Date of Issue: October 2015
Affected Publication: ANSI/API Technical Report 5C3/ISO 10400:2007, *Technical Report on Equations and Calculations or Casing, Tubing, and Line Pipe Used as Casing or Tubing; and Performance Properties Tables for Casing and Tubing*, First Edition, December 2008

ADDENDUM

Revise the ISO title on the Cover to read:

> **ISO 10400:2007 (Modified), Petroleum, petrochemical and natural gas industries—Equations and calculations for the properties of casing, tubing, drill pipe and line pipe used as casing or tubing**

After **Annex L**, *insert the attached:* **Annex M** (informative) **Identification and Explanation of Deviations**

Annex M
(informative)

Identification and Explanation of Deviations

M.1 Explanation

The API Subcommittee on Tubular Goods has determined that the following modifications are technically necessary to provide a more rigorous calculation for collapse by combining the effects of axial stress and internal pressure.

M.2 List of modifications

Below are the technical revisions to API 5C3.

(Red font text to be deleted)
(Blue font text to be added or edited)

Clause/Subclause	**Modifications**
Add Sentence to Introduction Annex M provides a list and explanation of the changes to the document.	
5 Symbols f_{yax} equivalent yield strength in the presence of axial stress p_{ci} collapse pressure in the presence of internal pressure p_c collapse pressure	Insert / modify the following: f_{ycom} combined loading equivalent grade p_c collapse resistance
8.4.6 Collapse pressure under axial tension stress The collapse resistance of casing in the presence of an axial stress is calculated by modifying the yield stress to an axial stress equivalent grade according to Equation (42): $f_{yax} = \{[1-0.75(\sigma_a/f_{ymn})^2]^{1/2} - 0.5\sigma_a/f_{ymn}\} f_{ymn}$ (42) where f_{yax} is the equivalent yield strength in the presence of axial stress; f_{ymn} is the specified minimum yield strength; σ_a is the component of axial stress not due to bending. Collapse resistance equation factors and D/t ranges for the axial stress equivalent grade are then calculated by means of Equations (36), (38), (40), (44) or (49), (45) or (50), (46) or (51), (47) or (52), and (48) or (53). Using equation factors for the axial stress equivalent grade, collapse resistance under axial stress is calculated by means of Equations (35), (37), (41) and (39).	**8.4.6 Collapse pressure under axial stress and internal pressure** The above formulas for collapse resistance p_c are valid for zero axial stress and zero internal pressure. The external pressure at collapse under combined axial stress and internal pressure can be calculated by replacing the collapse resistance p_c by the collapse pressure differential $p_c - p_i$ and at the same time modifying the yield stress to a combined loading equivalent grade according to Equation (42) for $\sigma_a + p_i \geq 0$: $f_{ycom} = \{[1-0.75((\sigma_a+p_i)/f_{ymn})^2]^{1/2} - 0.5(\sigma_a+p_i)/f_{ymn}\} f_{ymn}$ (42) where f_{ycom} is the combined loading equivalent grade, the equivalent yield strength in the presence of axial stress and internal pressure; f_{ymn} is the specified minimum yield strength; σ_a is the component of axial stress not due to bending; p_i is the internal pressure.

API collapse resistance equations are not valid for the yield strength of axial stress equivalent grade (f_{yax}) less than 24 000 psi.

Equation (42) is based on the Hencky-von Mises maximum strain energy of distortion theory of yielding.

Collapse resistance equation factors and D/t ranges for the combined loading equivalent grade are then calculated by means of Equations (36), (38), (40), (44) or (49), (45) or (50), (46) or (51), (47) or (52), and (48) or (53). Using equation factors for the combined loading equivalent grade, collapse resistance under axial stress and internal pressure is calculated by means of Equations (35), (37), (39) and (41).

API collapse resistance equations are not valid for the yield strength of combined loading equivalent grade (f_{ycom}) less than 24 000 psi.

Equation (42) is based on the Hencky-von Mises maximum strain energy of distortion theory of yielding.

8.7 Example calculations

Calculate the collapse pressure of size Label 1: 7, mass Label 2: 26, grade P110 casing with axial stress of 11 000 psi and internal pressure 1 000 psi. Wall thickness is 0.362 in.

The following table presents the results of the calculation in both SI and USC units.

Table 9 - Example calculation - Collapse resistance with internal pressure and tension

Term	SI		USC	
	Value	Units	Value	Units
Load				
σ_a	75,842	MPa	11 000	psi
p_i	6,895	MPa	1 000	psi
Geometry				
D	177,80	mm	7.000	in
t	9,19	mm	0.362	In
D/t	19,35			
Material				
f_{ymn}	758	MPa	110 000	psi
Calculations				
f_{yax}	717,7	MPa	104 087	psi
A_c	3.158			
B_c	0.078 9			
C_c	18,444	MPa	2 675	psi
F_c	2.051			
G_c	0.051 2			
Equation	Plastic			
p_c	42,1	MPa	6 110	psi
p_{ci}	48,3	MPa	7 010	psi

8.7 Example calculations

Calculate the collapse resistance p_c of size Label 1: 7, mass Label 2: 26, grade P110 casing with axial stress of 11 000 psi and internal pressure 1 000 psi. Wall thickness is 0.362 in.

The following table presents the results of the calculation in both SI and USC units.

