USFOS

Joint Capacity

Theory

Description of use

Verification

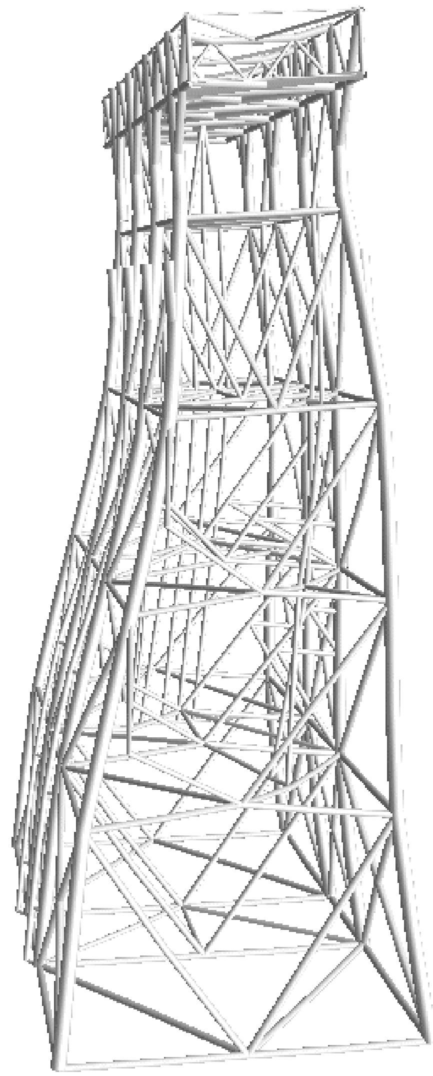


Table of Contents

1 INTRODUCTION

1.1 General

The current joint capacity check included in USFOS covers simple tubular joint and is based on capacity formulas and description of the joint behaviour developed during the MSL Joint Industry Projects as described in /1/, /2/. In addition to the original MSL formulations, code variants from:

- NORSOK N-004 /3/, /6/ and /9/
- ISO 19902 /4/ and /8/
- API RP 2A WSD /5/ and /10/

are also implemented.

1.2 MSL variants

The **MSL** Joint Industry Projects developed several sets of capacity formulas based on a large database of laboratory test results.

The original MSL versions you find in USFOS includes:

- Mean Ultimate
- Characteristic Ultimate
- Characteristic First Crack

Mean Ultimate represents the statistical mean failure of the joints tested (top of the force-displacement curve, "the most probable failure load").

Characteristic Ultimate is based on the same data, but the as the title say, the capacity is reduced in order to account for the spreading in the test results.

Characteristic First Crack is in most cases equal to "Characteristic Ultimate" but is further reduced in some cases in order to avoid degradation of the joint for repeated loading. This version is recommended for structures subjected to repeated load actions, e.g. wave loading.

1.3 Code variants

Note that the first crack characteristic capacity equations in the code variants are implemented in USFOS **excluding the safety factors given in the codes.** The additional safety level required by the code for the various limit states analysed must in USFOS be included on the load side (by increasing the applied loads).

NORSOK N-004 Revision 2, ISO:2007: The MSL capacity check formulas have been adopted and adjusted by NORSOK (rev 2) and ISO:2007. The code variants are based on the MSL First Crack capacity formulas. The (Q_u) expressions are nearly identical, but the correction factor for chord utilisation differs from MSL. Also the interaction between axial force, in-plane and out-of-plane bending differs, the code variants put more weight on the out-of plane bending component.

API RP 2A: The formulas are also based on the MSL database, however, the database used to develop the latest joint capacity equations for API RP2A are extended using results from FE analyses. The implementation is valid from 21'st ed ES3 (2007). No changes has been made to the code as of the R2020 version.

NORSOK N-004 Revision 3: The code is aligned with API RP 2A (2009) with some exceptions: -The basic capacity for X –joints in axial tension follows OMAE 2008-57650 /7/. In addition the expressions for chord utilisation factors are adjusted for X-joints. No changes has been made to the code as of the N-004:2021 version.

ISO 19902:2020: The code is aligned with NORSOK N-004 R3 with the following exception: For chord utilization factors, ISO:2020 is identical to API RP 2A (21'st ed 2007) -> 22 'ed R2020.

2 THEORY

2.1 Joint capacity formulas

2.1.1 General

The validity range for capacity equations given in Chapter 2 and implemented in USFOS are as follows:

$0.2 \leq \beta \leq 1.0$
$10 \leq \gamma \leq 50$
$30° \leq \theta \leq 90°$
$f_y \leq 500$ MPa
$\frac{g}{D} \geq -0.6$ (for K joints)

The above geometry parameters are defined as

$$\beta = \frac{d}{D}, \gamma = \frac{D}{2T}, \tau = \frac{t}{T}$$

Where d = brace diameter, D = Chord diameter, t = brace wall thickness, T = Chord thickness and g = gap between the two braces (for K-joints).

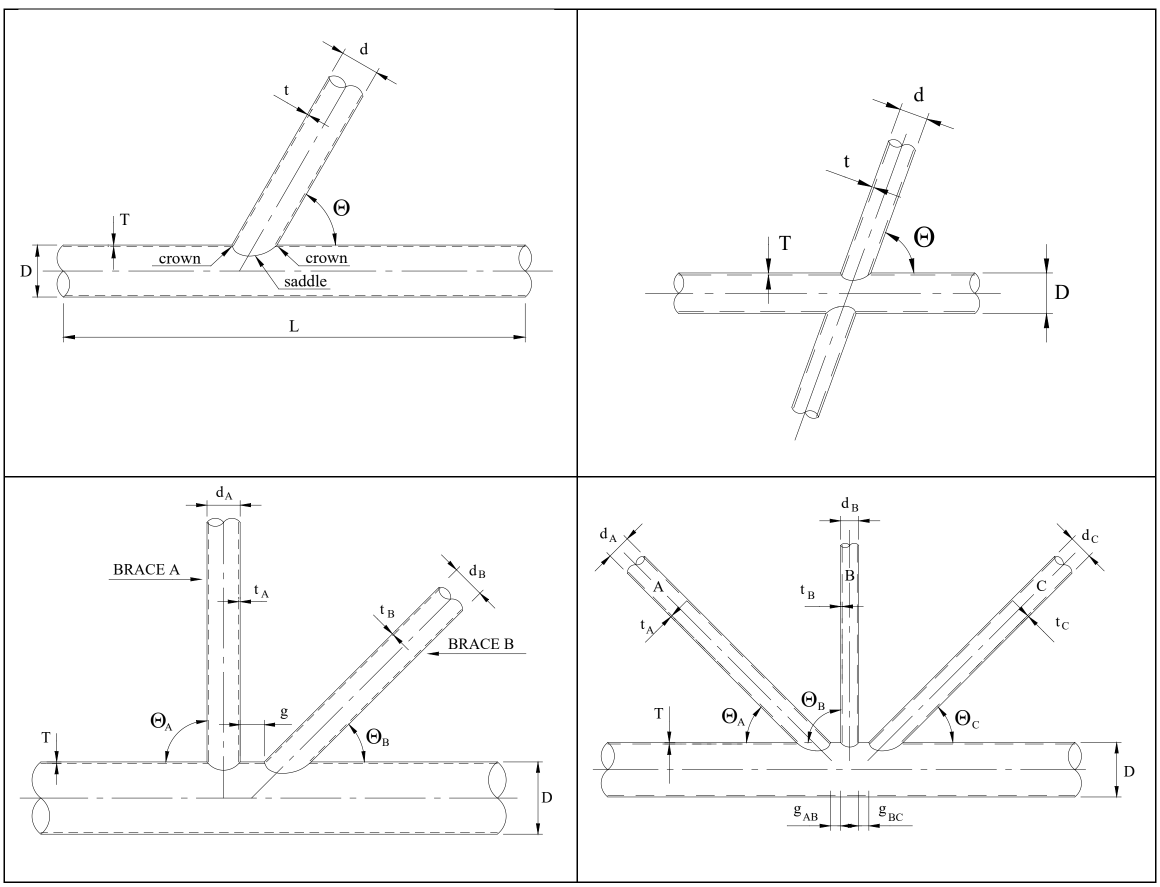


Figure 2-1 Definition of joint geometry parameters

2.2 Basic resistance, MSL

2.2.1.1 General

The resistances for simple tubular joints are defined as follows:

$$N_{\mathrm{Rd}} = \frac{f_y T^2}{\sin\theta} Q_u Q_f$$

$$M_{\mathrm{Rd}} = \frac{f_y T^2 d}{\sin\theta} Q_u Q_f$$

Where

N_{Rd} = the joint axial resistance
M_{Rd} = the joint bending moment resistance
f_y = the yield strength of the chord member at the joint

For braces with axial forces with a classification that is a mixture of K, Y and X joints, a weighted average of N_{Rd} based on the portion of each in the total action is used to calculate the resistance.

2.2.1.2 Strength factor Q_u

Q_u varies with the joint and action type, as given in Table 2-1 to Table 2-3.

Table 2-1 Values for Q_u, MSL Mean Ultimate

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$1.3(1.9+19\beta)Q_\beta^{0.5}Q_g Q_{yy}$	$1.3(1.9+19\beta)Q_\beta^{0.5}Q_g Q_{yy}$	$5.5\beta\gamma^{0.5}$	$4.2\gamma^{0.5\beta^2}$
Y	$42.3\beta + 17.6$	$1.27(1.9+19\beta)Q_\beta^{0.5}$	$5.5\beta\gamma^{0.5}$	$4.2\gamma^{0.5\beta^2}$
X	$37.3\beta + 6.6$ for $\beta \le 0.9$ $40 + (\beta\text{-}0.9)(37.6\gamma - 364)$ for $\beta > 0.9$	$1.16(2.8+14\beta)Q_\beta$	$5.5\beta\gamma^{0.5}$	$4.2\gamma^{0.5\beta^2}$

Mean Ultimate represents the statistical mean failure of the joints tested (top of the force-displacement curve, "the most probable failure load").

Table 2-2 Values for Q_u, MSL Characteristic Ultimate

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(1.9+19\beta)Q_\beta^{0.5}Q_g Q_{yy}$	$(1.9+19\beta)Q_\beta^{0.5}Q_g Q_{yy}$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
Y	$42\beta - 4.1$	$(1.9+19\beta)Q_\beta^{0.5}$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
X	$41\beta - 2.2$ for $\beta \le 0.9$ $35 + (\beta\text{-}0.9)(32\gamma - 285)$ for $\beta > 0.9$	$(2.8+14\beta)Q_\beta$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$

Characteristic Ultimate is based on the same data as for Mean Ultimate, the capacity is reduced in order to account for the spreading in the test results.

Table 2-3 Values for Q_u, MSL Characteristic First Crack

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(1.9+19\beta)Q_\beta^{0.5}Q_g Q_{yy}$	$(1.9+19\beta)Q_\beta^{0.5}Q_g Q_{yy}$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
Y	30β	$(1.9+19\beta)Q_\beta^{0.5}$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
X	23β for $\beta \le 0.9$ $21+(\beta\text{-}0.9)(17\gamma-220)$ for $\beta > 0.9$	$(2.8+14\beta)Q_\beta$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$

Characteristic First Crack is in most cases equal to "Characteristic Ultimate" but is further reduced in some cases in order to avoid degradation of the joint for repeated loading. This version is recommended for structures subjected to repeated load actions, e.g. wave loading.

Q_β is a geometric factor defined by:

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

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

Q_g is a gap factor defined by:

$Q_g = 1.9 - \left(\frac{g}{D}\right)^{0.5}$ for $\frac{g}{T} \ge 2.0$,but $Q_g \ge 1.0$

$Q_g = 0.13 + 0.65\varphi\gamma^{0.5}$ for $\frac{g}{T} \le -2.0$

$$where\ \varphi = \frac{t f_{y,b}}{T f_{y,c}}$$

$f_{y,b}$ = yield strength of brace (or brace stub if present)

$f_{y,c}$ = yield strength of chord (or chord can if present)

Q_g = linear interpolated value between the limiting values of the above expressions for $-2.0 \le \frac{g}{T} \le 2.0$

Q_{yy} is an angle correction factor defined by:

$Q_{yy} = 1.0$ when $\theta_t \le 4\theta_c - 90°$

$Q_{yy} = \frac{110° + 4\theta_c - \theta_t}{200°}$ when $\theta_t > 4\theta_c - 90°$

where θ_c and θ_t is the angle between the compression / tension brace and the chord respectively.

2.2.1.3 Chord action factor Q_f

Q_f is a factor to account for the presence of factored actions in the chord.

$$Q_f = 1.0 - \lambda U^2$$

where:

λ = 0.030 for brace axial tension or compression
= 0.045 for brace in-plane bending moment
= 0.021 for brace out-of-plane bending moment

The parameter U is defined as follows:

$$U = \frac{1}{\Gamma_q}\left[C_1\left(\frac{P}{N_P}\right)^2 + C_2\left(\frac{M}{M_P}\right)^2_{ipb} + C_2\left(\frac{M}{M_P}\right)^2_{opb}\right]^{0.5}$$

where:

P = axial load in chord
M = bending moment in chord, (ipb and opb)
N_P = axial capacity of chord
M_P = bending capacity of chord
C_1, C_2 = coefficients depending on joint and load type
Γ_q = assessment factor of safety, not to be taken greater than unity

Table 2-4 Values for C_1 and C_2, MSL

Joint Classification	C_1	C_2
T/Y joints under brace axial loading	25	11
DT/X joints under brace axial loading	25	43
K joints under balanced loading	14	43
All joints under brace moment loading	25	43

The chord thickness at the joint should be used in the above calculations. The highest value of U for the chord on either side of the brace intersection should be used. Apart from X joints with $\beta > 0.9$, Q_f may be set to unity if the magnitude of the chord axial tension stress is greater than the maximum combined stress due to chord moments.

2.2.1.4 Strength check

Joint resistance shall satisfy the following interaction equation for axial force and/or bending moments in the brace:

$$\left|\frac{N_{Sd}}{N_{Rd}}\right| + \left(\frac{M_{y,Sd}}{M_{y,Rd}}\right)^2 + \left(\frac{M_{z,Sd}}{M_{z,Rd}}\right)^2 \leq 1$$

Where:

N_{Sd} = axial force in the brace member
N_{Rd} = the joint axial resistance
$M_{y,Sd}$ = in-plane bending moment in the brace member
$M_{z,Sd}$ = out-of-plane bending moment in the brace member
$M_{y,Rd}$ = in-plane bending resistance
$M_{z,Rd}$ = out-of-plane bending resistance

2.2.1.5 Design axial resistance for X and Y joints with joint cans

For Y and X joints with axial force and where a joint can is specified, the joint design resistance should be calculated as follows:

$$N_{\mathrm{Rd}} = \left(r + (1\text{-r}) \left(\frac{T_n}{T_c}\right)^2 \right) N_{\mathrm{can,Rd}}$$

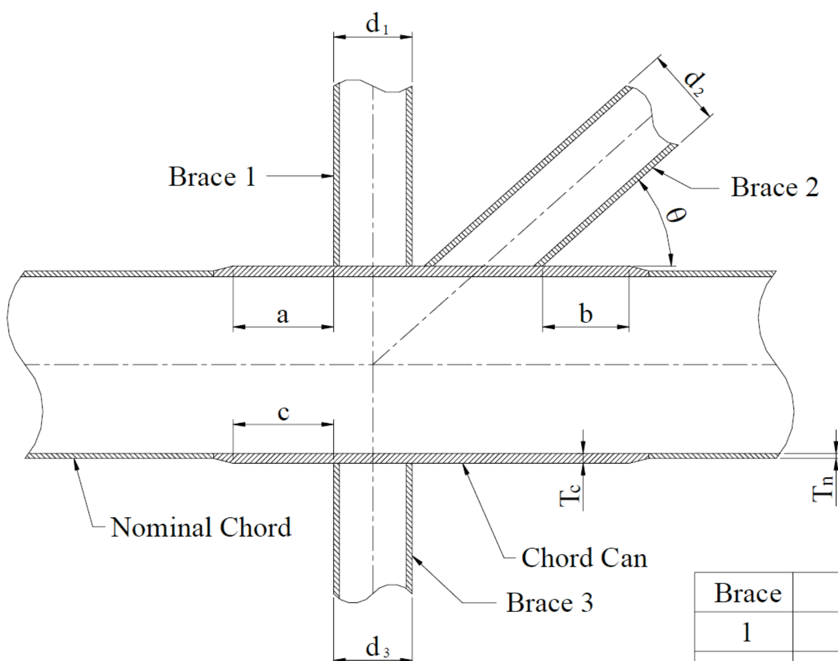
Where

$N_{can,Rd}$ = N_{Rd} based on chord can geometric and material properties
T_n = nominal chord member thickness
T_c = chord can thickness

DT/X Joints:
r = Lc/(2.5D) for joints with $\beta \le 0.9$
= $[(4\beta - 3)Lc/(1.5D)]$for joints with $\beta > 0.9$

Y/T Joints:
r = Lc/(2.0D) for joints with $\beta \le 0.9$
= $[(5\beta/3 - 1)Lc/D]$for joints with $\beta > 0.9$

Lc = effective total length of chord can, excluding taper, see Figure 2-2
In no case shall r be taken as greater than unity.



Brace	Length L_c
1	$2a + d_1$
2	$2b + d_2/\sin\theta$
3	$2c + d_3$

Figure 2-2 Calculation of Lc

2.2.2 Basic resistance, NORSOK N-004, Revision 2

2.2.2.1 General

The characteristic resistances for simple tubular joints are defined as follows:

$$N_{Rd} = \frac{f_y T^2}{\sin\theta} Q_u Q_f$$

$$M_{Rd} = \frac{f_y T^2 d}{\sin\theta} Q_u Q_f$$

Where

N_{Rd} = the joint axial resistance
M_{Rd} = the joint bending moment resistance
f_y = the yield strength of the chord member at the joint

For braces with axial forces with a classification that is a mixture of K, Y and X joints, a weighted average of N_{Rd} based on the portion of each in the total action is used to calculate the resistance.

2.2.2.2 Strength factor Q_u

Q_u varies with the joint and action type, as given in Table 2-5.

Table 2-5 Values for Q_u

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(1.9 + 19\beta)Q_\beta^{0.5}Q_g$	$(1.9 + 19\beta)Q_\beta^{0.5}Q_g$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
Y	30β	$(1.9 + 19\beta)Q_\beta^{0.5}$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
X	23β for $\beta \le 0.9$ $21 + (\beta\text{-}0.9)(17\gamma - 220)$ for $\beta > 0.9$	$(2.8 + 14\beta)Q_\beta$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$

Q_β is a geometric factor defined by:

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

$$Q_\beta = 1.0 \qquad \text{for } \beta \le 0.6$$

Q_g is a gap factor defined by:

$$Q_g = 1.9 - \left(\frac{g}{D}\right)^{0.5} \qquad \text{for } \frac{g}{T} \ge 2.0\text{, but } Q_g \ge 1.0$$

$$Q_g = 0.13 + 0.65\varphi\gamma^{0.5} \qquad \text{for } \frac{g}{T} \le -2.0$$

where $\varphi = \frac{t f_{y,b}}{T f_{y,c}}$

$f_{y,b}$ = yield strength of brace (or brace stub if present)

$f_{y,c}$ = yield strength of chord (or chord can if present)

Q_g = linear interpolated value between the limiting values of the above expressions for $-2.0 \leq \frac{g}{T} \leq 2.0$

2.2.2.3 Chord action factor Q_f

Q_f is a factor to account for the presence of factored actions in the chord.

$$Q_f = 1.0 - \lambda U^2$$

Where:

λ	=	0.030 for brace axial tension or compression
	=	0.045 for brace in-plane bending moment
	=	0.021 for brace out-of-plane bending moment

The parameter U is defined as follows:

$$U = \left[C_1 \left(\frac{P}{N_P} \right)^2 + C_2 \left(\frac{M}{M_P} \right)^2_{ipb} + C_2 \left(\frac{M}{M_P} \right)^2_{opb} \right]^{0.5}$$

where:

P	=	axial load in chord
M	=	bending moment in chord, (ipb and opb)
N_P	=	axial capacity of chord
M_P	=	bending capacity of chord
C_1, C_2	=	coefficients depending on joint and load type

Table 2-6 Values for C_1 and C_2, NORSOK N-004 r2

Joint Classification	C_1	C_2
T/Y joints under brace axial loading	25	11
DT/X joints under brace axial loading	20	22
K joints under balanced loading	20	22
All joints under brace moment loading	25	30

The chord thickness at the joint should be used in the above calculations. The highest value of U for the chord on either side of the brace intersection should be used.

