(3) If the effects of anchor motion, $M_{AM}$, from reversing dynamic loads are not considered in NB-3654, then the requirements of (b)(4) shall be satisfied.

(b) As an alternative to (a), for piping fabricated from material designated P-No. 1 through P-No. 9 in Table 2A, Section II, Part D and limited to $D_0/t_0 \leq 40$ if Level D Service Limits are designated which include reversing dynamic loads (NB-3622.2.2) that are not required to be combined with nonreversing dynamic loads (NB-3622.2.4), the requirements of (1) through (5) below shall apply.

(1) The pressure occurring coincident with the earthquake or other reversing type loading shall not exceed the Design Pressure.

(2) The sustained stress due to weight loading shall not exceed the following:

$$B_2 \frac{D_0}{2t} M_w \leq 0.5 S_m$$

where

$M_w =$ resultant moment due to weight effects, in.-lb (N-mm) (NB-3623)

(3) The stress due to weight and inertial loading due to reversing dynamic loads in combination with the Level D coincidence pressure shall not exceed the following:

$$B_1 \frac{P_0 D_0}{2t} + B_2' \frac{D_0}{2l} M_E \leq 3 S_m$$

where

$B_2' = B_2$ from Table NB-3681(a)-1, except as follows:

where

$$B_2' = 1.33$$

for girth butt welds between items which do not have nominally identical wall thicknesses [NB-3683.4(b)]

$$B_2' = 0.87 / h_k$$

for curved pipe or butt-welding elbows (h as defined in NB-3683.7), but not less than 1.0

$$B_{2b}' = 0.27 (R_m / T)_{b}$$

and

$$B_{2g}' = 0.33 (R_m / T)_{b}$$

for ASME B16.9 or MSS SP-87 butt-welding tees (terms as defined in NB-3683), but neither less than 1.0

$M_E =$ the amplitude of the resultant moment, in.-lb (N-mm). In the combination of loads, all directional moment components in the same direction shall be combined before determining the resultant moment. If the method of analysis is such that only magnitude without algebraic signs is obtained, the most conservative combination shall be assumed.

$P_0 =$ the pressure occurring coincident with the reversing dynamic load, psi (MPa)

(4) The range of the resultant moment $M_{AM}$ and the amplitude of the longitudinal force $F_{AM}$ resulting from the anchor motions due to earthquake and other reversing type dynamic loading shall not exceed the following:

$$\frac{M_{AM}}{D} \leq 6.0 S_m$$

$$\frac{F_{AM}}{A_M} \leq S_m$$

where

$A_M =$ cross-sectional area of metal in the piping component wall, in.$^2$ (mm$^2$)

(5) The use of the $6S_m$ limit in (4) assumes essentially linear behavior of the entire piping system. This assumption is sufficiently accurate for systems where plastic straining occurs at many points or over relatively wide regions, but fails to reflect the actual strain distribution in unbalanced systems where only a small portion of the piping undergoes plastic strain. In these cases, the weaker or higher stressed portions will be subjected to strain concentrations due to elastic follow-up of the stiffer or lower stressed portions. Unbalance can be produced

(a) by the use of small pipe runs in series with larger or stiffer pipe, with the small lines relatively highly stressed.

(b) by local reduction in size or cross section, or local use of a weaker material.

In the case of unbalanced systems, the design shall be modified to eliminate the unbalance or the piping shall be qualified to the equations given in (4) with $S_m$ replaced by $3S_m$.

(6) Piping displacements and allowable $6S_m$ replacements by $3S_m$.

(c) As an alternative to (a) and (b), the cases concerned in Appendix F may be used in evaluating these service loadings independently of all other Design and Service Loadings.

NB-3657 Test Loadings

The evaluation of Test Loadings shall be carried out in accordance with NB-3226.

