (620 MPa) at room temperature; where these materials of higher yield strengths are to be used in conditions where radiation may affect the material properties, the effect of radiation on the \( K_{ic} \) curve shall be determined for the material prior to its use in construction

(7) when functionality of a component is a requirement, the Design Specification shall make reference to other appropriate documents that specify those operating requirements

(b) The Design Specification shall identify those components and/or parts that require a preservice examination and shall include the following:

(1) examination

   (a) Edition of Section XI to be used
   (b) category and method
   (c) qualifications of personnel, procedures, and equipment

(2) welds

   (a) surface conditioning requirements
   (b) identification/marking system to be used

Section III Appendices, Nonmandatory Appendix KK provides additional guidance on what a Division 5 Design Specification should contain as well as additional insights.
ARTICLE HBB-2000
MATERIAL

HBB-2100

HBB-2120  PRESSURE-RETAINING MATERIALS

(a) All materials shall comply with the rules of Division 1, Article NB-2000, except for those paragraphs replaced by correspondingly numbered paragraphs of Subsection HB, Subpart B.

(b) In complying with (a) above, the base and weld material specifications of Tables HBB-I-14.1(a) and HBB-I-14.1(b), Tables HBB-I-14.10A-1 through HBB-I-14.10E-1, and Table HBB-I-14.11 and the allowable stress intensities in Tables HBB-I-14.3A through HBB-I-14.3E, and Figures HBB-I-14.13A through HBB-I-14.3C shall be considered extensions of Section II, Part D, Subpart 1, Tables 2A, 2B, and 4.

(c) Pressure-retaining material and material welded thereto, except for temporary or nonstructural attachments as per Division 1, NB-4435 and in (h) below, and except for hard surfacing metals and cladding which is 10% or less of the thickness of the base material, shall conform to the requirements of one of the specifications for material given in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4, including all applicable footnotes in the table, and to all of the special requirements of this Article which apply to the product form in which the material is used.

(d) The requirements of this Article do not apply to items not associated with the pressure-retaining function of a component such as shafts, stems, trim, spray nozzles, bearings, bushings, springs, wear plates, and associated piping for safety and control systems. The requirements of this Article do not apply to items not associated with the pressure-retaining function of a component such as shafts, stems, trim, spray nozzles, bearings, bushings, springs, wear plates, and associated piping for safety and control systems.

(e) Material made to specifications other than those specified in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4 may be used for safety and control systems. The requirements of this Article do not apply to items not associated with the pressure-retaining function of a component such as shafts, stems, trim, spray nozzles, bearings, bushings, springs, wear plates, and associated piping for safety and control systems.

(f) Material for instrument line fittings, NPS 1 (DN 25) and less, may be of material made to specifications other than those listed in Section II, Part D, provided that the fittings are in conformance with the requirements of Division 1, NB-3671.4 and the material is determined to be adequate for the service conditions by the piping system designer.

(g) Welding material used in the manufacture of items shall comply with Table HBB-I-14.1(b) and the SFA specifications in Section II, Part C, and shall also comply with the applicable requirements of this Article. The requirements of this Article do not apply to material used as backing rings or backing strips in welded joints.

(b) Attachments welded to a pressure boundary (including the weld metal used to make the attachment) expecting elevated temperature service need not comply with the limits on upper values of service temperatures and times, as stated in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4, provided the rules listed below are met.

(1) The design of the welded attachment complies with the rules in HBB-3354.

(2) The attachment material and weld are of similar alloy composition to the pressure boundary material.

HBB-2123  Design Stress Intensity Values

Design stress intensity values for material are listed in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4, as extended in coverage by the rules of HBB-2121(b). With the exception of attachment material covered by HBB-2121(h), no material shall be used at metal and design temperatures above those for which values are given.

HBB-2160  DETERIORATION OF MATERIAL IN SERVICE

(a) Consideration of deterioration of material caused by service is generally outside the scope of this Subsection. It is the responsibility of the Owner to select material suitable for the conditions stated in the Design Specifications (NCA-3250), with specific attention being given to the effects of service conditions upon the properties of the material.

(b) Special consideration shall be given to the effects of irradiation on the properties of the material (including welding material) in the core belt line region of the reactor vessel. Any special requirement shall be specified in the Design Specifications (NCA-3252 and Division 1, NB-3124). When so specified, the check analysis shall be made in accordance with the base metal specification and in accordance with Division 1, NB-2420 for the welding material.

(c) The combination of fabrication induced cold working and subsequent elevated temperature service may affect time-dependent material properties.
ARTICLE HBB-3000
DESIGN

HBB-3100 GENERAL REQUIREMENTS FOR DESIGN

HBB-3110 SCOPE, ACCEPTABILITY, AND LOADINGS

HBB-3111 Scope

(a) Article HBB-3000 is a self-contained set of design rules for metal structures serving as component pressure-retaining boundaries under temperatures that may at times exceed those for which design stress-intensity values $S_m$ are given in Section II, Part D, Subpart 1.

(b) The design rules of Division 1, Article NB 3000 shall apply only where specifically called out by the rules of Subsection HB, Subpart B.

HBB-3111.1 Acceptability. An acceptable design of a Class A Component for elevated temperature service is one that

(a) is capable of meeting the functional requirements as specified in the Design Specifications (NCA-3250); and

(b) satisfies the requirements for a design by analysis, either in HBB-3200 or in the Design Rules for components, while under the loadings described in HBB-3111.2 and the Design Specifications; and

(c) satisfies the general design rules of HBB-3130 and the applicable design rules for components that apply to a vessel (HBB-3300), pump (HBB-3400), valve (HBB-3500), or piping (HBB-3600). The Design Specifications shall state which subarticle applies to the given component.

(d) As an alternative to (b) and (c) above, the rules of Division 1, Article NB 3000 may be applied to those portions of the component that never experience temperatures that exceed the temperature limit in the applicability column for which design stress-intensity values are given in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4.

HBB-3111.2 Loadings. The loadings that shall be taken into account in designing a component include, but are not limited to, the following:

(a) internal and external pressure;

(b) weight of the component and its normal contents under service or test loadings, including additional pressure due to static and dynamic head of liquids;

(c) superimposed loads such as from other components, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping;

(d) wind loads, snow loads, vibrations, and earthquake loads where specified;

(e) reactions of supporting lugs, rings, saddles, or other types of supports;

(f) temperature effects;

(g) impact forces caused by either external or internal events.

HBB-3112 Design Parameters

(a) The design parameters are the pressures, temperatures, and mechanical load forces of nuclear power plant components. The simplest set of design parameters would consist of the temperature, pressure, and load forces that exist at some given time.

(b) To design a zone of a component for service at elevated temperature, two types of design parameter data are needed in the Design Specifications (NCA-3250): first, an expected loading history which consists of how each design parameter varies as a function of time; and second, a list of events that occur under each loading category defined in HBB-3113.

(c) The design parameter data stipulated in (1) and (2) below shall be specified in the Design Specifications (NCA-3250) for each component:

(1) the loading event history to be used in the structural analysis;

(2) the design parameters from which the designer will determine the most severe loading for each loading category defined in HBB-3113. (If fluid conditions are specified, the designer eventually must convert the data to metal temperatures and surface pressures.)

(d) It is permissible for the designer to establish the zone boundaries inside the component. However, the zone boundaries and applicable design parameters shall be fully described in the Design Report.

HBB-3112.1 Specified Pressure.

(a) The specified internal and external pressure histories shall describe pressure values not less than the maximum pressure differences between the inside and outside of the pressure boundary in a given zone of the component, or between any two chambers of a combination unit.

(b) The specified pressure histories shall be used in the computations made to show compliance with the limits of HBB-3200.
HBB-3112 Specified Temperature. The specified temperature history for the loading category shall enable the designer to describe a temperature value not less than the maximum local wall averaged temperature that will exist in the structural metal in a given zone of the component. And for the particular analyses of Service Loadings (HBB-3113.2), the designer shall determine the history of the maximum local metal temperature in a given zone and shall use these metal temperature histories in the computations to show compliance with the limits of HBB-3200.

(a) All temperatures referred to in this Article are the metal temperatures expressed in degrees Fahrenheit (°F) or degrees Celsius (°C).

(b) Where a component is heated by trace heating, induction coils, jacketing, or by internal heat generation, the designer shall consider the effect of such heating in the establishment of the design temperature histories.

(c) Elevated temperature mechanical properties are extremely sensitive to temperature. The Design Specifications shall specify any inaccuracies in temperature measurement and prediction that are to be considered in the design analyses made to show compliance with the limits of HBB-3200.

HBB-3112.3 Specified Mechanical Load Forces. The specified load forces for a given loading category (HBB-3113) shall define all expected mechanical loadings that must be considered in design analysis computations made to show compliance with the limits of HBB-3200.

HBB-3113 Loading Categories

Loading categories used in this Subsection consist of Design Loadings, Service Loadings (Levels A, B, C, and D), and Test Loadings.

HBB-3113.1 Design Loadings. The specified design parameters for the Design Loadings category shall equal or exceed those of the most severe combination of coincident pressure, temperature, and load forces specified under events which cause Service Level A Loadings (HBB-3113.3) for the same zone of the component. These specified design parameters for Design Loadings shall be called Design Temperature, Design Pressure, and Design Mechanical Loads. These specified design parameters shall be used in computations to show compliance with the requirements on Design Limits in HBB-3222.1.

HBB-3113.2 Service Loadings. Each loading to which the component may be subjected shall be categorized in accordance with the following definitions and shall be described in the Design Specifications (NCA-3250) in such detail as will provide a complete basis for construction in accordance with these rules. The Service Loading categories shall be as defined in HBB-3113.3, HBB-3113.4, HBB-3113.5, and HBB-3113.6.

HBB-3113.3 Level A Service Loadings. Level A Service Loadings are any loadings arising from system start-up, operation in the design power range, hot standby, and system shut-down, and excepting only those loadings covered by Level B, C, and D Service Loadings or Test Loading.

HBB-3113.4 Level B Service Loadings. (From incidents of moderate frequency.) These are deviations from Level A Service Loadings that are anticipated to occur often enough that design should include a capability to withstand the loadings without operational impairment. The events which cause Level B Service Loadings include those transients which result from any single operator error or control malfunction, transients caused by a fault in a system component requiring its isolation from the system, and transients due to loss of load or power. These events include any abnormal incidents not resulting in a forced outage and also forced outages for which the corrective action does not include any repair of mechanical damage. The estimated duration of a Level B Service Loading shall be included in the Design Specifications.

HBB-3113.5 Level C Service Loadings. (From infrequent incidents.) These are deviations from Level A Service Loadings that require shutdown for correction of the loadings or repair of damage in the system. The conditions have a low probability of occurrence, but are included to provide assurance that no gross loss of structural integrity will result as a concomitant effect of any damage developed in the system. The total number of postulated occurrences for such events may not exceed 25. If more than 25 are expected, then some types of events must be evaluated by the more stringent requirements of the Level B Service Limits.

HBB-3113.6 Level D Service Loadings. (From limiting faults.) These are combinations of loadings associated with extremely low probability, postulated events whose consequences are such that the integrity and functionality of the nuclear energy system may be impaired to the extent that only considerations of public health and safety are involved.

HBB-3113.7 Test Loadings. These are pressure loadings that occur during hydrostatic tests, pneumatic tests, and leak tests. Other types of tests shall be classified under either Service Level A or B loading categories given in HBB-3200. If any elevated temperature tests are specified as Test Loadings for a component, then these loadings shall be considered as part of the Service Level B loadings for the component.

Change to: NCA-3211.19
HBB-3114 Load Histogram

HBB-3114.1 Level A and B Service Events. The Design Specifications (NCA-3250) shall include an expected loading history or load histogram for all Service Loadings from Level A and B service events (including all Test Loadings). These load histograms shall give all expected mechanical load forces, pressure, and temperatures for the various zones of the component throughout its service life. These histograms are then used in meeting the analysis requirements of HBB-3200.

HBB-3114.2 Level C Service Events. The Design Specifications shall include a time history of the design parameters during each type of Level C Service event. However, these events need not be specified as to time of occurrence during the service life of the component. The design parameter data shall be used in meeting the analysis requirements of HBB-3200. Service events may be assumed to occur between operational cycles (HBB-3213.15) of Level A Service events unless otherwise specified in the Design Specifications (NCA-3250).

HBB-3120 SPECIAL CONSIDERATIONS

HBB-3121 Corrosion

Material subject to thinning by corrosion, erosion, mechanical abrasion, or other environmental effects shall have provision made for these effects during the design or specified life of the component by a suitable increase in or addition to the thickness of the base metal over that determined by the design formulas. Material added or included for these purposes need not be of the same thickness for all areas of the component if different rates of attack are expected for the various areas. It should be noted that the tests on which the design fatigue curves are based did not include tests in the presence of corrosive environments that might accelerate fatigue failure.

HBB-3122 Cladding

Cladding requirements are contained in HBB-3227.8.

HBB-3123 Welding

HBB-3123.1 Dissimilar Welds. In satisfying the requirements of this subarticle, caution should be exercised in design and construction involving dissimilar metals having different coefficients of thermal expansion in order to avoid difficulties in service.

HBB-3123.2 Fillet Welded Attachments. Fillet welded attachment requirements are contained in HBB-3356.2.

HBB-3124 Environmental Effects

Changes in material properties may occur due to environmental effects. In particular, fast neutron irradiation (>1 MeV) above a certain level may result in significant increase in the brittle fracture transition temperature and deterioration in the resistance to fracture at temperatures above the transition range (upper shelf energy). Therefore, nozzles or other structural discontinuities in ferritic vessels should preferably not be placed in regions of high neutron flux.