2.2.2.4 Strength check

Joint resistance shall satisfy the following interaction equation for axial force and/or bending moments in the brace:

$$\left| \frac{N_{Sd}}{N_{Rd}} \right| + \left(\frac{M_{y,Sd}}{M_{y,Rd}} \right)^2 + \left| \frac{M_{z,Sd}}{M_{z,Rd}} \right| \leq 1$$

where:

N_{Sd}	=	axial force in the brace member
N_{Rd}	=	the joint axial resistance

$M_{y,Sd}$ = in-plane bending moment in the brace member
$M_{z,Sd}$ = out-of-plane bending moment in the brace member
$M_{y,Rd}$ = in-plane bending resistance
$M_{z,Rd}$ = out-of-plane bending resistance

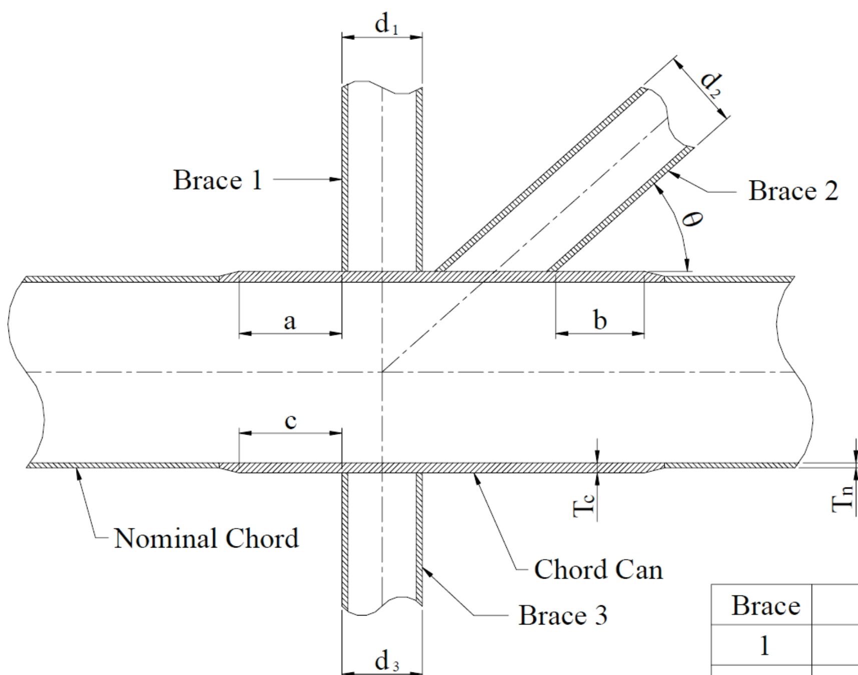
2.2.2.5 Design axial resistance for X and Y joints with joint cans

For Y and X joints with axial force and where a joint can is specified, the joint design resistance should be calculated as follows:

$$N_{Rd} = \left(r + (1\text{-}r)\left(\frac{T_n}{T_c}\right)^2\right) N_{can,Rd}$$

Where

$N_{can,Rd}$ = N_{Rd} based on chord can geometric and material properties
T_n = nominal chord member thickness
T_c = chord can thickness
r = Lc/(2.5D) for joints with $\beta \le 0.9$
= $[(4\beta - 3)Lc/(1.5D)]$ for joints with $\beta > 0.9$
Lc = effective total length of chord can, excluding taper, see Figure 2-3.
In no case shall r be taken as greater than unity.



Brace	Length Lc
1	2a + d_1
2	2b + d_2/sin θ
3	2c + d_3

Figure 2-3 Calculation of Lc

2.2.3 Basic resistance, NORSOK N-004 Revision 3 2013

2.2.3.1 General

The characteristic resistances for simple tubular joints are defined as follows:

$$N_{\mathrm{Rd}} = \frac{f_y T^2}{\sin\theta} Q_u Q_f$$

$$M_{\mathrm{Rd}} = \frac{f_y T^2 d}{\sin\theta} Q_u Q_f$$

Where

N_{Rd} = the joint axial resistance
M_{Rd} = the joint bending moment resistance
f_y = the yield strength of the chord member at the joint (or 0.8 of the tensile strength, if less)

For braces with axial forces with a classification that is a mixture of K, Y and X joints, a weighted average of N_{Rd} based on the portion of each in the total action is used to calculate the resistance.

2.2.3.2 Strength factor Q_u

Q_u varies with the joint and action type, as given in Table 2-7.

Table 2-7 Values for Q_u

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(16+1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(16+1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$
Y	30β	$2.8+(20+0.8\gamma)\beta^{1.6}$ but $\leq 2.8+36\beta^{1.6}$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$
X	$6.4\gamma^{(0.6\beta^2)}$	$[2.8+(12+0.1\gamma)\beta]Q_\beta$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$

Q_β is a geometric factor defined by:

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

$$Q_\beta = 1.0 \quad \text{for } \beta \leq 0.6$$

Q_g is a gap factor defined by:

$$Q_g = 1 + 0.2[1 - 2.8\, g/D]^3 \text{ for } g/D \geq 0.05\text{, but } Q_g \geq 1.0$$

$$Q_g = 0.13 + 0.65\varphi\gamma^{0.5} \text{ for } g/D \leq -0.05$$

where $\varphi = \dfrac{t f_{\mathrm{y,b}}}{T f_{\mathrm{y,c}}}$

$f_{y,b}$ = yield strength of brace (or brace stub if present)

$f_{y,c}$ = yield strength of chord (or chord can if present)

Q_g = linear interpolated value between the limiting values of the above expressions for $-0.05 \leq g/D \leq 0.05$

2.2.3.3 Chord action factor Q_f

Q_f is a factor to account for the presence of factored actions in the chord.

$$Q_f = 1.0 + C_1\left(\frac{P}{N_p}\right) - C_2\left(\frac{M_{ipb}}{M_p}\right) - C_3A^2$$

The parameter A is defined as follows:

$$A = \left[\left(\frac{P}{N_P}\right)^2 + \left(\frac{M_{ipb}}{M_P}\right)^2 + \left(\frac{M_{opb}}{M_P}\right)^2\right]^{0.5}$$

and:

P = axial load in chord
M_{ipb} = inplane bending moment in chord
M_{opb} = out of plane bending moment in chord
N_P = axial capacity of chord
M_P = bending capacity of chord
C_1 = coefficient depending on joint and load type, see Table 2-8
C_2 = coefficient depending on joint and load type, see Table 2-8
C_3 = coefficient depending on joint and load type, see Table 2-8

Table 2-8 Values for C_1 C_2 and C_3

Joint Classification	C_1	C_2	C_3
T/Y joints under brace axial loading	0.3	0	0.8
DT/X joints under brace axial loading, compression $\beta \leq 0.9$*	0.2	0	0.5
$\beta = 1$*	-0.2	0	0.2
DT/X joints under brace axial loading, tension $\beta \leq 0.9$*	0.0	0	0.4
$\beta = 1$*	0.2	0	0.2
K joints under balanced loading	0.2	0.2	0.3
All joints under brace moment loading	0.2	0.0	0.4

*) Linear interpolation for $0.9 \leq \beta \leq 1.0$

The chord thickness at the joint should be used in the above calculations. The average of the chord loads and bending moments on either side of the brace intersection should be used. Chord axial load is positive in tension, chord in-plane bending moment is positive when it produces compression on the joint footprint.

2.2.3.4 Strength check

Joint resistance shall satisfy the following interaction equation for axial force and/or bending moments in the brace:

$$\left|\frac{N_{\mathrm{Sd}}}{N_{\mathrm{Rd}}}\right| + \left(\frac{M_{\mathrm{y,Sd}}}{M_{\mathrm{y,Rd}}}\right)^2 + \left|\frac{M_{\mathrm{z,Sd}}}{M_{\mathrm{z,Rd}}}\right| \leq 1$$

where:

- N_{Sd} = axial force in the brace member
- N_{Rd} = the joint axial resistance
- $M_{y,Sd}$ = in-plane bending moment in the brace member
- $M_{z,Sd}$ = out-of-plane bending moment in the brace member
- $M_{y,Rd}$ = in-plane bending resistance
- $M_{z,Rd}$ = out-of-plane bending resistance

2.2.3.5 Design axial resistance for X and Y joints with joint cans

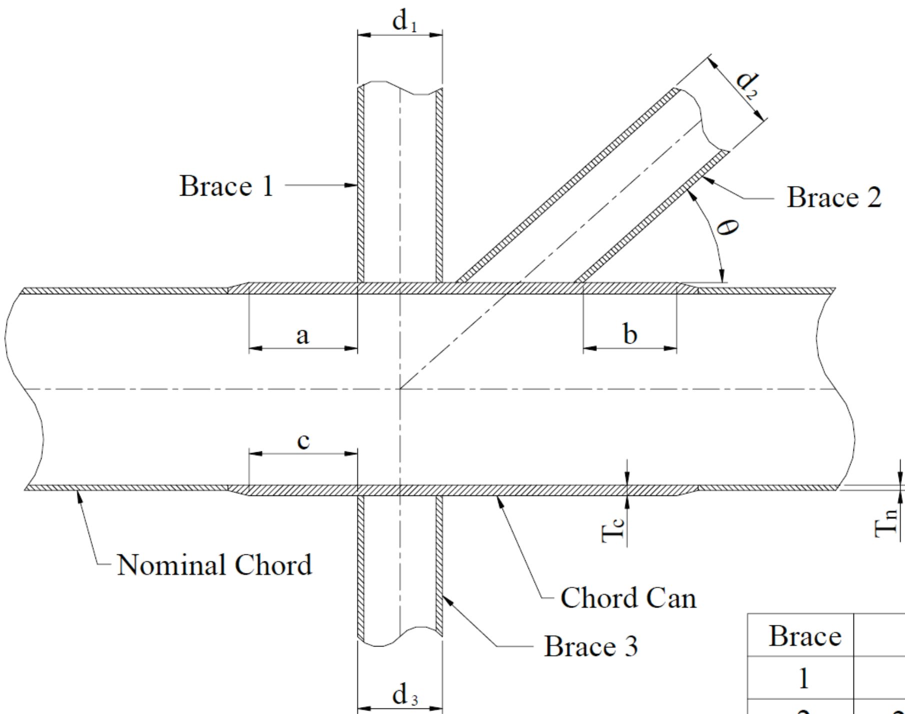
For Y and X joints with axial force and where a joint can is specified, the joint design resistance should be calculated as follows:

$$N_{\mathrm{Rd}} = \left(r + (1\text{-r})\left(\frac{T_n}{T_c}\right)^2\right) N_{\mathrm{can,Rd}}$$

where

- $N_{can,Rd}$ = N_{Rd} based on chord can geometric and material properties
- T_n = nominal chord member thickness
- T_c = chord can thickness
- r = Lc/(2.5D) for joints with $\beta \leq 0.9$
  = $[(4\beta - 3)Lc/(1.5D)]$ for joints with $\beta > 0.9$
- Lc = effective total length of chord can, excluding taper, see Figure 2-4

In no case shall r be taken as greater than unity.



Brace	Length L_c
1	$2a + d_1$
2	$2b + d_2/\sin\theta$
3	$2c + d_3$

Figure 2-4 Calculation of Lc

2.2.4 Basic resistance, NORSOK N-004:2021

2.2.4.1 General

The characteristic resistances for simple tubular joints are defined as follows:

$$N_{\mathrm{Rd}} = \frac{f_y T^2}{sin\,\theta} Q_u Q_f$$

$$M_{\mathrm{Rd}} = \frac{f_y T^2 d}{sin\,\theta} Q_u Q_f$$

Where

N_{Rd} = the joint axial resistance
M_{Rd} = the joint bending moment resistance
f_y = the yield strength of the chord member at the joint (or 0.8 of the tensile strength, if less)

For braces with axial forces with a classification that is a mixture of K, Y and X joints, a weighted average of N_{Rd} based on the portion of each in the total action is used to calculate the resistance.

2.2.4.2 Strength factor Q_u

Q_u varies with the joint and action type, as given in Table 2-9.

Table 2-9 Values for Q_u

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(16+1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(16+1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$
Y	30β	$2.8+(20+0.8\gamma)\beta^{1.6}$ but $\leq 2.8+36\beta^{1.6}$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$
X	$6.4\gamma^{(0.6\beta^2)}$	$[2.8+(12+0.1\gamma)\beta]Q_\beta$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$

Q_β is a geometric factor defined by:

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

$$Q_\beta = 1.0 \qquad \text{for } \beta \leq 0.6$$

Q_g is a gap factor defined by:

$$Q_g = 1 + 0.2[1 - 2.8\,g/D]^3 \text{ for } g/D \geq 0.05\,, \text{ but } Q_g \geq 1.0$$

$$Q_g = 0.13 + 0.65\varphi\gamma^{0.5} \text{ for } g/D \leq \text{-}0.05$$

where $\varphi = \dfrac{t f_{y,b}}{T f_{y,c}}$

$f_{y,b}$ = yield strength of brace (or brace stub if present)

$f_{y,c}$ = yield strength of chord (or chord can if present)

Q_g = linear interpolated value between the limiting values of the above expressions for $-0.05 \leq g/D \leq 0.05$

2.2.4.3 Chord action factor Q_f

Q_f is a factor to account for the presence of factored actions in the chord.

$$Q_f = 1.0 + C_1\left(\frac{P}{N_p}\right) - C_2\left(\frac{M_{ipb}}{M_p}\right) - C_3A^2$$

The parameter A is defined as follows:

$$A = \left[\left(\frac{P}{N_P}\right)^2 + \left(\frac{M_{ipb}}{M_P}\right)^2 + \left(\frac{M_{opb}}{M_P}\right)^2\right]^{0.5}$$

and:

P = axial load in chord
M_{ipb} = inplane bending moment in chord
M_{opb} = out of plane bending moment in chord
N_P = axial capacity of chord

M_P = bending capacity of chord
C_1 = coefficient depending on joint and load type, see Table 2-10
C_2 = coefficient depending on joint and load type, see Table 2-10
C_3 = coefficient depending on joint and load type, see Table 2-10

Table 2-10 Values for C_1 C_2 and C_3

Joint Classification	C_1	C_2	C_3
T/Y joints under brace axial loading	0.3	0	0.8
DT/X joints under brace axial loading, compression $\beta \le 0.9$*	0.2	0	0.5
$\beta = 1$*	-0.2	0	0.2
DT/X joints under brace axial loading, tension $\beta \le 0.9$*	0.0	0	0.5
$\beta = 1$*	0.2	0	0.2
K joints under balanced loading	0.2	0.2	0.3
All joints under brace moment loading	0.2	0.0	0.4

*) Linear interpolation for $0.9 \le \beta \le 1.0$

The chord thickness at the joint should be used in the above calculations. The average of the chord loads and bending moments on either side of the brace intersection should be used. Chord axial load is positive in tension, chord in-plane bending moment is positive when it produces compression on the joint footprint.

2.2.4.4 **Strength check**

Joint resistance shall satisfy the following interaction equation for axial force and/or bending moments in the brace:

$$\left|\frac{N_{Sd}}{N_{Rd}}\right| + \left(\frac{M_{y,Sd}}{M_{y,Rd}}\right)^2 + \left|\frac{M_{z,Sd}}{M_{z,Rd}}\right| \le 1$$

where:

N_{Sd} = axial force in the brace member
N_{Rd} = the joint axial resistance
$M_{y,Sd}$ = in-plane bending moment in the brace member
$M_{z,Sd}$ = out-of-plane bending moment in the brace member
$M_{y,Rd}$ = in-plane bending resistance
$M_{z,Rd}$ = out-of-plane bending resistance

2.2.4.5 **Design axial resistance for X and Y joints with joint cans**

For Y and X joints with axial force and where a joint can is specified, the joint design resistance should be calculated as follows:

$$N_{\text{Rd}} = \left(r + (1\text{-}r)\left(\frac{T_n}{T_c}\right)^2\right) N_{\text{can,Rd}}$$

where

$N_{can,Rd}$	=	N_{Rd} based on chord can geometric and material properties
T_n	=	nominal chord member thickness
T_c	=	chord can thickness
r	=	$Lc/(2.5D)$ for joints with $\beta \le 0.9$
	=	$[(4\beta - 3)Lc/(1.5D)]$ for joints with $\beta > 0.9$
Lc	=	effective total length of chord can, excluding taper, see Figure 2-6.

In no case shall r be taken as greater than unity.

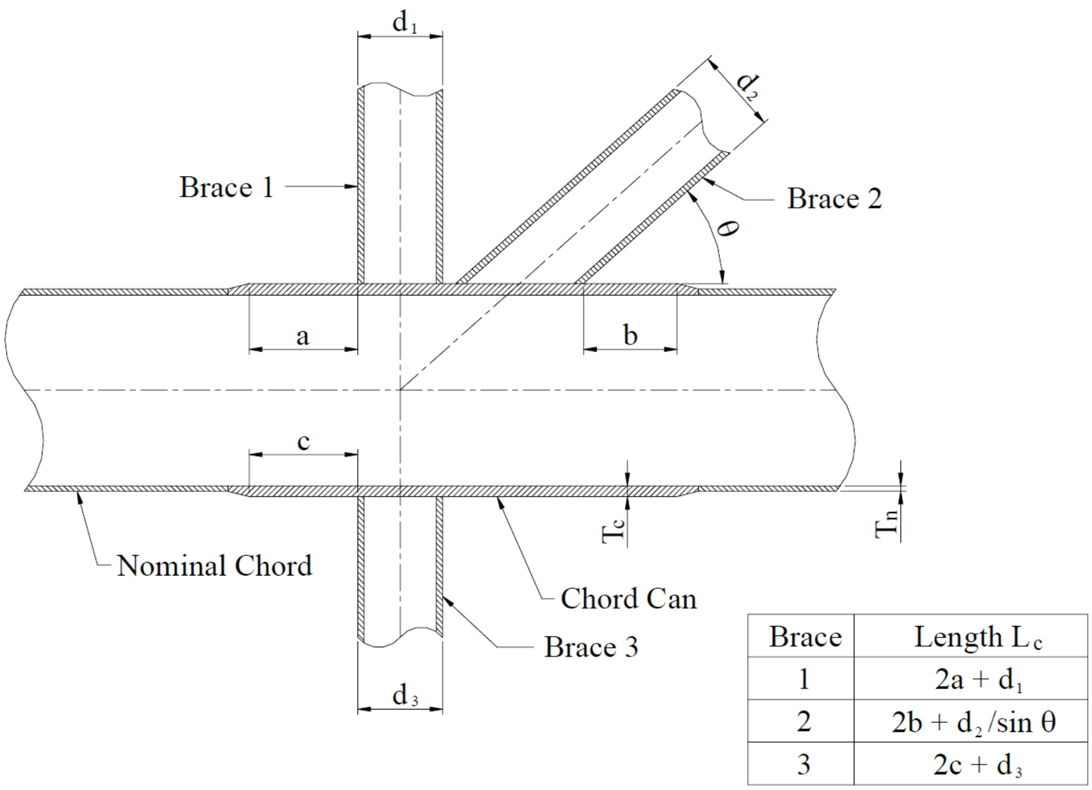


Figure 2-5 Calculation of Lc

2.2.5 Basic resistance, ISO 19902:2007

2.2.5.1 General

The characteristic resistances for simple tubular joints are defined as follows:

$$N_{\text{Rd}} = \frac{f_y T^2}{\sin\theta} Q_u Q_f$$

$$M_{\text{Rd}} = \frac{f_y T^2 d}{\sin\theta} Q_u Q_f$$

Where

N_{Rd} = the joint axial resistance
M_{Rd} = the joint bending moment resistance
f_y = the yield strength of the chord member at the joint

For braces with axial forces with a classification that is a mixture of K, Y and X joints, a weighted average of N_{Rd} based on the portion of each in the total action is used to calculate the resistance.

