STANDARDS AUSTRALIA

Amendment No. 1
to
AS 1210—2010
Pressure vessels

REVISED TEXT

The 2010 edition of AS 1210 is amended as follows; the amendments should be inserted in the appropriate places.

SUMMARY: This Amendment applies to Clauses 2.6.3.2, 3.19.1, 3.19.2, 3.21.5.4.2, 3.21.6.2, 3.26.3.4, Figures 3.15.1 and 3.21.6.2 and Appendices B, H, I, J, L and M.

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Clause 2.6.3.2

Delete Equation 2.6.3 and *replace* with the following:

$$T_R = T_{min} + T_S - T_L + T_{PPWHT} - T_{SHOCK} - T_C - T_{STRAIN} - T_H \quad \text{. . . 2.6.3}$$

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Figure 3.15.1

Item (a), 2nd row below the 4th column heading, *delete* the equation and *replace* with the following:

$$l \geq \left(1.1 - 0.8\frac{t_s^2}{t_h^2}\right)\sqrt{(Dt_h)}$$

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Clause 3.19.1

Add the following after existing paragraph:

In addition to the requirements of this Clause, consideration shall be given to connections subject to loadings as specified in Clause 3.2.3. The design for local nozzle and structural non-pressure loads shall be according to Appendix N.

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Clause 3.19.2

Delete the first paragraph and *replace* with the following:

'The following meet the requirements of Clause 3.19.2 for pressure loading and do not require strength calculations:

- Welded connections that comply with Figure 3.19.3(A), illustrations (a), (b), (c), (d), (e), (f), (g), (h), (j) and (k); Figure 3.19.3(B), illustrations (f), (g), (h), (j) and (k); Figure 3.19.3(C), illustrations (a) and (c); Figure 3.19.4, illustrations (e), (f), (k), (o) and (p); Figure 3.19.6, illustrations (g), (h) and (j); Figure 3.19.9(b), (c), (d), (e) and (f).

  NOTE: Strength calculations may be required for connections subject to loadings as specified in Clause 3.2.3 or where directed in the notes to the relevant figure.

- If A_1 is found to be greater than A in Clause 3.18 above.
- If the conditions stated in Clause 3.18.6.1 are met.

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Clause 3.21.5.4.2

Item (a), *delete* text and *replace* with the following:

(a) Materials for bolts (including screws, studs, stud-bolts and clamp bolts) shall comply with the specifications listed in Table B2, Appendix B (which also gives design strengths). Additional materials or grades specifically listed as bolting material in ASME BPV-VIII may be used, provided design stresses determined are in accordance with this Standard.

Alternatively, other non-bolting materials to recognized international Standards may be used, provided—

- (i) the selected material Standard lists yield and tensile strength at the design temperature of the equipment:
- (ii) the design strength is calculated in accordance with Table A1, Appendix A;
- (iii) the grain direction of the material is parallel to the axis of the fastener; and
- (iv) nuts meet the requirements of Clause 3.21.5.4.3 and load tested in accordance with the requirements of a nut material Standard listed in Table B2, Appendix B.

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Figure 3.21.6.2

Delete Note 6 and *replace* with the following:

6 Closure elements shall comply with Items (h) to (k) of Clause 3.27.2.

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Clause 3.26.3.4

Delete Item (f) and *replace* with the following:

(f) *Class 1H, 2H, 1S and 2S vessels*—fatigue loads and cycles to be agreed between the designer, purchaser/owner and design verifier (see Appendix M).

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Appendix B, Paragraph B1

Delete text of Paragraph B1 and *replace* with the following:

Tables B1(A) to (J) give design strength (*f*) values for a range of materials for use in vessel design. Table B1(A) gives design strength values for Classes 1H and 2H designs where $R_m/2.35$. Tables B1(B) to (H) give design strength values at $R_m/3.5$, for Classes 1, 2A, 2B and 3 vessels.

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Appendix B, Table B1(E)

Delete title of Table and *replace* with the following:

**DESIGN TENSILE STRENGTH FOR CLASS 1, 2A, 2B AND 3 VESSELS (MPa)—
COPPER AND COPPER ALLOYS**

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Appendix B, Table B2 Notes

Delete the current numbering for the Notes and *replace* as follows:

NOTES:

1 Stresses at intermediate temperatures may be obtained by linear interpolation.

2 $T_R = T_{CV} - 3°C$.

