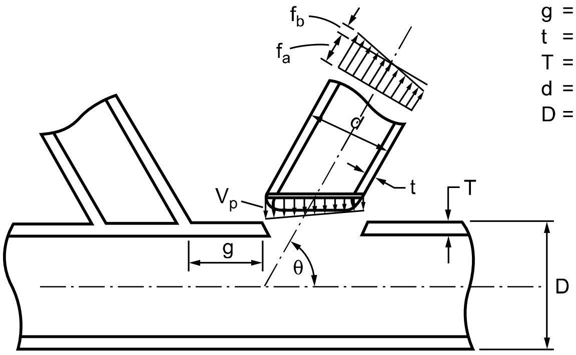

θ = Brace angle (measured from chord)
g = Gap, in. (mm)
t = Brace thickness, in. (mm)
T = Chord thickness, in. (mm)
d = Brace diameter, in. (mm)
D = Chord diameter, in. (mm)

$$\tau = \frac{t}{T}$$

$$\beta = \frac{d}{D}$$

$$\gamma = \frac{D}{2T}$$

Figure 4.1-1—Terminology and Geometric Parameters for Simple Tubular Connections

4.3 TUBULAR JOINTS

4.3.1 Simple Joints

Simple tubular joints, without overlap of principal braces and having no gussets, diaphragms, or stiffeners should use the following guidelines. Terminology is defined in Figure 4.1-1.

Joint classification as K, T & Y, or cross should apply to individual braces according to their load pattern for each load case. To be considered a K-joint, the punching load in a brace should be essentially balanced by loads on other braces in the same plane on the same side of the joint. In T and Y joints the punching load is reached as beam shear in the chord. In cross joints the punching load is carried through the chord to braces on the opposite side. For braces which carry part of their load as K-joints, and part as T & Y or cross joints, interpolate based on the portion of each in total. Examples are shown in Figure 4.3.1-1. See Commentary on Joint Classification.

Many properly designed tubular joints, especially those with brace to chord diameter ratios approaching 1.0, will exhibit different failure mechanisms and strength properties than the empirically based formulas contained herein. At present, insufficient experimental evidence exists to precisely quantify the degree of increased strength. Therefore, in lieu of the recommendations contained in Section 4.3 herein, reasonable alternative methods may be used for the design of such joints.

The adequacy of the joint may be determined on the basis of (a) punching shear or (b) nominal loads in the brace. These approaches are intended to give equivalent results. Brace axial loads and bending moments essential to the integrity of the structure** should be included in the calculations.

**Reductions in secondary (deflection-induced) bending moments due to joint flexibility or inelastic relaxation may be considered.

a. Punching shear

The acting punching shear should be calculated by

$$V_p = \tau f \sin\theta \qquad (4.3.1\text{-}1)$$

where

f = nominal axial, in-plane bending, or out-of-plane bending stress in the brace (punching shear for each kept separate).

The allowable punching shear stress in the chord wall is the lesser of the AISC shear allowable or

$$v_{pa} = Q_q\, Q_f \frac{F_{yc}}{0.6\gamma}$$

(plus 1/3 increase where applicable) (4.3.1-2)

Capacity v_{pa} must be evaluated separately for each component of brace loading, utilizing the appropriate Q_q and Q_f factors. Q_q is a factor to account for the effects of type of loading and geometry, as given in Table 4.3.1-1. Q_f is a factor to account for the presence of nominal longitudinal stress in the chord.

$$Q_f = 1.0 - \lambda\,\gamma A^2$$

where

λ = 0.030 for brace axial stress,

= 0.045 for brace in-plane bending stress,

= 0.021 for brace out-of-plane bending stress,

$$A = A = \frac{\sqrt{\bar{f}^{\,2}_{AX} + \bar{f}^{\,2}_{IPB} + \bar{f}^{\,2}_{OPB}}}{0.6\ F_{ye}},$$

(1/3 increase applicable to denominator).