2.2.5.2 Strength factor Q_u

Q_u varies with the joint and action type, as given in Table 2-11.

Table 2-11 Values for Q_u

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(1.9 + 19\beta)Q_\beta^{0.5}Q_g$	$(1.9 + 19\beta)Q_\beta^{0.5}Q_g$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
Y	30β	$(1.9 + 19\beta)Q_\beta^{0.5}$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$
X	23β for $\beta \leq 0.9$ $20.7 + (\beta\text{-}0.9)(17\gamma - 220)$ for $\beta > 0.9$	$(2.8 + (12 + 0.1\gamma)\beta)Q_\beta$	$4.5\beta\gamma^{0.5}$	$3.2\gamma^{0.5\beta^2}$

Q_β is a geometric factor defined by:

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

$$Q_\beta = 1.0 \qquad \text{for } \beta \leq 0.6$$

Q_g is a gap factor defined by:

$$Q_g = 1.9 - 0.7\gamma^{-0.5}\left(\frac{g}{T}\right)^{0.5} \quad \text{for } \frac{g}{T} \geq 2.0\text{,but } Q_g \geq 1.0$$

$$Q_g = 0.13 + 0.65\varphi\gamma^{0.5} \qquad \text{for } \frac{g}{T} \leq -2.0$$

where $\varphi = \dfrac{t f_{y,b}}{T f_{y,c}}$

$f_{y,b}$ = yield strength of brace (or brace stub if present)

$f_{y,c}$ = yield strength of chord (or chord can if present)

Q_g = linear interpolated value between the limiting values of the above expressions for $-2.0 \leq \frac{g}{T} \leq 2.0$

2.2.5.3 Chord action factor Q_f

Q_f is a factor to account for the presence of factored actions in the chord.

$$Q_f = 1.0 - \lambda U^2$$

Where:

λ = 0.030 for brace axial tension or compression

= 0.045 for brace in-plane bending moment
= 0.021 for brace out-of-plane bending moment

The parameter U is defined as follows:

$$U = \gamma_{R,q}\left[C_1\left(\frac{P}{N_P}\right)^2 + C_2\left(\frac{M}{M_P}\right)^2_{ipb} + C_2\left(\frac{M}{M_P}\right)^2_{opb}\right]^{0.5}$$

where:

- P = axial load in chord
- M = bending moment in chord, (ipb and opb)
- N_P = axial capacity of chord
- M_P = bending capacity of chord
- C_1, C_2 = coefficients depending on joint and load type
- γ_{Rq} = is the partial resistance factor for yield **(set to 1.0 in USFOS**)

Table 2-12 Values for C_1 and C_2, ISO 19902:2007

Joint Classification	**C_1**	**C_2**
T/Y joints under brace axial loading	25	11
DT/X joints under brace axial loading	20	22
K joints under balanced loading	14	43
All joints under brace moment loading	25	43

The chord thickness at the joint should be used in the above calculations. The highest value of U for the chord on either side of the brace intersection should be used.

2.2.5.4 **Strength check**

Joint resistance shall satisfy the following interaction equation for axial force and/or bending moments in the brace:

$$\left|\frac{N_{\text{Sd}}}{N_{\text{Rd}}}\right| + \left(\frac{M_{\text{y,Sd}}}{M_{\text{y,Rd}}}\right)^2 + \left|\frac{M_{\text{z,Sd}}}{M_{\text{z,Rd}}}\right| \leq 1$$

where:

- N_{Sd} = axial force in the brace member
- N_{Rd} = the joint axial resistance
- $M_{y,Sd}$ = in-plane bending moment in the brace member
- $M_{z,Sd}$ = out-of-plane bending moment in the brace member
- $M_{y,Rd}$ = in-plane bending resistance
- $M_{z,Rd}$ = out-of-plane bending resistance

2.2.5.5 **Design axial resistance for X and Y joints with joint cans**

For Y and X joints with axial force and where a joint can is specified, the joint design resistance should be calculated as follows:

$$N_{\mathrm{Rd}} = \left(r + (1\text{-r})\left(\frac{T_n}{T_c}\right)^2\right) N_{\mathrm{can,Rd}}$$

where

$N_{can,Rd}$	=	N_{Rd} based on chord can geometric and material properties
T_n	=	nominal chord member thickness
T_c	=	chord can thickness
r	=	Lc/(2.5D) for joints with β ≤ 0.9
	=	$[(4\beta - 3)Lc/(1.5D)]$for joints with β > 0.9
Lc	=	effective total length of chord can, excluding taper, see Figure 2-6.

In no case shall r be taken as greater than unity.

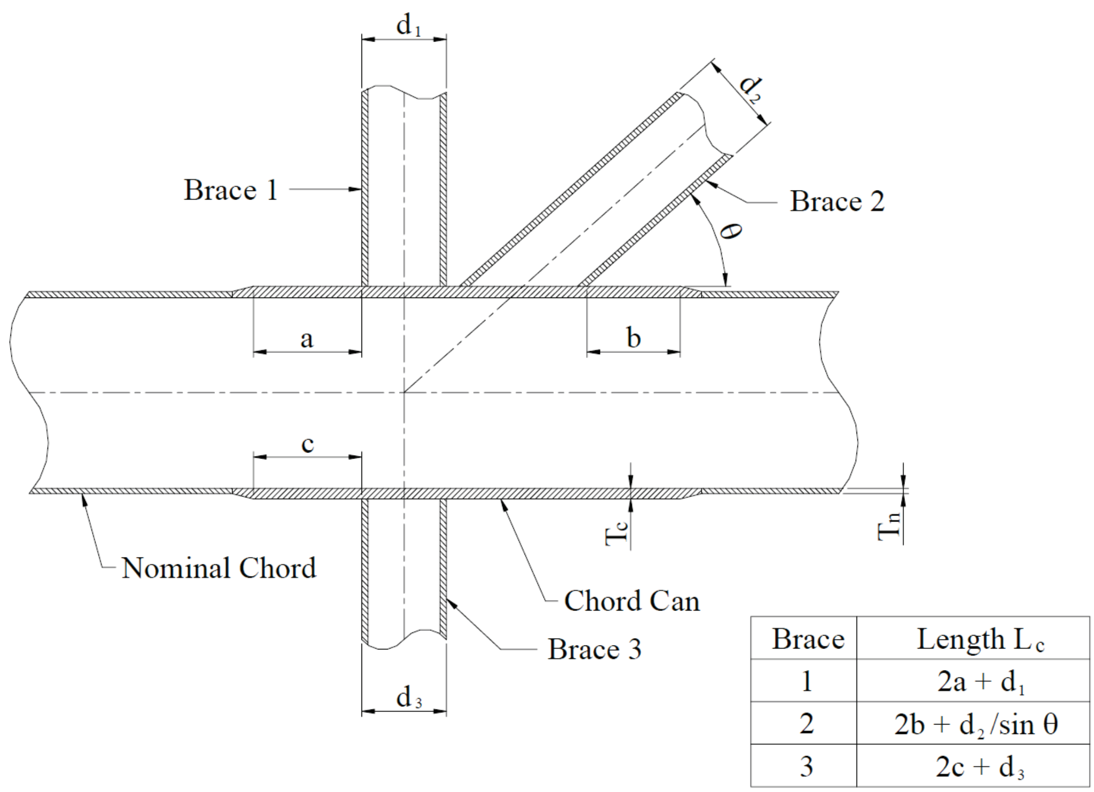


Figure 2-6 Calculation of Lc

2.2.6 Basic resistance, API RP 2A-WSD, 21'st ed. ES3 Oct. 2007 - 22'nd ed. R2020

2.2.6.1 General

The resistances for simple tubular joints are defined as follows:

$$N_{\mathrm{Rd}} = \frac{f_y T^2}{FS \sin\theta} Q_u Q_f$$

$$M_{\text{Rd}} = \frac{f_y T^2 d}{FS\, sin\, \theta} Q_u Q_f$$

Where

N_{Rd} = the joint axial resistance
M_{Rd} = the joint bending moment resistance
f_y = the yield strength of the chord member at the joint (or 0.8 of the tensile strength, if less)
FS = is the safety factor (**Default set to 1.0 in USFOS for characteristic capacity**)

For braces with axial forces with a classification that is a mixture of K, Y and X joints, a weighted average of N_{Rd} based on the portion of each in the total action is used to calculate the resistance.

2.2.6.2 Strength factor Q_u

Q_u varies with the joint and action type, as given in Table 2-13.

Table 2-13 Values for Q_u

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(16 + 1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(16 + 1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(5 + 0.7\gamma)\beta^{1.2}$	$2.5 + (4.5 + 0.2\gamma)\beta^{2.6}$
Y	30β	$2.8 + (20 + 0.8\gamma)\beta^{1.6}$ but $\leq 2.8 + 36\beta^{1.6}$	$(5 + 0.7\gamma)\beta^{1.2}$	$2.5 + (4.5 + 0.2\gamma)\beta^{2.6}$
X	23β for $\beta \leq 0.9$ $20.7 + (\beta\text{-}0.9)(17\gamma - 220)$ for $\beta > 0.9$	$[2.8 + (12 + 0.1\gamma)\beta]Q_\beta$	$(5 + 0.7\gamma)\beta^{1.2}$	$2.5 + (4.5 + 0.2\gamma)\beta^{2.6}$

Q_β is a geometric factor defined by:

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

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

Q_g is a gap factor defined by:

$Q_g = 1 + 0.2[1 - 2.8\, g/D]^3$ for $g/D \geq 0.05$, but $Q_g \geq 1.0$

$Q_g = 0.13 + 0.65\varphi\gamma^{0.5}$ for $g/D \leq -0.05$

where $\varphi = \frac{t f_{y,b}}{T f_{y,c}}$

$f_{y,b}$ = yield strength of brace (or brace stub if present)

$f_{y,c}$ = yield strength of chord (or chord can if present)

Q_g = linear interpolated value between the limiting values of the above expressions for $-0.05 \leq g/D \leq 0.05$

2.2.6.3 Chord action factor Q_f

Q_f is a factor to account for the presence of factored actions in the chord.

$$Q_f = 1.0 + C_1\left(\frac{FSP}{N_p}\right) - C_2\left(\frac{FSM_{ipb}}{M_p}\right) - C_3A^2$$

The parameter A is defined as follows:

$$A = \left[\left(\frac{FSP}{N_P}\right)^2 + \left(\frac{FSM_{ipb}}{M_P}\right)^2 + \left(\frac{FSM_{opb}}{M_P}\right)^2\right]^{0.5}$$

and:

P = axial load in chord
M_{ipb} = inplane bending moment in chord
M_{opb} = out of plane bending moment in chord
N_P = axial capacity of chord
M_P = bending capacity of chord
C_1 = coefficient depending on joint and load type, see Table 2-14
C_2 = coefficient depending on joint and load type, see Table 2-14
C_3 = coefficient depending on joint and load type, see Table 2-14
FS = is the safety factor (**Default set to 1.0 in USFOS for characteristic capacity**)

Table 2-14 Values for C_1 C_2 and C_3

Joint Classification	C_1	C_2	C_3
T/Y joints under brace axial loading	0.3	0	0.8
DT/X joints under brace axial loading $\beta \le 0.9$*	0.2	0	0.5
$\beta = 1$*	-0.2	0	0.2
K joints under balanced loading	0.2	0.2	0.3
All joints under brace moment loading	0.2	0.0	0.4

*) Linear interpolation for $0.9 \le \beta \le 1.0$

The chord thickness at the joint should be used in the above calculations. The average of the chord loads and bending moments on either side of the brace intersection should be used. Chord axial load is positive in tension, chord in-plane bending moment is positive when it produces compression on the joint footprint.

2.2.6.4 Strength check

Joint resistance shall satisfy the following interaction equation for axial force and/or bending moments in the brace:

$$\left|\frac{N_{\mathrm{Sd}}}{N_{\mathrm{Rd}}}\right| + \left(\frac{M_{\mathrm{y,Sd}}}{M_{\mathrm{y,Rd}}}\right)^2 + \left|\frac{M_{\mathrm{z,Sd}}}{M_{\mathrm{z,Rd}}}\right| \le 1$$

where:

N_{Sd} = axial force in the brace member
N_{Rd} = the joint axial resistance
$M_{y,Sd}$ = in-plane bending moment in the brace member
$M_{z,Sd}$ = out-of-plane bending moment in the brace member
$M_{y,Rd}$ = in-plane bending resistance
$M_{z,Rd}$ = out-of-plane bending resistance

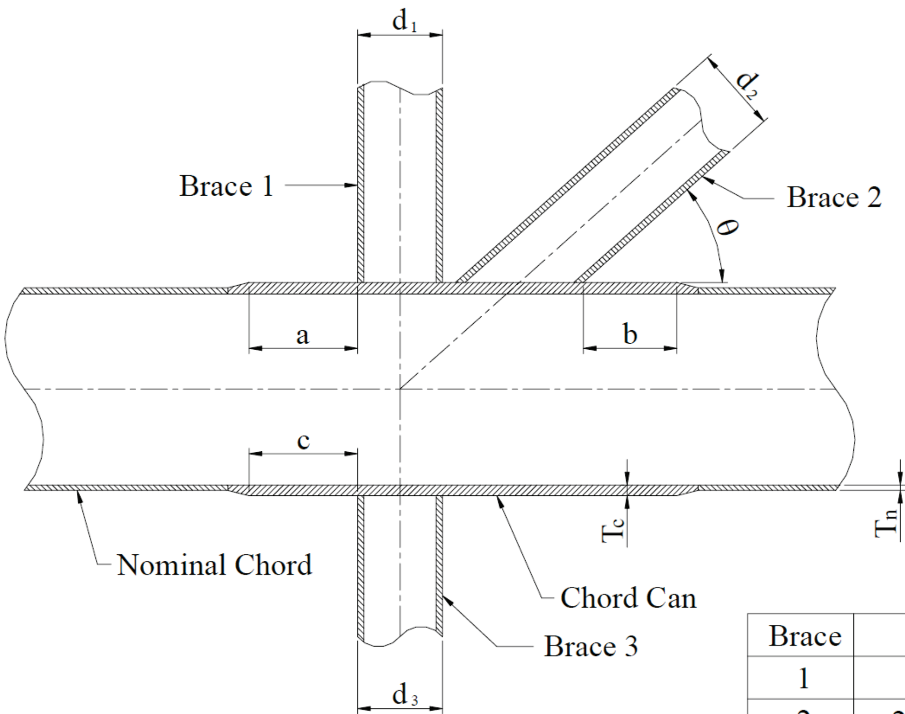
2.2.6.5 Design axial resistance for X and Y joints with joint cans

For Y and X joints with axial force and where a joint can is specified, the joint design resistance should be calculated as follows:

$$N_{\mathrm{Rd}} = \left(r + (1\text{-r})\left(\frac{T_n}{T_c}\right)^2\right) N_{\mathrm{can,Rd}}$$

where

$N_{can,Rd}$ = N_{Rd} based on chord can geometric and material properties
T_n = nominal chord member thickness
T_c = chord can thickness
r = Lc/(2.5D) for joints with $\beta \leq 0.9$
= $[(4\beta - 3)Lc/(1.5D)]$for joints with $\beta > 0.9$
Lc = effective total length of chord can, excluding taper, see Figure 2-6.
In no case shall r be taken as greater than unity.



Brace	Length L_c
1	$2a + d_1$
2	$2b + d_2/\sin\theta$
3	$2c + d_3$

Figure 2-7 Calculation of Lc

2.2.7 Basic resistance, ISO 19902:2020

2.2.7.1 **General**

The characteristic resistances for simple tubular joints are defined as follows:

$$N_{\text{Rd}} = \frac{f_y T^2}{sin\,\theta} Q_u Q_f$$

$$M_{\text{Rd}} = \frac{f_y T^2 d}{sin\,\theta} Q_u Q_f$$

Where

N_{Rd} = the joint axial resistance
M_{Rd} = the joint bending moment resistance
f_y = the yield strength of the chord member at the joint (or 0.8 of the tensile strength, if less)

For braces with axial forces with a classification that is a mixture of K, Y and X joints, a weighted average of N_{Rd} based on the portion of each in the total action is used to calculate the resistance.

2.2.7.2 **Strength factor Q_u**

Q_u varies with the joint and action type, as given in Table 2-15.

Table 2-15 Values for Q_u

	Brace action			
Joint Classification	**Axial Tension**	**Axial Compression**	**In-plane Bending**	**Out-of-plane bending**
K	$(16+1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(16+1.2\gamma)\beta^{1.2}Q_g$ but $\leq 40\beta^{1.2}Q_g$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$
Y	30β	$2.8+(20+0.8\gamma)\beta^{1.6}$ but $\leq 2.8+36\beta^{1.6}$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$
X	$6.4\gamma^{(0.6\beta^2)}$	$[2.8+(12+0.1\gamma)\beta]Q_\beta$	$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$

Q_β is a geometric factor defined by:

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

$$Q_\beta = 1.0 \qquad \text{for } \beta \leq 0.6$$

Q_g is a gap factor defined by:

$$Q_g = 1 + 0.2[1-2.8\,g/D]^3 \text{ for } g/D \geq 0.05\text{, but } Q_g \geq 1.0$$

$$Q_g = 0.13 + 0.65\varphi\gamma^{0.5} \text{ for } g/D \leq -0.05$$

where $\varphi = \dfrac{t f_{y,b}}{T f_{y,c}}$

$f_{y,b}$ = yield strength of brace (or brace stub if present)

$f_{y,c}$ = yield strength of chord (or chord can if present)

Q_g = linear interpolated value between the limiting values of the above expressions for $-0.05 \leq g/D \leq 0.05$

2.2.7.3 Chord action factor Q_f

Q_f is a factor to account for the presence of factored actions in the chord.

$$Q_f = 1.0 + C_1\left(\frac{P}{N_p}\right) - C_2\left(\frac{M_{ipb}}{M_p}\right) - C_3A^2$$

The parameter A is defined as follows:

$$A = \left[\left(\frac{\overleftrightarrow{P}}{N_P}\right)^2 + \left(\frac{M_{ipb}}{M_P}\right)^2 + \left(\frac{M_{opb}}{M_P}\right)^2\right]^{0.5}$$

and:

P	=	axial load in chord
M_{ipb}	=	in plane bending moment in chord
M_{opb}	=	out of plane bending moment in chord
N_P	=	axial capacity of chord
M_P	=	bending capacity of chord

C_1 = coefficient depending on joint and load type, see Table 2-16
C_2 = coefficient depending on joint and load type, see Table 2-16
C_3 = coefficient depending on joint and load type, see Table 2-16

Table 2-16 Values for C_1 C_2 and C_3

Joint Classification	C_1	C_2	C_3
T/Y joints under brace axial loading	0.3	0	0.8
DT/X joints under brace axial loading, compression $\beta \le 0.9$*	0.2	0	0.5
$\beta = 1$*	-0.2	0	0.2
DT/X joints under brace axial loading, tension $\beta \le 0.9$*	0.2	0	0.5
$\beta = 1$*	0.2	0	0.2
K joints under balanced loading	0.2	0.2	0.3
All joints under brace moment loading	0.2	0.0	0.4

*) Linear interpolation for $0.9 \le \beta \le 1.0$

The chord thickness at the joint should be used in the above calculations. The average of the chord loads and bending moments on either side of the brace intersection should be used. Chord axial load is positive in tension, chord in-plane bending moment is positive when it produces compression on the joint footprint.