HBB-3125 Configuration

Accessibility to permit the examinations required by the edition and addenda of Section XI as specified in the Design Specification for the component shall be provided in the design of the component.

HBB-3130 GENERAL DESIGN RULES

HBB-3131 Scope

Design rules generally applicable to all components are provided in HBB-3130. The Design subarticle for the specific component provides rules applicable to that particular component. In case of conflict between HBB-3130 and the design rules for a particular component, the component design rules shall govern.

HBB-3132 Dimensional Standards for Standard Products

Dimensions of standard products shall comply with the standards and specifications listed in Table NCA-7100-1 when the standard or specification is referenced in the specific design subarticle. However, compliance with these standards does not replace or eliminate the requirements for stress analysis when called for by the design subarticle for a specific component.

HBB-3133 Size Restrictions in Nozzle, Branch, Piping, and Other Connections

The size of certain design features is restricted on nozzles, branch, piping, and other connections. Table HBB-3133-1 provides assistance in understanding where the limits are imposed.

HBB-3134 Leak Tightness

Where a system leak tightness greater than that required or demonstrated by a hydrostatic test is required, the leak tightness requirements for each component shall be set forth in the applicable Design Specifications (NCA-3250).

HBB-3135 Attachments

Lugs, brackets, stiffeners, and other attachments may be welded, bolted, or studded to the outside or inside of a component. The effects of attachments in producing thermal stresses, stress concentrations, and restraints on pressure-retaining members shall be taken into account in the analysis for compliance with design criteria of HBB-3200. For example, the temperature patterns around an attachment may lead to higher thermal stresses simply due to the cooling-fin effect of the attachment.
HBB-3224(d). It is permissible and often advantageous to separate a loading history into several load levels and into several temperatures at any given load level.

(g) Under all conditions where a bending loading occurs across a section, the propensity for buckling of that part of the section in compression shall be investigated under the requirements of HBB-3250.

HBB-3224 Level C Service Limits

The stress calculations required for Level C Service Loadings analysis are based on a linearly elastic material model. The calculated stress intensity values shall satisfy the conditions of (a) through (d) below.

(a) The general primary membrane stress intensity, derived from $P_m$ for Level C Service Loadings, shall not exceed the smaller of $1.2S_m$ and $1.0S_t$:

$$P_m \leq \begin{cases} 1.2S_m \\ 1.0S_t \end{cases}$$  \hspace{1cm} (7)

(b) In addition, the use-fraction sum associated with the general primary membrane stresses for all increments of primary loadings during Level A, B, and C Loadings shall satisfy the following requirements:

$$\sum_{i} \left( \frac{t_i}{t_{im}} \right) \leq B \hspace{1cm} (8)$$

where

$B = \text{use-fraction factor and is equal to 1.0 (or less if so specified in the Design Specifications [NCA-3250])}$

$t_i = \text{the total duration of a specific loading, } P_m, \text{ at elevated temperature, } T_i, \text{ during the entire service life of the component. Note that } \sum_{i} t_i \text{ is that part of the component service life at elevated temperatures (i.e., temperatures above values governed by the rules of Division 1, Subsection NB as explained in HBB-3211).}$

$t_{im} = \text{maximum allowed time under the load stress intensity, } S_i, \text{ as determined from a graph of } S_i-\text{vs-time (see Figures HBB-I-14.4A through HBB-I-14.4E).}$

The use of Figures HBB-I-14.4A through HBB-I-14.4E for determining $t_{im}$ for two loading conditions at two different temperatures is shown schematically in Figure HBB-3224-1. In Figure HBB-3224-1, $P_{m_i}$ ($i = 1, 2, 3, \text{ etc.}$) represents the calculated membrane stress intensity for the loading condition and temperature in question; and $T_i$ represents the maximum local wall averaged temperature during $t_i$. Note that it may be desirable to consider that a given stress intensity, $P_{m_i}$, acts during several time periods, $t_i$, in order to take credit for the fact that the temperature varies with time.

(c) The combined primary membrane plus bending stress intensities, derived from $P_L$ and $P_b$ for Level C Service Loadings, shall satisfy the following limits, with $1.0 < K \leq 1.5$:

$$P_L + P_b \leq 1.2K S_m$$  \hspace{1cm} (9)

$$P_L + P_b/K_t \leq S_t$$  \hspace{1cm} (10)

Change to: NCA-3211.19 3(c).

(d) In addition, the sum of the use-fractions associated with the primary membrane plus bending stresses for all increments of primary loadings during Level A, B, and C Service Loadings shall not exceed the value, 1.00:

$$\sum_{i} \left( \frac{t_i}{t_{ib}} \right) \leq 1.00$$  \hspace{1cm} (11)

where

$t_i = \text{the total duration of the loading at temperature, } T_i$; and

$t_{ib} = \text{the time value determined by entering Figures HBB-I-14.4A through HBB-I-14.4E at a value of stress equal to } P_L + P_b/K_t, \text{ as shown in Figure HBB-3224-2.}$

HBB-3225 Level D Service Limits

The rules of this paragraph may be used in the evaluation of components subjected to loads specified as Level D Service Loadings.

(a) The rules in HBB-3225 (and in Section III Appendices, Mandatory Appendix XXVII) shall be applied in all instances unless replaced by criteria, as required by public health and safety considerations for specific components or systems, are defined in, and made applicable by, the Owner’s Design Specifications [NCA-3250]. The type of analysis (elastic or inelastic)
used by the system designer shall be indicated in the Design Specifications (see Section III Appendices, Mandatory Appendix XXVII, XXVII-2000).

(b) The general primary membrane stress intensity, derived from $P_m$, for the Level D Service Loadings, shall not exceed the smaller of $0.67S_r$, $0.8R_{Sr}$, and one of the Level D Service Limits in Section III Appendices, Mandatory Appendix XXVII:

$$P_m \leq \begin{cases} \text{Limit in Mandatory Appendix XXVII for } P_m \\
0.67S_r \\
0.8R_{Sr} \end{cases}$$

(12)

where

$R = \text{the appropriate ratio of the weld metal creep strength to the base metal strength from Tables HBB-I-14.10A-1 through HBB-I-14.10E-1}$

$S_r = \text{the expected minimum stress-to-rupture in time } t \text{ taken from Figures HBB-I-14.6A through HBB-I-14.6F}$

(c) In addition, the use-fraction sum associated with the general primary membrane stresses that arise from all Service Loadings, shall satisfy the requirement:

$$\sum_{i} t_i / t_{ibr} \leq B_{r}$$

where

$B_r = \text{use-fraction factor and is equal to 1.0 (or less if so specified in the Design Specifications [NCA-3250])}$

$t_i = \text{the total duration of a specific loading, } P_{m,i}, \text{ at elevated temperature, } T_i, \text{ during the entire service life of the component. Note that } \sum_i (t_i) \text{ is that part of the component service life at elevated temperatures (i.e., temperatures above values governed by the rules of Division 1, Subsection NB, as explained in HBB-3211).}$

$t_{ir} = \text{maximum allowed time under the load stress intensity } 1.5P_{m,i} \text{ for base metal or, for weldments, the higher of } 1.5P_{m,i} \text{ or } (1.25/R)P_{m,i}. \text{ The allowable time under load is determined from the graph of minimum stress-to-rupture versus time (see Figures HBB-I-14.6A through HBB-I-14.6F).}$

The use of Figures HBB-I-14.6A through HBB-I-14.6F for determining $t_{ir}$ for two loading conditions at two different temperatures is shown schematically in Figure HBB-3224-1. In Figure HBB-3224-1, $1.5P_{m,i} (i = 1, 2, 3, \text{ etc.})$ represents 1.5 times the calculated membrane stress intensity for the loading condition and temperature in question, and $T_i$ represents the maximum local wall averaged temperature during $t_i$. Note that it may be desirable to consider that a given stress intensity acts during several time periods, $t_i$, in order to take credit for the variation of temperature with time.

(d) The combined primary membrane plus bending stress intensities, derived from $P_L$ and $P_b$, shall satisfy the following limits, with $1.0 \leq K \leq 1.5$, and Level D Service Limits in Section III Appendices, Mandatory Appendix XXVII for $P_L + P_b$:

$$P_L + P_b / K_t \leq \begin{cases} 0.67S_r \\
0.8R_{Sr} \end{cases}$$

(13)

where $K_t$ is defined in HBB-3223(c).

(e) In addition, the sum of the use-fraction associated with the primary membrane plus bending stresses that arise from all Service Loadings, shall not exceed the value of 1.00:

$$\sum_{i} t_i / t_{ibr} \leq 1.00$$

where

$t_i = \text{the total duration of loading at temperature, } T_i$

$t_{ibr} = \text{the time value determined by entering Figures HBB-I-14.6A through HBB-I-14.6F at a value of stress equal to } 1.5(P_L + P_b / K_t) \text{ for base metal or higher of } 1.5(P_L + P_b / K_t) \text{ and } 1.25(P_L + P_b / K_t) / R \text{ for weldments as shown in Figure HBB-3224-2.}$

(f) For the purpose of Section III Appendices, Mandatory Appendix XXVII calculations, the yield strength and tensile strength values shall be defined as follows:

(1) Yield strength values shall be the product of the value shown in Table HBB-I-14.5 and the strength reduction factor shown in Tables HBB-3225-2, HBB-3225-3A, and HBB-3225-3B.
HBB-3233.2 Maximum Stress in the Cross Section. The maximum values for service stresses (averaged across the bolt cross section and neglecting stress concentrations), such as those produced by a combination of pre-load, pressure, and thermal expansion, shall not exceed two times the \( S_{m_t} \) values of Figures HBB-I.14.13A through HBB-I.14.13C unless the design lifetime is divided into two or more loading periods and the possibility of creep rupture due to membrane stresses is guarded against by satisfying the use-fraction rule described in HBB-3224(b), with the use-fraction factor, \( B \), set equal to 0.67. Stress intensity, rather than maximum stress, shall be limited to this value when bolts are tightened by devices which result in residual torsion stresses. Residual torsion stresses are minimized by devices such as heaters and stretchers. 

HBB-3233.3 Maximum Stress in the Bolt Periphery. The maximum value of service stress at the periphery of the bolt cross section (resulting from tension-plus-bending and neglecting stress concentrations) shall not exceed the lesser of three times the \( S_{m_t} \) values in Figures HBB-I.14.13A through HBB-I.14.13C or \( K_s S_t \) unless the design lifetime is divided into two or more loading periods and the possibility of creep rupture due to bending stresses is guarded against by satisfying the use-fraction rule described in HBB-3224(d), but with the use-fraction set at 0.67 instead of 1.0. Stress intensity, rather than maximum stress, shall be limited to this value when bolts are tightened by devices that result in residual torsion stresses. Residual torsion stresses are minimized by devices such as heaters and stretchers. 

HBB-3233.4 Nonductile Fracture. The rules of HBB-3241 shall apply to bolts. 

HBB-3234 Level C Service Limits 
The limits of HBB-3233 shall apply to primary loads in bolts. 

HBB-3235 Level D Service Limits 
The rules of HBB-3225 shall apply to primary loads in bolts. 

HBB-3240 SPECIAL REQUIREMENTS FOR ELEVATED TEMPERATURE COMPONENTS 

HBB-3241 Nonductile Fracture 
(a) A portion of the Design Report (NCA-3550) shall justify the ability of the component to withstand the expected service conditions without undergoing nonductile fracture. Even though components are not expected to fail by nonductile fracture while at elevated temperatures, the stress relaxation occurring under elevated temperatures will often lead to high residual stresses during the portion of the operational cycle with lowest temperatures. For loading times, stresses, and temperatures where creep effects are not significant (HBB-3211), an acceptable procedure for nonductile failure prevention is given in Section III Appendices, Nonmandatory Appendix G for ferritic materials. When Section III Appendices, Nonmandatory Appendix G is not applicable, the fracture analysis shall consider the anticipated stress level and flaw size, and compare these conditions with the fracture toughness of the material in the flaw region and at the appropriate temperature. 

(b) The above justification requirements do not apply to Type 304 SS, Type 316 SS, or Alloy 800H, unless the fabrication effects substantially alter the fracture characteristics of these materials in such a manner that nonductile fracture becomes a plausible failure mode. The Design Specifications shall state when and how environmental effects shall be considered for nonductile fracture behavior in these materials.
required for a shell of the same diameter. The adequacy of the transition shall be evaluated by stress analysis. See HBB-3200 for stress intensity limitations and other rules. The requirements of this paragraph do not apply to flange hubs.

**HBB-3362 Bolted Flange Connections**

It is recommended that the dimensional requirements of bolted flange connections to external piping conform to ASME B16.5, Steel Pipe Flanges and Flanged Fittings.

**HBB-3363 Access Openings**

Access openings, where provided, shall preferably consist of handhole or manhole openings having removable covers. These covers may be located on either the inside or outside of the shell or head openings and may be attached by studs or bolts in combination with gaskets and/or welded membrane seals or strength welds. Plugs using pipe threads are not permitted.

**HBB-3364 Supports**

All vessels shall be so supported and the supporting members shall be arranged and attached to the vessel wall in such a way as to provide for the maximum imposed loadings. The stresses produced in such loadings and by steady state and transient thermal conditions shall be subjected to the stress limits of Subsection HB, Subpart B (NCA-3240 and Division 1, Subsection NF).

**HBB-3400 DESIGN OF CLASS A PUMPS**

**HBB-3410 GENERAL REQUIREMENTS**

**HBB-3410.1 Scope.** The rules of this subarticle constitute requirements for the design of Class A pumps.

(a) The scope of these rules covers the strength and pressure integrity of the structural parts of pumps whose failure would violate the pressure boundary.

