(c) For each category, calculate the algebraic sum of the $\sigma_i$'s that result from the different types of loadings and similarly for the other five stress components. Certain combinations of the categories must also be considered.

(d) Translate the stress components for the $t$, $l$, and $r$ directions into principal stresses, $\sigma_1$, $\sigma_2$, and $\sigma_3$ (in many pressure component calculations, the $t$, $l$, and $r$ directions may be so chosen that the shearing stress components are zero and $\sigma_1$, $\sigma_2$, and $\sigma_3$ are identical to $\sigma_1$, $\sigma_2$, and $\sigma_3$).

(e) Calculate the stress differences $S_{12}$, $S_{23}$, and $S_{31}$ from the relations:

$$S_{12} = \sigma_1 - \sigma_2$$
$$S_{23} = \sigma_2 - \sigma_3$$
$$S_{31} = \sigma_3 - \sigma_1$$

The stress intensity, $S$, is the largest absolute value of $S_{12}$, $S_{23}$, and $S_{31}$.

HGB-3216 Derivation of Stress Differences and Strain Differences

The ability of the component to withstand the specified cyclic operation without creep-fatigue failure shall be determined as in HGB-3250. The evaluation shall demonstrate, by evaluating the stresses and strains at selected points of the component, that the combined creep-fatigue damage is everywhere within design limits. Only the stress and strain differences due to the operational cycles as specified in the Design Specifications need be considered.

HGB-3217 Classification of Stresses

Table HGB-3217-1 provides assistance in the determination of the category to which a stress shall be assigned. For portions of the component not exposed to elevated temperature service, the classification or category may be selected as in Division 1, Subsection NG-3000.

HGB-3220 DESIGN RULES AND LIMITS FOR LOAD-CONTROLLED STRESSES IN STRUCTURES OTHER THAN THREADED STRUCTURAL FASTENERS

HGB-3221 General Requirements

(a) The rules for design against failure from load-controlled stresses are illustrated in Fig. NH-3221-1 of Division 1, Subsection NH (with $P_I$ replaced with $P_m$) and are explained in HGB-3220. The allowable stress intensity values used in HGB-3220 are listed in Tables 2A and 2B of Section II, Part D, Subpart 1 and in Tables I-14.0 of Division 1, Subsection NH. Note that the strain, deformation, and fatigue limits of HGB-3250 require analyses beyond those required by the rules of HGB-3220.

(b) The stress intensity limits used in Fig. NH-3221-1 of Division 1, Subsection NH (with $P_I$ replaced with $P_m$) and throughout this Subpart are defined for base metal and at weldments as follows:

1) Base Metal

$S_{m0} = \text{the allowable limit of primary membrane stress intensity to be used as a reference for stress calculations for the actual service life and under the Level A and B Service Loadings; the allowable values are shown in Figs. I-14.3 and in Tables I-14.3 of Division 1, Subsection NH. The } S_{m0} \text{ values are the lower of two stress intensity values, } S_m \text{ (time-independent) and } S_t \text{ (time-dependent). As described in Division 1, Subsection NH-2160(d), it may be necessary to adjust the values of } S_m \text{ to account for the effects of long-time service at elevated temperature.}$

$S_m = \text{the lowest stress intensity value at a given temperature among the time-independent strength quantities that are defined in Section II, Part D, Subpart 1 as criteria for determining } S_{m0}; \text{ in this Subpart, the } S_m \text{ values are extended to elevated temperatures by using the same criteria. As described in Division 1, Subsection NH-2160(d), it may be necessary to adjust the values of } S_m \text{ to account for the effects of long-time service at elevated temperature.}$

$S_{m0} = \text{the maximum allowable value of general primary membrane stress intensity to be used as a reference for stress calculations under Design Loadings. The allowable values are given in Table I-14.2 of Division 1, Subsection NH. The values correspond to the } S \text{ values given in Section II, Part D, Subpart 1, Table 1A, except for a few cases at lower temperatures where values of } S_{m0} \text{ (defined below and given in Tables I-14.3 of Division 1, Subsection NH) at 300,000 hours exceed the } S \text{ values. In those limited cases, } S_{m0} \text{ is equal to } S_m \text{ at 300,000 hours rather than } S.$

$S_t = \text{a temperature and time-dependent stress intensity limit; the data considered in establishing these values are obtained from long-term, constant load, uniaxial tests. For each specific time, } t, \text{ the } S_t \text{ values shall be the lesser of:}$

(a) 100% of the average stress required to obtain a total (elastic, plastic, primary, and secondary creep) strain of 1%
(b) 80% of the minimum stress to cause initiation of tertiary creep; and
(c) 67% of the minimum stress to cause rupture.
(e) instantaneous and mean coefficients of thermal expansion

Other mechanical and physical property relations used in the analysis shall be described and justified in the Design Report.