2.2.7.4 Strength check

Joint resistance shall satisfy the following interaction equation for axial force and/or bending moments in the brace:

$$\left|\frac{N_{\mathrm{Sd}}}{N_{\mathrm{Rd}}}\right| + \left(\frac{M_{\mathrm{y,Sd}}}{M_{\mathrm{y,Rd}}}\right)^2 + \left|\frac{M_{\mathrm{z,Sd}}}{M_{\mathrm{z,Rd}}}\right| \le 1$$

where:

N_{Sd} = axial force in the brace member
N_{Rd} = the joint axial resistance
$M_{y,Sd}$ = in-plane bending moment in the brace member
$M_{z,Sd}$ = out-of-plane bending moment in the brace member
$M_{y,Rd}$ = in-plane bending resistance
$M_{z,Rd}$ = out-of-plane bending resistance

2.2.7.5 Design axial resistance for X and Y joints with joint cans

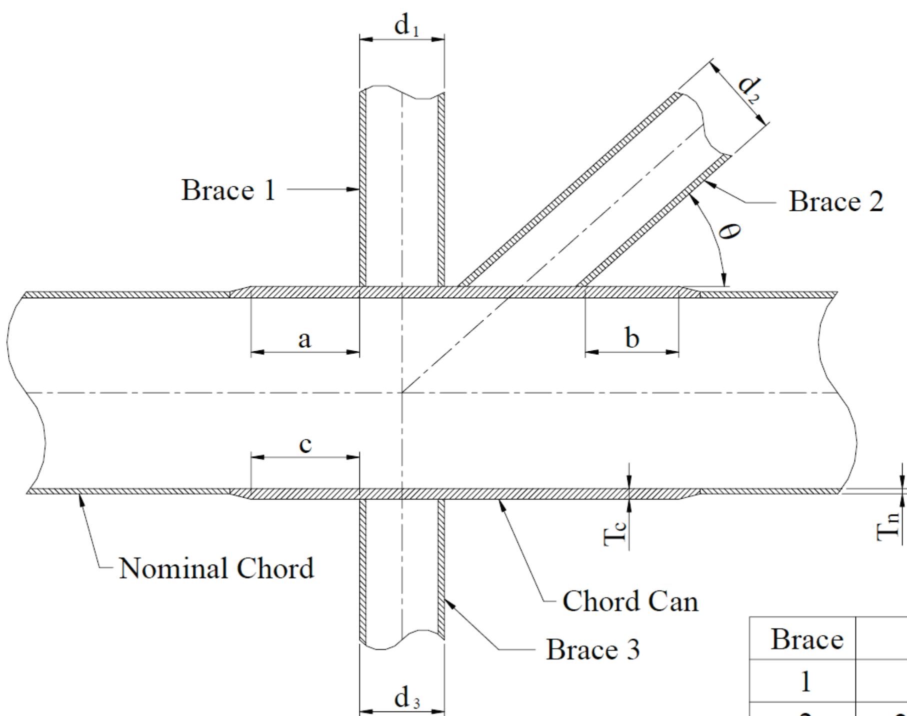
For Y and X joints with axial force and where a joint can is specified, the joint design resistance should be calculated as follows:

$$N_{\rm Rd} = \left(r + (1\text{-}r)\left(\frac{T_n}{T_c}\right)^2\right) N_{\rm can,Rd}$$

where

$N_{can,Rd}$	=	N_{Rd} based on chord can geometric and material properties
T_n	=	nominal chord member thickness
T_c	=	chord can thickness
r	=	Lc/(2.5D) for joints with β ≤ 0.9
	=	$[(4\beta - 3)Lc/(1.5D)]$for joints with β > 0.9
Lc	=	effective total length of chord can, excluding taper, see Figure 2-8

In no case shall r be taken as greater than unity.



Brace	Length L_c
1	$2a + d_1$
2	$2b + d_2/\sin\theta$
3	$2c + d_3$

Figure 2-8 Calculation of Lc

2.3 Joint classification

The joints are classified based on the axial force flow in the joint. This means that a brace in a joint with a K-joint topology can be classified as a T-joint if only one of the braces carry axial loads. Typically braces in complex joints will be classified as partly K, X and T joints. The ultimate capacity of each individual brace is based on the classification.

The joint classification may change during an analysis if the axial force flow changes.

2.4 Joint behaviour and ductility limits

2.4.1 Joint P-D curves

The following expressions show the original MSL proposed relationship between the joint force/moments and joint displacements/rotations as described in /2/.

$$P = \varphi P_u \left(1 - A \left[1 - \left(1 + \frac{1}{\sqrt{A}} \right) exp \left(-B \frac{\delta}{\varphi Q_f F_y D} \right) \right]^2 \right)$$

$$M = \phi M_u \left(1 - A \left[1 - \left(1 + \frac{1}{\sqrt{A}} \right) \exp \left(-B \frac{\theta}{\phi Q_f F_y} \right) \right]^2 \right)$$

Table 2-17 Coefficients A and B

Joint Type	Load Type	Coefficient	
		A	B
T/Y	Compression	$((\gamma - 4)\, sin^3\, \theta)/62$	$600\beta + 13500$
	Tension	0.001	$12000\beta + 1200$
	IPB	0.001	$9700\beta + 6700$
	OPB	0.001	$8600\beta + 1200$
DT/X	Compression	$(\gamma + 10)/100$	$90000\beta\gamma^{-0.4}$
	Tension	0.001	$3900\beta + 5000\ for\ \beta \le 0.9$ $8510 + (\beta - 0.9)\left(\frac{6000000}{\gamma} - 80000\right)$ $for\ 0.9 < \beta \le 1.0$
	IPB	0.001	$9700\beta + 6700$
	OPB	0.001	$8600\beta + 1200$
K	Balanced axial	$\phi(\gamma - 7)/18$ $where\quad \phi = \zeta - 0.1$ $but\quad 0.025 < \phi < 0.25$	$\psi(13 + 4\gamma)$ $where\quad \psi = 320 - 450\zeta$ $but\quad 170 \le \psi \le 320$
	IPB	0.001	$9700\beta + 6700$
	OPB	0.001	$8600\beta + 1200$

P, M = brace load at joint

P_u, M_u = mean strength

ϕ = strength scaling factor (P_{char}/P_u)

δ = joint deformation (pr brace)

θ = joint rotation (radians, pr brace)

D = chord diameter

A = constant for given joint geometry and load type

B = dimensional constant in units of MPa for given joint geometry and load type

γ = D/(2T) chord diameter / (2 chord wall thickness)

ζ = (g/D) gap between brace toes / chord diameter

2.4.2 MSL Ductility limits

Table 2-18 show the MSL proposed ductility limits as described in /2/.

Table 2-18 Ductility limits for axial deflection

Joint Type	Mean	Characteristic
X	$\frac{\delta}{D} = 0.13 - 0.11\beta$	$\frac{\delta}{D} = 0.089 - 0.075\beta$
T/Y	$\frac{\delta}{D} = 0.076$	$\frac{\delta}{D} = 0.044$
K	$\frac{\delta}{D} = 0.026$	$\frac{\delta}{D} = 0.015$

In USFOS, the ductility limit is implemented by reducing the axial joint capacity to a small number for deformations larger than the ductility limit.

No formulations are identified for mean and characteristic fracture criteria related to other degrees of freedom.

2.5 USFOS Specific adjustments

The Joint load-deformation curves described in 2.4.1 are developed with the mean capacity in mind. The scaling factor ϕ is intended to scale the curve when characteristic capacities are used, in a way that preserves the initial joint stiffness. However in some cases the produced curves are much softer near the characteristic capacity and the ductility limit is reached before the characteristic capacity. In order to avoid this, the B factors are increased for axial tension for the NORSOK, API and ISO variants. B' = B 1.5 is used.

The interaction formulas for all code variants (ISO, NORSOK and API) specify linear interaction between axial load and out-of-plane bending.

USFOS uses quadratic terms for both bending components in the yield surface formulation for all variants (of numerical reasons), and this could give different utilizations for cases with significant out-of-plane bending.

$$\left|\frac{N_{\mathrm{Sd}}}{N_{\mathrm{Rd}}}\right| + \left(\frac{M_{\mathrm{y,Sd}}}{M_{\mathrm{y,Rd}}}\right)^2 + \left(\frac{M_{\mathrm{z,Sd}}}{M_{\mathrm{z,Rd}}}\right)^2 \leq 1$$

N_{Sd} = axial force in the brace member
N_{Rd} = the joint axial resistance
$M_{y,Sd}$ = in-plane bending moment in the brace member
$M_{z,Sd}$ = out-of-plane bending moment in the brace member
$M_{y,Rd}$ = in-plane bending resistance
$M_{z,Rd}$ = out-of-plane bending resistance

3 DESCRIPTION OF USE

3.1 General

When using the USFOS CHJOINT record, additional elements are inserted in the FE-model, see Figure 3-1 The elements have properties representing both the stiffness and capacity of the tubular joint braces according to the selected rule.

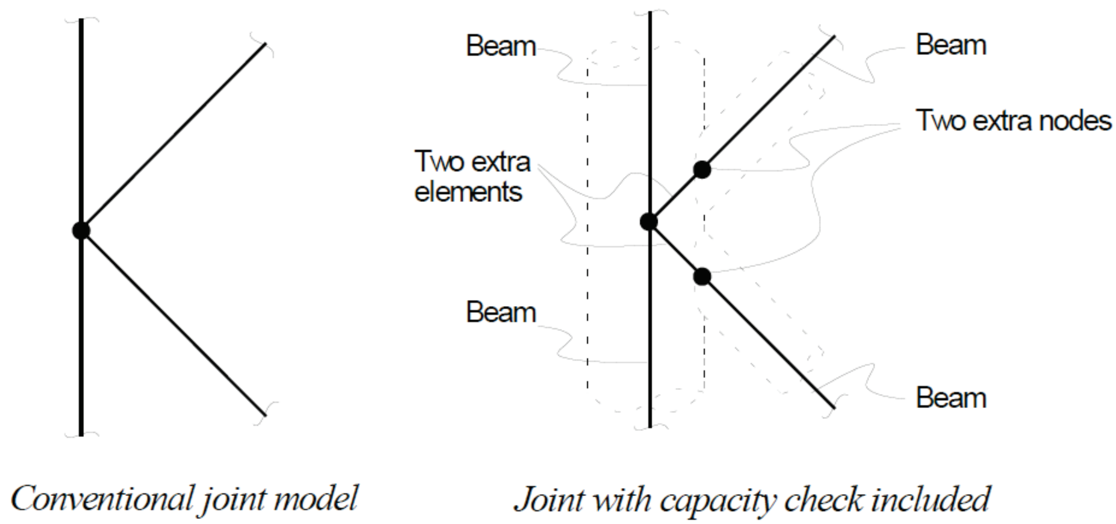


Figure 3-1 Tubular joint representation

A sample input for the joint given in Figure 3-2 is shown in Table 3-1.

Section 3.2 describes the most relevant input records in order to include joint check in an USFOS analysis.

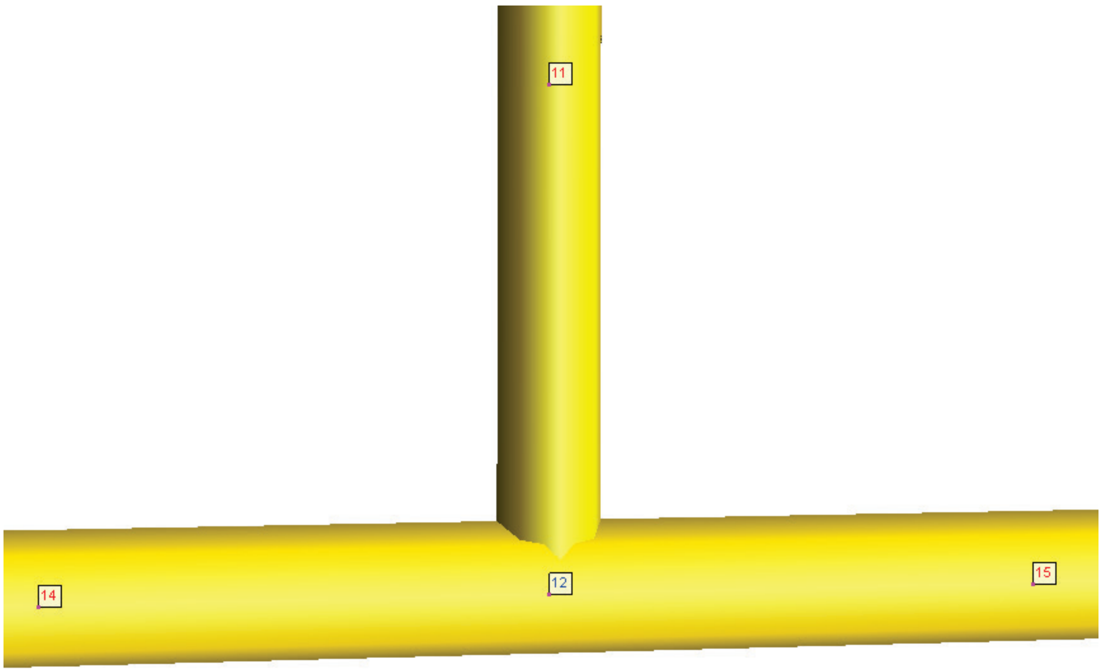


Figure 3-2 Tubular Joint

Table 3-1 Joint check input

```
'           nodex   chord1      chord2   geono   CapRule      CapLevel
 CHJOINT     12       14          15       0       MSL           FCrack
'
 JNTCLASS     1        !  0=OFF          1=ON
```

3.2 Input description

Below is given a selection of the most relevant input records in order to include joint check in an USFOS analysis.

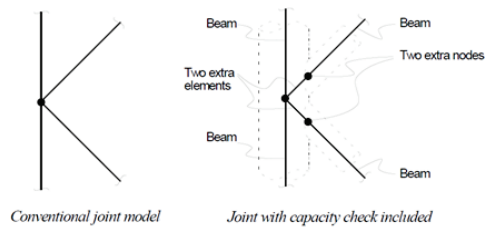
CHJOINT node Chord1 Chord2 Geono CapRule

Parameter	*Description*	*Default*
Node	Node number referring to the joint where shell effects should be considered	
Chord1	Element ID defining one of the two **CHORD** elements connected to the node	
Chord2	Element ID defining the second **CHORD** element	
Geono	Geometry reference number defining the diameter and thickness of the chord at the joint (canned joint). If omitted or equal to 0, the data for *Chord1* is used.	0
CapRule	Capacity rule switch: MSL : MSL non-linear joint characteristics, (see next pages). NORSOK : Latest implemented Norsok, (currently Rev4- 2021). NOR_R3 : NORSOK N-004, rev 3 non-linear joint characteristics NOR_2021: NORSOK N-004, rev 4 ISO19902: Latest implemented ISO, (currently 2020) ISO_2007: ISO 19902:2007 non-linear joint characteristics. ISO_2020: ISO 19902:2020 non-linear joint characteristics. API-WSD: API RP 2A WSD ES3 non-linear joint characteristics. Historic, ***not*** recommended: OldAPI: API-LRFD, 1993 (no more data required) OldDoe: DoE (no more data required) UserSurf: User defined capacity and surface definition, more data required, (see next pages). UserSpri: User defined Joint Springs, more data required, (see next pages).	NOR_2021

With this record, the capacity of each brace/chord connection at the tubular joint will be checked according to a selected joint capacity formulation.

This check will impose restrictions on the load transfer through each brace/chord connection at the specified joint.

The generated capacities are printed in the '.jnt' or the ‘.out’ – file (Historic options), and the **peak capacities** will be printed using the **Verify/Element/Information** option in **Xact**.



CHJOINT Node Chord1 Chord2 Geono CapRule CapLevel Q_f_SafetyCoeff

Parameter	*Description*	*Default*
Node	Node number referring to the joint where joint capacity and non-linear joint behaviour should be considered	
Chord1	External element number defining one of the two **CHORD** elements connected to the node	
Chord2	External element number defining the second **CHORD** element	
Geono	Geometry reference number defining the diameter and thickness of the chord at the joint (canned joint). If omitted or equal to 0, the data for *Chord1* is used.	
CapRule	Capacity rule: **MSL**: *MSL* non-linear joint characteristics	
CapLevel	Capacity level or capacity multiplier. mean : use mean ultimate joint capacities char : use characteristic ultimate joint capacities fcrack : use characteristic first crack joint capacities scalfact : joint capacities are set to mean value capacities multiplied by scalfact, (where "scalfact" is a positive real number). This option is only available with the MSL joint formulation.	mean
Q_f_Safety Coeff	The Qf factor for joint capacities includes a safety factor (or partial safety coefficient) in the chord stress utilization factor.	1.0

With this record, the capacity of each brace/chord connection at the tubular joint will be checked according to a selected joint capacity equation.

This check will impose restrictions on the load transfer through each brace/chord connection at the specified joint, and the non-linear joint characteristics will be included in the USFOS analysis.

Extra elements will be introduced in the FE model, and the behavior of these elements assigned according to the selected joint capacity rule or specified joint capacity, and the FE formulation selected for the "joint elements".

The joint capacity rule or joint capacity is specified by the CHJOINT record(s).
The Finite Element formulation for the "joint elements" is selected automatically. (JNT_FORM record is not needed to specify).

JNTOPTION Keyword Value *ListType* { Data } ………

Parameter	*Description*	*Default*
Keyword	Subcommand defining the actual can geometry parameters: *CanLength* : Specify Lc and account for short can reduction *CanThick* : Specify Can Thickness. Override Default (Chord-1) thick *CanDiam* : Specify Can Diameter. Override Default (Chord-1) diam	
Value	Actual geometry value.	
ListType	Keyword defining how to list the actual joint connections: Joint : All connections at the specified joint(s) are scaled Connection : Only one connection is scaled.	
Data	Input defining the connection(s). Depends on "ListType": "joint" : Actual Node ID(s). (Several nodes could be specified). "connection" : Actual Node and Brace ID defining connection	

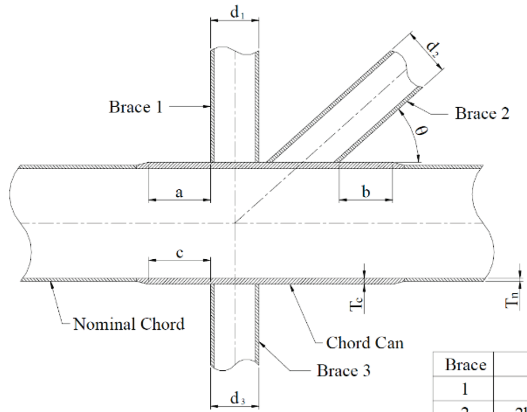
This record is only valid in combination with CHJOINT option, and is used to define geometry input parameters used to compute the joint capacity curves. I.e. override the data derived from the FE-model.

