

# ALUMINUM DESIGN MANUAL 2015



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# ***2015 Aluminum Design Manual***

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## FOREWORD

The *Aluminum Design Manual* includes an aluminum structural design specification and accompanying commentary, a supplemental design guide, material properties, properties of common shapes, design aid tables, illustrative design examples, and guidelines for aluminum sheet metal used in construction.

This edition of the *Aluminum Design Manual* is the product of the efforts of the Aluminum Association Engineering and Design Task Force, whose members are listed below.

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Please check **[www.aluminum.org](http://www.aluminum.org)** for postings of 2015 *Aluminum Design Manual* errata.



# ***Aluminum Design Manual***

## **PART I**

### **Specification for Aluminum Structures**







## Specification for Aluminum Structures

### FOREWORD

The first edition of the *Specification for Aluminum Structures* was published in November, 1967, followed by subsequent editions in 1971, 1976, 1982, 1986, 1994, 2000, 2005, 2010, and 2015. This 10th edition of the *Specification*, developed as a consensus document, includes new or revised provisions concerning

- material specifications (A.3.1)
- modulus of elasticity, compressive yield strength and shear ultimate strength (A.3.1)
- cast alloy strengths (A.3.3)
- effective net area (D.3.2)
- axial compression member buckling strength (E.2)
- alternative methods for determining column and beam elastic strengths (E.2, F.2.1.4)
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- contact with dissimilar materials (M.7)
- quality control and quality assurance (Chapter N)
- testing (Appendix 1)
- fatigue (Appendix 3)

The Aluminum Association gratefully acknowledges the efforts of the Engineering Advisory Committee in developing the *Specification*.

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I  
**Specification for Aluminum Structures**

**GUIDELINES FOR THE PREPARATION OF TECHNICAL INQUIRIES  
ON THE SPECIFICATION FOR ALUMINUM STRUCTURES**

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Comments on other parts of the *Aluminum Design Manual* are also welcome.

Inquiries should include the inquirer's name, affiliation, and address. Each inquiry should address a single section of the *Specification* unless the inquiry involves two or more interrelated sections. The section and edition of the *Specification* should be identified.

Requests for interpretations should be phrased, where possible, to permit a "yes" or "no" answer and include the necessary background information, including figures where appropriate.

Requests for revisions should include proposed wording for the revision and technical justification.

Inquiries are considered at the first meeting of the Aluminum Association Engineering and Design Task Force following receipt of the inquiry.

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## Symbols

The section numbers in which the symbol appears is given in parentheses after the symbol.

$A_b$ = nominal cross-sectional area of the bolt (unthreaded body area) (J.3.7.4)	$C_b$ = coefficient that accounts for moment gradient along a beam's length (F.4.1, F.4.1.1, F.4.1.2, F.4.2.1, F.4.2.3, F.4.2.4, F.4.2.5, F.4.3, F.5(c), F.5.1, F.5.2, 6.3.2.1)
$A_{BM}$ = cross-sectional area of the base metal (J.2.5, Table J.2.2)	$C_{br}$ = buckling constant intersection for flexural compression in flat elements (Table B.4.1, Table B.4.2, B.5.5.2, F.5)
$A_e$ = effective net area (D.2, D.3.2, J.7.1)	$C_c$ = buckling constant intersection for member buckling (Table B.4.1, Table B.4.2, B.5.4.4, E.2, F.4)
$A_{ewz}$ = effective net area in the weld-affected zone (D.2)	$C_d$ = brace coefficient (6.3.1.1, 6.3.1.2)
$A_f$ = area of the member farther than $2c/3$ from the neutral axis, where $c$ is the distance from the neutral axis to the extreme compression fiber (F.4)	$C_f$ = coefficient used to determine the allowable stress range for fatigue (Table 3.2, 3.2, 3.3)
$A_g$ = gross cross-sectional area (B.5.4, D.2, E.2, E.2.2, E.3.1, E.3.2, E.4, H.2, J.7.1, J.7.2)	$C_n$ = correction factor for the number of tests (1.3.2)
$A_{gc}$ = gross cross sectional area of the element in compression (B.5.5)	$C_p$ = buckling constant intersection for uniform compression in flat elements (Table B.4.1, Table B.4.2, B.5.4.1, B.5.5.5, F.5)
$A_{gt}$ = gross cross sectional area of the element in tension (J.7.3)	$C_{pov}$ = coefficient for determining the pull-over strength of a screw (J.5.4.2)
$A_{gv}$ = gross area in shear (J.7.3)	$C_s$ = buckling constant intersection for shear in flat elements (Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1)
$A_i$ = area of element $i$ (E.3.1)	$C_t$ = buckling constant intersection for uniform compression in curved elements (Table B.4.1, Table B.4.2, B.5.4.5, B.5.5.4)
$A_L$ = cross-sectional area of the longitudinal stiffener (B.5.5.3)	$C_{tb}$ = buckling constant intersection for flexural compression in curved elements (Table B.4.1, Table B.4.2, B.5.5.4)
$A_n$ = net area (D.3.1, D.3.2, G.2, G.3, G.4, G.5, J.7.1)	$C_w$ = warping constant (E.2.2, F.4.2.1, F.4.2.5)
$A_{nt}$ = net area in tension (J.7.3)	$C_{wb}, C_{wb1}, C_{wb2}, C_{wb3}$ = coefficients used to determine web crippling strength (J.9.1)
$A_{nv}$ = net area in shear (J.7.2, J.7.3)	$C_1$ = coefficient used to determine $U$ (F.4.2.5)
$A_{pb}$ = projected bearing area (J.8)	$C_2$ = coefficient used to determine $U$ (F.4.2.5)
$A_r$ = root area of the screw (J.5.4.3, J.5.5.3)	$D$ = nominal diameter of the fastener (Table J.2.2, J.3.1, J.3.4, J.3.5, J.3.6, J.5, J.5.4.1.1, J.5.4.1.2, J.5.4.2, J.5.5.1, J.5.5.2, J.6.4, J.6.5)
$A_s$ = area of the intermediate stiffener (B.5.4.4)	$D$ = diameter of a rod (H.2.3, G.5)
$A_{st}$ = thread stripping area of internal thread per unit length of engagement (J.5.4.1.1)	$D$ = outside diameter of a tube (Table 3.1)
$A_v$ = web area (G.1, G.2, G.3, G.4, G.5)	$D_{br}$ = buckling constant slope for flexural compression in flat elements (Table B.4.1, Table B.4.2, B.5.5.1, B.5.5.2, B.5.5.3, F.5)
$A_{we}$ = effective area of a weld (J.2.3, J.2.5, Table J.2.2)	$D_c$ = buckling constant slope for member buckling (Table B.4.1, Table B.4.2, B.5.4.4, E.2)
$A_{wz}$ = cross-sectional area of the weld-affected zone, which extends 1 in. (25 mm) to each side of the centerline of a weld (B.5.4, D.2, E.2, F.4, G.1, G.2, G.3, G.4, G.5, H.2)	$D_h$ = nominal diameter of the hole (J.4.5, J.4.6, Table J.5.1, Table J.5.2, J.5.4.2)
$A_{wzc}$ = cross sectional area of the weld-affected zone in compression (B.5.5)	$D_i$ = inside diameter of the pipe or tube (G.4)
$B_{br}$ = buckling constant intercept for flexural compression in flat elements (Table B.4.1, Table B.4.2, B.5.5.1, B.5.5.2, B.5.5.3, F.5)	$D_n$ = nominal dead load (1.3.2, 4.1.3, 5.4)
$B_c$ = buckling constant intercept for member buckling (Table B.4.1, Table B.4.2, B.5.4.4, E.2)	$D_o$ = outside diameter of the pipe or tube (G.4)
$B_p$ = buckling constant intercept for uniform compression in flat elements (Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.5, F.5)	$D_p$ = buckling constant slope for uniform compression in flat elements (Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.5, F.5)
$B_s$ = buckling constant intercept for shear in flat elements (Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1)	$D_s$ = depth of a stiffener (B.5.4.3)
$B_t$ = buckling constant intercept for uniform compression in curved elements (Table B.4.1, Table B.4.2, B.5.4.5, B.5.5.4)	$D_s$ = buckling constant slope for shear in flat elements (Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1)
$B_{tb}$ = buckling constant intercept for flexural compression in curved elements (Table B.4.1, Table B.4.2, B.5.5.4)	
$C$ = torsional shear constant (H.2.2)	

