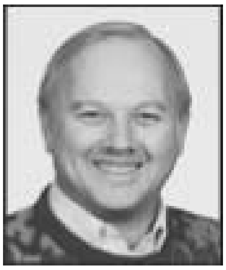
ABOUT THE AUTHORS

Glynn Woods, P.E., graduated from the University of Houston with a Bachelor of Science degree in Mechanical Engineering. Since 1973 he has been involved with pipe pressure and fatigue analysis, support design, and testing of piping systems and components to insure their adequacy for the intended service and piping code requirements.

Mr. Woods has been providing this expertise for both new and operating petrochemical, non-nuclear power plants, and pipelines using computer evaluations, field experience and common sense in arriving at safe, economical piping designs and solutions to piping problems. Mr. Woods is a member of the ASME B31.3 Process Piping Committee and the ASME B31 Mechanical Design Committee, ASME Professional Development for the ASME B31.3 Code, and is a faculty member for the University of Houston-Downtown continuing education program.



Roy Baguley, P.Eng., graduated from the University of Alberta with a Bachelor of Science degree in Metallurgical Engineering and a Masters degree in Metallurgical Engineering (Welding). He is a registered Professional Engineer in the Province of Alberta, Canada. He is also a certified CGSB technician with Level II radiographic, ultrasonic, magnetic particle, and liquid penetrant nondestructive test methods.

With more than 20 years of domestic and international experience with consulting engineers and operating companies, Mr. Baguley is now President of Metal Engineers International Inc., offering metallurgical, welding, corrosion, and nondestructive testing expertise to various industries. He is also involved with Global Inspection Services Ltd., a line pipe and pipeline components inspection company and with MICA Software Inc., a company developing and selling inspection and corrosion management software for the petroleum and petrochemical industries.

Sustained Load Stress

Sustained load stresses are primary stresses caused by pressure or weight and will not diminish with time or as local yielding of the stressed pipe occurs.

B31.3 establishes limits for sustained load stresses. In the Design Conditions section found in Chapter 2, the first sustained stress limit is listed: "The nominal pressure stress shall not exceed the yield strength of the material at temperature" [¶302.2.4(b)].

The nominal pressure stress is the hoop stress, sometimes called the circumferential pressure stress. The hoop stress, σ_h, is calculated as follows using the *thin wall formula*:

$$\sigma_h = \frac{PD}{2t} \text{ psi}$$

where

P = internal pressure, psig
D = pipe outside diameter, in.
t = pipe nominal wall thickness less corrosion, erosion, and mechanical allowances, in.

Example: Find the hoop stress in a 12.75 in., 0.375 in. wall thick pipe, ASTM A 106 Grade B seamless, at 500 psig internal pressure. The pipe service requires a corrosion allowance of 0.0625 in.

Solution: The nominal wall of the pipe is 0.375 in. The mill under-run tolerance for seamless pipe is 12.5%; therefore, the wall thickness to be used is:

$$t = 0.375\ (1 - 0.125) - 0.0625 = 0.2656$$

then $\sigma_h = 500 \times 12.75/(2 \times 0.2656) = 12{,}000$ psi

This pipe wall thickness is adequate to protect against a primary stress failure of bursting, provided the yield strength of the pipe material is greater than 12,000 psi at the temperature of the pressurized condition. (Note: The stress limit for pressure design is S_h, not the yield strength of the material.)

The second sustained load stress limit B31.3 presents is on longitudinal stresses due to sustained loads, S_L [¶302.3.5(c)]. These are stresses that are directed along the axis of the stressed pipe (tensile or compressive) and are caused by pressure, weight, and other sustained loads.

B31.3 does not provide an equation for calculating S_L. Consideration is being given by B31.3 to adopt the B31.1 code S_L equation. The B31.1 equation is :

$$S_L = \frac{PD}{4t} + \frac{0.75iM_A}{Z} \le 1.0\ S_h$$

where

t = nominal wall less corrosion, erosion allowance, inches, mill tolerance is not removed.