NB-3658 Analysis of Flanged Joints

The pressure design of flanged joints is covered by NB-3647.1. Flanged joints subjected to combinations of moment and pressure shall meet the requirements of this paragraph. In addition, the pipe-to-flange welds shall meet the requirements of NB-3652 through NB-3656 using appropriate stress indices from Table NB-3681(a)-1. Flanged Joints using flanges, bolting, and gaskets as specified in ASME B16.5 and using a bolt material having an $S_m$ value at 100°F (38°C) not less than 20.0 ksi (138 MPa) may be analyzed in accordance with the
where

\[ f = \text{stress range reduction factor for cyclic conditions for total number } N \text{ of full temperature cycles over total number of years during which system is expected to be in service from Table NC-3611.2(e)-1} \]

\[ S_e = \text{basic material allowable stress at minimum (cold) temperature, psi (MPa)} \]

\[ S_h = \text{basic material allowable stress at maximum (hot) temperature, psi (MPa)} \]

(1) In determining the basic material allowable stresses \( S_e \) and \( S_h \), joint efficiencies need not be applied.

(2) Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials, where employed to minimize the reduction in cyclic life caused by corrosive action.

(3) If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

\[ N = N_e + r_1^5 N_1 + r_2^5 N_2 + \ldots + r_n^5 N_n \]  

where

\[ N_e = \text{number of cycles at full temperature change } \Delta T_e \text{ for which expansion stress } S_e \text{ has been calculated} \]

\[ N_1, N_2, \ldots, N_n = \text{number of cycles at lesser temperature changes, } \Delta T_1, \Delta T_2, \ldots, \Delta T_n \]

\[ r_1, r_2, \ldots, r_n = \frac{(\Delta T_1)/(\Delta T_e), (\Delta T_2)/(\Delta T_e), \ldots, (\Delta T_n)/(\Delta T_e)}{\text{the ratio of any lesser temperature cycles for which the expansion stress } S_e \text{ has been calculated}} \]

(4) Allowable Stress for Nonrepeated Stresses. The allowable stress due to any single nonrepeated anchor movement (e.g., predicted building settlement) calculated in accordance with eq. NC-3653.2(b)(10b) shall be 3.05e.

NC-3611.3 Alternative Analysis Methods. The specific design requirements of NC-3600 are based on a simplified engineering approach. A more rigorous analysis such as described in NB-3600 or NB-3200 may be used to calculate the stresses required to satisfy these requirements. These calculated stresses must be compared to the allowable stresses in this Subsection. In such cases, the designer shall include appropriate justification for the approach taken in the Certified Design Report.

NC-3612 Pressure–Temperature Ratings for Piping Products

NC-3612.1 Piping Products Having Specific Ratings.

(a) Pressure–temperature ratings for certain piping products have been established and are contained in some of the standards listed in Table NCA-7100-1. The pressure ratings at the corresponding temperatures given in the standards listed in Table NCA-7100-1 shall not be exceeded, and piping products shall not be used at temperatures in excess of those given in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1 for the materials of which the products are made.

(b) Where piping products have established pressure-temperature ratings which do not extend to the upper material temperature limits permitted by this Subsection, the pressure–temperature ratings between those established and the upper material temperature limit may be determined in accordance with the rules of this Subsection.

NC-3612.2 Piping Products Not Having Specific Ratings. Should it be desired to use methods of manufacture or design of piping products not now covered by this Subsection, it is intended that the manufacturer shall comply with the requirements of NC-3640 and NC-3690 and other applicable requirements of this Subsection for the Design Loadings involved. The manufacturer’s recommended pressure ratings shall not be exceeded.

NC-3612.4 Considerations for Local Conditions and Transients.

(a) Where piping systems operating at different pressures are connected by a valve or valves, the valve or valves shall be designed for the higher pressure system requirements of pressure and temperature. The lower pressure system shall be designed in accordance with (1), (2), or (3) below.

(1) The requirement of the higher pressure system shall be met.

(2) Pressure relief devices or safety valves shall be included to protect the lower pressure system in accordance with NC-7311 and NC-7321.

(3) Assure compliance with all the conditions of (a) through (e) below.