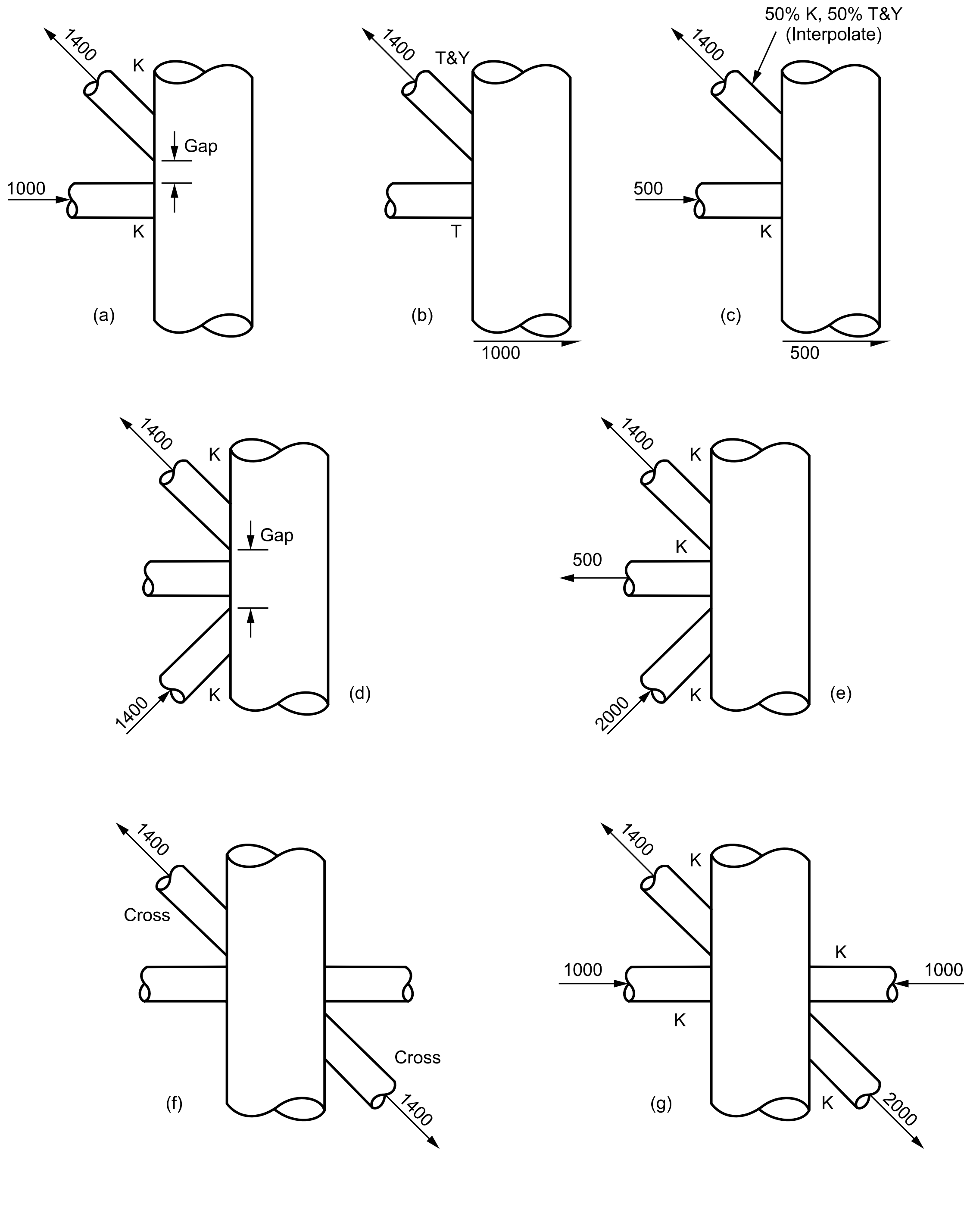

Figure 4.3.1-1—Example of Joint Classification

$\bar{f}_{AX}, \bar{f}_{IPB}, \bar{f}_{OPB}$ are the nominal axial, in plane bending, and out-of-plane bending stresses in the chord.

Set $Q_f = 1.0$ when all extreme fiber stresses in the chord are tensile.