Table 9 - Example calculation - Collapse resistance with internal pressure and tension

Term	SI		USC	
	Value	Units	Value	Units
Load				
σ_a	75,842	MPa	11 000	psi
p_i	6,895	MPa	1 000	psi
Geometry				
D	177,80	mm	7.000	in
t	9,19	mm	0.362	in
D/t	19,35			
Material				
f_{ymn}	758	MPa	110 000	psi
Calculations				
f_{ycom}	713,7	MPa	103 508	psi
A_c	3.156			
B_c	0.078 6			
C_c	18,33	MPa	2 658	psi
F_c	2.050			
G_c	0.051 1			
Equation	Plastic			
$p_c - p_i$	42,1	MPa	6 100	psi

<table>
<tr>
<td>

E.1.6 Collapse pressure under axial tension stress

The collapse resistance of casing in the presence of an axial stress is calculated by modifying the yield stress to an axial stress equivalent grade according to Equation (E.8):

$$f_{yax} = \{[1 - 0.75(\sigma_a / f_{ym})^2]^{1/2} - 0.5\sigma_a / f_{ym}\} f_{ym} \qquad \text{(E.8)}$$

where

f_{yax} is the equivalent yield strength in the presence of axial stress;
f_{ymn} is the specified minimum yield strength;
σ_a is the component of axial stress not due to bending.

Collapse resistance equation factors and D/t ranges for the axial stress equivalent grade are then calculated by means of Equations (E.2), (E.4), (E.6), (E.21), (E.22), (E.23), (E.26), and (E.27). Using equation factors for the axial stress equivalent grade, collapse resistance under axial stress is calculated by means of Equations (E.1), (E.3), (E.5) and (E.7).

API collapse resistance equations are not valid for the yield strength of axial stress equivalent grade (f_{yax}) less than 24 000 psi.

Equation (E.8) is based on Hensky-von Mises maximum strain energy of distortion theory of yielding.

</td>
<td>

E.1.6 Collapse pressure under axial stress and internal pressure

The above formulas for collapse resistance p_c are valid for zero axial stress and zero internal pressure. The external pressure at collapse under combined axial stress and internal pressure can be calculated by replacing the collapse resistance p_c by the collapse pressure differential $p_c - p_i$ and at the same time modifying the yield stress to a combined loading equivalent grade according to Equation (E.8) for $\sigma_a + p_i \geq 0$ and was taken from Reference [122]:

$$f_{ycom} = \{[1 - 0.75((\sigma_a + p_i) / f_{ym})^2]^{1/2} - 0.5(\sigma_a + p_i) / f_{ym}\} f_{ym} \qquad \text{(E.8)}$$

where

f_{ycom} is the combined loading equivalent grade, the equivalent yield strength in the presence of axial stress and internal pressure;
f_{ymn} is the specified minimum yield strength;
σ_a is the component of axial stress not due to bending;
p_i is the internal pressure.

Collapse resistance equation factors and D/t ranges for the combined loading equivalent grade are then calculated by means of Equations (E.2), (E.4), (E.6), (E.21) (E.22), (E.23) (E.26), and (E.27). Using equation factors for the combined loading equivalent grade, collapse resistance under axial stress and internal pressure is calculated by means of Equations (E.1), (E.3), (E.5) and (E.7).

API collapse resistance equations are not valid for the yield strength of combined loading equivalent grade (f_{ycom}) less than 24 000 psi.

Equation (E.8) is based on Hensky-von Mises maximum strain energy of distortion theory of yielding.

</td>
</tr>
<tr>
<td>

8.4.7 Effect of internal pressure on collapse

The external pressure equivalent of external pressure and internal pressure is determined by means of Equation (43). The equation is based on the internal pressure acting on the inside diameter and the external pressure acting on the outside diameter.

$$p_{ci} = p_c + (1 - 2\,t/D)\,p_i \qquad (43)$$

where

D is the specified pipe outside diameter;
p_c is the collapse pressure;
p_{ci} is the collapse pressure in the presence of internal pressure;
p_i is the internal pressure;
t is the specified pipe wall thickness.

</td>
<td>

Delete 8.4.7

</td>
</tr>
</table>

The value *pc* is the collapse resistance calculated neglecting internal pressure, but accounting for any axial load as described in 8.4.6. Equation (43) was taken from Reference [56].	
E.1.7 Effect of internal pressure on collapse The external pressure equivalent of external pressure and internal pressure is determined by means of Equation (E.9) where p_{ci} is the collapse pressure in the presence of internal pressure. The equation is based on the internal pressure acting on the inside diameter and the external pressure acting on the outside diameter. $p_{ci} = p_c + (1 - 2\ t/D)\ p_i$ (E.9) where *D* is the specified pipe outside diameter; *pc* is the collapse pressure; *pi* is the internal pressure; *t* is the specified pipe wall thickness. The value *pc* is the collapse resistance calculated neglecting internal pressure, but accounting for any axial load as described in E.1.6. Equation (E.9) was taken from Reference [56].	**Delete E.1.7**
Add Reference to Bibliography [122] CLINEDINST, W.O., Calculating Collapse Resistance under Axial Stress using Existing API Collapse Formulas and the Strain Energy of Distortion Theory of Yielding, report prepared for the American Petroleum Institute, December 1, 1980	