moment  $(M_A + M_B)$ , which result in the maximum calculated stress. The allowable stress to be used for this condition is  $3.0S_h$ , but not greater than  $2.0S_v$ .

(3) If the effects of anchor motion  $M_{AM}$ , from reversing dynamic loads are not considered in NC-3653, then the requirements of NC-3655(b)(4) shall be satisfied.

(b) As an alternative to NC-3655(a), for piping fabricated from material designated P-No. 1 through P-No. 9 in Table 2A, Section II, Part D, and limited to  $D_o/t_n \le 40$ , if Level D Service Limits are designated, which include reversing 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:

$$B_2 \frac{D_o}{2I} \ M_W \le 0.5 \ S_h$$

where

 $M_W$  = resultant moment due to weight effects

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

$$B_1 \frac{P_D D_o}{2t} + B_2 \frac{D_o}{2I} M_E \le 3 S_h$$

where

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- $B_2' = B_2$  from Fig. NC-3673.2(b)-1, except as follows:  $B_2' = 0.87/h^{2/3}$  for curved pipe or butt welding elbows *h* as defined in Fig. NC-3673.2(b)-1, but not less than 1.0
  - $B_2' = 1.33$  for girth butt welds between items which do *not* have nominally identical wall thicknesses [NB-3683.4(b)]

$$B_{2b}' = 0.27 (R_m/T_r)^{2/3}$$
 and

- $B_{2r}' = 0.33 (R_m/T_r)^{2/3}$  for ANSI B16.9 or MSS SP-87 butt welding tees [terms as defined in Fig. NC-3673.2(b)-1], but neither less than 1.0
- $M_E$  = the amplitude of the resultant moment in.-lb (N·m). 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 are obtained, the most conservative combination shall be assumed.
- $P_D$  = the pressure occurring coincident with the reversing dynamic load, psi (MPa)
- $S_h$  = 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:

$$C_2 \frac{M_{AM} D_O}{2I} < 6S_h$$
$$\frac{F_{AM}}{A_M} < S_h$$

where

 $A_M$  = cross-sectional area of metal in the piping component wall

(5) The use of the  $6S_h$  limit in NC-3655(b)(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 NC-3655(b)(4) with  $6S_h$  as  $3S_h$ .

(6) Piping displacements shall satisfy Design Specification limitations.

(c) As an alternative to NC-3655(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 NC-3651 through NC-3655 using appropriate stress intensification factors from Fig. NC-3673.2(b)-1. The following nomenclature applies for NC-3658:

 $A_b$  = total cross-sectional area of bolts at root of thread or section of least diameter under stress, in.<sup>2</sup> (mm<sup>2</sup>)

C = bolt circle diameter, in. (mm)

 $D_f$  = outside diameter of raised face, in. (mm)

- G = diameter at location of gasket load reaction as defined in XI-3130, in. (mm)
- $M_{fd}$  = bending or torsional moment (considered separately) as defined for  $M_{fs}$  but including dynamic loadings applied to the flanged joint during the design or service condition, in.-lb (N·m)
- $M_{fs}$  = bending or torsional moment (considered separately) applied to the joint due to weight, thermal expansion of the piping, sustained anchor move ments, relief valve steady-state thrust, and other sustained mechanical loads applied to the flanged joint during the design or service condition, in.-lb. (N·m). If cold springing is used, the moment may be reduced to the extent permitted by NC-3673.5.
- P = Design or Service Condition Pressure as defined in NCA-2140, psi (MPa)
- $P_{eq}$  = equivalent pressure to account for the moments applied to the flange joint during the Condition, psi (MPa)
- $P_{fd}$  = pressure concurrent with  $M_{fd}$ , psi (MPa)
- S = allowable bolt stress for the bolt material, psi (MPa)
- $S_y$  = yield strength, psi (MPa), of flange material at Design Temperature (Section II, Part D, Tables Y-1 and Y-2)

**NC-3658.1** Any Flanged Joint. Flanged joints may be analyzed and the stresses evaluated by using the methods given in Appendix XI as modified by NC-3658.1(a) or by NC-3658.1(b). Alternatively, they may be analyzed in accordance with Appendix XIII.

(a) If the flanged joint conforms to one of the standards listed in Table NC-3132-1, and if each P' as calculated by NC-3658.1(b) is less than the rated pressure at the Design or Service Temperature utilized, the requirements of NC-3658 are satisfied.

(b) The Design Pressure used for the calculation of H in Appendix XI shall be replaced by a flange design pressure

$$P' = P + P_{ea}$$

The equivalent pressure  $P_{eq}$  shall be determined by the greater of:

 $P_{eq} = 16M_{fs}/\pi G^3$ 

or

$$P_{ea} = 8M_{fd}/\pi G$$

NC-3658.2 Standard Flanged Joints at Moderate Pressures and Temperatures. Flanged joints conforming to ASME B16.5a, MSS SP-44, ASME B16.47a, or ANSI/ AWWA C207 Class E [275 psi (1.9 MPa)], and used where neither the Design nor Service Pressure exceeds 100 psi (700 kPa) and neither the Design nor Service Temperature exceeds 200°F (95°C), meet the requirements of NC-3658, provided the following equations are satisfied:

 $M_{fs} \leq A_b CS/4$ 

and

$$M_{fd} \le A_b CS / 2$$

NC-3658.3 ASME B16.5a Flanged Joints With High 07 Strength Bolting. Flanged joints using flanges, bolting, and gaskets as specified in ASME B16.5a and using bolting material having an *S* value at 100°F (38°C) not less than 20,000 psi (138 MPa) may be analyzed in accordance with the following rules.

(a) Design Limits and Levels A and B Service Limits

(1) The pressure shall not exceed the rated pressure for Level A Service Limits or 1.1 times the rated pressure for Level B Service Limits.

(2) The limitations given by eqs. (12) and (13) shall be met:

(U.S. Customary Units)

$$M_{fs} \le 3,125(S_y/36,000)CA_b$$
 (12)

(SI Units)

$$M_{fs} \le 21.7(S_{\nu}/250)CA_b$$

(U.S. Customary Units)

$$M_{fd} \le 6,250(S_{\rm v}/36,000)CA_b \tag{13}$$

(SI Units)

$$M_{fd} \le 43.4(S_v/250)CA_b$$

where the values of  $S_y/36,000$  and  $S_y/250$  shall not be taken as greater than unity.

(b) Level C Service Limits

(1) The pressure shall not exceed 1.5 times the rated pressure.

(2) The limitation given by eq. (17) shall be met:

(U.S. Customary Units)

$$M_{fd} \le [11,250A_b - (\pi/16)D_f^2 P_{fd}]C(S_y/36,000)$$
(17)

(SI Units)

$$M_{fd} \leq [78.1A_b - (\pi/16)D_f^2 P_{fd}]C(S_v/250)$$

where the values of  $S_y/36,000$  and  $S_y/250$  shall not be taken as greater than unity.

(c) Level D Service Limits

(1) The pressure shall not exceed 2.0 times the rated pressure.

(2) The limitation given by eq. (17) shall be met, where  $P_{fd}$  and  $M_{fd}$  are pressures, psi (MPa), and moments, in.-lb (N·m), occurring concurrently.

(d) Test Loadings. Analysis for test loadings is not required.