(a) Redundant check or remote actuated valves shall be used in series at the interconnection, or a check in series with a remote actuated valve.

(b) When mechanical or electrical controls are provided, redundant and diverse controls shall be installed which will prevent the interconnecting valves from opening when the pressure in the high pressure system exceeds the Design Pressure of the low pressure system.
Figure NC-3643.3(c)(1)-1
Reinforcement of Branch Connections

Required reinforcement = \((f_{mb}) (d_1) (2 - \sin \alpha)\)
Reinforcement areas = \(A_1, A_2, A_3, A_4\)

Explanation of areas:
- Required reinforcement area
- Area \(A_1\) - Excess wall in header
- Area \(A_2\) - Excess wall in branch
- Area \(A_3\) - Fillet weld metal
- Area \(A_4\) - Metal in reinforcement

GENERAL NOTES:
(a) When metal is added as reinforcement (Example B), the value of reinforcing area may be taken in the same manner in which excess header metal is considered. Typical acceptable methods of meeting the above requirement are shown in Fig. NC-3643.3(c)(1)-2.
(b) Width to height of reinforcement shall be reasonably proportioned, preferably on a ratio as close as 4 to 1 as the available horizontal space within the limits of the reinforcing zone along the run and the O.D. of the branch will permit, but in no case may the ratio be less than 1.
(c) This Figure is to be used only for definitions of terms, not for fabrication details.
(d) Use of reinforcing saddles and pads is limited as stated in NC-3643.3(c)(7).
Figure NC-3643.4(a)-1
Reinforced Extruded Outlets

NOTES:
(1) Sketch to show method of establishing $T_b$ when the taper engaeches on the crotch radius.
(2) Sketch is drawn for condition where $K = 1.00$. 
dynamic loads (NC-3622.4) that are not required to be combined with nonreversing dynamic loads (NC-3622.5), the requirements of (1) through (5) below shall apply.

(1) The pressure occurring coincident with the earthquake or other reversing type loading shall not exceed the Design Pressure.

(2) The sustained stress due to weight loading shall not exceed the following:

\[ B_2 \frac{D}{2l} M_W \leq 0.5S_h \]

where

\[ M_W = \text{resultant moment due to weight effects, in.-lb (N-mm)} \]

(3) The stress due to weight and inertial loading due to reversing dynamic loads in combination with the Level D coincident pressure shall not exceed the following:

\[ B_2' = \text{from Table NC-3673.2(b)-1, except as follows:} \]

\[ B_2' = 0.87h^{\frac{1}{6}} \text{for curved pipe or butt welding elbows: h as defined in Table NC-3673.2(b)-1 but not less than 1.0} \]

\[ B_2' = 1.33 \text{for girth butt welds between items which do not have nominally identical wall thicknesses [NB-3683.4(b)]} \]

\[ B_2'' = 0.27 (R_m/T_s)^{\frac{1}{6}} \text{and} \]

\[ B_2''' = 0.33 (R_m/T_s)^{\frac{1}{6}} \text{for ASME B16.9 or MSS SP-97 butt welding tees [terms as defined in Table NC-3673.2(b)-1], but neither less than 1.0} \]

\[ M_E = \text{the amplitude of the resultant moment in.-lb (N-mm). In the combination of loads, all directional moment components in the same direction shall be combined before determining the resultant moment. If the method of analysis is such that only magnitude without algebraic sign are obtained, the most conservative combination shall be assumed.} \]

\[ P_D = \text{the pressure occurring coincident with the reversing dynamic load, psi (MPa)} \]

\[ S_h = \text{as defined in NC-3653.1} \]

(4) The range of the resultant moment \( M_{AM} \) and the amplitude of the longitudinal force \( F_{AM} \) resulting from the anchor motions due to earthquake and other reversing type dynamic loading shall not exceed the following:

\[ C_2 \frac{M_{AM}D_0}{2l} < 6S_h \]

\[ \frac{F_{AM}}{A_M} < S_h \]

where

\[ A_M = \text{cross-sectional area of breach in the piping component wall - in.}^2 \text{ (mm}^2) \]

\[ C_2 = \text{secondary stress index from Table NB-3681(a)-1} \]