$D_{ss}$ = screw slot inside diameter (Table J.5.3, J.5.4.1.2)	$F_{nBM}$ = nominal stress of the base metal corresponding to its welded ultimate strength from Table A.3.3 or Table A.3.3M (J.2.5)
$D_t$ = buckling constant slope for uniform compression in curved elements (Table B.4.1, Table B.4.2, B.5.4.5, B.5.5.4)	$F_{nt}$ = tensile strength of an A 325 bolt determined in accordance with the <i>Specification for Structural Steel Buildings</i> (ANSI/AISC 360) (J.3.7.4)
$D_{tb}$ = buckling constant slope for flexural compression in curved elements (Table B.4.1, Table B.4.2, B.5.5.4)	$F_{nv}$ = shear strength of an A 325 bolt determined in accordance with the <i>Specification for Structural Steel Buildings</i> (ANSI/AISC 360) (J.3.7.4)
$D_{ws}$ = larger of the nominal washer diameter and the screw head diameter, but no greater than 5/8 in. (16 mm) (J.5.4.2)	$F_{nw}$ = nominal stress of the weld metal corresponding to its ultimate strength from Table A.3.6 (J.2.5)
$E$ = modulus of elasticity (Table A.3.1, Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.4.6, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, B.5.5.5, B.5.6, E.2, E.2.2, E.4, F.4, F.4.2.5, F.4.3, F.5, F.5.1, F.5.2, G.2, G.3, G.4, H.2.1, J.9.1, Table 4.1, 6.3.2.1, 6.3.2.2)	$F_s$ = shear stress corresponding to the shear strength (G.1, G.2, G.3, G.4, G.5, H.2, H.2.1, H.2.2, H.3.1, H.3.2)
$E_m$ = modulus of elasticity at elevated temperatures (4.2.3.1, Table 4.1)	$F_{so}$ = shear stress corresponding to the unwelded shear strength (G.1, H.2)
$F_b$ = stress corresponding to the flexural strength (B.5.5, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, F.4.3, F.3.1, F.3.2, H.3.1, H.3.2)	$F_{ST}$ = stress corresponding to the uniform compressive strength of an element supported on both edges (B.5.4.3)
$F_{bo}$ = stress corresponding to the flexural compressive strength for an element if no part of the cross section were weld-affected (B.5.5)	$F_{su}$ = shear ultimate strength (Table A.3.1, A.3.5, A.3.6, G.2, G.3, G.4, G.5, H.2, J.3.5, J.4.5, J.5.5.3, J.6.4, J.7.2, J.7.3)
$F_{bw}$ = stress corresponding to the flexural compressive strength for an element if the entire cross section were weld-affected (B.5.5)	$F_{suw}$ = shear ultimate strength of weld-affected zones (G.2, G.3, G.4, G.5, H.2)
$F_c$ = stress corresponding to the uniform compressive strength (B.5.4, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.4.6, E.2, E.3.2, E.4, F.3.1, H.3.1, H.3.2)	$F_{sw}$ = shear stress corresponding to the welded shear strength (G.1, H.2)
$F_{ci}$ = local buckling stress of element $i$ computed per Section B.5.4.1 through B.5.4.5 (E.3.1)	$F_{sy}$ = shear yield strength (Table A.3.1, Table B.4.1, Table B.4.2, G.2, G.3, G.4, H.2.1, H.2.3, J.6.4, J.7.2, J.7.3)
$F_{co}$ = stress corresponding to the uniform compressive strength for an element if no part of the cross section were weld-affected (B.5.4)	$F_{syw}$ = shear yield strength of weld-affected zones (G.2, H.2.3)
$F_{cw}$ = stress corresponding to the uniform compressive strength for an element if the entire cross section were weld-affected (B.5.4)	$F_{tu}$ = tensile ultimate strength (Table A.3.1, Table A.3.3, A.3.2, A.3.3, A.3.5, D.2, F.2, J.3.4, J.3.6, J.4.6, J.5.4.1.2, J.5.4.3, J.5.5.1, J.6.4, J.6.5, J.7.3, J.8, Table 4.2)
$F_{cy}$ = compressive yield strength (Table A.3.1, Table B.4.1, Table B.4.2, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.4.6, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, B.5.5.5, E.2, E.3.1, F.2, F.3.1, F.4, F.5, J.9.1)	$F_{tum}$ = tensile ultimate strength at elevated temperatures (4.2.3.1)
$F_{cyw}$ = compressive yield strength of weld-affected zones (E.2)	$F_{tuw}$ = tensile ultimate strength of weld-affected zones (A.3.2, A.3.4, D.2, Table J.2.2)
$F_e$ = elastic buckling stress (B.5.4.6, B.5.5.5, Table B.5.1, E.2.2, E.4, F.4.3, L.3)	$F_{tul}$ = tensile ultimate strength of the part in contact with the screw head or washer (J.5.4.2)
$F_{ex}$ = elastic buckling stress for buckling about the $x$ -axis (E.2.2)	$F_{tu2}$ = tensile ultimate strength of member not in contact with the screw head (J.5.4.1.1, J.5.5.2)
$F_{ey}$ = elastic buckling stress for buckling about the $y$ -axis (E.2.2)	$F_{ty}$ = tensile yield strength (Table A.3.1, Table A.3.3, Table A.3.4, A.3.2, A.3.3, D.2, F.2, J.6.4, J.7.3, 1.4, Table 4.2)
$F_{ez}$ = elastic buckling stress for torsional buckling (E.2.2)	$F_{tym}$ = tensile yield strength at elevated temperatures (4.2.3.1)
$F_m$ = mean value of the fabrication factor (1.3.2)	$F_{tyw}$ = tensile yield strength of weld-affected zones (A.3.2, D.2)
$F_n$ = strength of an A 325 bolt (J.3.7.4)	$F_{tyl}$ = tensile yield strength of the part in contact with the screw head (J.5.4.2)
	$F_{ty2}$ = tensile yield strength of member not in contact with the screw head (J.5.4.1.1)
	$F_{UT}$ = stress corresponding to the uniform compressive strength of an element supported on one edge only (B.5.4.3)