For combined axial and bending stresses in the brace, the following interaction equations should be satisfied:

$$\left(\frac{v_p}{v_{pa}}\right)^2_{IPB} + \left(\frac{v_p}{v_{pa}}\right)^2_{OPB} \leq 1.0 \qquad (4.3.1\text{-}3a)$$

$$\left|\frac{v_p}{v_{pa}}\right|_{AX} + \frac{2}{\pi}\arcsin\sqrt{\left(\frac{v_p}{v_{pa}}\right)^2_{IPB} + \left(\frac{v_p}{v_{pa}}\right)^2_{OPB}} \leq 1.0$$

where the arcsin term is in radians (4.3.1-3b)

b. Nominal Loads

Allowable joint capacities in terms of nominal brace loads are

$$P_a = Q_u Q_f \frac{F_{yc}T^2}{1.7\sin\theta}$$

(plus 1/3 increase where applicable) (4.3.1-4a)

$$M_a = Q_u Q_f \frac{F_{yc}T^2}{1.7\sin\theta}(0.8d)$$

(plus 1/3 increase where applicable) (4.3.1-4b)

where

P_a = allowable capacity for brace axial load,

M_a = allowable capacity for brace bending moment.

Other terms, except Q_u, are defined in 4.3.1(a)

Q_u is the ultimate strength factor which varies with the joint and load type, as given in Table 4.3.1-2.

Table 4.3.1-1—Values for *Qq*

$$Q_\beta = \frac{0.3}{\beta(1-0.833\beta)} \text{ for } \beta > 0.6$$

$Q_\beta = 1.0$ for $\beta \leq 0.6$

$Q_g = 1.8 - 0.1\, g/T$ for $\gamma \leq 20$

$Q_g = 1.8 - 4\, g/D$ for $\gamma > 20$

but in no case shall Q_g be taken as less than 1.0.

Type of Joint and Geometry		Type of Load in Brace Member			
		Axial Tension	Axial Compression	In-Plane Bending	Out-of-Plane Bending
K	overlap	1.8 plus see 4.3.2		$(3.72 + 0.67/\beta)$	$(1.37 + 0.67/\beta)Q_\beta$
K	gap	$(1.10 + 0.20/\beta)\,Q_g$			
T&Y		$(1.10 + 0.20/\beta)$			
Cross	w/o diaphragms	$(1.10 + 0.20/\beta)$	$(0.75 + 0.20/\beta)Q_\beta$		
Cross	w/diaphragms per 2.5.5c.4	$(1.10 + 0.20/\beta)$			

Table 4.3.1-2—Values for Q_u(1)

Type of Joint and Geometry		Type of Load in Brace Member			
		Axial Tension	Axial Compression	In-Plane Bending	Out-of-Plane Bending
K		$(3.4 + 19\beta)Q_g$		$(3.4 + 19\beta)$	$(3.4 + 7\beta)Q_\beta$
T&Y		$(3.4 + 19\beta)$			
Cross	w/o diaphragms	$(3.4 + 19\beta)$	$(3.4 + 13\beta)Q_\beta$		
Cross	w/diaphragms per 2.5.5c.4	$(3.4 + 19\beta)$			

(1) Terms are defined in Figure 4.1-1 and Table 4.3.1-1.

For combined axial and bending loads in the brace, the following interaction equations should be satisfied:

$$\left(\frac{M}{M_a}\right)^2_{IPB} + \left(\frac{M}{M_a}\right)^2_{OPB} \le 1.0 \qquad (4.3.1\text{-}5a)$$

$$\left|\frac{P}{P_a}\right| + \frac{2}{\pi}\arcsin\sqrt{\left(\frac{M}{M_a}\right)^2_{IPB} + \left(\frac{M}{M_a}\right)^2_{OPB}} \le 1.0$$

where the arcsin term is in radians (4.3.1-5b)

c. Design Practice

If an increased wall thickness in the chord at the joint is required, it should be extended past the outside edge of the bracing a minimum of one quarter of the chord diameter or 12 inches (305 mm) including taper, whichever is greater. See Figure 4.3.1-2. The effect of joint can length on the capacity of cross joints is discussed in Section 4.3.4.

Where increased wall thickness or special steel is used for braces in the tubular joint area, it should extend a minimum of one brace diameter or 24 inches (610 mm) from the joint, including taper, whichever is greater.