(5) The use of the \( 6S_h \) limit in (4) assumes essentially linear behavior of the entire piping system. This assumption is sufficiently accurate for systems where plastic straining occurs at many points or over relatively wide regions, but fails to reflect the actual strain distribution in unbalanced systems where only a small portion of the piping undergoes plastic strain. In these cases, the weaker or higher stressed portions will be subjected to strain concentrations due to elastic follow-up of the stiffer or lower stressed portions. Unbalance can be produced

(a) by the use of small pipe runs in series with larger or stiffer pipe, with the small lines relatively highly stressed.

(b) by local reduction in size or cross section, or local use of a weaker material.

In the case of unbalanced systems, the design shall be modified to eliminate the unbalance or the piping shall be qualified to the equations given in (4) with \( 6S_h \) as \( 3S_h \).

(6) Piping displacements shall satisfy Design Specification limitations.

(c) As an alternative to (a) and (b), the rules contained in Appendix F may be used in evaluating these service loadings independently of all other Design and Service Loadings.

**NC-3658 Analysis of Flanged Joints**

The pressure design of flanged joints is covered by NC-3647.1. Flanged joints subjected to combinations of moment and pressure shall meet the requirements of either NC-3658.1, NC-3658.2, or NC-3658.3. In addition, the pipe-to-flange welds shall meet the requirements of C-3651 through C-3655 using appropriate stress intensification factors from Table NC-3673.2(b)-1. The following nomenclature applies for NC-3658:

\[ A_b = \text{total cross-sectional area of bolts at root of thread or section of least diameter under stress, in.}^2 \text{ (mm}^2) \]

\[ C = \text{bolt circle diameter, in. (mm)} \]

\[ D_P = \text{outside diameter of raised face, in. (mm)} \]

\[ G = \text{diameter at location of gasket load reaction as defined in XI-3130, in. (mm)} \]

\[ M_{fl} = \text{bending or torsional moment (considered separately) as defined for } M_R \text{ but including dynamic loadings applied to the flanged joint during the design or service condition, in.-lb (N-mm)} \]

\[ M_R = \text{bending or torsional moment (considered separately) applied to the joint due to weight, thermal expansion of the piping, sustained anchor movements, relief valve steady-state thrust, and other sustained mechanical loads applied to the flanged} \]
NC-3660  DESIGN OF WELDS

NC-3661  Welded Joints

NC-3661.1 General Requirements. Welded joints shall be made in accordance with NC-4200.

NC-3661.2 Socket Welds.34  
(a) Socket welded piping joints shall be limited to pipe sizes of NPS 2 (DN 50) and less.
(b) Socket welds shall comply with the requirements of NC-4427.
(c) Drains and bypasses may be attached to a valve or a fitting using socket welded joints up to a maximum of NPS 4 (DN 100).

NC-3661.3 Fillet Welds and Partial Penetration Welds for Branch Connections.39  
(a) Fillet welds and partial penetration welds may be used within the limitations of NC-3643.1(c).
(b) For fillet welds, the size of the weld shall be specified on the design drawings.
(c) For partial penetration welds, the size of the weld, the depth of the weld groove, and the groove angle shall be specified on the design drawings.

NC-3670  SPECIAL PIPING REQUIREMENTS

NC-3671  Selection and Limitations of Nonwelded Piping Joints

The type of piping joint used shall be suitable for the Design Loadings and shall be selected with consideration of joint tightness, mechanical strength, and the nature of the fluid handled.

NC-3671.1 Flanged Joints. Flanged joints shall conform to NC-3647 and NC-3658.

NC-3671.2 Expanded or Rolled Joints. Expanded or rolled joints may be used when experience or test (NC-3649) has demonstrated that the joint is suitable for the Design Loadings and when adequate provisions are made to prevent separation of the joint.