M_A = resultant moment due to weight and other sustained loads, in.-lb.

i = stress intensification factor for the component under analysis. Note, B31.1 has only one SIF where B31.3 has two, in-plane and out-plane. If the designer wishes to adopt the B31.1 S_L equation for B31.3 analysis, then the SIF to be selected would be the greater of i_i or i_o.

An example of the B31.3 implied S_L approach is as follows.

The longitudinal stress due to pressure, S_{LP} is calculated as:

$$S_{LP} = \frac{PD}{4t}$$

The terms of this equation are the same as for σ_h except mill under-run tolerances are not to be removed from t. The value of t used in the calculation of S_{LP} is the nominal wall thickness less mechanical, corrosion, and erosion allowances, $\overline{T}$ - c.

The weight stress contribution to this S_L is longitudinal bending stresses caused by pipe sag, pipe overhang, or any other bending caused by gravity. The bending stress caused by weight is calculated as:

$$S_{WL} = \frac{WL}{Z}$$

where

W = weight of the overhang, concentrated at the center of gravity of the system, lb

L = length from point of support to W, in.

Z = section modulus of pipe, $in.^3$

Example: Calculate the S_L of a 12.75 in. outside diameter, 0.375 in. nominal wall, seamless pipe with the following conditions.

P = 650 psig; ca = 0.0625 in.; and the center of gravity load of 400 lb is located 10 ft from the pipe support.

Solution:

t = 0.375 - 0.0625 = 0.3125 in.

O.D. = 12.75 in.

I.D. = 12.75 - 2 x 0.3125 = 12.125 in.

$Z = \pi(12.75^4 - 12.125^4)/(32 \times 12.75) = 37.06\ in.^3$

then S_{LP} = 650 x 12.75/(4 x 0.3125) = 6,630 psi

and S_{LW} = 10 x 12 x 400/37.06 = 1,295 psi

finally $S_L = S_{LP} + S_{LW}$ = 6,630 + 1,295 = 7,925 psi

The allowable stress for S_L is S_h, the hot allowable stress of the material at temperature. The allowable stress for S_L in cold pipe service is S_c. The allowable stress for S_L in cold pipe service is the lesser of S_c or S_h.

Occasional Load Stresses

Occasional load stresses in piping systems are the sum of those stresses caused by loads such as relief valve discharge, wind or earthquake [¶302.3.6]. These stresses are calculated considering:

a) the pipe deflection caused by wind load, acting as a horizontal constant pressure on the outside surface of the pipe, or
b) the pipe deflection caused by earthquake loads, acting as a horizontal or vertical acceleration of the mass or weight of the piping system. The typical method of analysis for earthquake loadings, in a location subject to a horizontal acceleration of 0.28 G, for example, is to determine the stresses resulting from deflections caused by a horizontal constant force equal to 28% of the pipe weight applied in the same horizontal (or vertical) manner as a wind load.

The allowable stress for occasional loads, S_{OL}, summed with the stresses due to sustained loads, S_L, is $1.33S_h$.

$$S_{OL} + S_L \leq 1.33S_h$$

Wind and earthquake need not be considered as acting concurrently.

Wind Loads

B31.3 directs the designer to use the method of analysis stated in ASCE 7-93 [¶301.5.2] for the determination of wind loads based on exposure categories. Wind loads, W_{WL}, are calculated by the equation (**Note**: The current Code edition references ASCE 7-88. This will soon change to ASCE 7-93.):

$$W_{WL} = q_z G_z C_f A \text{ lb}$$

Table 302.3.3C Increased Casting Quality Factors, E_c

Supplementary Examination in Accordance With Note(s)	Factor, E_c
(1)	0.85
(2)(a) or (2)(b)	0.85
(3)(a) or (3)(b)	0.95
(1) and (2)(a) or (2)(b)	0.90
(1) and (3)(a) or (3)(b)	1.00
(2)(a) or (2)(b) and (3)(a) or (3)(b)	1.00