3 For $d \leq 152$ mm, $T_R = T_{CV} - 3°C$. For $d > 152$ mm, $T_R = T_{CV}$.

4 For $d \leq 203$ mm, $T_R = T_{CV} - 3°C$. For $d > 203$ mm, $T_R = T_{CV}$.

5 For $d \leq 178$ mm, $T_R = T_{CV} - 3°C$. For $d > 178$ mm, $T_R = T_{CV}$.

6 For $d \leq 205$ mm, $T_R = T_{CV} - 3°C$. For $d > 205$ mm, $T_R = T_{CV}$.

7 For $d \leq 241$ mm, $T_R = T_{CV} - 3°C$.

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Appendix H, Paragraph H4.2

Delete—

‘thus $t = \dfrac{PD}{2f - P}$ which is Equation 3.7.3(1) with joint efficiency (η) equal to 1, and with K = 1 (Table 3.1.5)’

and *replace* with the following:

thus $t = \dfrac{PD}{2f - P}$ which is Equation 3.7.3(1) with joint efficiency (η) equal to 1, and with $k = 1$ (Table 3.1.6)

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Appendix H, Paragraph H5 (new)

Add the following new Paragraph H5, as follows:

H5 VON MISES CRITERION

While this Standard generally cites the Tresca criterion, the Tresca criterion is a linear approximation of the von Mises criterion. Accordingly, it is permissible for the purposes of stress analyses in this Standard to substitute von Mises stresses for Tresca stresses.

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Appendix I, Paragraph I7

Delete Paragraph I7 and *replace* with the following:

I7 STRENGTH DESIGN BASED ON STRAINS FROM NON-LINEAR ANALYSIS

I7.1 General

As an alternative to the strength design methods, based on linear elastic analysis and stress categories, given in Appendix H, this Paragraph provides a means to demonstrate the design integrity of a vessel or pressure component with respect to strength, using non-linear finite element analysis.

NOTE: While this Paragraph specifically addresses design for strength using non-linear finite element analysis, many vessels will also have deformation-related serviceability limits that may be analysed concurrently with the strength requirements.

I7.2 Requirements

The following requirements apply:

(a) The finite element analysis (FEA) shall be non-linear, including both non-linear geometry and non-linear material properties (see Paragraph I7.3) excepting fatigue analysis [see Item (h)].

(b) All reasonably foreseeable significant loads and load combinations shall be analysed, including normal design conditions, start-up, shut down, upset conditions, thermal loading, wind and seismic loading, with the vessel in its corroded condition.

(c) Non-linear analysis shall be used to determine the vessel shape after the hydrostatic test. The resulting calculated strains shall be limited to the following values:

   (i) The inelastic strain (see Note 1) remote from discontinuities and peak strain regions at the hydrostatic test pressure and hydrostatic test temperature to be less than 1% for vessels other than cold stretched austenitic stainless steel vessels and to be less than 5.2% for cold stretched austenitic stainless steel vessels (see Paragraph L5.3, Appendix L).

   (ii) The inelastic strain at all locations, excluding peak strain locations at the hydrostatic test pressure and at the hydrostatic test temperature, to be the lesser of 5% and one-third of the material's failure elongation (see Note 2) for vessels other than cold stretched austenitic stainless steel vessels and to be the lesser of 25% and one-third of the material's failure elongation for cold stretched austenitic stainless steel vessels.

   If the hydrostatic test simulation results in greater inelastic strains, the design shall be revised until it is in compliance with the strain limits given above.

(d) All reasonably foreseeable significant loads and load combinations applied in service after hydrostatic testing shall result in elastic only strain, excluding peak strain regions (see Notes 3 and 4).

(e) 1.5 times all reasonably foreseeable significant loads and load combinations applied in service after hydrostatic testing shall result in elastic only surface strain remote from discontinuities and peak strain regions.

(f) For materials having a stress/strain curve in which the magnitude of $R_m/2.35$ (or for austenitic steels $R_m/2.5$) is less than $R_e/1.5$, all reasonably foreseeable significant loads and load combinations applied in service after hydrostatic testing multiplied by 2 (2.15 for austenitic steels) shall be capable of being applied to the vessel without causing collapse or bursting (see Note 5).

(g) Where the hydrostatic test and service load analyses of the vessel are carried out at the same temperature and that temperature differs from the actual service temperature, for the purposes of the service load analysis, the service loads shall be multiplied by the ratio of the design strength at hydrostatic temperature to the design strength at the service temperature.

(h) For vessels subject to cyclic loading, fatigue analysis shall be carried out using linear elastic stress/strain material properties according to Appendix M, based on the vessel shape after hydrostatic testing as determined by non-linear analysis.