Example 1:

```
'            Key          Value    ListOpt    JointID …
JntOption   CanLength    0.400     joint     100      110
JntOption   CanThick     0.010     joint     100      110
JntOption   CanDiam      0.500     joint     100      110

'           KeyWord      Value     ListType    JointID    BraceID
JntOption   CanLength    0.350    Connection     100        130
```

Means that *all connections* at the joints 100 and 110 will account for "short can reduction" and use the specified geometry data. Exception for one connection (joint-100, brace 130).



Brace	Length L_c
1	$2a + d_1$
2	$2b + d_2/\sin\theta$
3	$2c + d_3$

Figure 3-3 Calculation of CanLength Lc

The data used for the joint calculations are printed in the “out” file:

```
-----------------------------

Joint  :      100

Connect  Brace  Can_Lc  D_Chord T_Chord  T_Nom  d_Brace t_Brace  (CanRed)

  1        60    0.400   0.500   0.010   0.007   0.127   0.003  0.67-1.0

  2       130    0.350   0.500   0.010   0.007   0.150   0.005  0.65-1.0
```

Print from the USFOS “out” file.

Data are also printed in the .jnt file:
Print from the USFOS “jnt” file.

```
    NODE          Capacity                     Chord      Chord      Chord
     ID             rule                      diameter   thickness  yield str.
     100       NORSOK N-004 Rev2              5.000E-01  1.000E-02  3.240E+08


  Brace   Angle   Conn    Facing   Gap         Axial      MipB       MopB
     ID   (deg)   Type     brace              Cap/Qf     Cap/Qf     Cap/Qf


      60    45      Y                         2.054E+05  3.326E+04  2.066E+04
                                                   1.00       1.00       1.00
     130    90      T                         1.593E+05  3.281E+04  1.798E+04
                                                   1.00       1.00       1.00



    NODE          Capacity                     Chord      Chord      Chord
```

NOTE 1.
If "**`SWITCHES Joint ShortCan ON`**" is specified, all connections are checked for short can reduction. The geometry data are found in the FE-model unless specified explicitly.

NOTE 2.
A tubular joint has only **one** diameter and **one** thickness. I.e. D and T are Joint data.
The chord diameter and thickness are found and stored in the following sequence:

1. From the FE-model, chord element no 1
2. The chord geometry specified under CHJOINT (if ≠ 0)
3. Specified CanDiam and/or CanThick.
4. The ***latest*** defined CanDiam & CanThick are used for ***all connections*** to this joint.

This record may be repeated.

SWITCHES Joint EccUpdate Switch

Parameter	Description			Default
Switch	ON	:	Joint eccentricities are “repaired”	OFF
	OFF	:	No checking	

If the switch is ON, the joints defined using CHJOINT is checked for “bad shaped” eccentricities, and the following is done for braces with eccentricities:

- The eccentricity is moved from the chord surface to the chord centre
- The brace keeps the same position as before
- The new joint capacity element gets a reasonable length
- The new node is located on the chord surface (same as for EyeLift = 1.0)

This record is given once

SWITCHES Joint ShortCan Switch

Parameter	Description			Default
Switch	ON	:	Automatic short can detection	OFF
	OFF	:	Switch OFF all short can including manually defined	

If the switch is ON, the FE-model is checked for cans:

- If CAN is found, the short can parameters are computed
- If no can is found for a connection, this is printed in the out file
- The label file, ***short_can_info.usl*** is created, and info could be displayed on the model.

This record is given once

SWITCHES Joint EyeLift Value

Parameter	*Description*	*Default*
Value	The radial distance from chord centre to the location of the new joint node. Value=1.0 means that the node is located on the chord surface	1.2

If the joints are defined as recommended (means that the brace does not end on the chord surface, but goes into the chord axis), it is possible to define where the new nodes are located.

This record is given once

JNTCLASS interval

Parameter	*Description*	*Default*
interval	Joints will be (re)classified according to geometry and force state at specified intervals during the analysis. The joint capacities will be updated according to the revised classification, P-δ curves for each joint degree of freedom and the Q_f factor will be updated. 0 : No joint classification. 1 : Continuous joint (re)classification. Joint capacities, non-linear joint characteristics and the Qf factor will be updated at every step in the USFOS analysis. n >1 : Joints will be (re)classified at every n'th step. Joint capacities, non-linear joint characteristics and the Qf factor will be updated at every n'th step in the USFOS analysis.	1

If the record is not given, the default value of one (classified every step) is used for the MSL, NORSOK, ISO and API-WSD variants.

This record is given once

4 VERIFICATION

4.1 K-Joints

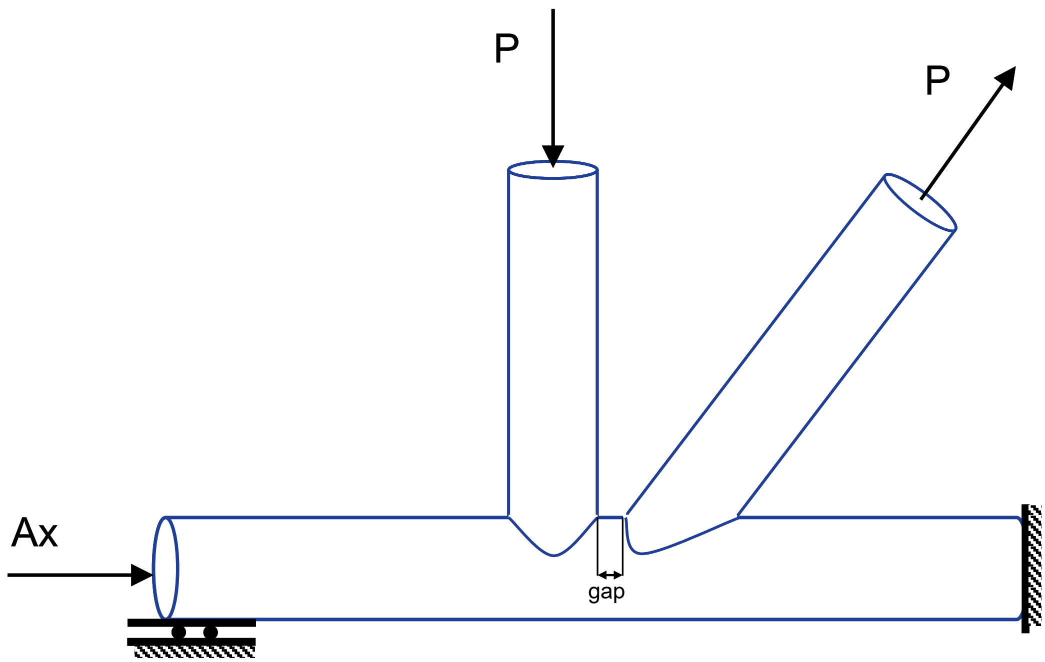


Figure 4-1 Simple K-Joint with gap

4.1.1 Gamma = 10, Beta =0.8, gap/T=2.5

Table 4-1 Joint data

Input	Value
Joint type	**K**
Geometry	[mm]
db	320
tb	20
Dc	400
Tc	20
theta	90
gap	50
Material	[MPa]
fyb	350
fy	350
Chord loads	[N]
-Axial	-1.30E+06
Chord Capacity	
Np	8.357E+06
Mp	1.012E+09

Table 4-2 Expected capacities [N, mm]

	Results for Joint Type:	K							
	MSL Mean	**MSL Char**	**MSL Fcrack**	**NORSOK R2**	**ISO:2007**	**ISO:2020**	**API WSD**	**NORSOK R3**	**NORSOK 2021**
Nrd.c	5.103E+06	3.925E+06	3.925E+06	3.925E+06	3.934E+06	3.164E+06	3.164E+06	3.164E+06	3.164E+06
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	5.051E+06	3.886E+06	3.886E+06	3.869E+06	3.895E+06	3.043E+06	3.043E+06	3.043E+06	3.043E+06
Nrd.t	5.103E+06	3.925E+06	3.925E+06	3.925E+06	3.934E+06	3.164E+06	3.164E+06	3.164E+06	3.164E+06
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	5.051E+06	3.886E+06	3.886E+06	3.869E+06	3.895E+06	3.043E+06	3.043E+06	3.043E+06	3.043E+06
Mipb	6.233E+08	5.100E+08	5.100E+08	5.100E+08	5.100E+08	4.113E+08	4.113E+08	4.113E+08	4.113E+08
Qf	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96
Mipb*Qf	6.065E+08	4.962E+08	4.962E+08	4.962E+08	4.962E+08	3.946E+08	3.946E+08	3.946E+08	3.946E+08
Mopb	3.931E+08	2.995E+08	2.995E+08	2.995E+08	2.995E+08	2.750E+08	2.750E+08	2.750E+08	2.750E+08
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Mopb*Qf	3.882E+08	2.957E+08	2.957E+08	2.957E+08	2.957E+08	2.638E+08	2.638E+08	2.638E+08	2.638E+08

Table 4-3 USFOS results [N, m]

```
MSL-Mean
MSL-Mean

     NODE          Capacity                   Chord      Chord      Chord
      ID             rule                   diameter   thickness   yield str.
      12           MSL mean                 4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
    ID     (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12   0.050     5.103E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                   29% T                       3.224E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                  100% =>                      4.552E+06   6.233E+05   3.931E+05
                                                    0.99        0.97        0.99
      12     45       K         11   0.050     7.113E+06   8.815E+05   5.560E+05  N/A     N/A      N/A
                                                    0.99        0.97        0.99
MSL-Char

     NODE          Capacity                   Chord      Chord      Chord
      ID             rule                   diameter   thickness   yield str.
      12           MSL characteristic       4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
    ID     (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12   0.050     3.925E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      3.519E+06   5.100E+05   2.995E+05
                                                    0.99        0.97        0.99
      12     45       K         11   0.050     4.720E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                    0.99        0.97        0.99
MSL-FCrack

     NODE          Capacity                   Chord      Chord      Chord
      ID             rule                   diameter   thickness   yield str.
      12           MSL first crack          4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
    ID     (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12   0.050     3.925E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      3.519E+06   5.100E+05   2.995E+05
                                                    0.99        0.97        0.99
      12     45       K         11   0.050     4.720E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                    0.99        0.97        0.99
NOR_R2

     NODE          Capacity                   Chord      Chord      Chord
      ID             rule                   diameter   thickness   yield str.
      12        Norsok N-004 Rev2           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
    ID     (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12   0.050     3.925E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      3.519E+06   5.100E+05   2.995E+05
                                                    0.98        0.97        0.99
      12     45       K         11   0.050     5.263E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                    0.98        0.97        0.99
ISO-19902

     NODE          Capacity                   Chord      Chord      Chord
      ID             rule                   diameter   thickness   yield str.
      12     ISO 19902 2007-12-01           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
    ID     (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12   0.050     3.925E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      3.519E+06   5.100E+05   2.995E+05
                                                    0.99        0.97        0.99
      12     45       K         11   0.050     5.258E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                    0.99        0.97        0.99
```

```
ISO_2020

     NODE          Capacity                    Chord        Chord        Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902  2020-11              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   71% K        12   0.050     3.164E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      3.155E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
       12     45       K        11   0.050     4.387E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
API-WSD

     NODE          Capacity                    Chord        Chord        Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   71% K        12   0.050     3.164E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      3.155E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
       12     45       K        11   0.050     4.387E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
NOR_R3

     NODE          Capacity                    Chord        Chord        Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   71% K        12   0.050     3.164E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      3.155E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
       12     45       K        11   0.050     4.387E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
NOR_2021

     NODE          Capacity                    Chord        Chord        Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   71% K        12   0.050     3.164E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      3.155E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
       12     45       K        11   0.050     4.387E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
```

4.1.2 Gamma = 10, Beta = 0.8, gap/T = -2.5

Table 4-4 Joint data

Input	**Value**
Joint type	**K**
Geometry	[mm]
Db	320
Tb	20
Dc	400
Tc	20
Theta	90
gap	-50
Material	[MPa]
fyb	350
fy	350
Chord loads	[N]
-Axial	-1.30E+06
Chord Capacity	
Np	8.357E+06
Mp	1.012E+09

Table 4-5 Expected capacities [N, mm]

	Results for Joint Type:	**K**							
	MSL Mean	**MSL Char**	**MSL Fcrack**	**NORSOK R2**	**ISO:2007**	**ISO:2020**	**API WSD**	**NORSOK R3**	**NORSOK 2021**
Nrd.c	7.211E+06	5.547E+06	5.547E+06	5.547E+06	5.547E+06	6.555E+06	6.555E+06	6.555E+06	6.555E+06
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	7.139E+06	5.491E+06	5.491E+06	5.467E+06	5.491E+06	6.304E+06	6.304E+06	6.304E+06	6.304E+06
Nrd.t	7.211E+06	5.547E+06	5.547E+06	5.547E+06	5.547E+06	6.555E+06	6.555E+06	6.555E+06	6.555E+06
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	7.139E+06	5.491E+06	5.491E+06	5.467E+06	5.491E+06	6.304E+06	6.304E+06	6.304E+06	6.304E+06
Mipb	6.233E+08	5.100E+08	5.100E+08	5.100E+08	5.100E+08	4.113E+08	4.113E+08	4.113E+08	4.113E+08
Qf	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96
Mipb*Qf	6.065E+08	4.962E+08	4.962E+08	4.962E+08	4.962E+08	3.946E+08	3.946E+08	3.946E+08	3.946E+08
Mopb	3.931E+08	2.995E+08	2.995E+08	2.995E+08	2.995E+08	2.750E+08	2.750E+08	2.750E+08	2.750E+08
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Mopb*Qf	3.882E+08	2.957E+08	2.957E+08	2.957E+08	2.957E+08	2.638E+08	2.638E+08	2.638E+08	2.638E+08

Table 4-6 USFOS Results [N, m]

```
MSL-Mean
     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL mean                   4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12  -0.050     7.211E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                   29% T                       3.224E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                  100% =>                      6.043E+06   6.233E+05   3.931E+05
                                                    0.99        0.97        0.99
       12     45       K        11  -0.050     1.110E+07   8.815E+05   5.560E+05  N/A     N/A      N/A
                                                  0.99        0.97        0.99
MSL-Char

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL characteristic         4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12  -0.050     5.547E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      4.666E+06   5.100E+05   2.995E+05
                                                    0.99        0.97        0.99
       12     45       K        11  -0.050     7.845E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                    0.99        0.97        0.99
MSL-FCrack

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL first crack            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12  -0.050     5.547E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      4.666E+06   5.100E+05   2.995E+05
                                                    0.99        0.97        0.99
       12     45       K        11  -0.050     7.845E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                    0.99        0.97        0.99
NOR_R2

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12       Norsok N-004 Rev2             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12  -0.050     5.547E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      4.666E+06   5.100E+05   2.995E+05
                                                    0.98        0.97        0.99
       12     45       K        11  -0.050     7.845E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                    0.98        0.97        0.99
```

```
ISO-19902

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902 2007-12-01            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf       Cap/Qf       Cap/Qf

       11     90    71% K        12  -0.050     5.547E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                    29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   100% =>                      4.666E+06   5.100E+05   2.995E+05
                                                     0.99        0.97        0.99
       12     45       K         11  -0.050     7.845E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                     0.99        0.97        0.99
ISO_2020

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902  2020-11              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf       Cap/Qf       Cap/Qf

       11     90    71% K        12  -0.050     6.555E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                    29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   100% =>                      5.553E+06   4.113E+05   2.750E+05
                                                     0.95        0.96        0.96
       12     45       K         11  -0.050     9.269E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                     0.96        0.96        0.96
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf       Cap/Qf       Cap/Qf

       11     90    71% K        12  -0.050     6.555E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                    29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   100% =>                      5.553E+06   4.113E+05   2.750E+05
                                                     0.95        0.96        0.96
       12     45       K         11  -0.050     9.269E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                     0.96        0.96        0.96
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf       Cap/Qf       Cap/Qf

       11     90    71% K        12  -0.050     6.555E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                    29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   100% =>                      5.553E+06   4.113E+05   2.750E+05
                                                     0.95        0.96        0.96
       12     45       K         11  -0.050     9.269E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                     0.96        0.96        0.96
NOR_2021

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf       Cap/Qf       Cap/Qf

       11     90    71% K        12  -0.050     6.555E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                    29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   100% =>                      5.553E+06   4.113E+05   2.750E+05
                                                     0.95        0.96        0.96
       12     45       K         11  -0.050     9.269E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                     0.96        0.96        0.96
```

4.1.3 Gamma = 10, Beta = 0.8, gap/T = -0.5

Table 4-7 Joint data

Input	Value
Joint type	**K**
Geometry	[mm]
db	320
tb	20
Dc	400
Tc	20
theta	90
gap	-10
Material	[MPa]
fyb	350
fy	350
Chord loads	[N]
-Axial	-1.30E+06
Chord Capacity	
Np	8.357E+06
Mp	1.012E+09

Table 4-8 Expected Capacities [N,mm]

		Results for Joint Type:	K						
	MSL Mean	**MSL Char**	**MSL Fcrack**	**NORSOK R2**	**ISO:2007**	**ISO:2020**	**API WSD**	**NORSOK R3**	**NORSOK 2021**
Nrd.c	6.467E+06	4.974E+06	4.974E+06	4.974E+06	4.974E+06	5.761E+06	5.761E+06	5.761E+06	5.761E+06
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	6.402E+06	4.924E+06	4.924E+06	4.903E+06	4.924E+06	5.541E+06	5.541E+06	5.541E+06	5.541E+06
Nrd.t	6.467E+06	4.974E+06	4.974E+06	4.974E+06	4.974E+06	5.761E+06	5.761E+06	5.761E+06	5.761E+06
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	6.402E+06	4.924E+06	4.924E+06	4.903E+06	4.924E+06	5.541E+06	5.541E+06	5.541E+06	5.541E+06
Mipb	6.233E+08	5.100E+08	5.100E+08	5.100E+08	5.100E+08	4.113E+08	4.113E+08	4.113E+08	4.113E+08
Qf	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96
Mipb*Qf	6.065E+08	4.962E+08	4.962E+08	4.962E+08	4.962E+08	3.946E+08	3.946E+08	3.946E+08	3.946E+08
Mopb	3.931E+08	2.995E+08	2.995E+08	2.995E+08	2.995E+08	2.750E+08	2.750E+08	2.750E+08	2.750E+08
Qf	0.99	0.99	0.99	0.99	0.99	0.96	0.96	0.96	0.96
Mopb*Qf	3.882E+08	2.957E+08	2.957E+08	2.957E+08	2.957E+08	2.638E+08	2.638E+08	2.638E+08	2.638E+08