$G$  = shear modulus of elasticity (Table A.3.1, E.2.2)  
 $G_f$  = the grip of a bolt (J.3.5)

$$H = 1 - \frac{x_0^2 + y_0^2}{r_0^2} \quad (\text{E.2.2})$$

$I_f$  = moment of inertia of the flange group about the cross section's neutral axis. The flange group consists of the flat elements in uniform compression or uniform tension and their edge or intermediate stiffeners (F.3.1)  
 $I_L$  = moment of inertia of the longitudinal stiffener about the web of the beam (B.5.5.3)  
 $I_o$  = moment of inertia of a section comprising the stiffener and one half of the width of the adjacent sub-elements and the transition corners between them taken about the centroidal axis of the section parallel to the stiffened element (B.5.4.4)  
 $I_s$  = moment of inertia of the transverse stiffener (G.2)  
 $I_w$  = moment of inertia of the web group about the cross section's neutral axis. The web group consists of the flat elements in flexure and their intermediate stiffeners. (F.3.1)  
 $I_w$  = moment of inertia about the major principal axis (F.5.2)  
 $I_x$  = moment of inertia about the  $x$ -axis (E.2.2, F.4.2.5)  
 $I_y$  = moment of inertia about the  $y$ -axis (E.2.2, F.4.1.2, F.4.2.1, F.4.2.2, F.4.2.3, F.4.2.5, 6.3.2.1)  
 $I_{yc}$  = moment of inertia of the compression flange about the  $y$ -axis (F.4.1.2, F.4.2.2, F.4.2.5)  
 $I_{yt}$  = moment of inertia of the tension flange about the  $y$ -axis (F.4.2.2)  
 $I_z$  = moment of inertia about the minor principal axis (F.5.2)  
 $J$  = torsion constant (E.2.2, F.4.2.1, F.4.2.2, F.4.2.3, F.4.2.5, H.2.1)  
 $K$  = statistical coefficient based on the number of tests  $n$  (1.3.1)  
 $K_s$  = a coefficient used to determine the pull-out strength of a screw (J.5.4.1.1)  
 $L$  = member length (E.2, E.2.1, F.4, J.1.3, 6.1, 6.2.2, 6.3.2.1, 6.3.2.2)  
 $L_b$  = length of a beam between brace points or between a brace point and a cantilever's free end (F.4.2.1, F.4.2.3, F.4.2.4, F.4.2.5, F.4.3, F.5.1, F.5.2, 6.1, 6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2, 6.3.2.1, 6.3.2.2, 6.4)  
 $L_C$  = length of the connection in the direction of load, measured from the center of fasteners or the end of welds (D.3.2)  
 $L_e$  = length of full thread engagement of a screw in a hole or screw slot not including tapping or drilling point (J.5.4.1.1, J.5.4.1.2)  
 $L_n$  = nominal live load (1.3.2, 4.1.3, 5.4)  
 $L_s$  = length of pipe or tube between transverse stiffeners, or overall length if no transverse stiffeners are present (H.2.1)