Nominally concentric joints may be detailed with the working points (intersections of brace and chord centerlines) offset in either direction by as much as one quarter of the chord diameter in order to obtain a minimum clear distance of 2 inches (51 mm) between nonoverlapping braces or to reduce the required length of heavy wall in the chord. See Figure 4.3.1-2. For joints having a continuous chord of diameter substantially greater than the brace members (e.g., jacket leg joints), the moments caused by this minor eccentricity may be neglected. For K and X joints where all members are of similar diameter, the moments caused by eccentricity may be important and should be assessed by the designer.

Simple joints which cannot be detailed to provide the 2 inch (51 mm) minimum clear distance between braces within the limits of allowable offset of the working point, as established above, should be designed for stress transfer as discussed in 4.3.2 below and specially detailed on the drawings.

4.3.2 Overlapping Joints

Overlapping joints, in which brace moments are insignificant and part of the axial load is transferred directly from one brace to another through their common weld, may be designed as follows:

The allowable axial load component perpendicular to the chord. P⊥ in kips (N), should be taken as

$$P\perp = (v_{pa}\, T l_1) + (2 v_{wa} t_w l_2) \qquad (4.3.2\text{-}1)$$

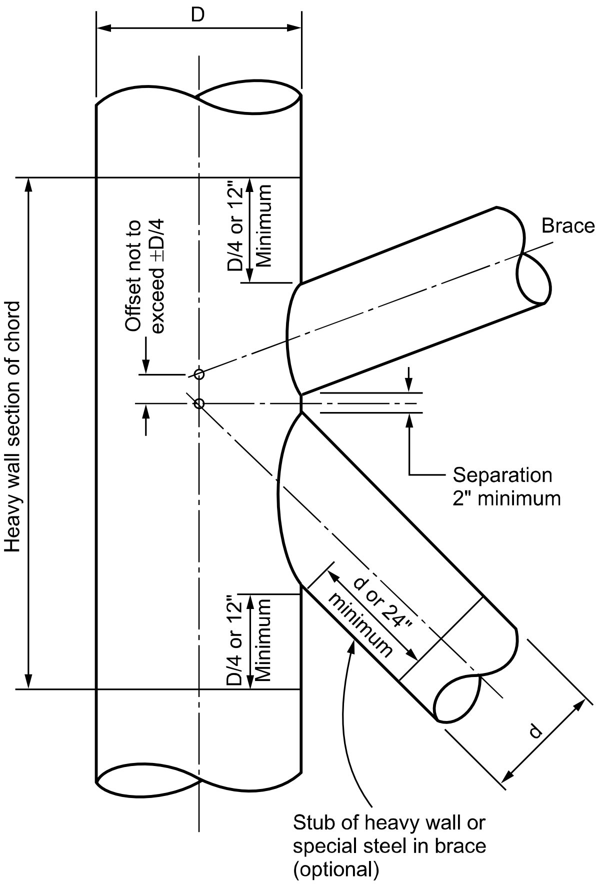

Figure 4.3.1-2—Detail of Simple Joint

for punching shear format or

$$P\perp = (P_a \sin\theta \, \frac{l_1}{l}) + (2 v_{wa} t_w l_2) \qquad (4.3.2\text{-}2)$$

for nominal load format.

where

v_{pa} = allowable punching shear stress in ksi (MPa) as defined in 4.3.1(a) for axial stress,

P_a = Allowable axial load in kips (N) as defined in 4.3.1(b),

V_{wa} = AISC allowable shear stress in ksi (MPa) for weld between braces,

t_w = the lesser of the weld throat thickness or the thickness t of the thinner brace, in. (mm),

l_1 = circumference for that portion of the brace which contacts the chord (actual length) in. (mm),

l = circumference of brace contact with chord, neglecting presence of overlap,

l_2 = the projected chord length (one side) of the overlapping weld, measured perpendicular to the chord, in. (mm).

These terms are illustrated in Figure 4.3.2-1.

The overlap should preferably be proportioned for at least 50% of the acting $P\perp$.

Where the braces carry substantially different loads and/or one brace is thicker than the other, the heavier brace should preferably be the through brace (as illustrated in Figure 4.3.2-1) with its full circumference welded to the chord.

In no case should the brace wall thickness exceed the chord wall thickness.

Moments caused by eccentricity of the brace working lines and exceeding that in 4.3.1(c) may be important and should be assessed by the designer.