(b) Such parts include

1. pump casing
2. pump inlets and outlets
3. pump cover
4. clamping ring
5. seal housings
6. related bolting
7. pump internal heat exchanger piping
8. pump auxiliary nozzle connections up to the face of the first flange or circumferential joint, except as noted below
9. piping identified with the pump and external to or forming a part of the pressure-retaining boundary and supplied with the pump
10. mounting feet or pedestal supports when integrally attached to the pump pressure-retaining boundary and supplied with the pump

(c) The requirements of this subarticle do not apply to the pump shaft, nonstructural internals, or the seal package. Compliance with the requirements of this subarticle does not guarantee proper functioning of the component.

**HBB-3410.2 Definitions.**

(a) A radially split casing shall be interpreted as one in which the primary sealing joint is radially disposed around the shaft.

(b) An axially split casing shall be interpreted as one in which the primary sealing joint is axially disposed with respect to the shaft.

(c) Seal housing is defined as that portion of the pump cover or casing that forms the primary pressure boundary.

(d) The figures accompanying the pump types are intended to be typical examples to aid in the determination of a pump type and are not to be considered as limiting. Bearing locations and inlet and outlet orientations are optional.

(e) The seal gland plate is to be considered a part of the seal housing and therefore is subject to Code requirements. The seal chamber pressure shall be specified in the Design Specification.

(f) Figures HBB-3410.2-1 and HBB-3410.2-2 show typical single and double volute casings, respectively.

**HBB-3411 Acceptability of Large Pumps**

(a) The requirements for the design of a Class A pump having an inlet connection greater than NPS 4 (DN 100) are stated in HBB-3111.1.
HBB-3421.11 Stress Analysis, Nozzle Loads, and Reinforcement.

(a) Stress Analysis. The analysis methods in Division 1, NB-3400 shall apply only to elastic analysis. In particular, stress equations may be used in satisfying the limits on load-controlled stresses, and they may be applied to analysis under HBB-3250 when creep effects are insignificant [HBB-3211(c)].

(b) Nozzle Loads. The forces and moments produced by the connected piping on the pump inlet and outlet shall be furnished to the pump supplier by the user in accordance with NCA-3254.

(c) Reinforcement. The distance \( \ell \) in Figure HBB-3421.11-1 is the limit of reinforcement. The value of \( \ell \) shall be determined from the relationship:

\[
\ell = 0.5 \sqrt{r_m t_m}
\]

where

- \( r_i = \text{inlet or outlet inside radius} \)
- \( r_m = r_i + 0.5t_m \)
- \( t_m = \text{mean inlet or outlet wall thickness taken between section } x-x \text{ and a parallel section } y-y \text{ tangent to crotch radius} \)

HBB-3421.12 Earthquake Design Analysis. When earthquake loadings are specified in the Design Specification (NCA-1260), the designer shall assess the ability of the pump to withstand such loadings while maintaining the integrity of the pressure-retaining materials. For example, the assessment should include inertia effects from moving parts and piping reactions.

HBB-3421.13 Attachments. Attachments are permitted when designed in accordance with HBB-3135 and Division 1, NB-4430.

HBB-3421.14 Appurtenances. Appurtenances as defined in NCA-1260 are permitted provided the requirements for documentation are fulfilled as described in NCA-1260.

HBB-3421.15 Pump Covers. Pump covers shall be designed in accordance with HBB-3200.

HBB-3421.17 Cladding. The design of clad pressure-retaining parts shall be in accordance with HBB-3227.8.

HBB-3421.19 Cutwater Tip Stresses. It is recognized that localized high stresses can occur at the cutwater tip of volute casings (Division 1, Figure NB-3441.3-2). Adequacy of the design in this area shall be demonstrated as follows:

(a) an evaluation of load-controlled stresses showing that sufficient area is available in the volute casing to meet the stress limit of HBB-3220; and

(b) an evaluation of the localized stress at the cutwater tip by:

(1) an investigation through experimental analysis in accordance with Section III Appendices, Mandatory Appendix II; or by

(2) a detailed stress analysis; or by

(3) a combination of the above.

(c) Where experimental and/or detailed stress analysis is used, stress and strain intensity at this point shall meet the requirements of HBB-3250.

HBB-3430 PUMP TYPES

Design requirements for specific pump types are listed in Division 1, NB-3430.

HBB-3500 DESIGN OF CLASS A VALVES

HBB-3510 DESIGN REQUIREMENTS

HBB-3511 Acceptability

(a) The requirements for acceptability of a Class A valve design are stated in HBB-3111.1.

(b) Compliance with the requirements of this subarticle does not guarantee proper functioning of the component.

(c) In cases of conflict between this subarticle and the rules of HBB-3100 and HBB-3200, the requirements of HBB-3500 shall govern.

HBB-3512 Stress Analysis

The analysis methods in Division 1, NB-3500 shall apply only to elastic analysis. In particular, the stress indices and stress equations may be used in satisfying the limits
on load-controlled stresses, or they may be applied to analyses under HBB-3250 when creep effects are insignificant [HBB-3211(c)].

HBB-3520

HBB-3524 Earthquake Design Analysis

(a) When earthquake loadings are specified in the Design Specifications (NCA-3250), the designer shall assess the ability of the valve to withstand such loadings while maintaining the integrity of the pressure boundary materials. For example, the assessment should include inertia effects from moving parts and piping reactions.

(b) Where valves are provided with operators having extended structures and the Design Specifications state that these structures are essential to maintaining pressure integrity, an analysis may be based on static forces resulting from equivalent earthquake accelerations acting at the centers of gravity of the extended masses.

HBB-3526 Level C Service Limits

(a) If valve function is not required during any Level C Service Loadings included in the Design Specifications, the rules used in evaluating these conditions shall be those of HBB-3510.

(b) If valve function must be assured during Level C Service Loadings, this requirement shall be included in the Design Specifications and the specified emergency conditions for the plant shall be considered as the Level A Service Loadings for the valve.

HBB-3540

HBB-3544 Body Shape Rules

The rules of Division 1, NB-3544 provide a convenient guide for design of valve bodies for elevated temperature service. However, specific rules may be bypassed when justified by analysis.

HBB-3546 Other Valve Parts

(a) For valve stems, stem retaining structures, and other significantly stressed valve parts whose failure can lead to gross violation of the pressure-retaining boundary, the primary stresses shall not exceed the stress intensity limit, \( S_o \). For materials not covered in Tables HBB-1-14.1(a), HBB-1-14.1(b), and HBB-1-14.2 but allowed under the rules of Division 1, NB-2121(c), the \( S_o \) values are those given in Section II, Part D, Subpart 1, Tables 2A and 2B.

(b) Valve designs requiring solenoid plunger type or electromagnetic indicator type core tubes may substitute HBB-3600 rules to govern the requirements for the extension.

HBB-3550 CYCLIC LOADING REQUIREMENTS

When cyclic conditions exist, the rules for analysis are covered by HBB-3250 and HBB-3512.
Where a fluid passes through heat exchangers in series, the design temperature of the piping in each section of the system shall conform to the most severe temperature condition expected to be produced by heat exchangers in that section of the system.

HBB-3620 DESIGN CONSIDERATIONS

HBB-3622 Dynamic Effects

HBB-3622.1 Impact. Impact forces caused by either external or internal conditions shall be considered in the piping design.

HBB-3622.2 Earthquake. The effects of earthquake shall be considered in the design of piping and supports. The loadings, movements (earthquake anchor movements), and number of cycles to be used in the analysis shall be part of the Design Specifications (NCA-3250). The stresses resulting from these earthquake effects must be included with weight, pressure, or other applied loads when making the required analysis.

HBB-3622.3 Vibration. Piping shall be arranged and supported so that vibration will be minimized. The designer shall be responsible, by design and by observation under startup or initial operating conditions, for ensuring that vibration of piping systems is within acceptable levels.

HBB-3623 Weight Effects

Piping systems shall be supported to provide for the dynamic effects of any contained fluid and for the fixed weights of piping, insulation, and other imposed mechanical loads in the piping.

HBB-3624 Loadings, Displacements, and Restraints

The design of piping systems shall take into account the forces and moments resulting from thermal expansion and contraction, equipment displacements and rotations, and the restraining effects of hangers, supports, and other localized loadings.

HBB-3626 Special Drainage Problems

(a) For piping systems that must be drained, consideration shall be given to creep induced sag that may develop between pipe supports in elevated temperature systems.

(b) For piping systems that drain at intermediate or elevated temperatures, consideration shall be given to load cycles associated with this condition.

HBB-3627 Considerations for Liquid Metal Piping

HBB-3627.1 Location. Routing of liquid metal piping in the vicinity of steam and water piping shall be avoided.

HBB-3627.2 Heat Tracing. Liquid metal piping shall be provided with heat tracing that shall be capable at least of maintaining the liquid metal in a molten condition. The use of steam or water for heat tracing shall not be permitted. Control of heat tracing shall provide for melting solidified liquid metal progressively from a free surface so that overpressure protection for the expansion of melting will not be required. Control shall also be adequate to assure that design rate of temperature change and temperature limits will not be exceeded.

HBB-3627.3 Filling and Draining.

(a) Liquid metal fill and drain shall be accommodated by means of an inert cover-gas purge and vent system. Volumetric expansion of liquid metal shall be provided for by a free liquid surface and a vented cover-gas space.

(b) All liquid metal piping shall be sloped to permit complete drainage by gravity into drain reservoirs. The use of small auxiliary drain lines shall be avoided.

HBB-3640 PRESSURE DESIGN OF COMPONENTS

HBB-3641

HBB-3641.1 Straight Pipe. The minimum wall thickness of pipe shall not be less than \( t_m \), where \( t_m \) is determined from the requirements for Design Loadings analysis in HBB-3222.1.

HBB-3642 Curved Segments of Pipe

HBB-3642.1 Pipe Bends. The design of pipe bends shall provide that the completed bend will satisfy the analysis requirements of HBB-3200. In addition to the basic dimensions of the bend (i.e., pipe diameter, wall thickness, and bend radius), the designer shall consider the secondary deformations and irregularities inherent to the bending process and shall define tolerances as needed to ensure conformance of the finished piping with the rules for analysis. In particular, the considerations of (a) through (e) below shall be taken into account.

(a) Wall thickness after bending shall not be less than the minimum wall thickness required for straight pipe.

<table>
<thead>
<tr>
<th>Bend Radius Versus Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of Bends</td>
</tr>
<tr>
<td>6 pipe diameters or greater</td>
</tr>
<tr>
<td>5 pipe diameters</td>
</tr>
<tr>
<td>4 pipe diameters</td>
</tr>
<tr>
<td>3 pipe diameters</td>
</tr>
</tbody>
</table>

NOTE:
(1) \( t_m \) is the required minimum thickness of the finished bend.
of the weakest pipe to be attached to the component, where the pipe burst pressure is calculated by the equation:

\[ P = \frac{2St}{D_0} \]

where

- \( D_0 \) = outside diameter of pipe
- \( S \) = specified minimum tensile strength of pipe material
- \( t \) = minimum specified wall thickness of pipe

**HBB-3650  ANALYSIS OF PIPING COMPONENTS**

**HBB-3651  General Requirements**

Until special rules for piping components are developed for elevated temperature service, the analysis requirements are given by (a), (b), and (c).

(a) The structural analysis shall demonstrate (by analysis or experiment or both) that the component fully complies with the requirements of **HBB-3200**.

(b) The primary and secondary stress indices (B and C) and corresponding stress equations of Division 1, NB-3600 may be used to determine stress intensities in satisfying the limits on load-controlled stresses (**HBB-3220**) and strain limits using elastic analysis (**HBB-T-1320**). Stress components determined from the stress indices given in Division 1, NB-3684, NB-3685, and, by reference, NB-3338 may be used in satisfying strain and creep-fatigue limits using elastic and simplified inelastic analyses (**HBB-T-1320**, **HBB-T-1330**, **HBB-T-1430**).

(c) Analytical methods such as finite element computer analyses may be used to provide detailed stress distributions.

**HBB-3660  DESIGN OF WELDS**

(a) Weld designs shall comply with the requirements of **HBB-3350** and **HBB-3337**.

(b) Socket welds and seal welded threads are generally not permitted for joints exposed to elevated temperature service. Exceptions shall be allowed only if the analytical requirements of this Subsection are satisfied at each junction and only if each application is specifically described as part of the Design Specifications (**NCA-3250**). In almost all systems containing nuclear coolant, such crevices and cracks are undesirable due to potential for trapped radioactive particles, problems with cleaning fluids, and impurities in the coolant. Joints allowed under the rules of this paragraph shall be limited to nominal diameters of 1 in. (25 mm) and smaller.

(c) Full penetration corner welds may be used (in addition to butt welds) for attaching branch connections and closures to piping in accordance with **HBB-3643.2** and **HBB-3646**, respectively.

**HBB-3670  SPECIAL PIPING REQUIREMENTS**

**HBB-3671  Nonwelded Piping Joints**

**HBB-3671.1  Excluded Designs.**

(a) Flared, flareless, and compression-type tubing fittings shall not be used.

(b) Expanded joints shall not be used.

(c) Caulked or leaded joints shall not be used.

(d) Soldered joints shall not be used.

**HBB-3671.6  Brazed Joints.** The rules of Division 1, NB-3671.6 apply. Any cooling liquid (or gas), including liquid sodium, is acceptable in the proximity of such joints provided the selected brazing material is compatible with the liquid.

**HBB-3671.7  Patented Joints.** Mechanical joints, for which no standards exist, and other patented joints may be used, provided that

(a) provision is made to prevent separation of the joints under all conditions of service.

(b) they are accessible for maintenance, removal, and replacement after operation.

(c) a prototype joint has been subjected either to performance tests to determine the safety of the joint under simulated service conditions (including the service fluid), or the joint meets all analysis requirements of **HBB-3200**.