NC-3671.3 Threaded Joints. Threaded joints may be used within the limitations specified in (a), (b), and (c) below.
(a) All threads on piping products shall be taper pipe threads in accordance with the applicable standard listed in Table NCA-7100-1. Threads other than taper pipe threads may be used for piping components where tightness of the joint depends on a seal weld or a seating surface other than the threads and when experience or test (NC-3649) has demonstrated that such threads are suitable.
(b) Threaded joints shall not be used when severe erosion, crevice corrosion, shock, or vibration is expected to occur. Size limits for steam and hot water service above 220°F (104°C) shall be [maximum values listed].
(c) Pipe with a wall thickness less than that of standard weight of ASME B36.10M steel pipe shall not be threaded, regardless of service. When steel pipe is threaded and used in steam service above 250 psi (1.7 MPa) or water service above 100 psi (700 kPa) and 220°F (104°C), the pipe shall be seamless and at least Schedule 60.

NC-3671.4 Flared, Flareless, and Compression Joints. Flared, flareless, and compression type tubing fittings may be used for tube sizes not exceeding 2 in. (50 mm) O.D. within the limitations of applicable standards and specifications in Table NCA-7100-1 and as specified in (a) through (e) below.
(a) Fittings and their joints shall be compatible with the tubing with which they are to be used and shall conform to the range of wall thicknesses and method of assembly recommended by the manufacturer.
(b) Fittings shall be used at pressure-temperature ratings not exceeding the recommendations of the manufacturer. Service conditions, such as vibration and thermal cycling, shall be considered in the application.
(c) All threads on piping products shall be taper pipe threads in accordance with applicable standard listed in Table NCA-7100-1. Exceptions are that threads other than taper pipe threads may be used for piping components where tightness of the joint depends on a seating surface other than the threads and when experience or test (NC-3649) have demonstrated that such threads are suitable.
(d) In the absence of standards or specifications, the designer shall determine that the type of fitting selected is adequate and safe for the Design Loadings in accordance with the following requirements.
(1) The pressure design shall meet the requirements of NC-3649.
(2) Prototypes of the fittings to be used shall successfully meet performance tests (NC-3649) to determine the safety of the joint under simulated Service Loadings. When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or hydraulic shock are expected, the applicable conditions shall be incorporated in the test.
= ratio of the bending moment producing fatigue in a given number of cycles in a straight pipe with a girth butt weld to that producing failure in the same number of cycles in the fitting or joint under consideration.

\[ N = \text{number of cycles to failure} \]

\[ S = \text{amplitude of the applied bending stress at the point of failure, psi (MPa)} \]

(a) For piping products or joints not listed in Table NC-3673.2(b)-1, flexibility or stress intensification factors shall be established by experimental or analytical means.

(f) Experimental determination of flexibility factors shall be in accordance with Appendix II, II-1900. Experimental determination of stress intensification factors shall be in accordance with Appendix II, II-2000.

(g) Analytical determination of flexibility factors shall be consistent with the definition above.

(h) Analytical determination of stress intensification factors may be based on the empirical relationship

\[ i = \frac{C_2K_2}{2}, \text{but not less than 1.0} \]

where \( C_2 \) and \( K_2 \) are stress indices for Class 1 piping products or joints from NB-3681(a)-1, or are determined as explained below.

Analytical determination of stress intensification factors shall be correlated with experimental fatigue results. Experimental correlation may be with new test data or with test data from similar products or joints reported in literature. Finite element analyses or other stress analysis methods may be used to determine \( C_2 \); however, tests or established stress concentration factor data should then be used to determine \( K_2 \).

(i) For certain piping products or joints the stress intensification factor may vary depending on the direction of the applied moment, such as in an elbow or branch connection. For these cases, the stress intensification factor used in eqs. NC-3653.2(a)(10a), NC-3653.2(b)(10b), and NC-3653.2(c)(11) shall be the maximum stress intensification factor for all loading directions as determined in accordance with (j) or (h) above.