NOTES:

1 It is necessary that the non-linear FEA software used be capable of giving a contour plot of inelastic strain (often referred to as plastic strain) in order that the inelastic strains resulting from the hydrostatic test can be verified as being within the permissible limits.

2 For the purposes of Paragraph I7.2(c)(ii), the failure elongation is the engineering strain at failure taken from the engineering stress/strain curve used as the basis for the true stress/strain curve employed in the non-linear analysis.

3 The non-linear FEA of the hydrostatic test should result in the unloaded empty vessel having the modified shape, the residual stress distribution, and the strain hardening distribution resulting from the hydrostatic test. Starting from this post-hydrostatic test condition enables the subsequent non-linear FEA of the service loads to fully capture the benefits of stretching during hydrostatic testing. It is necessary that the non-linear FEA software used be capable of giving a contour plot of inelastic strain in order that elastic action resulting from the service loads (at service temperature) can be verified.

4 For those cases where the service loads result in secondary stresses not shaken down to elastic action during the hydrostatic test, it is permissible to apply the service loads more than once after the hydrostatic test during the non-linear analysis to demonstrate elastic only action (excluding peak strain locations) resulting from the service loads. For example, the non-linear FEA would comprise the following loading sequence:

Step 1 Hydrostatic pressure applied and removed.

Step 2 Service loads applied and removed.

Step 3 Service loads applied a second time.

Step 4 Service loads increased by a factor of 1.5.

With elastic only strain (including at discontinuities but excluding peak strains) demonstrated to result from Step 3 (Step 2 ignored) and elastic only strain demonstrated to result from the combination of Steps 3 and 4 remote from discontinuities for compliance.

5 R_e and R_m are to be taken from the engineering stress/strain curve used as the basis for the true stress/strain curve employed in the non-linear analysis. The absence of collapse or bursting may be demonstrated by convergence to a solution in which strains have not exceeded the maximum strain in the true stress/strain curve used in the analysis.

I7.3 Stress/strain properties

For stress/strain properties, the following applies:

(a) Non-linear FEA uses the true stress and true strain properties of the material.

(b) The following relationships may be used to convert engineering stress (σ) and engineering strain (ε) to true stress and true strain. These relationships are valid up to but not beyond the onset of necking at the maximum value of engineering stress (R_m).

$$\varepsilon_t = \ln(1 + \varepsilon) \quad \sigma_t = \sigma(1 + \varepsilon) \qquad \text{. . . I7.3(1)}$$

where

ε_t = true strain

σ_t = true stress

(c) In those cases where the actual strengths of the material being used exceed the specified minimums (R_e and R_m), it is permissible to use a stress/strain relationship having—

(i) the average of the actual and minimum specified yield strengths;

(ii) the average of the actual and minimum specified tensile strengths; and

(iii) the average of the actual and minimum specified elongations.

(d) For those classes of vessel having a weld efficiency less than 1, the engineering stress/strain relationship shall be scaled down in proportion to the weld efficiency (see Note 1 of Table I1).

(e) If the stress/strain curve for the material is not available, it is permissible to—

(i) assume elastic perfect plastic material;

(ii) assume an elastic linear true strain hardening relationship; or

(iii) approximate a true stress/strain curve from the specified minimum strengths of the material as follows (see Note 2 of Table I1):

For a given true stress (σ_t) the corresponding true strain (ε_t) is given by the following:

$$\varepsilon_\mathrm{t} = \frac{\sigma_\mathrm{t}}{E} + \ln(1+\varepsilon_\mathrm{y})\left(\frac{\sigma_\mathrm{t}}{R_\mathrm{p0.2}(1+\varepsilon_\mathrm{y})}\right)^{\frac{1}{m_1}}\frac{(1-H)}{2} + \frac{m_2}{e}\left(\frac{\sigma_\mathrm{t}}{\mathrm{R}_\mathrm{m}}\right)^{\frac{1}{m_2}}\frac{(1+H)}{2} \qquad \text{. . . I7.3(2)}$$

where

E = Young’s modulus at the temperature of interest

e = natural logarithm base 2.71828…

$$H = \tanh\left(\frac{2[\sigma_\mathrm{t} - R_\mathrm{p0.2} - K(R_\mathrm{m} - R_\mathrm{p0.2})]}{K(R_\mathrm{m} - R_\mathrm{p0.2})}\right) \qquad \text{. . . I7.3(3)}$$

$$K = 1.5R^{1.5} - 0.5R^{2.5} - R^{3.5} \qquad \text{. . . I7.3(4)}$$

$$m_1 = \frac{\ln(R) + \varepsilon_\mathrm{p} - \varepsilon_\mathrm{y}}{\ln\left(\dfrac{\ln(1+\varepsilon_\mathrm{p})}{\ln(1+\varepsilon_\mathrm{y})}\right)} \qquad \text{. . . I7.3(5)}$$

m_2 = curve fitting exponent from Table I1

$$R = \frac{R_\mathrm{p0.2}}{R_\mathrm{m}} \qquad \text{. . . I7.3(6)}$$

ε_t = true strain

ε_p = curve-fitting parameter from Table I1

ε_y = 0.002 (for 0.2% offset strain)