$L_v$  = length of pipe or tube from maximum to zero shear force (G.4)  
 $L_{we}$  = effective length of a weld (J.2.1.3, J.2.2.2, Table J.2.2)  
 $L_x$  = unbraced length for buckling about the  $x$ -axis (E.2.2)  
 $L_y$  = unbraced length for buckling about the  $y$ -axis (E.2.2)  
 $L_z$  = unbraced length for twisting (E.2.2)  
 $M_A$  = absolute value of the moment at the quarter point of the unbraced segment (F.4.1.1)  
 $M_B$  = absolute value of the moment at the midpoint of the unbraced segment (F.4.1.1)  
 $M_C$  = absolute value of the moment at the three-quarter point of the unbraced segment (F.4.1.1)  
 $M_c$  = design or allowable flexural strength (H.1, J.6.4, J.9.3)  
 $M_e$  = elastic lateral-torsional buckling moment (F.4.2.5, F.5, F.5.1, F.5.2)  
 $M_i$  = flexural strength of member of intermediate thickness  $t_i$  (1.4.2)  
 $M_m$  = mean value of the material factor (1.3.2)  
 $M_{max}$  = absolute value of the maximum moment in the unbraced segment (F.4.1.1, F.4.1.2)  
 $M_n$  = nominal strength moment (F.1, F.5, F.5.1, F.5.2, J.6.4)  
 $M_{nlb}$  = nominal flexural strength for the limit state of local buckling (F.3, F.3.1, F.3.2, F.3.3)  
 $M_{nmb}$  = nominal flexural strength for the limit state of lateral-torsional buckling (F.4, F.4.3)  
 $M_{nmbo}$  = lateral-torsional buckling strength if no part of the cross section were weld-affected (F.4)  
 $M_{np}$  = nominal flexural strength for the limit state of yielding (B.5.5.4, B.5.5.5, F.2, F.4)  
 $M_{nmbw}$  = lateral-torsional buckling strength if the entire cross section were weld-affected (F.4)  
 $M_r$  = required flexural strength using LRFD or ASD load combinations (H.1, J.6.4, J.9.3, 6.3.1.1, 6.3.1.2, 6.3.2.1, 6.3.2.2, 6.4)  
 $M_{rb}$  = required bracing flexural strength using LRFD or ASD load combinations (6.3.2.1)  
 $M_y$  = yield moment about the axis of bending (F.5)  
 $M_1$  = flexural strength of member of thinnest material (1.4.2)  
 $M_2$  = flexural strength of member of thickest material (1.4.2)  
 $N$  = number of stress cycles (3.2, 3.3, Table 3.2)  
 $N_s$  = number of stress ranges in the spectrum (3.3)  
 $P_c$  = available axial force (H.1)  
 $P_{nc}$  = nominal axial compressive strength (E.1, E.2, E.3.1, E.3.2, E.4)  
 $P_{no}$  = nominal member buckling strength if no part of the cross section were weld-affected (E.2)  
 $P_{nt}$  = nominal axial tensile strength (D.1, D.2)  
 $P_{nw}$  = nominal member buckling strength if the entire cross section were weld-affected (E.2)

$P_r$ = required axial force using LRFD or ASD load combinations (C.2, H.1, 6.2.1, 6.2.2, 6.4)	$V_n$ = nominal shear strength (G.1, G.2, G.3, G.4, G.5, J.6.4)
$P_{rb}$ = required bracing strength (6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2)	$V_p$ = coefficient of variation of the ratio of the observed failure loads divided by the average value of all the observed failure loads (1.3.2)
$P_y$ = axial yield strength (C.2)	$V_Q$ = coefficient of variation of the loads (1.3.2)
$R$ = outside radius of a pipe or tube (H.2.1)	$V_r$ = required shear strength (J.6.4)
$R$ = transition radius of a fatigue detail (Table 3.1)	$X_i$ = result of the $i$ th test (1.3.2)
$R_a$ = required strength for ASD (B.3.2.2)	$Z$ = plastic section modulus (F.2)
$R_b$ = radius of curved elements taken at the mid-thickness of the element (B.5.2, B.5.4.5, B.5.5.4, Table B.5.1, G.4, H.2.1)	$a$ = fatigue detail dimension parallel to the direction of stress (Table 3.1)
$R_c$ = available concentrated force determined in accordance with Section J.9.1 (J.9.3)	$a_1$ = shorter dimension of rectangular panel (G.2)
$R_i$ = inside bend radius at the juncture of the flange and web; for extruded shapes, $R_i = 0$ (J.9.1)	$a_2$ = longer dimension of rectangular panel (G.2)
$R_{ti}$ = strength of $i$ th test (1.3.2)	$b$ = element width (B.5.1, B.5.3, B.5.4, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.5.1, B.5.5.2, B.5.5.3, Table B.5.1, F.5, F.5.1, F.5.2, G.2, G.3, J.1.3, L.3)
$R_{tm}$ = mean strength of all tests (1.3.1, 1.3.2)	$b$ = fatigue detail dimension normal to the direction of stress and the surface of the base metal (Table 3.1)
$R_n$ = nominal strength (B.3.2.1, B.3.2.2, J.2, J.2.5, J.3.4, J.3.5, J.3.6, J.3.7.4, J.4.5, J.4.6, J.5.4, J.5.4.1.1, J.5.4.1.2, J.5.4.2, J.5.4.3, J.5.5, J.5.5.1, J.5.5.2, J.5.5.3, J.6.4, J.6.5, J.7.1, J.7.2, J.7.3, J.7.4, J.8, J.9.1, 1.3.1)	$b_e$ = element's effective width for determining deflections (L.3)
$R_r$ = required concentrated force (J.9.3)	$b_s$ = stiffener width (6.3.2.1)
$R_s$ = the ratio of minimum stress to maximum stress for fatigue design (Table 3.1)	$c$ = distance from the neutral axis to the extreme fiber (F.4)
$R_u$ = required strength for LRFD (B.3.2.1)	$c_c$ = distance from neutral axis to the element extreme fiber with the greatest compressive stress (B.5.5.1)
$S$ = section modulus (B.5.5.4)	$c_{cf}$ = distance from the centerline of the compression flange to the cross section's neutral axis (F.3.1)
$S_c$ = section modulus on the compression side of the neutral axis (F.2, F.5, F.5.1)	$c_{cs}$ = distance from the cross section's neutral axis to the extreme fiber of compression flange stiffeners (F.3.1)
$S_n$ = nominal snow load (4.1.3)	$c_{cw}$ = distance from the web group's extreme compression fiber to the cross section's neutral axis (F.3.1)
$S_{ra}$ = applied stress range, the algebraic difference between the minimum and maximum nominal stresses perpendicular to the plane of expected cracking determined by elastic methods (3.2)	$c_o$ = distance from neutral axis to other extreme fiber of the element (see $c_c$ ) (B.5.5.1)
$S_{rd}$ = design stress range (3.2, 3.3)	$d$ = full depth of the section (F.4.2.1, F.4.2.2, F.4.2.4, G.2, J.9.1, J.10.1)
$S_{re}$ = equivalent applied stress range (3.3)	$d_e$ = distance from the center of the fastener to the edge of the part in the direction of force (J.3.6, J.4.6, J.5.5.1, J.6.5)
$S_{ri}$ = $i$ th applied stress range in the spectrum (3.3)	$d_f$ = the distance between the flange centroids; for T-shapes $d_f$ is the distance between the flange centroid and the tip of the stem. (F.4.2.5)
$S_t$ = section modulus on the tension side of the neutral axis (F.2)	$d_s$ = stiffener's flat width (B.5.4.3)
$S_w$ = size of a weld (J.2.1.2, J.2.2.2, Table J.2.2)	$d_t$ = distance from the neutral axis to the compression flange (B.5.5.3)
$S_{we}$ = effective throat of a fillet weld (J.2.2.1)	$e$ = base for natural logarithms = 2.71828... (1.3.2)
$S_x$ = section modulus about the $x$ -axis (F.4.2.1, F.4.2.2)	$f$ = compressive stress at the toe of the flange (B.5.5.3)
$S_{xc}$ = section modulus about the compression side of the $x$ -axis (B.5.5.5, F.3.2, F.4, F.4.2.3, F.4.2.5, F.4.3)	$f_a$ = maximum compressive stress in the element from the service load combinations (L.3)
$T, T_1, T_2$ = temperature (A.3.1.1)	$f_b$ = compressive stress due to flexure (H.3.1, H.3.2)
$T$ = nominal forces and deformations due to the design-basis fire defined in Section 4.2.1 (4.1.3)	$f_c$ = compressive stress due to axial compression (H.3.1, H.3.2)
$T_n$ = nominal torsional strength (H.2, H.2.1, H.2.2, H.2.3, H.2.4)	$f_s$ = shear stress due to shear and torsion (H.3.1, H.3.2)
$U$ = coefficient used to determine $M_e$ (F.4.2.5)	$g$ = transverse center-to-center spacing (gage) between fastener gage lines (D.3.1, J.1.3)
$V$ = shear force on the web at the transverse stiffener (G.2)	
$V_c$ = available shear strength (J.6.4)	
$V_F$ = coefficient of variation of the fabrication factor (1.3.2)	
$V_M$ = coefficient of variation of the material factor (1.3.2)	