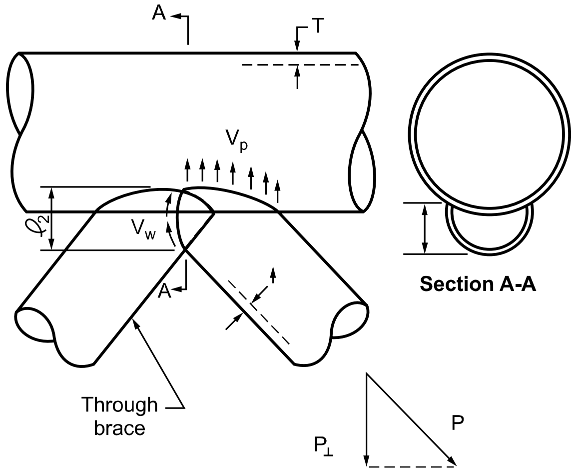

Figure 4.3.2-1—Detail of Overlapping Joint

4.3.3 Congested Joints

Where bracing members in adjacent planes tend to overlap in congested joints, the following corrective measures may be considered by the designer.

Where primary braces are substantially thicker than the secondary braces, they may be made the through member, with the secondary braces designed as overlapping braces per Section 4.3.2. See Figure 4.3.2-2, Detail A.

An enlarged portion of the through member may be used as indicated in Figure 4.3.2-2, Detail B designed as a simple joint per Section 4.3.1.

A spherical joint, Figure 4.3.2-2, Detail C may be used, designed on the basis of punching shear per Section 4.3.1, assuming:

γ = D/4T

θ = arc cos (β)

Q_q = 1.0

Q_f = 1.0

Secondary braces causing interference may be spread out as indicated in Figure 4.3.2-2, Det. D, provided the moments caused by the eccentricity of their working lines are considered in the design analysis.

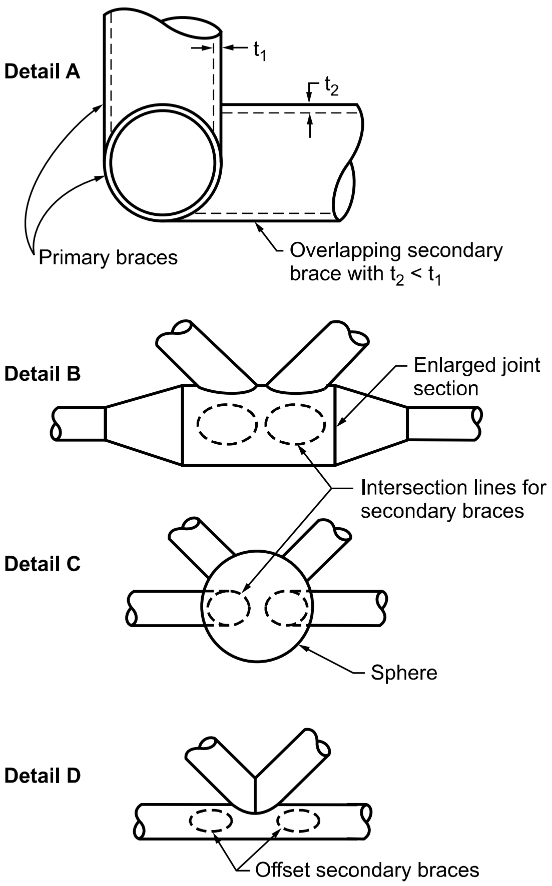

Figure 4.3.2-2—Secondary Bracing

4.3.4 Load Transfer Across Chords

Cross joints, launch leg joints, and other joints in which load is transferred across the chord should be designed to resist general collapse. However, for such joints reinforced only by a joint can having increased thickness T_c and length L (for cases where joint cans are centered on the brace of interest L is defined as shown in Figure 4.3.4-1a) and having brace