Table 4-9 USFOS Results [N, m]

```
MSL-Mean

    NODE          Capacity                    Chord      Chord      Chord
     ID             rule                    diameter   thickness   yield str.
     12           MSL mean                  4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
     ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

     11    90   71% K        12  -0.010     6.467E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                29% T                       3.224E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
               100% =>                      5.517E+06   6.233E+05   3.931E+05
                                                 0.99        0.97        0.99
     12    45       K        11  -0.010     9.958E+06   8.815E+05   5.560E+05  N/A     N/A      N/A
                                                 0.99        0.97        0.99
MSL-Char

    NODE          Capacity                    Chord      Chord      Chord
     ID             rule                    diameter   thickness   yield str.
     12           MSL characteristic        4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
     ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

     11    90   71% K        12  -0.010     4.974E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
               100% =>                      4.261E+06   5.100E+05   2.995E+05
                                                 0.99        0.97        0.99
     12    45       K        11  -0.010     7.035E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                 0.99        0.97        0.99
MSL-FCrack

    NODE          Capacity                    Chord      Chord      Chord
     ID             rule                    diameter   thickness   yield str.
     12           MSL first crack           4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
     ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

     11    90   71% K        12  -0.010     4.974E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
               100% =>                      4.261E+06   5.100E+05   2.995E+05
                                                 0.99        0.97        0.99
     12    45       K        11  -0.010     7.035E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                 0.99        0.97        0.99
NOR_R2

    NODE          Capacity                    Chord      Chord      Chord
     ID             rule                    diameter   thickness   yield str.
     12        Norsok N-004 Rev2            4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
     ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

     11    90   71% K        12  -0.010     4.974E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
               100% =>                      4.261E+06   5.100E+05   2.995E+05
                                                 0.98        0.97        0.99
     12    45       K        11  -0.010     7.035E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                 0.98        0.97        0.99
ISO-19902

    NODE          Capacity                    Chord      Chord      Chord
     ID             rule                    diameter   thickness   yield str.
     12     ISO 19902 2007-12-01            4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
     ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

     11    90   71% K        12  -0.010     4.974E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                29% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
               100% =>                      4.261E+06   5.100E+05   2.995E+05
                                                 0.99        0.97        0.99
     12    45       K        11  -0.010     7.035E+06   7.213E+05   4.236E+05  N/A     N/A      N/A
                                                 0.99        0.97        0.99
```

```
ISO_2020

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12    ISO 19902  2020-11              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12  -0.010     5.761E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      4.992E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
      12     45       K         11  -0.010     8.147E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
API-WSD

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12 API RP2A-WSD 21st ES3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12  -0.010     5.761E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      4.992E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
      12     45       K         11  -0.010     8.147E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
NOR_R3

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12  -0.010     5.761E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      4.992E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
      12     45       K         11  -0.010     8.147E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
NOR_2021

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12       Norsok  2021-01              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

      11     90    71% K        12  -0.010     5.761E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   29% T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                      4.992E+06   4.113E+05   2.750E+05
                                                    0.95        0.96        0.96
      12     45       K         11  -0.010     8.147E+06   5.817E+05   3.889E+05  N/A     N/A      N/A
                                                    0.96        0.96        0.96
```

4.1.4 Gamma = 25, Beta = 0.8, gap/T = 6.25

Table 4-10 Joint data

Input	Value
Joint type	**K**
Geometry	[mm]
db	320
tb	8
Dc	400
Tc	8
theta	90
gap	50
Material	[MPa]
fyb	350
fy	350
Chord loads	[N]
-Axial	-1.05E+06
Chord Capacity	
Np	3.448E+06
Mp	4.303E+08

Table 4-11 Expected Capacities [N,mm]

	Results for Joint Type:	**K**							
	MSL Mean	**MSL Char**	**MSL Fcrack**	**NORSOK R2**	**ISO:2007**	**ISO:2020**	**API WSD**	**NORSOK R3**	**NORSOK 2021**
Nrd.c	8.164E+05	6.280E+05	6.280E+05	6.280E+05	6.295E+05	7.232E+05	7.232E+05	7.232E+05	7.232E+05
Qf	0.96	0.96	0.96	0.95	0.96	0.91	0.91	0.91	0.91
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	7.856E+05	6.043E+05	6.043E+05	5.941E+05	6.057E+05	6.602E+05	6.602E+05	6.602E+05	6.602E+05
Nrd.t	8.164E+05	6.280E+05	6.280E+05	6.280E+05	6.295E+05	7.232E+05	7.232E+05	7.232E+05	7.232E+05
Qf	0.96	0.96	0.96	0.95	0.96	0.91	0.91	0.91	0.91
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	7.856E+05	6.043E+05	6.043E+05	5.941E+05	6.057E+05	6.602E+05	6.602E+05	6.602E+05	6.602E+05
Mipb	1.577E+08	1.290E+08	1.290E+08	1.290E+08	1.290E+08	1.234E+08	1.234E+08	1.234E+08	1.234E+08
Qf	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Mipb*Qf	1.417E+08	1.160E+08	1.160E+08	1.160E+08	1.160E+08	1.115E+08	1.115E+08	1.115E+08	1.115E+08
Mopb	8.433E+07	6.425E+07	6.425E+07	6.425E+07	6.425E+07	5.604E+07	5.604E+07	5.604E+07	5.604E+07
Qf	0.95	0.95	0.95	0.95	0.95	0.90	0.90	0.90	0.90
Mopb*Qf	8.035E+07	6.122E+07	6.122E+07	6.122E+07	6.122E+07	5.066E+07	5.066E+07	5.066E+07	5.066E+07

Table 4-12 USFOS Results [N, m]

```
MSL-Mean

    NODE          Capacity                  Chord      Chord      Chord
     ID             rule                  diameter   thickness  yield str.
      12          MSL mean                4.000E-01   8.000E-03  3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   71% K        12   0.050     8.164E+05   1.577E+05   8.433E+04  N/A     N/A      N/A
                  29% T                       5.158E+05   1.577E+05   8.433E+04  N/A     N/A      N/A
                 100% =>                      7.284E+05   1.577E+05   8.433E+04
                                                   0.95        0.89        0.95
      12     45       K        11   0.050     1.257E+06   2.230E+05   1.193E+05  N/A     N/A      N/A
                                                   0.95        0.88        0.94
MSL-Char

    NODE          Capacity                  Chord      Chord      Chord
     ID             rule                  diameter   thickness  yield str.
      12          MSL characteristic      4.000E-01   8.000E-03  3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   71% K        12   0.050     6.280E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  29% T                       4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                      5.630E+05   1.290E+05   6.425E+04
                                                   0.95        0.89        0.95
      12     45       K        11   0.050     8.879E+05   1.825E+05   9.087E+04  N/A     N/A      N/A
                                                   0.95        0.88        0.94
MSL-FCrack

    NODE          Capacity                  Chord      Chord      Chord
     ID             rule                  diameter   thickness  yield str.
      12          MSL first crack         4.000E-01   8.000E-03  3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   71% K        12   0.050     6.280E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  29% T                       4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                      5.630E+05   1.290E+05   6.425E+04
                                                   0.95        0.89        0.95
      12     45       K        11   0.050     8.879E+05   1.825E+05   9.087E+04  N/A     N/A      N/A
                                                   0.95        0.88        0.94
NOR_R2

    NODE          Capacity                  Chord      Chord      Chord
     ID             rule                  diameter   thickness  yield str.
      12       Norsok N-004 Rev2          4.000E-01   8.000E-03  3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   71% K        12   0.050     6.280E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  29% T                       4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                      5.630E+05   1.290E+05   6.425E+04
                                                   0.94        0.89        0.95
      12     45       K        11   0.050     8.882E+05   1.825E+05   9.087E+04  N/A     N/A      N/A
                                                   0.94        0.89        0.95
ISO-19902

    NODE          Capacity                  Chord      Chord      Chord
     ID             rule                  diameter   thickness  yield str.
      12    ISO 19902 2007-12-01          4.000E-01   8.000E-03  3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   71% K        12   0.050     6.280E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  29% T                       4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                      5.630E+05   1.290E+05   6.425E+04
                                                   0.95        0.89        0.95
      12     45       K        11   0.050     8.882E+05   1.825E+05   9.087E+04  N/A     N/A      N/A
                                                   0.96        0.89        0.95
```

```
ISO_2020

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902  2020-11              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12   0.050     7.232E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                   29% T                       6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  100% =>                      6.950E+05   1.234E+05   5.604E+04
                                                    0.88        0.90        0.90
       12     45       K        11   0.050     1.023E+06   1.745E+05   7.925E+04  N/A     N/A      N/A
                                                    0.90        0.90        0.90
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12   0.050     7.232E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                   29% T                       6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  100% =>                      6.950E+05   1.234E+05   5.604E+04
                                                    0.88        0.90        0.90
       12     45       K        11   0.050     1.023E+06   1.745E+05   7.925E+04  N/A     N/A      N/A
                                                    0.90        0.90        0.90
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12   0.050     7.232E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                   29% T                       6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  100% =>                      6.950E+05   1.234E+05   5.604E+04
                                                    0.88        0.90        0.90
       12     45       K        11   0.050     1.023E+06   1.745E+05   7.925E+04  N/A     N/A      N/A
                                                    0.90        0.90        0.90
NOR_2021

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90   71% K        12   0.050     7.232E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                   29% T                       6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  100% =>                      6.950E+05   1.234E+05   5.604E+04
                                                    0.88        0.90        0.90
       12     45       K        11   0.050     1.023E+06   1.745E+05   7.925E+04  N/A     N/A      N/A
                                                    0.90        0.90        0.90
```

4.2 T/Y-Joints

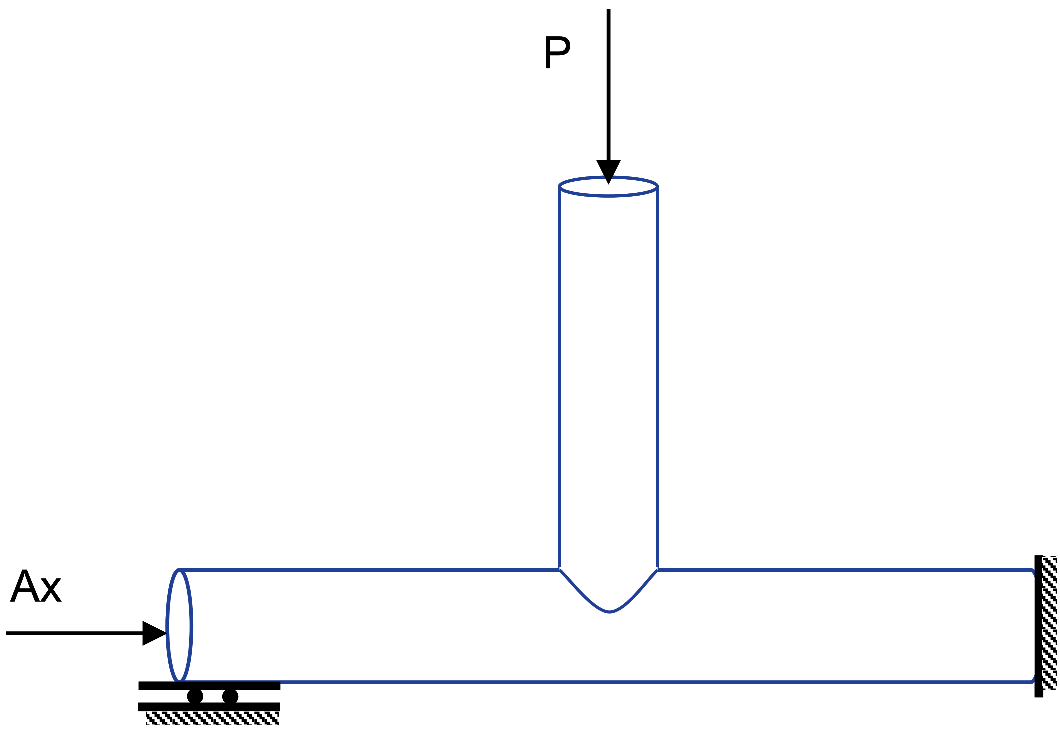


Figure 4-2 Simple T/Y-Joint

4.2.1 Gamma = 25, Beta =0.8

Table 4-13 Joint data

Input	Value
Joint type	**T/Y**
Geometry	[mm]
db	320
tb	8
Dc	400
Tc	8
theta	90
gap	0
Material	
fyb	350
fy	350
Chord loads	[N]
-Axial	-1.03E+06
Chord Capacity	
Np	3.448E+06
Mp	4.303E+08

Table 4-14 Expected capacities [N, mm]

	Results for Joint Type:	**T/Y**							
	MSL Mean	**MSL Char**	**MSL Fcrack**	**NORSOK R2**	**ISO:2007**	**ISO:2020**	**API WSD**	**NORSOK R3**	**NORSOK 2021**
Nrd.c	5.158E+05	4.061E+05	4.061E+05	4.061E+05	4.061E+05	6.270E+05	6.270E+05	6.270E+05	6.270E+05
Qf	0.93	0.93	0.93	0.93	0.93	0.84	0.84	0.84	0.84
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	4.809E+05	3.787E+05	3.787E+05	3.787E+05	3.787E+05	5.254E+05	5.254E+05	5.254E+05	5.254E+05
Nrd.t	1.152E+06	6.608E+05	5.376E+05	5.376E+05	5.376E+05	5.376E+05	5.376E+05	5.376E+05	5.376E+05
Qf	0.93	0.93	0.93	0.93	0.93	0.84	0.84	0.84	0.84
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	1.074E+06	6.162E+05	5.013E+05	5.013E+05	5.013E+05	4.505E+05	4.505E+05	4.505E+05	4.505E+05
Mipb	1.577E+08	1.290E+08	1.290E+08	1.290E+08	1.290E+08	1.234E+08	1.234E+08	1.234E+08	1.234E+08
Qf	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Mipb*Qf	1.417E+08	1.160E+08	1.160E+08	1.160E+08	1.160E+08	1.115E+08	1.115E+08	1.115E+08	1.115E+08
Mopb	8.433E+07	6.425E+07	6.425E+07	6.425E+07	6.425E+07	5.604E+07	5.604E+07	5.604E+07	5.604E+07
Qf	0.95	0.95	0.95	0.95	0.95	0.90	0.90	0.90	0.90
Mopb*Qf	8.035E+07	6.122E+07	6.122E+07	6.122E+07	6.122E+07	5.066E+07	5.066E+07	5.066E+07	5.066E+07

Table 4-15 USFOS results [N, m] (compression)

```
MSL-Mean
     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL mean                   4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                        5.158E+05   1.577E+05   8.433E+04  N/A     N/A      N/A
                                                    0.92        0.85        0.93
MSL-Char
     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL characteristic         4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                        4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                    0.92        0.85        0.93
MSL-FCrack
     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL first crack            4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                        4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                    0.92        0.85        0.93
NOR_R2
     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12       Norsok N-004 Rev2             4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                        4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                    0.93        0.87        0.94
ISO-19902
     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12    ISO 19902 2007-12-01             4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                        4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                    0.93        0.85        0.93
ISO_2020
     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12    ISO 19902  2020-11               4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                        6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                    0.82        0.89        0.89
```

```
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                  0.82        0.89        0.89
NOR_R3
     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                  0.82        0.89        0.89
NOR_2021
     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                  0.82        0.89        0.89
```

Table 4-16 USFOS results [N, m] (tension)

```
MSL-Mean
MSL-Mean

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL mean                  4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      1.149E+06   1.577E+05   8.433E+04  N/A     N/A      N/A
                                                  0.92        0.85        0.93
MSL-Char

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL characteristic        4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      6.593E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                  0.92        0.85        0.93
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      5.375E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                  0.92        0.85        0.93
NOR_R2

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 Rev2            4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      5.376E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                  0.93        0.87        0.94
ISO-19902

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902 2007-12-01            4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      5.376E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                  0.93        0.85        0.93
ISO_2020

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902  2020-11              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      5.376E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                  0.82        0.89        0.89
```

```
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      5.376E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                  0.82        0.89        0.89
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      5.376E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                  0.82        0.89        0.89
NOR_2021

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      5.376E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                  0.82        0.89        0.89
```

4.2.2 Gamma = 10, Beta =0.8

Table 4-17 Joint data

Input	Value
Joint type	**T/Y**
Geometry	[mm]
Db	320
Tb	20
Dc	400
Tc	20
theta	90
gap	0
Material	
fyb	350
fy	350
Chord loads	[N]
-Axial	-2.51E+06
Chord Capacity	
Np	8.357E+06
Mp	1.012E+09

Table 4-18 Expected capacities [N, mm]

			Results for Joint Type:	T/Y					
	MSL Mean	**MSL Char**	**MSL Fcrack**	**NORSOK R2**	**ISO:2007**	**ISO:2020**	**API WSD**	**NORSOK R3**	**NORSOK 2021**
Nrd.c	3.224E+06	2.538E+06	2.538E+06	2.538E+06	2.538E+06	3.135E+06	3.135E+06	3.135E+06	3.135E+06
Qf	0.93	0.93	0.93	0.93	0.93	0.84	0.84	0.84	0.84
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	3.006E+06	2.367E+06	2.367E+06	2.367E+06	2.367E+06	2.627E+06	2.627E+06	2.627E+06	2.627E+06
Nrd.t	7.202E+06	4.130E+06	3.360E+06	3.360E+06	3.360E+06	3.360E+06	3.360E+06	3.360E+06	3.360E+06
Qf	0.93	0.93	0.93	0.93	0.93	0.84	0.84	0.84	0.84
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	6.715E+06	3.851E+06	3.133E+06	3.133E+06	3.133E+06	2.816E+06	2.816E+06	2.816E+06	2.816E+06
Mipb	6.233E+08	5.100E+08	5.100E+08	5.100E+08	5.100E+08	4.113E+08	4.113E+08	4.113E+08	4.113E+08
Qf	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Mipb*Qf	5.602E+08	4.584E+08	4.584E+08	4.584E+08	4.584E+08	3.718E+08	3.718E+08	3.718E+08	3.718E+08
Mopb	3.931E+08	2.995E+08	2.995E+08	2.995E+08	2.995E+08	2.750E+08	2.750E+08	2.750E+08	2.750E+08
Qf	0.95	0.95	0.95	0.95	0.95	0.90	0.90	0.90	0.90
Mopb*Qf	3.745E+08	2.854E+08	2.854E+08	2.854E+08	2.854E+08	2.486E+08	2.486E+08	2.486E+08	2.486E+08

Table 4-19 USFOS results [N, m] (compression)

```
MSL-Mean

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL mean                  4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      3.224E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
MSL-Char

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL characteristic        4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
NOR_R2

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 Rev2            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
```

```
ISO-19902

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12    ISO 19902 2007-12-01             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                   0.93        0.89        0.95
ISO_2020

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12    ISO 19902  2020-11               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                   0.83        0.90        0.90
API-WSD

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                   0.83        0.90        0.90
NOR_R3

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12       Norsok N-004 R3               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                   0.83        0.90        0.90
NOR_2021

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12       Norsok  2021-01               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                       3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                   0.83        0.90        0.90
```

Table 4-20 USFOS results [N, m] (tension)

```
MSL-Mean

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL mean                  4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90      T                      7.183E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
MSL-Char

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL characteristic        4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90      T                      4.120E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90      T                      3.359E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
NOR_R2

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 Rev2            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90      T                      3.360E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                  0.93        0.89        0.95
```

```
ISO-19902

     NODE          Capacity                   Chord       Chord       Chord
      ID             rule                   diameter   thickness   yield str.
       12    ISO 19902 2007-12-01           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90       T                    3.360E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                 0.93        0.89        0.95
ISO_2020

     NODE          Capacity                   Chord       Chord       Chord
      ID             rule                   diameter   thickness   yield str.
       12    ISO 19902  2020-11             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90       T                    3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                 0.83        0.90        0.90
API-WSD

     NODE          Capacity                   Chord       Chord       Chord
      ID             rule                   diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90       T                    3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                 0.83        0.90        0.90
NOR_R3

     NODE          Capacity                   Chord       Chord       Chord
      ID             rule                   diameter   thickness   yield str.
       12       Norsok N-004 R3             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90       T                    3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                 0.83        0.90        0.90
NOR_2021

     NODE          Capacity                   Chord       Chord       Chord
      ID             rule                   diameter   thickness   yield str.
       12       Norsok  2021-01             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90       T                    3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                 0.83        0.90        0.90
```