σ_t = true stress

R_m = engineering ultimate tensile strength at temperature of interest

$R_\mathrm{p0.2}$ = engineering proof strength at the 0.2% offset strain at temperature of interest

The 1% proof strength properties $R_\mathrm{p1.0}$ and $\varepsilon_\mathrm{y} = 0.01$ may be substituted for the 0.2% proof strength properties $R_\mathrm{p0.2}$ and $\varepsilon_\mathrm{y} = 0.002$.

TABLE I1

STRESS/STRAIN CURVE-FITTING PARAMETERS

Material type	Temperature limit	m_2	ε_p
Ferritic steel	480°C	$0.60(1.0 - R)$	2.0×10^{-5}
Austenitic steel and nickel alloys	480°C	$0.75(1.0 - R)$	2.0×10^{-5}
Duplex stainless steel	480°C	$0.70(0.95 - R)$	2.0×10^{-5}
Precipitation hardenable nickel alloys	540°C	$1.90(0.93 - R)$	2.0×10^{-5}
Auminium alloys	120°C	$0.52(0.98 - R)$	5.0×10^{-6}
Copper alloys	65°C	$0.50(1.0 - R)$	5.0×10^{-6}
Titanium and zirconium alloys	260°C	$0.50(0.98 - R)$	2.0×10^{-5}

NOTES:

1 To incorporate the reduction in strength implied by the weld efficiency, prior to generating the true stress/strain relationship, multiply the engineering stress and the strain at each point in the engineering stress/strain graph by the weld efficiency. It is necessary to multiply both stress and strain by the weld efficiency to preserve the gradients (such as Young's Modulus) in the relationship.

2 These relationships are for use with the specified minimum strengths, not for strengths of the material in its ¼ hard ½ hard condition.

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Appendix J, Paragraph J3

Delete the last paragraph and *replace* with the following:

The probability of exceedance for a pressure vessel shall be determined according to Table 3.3 in AS/NZS 1170.0:2002.

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Appendix L, Equation L5.3(2)

Delete Equation L5.3(2) and *replace* with the following:

$$P_h = 1.5 \times \frac{f_h}{f}(P + h\, g\, \rho \times 10^{-6}) - (h_h\, g\, \rho_h \times 10^{-6}) \qquad \ldots \text{L5.3(2)}$$

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Appendix M, Paragraph M3

1 *Delete* Item (a) and *replace* with the following:

(a) *Cut-off limit* (applicable to steels only)—the largest variable stress range that does not require consideration when carrying out cumulative damage calculations (see Figure M1, dashed line or the value of S_r at 10^8 cycles).

2 *Delete* Item (m) including the NOTE and *replace* with the following:

(m) *Stress cycle*—one cycle of Tresca stress as defined by stress cycle counting. This is established from the changes in the component stresses between extremes of the cycle at the point being considered.

NOTE: It is not valid to determine a Tresca stress intensity range by taking the difference between Tresca stress calculated at the extremes of the cycle. For example, given the following case where principal stress directions do not change and the three principal stresses in directions a, b and c cycle between the extremes:

$\sigma_a = +100$ MPa, $\sigma_b = 0$ MPa, $\sigma_c = -200$ MPa

and

$\sigma_a = -200$ MPa, $\sigma_b = 0$ MPa, $\sigma_c = +100$ MPa

that is the principal stresses range through

$\Delta\sigma_a = -300$ MPa, $\Delta\sigma_b = 0$ MPa, $\Delta\sigma_c = +300$ MPa

and accordingly, the range in Tresca stress is 300 – (–300) = 600 MPa.

As the Tresca stress is exactly the same at both extremes (i.e. 300 MPa) such that taking the difference between the Tresca stresses at the extremes would give an erroneous zero result for the Tresca stress range. An identical observation may be made with respect to calculation of the von Mises stress intensity range.

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Appendix M, Paragraph M4.2.2

Delete Paragraph title and *replace* with the following:

M4.2.2 *Stress range for steels with constant amplitude loads—that is, dashed curves on Figure M1*

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