$g_o$ = distance from the shear center to the point of application of the load; $g_o$ is positive when the load acts away from the shear center and negative when the load acts towards the shear center. If there is no transverse load (pure moment cases) $g_o = 0$ . (F.4.2.5)	$t$ = element thickness (B.5.4, B.5.4.1, B.5.4.2, B.5.4.3, B.5.4.4, B.5.4.5, B.5.5.1, B.5.5.2, B.5.5.3, B.5.5.4, Table B.5.1, F.4.2.4, F.5, F.5.1, F.5.2, G.2, G.3, G.4, H.2.1, J.1.3, J.2.2.1, J.3.6, J.4.6, J.5.5.1, J.6.5, J.9.1)
$h_o$ = distance between flange centroids (6.3.1.1, 6.3.1.2, 6.3.2.1, 6.3.2.2)	$t$ = time (A.3.1.1)
$k$ = effective length factor for buckling (C.3, E.2.1, J.1.3, 6.1, 6.2.2)	$t_{avg}$ = average thickness of a tapered thickness element (B.5.3)
$k_t$ = tension coefficient (Table A.3.3, A.3.2, D.2, F.2, G.2, G.3, G.4, G.5, H.2, H.2.3, J.6.4, J.7.2, J.7.3)	$t_i$ = thickness of intermediate thickness material (1.4.2)
$k_x$ = effective length factor for flexural buckling about the $x$ -axis (E.2.2)	$t_{max}$ = maximum thickness of a tapered thickness element (B.5.3)
$k_y$ = effective length factor for flexural buckling about the $y$ -axis (E.2.2)	$t_{max}$ = thickness of thickest material tested (1.4.2)
$k_z$ = effective length factor for torsional buckling (E.2.2)	$t_{min}$ = minimum thickness of a tapered thickness element (B.5.3)
$k_l$ = coefficient for determining the $\lambda_2$ slenderness limit for elements with postbuckling strength (Table B.4.3, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.1, B.5.5.3)	$t_{min}$ = thickness of thinnest material tested (1.4.2)
$k_2$ = coefficient for determining postbuckling strength (Table B.4.3, B.5.4.1, B.5.4.2, B.5.4.6, B.5.5.1, B.5.5.3, B.5.5.5)	$t_s$ = beam web stiffener thickness (6.3.2.1)
$l_b$ = length of the bearing at the concentrated force (J.9.1)	$t_w$ = beam web thickness (6.3.2.1, 6.3.2.2)
$m$ = coefficient for elements in flexure and supported on both edges (B.5.5.1)	$t_l$ = nominal thickness of the part in contact with the screw head or washer (J.5.4.2, J.5.5.2)
$m$ = coefficient used to determine the allowable stress range for fatigue (Table 3.2, 3.2, 3.3)	$t_1$ = time corresponding to temperature $T_1$ (A.3.1.1)
$n$ = number of threads/in. (mm) (Table J.2.2, J.3.4, J.3.5, J.5.4.1.1)	$t_2$ = nominal thickness of the part not in contact with the screw head or washer (J.5.5.2)
$n$ = number of nodal braced points in the span (6.3.2.1, 6.3.2.2)	$t_2$ = time corresponding to temperature $T_2$ (A.3.1.1)
$n$ = number of tests (1.3.1, 1.3.2)	$\bar{x}$ = eccentricity of the connection in the $x$ -axis direction (D.3.2)
$q$ = design pressure load for roofing and siding (1.4)	$x_o$ = the shear center's $x$ -coordinate (E.2.2)
$r$ = radius of gyration (E.2.1)	$\bar{y}$ = eccentricity of the connection in the $y$ -axis direction (D.3.2)
$r_o$ = polar radius of gyration of the cross section about the shear center (E.2.2)	$y_o$ = the shear center's $y$ -coordinate (E.2.2, F.4.2.5)
$r_s$ = stiffener's radius of gyration about the stiffened element's mid-thickness (B.5.4.3)	$z_o$ = coordinate along the $z$ -axis of the shear center with respect to the centroid (F.5.2)
$r_x$ = radius of gyration about the $x$ -axis (E.2.2, F.4.2.1)	$\alpha$ = factor used to determine reduced flexural stiffness (C.2)
$r_y$ = radius of gyration about the $y$ -axis (E.2.2, F.4.2.1)	$\alpha$ = ratio of nominal dead load to nominal live load (1.3.2)
$r_{ye}$ = effective radius of gyration about the $y$ -axis for lateral-torsional buckling (F.4.2.1, F.4.2.2, F.4.3)	$\alpha$ = coefficient of thermal expansion (Table A.3.1)
$r_z$ = radius of gyration about the minor principal axis (F.5.2)	$\alpha_i$ = number of stress cycles in the spectrum of the $i$ th stress range divided by the total number of stress cycles (3.3)
$s$ = transverse stiffener spacing. For a stiffener composed of a pair of members, one on each side of the web, the stiffener spacing $s$ is the clear distance between the pairs of stiffeners. For a stiffener composed of a member on only one side of the web, the stiffener spacing $s$ is the distance between fastener lines or other connecting lines. (B.5.5.3, G.2)	$\alpha_s$ = coefficient for a longitudinal stiffener (B.5.5.3)
$s$ = longitudinal center-to-center spacing (pitch) of any two consecutive holes (D.3.1, J.1.3)	$\beta_{br}$ = required bracing stiffness (6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2)
	$\beta_o$ = target reliability index (1.3.2)
	$\beta_{sec}$ = web distortional stiffness (6.3.2.1, 6.3.2.2)
	$\beta_T$ = overall brace system stiffness (6.3.2.1)
	$\beta_{Tb}$ = required bracing torsional stiffness (6.3.2.1)
	$\beta_x$ = coefficient of monosymmetry about the $x$ -axis (F.4.2.5)
	$\beta_w$ = coefficient of monosymmetry (F.5.2)
	$\gamma$ = density (Table A.3.1)
	$\delta = \frac{(t_{max} - t_{min})}{t_{min}}$ = a measure of taper in tapered thickness elements (B.5.3)
	$\kappa$ = metric conversion factor (Table B.4.1, Table B.4.2)
	$\nu$ = Poisson's ratio (Table A.3.1)