4.3 X-Joints

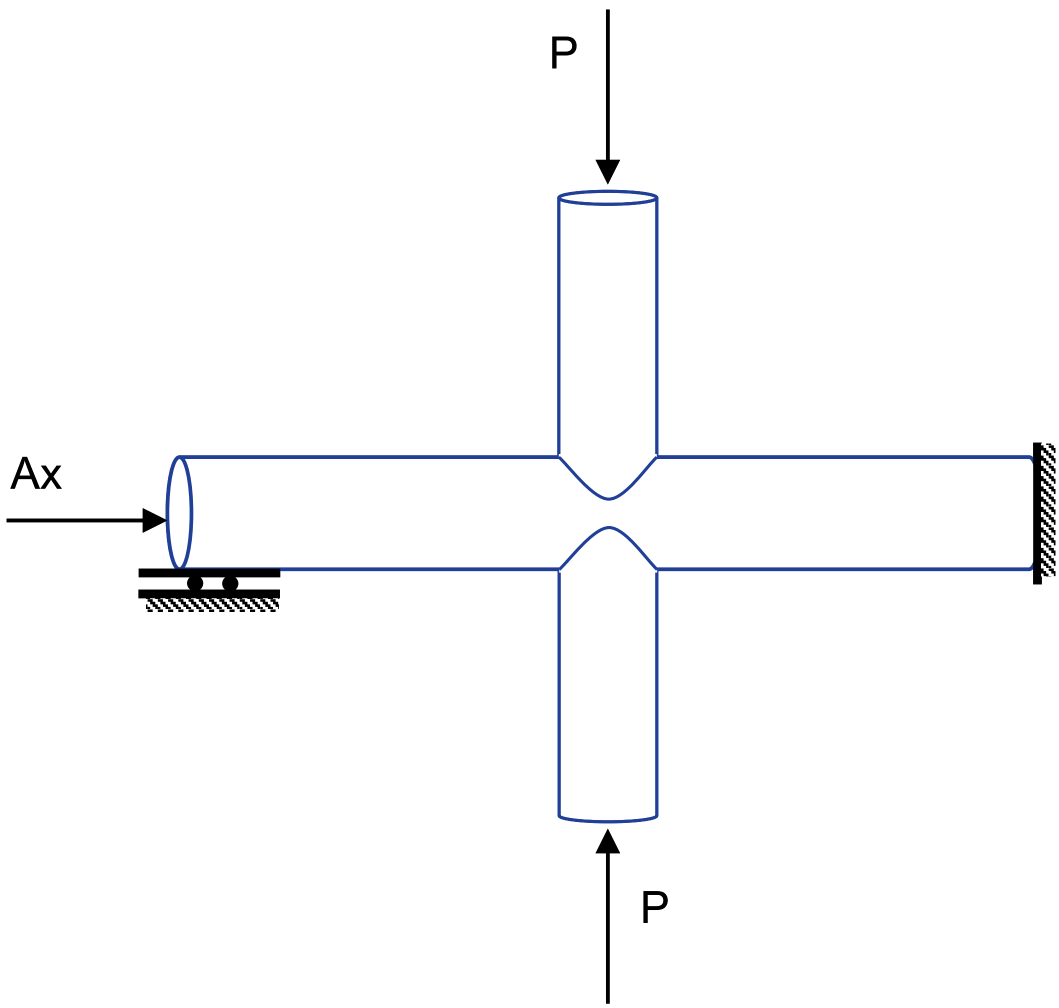


Figure 4-3 Simple DT/X-Joint

4.3.1 Gamma = 25, Beta =0.8

Table 4-21 Joint data

Input	Value
Joint type	**X**
Geometry	[mm]
db	320
tb	8
Dc	400
Tc	8
theta	90
gap	0
Material	
fyb	350
fy	350
Chord loads	[N]
-Axial	-1.03E+06
Chord Capacity	
Np	3.448E+06
Mp	4.303E+08

Table 4-22 Expected capacities [N, mm]

			Results for Joint Type:	X					
	MSL Mean	**MSL Char**	**MSL Fcrack**	**NORSOK R2**	**ISO:2007**	**ISO:2020**	**API WSD**	**NORSOK R3**	**NORSOK 2021**
Nrd.c	4.089E+05	3.525E+05	3.525E+05	3.525E+05	3.626E+05	3.626E+05	3.626E+05	3.626E+05	3.626E+05
Qf	0.93	0.93	0.93	0.95	0.95	0.90	0.90	0.90	0.90
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	3.813E+05	3.287E+05	3.287E+05	3.335E+05	3.430E+05	3.245E+05	3.245E+05	3.245E+05	3.245E+05
Nrd.t	8.163E+05	6.854E+05	4.122E+05	4.122E+05	4.122E+05	4.934E+05	4.122E+05	4.934E+05	4.934E+05
Qf	0.93	0.93	0.93	0.95	0.95	0.90	0.90	0.96	0.96
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	7.612E+05	6.392E+05	3.843E+05	3.899E+05	3.899E+05	4.416E+05	3.689E+05	4.757E+05	4.712E+05
Mipb	1.577E+08	1.290E+08	1.290E+08	1.290E+08	1.290E+08	1.234E+08	1.234E+08	1.234E+08	1.234E+08
Qf	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Mipb*Qf	1.417E+08	1.160E+08	1.160E+08	1.160E+08	1.160E+08	1.115E+08	1.115E+08	1.115E+08	1.115E+08
Mopb	8.433E+07	6.425E+07	6.425E+07	6.425E+07	6.425E+07	5.604E+07	5.604E+07	5.604E+07	5.604E+07
Qf	0.95	0.95	0.95	0.95	0.95	0.90	0.90	0.90	0.90
Mopb*Qf	8.035E+07	6.122E+07	6.122E+07	6.122E+07	6.122E+07	5.066E+07	5.066E+07	5.066E+07	5.066E+07

Table 4-23 USFOS results [N, m] (compression)

```
MSL-Mean

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL mean                   4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   78% X        12               4.089E+05   1.577E+05   8.433E+04  N/A     N/A      N/A
                  22% T                         5.158E+05   1.577E+05   8.433E+04  N/A     N/A      N/A
                 100% =>                        4.325E+05   1.577E+05   8.433E+04
                                                     0.93        0.90        0.95
      12     90       X        11               4.089E+05   1.577E+05   8.433E+04  N/A     N/A      N/A
                                                     0.93        0.90        0.95
MSL-Char

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL characteristic         4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   78% X        12               3.525E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  22% T                         4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                        3.643E+05   1.290E+05   6.425E+04
                                                     0.93        0.90        0.95
      12     90       X        11               3.525E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                     0.93        0.90        0.95
MSL-FCrack

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL first crack            4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   78% X        12               3.525E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  22% T                         4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                        3.643E+05   1.290E+05   6.425E+04
                                                     0.93        0.90        0.95
      12     90       X        11               3.525E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                     0.93        0.90        0.95
NOR_R2

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12       Norsok N-004 Rev2             4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   79% X        12               3.525E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  21% T                         4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                        3.640E+05   1.290E+05   6.425E+04
                                                     0.94        0.90        0.95
      12     90       X        11               3.525E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                     0.95        0.90        0.95
ISO-19902

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12    ISO 19902 2007-12-01             4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90   79% X        12               3.626E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                  21% T                         4.061E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                 100% =>                        3.719E+05   1.290E+05   6.425E+04
                                                     0.94        0.90        0.95
      12     90       X        11               3.626E+05   1.290E+05   6.425E+04  N/A     N/A      N/A
                                                     0.95        0.90        0.95
```

```
ISO_2020

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902  2020-11              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   79% X        12               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  21% T                         6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                 100% =>                        4.193E+05   1.234E+05   5.604E+04
                                                     0.88        0.90        0.90
       12    90       X        11               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                     0.90        0.90        0.90
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   79% X        12               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  21% T                         6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                 100% =>                        4.193E+05   1.234E+05   5.604E+04
                                                     0.88        0.90        0.90
       12    90       X        11               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                     0.90        0.90        0.90
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   79% X        12               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  21% T                         6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                 100% =>                        4.193E+05   1.234E+05   5.604E+04
                                                     0.88        0.90        0.90
       12    90       X        11               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                     0.90        0.90        0.90
NOR_2021

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   8.000E-03   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   79% X        12               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                  21% T                         6.270E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                 100% =>                        4.193E+05   1.234E+05   5.604E+04
                                                     0.88        0.90        0.90
       12    90       X        11               3.626E+05   1.234E+05   5.604E+04  N/A     N/A      N/A
                                                     0.90        0.90        0.90
```

4.3.2 Gamma = 10, Beta =0.8

Table 4-24 Joint data

Input	Value
Joint type	X
Geometry	[mm]
Db	320
Tb	20
Dc	400
Tc	20
theta	90
gap	0
Material	
fyb	350
fy	350
Chord loads	[N]
-Axial	+/- 4.18E+06
Chord Capacity	
Np	8.357E+06
Mp	1.012E+09

Table 4-25 Expected capacities [N, mm]

Results for Joint Type: X									
	MSL Mean	MSL Char	MSL Fcrack	NORSOK R2	ISO:2007	ISO:2020	API WSD	NORSOK R3	NORSOK 2021
Nrd.c	2.556E+06	2.203E+06	2.203E+06	2.203E+06	2.077E+06	2.077E+06	2.077E+06	2.077E+06	2.077E+06
Qf*	1.00	1.00	1.00	0.85	0.85	0.98	0.98	0.98	0.98
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	2.556E+06	2.203E+06	2.203E+06	1.873E+06	1.766E+06	2.025E+06	2.025E+06	2.025E+06	2.025E+06
Nrd.t	5.102E+06	4.284E+06	2.576E+06	2.576E+06	2.576E+06	2.169E+06	2.576E+06	2.169E+06	2.169E+06
Qf	0.81	0.81	0.81	0.85	0.85	0.78	0.78	0.90	0.88
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	4.145E+06	3.481E+06	2.093E+06	2.190E+06	2.190E+06	1.681E+06	1.996E+06	1.952E+06	1.898E+06
Mipb	6.233E+08	5.100E+08	5.100E+08	5.100E+08	5.100E+08	4.113E+08	4.113E+08	4.113E+08	4.113E+08
Qf	0.72	0.72	0.72	0.72	0.72	0.80	0.80	0.80	0.80
Mipb*Qf	4.480E+08	3.666E+08	3.666E+08	3.666E+08	3.666E+08	3.290E+08	3.290E+08	3.290E+08	3.290E+08
Mopb	3.931E+08	2.995E+08	2.995E+08	2.995E+08	2.995E+08	2.750E+08	2.750E+08	2.750E+08	2.750E+08
Qf	0.87	0.87	0.87	0.87	0.87	0.80	0.80	0.80	0.80
Mopb*Qf	3.415E+08	2.602E+08	2.602E+08	2.602E+08	2.602E+08	2.200E+08	2.200E+08	2.200E+08	2.200E+08

*) chord axial tension

Table 4-26 USFOS results [N, m] (compression)

```
MSL-Mean
MSL-Mean

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL mean                  4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12             2.556E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                   11% T                       3.224E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                  100% =>                      2.629E+06   6.233E+05   3.931E+05
                                                    1.00        1.00        1.00
       12     90       X        11             2.556E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                                                    1.00        1.00        1.00
MSL-Char

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL characteristic        4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12             2.203E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   11% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      2.240E+06   5.100E+05   2.995E+05
                                                    1.00        1.00        1.00
       12     90       X        11             2.203E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                    1.00        1.00        1.00
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12             2.203E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   11% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      2.240E+06   5.100E+05   2.995E+05
                                                    1.00        1.00        1.00
       12     90       X        11             2.203E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                    1.00        1.00        1.00
NOR_R2

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 Rev2            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12             2.203E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   11% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      2.241E+06   5.100E+05   2.995E+05
                                                    0.85        0.73        0.87
       12     90       X        11             2.203E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                    0.86        0.73        0.87
ISO-19902

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902 2007-12-01            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12             2.077E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                   11% T                       2.538E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      2.129E+06   5.100E+05   2.995E+05
                                                    0.85        0.73        0.87
       12     90       X        11             2.077E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                    0.86        0.73        0.87
```

```
ISO_2020

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902  2020-11              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   11% T                         3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                        2.195E+06   4.113E+05   2.750E+05
                                                      0.97        1.00        1.00
       12     90       X        11               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                      0.98        1.00        1.00
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   11% T                         3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                        2.195E+06   4.113E+05   2.750E+05
                                                      0.97        1.00        1.00
       12     90       X        11               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                      0.98        1.00        1.00
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   11% T                         3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                        2.195E+06   4.113E+05   2.750E+05
                                                      0.97        1.00        1.00
       12     90       X        11               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                      0.98        1.00        1.00
NOR_2021

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90   89% X        12               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                   11% T                         3.135E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  100% =>                        2.195E+06   4.113E+05   2.750E+05
                                                      0.97        1.00        1.00
       12     90       X        11               2.077E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                      0.98        1.00        1.00
```

The tension test runs reveals that for this geometry, the ductility limits results in capacities less than given in Table 4-26 for the MSL variants. This is inconsistent and the reason for the adjustment to the P-D curves for NORSOK, ISO, and API described in section 2.5.

Table 4-27 USFOS results [N, m] (tension)

```
MSL-Mean
MSL-Mean

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL mean                  4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90    93% X        12            4.693E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                     7% T                      7.197E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                  100% =>                      4.903E+06   6.233E+05   3.931E+05
                                                    0.82        0.73        0.87
       12     90       X         11            4.693E+06   6.233E+05   3.931E+05  N/A     N/A      N/A
                                                    0.82        0.73        0.87
MSL-Char

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL characteristic        4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90    93% X        12            3.738E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                     7% T                      4.127E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      3.812E+06   5.100E+05   2.995E+05
                                                    0.82        0.73        0.87
       12     90       X         11            3.738E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                    0.82        0.73        0.87
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90    93% X        12            2.500E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                     7% T                      3.360E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      2.570E+06   5.100E+05   2.995E+05
                                                    0.82        0.73        0.87
       12     90       X         11            2.500E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                    0.82        0.73        0.87
NOR_R2

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 Rev2            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf

       11     90    94% X        12            2.564E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                     6% T                      3.360E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  100% =>                      2.611E+06   5.100E+05   2.995E+05
                                                    0.85        0.73        0.87
       12     90       X         11            2.564E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                    0.86        0.73        0.87
ISO-19902

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902 2007-12-01            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace              Cap/Qf      Cap/Qf      Cap/Qf
```

```
      11    90   94% X        12             2.564E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                  6% T                       3.360E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                100% =>                      2.611E+06   5.100E+05   2.995E+05
                                                  0.85        0.73        0.87
      12    90       X        11             2.564E+06   5.100E+05   2.995E+05  N/A     N/A      N/A
                                                  0.86        0.73        0.87
ISO_2020

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
      12    ISO 19902  2020-11               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   94% X        12             2.169E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  6% T                       3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                100% =>                      2.236E+06   4.113E+05   2.750E+05
                                                  0.77        0.81        0.81
      12    90       X        11             2.169E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                  0.78        0.81        0.81
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
      12 API RP2A-WSD 21st ES3               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   94% X        12             2.570E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  6% T                       3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                100% =>                      2.616E+06   4.113E+05   2.750E+05
                                                  0.77        0.81        0.81
      12    90       X        11             2.570E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                  0.78        0.81        0.81
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
      12       Norsok N-004 R3               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   94% X        12             2.165E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  6% T                       3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                100% =>                      2.234E+06   4.113E+05   2.750E+05
                                                  0.88        0.81        0.81
      12    90       X        11             2.165E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                  0.90        0.81        0.81
NOR_2021

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
      12       Norsok  2021-01               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   94% X        12             2.166E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                  6% T                       3.360E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                100% =>                      2.235E+06   4.113E+05   2.750E+05
                                                  0.86        0.81        0.81
      12    90       X        11             2.166E+06   4.113E+05   2.750E+05  N/A     N/A      N/A
                                                  0.88        0.81        0.81
```

4.3.3 Gamma = 10, Beta =1.0

Table 4-28 Joint data

Input	Value
Joint type	**X**
Geometry	[mm]
Db	400
Tb	20
Dc	400
Tc	20
theta	90
gap	0
Material	
fyb	350
fy	350
Chord loads	[N]
-Axial	+/- 2.51E+06
Chord Capacity	
Np	8.357E+06
Mp	1.012E+09

Table 4-29 Expected capacities [N, mm]

Results for Joint Type: X

	MSL Mean	MSL Char	MSL Fcrack	NORSOK R2	ISO:2007	ISO:2020	API WSD	NORSOK R3	NORSOK 2021
Nrd.c	4.901E+06	4.225E+06	4.225E+06	4.225E+06	3.974E+06	3.974E+06	3.974E+06	3.974E+06	3.974E+06
Qf*	0.93	0.93	0.93	0.95	0.95	0.92	0.92	0.92	0.92
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.c*Qf	4.570E+06	3.940E+06	3.940E+06	3.997E+06	3.759E+06	3.664E+06	3.664E+06	3.664E+06	3.664E+06
Nrd.t	5.768E+06	5.390E+06	2.240E+06	2.240E+06	2.198E+06	3.567E+06	2.198E+06	3.567E+06	3.567E+06
Qf	0.93	0.93	0.93	0.95	0.95	0.92	1.00	0.92	0.92
Rd	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Nrd.t*Qf	5.379E+06	5.026E+06	2.089E+06	2.119E+06	2.079E+06	3.289E+06	2.290E+06	3.289E+06	3.289E+06
Mipb	9.740E+08	7.969E+08	7.969E+08	7.969E+08	7.969E+08	6.720E+08	6.720E+08	6.720E+08	6.720E+08
Qf	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Mipb*Qf	8.754E+08	7.162E+08	7.162E+08	7.162E+08	7.162E+08	6.075E+08	6.075E+08	6.075E+08	6.075E+08
Mopb	7.438E+08	5.667E+08	5.667E+08	5.667E+08	5.667E+08	5.040E+08	5.040E+08	5.040E+08	5.040E+08
Qf	0.95	0.95	0.95	0.95	0.95	0.90	0.90	0.90	0.90
Mopb*Qf	7.086E+08	5.399E+08	5.399E+08	5.399E+08	5.399E+08	4.556E+08	4.556E+08	4.556E+08	4.556E+08