HGB-3215 Derivation of Stress Intensities

One requirement for the acceptability of a design (HGB-3210) is that the calculated stress intensities shall not exceed specified allowable limits. These limits differ depending on the stress category (primary, secondary, etc.) from which the stress intensity is derived. This paragraph describes the procedure for the calculation of the stress intensities that are subject to the specified limits. The steps in the procedure are stipulated in the following subparagraphs.

(a) At the point on the component that is being investigated, choose an orthogonal set of coordinates such as tangential, longitudinal, and radial, and designate them by the subscripts, t, l, and r. The stress components in these directions are then designated \( \sigma_t, \sigma_l, \sigma_r \) for direct stresses and \( \tau_{rl}, \tau_{lr}, \) and \( \tau_{rt} \) for shearing stresses.

(b) Calculate the stress components for each type of loading to which the part will be subjected and assign each set of stress values to one or a group of the following categories:

\[ F = \text{peak stress components as defined in HGB-3213.11} \]

\[ P_b = \text{primary bending stress components at a surface as defined in HGB-3213.8} \]

\[ P_m = \text{primary membrane stress components as defined in HGB-3213.8} \]

\[ Q = \text{secondary stress components as defined in HGB-3213.9} \]

Table HGB-3217-1 provides assistance in the determination of the category to which a stress shall be assigned.

It should be noted that each of the symbols for the above stress categories represents six scalar quantities corresponding to the six stress components, \( \sigma_t, \sigma_l, \sigma_r, \tau_{rl}, \tau_{lr}, \) and \( \tau_{rt} \). In the particular case of the six membrane stress components, each component shall be averaged across the thickness of the structural section.

(c) For each category, calculate the algebraic sum of the \( \sigma_j \)'s that result from the different types of loadings and similarly for the other five stress components. Certain combinations of the categories must also be considered.

(d) Translate the stress components for the t, l, and r directions into principal stresses, \( \sigma_1, \sigma_2, \) and \( \sigma_3 \). (In many pressure component calculations, the t, l, and r directions may be so chosen that the shearing stress components are zero and \( \sigma_1, \sigma_2, \) and \( \sigma_3 \) are identical to \( \sigma_t, \sigma_l, \) and \( \sigma_r \)).

(e) Calculate the stress differences \( S_{12}, S_{23}, \) and \( S_{31} \) from the relations:

\[ S_{12} = \sigma_1 - \sigma_2 \]
\[ S_{23} = \sigma_2 - \sigma_3 \]
\[ S_{31} = \sigma_3 - \sigma_1 \]

The stress intensity, \( S \), is the largest absolute value of \( S_{12}, S_{23}, \) and \( S_{31} \).

HGB-3216 Derivation of Stress Differences and Strain Differences

The ability of the component to withstand the specified cyclic operation without creep-fatigue failure shall be determined as in HGB-3250. The evaluation shall demonstrate, by evaluating the stresses and strains at selected points of the components, that the combined creep-fatigue damage is everywhere within design limits. Only the stress and strain differences due to the operational cycles as specified in the Design Specifications need be considered.

HGB-3217 Classification of Stresses

Table HGB-3217-1 provides assistance in the determination of the category to which a stress shall be assigned. For portions of the component not exposed to elevated temperature service, the classification or category may be selected as in Division I, Article NG-3000.

HGB-3220 Design Rules and Limits or Load-Controlled Stresses in Structures Other Than Threaded Structural Fasteners

(a) The rules for design against failure from load-controlled stresses are illustrated in Division I, Fig. NH-3221-1 (with \( P_b \) replaced with \( P_m \)) and are explained in HGB-3220. The allowable stress intensity values used in HGB-3220 are listed in Tables 2A and 2B of Section II, Part D, Subpart 1 and in the tables of Mandatory Appendix I-14 of Division I, Subsection NH. Note that the strain, deformation, and fatigue limits of HGB-3250 require analyses beyond those required by the rules of HGB-3220.

(b) The stress intensity limits used in Division I, Fig. NH-3221-1 (with \( P_b \) replaced with \( P_m \)) and throughout this Subpart are defined for base metal and at weldments as follows:

1. Base Metal

\( S_m \) = the lowest stress intensity value at a given temperature among the time-independent strength quantities that are defined in Section II, Part D, Subpart 1 as criteria for determining \( S_m' \). In this Subpart, the \( S_m \) values are extended to elevated temperatures by using the same criteria. As described in Division I, NH-2160(d), it may be
(d) Translate the stress components for the \( t, l \), and \( r \) directions into principal stresses, \( \sigma_1, \sigma_2, \) and \( \sigma_3 \). (In many pressure component calculations, the \( t, l \), and \( r \) directions may be so chosen that the shearing stress components are zero and \( \sigma_1, \sigma_2, \) and \( \sigma_3 \) are identical to \( \sigma_t, \sigma_l, \) and \( \sigma_r \).)