GENERAL NOTE: Titles of standards referenced in this Table's Notes are as follows:
ASTM E 114, Practice for Ultrasonic Pulse-Echo Straight-Beam Testing by the Contact Method
ASTM E 125, Reference Photographs for Magnetic Particle Indications on Ferrous Castings
ASTM E 142, Method for Controlling Quality of Radiographic Testing
ASTM E 165, Practice for Liquid Penetrant Inspection Method
ASTM E 709, Practice for Magnetic Particle Examination
ASME B46.1, Surface Texture (Surface Roughness, Waviness and Lay)
MSS SP-53, Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Magnetic Particle Examination Method

NOTES:
(1) Machine all surfaces to a finish of 6.3 μm R_a (250 μin. R_a per ASME B46.1), thus increasing the effectiveness of surface examination.
(2) (a) Examine all surfaces of each casting (magnetic material only) by the magnetic particle method in accordance with ASTM E 709. Judge acceptability in accordance with MSS SP-53, using reference photos in ASTM E 125.
(b) Examine all surfaces of each casting by the liquid penetrant method, in accordance with ASTM E 165. Judge acceptability of flaws and weld repairs in accordance with Table 1 of MSS SP-53, using ASTM E 125 as a reference for surface flaws.
(3) (a) Fully examine each casting ultrasonically in accordance with ASTM E 114, accepting a casting only if there is no evidence of depth of defects in excess of 5% of wall thickness.
(b) Fully radiograph each casting in accordance with ASTM E 142. Judge in accordance with the stated acceptance levels in Table 302.3.3D.

Table 302.3.3D Acceptance Levels for Castings

Material Examined Thickness, T	Applicable Standard	Acceptance Level (or Class)	Acceptable Discontinuities
Steel $T \le 25$ mm (1 in.)	ASTM E 446	1	Types A, B, C
Steel $T > 25$ mm, ≤ 51 mm (2 in.)	ASTM E 446	2	Types A, B, C
Steel $T > 51$ mm, ≤ 114 mm ($4\frac{1}{2}$ in.)	ASTM E 186	2	Categories A, B, C
Steel $T > 114$ mm, ≤ 305 mm (12 in.)	ASTM E 280	2	Categories A, B, C
Aluminum & magnesium	ASTM E 155	. . .	Shown in reference radiographs
Copper, Ni–Cu	ASTM E 272	2	Codes A, Ba, Bb
Bronze	ASTM E 310	2	Codes A and B

GENERAL NOTE: Titles of ASTM standards referenced in this Table are as follows:
ASTM
E 155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings
E 186 Reference Radiographs for Heavy-Walled [2 to 4-½-in. (51 to 114-mm)] Steel Castings
E 272 Reference Radiographs for High-Strength Copper-Base and Nickel-Copper Castings
E 280 Reference Radiographs for Heavy-Walled [4-½ to 12-in. (114 to 305-mm)] Steel Castings
E 310 Reference Radiographs for Tin Bronze Castings
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

if additional examination is performed beyond that required by the product specification.

(04) **302.3.5 Limits of Calculated Stresses Due to Sustained Loads and Displacement Strains**

(a) Internal Pressure Stresses. Stresses due to internal pressure shall be considered safe when the wall thickness of the piping component, including any reinforcement, meets the requirements of para. 304.

(b) External Pressure Stresses. Stresses due to external pressure shall be considered safe when the wall thickness of the piping component, and its means of stiffening, meet the requirements of para. 304.

(c) Longitudinal Stresses S_L. The sum of the longitudinal stresses S_L in any component in a piping system, due to sustained loads such as pressure and weight, shall not exceed the product S_hW; S_h and W are defined in (d) and (e) below. The weld joint strength reduction factor, W, may be taken as 1.0 for longitudinal welds. The thickness of pipe used in calculating S_L shall be the nominal thickness, $\overline{T}$, minus mechanical, corrosion, and erosion allowance, c, for the location under consideration. The loads due to weight should be based on the nominal thickness of all system components unless otherwise justified in a more rigorous analysis.

(d) Allowable Displacement Stress Range S_A. The computed displacement stress range S_E in a piping system (see para. 319.4.4) shall not exceed the allowable displacement stress range S_A (see paras. 319.2.3 and 319.3.4) calculated by Eq. (1a):

$$S_A = f(1.25S_c + 0.25S_h) \tag{1a}$$