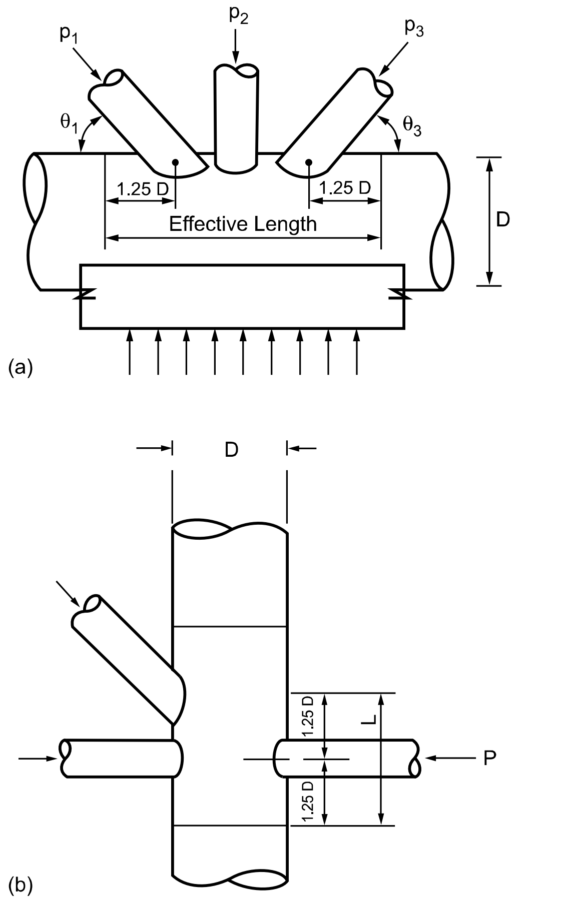

Figure 4.3.4-1—Definition of Effective Cord Length

chord diameter ratio less than 0.9, the allowable axial branch load shall be taken as:

$$P = P(1) + \frac{L}{2.5D}\,[P(2) - P(1)] \text{ for } L < 2.5D \qquad (4.3.4\text{-}1a)$$

$$P = P(2) \text{ for } L > 2.5D \qquad (4.3.4\text{-}1b)$$

where

$P(1)$ = P_a from Eq. 4.3.1-4a using the nominal chord member thickness,

$P(2)$ = P_a from Eq. 4.3.1-4a using thickness T_c.

Special consideration is required for more complex joints. For multiple branches in the same plane, dominantly loaded in the same sense, the relevant crushing load is $\Sigma_i P_i \sin \theta_i$. An approximate closed ring analysis may be employed, including plastic analysis with appropriate safety factors, using an effective chord length as shown in Figure 4.3.4-1b. Any reinforcement within this dimension (e.g., diaphragms, rings, gussets or the stiffening effect of out of plane members) may be considered in the analysis, although its effectiveness decreases with distance from the branch footprint.

Joints having two or more appropriately located diaphragms at each branch need only be checked for local capacity. The diaphragms shall be at least as thick as the wall thickness of the corresponding branch member. The capacity may be calculated using Table 4.3.1-1 or 4.3.1-2 for cross joints with diaphragms.

4.3.5 Other Complex Joints

Joints not covered by Sections 4.3.1 through 4.3.4 may be designed on the basis of appropriate experimental or in service evidence. In lieu of such evidence, an appropriate analytical check should be made. This check may be done by cutting sections which isolate groups of members, individual members, and separate elements of the joint (e.g., gussets, diaphragms, stiffeners, welds in shear, surfaces subjected to punching shear), and verifying that a distribution of stress can be assumed that satisfies equilibrium without exceeding the allowable stress of the material.

5 Fatigue

5.1 FATIGUE DESIGN

In the design of tubular connections, due consideration should be given to fatigue problems as related to local cyclic stresses.

A detailed fatigue analysis should be performed for template type structures. It is recommended that a spectral analysis technique be used. Other rational methods may be used provided adequate representation of the forces and member responses can be shown.

In lieu of detailed fatigue analysis, simplified fatigue analyses, which have been calibrated for the design wave climate, may be applied to tubular joints in template type platforms that:

1. Are in less than 400 feet (122 m) of water.
2. Are constructed of ductile steels.
3. Have redundant structural framing.
4. Have natural periods less than 3 seconds.

5.2 FATIGUE ANALYSIS

A detailed analysis of cumulative fatigue damage, when required, should be performed as follows:

5.2.1 The wave climate should be derived as the aggregate of all sea states to be expected over the long term. This may be condensed for purposes of structural analysis into representative sea states characterized by wave energy spectra and physical parameters together with a probability of occurrence.