(e) Calculate the stress differences \( S_{12}, S_{23}, \) and \( S_{31} \) from the relations:

\[
S_{12} = \sigma_1 - \sigma_2 \\
S_{23} = \sigma_2 - \sigma_3 \\
S_{31} = \sigma_3 - \sigma_1
\]

The stress intensity, \( S \), is the largest absolute value of \( S_{12}, S_{23}, \) and \( S_{31} \).

HGB-3216 Derivation of Stress Differences and Strain Differences

The ability of the component to withstand the specified cyclic operation without creep-fatigue failure shall be determined as in HGB-3250. The evaluation shall demonstrate, by evaluating the stresses and strains at selected points of the components, that the combined creep-fatigue damage is everywhere within design limits. Only the stress and strain differences due to the operational cycles as specified in the Design Specifications need be considered.

HGB-3217 Classification of Stresses

Table HGB-3217-1 provides assistance in the determination of the category to which a stress shall be assigned. For portions of the component not exposed to elevated temperature service, the classification or category may be selected as in Division 1, Article NG-3000.

HGB-3220 DESIGN RULES AND LIMITS OR LOAD-CONTROLLED STRESSES IN STRUCTURES OTHER THAN THREADED STRUCTURAL FASTENERS

HGB-3221 General Requirements

(a) The rules for design against failure from load-controlled stresses are illustrated in Division 1, Fig. NH-3221-1 (with \( P_t \) replaced with \( P_m \)) and are explained in HGB-3220. The allowable stress intensity values used in HGB-3220 are listed in Tables 2A and 2B of Section II, Part D, Subpart 1 and in the tables of Mandatory Appendix NH-I-14 of Division 1, Subsection NH. Note that the strain, deformation, and fatigue limits of HGB-3250 require analyses beyond those required by the rules of HGB-3220.

(b) The stress limits intensities used in Division 1, Fig. NH-3221-1 (with \( P_t \) replaced with \( P_m \)) and throughout this Subpart are defined for base metal and at weldments as follows:

1) Base Metal

\[ S_m = \text{the lowest stress intensity value at a given temperature among the time-independent strength quantities that are defined in Section II, Part D, Subpart 1 as criteria for determining } S_m; \text{ in this Subpart, the } S_m \text{ values are extended to elevated temperatures by using the same criteria. As described in Division 1, NH-2160(d), it may be necessary to adjust the values of } S_m \text{ to account for the effects of long-time service at elevated temperature.} \]

\[ S_{mt} = \text{the allowable limit of primary membrane stress intensity to be used as a reference for stress calculations for the actual service life and under the Level A and B Service Loadings; the allowable values are shown in Figs. NH-I-14.3A through NH-I-14.3E and in Tables NH-I-14.3A through NH-I-14.3E of Division 1, Subsection NH. The } S_{mt} \text{ values are the lower of two stress intensity values, } S_m \text{ (time-independent) and } S_t \text{ (time-dependent). As described in Division 1, NH-2160(d), it may be necessary to adjust the values of } S_{mt} \text{ to account for the effects of long-time service at elevated temperature.} \]

\[ S_o = \text{the maximum allowable value of general primary membrane stress intensity to be used as a reference for stress calculations under Design Loadings. The allowable values are given in Table NH-I-14.2 of Division 1, Subsection NH. [The values correspond to the } S \text{ values given in Section II, Part D, Subpart 1, Table 1A, except for a few cases at lower temperatures where values of } S_{mt} \text{ defined below and given in Tables NH-I-14.3A through NH-I-14.3E of Division 1, Subsection NH] at } 300,000 \text{ hr exceed the } S \text{ values. In those limited cases, } S_o \text{ is equal to } S_{mt} \text{ at } 300,000 \text{ hr rather than } S \text{.} \]

\[ S_t = \text{a temperature and time-dependent stress intensity limit; the data considered in establishing these values are obtained from long-term, constant load, uniaxial tests. For each specific time, } t, \text{ the } S_t \text{ values shall be the lesser of:} \]

\[ (a) \text{100% of the average stress required to obtain a total (elastic, plastic, primary, and secondary creep) strain of 1%;} \]

\[ (b) \text{80% of the minimum stress to cause initiation of tertiary creep; and} \]

\[ (c) \text{67% of the minimum stress to cause rupture.} \]

(2) Weldments

\[ S_{mt} = \text{the allowable limit of primary membrane stress intensity, and shall be taken as the lower of the } S_{mt} \text{ values from Tables NH-I-14.3A through NH-I-14.3E of Division 1, Subsection NH or:} \]

\[ 0.8 S_o \times \kappa \]

As described in Division 1, NH-2160(d), it may be necessary to adjust the values of \( S_{mt} \) to account for the effects of long-time service at elevated temperature.