(j) Stress intensification factors determined in accordance with (f) above shall be documented in accordance with Appendix II, II-2050. The test report may be included and certified with the Design Report (NCA-3551.1 and NCA-3555) for the individual piping system or a separate report furnished (II-2050).

(k) Stress intensification factors determined in accordance with (h) above shall be documented in a report with sufficient detail to permit independent review. The review shall be performed by an engineer competent in the applicable field of design in accordance with Appendix XXIII. The report shall be included and certified as part of the design report for the piping system (NCA-3551.1 and NCA-3555).

(l) The total expansion range as determined from NC-3672.3 shall be used in all calculations, whether or not the piping is cold sprung. Expansion of the line, linear and angular movements of the equipment, supports, restraints, and anchors shall be considered in the determination of the total expansion range.

(m) Where simplifying assumptions are used in calculations or model tests, the likelihood of underestimates of forces, moments, and stresses, including the effects of stress intensification, shall be evaluated.

(n) Dimensional properties of pipe and fittings used in flexibility calculations shall be based on nominal dimensions.

(o) When determining stress intensification factors by experimental methods, NC-3653.3(d) shall not apply. The nominal stress at the point under consideration (crack site, point of maximum stress, etc.) shall be used.

NC-3673.3 Cold Springing. The beneficial effect of judicious cold springing in assisting a system to attain its most favorable position is recognized. Inasmuch as the life of a system under cyclic conditions depends on the stress range rather than the stress level at any one time, no credit for cold spring is allowed with regard to stresses. In calculating end thrusts and moments acting on equipment, the actual reactions at any one time, rather than their range, shall be used. Credit for cold springing is allowed in the calculations of thrusts and moments, provided the method of obtaining the designed cold spring is specified and used.

NC-3673.4 Movements. Movement caused by thermal expansion and loadings shall be determined for consideration of obstructions and design of proper supports.

NC-3673.5 Computing Hot and Cold Reactions.

(a) In a piping system with no cold spring or an equal percentage of cold springing in all directions, the reactions of \( R_h \) and \( R_c \) in the hot and cold conditions, respectively, shall be obtained from the reaction \( R \) derived from the flexibility calculations based on the modulus of elasticity at room temperature \( E_r \) using eqs. (14) and (15).

\[ R_h = \left(1 - \frac{2}{3} C \right) \left( \frac{E_h}{E_r} \right) R \]  \hspace{1cm} (14)

\[ R_c = CR = \left[1 - \left( \frac{S_h}{S_c} \right) \left( \frac{E_c}{E_h} \right) \right] R \]  \hspace{1cm} (15)

whichever is greater, and with further condition that

\[ \left( \frac{S_h}{S_c} \right) \left( \frac{E_c}{E_h} \right) < 1 \]
Figure ND-3643.3(c)(1)-1
Reinforcement of Branch Connections

Required reinforcement = \( (f_{mb}) (d_t) (2 - \sin \alpha) \)
Reinforcement areas = \( A_1, A_2, A_3, A_4 \)

Explanation of areas:
- Required reinforcement area
- Area \( A_1 \) - Excess wall in header
- Area \( A_2 \) - Excess wall in branch
- Area \( A_3 \) - Fillet weld metal
- Area \( A_4 \) - Metal in reinforcement

GENERAL NOTES:
(a) When metal is added as reinforcement (Example B), the value of reinforcing area may be taken in the same manner in which excess header metal is considered. Typical acceptable methods of meeting the above requirement are shown in Figure ND-42443(d)-1.
(b) Width to height of reinforcement shall be reasonably proportioned, preferably on a ratio as close as 4 to 1 as the available horizontal space within the limits of the reinforcing zone along the run and the outside diameter of the branch will permit, but in no case may the ratio be less than 1.
(c) This Figure is to be used only for definitions of terms, not for fabrication details.
(d) Use of reinforcing saddles and pads is limited as stated in ND-3643.3(c)(7).
including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, shall be considered.