When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or hydraulic shock is anticipated, a prototype joint has been subjected either to performance tests to determine the safety of the joint under service, thermal expansion, or hydraulic shock is anticipated, and, by reference, **HBB-3250**.

**HBB-3672  Expansion and Flexibility**

(a) In addition to meeting the design requirements for pressure, weight, and other loadings, piping systems shall be designed to absorb or resist thermal expansion or contraction or similar movements imposed by other sources, and shall meet the criteria as specified in **HBB-3200**. Piping systems shall be designed to have sufficient flexibility to prevent later installation or small branch lines, shall be considered.
ARTICLE HBB-7000
OVERPRESSURE PROTECTION

HBB-7100  GENERAL REQUIREMENTS

Overpressure protection for Section III, Class A components, when the metal temperature exceeds the Applicability and Max. Temp. Limits listed in Section II, Part D, Subpart 1, Tables 2A and 2B, shall be in accordance with the rules of Division 1, Article NB-7000, except as modified by Subsection HB, Subpart B.

HBB-7110  SCOPE

(a) Subsection HB, Subpart B provides overpressure protection rules for the pressure boundary structures which, having been designated by the Owner (NCA-1140 and NCA-3230) as a group of items requiring such protection, are not covered by Division 1, Article NB-7000 rules because some of the structures are expecting service temperatures above those currently allowed under the rules of Division 1, Subsection NB.

(b) Whereas the rules of Division 1, Article NB-7000 are oriented toward water and steam cooled reactor systems, the rules of Subsection HB, Subpart B encompass a wider variety of coolant fluids.

(c) The rules of Division 1, Article NB-7000 shall govern unless paragraphs are specifically altered by the rules of Subsection HB, Subpart B. All references to other Division 1, Article NB-7000 paragraphs are to be interpreted as referring to the Division 1, Article NB-7000 paragraphs as modified by Subsection HB, Subpart B.

(d) As with Division 1, Article NB-7000, the rules of this Subsection require that all system conditions, including transients, are described in the Design Specifications for the components being protected.

(e) In the evaluation of the effects of overpressure events, structural loadings shall include, but not be limited to, the types of events listed below.

   (1) system overpressure due to a closed valve, a blocking object, or a solid core of metal coolant
   (2) overpressure due to the addition of heat to an isolated portion of the system
   (3) overpressure due to nuclear transients
   (4) overpressure due to failure of a system component, including the effects of leaks from adjacent systems and possible resulting chemical reactions
   (5) overpressure resulting from operator error
   (6) overpressure due to constant pressure in combination with a rising overtemperature condition
   (7) overpressure due to pump overspeed

(f) Events whose overpressure effects are beyond the Scope of the rules of Subsection HB, Subpart B are covered by Division 1, NB-7110(b) and include, for example:
   (1) rapid closure of a check valve gate leads to fluid shock conditions in a local region
   (2) earthquake motions induce sloshing of fluids contained in large tanks
   (3) nuclear incident induces a severe pressure spike in a local region
   (4) rapid closure of a valve during high flow rate conditions introduces pressure shocks

HBB-7130  VERIFICATION OF THE OPERATION OF PRESSURE RELIEF DEVICES

Revise Division 1, NB-7131 to read:

(a) Pressure relief devices shall be designed so that potential impairment of the overpressure protection function from service exposure to fluids can be determined by test or examination.

HBB-7170  PERMITTED USE OF PRESSURE RELIEF DEVICES

Revise title of Division 1, NB-7173 to read:
Valve Types Permitted for Water Service
Revise Division 1, NB-7174 to read:
Division 1, NB-7174 Nonreclosing Devices
Rupture disk devices may be used in air, gas, or liquid metal service in accordance with Division 1, NB-7600.

HBB-7200  CONTENT OF OVERPRESSURE PROTECTION REPORT

Add to Division 1, NB-7220, the listing below:

(o) the effects of any thermal dissipation or discharge storage system on the pressure relief devices;

(p) the disposition of effluent from pressure relief devices for both primary and secondary reactor coolant fluids.

HBB-7300  RELIEVING CAPACITY

Revise Division 1, NB-7321(c) to read:
The system overpressure established for setting the required total rated relieving capacity of (b) above shall be such that the calculated stress intensity and other design
NONMANDATORY APPENDIX HBB-T
RULES FOR STRAIN, DEFORMATION, AND FATIGUE LIMITS AT ELEVATED TEMPERATURES

HBB-T-1100 INTRODUCTION

HBB-T-1110 OBJECTIVE

The objective of this Appendix is to provide rules that may be used by Owners and N Certificate Holders with respect to evaluation by analysis of strain, deformation, and fatigue limits for components whose load-controlled stresses are evaluated by the rules of Subsection HB, Subpart B.

HBB-T-1120 GENERAL REQUIREMENTS

HBB-T-1121 Type of Analysis

Where creep effects are presumed significant, inelastic analysis is generally required to provide a quantitative assessment of deformations and strains. However, elastic and simplified inelastic methods of analysis may sometimes be justified and used to establish conservative bounds for deformations, strains, strain ranges, and maximum stress in order to reduce the number of locations in a structure requiring detailed inelastic analysis.

HBB-T-1122 Analysis Required

The rules for design against gross distortion and fatigue are illustrated in Figure HBB-3221-1. The Design Loadings and Level D Service Loadings are exempted from strain and deformation limits as summarized below.

<table>
<thead>
<tr>
<th>Loadings</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>No deformation analysis required.</td>
</tr>
<tr>
<td>Service Levels A, B, and C</td>
<td>Apply the strain and deformation limits of Nonmandatory Appendix HBB-T. Regions not expecting any service time under elevated temperatures may use the secondary stress and fatigue limits of Section III Appendices, Mandatory Appendix XIII, XIII-3400, and XIII-3500 in place of the rules in HBB-T-1300, HBB-T-1400, and HBB-T-1700.</td>
</tr>
<tr>
<td>Service Level D</td>
<td>Strain and deformation limits not applicable except as necessary to satisfy Level D Service Loadings functional requirements.</td>
</tr>
<tr>
<td>Test</td>
<td>Consider as additional Level B Service Loadings.</td>
</tr>
</tbody>
</table>

HBB-T-1200 DEFORMATION LIMITS FOR FUNCTIONAL REQUIREMENTS

HBB-T-1210 STATEMENT IN DESIGN SPEC

Deformation limits to ensure proper component functioning shall be specified in the Design Specification (NCA-3250) for the component or shall be established by the N Certificate Holder for the proper performance of the component. Any such limits may restrict the design more severely than those specified for load-controlled stresses in HBB-3220.

HBB-T-1220 ELASTIC ANALYSIS METHOD

The limitations on loads from the rules and the other limits contained in HBB-3200 are intended to restrict the accumulated inelastic strain (averaged across a wall thickness) to 1% or less. However, when elastic analysis is used, the occurrence of inelastic strains of this magnitude may not be apparent. If functional deformation requirements are specified, the designer shall ensure that they are not violated by assuming that strains of 1% occur within the structure in that distribution which leads to the worst possible deformation state consistent with the directions of loading. If this deformation state does not lead to deformations greater than the specified limits, then all functional requirements shall be considered as demonstrated for the design.

HBB-T-1230 USE OF INELASTIC ANALYSIS

Inelastic analysis of deformations shall be used to demonstrate that deformations do not exceed specified limits, unless the elastic method of HBB-T-1220 has demonstrated compliance.

HBB-T-1300 DEFORMATION AND STRAIN LIMITS FOR STRUCTURAL INTEGRITY

HBB-T-1310 LIMITS FOR INELASTIC STRAINS

In regions expecting elevated temperatures, the maximum accumulated inelastic strain shall not exceed the following values.

(a) strains averaged through the thickness, 1%;
radius-to-thickness ratio. The temperature limits of Figure HBB-T-1522-3 are given in terms of radius-to-thickness ratio and are applicable for any design life.

HBB-T-1700 SPECIAL REQUIREMENTS

HBB-T-1710 SPECIAL STRAIN REQUIREMENTS AT WELDS

HBB-T-1711 Scope

Because of the potential for limited ductility of weld metal at elevated temperatures and the potential for high strain concentrations (both metallurgical and geometric) in the heat-affected zone of weldments, the additional analysis requirements of this Appendix shall be satisfied for all pressure boundary and other primary structural welds subjected under Service Level A, B, and C Loadings to metal temperatures where creep effects are significant (see HBB-3211). The potential for reduced ductility often precludes locating welds in regions of high loading.

HBB-T-1712 Material Properties

In calculating strain deformations in a weld region, the parent material properties shall be used up to the centerline of the weld.

HBB-T-1713 Strain Limits

Inelastic strains accumulated in the weld region shall not exceed one-half the strain values permitted for the parent material (see HBB-T-1310).

HBB-T-1714 Analysis of Geometry

The analysis for strains and creep–fatigue interactions at welds shall use stress and strain concentration factors appropriate for the worst surface geometry and shall be included in the Design Report (NCA-3550). The worst surface geometry for a given weld shall be determined by the methods described in HBB-3353.

HBB-T-1715 Creep–Fatigue Reduction Factors

In the vicinity of a weld (defined by ±3 times the thickness to either side of the weld centerline), the creep–fatigue evaluation of HBB-T-1400 shall utilize reduced values of the allowable number of design cycles \(N_d\) and the allowable time duration \(T_d\) in eq. HBB-T-1411(10). The \(N_d\) value shall be one-half the value permitted for the parent material (Figures HBB-T-1420-1A through HBB-T-1420-1E). The \(T_d\) value shall be determined from a stress-to-rupture curve obtained by multiplying the parent material stress-to-rupture values (Tables HBB-I-14.6A through HBB-I-14.6F) by the weld strength reduction factors given in Tables HBB-I-14.10A-1 through HBB-I-14.10E-1, and defined in HBB-3220. The factor \(K'\) (Table HBB-T-1411-1) must still be applied in this determination of \(T_d\).

HBB-T-1720 STRAIN REQUIREMENTS FOR BOLTING

HBB-T-1721 Strain Limits

The limits of HBB-T-1300 shall apply.

HBB-T-1722 Creep–Fatigue Damage Accumulation

The fatigue analysis exemptions in Section III Appendices, Mandatory Appendix XIII, XIII-3510 shall not apply. Creep and fatigue damage shall be assessed using eq. HBB-T-1411(10). The total damage factor, \(D\), shall be set at the appropriate value determined from Figure HBB-T-1420-2. Additional requirements are given in (a) and (b) below.

---

**Table HBB-T-1521-1**

<table>
<thead>
<tr>
<th>Time-Independent Buckling Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load Factor</strong></td>
</tr>
<tr>
<td><strong>Note (1)</strong></td>
</tr>
<tr>
<td><strong>Note (2)</strong></td>
</tr>
<tr>
<td>Design Loadings</td>
</tr>
<tr>
<td>Service Loadings</td>
</tr>
<tr>
<td>Level A</td>
</tr>
<tr>
<td>Level B</td>
</tr>
<tr>
<td>Level C</td>
</tr>
<tr>
<td>Level D</td>
</tr>
<tr>
<td>Test Loadings</td>
</tr>
</tbody>
</table>

**NOTES:**

(1) Changes in configuration induced by service need not be considered in calculating the buckling load.

(2) For thermally induced strain controlled buckling, the Strain Factor is applied to loads induced by thermal strain. To determine the buckling strain, it may be necessary to artificially induce high strains concurrent with the use of realistic stiffness properties. The use of an adjusted thermal expansion coefficient is one technique for enhancing the applied strains without affecting the associated stiffness characteristics.

(3) These factors apply to hydrostatic, pneumatic, and leak tests. Other types of tests shall be classified according to HBB-3113.7.

---

**Table HBB-T-1522-1**

<table>
<thead>
<tr>
<th>Time-Dependent Load-Controlled Buckling Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Service Loadings</strong></td>
</tr>
<tr>
<td>Level A</td>
</tr>
<tr>
<td>Level B</td>
</tr>
<tr>
<td>Level C</td>
</tr>
<tr>
<td>Level D</td>
</tr>
</tbody>
</table>
SUBPART B
ELEVATED TEMPERATURE SERVICE

ARTICLE HCB-1000
INTRODUCTION

HCB-1100 GENERAL

HCB-1110 SCOPE

The rules of this Subsection HC, Subpart B constitute the requirements associated with Class B metallic components used in the construction of high temperature reactor systems and their supporting systems when subjected to elevated temperature service.

(a) Subsection HC, Subpart B provides rules for the material, design, fabrication, examination, installation, testing, overpressure relief, marking, stamping, and preparation of reports by the Certificate Holder of metallic pressure boundary components or portions of those components that are intended to conform to the requirements for Class B construction for service when Service Loading temperatures exceed the appropriate temperature limits established in Table HAA-1130-1 for the material under consideration. These zones of elevated temperature service shall have their finalized geometry descriptions and temperature profile details finalized in the Design Report prior to any fabrication and examination efforts.

(b) The rules of Subsection HC, Subpart B are contained in Division 1, Subsection NC, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered HCB paragraphs or subparagraphs in this Subpart or new numbered HCB paragraphs or subparagraphs added to this Subpart.

(c) Division 1 rules may use different terminology than Division 5 (e.g., Class 2 versus Class B, etc.), but the application of these rules is identical for Division 5 use.

(d) References to Appendices are to the Section III Appendices, unless otherwise identified as a Subsection HC, Subpart B Appendix, or other subsection-specific Appendix.

(e) The rules of this Subpart cover the strength and pressure integrity of items the failure of which would violate the pressure-retaining boundary load stresses but do not cover deterioration that may occur in service as a result of corrosion, radiation effects, or instability of materials.