$\phi$  = resistance factor (B.3.2.1, D.1, E.1, F.1, G.1, H.2, H.3.1, H.3.2, J.2, J.3.4, J.3.5, J.3.6, J.3.7.4, J.3.7.5, J.4.5, J.4.6, J.5.4, J.5.5, J.6.4, J.6.5, J.7.1, J.7.2, J.7.3, J.7.4, J.8, J.9.1, 1.3.2, 6.1, 6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2, 6.3.2.1)

$\Omega$  = safety factor (B.3.2.2, D.1, E.1, F.1, G.1, H.2, H.3.1, H.3.2, J.2, J.3.4, J.3.5, J.3.6, J.3.7.4, J.3.7.5, J.4.5, J.4.6, J.5.4, J.5.5, J.6.4, J.6.5, J.7.1, J.7.2, J.7.3, J.7.4, J.8, J.9.1, 1.3.2, 6.1, 6.2.1, 6.2.2, 6.3.1.1, 6.3.1.2, 6.3.2.1)

$\theta_s$  = angle between a stiffener and the stiffened element (B.5.4.3)

$\theta_w$  = angle between the plane of web and the plane of the bearing surface ( $\theta_w \leq 90^\circ$ ) (J.9.1)

$\rho_{ST}$  = stiffener effectiveness ratio (B.5.4.3, B.5.6)

$\lambda$  = slenderness

$\lambda_1$  = slenderness at the intersection of the equations for yielding and inelastic buckling

$\lambda_2$  = slenderness at the intersection of the equations for inelastic buckling and elastic buckling

$\lambda_e = 1.28\sqrt{E/F_{cy}}$  (B.5.4.3)

$\lambda_{eq} = \pi\sqrt{\frac{E}{F_e}}$

= equivalent slenderness for alternate determination of compressive strength for flexural or axial compression (B.5.4.6, B.5.5.5)

$\lambda_s$  = slenderness of an element with an intermediate stiffener (B.5.4.4, B.5.6)

$\sigma_x$  = standard deviation of the test strengths (1.3.1)

$\tau_b$  = parameter for reduced flexural stiffness (C.2)

$\mu$  = mean slip coefficient (J.3.7.5)

## Glossary

*allowable strength*: nominal strength divided by the safety factor,  $R_n/\Omega$ .

*allowable stress*: allowable strength divided by the appropriate section property, such as section modulus or cross section area.

*aluminum*: aluminum or an aluminum alloy.

*analysis*: the rational determination of the effects of loads on and the strength of structures, members, and connections based on appropriate theory, relevant test data, and sound engineering judgment.

*applicable building code*: the building code under which the structure is designed.

*ASD (Allowable Strength Design)*: the method of proportioning structural components such that the allowable strength equals or exceeds the required strength of the component under the action of the ASD load combinations.

*ASD load combination*: the load combination in the applicable building code intended for allowable strength design.

*available strength*: for LRFD, design strength; for ASD, allowable strength.

*beam*: a structural member that has the primary function of resisting bending moments.

*bearing-type connection*: a bolted connection where shear forces are transmitted by the bolt bearing against the connection elements.

*blind rivet*: a rivet that can be installed with access to only one side of the parts being joined.