(b) Comprehensive calculations shall take into account the flexibility factors found to exist in piping products or joints other than straight pipe. Credit may be taken where extra flexibility exists in such products or joints. Flexibility factors and stress intensification factors for commonly used piping products and joints are shown in Table ND-3673.2(b)-1. The stress intensification factors and flexibility factors in Table ND-3673.2(b)-1 shall be used unless specific experimental or analytical data exist that would warrant lower stress intensification factors or higher flexibility factors.

(c) Flexibility factors are identified herein by \( k \) with appropriate subscripts. The general definition of a flexibility factor is

\[
k = \frac{\theta_{ab}}{\theta_{nom}}
\]

where

\( \theta_{ab} \) = rotation of end \( a \), with respect to end \( b \), due to a moment load \( M \) and in the direction of the moment \( M \)

\( \theta_{nom} \) = nominal rotation assuming the component acts as a beam with the properties of the nominal pipe. For an elbow, \( \theta_{nom} \) is the nominal rotation assuming the elbow acts as a curved beam.

The flexibility factor \( k \) is defined in detail for specific components in Table ND-3673.2(b)-1.

(d) Stress intensification factors are identified herein by \( i \). The definition of a stress intensification factor is based on fatigue bend testing of mild carbon steel fittings and is

(U.S. Customary Units)

\[
iS = \frac{245,000}{N^{0.2}}
\]

(SI Units)

\[
iS = 1700 \times N^{-0.2}
\]

where

\( i = \) stress intensification factor
\( = \) ratio of the bending moment producing fatigue in a given number of cycles in a straight pipe with a girth butt weld to that producing failure in the same number of cycles in the fitting or joint under consideration.
\( N = \) number of cycles to failure
\( S = \) amplitude of the applied bending stress at the point of failure (ksi (MPa)).

(e) For piping products or joints not listed in Table ND-3673.2(b)-1, flexibility or stress intensification factors shall be established by experimental or analytical means.

(f) Experimental determination of flexibility factors shall be in accordance with Appendix II, II-1900. Experimental determination of stress intensification factors shall be in accordance with Appendix II, II-2000.

(g) Analytical determination of flexibility factors shall be consistent with the definition above.

(h) Analytical determination of stress intensification factors may be based on the empirical relationship

\[
i = C_2 K_2 / 2, \text{ but not less than } 1.0
\]

where \( C_2 \) and \( K_2 \) are stress indices for Class 1 piping products or joints from NB-3681(a)-1, or are determined as explained below.

Analytical determination of stress intensification factors shall be correlated with experimental fatigue results. Experimental correlation may be with new test data or with test data from similar products or joints reported in literature. Finite element analyses or other stress analysis methods may be used to determine \( C_2 \); however, test or established stress concentration factor data should then be used to determine \( K_2 \).

(i) For certain piping products or joints the stress intensification factor may vary depending on the direction of the applied moment, such as in an elbow or branch connection. For these cases, the stress intensification factor used in eqs. ND-3653.2(a)(10a), ND-3653.2(b)(10b) and ND-3653.2(c)(11) shall be the maximum stress intensification factor for all loading directions as determined in accordance with (f) or (h) above.

(j) Stress intensification factors determined in accordance with (f) above shall be documented in accordance with Appendix II, II-2050. The test report may be included and certified with the Design Report (NCA-3551.1 and NCA-3555) for the individual piping system or a separate report furnished (II-2050).

(k) Stress intensification factors determined in accordance with (h) above shall be documented in a report with sufficient detail to permit independent review. The review shall be performed by an engineer competent in the applicable field of design in accordance with Appendix XXIII. The report shall be included and certified as part of the design report for the piping system (NCA-3551.1 and NCA-3555).

(l) The total expansion range as determined from ND-3672.3 shall be used in all calculations, whether or not the piping is cold sprung. Expansion of the line, linear and angular movements of the equipment, supports, restraints, and anchors shall be considered in the determination of the total expansion range.