*) chord axial tension

Table 4-30 USFOS results [N, m] (compression)

```
MSL-Mean

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL mean                  4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90    95% X        12              4.901E+06   9.740E+05   7.438E+05  N/A     N/A      N/A
                     5% T                        4.981E+06   9.740E+05   7.438E+05  N/A     N/A      N/A
                  100% =>                        4.905E+06   9.740E+05   7.438E+05
                                                      0.94        0.90        0.95
       12     90       X        11               4.901E+06   9.740E+05   7.438E+05  N/A     N/A      N/A
                                                      0.94        0.90        0.95
MSL-Char

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL characteristic        4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90    95% X        12              4.225E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                     5% T                        3.922E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                        4.211E+06   7.969E+05   5.667E+05
                                                      0.94        0.90        0.95
       12     90       X        11               4.225E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                      0.94        0.90        0.95
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90    95% X        12              4.225E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                     5% T                        3.922E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                        4.211E+06   7.969E+05   5.667E+05
                                                      0.94        0.90        0.95
       12     90       X        11               4.225E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                      0.94        0.90        0.95
NOR_R2

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 Rev2            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90    95% X        12              4.225E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                     5% T                        3.922E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                        4.211E+06   7.969E+05   5.667E+05
                                                      0.95        0.90        0.95
       12     90       X        11               4.225E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                      0.95        0.90        0.95
ISO-19902

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12    ISO 19902 2007-12-01            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn     Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace                Cap/Qf      Cap/Qf      Cap/Qf

       11     90    95% X        12              3.974E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                     5% T                        3.922E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                        3.971E+06   7.969E+05   5.667E+05
                                                      0.95        0.90        0.95
       12     90       X        11               3.974E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                      0.95        0.90        0.95
```

```
ISO_2020

    NODE          Capacity                     Chord       Chord       Chord
     ID             rule                     diameter   thickness   yield str.
      12    ISO 19902  2020-11               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90    95% X        12               3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                    5% T                         4.312E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  100% =>                        3.989E+06   6.720E+05   5.040E+05
                                                      0.93        1.00        1.00
      12     90       X        11                3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                      0.92        1.00        1.00
API-WSD

    NODE          Capacity                     Chord       Chord       Chord
     ID             rule                     diameter   thickness   yield str.
      12 API RP2A-WSD 21st ES3               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90    95% X        12               3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                    5% T                         4.312E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  100% =>                        3.989E+06   6.720E+05   5.040E+05
                                                      0.93        1.00        1.00
      12     90       X        11                3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                      0.92        1.00        1.00
NOR_R3

    NODE          Capacity                     Chord       Chord       Chord
     ID             rule                     diameter   thickness   yield str.
      12       Norsok N-004 R3               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90    95% X        12               3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                    5% T                         4.312E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  100% =>                        3.989E+06   6.720E+05   5.040E+05
                                                      0.93        1.00        1.00
      12     90       X        11                3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                      0.92        1.00        1.00
NOR_2021

    NODE          Capacity                     Chord       Chord       Chord
     ID             rule                     diameter   thickness   yield str.
      12       Norsok  2021-01               4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
     ID    (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11     90    95% X        12               3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                    5% T                         4.312E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  100% =>                        3.989E+06   6.720E+05   5.040E+05
                                                      0.93        1.00        1.00
      12     90       X        11                3.974E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                      0.92        1.00        1.00
```

Table 4-31 USFOS results [N, m] (tension)

```
MSL-Mean
MSL-Mean

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL mean                   4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   96% X        12            5.768E+06   9.740E+05   7.438E+05  N/A     N/A      N/A
                    4% T                      8.384E+06   9.740E+05   7.438E+05  N/A     N/A      N/A
                  100% =>                     5.872E+06   9.740E+05   7.438E+05
                                                   0.94        0.90        0.95
       12     90       X        11            5.768E+06   9.740E+05   7.438E+05  N/A     N/A      N/A
                                                   0.94        0.90        0.95
MSL-Char

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL characteristic         4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   96% X        12            5.384E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                    4% T                      5.301E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                     5.381E+06   7.969E+05   5.667E+05
                                                   0.94        0.90        0.95
       12     90       X        11            5.384E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                   0.94        0.90        0.95
MSL-FCrack

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12          MSL first crack            4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   96% X        12            2.240E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                    4% T                      4.200E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                     2.318E+06   7.969E+05   5.667E+05
                                                   0.94        0.90        0.95
       12     90       X        11            2.240E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                   0.94        0.90        0.95
NOR_R2

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12       Norsok N-004 Rev2             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   97% X        12            2.240E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                    3% T                      4.200E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                     2.307E+06   7.969E+05   5.667E+05
                                                   0.95        0.90        0.95
       12     90       X        11            2.240E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                   0.95        0.90        0.95
ISO-19902

     NODE          Capacity                     Chord       Chord       Chord
      ID             rule                     diameter   thickness   yield str.
       12    ISO 19902 2007-12-01             4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap         Axial        MipB         MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf       Cap/Qf

       11     90   97% X        12            2.198E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                    3% T                      4.200E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                  100% =>                     2.266E+06   7.969E+05   5.667E+05
                                                   0.95        0.90        0.95
       12     90       X        11            2.198E+06   7.969E+05   5.667E+05  N/A     N/A      N/A
                                                   0.95        0.90        0.95
```

```
ISO_2020

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12    ISO 19902  2020-11              4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
     ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   97% X        12              3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  3% T                        4.200E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                100% =>                       3.589E+06   6.720E+05   5.040E+05
                                                   0.92        0.91        0.91
      12    90       X        11              3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                   0.92        0.91        0.91
API-WSD

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12 API RP2A-WSD 21st ES3              4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
     ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   97% X        12              2.198E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  3% T                        4.200E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                100% =>                       2.266E+06   6.720E+05   5.040E+05
                                                   0.99        0.91        0.91
      12    90       X        11              2.198E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                   1.00        0.91        0.91
NOR_R3

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
     ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   97% X        12              3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  3% T                        4.200E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                100% =>                       3.589E+06   6.720E+05   5.040E+05
                                                   0.92        0.91        0.91
      12    90       X        11              3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                   0.92        0.91        0.91
NOR_2021

    NODE          Capacity                    Chord       Chord       Chord
     ID             rule                    diameter   thickness   yield str.
      12       Norsok  2021-01              4.000E-01   2.000E-02   3.500E+08


  Brace   Angle   Conn    Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc   ThickNom
     ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

      11    90   97% X        12              3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                  3% T                        4.200E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                100% =>                       3.589E+06   6.720E+05   5.040E+05
                                                   0.92        0.91        0.91
      12    90       X        11              3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                   0.92        0.91        0.91
```

```
API-WSD

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12 API RP2A-WSD 21st ES3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   97% X        12               2.198E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                   3% T                         4.200E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                 100% =>                        2.266E+06   6.720E+05   5.040E+05
                                                     0.99        0.91        0.91
       12    90       X        11               2.198E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                     1.00        0.91        0.91
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   97% X        12               3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                   3% T                         4.200E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                 100% =>                        3.589E+06   6.720E+05   5.040E+05
                                                     0.92        0.91        0.91
       12    90       X        11               3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                     0.92        0.91        0.91
NOR_2021

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok  2021-01              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   97% X        12               3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                   3% T                         4.200E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                 100% =>                        3.589E+06   6.720E+05   5.040E+05
                                                     0.92        0.91        0.91
       12    90       X        11               3.567E+06   6.720E+05   5.040E+05  N/A     N/A      N/A
                                                     0.92        0.91        0.91
```

4.4 ShortCan verification

4.4.1 General

The ShortCan reduction is the same for NORSOK, ISO and API. For MSL a different formulation was used for T/Y Joints. The verification examples below include:

- MSL Fcrack (covers all MSL variants) and
- NORSOK R3 (covers NORSOK R2, R3 and R4, ISO 19902:2007, ISO 19902:2020 and API-WSD)

4.4.2 T/Y-joint

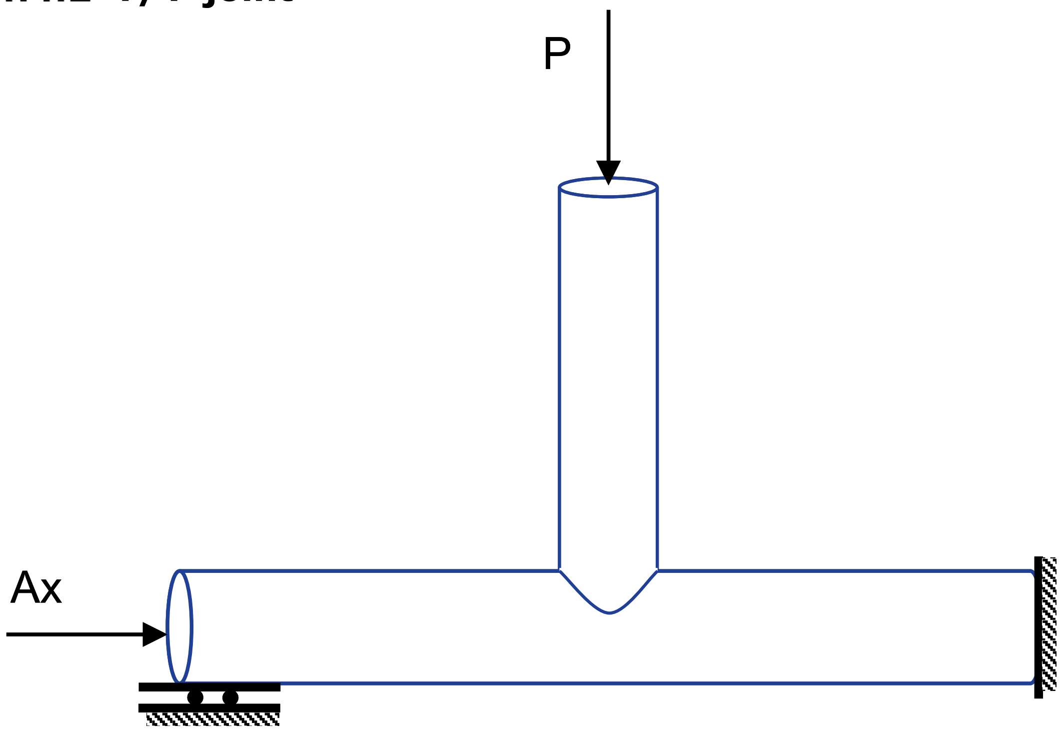


Figure 4-4 Simple T/Y-Joint

4.4.2.1 Gamma = 10, Beta =0.8

Table 4-32 Joint data

Input	Value
Joint type	**T/Y**
Geometry	[mm]
Db	320
Tb	20
Dc	400
Tc	20
Theta	90
Gap	0
Material	[N/mm^2]
fyb	350
fy	350
Chord loads	[N]
-Axial	-2.51E+06

ShortCan input	
a (or b or c)	200
Tn	10
LC	720

Table 4-33 Expected capacities [N, mm]

Results for Joint Type: T		
	MSL Fcrack	**NORSOK R3**
Nrd.t	3.360E+06	3.360E+06
Qf	0.933	0.838
Rd	0.925	0.790
Nrd.c*Rd	3.108E+06	2.654E+06
Nrd.c*Rd*Qf	2.898E+06	2.224E+06

Table 4-34 USFOS results [N, m] (tension)

```
MSL-FCrack
               Load level                             =    0.900



     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      3.108E+06   5.100E+05   2.995E+05  0.925    0.720    0.010
                                                  0.93        0.89        0.95
NOR_R3
               Load level                             =    0.900



     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90       T                      2.654E+06   4.113E+05   2.750E+05  0.790    0.720    0.010
                                                  0.83        0.90        0.90
```

4.4.3 X-joint

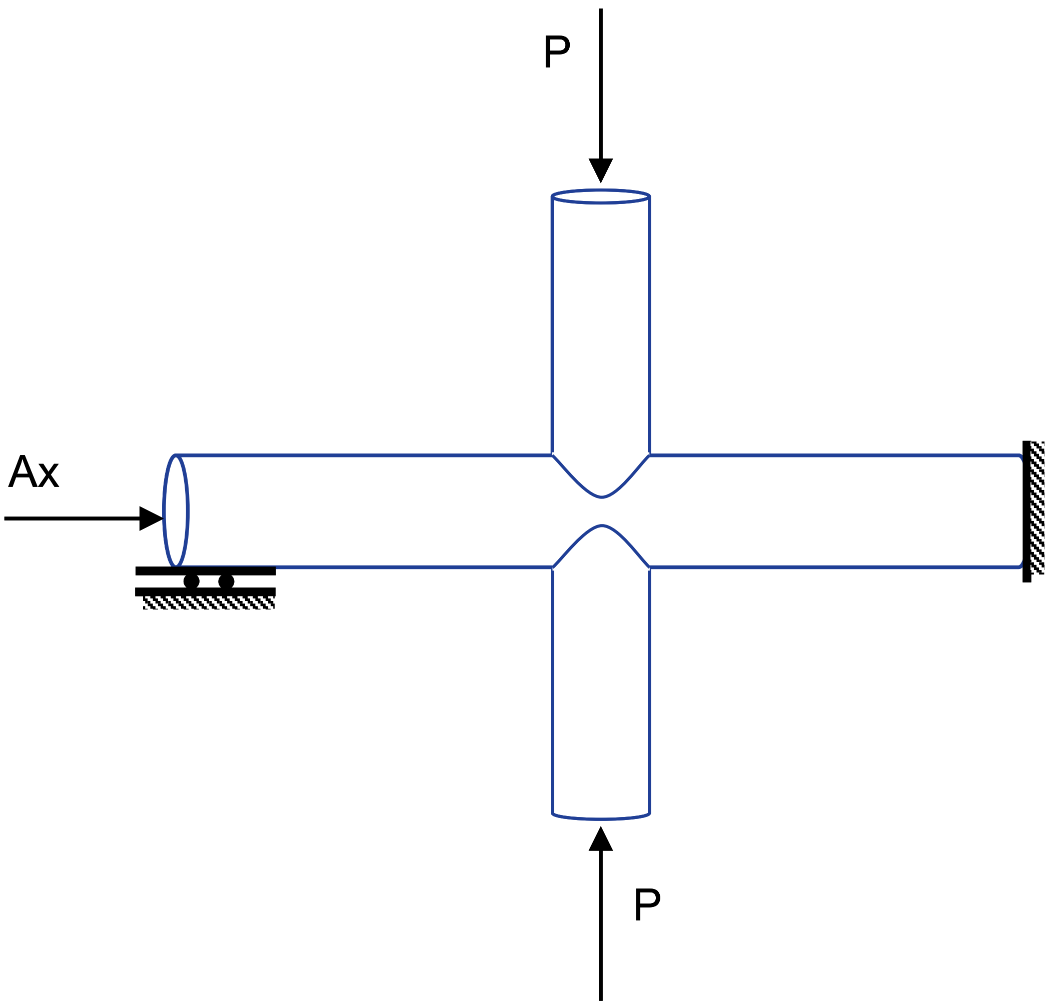


Figure 4-5 Simple DT/X-Joint

4.4.3.1 Gamma = 10, Beta =0.8

Table 4-35 Joint data

Input	**Value**
Joint type	**X**
Geometry	[mm]
Db	320
Tb	20
Dc	400
Tc	20
Theta	90
Gap	0
Material	[N/mm^2]
fyb	350
fy	350
Chord loads	[N]
-Axial	-1.29E+06

ShortCan input	
a (or b or c)	200
Tn	10
LC	720

Table 4-36 Expected capacities [N, mm]

	Results for Joint Type:	**X**
	MSL Fcrack	**NORSOK R3**
Nrd.t	2.576E+06	2.169E+06
Qf	0.982	0.991
Rd	0.790	0.790
Nrd.c*Rd	2.035E+06	1.714E+06
Nrd.c*Rd*Qf	1.999E+06	1.697E+06

The tension test runs reveals that for this geometry, the ductility limits results in capacities less than given in Table 4-26 for the MSL variants. This is inconsistent and the reason for the adjustment to the P-D curves for NORSOK, ISO, and API described in section 2.5.

Table 4-37 USFOS results [N, m] (tension)

```
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90   88% X        12               1.987E+06   5.100E+05   2.995E+05  0.790    0.720    0.010
                   12% T                         3.108E+06   5.100E+05   2.995E+05  0.925    0.720    0.010
                  100% =>                        2.121E+06   5.100E+05   2.995E+05
                                                      0.98        0.97        0.99
       12     90       X        11               1.987E+06   5.100E+05   2.995E+05  0.790    0.720    0.010
                                                      0.98        0.97        0.99
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial        MipB        MopB    ShortCanRd  Lc    ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11     90   91% X        12               1.713E+06   4.113E+05   2.750E+05  0.790    0.720    0.010
                    9% T                         2.654E+06   4.113E+05   2.750E+05  0.790    0.720    0.010
                  100% =>                        1.799E+06   4.113E+05   2.750E+05
                                                      0.98        0.96        0.96
       12     90       X        11               1.713E+06   4.113E+05   2.750E+05  0.790    0.720    0.010
                                                      0.99        0.96        0.96
```

4.4.3.2 Gamma = 10, Beta =1.0

Table 4-38 Joint data

Input	Value
Joint type	**X**
Geometry	[mm]
Db	400
Tb	20
Dc	400
Tc	20
Theta	90
Gap	0
Material	[N/mm^2]
fyb	350
fy	350
Chord loads	[N]
-Axial	-2.51E+06

ShortCan input	
a (or b or c)	75
Tn	10
LC	550

Table 4-39 Expected capacities [N, mm]

Results for Joint Type: X		
	MSL Fcrack	**NORSOK R3**
Nrd.t	2.240E+06	3.567E+06
Qf	0.933	0.922
Rd	0.938	0.938
Nrd.c*Rd	2.100E+06	3.344E+06
Nrd.c*Rd*Qf	1.958E+06	3.083E+06

Table 4-40 USFOS results [N, m] (tension)

```
MSL-FCrack

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12          MSL first crack           4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   96% X        12              2.100E+06   7.969E+05   5.667E+05  0.938    0.550    0.010
                   4% T                        3.938E+06   7.969E+05   5.667E+05  0.938    0.550    0.010
                 100% =>                       2.173E+06   7.969E+05   5.667E+05
                                                    0.94        0.90        0.95
       12    90       X        11              2.100E+06   7.969E+05   5.667E+05  0.938    0.550    0.010
                                                    0.94        0.90        0.95
NOR_R3

     NODE          Capacity                    Chord       Chord       Chord
      ID             rule                    diameter   thickness   yield str.
       12       Norsok N-004 R3              4.000E-01   2.000E-02   3.500E+08


   Brace   Angle   Conn    Facing   Gap          Axial       MipB        MopB    ShortCanRd  Lc   ThickNom
      ID   (deg)   Type     brace               Cap/Qf      Cap/Qf      Cap/Qf

       11    90   97% X        12              3.344E+06   6.720E+05   5.040E+05  0.938    0.550    0.010
                   3% T                        3.938E+06   6.720E+05   5.040E+05  0.938    0.550    0.010
                 100% =>                       3.364E+06   6.720E+05   5.040E+05
                                                    0.92        0.91        0.91
       12    90       X        11              3.344E+06   6.720E+05   5.040E+05  0.938    0.550    0.010
                                                    0.92        0.91        0.91
```

5 REFERENCES

/1/ MSL Engineering limited: "*JIP Assessment Criteria Reliability and Reserve Strength of Tubular Joints*" Doc No. C14200R018 Rev0, March 1996

/2/ MSL Engineering limited: *JIP Assessment criteria, reliability and reserve strength of tubular joints. Phase II, Tubular Joints – Nonlinear modelling algorithms for frame analysis. Final Report*. Doc Ref C20400R014 rev 1 November 2000.

/3/ NORSOK: *N-004 Design of Steel Structures*, rev2, October 2004

/4/ ISO: *Petroleum and natural gas industries –Fixed steel offshore structures,* ISO 19902:2007

/5/ API: *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms -Working Stress Design,* API RP 2A-WSD, 21'st edition, ES3, October 2007

/6/ NORSOK: *N-004 Design of Steel Structures*, rev3, 2013

/7/ A F Dier, P Smedley, G Solland, H Bang: New data on the capacity of X-joints under tension and implications for codes, OMAE2008-57650, June 2008 Estoril, Portugal

/8/ ISO: *Petroleum and natural gas industries –Fixed steel offshore structures,* ISO 19902:2020, 2020-11

/9/ NORSOK: *N-004:2021 Design of Steel Structures*, 2021

/10/ API: *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms -Working Stress Design,* API RP 2A-WSD, 22'nd edition (R2020)