*block shear rupture*: in a connection, the limit state of tensile fracture or yielding along one path and shear yielding or fracture along another path.

*bolt*: a headed and externally threaded mechanical device designed for insertion through holes in assembled parts to mate with a nut and normally intended to be tightened or released by turning that nut.

*bridge-type structure*: a structure not addressed by building codes and designed for highway, pedestrian, or rail traffic.

*buckling*: the limit state of a sudden change in the geometry of a structure or any of its elements under a critical loading condition.

*building-type structure*: a structure of the type addressed by a building code.

*camber*: curvature fabricated into a beam or truss so as to compensate for deflection induced by loads.

*closed shape*: a hollow shape that resists lateral-torsional buckling primarily by torsional resistance rather than warping resistance, that is, for which  $C_w$  is much less than  $0.038JL_b^2$ . See Section F.4.2.3.

*column*: a structural member that has the primary function of resisting a compressive axial force.

*contract documents*: documents that define the responsibilities of the parties that design, fabricate, or erect the structure.

*design load*: the applied load determined in accordance with either LRFD load combinations or ASD load combinations, whichever is applicable.

*design strength*: the resistance factor multiplied by the nominal strength,  $\phi R_n$ .

*design stress*: the design strength divided by the appropriate section property, such as section modulus or cross section area.

*effective length*: the length of an otherwise identical column with the same strength when analyzed with pinned end conditions.

*effective length factor*: ratio between the effective length and the unbraced length of the member.

*effective net area*: net area modified to account for the effect of shear lag.

*elastic analysis*: structural analysis based on the assumption that the structure returns to its original geometry on removal of the load.

*element*: a component of a shape's cross section. Elements are connected to other elements only along their longitudinal edges. Elements addressed by the *Specification* include flat elements, described by their width  $b$  and thickness  $t$ , and curved elements, described by their mid-thickness radius  $R_b$  and thickness  $t$ . An Aluminum Association standard I beam, for example, consists of five flat elements: a web element and two elements in each flange.

*engineer of record*: engineer responsible for the structural design.

*factored load*: the product of a load factor and the nominal load.

*fastener*: a device such as a bolt, rivet, screw, or pin used to mechanically connect two or more parts.

*fatigue*: the limit state of crack initiation and growth resulting from repeated application of loads.

*filler metal*: metal to be added in making a welded joint.

*fillet weld*: weld of generally triangular cross section made between intersecting surfaces of elements.

*flexural buckling*: a buckling mode in which a compression member deflects laterally without twist or change in cross-sectional shape.

*flexural-torsional buckling*: a buckling mode in which a compression member bends and twists simultaneously without change in cross-sectional shape.

*gage*: transverse center-to-center spacing of fasteners.

*gauge*: a term previously used in referring to the thickness of a wrought product. Thickness is preferred in dimension description.

*geometric axis*: axis parallel to a web, flange, or angle leg.

*grip*: thickness of material through which a fastener passes.

*lateral-torsional buckling*: the buckling mode of a flexural member involving deflection normal to the plane of bending occurring simultaneously with twist about the shear center of the cross-section.

*limit state*: a condition in which a structure or component becomes unfit for service and is judged either to be no longer useful for its intended function (serviceability limit state) or to have reached its ultimate load-carrying capacity (strength limit state).

*load effect*: forces, stresses, and deformations produced in a structural component by the applied loads.

*load factor*: a factor that accounts for deviations of the nominal load from the actual load, for uncertainties in the analysis that transforms the load into a load effect and for the probability that more than one extreme load will occur simultaneously.

*local buckling*: the limit state of buckling of a compression element within a cross section.

*lockbolt*: a two-piece fastener consisting of a shaft (bolt) and collar. The softer, smooth bore collar is mechanically swaged (reduced or tapered by squeezing) onto the pin and into either zero pitch, annular lock grooves or special thread form grooves in a tension-tension installation method. Hydraulic or pneumatic installation tools provide the tension and swaging action.

*longitudinal centroidal axis*: axis through the centroid of a member along its length.

*LRFD (Load and Resistance Factor Design)*: a method of proportioning structural components such that the design strength equals or exceeds the required strength of the component under the action of the LRFD load combinations.

*LRFD load combination*: a load combination in the applicable building code intended for strength design (load and resistance factor design).

*member*: an individual, discrete component of a larger structure, such as a beam or column.

*member buckling*: flexural, torsional, or flexural-torsional buckling of the overall member.

*net area*: gross area reduced to account for removed material.

*nominal dimension*: designated or theoretical dimension, as in the tables of section properties.

*nominal load*: magnitude of the load specified by the applicable building code.

*nominal strength*: strength of a structure or component (without the resistance factor or safety factor applied) available to resist load effects, as determined in accordance with this *Specification*.

*pin*: a fastener that is a rod about which the connected parts are free to rotate.

*pitch*: longitudinal center-to-center spacing of fasteners; center-to-center spacing of bolt threads along the axis of a bolt.

*post-buckling strength*: the load or force that can be carried by an element, member, or frame after initial elastic buckling has occurred.

*pull-out*: the tensile load required to pull a screw out of a threaded part.

*pull-over*: the tensile load required to pull a part over the head of a screw.

*quality assurance*: monitoring and inspection tasks performed by an agency or firm other than the fabricator or erector to ensure that the material provided and work performed by the fabricator and erector meet the requirements of the approved construction documents and referenced standards. Quality assurance includes those tasks designated "special inspection" by the applicable building code.

*quality control*: controls and inspections implemented by the fabricator or erector, as applicable, to ensure that the material provided and the work performed meet the requirements of the approved construction documents and referenced standards.

*required strength*: Forces, stresses and deformations acting on a structural component determined by either structural analysis, for the LRFD or ASD load combinations, as appropriate, or as specified by this *Specification*.

*resistance factor*: a factor that accounts for unavoidable deviations of the actual strength from the nominal strength and for the manner and consequences of failure.