(f) This Subpart does not contain rules to cover all details of construction of Class B components. Where complete details are not provided in this Subpart, it is intended that the N Certificate Holder, subject to the approval of the Owner or his designee and acceptance by the Inspector, shall provide details of construction that will be consistent with those provided by the rules of this Subpart.

(g) The rules of this Subpart are independent of the type of nonlethal fluid contained by the component. However, if the Owner (or his designee) specifies in the Design Specification that the component will contain lethal substances or other hazardous substances such as sodium, then the additional requirements of HCB-3160, HCB-4160, and HCB-5160 shall also apply. The limited weld joint types and requirement that the welds shall be properly examined by radiography (HCB-3160 and HCB-5160, respectively) are intended to yield weld joints with no crevices.

(h) Design procedures and material data not contained in this Subpart may be required to ensure the structural integrity or continued functioning of the structural part during the specified service life. For example, the rules do not provide methods to evaluate deterioration that may occur in service as a result of corrosion, mass transfer phenomena, radiation effects, or other material instabilities. Nor do the rules ensure continued functional performance of deformation-sensitive structures such as valves and pumps.

(i) This Subpart is not applicable to storage tanks constructed in accordance with Division 1, NC-3900. This Subpart is not applicable to internal structures outside the scope of(j) below.

(j) The rules of this Subpart apply to those permanent attachments as described in the Design Specifications and to portions of components covered by the Code, as follows:

(1) Divisions 1 and 2, NCA-3252(a): Code Boundary Description in Design Specification

(2) Divisions 1 and 2, NCA-3254.1: Limits on Code Boundaries of Attachments

(3) Divisions 1 and 2, NCA-3251.1: Code Boundaries of Attachments
ARTICLE HCB-3000
DESIGN

HCB-3100 GENERAL DESIGN

All pressure-retaining material and material welded thereto shall meet the requirements of Division 1, Article NC-3000, except as modified herein.

HCB-3110

HCB-3114 Acceptability

An acceptable component design is one that meets the requirements of (a) through (c) below. Alternative methods are provided under (d) below.

(a) The design satisfies the general design requirements of HCB-3100.

(b) The design satisfies the appropriate component rules in either HCB-3300 (vessels designed by formula), HCB-3400 (pumps), HCB-3500 (valves), or HCB-3600 (piping). The Design Specification shall state which subarticle (HCB-3300, HCB-3400, HCB-3500, or HCB-3600) is appropriate for the particular component.

(c) The design shall guard against failure from low-energy fracture. The Design Specification may contain additional requirements as to tests, analyses, or other methods by which the designer can demonstrate proper consideration of this failure mode.

(d) The Certificate Holder may invoke alternative methods for demonstrating compliance to those portions of (a) and (b) above that relate to buckling, ratcheting, and creep–fatigue failure. However, these alternative methods shall be approved by the Owner. The Owner’s approval shall be indicated by incorporating the alternative methods and criteria into the Design Specifications.

HCB-3115 Design Report and Certification

(a) In addition to the requirements of Divisions 1 and 2, NCA-3550, a Design Report shall be prepared for a component if any portion (zone of elevated temperature service) is

1. designed in accordance with the rules in HCB-3630 of this Article
2. designed using either buckling rules in HCB-3114(d), HCB-3142, or HCB-3143 of this Article

(b) In addition to the applicable requirements from Divisions 1 and 2, NCA-3550, the contents of the Design Report shall include an evaluation of those zones of elevated temperature service of the component (and the details related to failure modes) described in (a)(1) and (a)(2) above.

(c) Design Reports shall be certified as being complete and correct by Certifying Engineers competent in elevated temperature component design.

HCB-3140 BUCKLING INSTABILITY LOADINGS

HCB-3141 General Requirements

(a) If a portion (zone of elevated temperature service) of a Class B component is subjected to buckling instability loadings and the conditions of Mandatory Appendix HCB-III are satisfied, then the rules of Division 1, NC-3133 shall apply for external pressure loadings.

(b) If Mandatory Appendix HCB-III is not satisfied, the limits on buckling loadings given in the remaining rules of HCB-3141, HCB-3142, and HCB-3143 shall be satisfied.

HCB-3141.1 Scope of Rules. The stability limits in Division 1, NC-3133 pertain only to specific geometrical configurations under specific loading conditions. These limits include the effects of initial geometrical imperfections permitted by fabrication tolerances. However, they do not consider the effects of creep due to long-term loadings at elevated temperatures and the effects of the other loads or other geometries. The rules in HCB-3141, HCB-3142, and HCB-3143 provide additional limits that are applicable to general configurations and loading conditions that may cause buckling or instability due to time-dependent creep behavior of the material. These additional limits are applicable to all loading conditions.

HCB-3141.2 Load-Controlled and Strain-Controlled Buckling. For the limits specified here, distinction is made between load-controlled buckling and strain-controlled buckling. Load-controlled buckling is characterized by continued application of an applied load in the post-buckling regime leading to failure, as exemplified by collapse of a tube under external pressure. Strain-controlled buckling is characterized by the immediate reduction of load due to strain-induced deformations. Even though it is self-limiting, strain-controlled buckling must be guarded against failure by fatigue, excessive strain, loss of function due to excessive deformation, and interaction with load-controlled buckling.

HCB-3141.3 Interaction of Load-Controlled and Strain-Controlled Buckling. For conditions under which strain-controlled and load-controlled buckling may interact, as exemplified by elastic follow-up, the higher Load
Factors applicable to load-controlled buckling shall be used for the combinations of load-controlled and strain-controlled loadings.

HCB-3141.4 Effects of Initial Geometry Imperfections. The requirements listed in (a) and (b) below shall be addressed.

(a) For load-controlled buckling, the effects of initial geometrical imperfections and tolerances shall be considered in the time-independent calculations according to the requirements of HCB-3142. The effects of geometrical imperfections and tolerances, whether initially present or induced by service, shall be considered in the time-dependent calculations of HCB-3143.

(b) In calculating the instability strain under pure strain-controlled buckling, the effects of geometrical imperfections and tolerances, whether initially present or induced by service, need not be considered. However, if significant geometrical imperfections are initially present, enhancement due to creep may cause excessive deformation or strain, and these effects shall be considered in the application of deformation and strain limits.

HCB-3141.5 Stress–Strain Data. The expected minimum stress–strain curve for the material at the specified temperatures shall be used. The expected minimum curve values may be obtained by taking the inelastic portion of the average hot tensile strength values (shown on isochronous stress–strain curves) and normalizing them to the tabulated yield strength values at the specified temperatures. Properties data are available in the rules for Class A components in elevated temperature service.

When re-solution annealed (see HCB-4215) Type 300 series austenitic stainless steel is utilized, the tabulated yield strength shall be further reduced by 17%. This reduction is not required if it is demonstrated by test that the room temperature yield strength meets the specified minimum values following re-solution annealing.

HCB-3142 Time-Independent Buckling Limits

For load-controlled buckling, the Load Factor, and for strain-controlled buckling, the Strain Factor, shall equal or exceed the values given in Table HBB-T-1521-1 for the specified Design and Service Loadings to protect against time-independent (instantaneous) buckling.

HCB-3143 Time-Dependent Buckling Limits

To protect against load-controlled time-dependent creep buckling, it shall be demonstrated that instability will not occur during the specified lifetime for a load history obtained by multiplying the specified service loads by the factors given in Table HBB-T-1522-1. A design factor is not required for purely strain-controlled buckling because strain-controlled loads are reduced concurrently with resistance of the structure to buckling when creep is significant.

HCB-3150 LIMITATIONS ON USE

(a) Unless the requirements of Mandatory Appendix HCB-III are satisfied, components with non-integral reinforcement, such as pad-type nozzles and pad-type branch connections, are not acceptable for elevated temperature service. The reinforcement requirements of Division 1, NC-3300 shall be satisfied only by material that is integral with either the nozzle, or vessel, or both. Weld metal added as reinforcement may be considered as integral metal.

(b) Socket welds may be used only for nominal diameter 2 in. (50 mm) or less.

HCB-3160 COMPONENTS CONTAINING LETHAL OR HAZARDOUS SUBSTANCES

For those components containing lethal substances or other hazardous substances such as sodium, the acceptable weld types shall comply with requirements (a) through (c) listed below.

(a) Category A weld joints in vessels and similar weld joints in other components shall be Type No. (1) (see Division 1, Subsection NC, NC-4262 for definitions).

(b) Category B and C weld joints in vessels and similar weld joints in other components shall be Type No. (1) or Type No. (2).

(c) Category D weld joints in vessels and similar weld joints in other components shall be full penetration welds extending through the entire thickness of the pressure boundary wall.

HCB-3300 VESSEL DESIGN

HCB-3310 GENERAL REQUIREMENTS

Class B vessel requirements for elevated temperature service as stipulated in the Design Specifications (Divisions 1 and 2, NCA-3250) shall conform to the design requirements of this Article.

(a) Elevated temperature Class B vessels designed by equation shall satisfy the requirements of Division 1, NC-3300, except as modified per HCB-3100.

(b) The rules of (a) above do not explicitly address fatigue damage resulting from cyclic service.

(c) For design calculations, the allowable stress values, \( S \), at elevated temperatures shall be obtained from the tables of Mandatory Appendix HCB-II. These tables are extensions of Section II, Part D, Subpart 1, Tables 1A, 1B, and 3.

HCB-3400 PUMP DESIGN

(a) Elevated temperature Class B pumps designed by equation shall satisfy the requirements of Division 1, NC-3400, except as modified per HCB-3100.
ARTICLE HCB-7000
OVERPRESSURE PROTECTION

HCB-7100  GENERAL REQUIREMENTS

All pressure-retaining material and material welded thereto shall meet the requirements of Division 1, Article NC-7000, except as modified herein.

(a) This Article provides Class B overpressure protection rules for those pressure boundary components, which having been designated by the Owner (Divisions 1 and 2, NCA-1140 and NCA-3220) as a group of items requiring such protection, are not covered by Division 1, Article NC-7000 rules because some of the components are expecting service temperatures above those currently allowed under the rules of Division 1, Subsection NC.

(b) Whereas the rules of Division 1, Article NC-7000 are oriented toward water and steam-cooled reactor systems, the rules of this Article envision a wider variety of coolant fluids.

(c) All references to other Division 1, Article NC-7000 paragraphs are to be interpreted as referring to the Division 1, Article NC-7000 paragraphs as modified by this Article.

(d) As with Division 1, Article NC-7000, the rules of this Article presume that all system conditions, including transients, are accurately described in the Design Specifications for the components being protected.

(e) In the evaluation of the effects of overpressure events, structural loadings shall include, but not be limited to, the types of events listed in (1) through (7) below.

1. system overpressure due to a closed valve, a blocking object, or a solid core of metal coolant
2. overpressure due to the addition of heat to an isolated portion of the system
3. overpressure due to nuclear transient effects
4. overpressure due to failure of a system component, including the effects of leaks from adjacent systems and possible resulting chemical reactions
5. overpressure resulting from operator error
6. overpressure due to constant pressure in combination with a rising over-temperature condition
7. overpressure due to pump overspeed

HCB-7110  SCOPE

(a) A system shall be protected from the consequences arising from the application of conditions of pressure and coincident temperature that would cause either the Design Pressure or the Service Limits specified in the Design Specification to be exceeded.

(b) Pressure relief devices are required when the operating conditions considered in the Overpressure Protection Report would cause the Service Limits specified in the Design Specification to be exceeded.

(c) Protection of components in the system from the effects of pressure increases of extremely short duration, such as water hammer resulting from the rapid closing of a valve, is beyond the scope of this Article. These effects shall be included in the Design Specification. Some examples of events whose overpressure transients are not considered in detail by the rules of this Article are

1. rapid closure of a check valve leading to fluid shock conditions in a local region
2. earthquake motions inducing sloshing of fluids contained in large tanks
3. nuclear incidents inducing a severe pressure spike in a local region
4. rapid closure of a valve during high flow rate conditions introducing pressure shocks

Note that each of the above events may lead to loss of coolant in systems utilizing nonreclosing overpressure relief devices.

HCB-7140  Draining of Pressure Relief Devices

(a) A pressure relief device installation shall be fitted with a drain at its lowest point where liquid or residue can collect if such liquid or residue could interfere with proper relieving operation.

(b) If the design of a pressure relief device permits liquid or residue to collect on the discharge side of the disk and could interfere with proper relieving operation, the device shall be fitted with a drain to minimize the collection of liquid or residue.

(c) Such drains shall discharge to a controlled thermal dissipation or discharge storage system, such as those provided for pressure relief devices.

HCB-7200  CONTENT OF REPORT

The Overpressure Protection Report shall define the protected systems and the integrated overpressure protection provided. As a minimum, the report shall include the following:
SUBSECTION HF
CLASS A AND CLASS B METALLIC SUPPORTS

SUBPART A
LOW TEMPERATURE SERVICE

ARTICLE HFA-1000
INTRODUCTION

HFA-1100 GENERAL

HFA-1110 SCOPE

The rules of this Subsection HF, Subpart A constitute the requirements associated with metallic component supports used in the construction of high temperature reactor systems and their supporting systems.

(a) Subsection HF provides rules for the material, design, fabrication, examination, and preparation of certification documents (Certificate of Compliance and NS-1 Certificate of Conformance) of supports for components and piping that are intended to conform to the requirements for Class A and B construction as set forth in Subsections HB and HC, respectively, of this Division. These rules are intended to address supports that do not exceed the temperature limits established in Table HAA-1130-1 for the material under consideration.

(b) The rules of Subsection HF, Subpart A are contained in Division 1, Subsection NF, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered HFA paragraphs or subparagraphs in this Subpart or new numbered HFA paragraphs or subparagraphs added to this Subpart.

(c) Division 1 rules may use different terminology than Division 5 (e.g., Class 1 and Class 2 versus Class A and Class B, etc.) but the application of these rules is identical for Division 5 use.

(d) Subsection HF rules do not cover deterioration that may occur in service as a result of corrosion, erosion, radiation effects, or metallurgical instability of the materials.

(e) Supports for which the rules are specified in this Subsection are those metal elements that transmit loads between components (Divisions 1 and 2, NCA-1210), including piping systems, and intervening elements, and the building structure. However, the term supports does not encompass a structural element, the sole function of which is to carry dynamic loss of pressure-retaining integrity.

(f) The Owner shall be responsible for ensuring the adequacy of the building structure and all intervening elements in the support load path in accordance with the requirements of Divisions 1 and 2, NCA-3240 and NCA-3250. To the extent necessary, the support designer shall consider the structural interaction with intervening elements and the building structure.

(g) Except for the requirements listed in (1) through (10) below, the requirements of Division 1, Subsection NF do not apply to bearings, bushings, gaskets, hydraulic fluids, seals, shims, slide plates, retaining rings, wear shoes, springs, washers, wire rope, compression spring end plates, thread locking devices, cotter pins, sight glass assemblies, spring hanger travel and hydro stops, nameplates, nameplate attachment devices, or for compression dynamic stops used as stops for seismic and other dynamic loads that are designed primarily for compressive loading and are not connected to the support or pressure boundary.

(1) The material of the exempt items shall be selected to tolerate the environmental conditions to which they will be exposed, such as temperature, fluids, humidity, and irradiation.
(2) The exempt item shall be designed for the loading conditions and other requirements identified in the Design Specification.

(3) Design Output Documents (Divisions 1 and 2, NCA-3550) shall indicate items that are exempt.

(4) Materials, fabrication, and installation of the exempt items shall comply with Design Output Documents.

(5) Spring coils for Class A system mounted variable, constant, and sway brace standard supports shall be inspected in accordance with Division 1, NF-2520.

(6) Washers shall comply with the requirements of Division 1, NF-4700.

(7) Wire rope shall comply with the requirements of Division 1, NF-2530 and Article NF-3000.

(8) Compression spring end plates shall comply with the requirements of Division 1, Articles NF-3000, NF-4000, NF-5000, and NF-8000.

(9) Compression dynamic stops shall comply with the requirements of Division 1, Articles NF-3000, NF-4000, NF-5000, and NF-8000.

(10) Thread locking devices shall comply with the requirements of Division 1, NF-4725.1.

Change to: NCA-3211.40
SUBPART B
ELEVATED TEMPERATURE SERVICE

ARTICLE HGB-1000
INTRODUCTION

HGB-1100  GENERAL

HGB-1110  SCOPE

The rules of this Subsection HG, Subpart B constitute the requirements associated with Class SM metallic core support structures used in the construction of high temperature reactor systems when subjected to elevated temperature service.

(a) Subsection HG, Subpart B provides rules for the material, design, fabrication, examination, marking, stamping, and preparation of reports by the Certificate Holder of metallic core support structures or portions of those core support structures that are intended to conform to the requirements for Class SM construction for service when Service Loading temperatures exceed the appropriate temperature limits established in Table HAA-1130-1 for the material under consideration. These zones of elevated temperature service shall have their finalized geometry descriptions and temperature profile details finalized in the Design Report prior to any fabrication and examination efforts.

(b) The rules of Subsection HG, Subpart B are contained in Division 1, Subsection NG, except for those paragraphs or subparagraphs (with numbered headers) replaced by corresponding numbered HGB paragraphs or subparagraphs in this Subpart or new numbered HGB paragraphs or subparagraphs added to this Subpart.

(c) Division 1 rules may use different terminology than Division 5 (e.g., Class CS versus Class SM, etc.), but the application of these rules is identical for Division 5 use.

(d) References to Appendices are to the Section III Appendices, unless otherwise identified as a Subsection HG, Subpart B Appendix, or other subsection-specific Appendix.

HGB-1111  Use of This Subpart

For low temperature service, Division 5 refers to Division 1, Subsection NG, which establishes rules for materials, design, fabrication, examination, and certification, required in the manufacture and installation of core support structures whose service metal temperatures (during the specified conditions of service) do not exceed those for which Section II, Part D, Subpart 1, Tables 2A and 2B provide allowable stress intensity values.

For elevated temperature service under Division 5, special rules are established in this Subpart that are required only for those zones of elevated temperature service of core support structures whose service metal temperatures (during the specified conditions of service) exceed those to which Section II, Part D, Subpart 1, Tables 2A and 2B apply. The interface, if any, between the low and elevated temperature portions (zones of elevated temperature service) of the core support structure shall be identified in the Design Report (Divisions 1 and 2, NCA-3550).

(a) At temperatures and loading conditions where creep effects are significant, the design analysis shall also consider the time-dependent material properties and structural behavior by guarding against the four modes of failure shown below:
   (1) ductile rupture from short-term loadings
   (2) creep rupture from long-term loadings
   (3) creep-fatigue failure
   (4) gross distortion due to incremental collapse and ratcheting

(b) Brief guidelines are also provided in this Subpart for the three modes of failure shown below:
   (1) loss of function due to excessive deformation
   (2) buckling due to short-term loadings
   (3) creep buckling due to long-term loadings

The rules for construction of core support structures are found in the Articles of Subsection HG, Subpart B and Mandatory Appendix HGB-I where appropriate, where the time/temperature requirements of Mandatory Appendix HGB-IV are exceeded. These rules provide explicit consideration of creep and stress rupture at elevated temperature service. These rules for construction alter the rules of Division 1, Subsection NG to suitably account for creep and stress rupture effects. These rules may also be used when the time/temperature requirements of Mandatory Appendix HGB-IV are satisfied. References are made to paragraphs in Divisions 1 and 2,
ARTICLE HGB-2000
MATERIAL

HGB-2100
GENERAL REQUIREMENTS FOR MATERIAL

All core support structure material and material welded thereto shall meet the requirements of Division 1, Article NG-2000, except as modified herein.

HGB-2120
HGB-2121 Permitted Material Specifications

(a) Core support structural material, and material welded thereto, and threaded structural fasteners, with the exception of welding material (Division 1, NG-2430), hard surfacing material (Section IX, QW-251.4), cladding that is 10% or less of the thickness of the base material (Division 1, NG-3122), or the material excluded by Division 1, NG-4430, shall conform to the requirements of the specifications for material given in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4, including all applicable notes in the table, and to all of the special requirements of this Article (including material limitations) that apply to the product form in which the material is used. Materials used for zones of elevated temperature service of core support structures shall also conform to the material specifications identified in Table HBB-I-14.1(a) for base materials, and in Table HBB-I-14.11 for threaded structural fasteners, and in Table HBB-I-14.1(b) for weld materials. Nonmandatory Appendix HBB-U provides guidelines for restricted material specifications to improve performance in certain elevated temperature applications where creep effects are significant.

(b) The requirements of this Article apply to the internal structures (Division 1, NG-1122) only as specifically stipulated by the Certificate Holder; however, the Certificate Holder shall certify that the material used for the internal structures shall not adversely affect the integrity of the core support structure.

(c) Welding material used in the manufacture of items shall comply with an SFA Specification in Section II, Part C, except as otherwise permitted in Section IX, and shall also comply with the applicable requirements of this Article. The requirements of this Article do not apply to materials used as backing rings or backing strips in welded joints.

HGB-2160
DETERIORATION OF MATERIAL IN SERVICE

(a) Consideration of deterioration of material caused by service is generally outside the scope of this Subpart. It is the responsibility of the Owner to select material suitable for the conditions stated in the Design Specifications (Divisions 1 and 2, NCA-3250), with specific attention being given to the effects of service conditions upon the properties of the material. Long-time, elevated temperature service may result in the reduction of the subsequent yield and ultimate tensile strengths. Refer to the rules of HBB-2160(d).

(b) The combination of fabrication-induced cold working and subsequent elevated temperature service may affect time-dependent material properties.

HGB-2400
HGB-2430
HGB-2433

HGB-2433.2 Acceptance Standards. For design temperatures up to and including 800°F (425°C), the minimum acceptable delta ferrite shall be 5 FN (Ferrite Number). For design temperatures exceeding 800°F (425°C), the delta ferrite shall be limited to the range 3 FN to 10 FN. The results of the delta ferrite determination shall be included in the Certified Material Test Report of Division 1, NG-2130 or NG-4120.
ARTICLE HGB-3000
DESIGN

HGB-3100 GENERAL DESIGN

All core support structure material and material welded thereto shall meet the requirements of Division 1, Article NG-3000, except as modified herein. HGB-3200 contained herein fully replaces the requirements of Division 1, NG-3200.

HGB-3110

HGB-3112 Design Parameters

(a) The design parameters are the pressure differences, temperatures, and mechanical load forces applicable to the design of nuclear power plant components. The simplest set of design parameters would consist of the temperature, pressure differences, and load forces that exist at some given time.

(b) To design a zone of elevated temperature service, two types of design parameter data are needed in the Design Specifications (Divisions 1 and 2, NCA-3250). First, an expected loading history that consists of how each design parameter varies as a function of time; and second, a list of events that occur under each loading category defined in HGB-3113.

(c) The design parameter data stipulated in (1) and (2) below shall be specified in the Design Specifications (Divisions 1 and 2, NCA-3250) for each component.

(1) the loading event history to be used in the structural analysis.

(2) the design parameters from which the designer will determine the most severe loading for each loading category defined in HGB-3113. (If fluid conditions are specified, the designer eventually must convert the data to metal temperatures and surface pressures.)

(d) It is permissible for the designer to establish the zone of elevated temperature service boundaries inside the component. However, the zone of elevated temperature service boundaries and applicable design parameters shall be fully described in the Design Report.

HGB-3112.1 Specified Pressure Difference.

(a) The specified internal and external pressure difference histories shall describe pressure difference values not less than the maximum pressure differences between the inside and outside of the core support structure. When the occurrence of different pressure differences during service can be predicted for different zones of elevated temperature service of a structure, the specified pressure difference histories of the different zones of elevated temperature service may be based on their predicted pressure difference.

(b) The specified pressure difference histories shall include allowances for pressure difference surges.

(c) The specified pressure difference histories shall be used in the computations made to show compliance with the limits of HGB-3200.

HGB-3112.2 Specified Temperature. The specified temperature history for the loading category shall enable the designer to describe a temperature value not less than the maximum local wall-averaged temperature that will exist in the structural metal in a given zone of elevated temperature service of the component. and for the particular loadings (HGB-3113.2), the designer shall determine the history of the maximum local metal temperature in a given zone of elevated temperature service and shall use these metal temperature histories in the computations to show compliance with the limits of HGB-3200.

(a) All temperatures referred to in this Article are the temperatures expressed in degrees Fahrenheit (°F) or degrees Celsius (°C).

(b) Where a component is heated by trace heating, induction coils, jacketing, or by internal heat generation, the designer shall consider the effect of such heating in the establishment of the design temperature histories.

(c) Elevated temperature mechanical properties are extremely sensitive to temperature. The Design Specifications shall specify any inaccuracies in temperature measurement and prediction that are to be considered in the design analyses made to show compliance with the limits of HGB-3200.

HGB-3112.3 Specified Mechanical Load Forces. The specified load forces for a given loading category (HGB-3113) shall define all expected mechanical loadings that must be considered in design analysis computations made to show compliance with the limits of HGB-3200. The requirements of (a), (b), and (c) below shall also apply.

(a) Impact forces caused by either external or internal conditions shall be considered.

(b) The effects of earthquake shall be considered in the design of core support structures. The loadings, movements, and number of cycles to be used in the analysis...
shall be part of the Design Specifications. The stresses resulting from these earthquake effects shall be included with pressure differences or other applied loads.

(c) Core support structures shall be arranged and supported so that vibration will be minimized to the extent practicable.

HGB-3112.4 Design Stress Intensity Values. Design stress intensity values for materials are listed in Section II, Part D, Subpart 1, Tables 2A and 2B. These stress intensity tables may be extended to higher metal temperatures using the values in Tables HBB-I-14.3A through HBB-I-14.3E. The material shall not be used at metal temperatures or Design Temperatures above those for which stress intensity values are listed. The values in the tables may be interpolated for intermediate temperatures.

HGB-3113 Loading Categories

Loading categories used in this Subpart consist of Design Loadings and Service Loadings (Levels A, B, C, and D).

HGB-3113.1 Design Loadings. The specified design parameters for the Design Loadings category shall equal or exceed those of the most severe combination of coincident pressure difference, temperature, and load forces specified under events that cause Level A Service Loadings (HGB-3113.3) for the same zone of elevated temperature service of the component. These specified design parameters for Design Loadings shall be called Design Temperature, Design Pressure Difference, and Design Mechanical Loads. These specified design parameters shall be used in computations to show compliance with the requirements on Design Limits in HGB-3222.

HGB-3113.2 Service Loadings. Each loading to which the component may be subjected shall be part of the Design Specifications. The stresses resulting from these earthquake effects shall be included with pressure differences or other applied loads.

HGB-3113.3 Level A Service Loadings. Level A Service Loadings are any loadings arising from system start-up, operation in the design power range, hot standby, and system shutdown, and excepting only those loadings covered by Level B, C, and D Service Loadings.

HGB-3113.4 Level B Service Loadings (From Incidents of Moderate Frequency). These are deviations from Level A Service Loadings that are anticipated to occur often enough that design should include a capability to withstand the loadings without operational impairment. The events that cause Level B Service Loadings include those transients that result from any single operator error or control malfunction, transients caused by a fault in a system component requiring its isolation from the system, and transients due to loss of load or power. These events include any abnormal incidents not resulting in a forced outage and also forced outages for which the corrective action does not include any repair of mechanical damage. The estimated duration of a Level B Service Loading shall be included in the Design Specifications.

HGB-3113.5 Level C Service Loadings (From Infrequent Incidents). These are deviations from Level A Service Loadings that require shutdown for correction of the loadings or repair of damage in the system. The conditions have a low probability of occurrence but are included to provide assurance that no gross loss of structural integrity will result as a concomitant effect of any damage developed in the system. The total number of postulated occurrences for such events may not exceed 25. If more than 25 are expected, then some types of events must be evaluated by the more stringent requirements of the Level B Service Limits.

HGB-3113.6 Level D Service Loadings (From Limiting Faults). These are combinations of loadings associated with extremely low probability, postulated events whose consequences are such that the integrity and functionality of the nuclear energy system may be impaired to the extent that only considerations of public health and safety require the loadings or repair of damage in the system. The estimated duration of a Level B Service Loading shall be included in the Design Specifications.

HGB-3114 Load Histogram

HGB-3114.1 Level A and B Service Events. The Design Specifications (Divisions 1 and 2, NCA-3250) shall include an expected loading history or load histogram for all Service Loadings from Level A and B service events. These loads histograms shall give all expected mechanical load forces, pressure differences and temperatures for the various zones of elevated temperature service of the component throughout its service life. These histograms are then used in meeting the analysis requirements of HGB-3200.

HGB-3114.2 Level C Service Events. The Design Specifications shall include a time history of the design parameters during each type of Level C Service event. However, these events need not be specified as to time of occurrence during the service life of the component. The design parameter data shall be used in meeting the analysis requirements of HGB-3200. Level C Service events may be assumed as occurring between operational cycles (HGB-3213.15) of Level A Service events unless otherwise specified in the Design Specifications (Divisions 1 and 2, NCA-3250).

HGB-3120

HGB-3122 Cladding

The requirements of Division 1, NG-3122 shall not be used.
HGB-3213.25 Plastic Analysis — Collapse Load. A plastic analysis may be used to determine the collapse load for a given combination of loads on a given structure. The following criteria for determination of the collapse load shall be used. A load-deflection or load-strain curve is plotted with load as the ordinate and deflection or strain as the abscissa. The angle that the linear part of the load deflection or load strain curve makes with the ordinate is called \( \theta \). A second straight line, hereafter called the collapse limit line, is drawn through the origin so that it makes an angle \( \phi = \tan^{-1} \left( \frac{2}{\tan \theta} \right) \) with the ordinate. The collapse load is the load at the intersection of the load-deflection or load-strain curve and the collapse limit line. If this method is used, particular care should be given to assuring that the strains or deflections that are used are indicative of the load-carrying capacity of the structure.

HGB-3213.26 Plastic Instability Load. The plastic instability load for members under predominantly tensile or compressive loading is defined as that load at which unbounded plastic deformation can occur without an increase in load. At the plastic-tensile instability load, the true stress in the material increases faster than strain hardening can accommodate.

HGB-3213.27 Limit Analysis. Limit analysis is a special case of plastic analysis in which the material is assumed to be ideally plastic (non-strain hardening). In limit analysis, the equilibrium and flow characteristics at the limit state are used to calculate the collapse load. The two bounding methods that are used in limit analysis are the lower bound approach, which is associated with a kinematically admissible stress field, and the upper bound approach, which is associated with a kinematically admissible velocity field. For beams and frames, the term mechanism is commonly used in lieu of kinematically admissible velocity field.

HGB-3213.28 Limit Analysis — Collapse Load. The methods of limit analysis are used to compute the maximum carrying load for a structure assumed to be made of ideally plastic material. If creep effects exist, then the influence of time-dependent deformations on the collapse load shall be considered.

HGB-3213.29 Calculated Collapse Load — Lower Bound. If, for a given load, any system of stresses can be found that everywhere satisfies equilibrium, and nowhere exceeds the material yield strength, the load is at or below the collapse load. This is the lower bound theorem of limit analysis that permits calculations of a lower bound to the collapse load. If creep effects exist, then the influence of time-dependent deformations on the collapse load shall be considered.

HGB-3213.30 Plastic Hinge. A plastic hinge is an idealized concept used in Limit Analysis. In a beam or a frame, a plastic hinge is formed at the point where the moment, shear, and axial force lie on the yield interaction surface. In plates and shells, a plastic hinge is formed where the generalized stresses lie on the yield surface.

HGB-3213.31 Strain Limiting Load. When a limit is placed upon a strain, the load associated with the strain limit is called the strain limiting load.

HGB-3213.33 Ratcheting. Ratcheting is a progressive cyclic inelastic deformation. Total inelastic strain per cycle may vary from cycle to cycle in the most general situation. Stable ratcheting occurs when the net inelastic strain from a given load cycle is constant for subsequent cycles. The progressive incremental inelastic deformation can occur in a component that is subjected to cyclic variations of mechanical secondary stress, thermal secondary stress; or both in the presence of a primary stress.

HGB-3213.34 Shakedown. Shakedown is the absence of significant progressive, cyclic, inelastic deformation, or ratcheting (HGB-3213.33). A structure shakes down if, after a few cycles of load application, the deformation stabilizes.

HGB-3213.36 Use-Fraction. Use-fraction is the material damage due to primary stresses expressed as a time ratio.

HGB-3213.37 Fatigue Damage. Fatigue damage is that part of the total material damage caused by cyclic deformation that is independent of time effects (e.g., stress hold time, strain hold time, frequency). The damage is expressed in terms of a cycle ratio.

HGB-3213.38 Creep Damage. Creep damage is that part of the total material damage caused by time exposure to steady and transient stresses at elevated temperatures, expressed as a time ratio. (Relaxation damage is a form of creep damage.)

HGB-3213.39 Creep–Fatigue Interaction. Creep–fatigue interaction is the effect of combined creep and fatigue on the total creep–fatigue damage accumulated at failure.

HGB-3214 Stress Analysis

A detailed stress analysis of all major structural components shall be prepared in sufficient detail to show that each rule or limit of HGB-3220 and HGB-3230 is satisfied when the core support structure is subjected to the loadings described in Division 1, NG-3111. This detailed analysis shall become a part of the Design Report (Divisions 1 and 2, NCA-3550).

Change to: NCA-3211.40
(c) The combined primary membrane plus bending stress intensities, derived from $P_m$ and $P_b$ for Level A and B Service Loadings, shall satisfy the following limits with

$$P_m + P_b \leq KS_m$$

(4)

$$P_m + P_b/K_t \leq S_t$$

(5)

The factor $K_t$ accounts for the reduction in extreme fiber bending stress due to the effect of creep. The factor is given by the following:

$$K_t = (K + 1)/\ell$$

(6)

The factor, $K$, is the section factor for the cross section being considered. It is the ratio of the load set producing a fully plastic section to a load set producing initial yielding of the extreme fiber of the cross section. In evaluating the initial yield and fully plastic section capabilities, the ratios of each individual load in the respective load set to each other load in that load set shall be the same as the respective ratios of the individual loads in the specified service load set.

(d) In evaluating across-the-wall bending of shell-type structures, $K = 1.5$ (for rectangular sections) shall be used. Thus, for across-the-wall shell bending, $K_t = 1.25$ in eq. (6).

(e) In eq. (c)(5), the $S_t$ value is determined for the time, $t$, corresponding to the total duration of the combined stress intensity derived from $P_m$ and $P_b/K_t$ and the maximum wall-averaged temperature, $T$, during the entire service life of the component.

(f) When $t$ is less than the total service life of the component, the cumulative effect of all $[P_m + (P_b/K_t)]$ loadings shall be evaluated by the use-fraction sum of HGB-3224(d). It is permissible and often advantageous to separate a loading history into several load levels and into several temperatures at any given load level.

(g) Under all conditions where a bending loading occurs across a section, the propensity for buckling of that part of the section in compression shall be investigated under the requirements of HGB-3250.

**HGB-3224 Level C Service Limits**

The stress calculations required for Level C Service Loadings analysis are based on a linear elastic material model. The calculated stress intensity values shall satisfy the conditions of (a) through (d) below.

(a) The primary membrane stress intensity, derived from $P_m$ for Level C Service Loadings, shall not exceed the smaller of $1.2S_m$ and $1.0S_t$.

$$P_m \leq \begin{cases} 1.2S_m, \\ 1.0S_t \end{cases}$$

(7)

(b) In addition, the use-fraction sum associated with the primary membrane stresses for all increments of primary loadings during Level A, B, and C Loadings shall satisfy the following requirements:

$$\sum_{i=1}^{t_i} \left( \frac{t_i}{t_{im}} \right) \leq B$$

(8)

where

- $B$ = use-fraction factor and is equal to 1.0 [or less if so specified in the Design Specifications (Divisions 1 and 2, NCA-3250)].
- $t_i$ = the total duration of a specific loading, $P_{mi}$, at elevated temperature, $T$, during the entire service life of the component. Note that $\sum_{i=1}^{t_i}$ is that part of the component service life at elevated temperatures (i.e., temperatures above values governed by the rules of Division 1, Subsection NG as explained in HGB-3211).

- $t_{im}$ = maximum allowed time under the load stress intensity, $S_i$, as determined from a graph of $S_i$–versus–time (see Figures HBB-I-14.4A through HBB-I-14.4E).

The use of Figures HBB-I-14.4A through HBB-I-14.4E for determining $t_{im}$ for two loading conditions at two different temperatures is shown schematically in Figure HGB-3224-1. In Figure HGB-3224-1, $P_{mi}$ (i = 1, 2, 3, etc.) represents the calculated membrane stress intensity for the loading condition and temperature in question; and $T_i$ represents the maximum local wall-averaged temperature during $t_i$. Note that it may be desirable to consider that a given stress intensity, $P_{mi}$, acts during several time periods, $t_{im}$, in order to take credit for the fact that the temperature varies with time.

(c) The combined primary membrane plus bending stress intensities, derived from $P_m$ and $P_b$ for Level C Service Loadings, shall satisfy the following limits, with $1.0 < K \leq 1.5$:

$$P_m + P_b \leq 1.2KS_m$$

(9)

$$P_m + P_b/K_t \leq S_t$$

(10)

where $K_t$ is defined as in HGB-3223(c).
(d) In addition, the sum of the use-fractions associated with the primary membrane plus bending stresses for all increments of primary loadings during Level A, B, and C Service Loadings shall not exceed the value 1.00.

\[
\sum \left( \frac{t_i}{t_{ib}} \right) \leq 1.00 \quad (11)
\]

where \( t_i \) is the total duration of the loading at temperature, \( T_i \), and \( t_{ib} \) is the time value determined by entering Figures HBB-I-14.4A through HBB-I-14.4E at a value of stress equal to \( P_m + P_b/K_b \) as shown in Figure HGB-3224-2. Note that it is permissible to extrapolate the allowable stress intensity at temperature curve (Figures HBB-I-14.3A through HBB-I-14.3E and Figures HBB-I-14.4A through HBB-I-14.4E) to determine time value \( t_{ib} \) when computing use-fractions. Any such extrapolation and the method used shall be reported in the Design Report (Divisions 1 and 2, NCA-3551.1).

HGB-3225 Level D Service Limits

The rules of this paragraph may be used in the evaluation of components subjected to loads specified as Level D Service Loadings.

(a) The rules in HGB-3225 (and in Section III Appendices, Mandatory Appendix XXVII) shall be applied in all instances unless alternative or supplementary criteria, as required by public health, specific components or systems, are defined in, and made applicable by the Owner’s Design Specifications [Divisions 1 and 2, NCA-3250]. The type of analysis (elastic or inelastic) used by the system designer shall be indicated in the Design Specifications (see Section III Appendices, Mandatory Appendix XXVII, XXVII-2000).

(b) The primary membrane stress intensity, derived from \( P_m \) for the Level D Service Loadings, shall not exceed the smaller of 0.67\( S_r \), 0.8\%R, and one of the Level D Service Limits in Section III Appendices, Mandatory Appendix XXVII.

\[
P_m \leq \begin{cases} 
0.67S_r \\
0.8S_R 
\end{cases}
\]

where \( S_r \) is the expected minimum stress-to-rupture in time \( t \) taken from Figures HBB-I-14.6A through HBB-I-14.6F and \( R \) is the appropriate ratio of the weld metal creep–fatigue strength to the base metal strength from Tables HBB-I-14.10A-1 through HBB-I-14.10E-1.

(c) In addition, the use-fraction sum associated with the primary membrane stresses that arise from all Service Loadings, shall satisfy the requirement

\[
\sum \left( \frac{t_i}{t_{ir}} \right) \leq B_r
\]

where

- \( B_r \) = use-fraction factor and is equal to 1.0 (or less if so specified in the Design Specifications [Divisions 1 and 2, NCA-3250])
- \( t_i \) = the total duration of a specific loading, \( P_m, \) at elevated temperature, \( T_i, \) during the entire service life of the component. Note that \( \sum \left( \frac{t_i}{t_{ir}} \right) \) is that part of the component service life at elevated temperatures (i.e., temperatures above values governed by the rules of Division 1, Subsection NG, as explained in HGB-3211).
(1) The maximum value of the membrane stress averaged across either the area of the fastener shank or the stress area of the threads, and neglecting stress concentrations, shall be no greater than $S_{mt}$, for the design life at the maximum service temperature, unless the design lifetime is divided into two or more loading periods and the possibility of creep rupture due to membrane stresses is guarded against by satisfying the use-fraction rule described in HGB-3224(b) with the use-fraction factor, $B$, set equal to 0.5.4. Stress intensity, rather than maximum stress, shall be limited to this value when threaded structural fasteners are

(a) tightened by devices that result in residual torsion stresses (residual torsion stresses are minimized by devices such as heaters and stretchers)

(b) loaded in transverse shear, or

(c) both

(2) If a tight joint is required, the stress due to preload shall be shown to remain greater than that due to primary and secondary membrane stress excluding preload, throughout the design life of the joint.

HGB-3232.2 Maximum Stress. The maximum value of the primary membrane and bending plus secondary membrane and bending stresses produced by the combination of all primary loads and secondary loads but excluding effects of stress concentrations shall not exceed the lesser of 1.5$S_{mt}$ or $K_s S_t$ for the design life at the maximum service temperature, unless the design lifetime is divided into two or more loading periods and the possibility of creep rupture due to bending stresses is guarded against by satisfying the use-fraction rule described in HGB-3224(d) but with the use-fraction set at 0.67 instead of 1.0.4 Stress intensity, rather than maximum stress, shall be limited to this value when threaded structural fasteners are

(a) tightened by devices that result in residual torsion stresses (residual torsion stresses are minimized by devices such as heaters and stretchers)

(b) loaded in transverse shear, or

(c) both

HGB-3232.3 Nonductile Fracture. The rules of HGB-3241 shall apply to threaded structural fasteners.

HGB-3233 Level B Service Limits

Level A Service Limits (HGB-3232) apply.

HGB-3234 Level C Service Limits for Threaded Structural Fasteners

The number and cross-sectional area of threaded structural fasteners shall be such that the requirements of HGB-3224 are satisfied for the Service Loadings for which Level C Limits are designated in the Design Specifications. Any deformation limit prescribed in the Design Specifications shall be considered.

HGB-3235 Level D Service Limits for Threaded Structural Fasteners

The number and cross-sectional area of threaded structural fasteners shall be such that the requirements of HGB-3225 are satisfied for the Service Loadings for which Level D Limits are designated [Divisions 1 and 2, NCA-2142.4(b)(4)] in the Design Specifications. Any deformation limit prescribed in the Design Specifications shall be considered.

HGB-3240 SPECIAL REQUIREMENTS FOR ELEVATED TEMPERATURE COMPONENTS

HGB-3241 Nonductile Fracture

(a) The Design Report (Divisions 1 and 2, NCA-3550) shall justify the ability of the component to withstand the expected service conditions without undergoing nonductile fracture. Even though components are not expected to fail by nonductile fracture while at elevated temperatures, the stress relaxation occurring under elevated temperature conditions will often lead to high residual stresses during the portion of the operational cycle with lowest temperatures. For loading times, stresses and temperatures where creep effects are not significant, an acceptable procedure for nonductile failure prevention is given in Section III Appendices, Nonmandatory Appendix G for ferritic materials. When Section III Appendices, Nonmandatory Appendix G is not applicable, the fracture analysis shall consider the anticipated stress level and flaw size and compare these conditions with the fracture toughness of the material in the flaw region and at the appropriate temperature.

(b) The above justification requirements do not apply to Type 304SS, Type 316SS, or Alloy 800H, unless the fabrication effects substantially alter the fracture characteristics of these materials in such a manner that nonductile fracture becomes a plausible failure mode. The Design Specifications shall state when and how environmental effects shall be considered for nonductile fracture behavior in these materials.

HGB-3250 LIMITS ON DEFORMATION-CONTROLLED QUANTITIES

HGB-3251 General Requirements

The strains and deformation resulting from the specified operating conditions shall be evaluated. This evaluation shall include the consideration of creep and fatigue and structural instability. The N Certificate Holder shall document, as a portion of the Design Report (Divisions 1 and 2, NCA-3550), what effects and conditions were considered, the final analysis procedures, the evaluation criteria, and the conclusions of the evaluation.
HGB-3252 Criteria

It is the responsibility of the Owner to define the acceptability criteria to be applied as buckling, strain, deformation, and fatigue limits in the Design Specifications (Divisions 1 and 2, NCA-3250). The acceptability criteria and material properties contained in Nonmandatory Appendix HBB-T (referenced from Mandatory Appendix HGB-I) may be used. However, alternative criteria may be applied by the Certificate Holder subject to the approval by the Owner. The Owner’s approval shall be indicated by incorporating the alternative criteria into the Design Specifications.

HGB-3300

HGB-3350

HGB-3352 Permissible Types of Welded Joints

Subject to the limitations given in Division 1, NG-3351, core support structures may use any of the types of joints described in the following subparagraphs, providing the quality factor, \( n \), and fatigue factor, \( f \), used in the analysis meet the requirements of Division 1, Table NG-3352-1 for the method of examinations employed. The allowable stress limits of HGB-3220, the strain limits of HGB-3250, and the damage limits of both HGB-3220 and HGB-3250 shall be multiplied by the quality factor, \( n \), to evaluate the design of welded joints. The fatigue factor, \( f \), shall be used as a stress concentration factor for the creep-fatigue analysis required by HGB-3250, unless a larger stress concentration factor is obtained per HGB-3353(b).

HGB-3352.2 Type II Joints. Full penetration welds between plates or other elements meet the intent of this subparagraph when made either according to Division 1, NG-3352.1 or with edges of the joint prepared with opposing lips to form an integral backing strip, or with metal backing strips that are not later removed, except that the suitability for cyclic operation shall be analyzed as required by HGB-3250.

HGB-3353 Design of Welded Construction at Elevated Temperatures

(a) Because of the potential for limited ductility of weld metal at elevated temperatures and the potential for high strain concentrations (both metallurgical and geometric) in the heat-affected zones of weldments, the analysis requirements of this paragraph shall be satisfied for the design and location of all pressure-retaining and other primary structural welds subjected to metal temperatures where creep effects are significant. The potential for reduced ductility often precludes locating welds in regions of high loading.

(b) For meeting the analysis requirements of HGB-3251 at elevated temperature weld regions, the assumed weld surface shall model the most severe strain concentrations expected in the actual weld placed in service. This geometry may be prescribed on a drawing or may be recorded by prior observation. Prior observations of weld surface geometry can be visual, remote visual (e.g., using a borescope device or making a surface replica), ultrasonic, based on a weld mockup test in which the same weld procedures are used on the same nominal diameter and wall thickness, or, based on a radiographic technique that is suitable for inspection of internal surfaces. The assumed strain concentration shall not be smaller than the applicable fatigue factor from Division 1, Table NG-3352-1.
MANDATORY APPENDIX HGB-II
RULES FOR CONSTRUCTION OF CORE SUPPORT STRUCTURES,
EXTENDED FOR RESTRICTED SERVICE AT ELEVATED
TEMPERATURE, WITHOUT EXPLICIT CONSIDERATION OF CREEP
AND STRESS-RUPTURE

ARTICLE HGB-II-1000
INTRODUCTION

HGB-II-1100 GENERAL

The rules of Division 1, Article NG-1000 apply except as modified below.

HGB-II-1110 ASPECTS OF CONSTRUCTION COVERED BY THESE RULES

Division 1, Subsection NG establishes rules for materials, design, fabrication, examination, and certification required in the manufacture and installation of core support structures whose service metal temperatures (during the specified conditions of service) do not exceed those for which Section II, Part D, Subpart 1, Tables 2A and 2B provide design stress intensity values.

For elevated temperature service, special rules are established in this Appendix that are required only for those zones of elevated temperature service of core support structures whose service metal temperatures (during the specified conditions of service) exceed those to which Section II, Part D, Subpart 1, Tables 2A and 2B apply, provided the time and temperature requirements of Mandatory Appendix HGB-IV are satisfied. The interface, if any, between low temperature portions and elevated temperature portions (zones of elevated temperature service) of the core support structure shall be identified in the Design Report (Divisions 1 and 2, NCA-3550).

The rules of this Appendix are contained in Division 1, Subsection NG, except for those paragraphs or subparagraphs (with numbered headings) replaced by corresponding numbered HGB-II paragraphs or subparagraphs in this Appendix or newly numbered HGB-II paragraphs or subparagraphs added to this Appendix.
ENDNOTES

1 Plant and system operating conditions are commonly referred to as normal, upset, emergency, and faulted conditions.
2 See Section III Appendices, Nonmandatory Appendix KK.
3 See Section III Appendices, Nonmandatory Appendix C.
4 See Mandatory Appendix HHA-II and Mandatory Appendix HHA-III.
5 ASME NQA-1, Part IV provides guidance for various applications.
6 Includes Graphite Inspectors and Authorized Nuclear Inspector for Graphite Supervisors.
7 A list of acceptable Authorized Inspection Agencies may be obtained from the Society.
8 Copies of these forms may be obtained from the Society. (Samples of the forms referred to in this Article are in course of preparation.)
9 Different product forms, such as castings, are acceptable for the attachment.
10 A report documenting the experimental data or calculations based on experimental data or both shall demonstrate that the elevated temperature service does not introduce creep effects. This document shall be incorporated into the Design Report (NCA-3550) and shall be approved by the Owner by means of a certified revision to the Design Specifications (NCA-3250).
11 Note that the expansion stress \( P_e \) defined in Section III Appendices, Mandatory Appendix XIII, XIII-3410 is deleted for Subsection HB, Subpart B. Stresses resulting from the constraint of free end displacement and the effects of anchor motion shall be assigned to either primary or secondary stress categories [see HBB-3213(a), HBB-3213(b), and HBB-3217].
12 This definition of stress intensity is not related to the definition of stress intensity applied in the field of Fracture Mechanics.
13 Equivalent linear stress is defined as the linear stress distribution that has the same net bending moment as the actual stress distribution.
14 To satisfy eq. HBB-3222.1(a)(1) for straight cylindrical shapes, the minimum wall thickness may be calculated by the equations in PG-27 of Section I, Power Boilers, using \( S_o \) in place of \( S \).
15 \( S_r \) values to be used are twice those given in Figures HBB-I-14.13A through HBB-I-14.13C.
16 Communicating chambers are defined as appurtenances to the vessel that intersect the shell or heads of a vessel and form an integral part of the pressure-retaining closure, e.g., sumps.
17 Side plates of a flat-sided vessel are defined as any of the flat plates forming an integral part of the pressure-retaining enclosure.
18 Strain is defined as the maximum local fiber elongation or contraction per unit length; and where more than one strain increment occurs (e.g., biaxiality or reversed bending), it shall be the sum of the absolute values of all the strain increments.
19 Strain resulting from final straightening operations performed on materials furnished in the solution annealed or heat-treated condition need not be included in the computation of strain.
20 Definitions are contained in the rules governing the design of Class A components in elevated temperature service.
21 Prior to the 2015 Edition of Section III of the BPV Code, Subsection HB, Subpart B was published as Subsection NH under Division 1.
ARTICLE KK-2000
GENERIC REQUIREMENTS

KK-2100 DESIGN SPECIFICATION REQUIREMENTS

The information in this Article addresses those portions of the Design Specification that are generic in nature and therefore applicable to the construction of all Division 5 metallic items unless otherwise stated.

KK-2110 GENERAL

(a) All information and requirements contained in the Design Specifications that are beyond the jurisdiction of Division 5 should be so specified.

(b) The Design Specifications should stipulate any specific additional requirements that the Owner intends to be incorporated in the specific components and supports covered by the Design Specifications or any additional requirements intended to be more specific or more restrictive than the minimum requirements of Division 5.

(c) Where additional terms, definitions, or expressions are required, they should be clearly defined and explained and adequately referenced.

KK-2110.1 Contents of the Design Specification.

(a) Subsection HA, Subpart A, General Requirements and specifically HAA-3252 provides the minimum requirements for the contents of the Design Specification. Additional content requirements are also identified in the construction subsection.

(b) With respect to HAA, recognize that the boundary defines an interface between two items that are dependent on each other for the transmittal of loads. In order to properly design the item on either side of the boundary, the effect of the attached item is required. The effect may be furnished directly by supplying the forces and moments that are transmitted across the boundary or, alternatively, by providing sufficient information to enable the designer to determine the interaction across the boundary. Division 5 provides rules to accomplish this in NCA-3254.

(c) Any Code Cases applicable to the construction of an item should be included in the Design Specification.

KK-2110.2 Certification. NCA-3255 provides the requirements for certification of the Design Specification. The required certification is not applicable to supplementary, regulatory, or functionality requirements that are outside of the scope of Division 5.

KK-2110.3 Records. NCA-4134.17 provides the requirements for the continued maintenance and retention location for nonpermanent and lifetime records.

KK-2110.4 Handling, Storage, and Shipping. The Design Specification should include any special measures to control handling, storage, and shipping of the component (NCA-4134.13).

KK-2110.5 Identification of Regulatory Authorities. The Design Specification should include identification of regulatory and enforcement authorities at locations of component installation with whom Data Reports should be made available.

KK-2110.6 Filing. NCA-3256 provides the requirements for filing of the Design Specification.

KK-2111 Classification

KK-2111.1 Responsibility. HAA-2130 provides the requirements for classification of items.

KK-2111.2 Multiple Code Class Components. HAA-2133 provides the requirements for multiple Code Class components.

KK-2111.3 Optional Use of Code Classes. HAA-2134 provides the requirements for optional use of Code Classes.

KK-2111.4 Special Requirements. NCA-2160 provides the requirements for contractual arrangements that are beyond the scope of Division 5.

KK-2112 Design Basis and Service Limits

KK-2112.1 Plant and System Service Conditions. The definition of plant and system service conditions, and the determination of their significance to the design and functionality of components and supports of a nuclear facility, may be derived from systems safety criteria documents for specific types of nuclear facilities and may be found in the requirements of regulatory and enforcement authorities having jurisdiction at the site [NCA-2141(b)].

KK-2112.2 Design Loadings and Service Loadings. The Design Specification should specify the Design Loadings (NCA-2142.1) and the Service Loadings (NCA-2142.2).