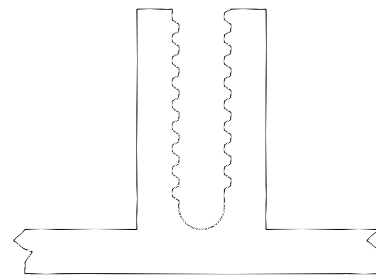
*rivet*: a headed and unthreaded mechanical device used to assemble two or more components by an applied force which deforms the plain rivet end to develop a completed mechanical joint.

*rod*: a solid wrought product that is long in relation to its circular cross section, which is not less than 0.375 in. diameter.

*safety factor*: a factor that accounts for deviations of the actual strength from the nominal strength, deviations of the actual load from the nominal load, uncertainties in the analysis that transforms the load into a load effect, and for the manner and consequences of failure.

*screw*: a headed and externally threaded fastener held in place by threading into one of the connected parts.

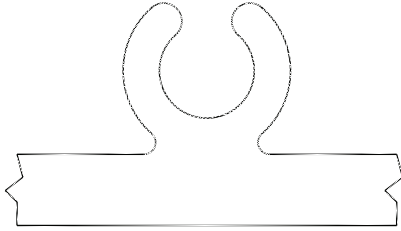
*screw chase*: a groove parallel to the longitudinal axis of an extrusion, intended to retain a screw whose axis is perpendicular to the longitudinal axis of the extrusion. (See Figure GL.1).



**Figure GL.1**  
**TRANSVERSE CROSS SECTION**  
**OF A SCREW CHASE**



*screw slot*: a semi-hollow in an extrusion intended to retain a screw parallel to the axis of the extrusion. (See Figure GL.2).



**Figure GL. 2**  
**TRANSVERSE CROSS SECTION**  
**OF A SCREW SLOT**

*self-drilling screw*: a screw that drills and taps its own hole as it is being driven.

*service load*: load under which serviceability limit states are evaluated.

*service load combination*: load combinations under which serviceability limit states are evaluated.

*slip-critical connection*: a bolted connection designed to resist movement by friction on the faying surface of the connection under the clamping forces of the bolts.

*stiffener*: a structural element attached or integral to a member to distribute load, transfer shear, or prevent buckling.

*structural component*: member, connector, connecting element or assemblage.

*structure*: an object, including but not limited to buildings, walls, fences, towers, bridges, railings, signs, and luminaires, designed to support loads.

*tapping screw*: a screw that threads a preformed hole as it is being driven.

*thread cutting screw*: a tapping screw that is installed into a preformed hole, with internal mating threads formed as a result of cutting out the material being tapped to form the relief area of the threaded shank.

*thread forming screw*: a tapping screw that is installed into a preformed hole, with internal mating threads formed as a result of cold flow of the material being tapped into the relief area of the threaded shank.

*torsional buckling*: a buckling mode in which a compression member twists about its shear center axis.

*unbraced length*: the length of a member between brace points or between a brace point and a cantilever's free end, measured between the longitudinal centroidal axes of the bracing members. For columns, brace points are points at which lateral translation is restrained for flexural buckling or twisting is restrained for torsional buckling. For beams, brace points are points at which the compression flange is restrained against lateral deflection or the cross section is restrained against twisting.

*weld-affected zone*: metal within 1 in. (25 mm) of the centerline of a weld.

## Chapter A General Provisions

### A.1 SCOPE

The *Specification for Aluminum Structures*, hereafter referred to as the *Specification*, applies to the design of aluminum load-carrying structures, members, and connections.

This *Specification* includes the symbols, glossary, Chapters A through N, and Appendices 1, 3, 4, 5, and 6.

The provisions of this *Specification*, or a more rigorous analysis, shall be used for all cases addressed by this *Specification*. Appropriate analysis shall be used for cases not addressed by this *Specification*.

### A.2 REFERENCED DOCUMENTS

The following documents are referenced in this *Specification*:

Aluminum Association

*Aluminum Standards and Data 2013*

*Aluminum Standards and Data 2013 Metric SI*

*Standards for Aluminum Sand and Permanent Mold Castings (2008)*

American Association of State Highway and Traffic Officials (AASHTO)

*Guide Specifications for Design of Pedestrian Bridges (1997)*

*Standard Specifications for Highway Bridges (2002)*

*Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (2013)*

American Institute for Steel Construction

*Specification for Structural Steel Buildings (ANSI/AISC 360-10)*

American Society for Nondestructive Testing (ASNT)

*ASNT CP-189, Standard for the Qualification and Certification of Nondestructive Testing Personnel*

American Society of Civil Engineers (ASCE)

*ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures*

American Society of Mechanical Engineers (ASME)

*ASME B18.6.4-1998(R2005) Thread Forming and Thread Cutting Tapping Screws and Metallic Drive Screws, Inch Series*

*ASME B46.1-2009 Surface Texture (Surface Roughness, Waviness, and Lay)*

American Welding Society (AWS)

*AWS A.5.10/A5.10M:2012 Welding Consumables – Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum-Alloys - Classification*

*AWS B5.1, Standard for the Qualification of Welding Inspectors*

*AWS D1.2/D1.2M:2014 Structural Welding Code – Aluminum*

ASTM International (ASTM)

A 194/A 194M-12a *Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

A 325-10e1 *Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength*

A 325M-13 *Standard Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength [Metric]*

A 563-07a *Standard Specification for Carbon and Alloy Steel Nuts*

A 563M-07 *Standard Specification for Carbon and Alloy Steel Nuts [Metric]*

B 26/B 26M-12 *Standard Specification for Aluminum-Alloy Sand Castings*

B 108/B 108M-12e1 *Standard Specification for Aluminum-Alloy Permanent Mold Castings*

B 209-10 *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate*

B 209M-10 *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate [Metric]*

B 210-12 *Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes*

B 210M-12 *Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes [Metric]*

B 211-12e1 *Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire*

B 211M-12e1 *Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire [Metric]*

B 221-13 *Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes*

B 221M-13 *Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes [Metric]*

B 241/B 241M-12e1 *Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube*

B 247-09 *Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings*

B 247M-09 *Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings [Metric]*

B 308/B 308M-10 *Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles*

B 316/B 316M-10 *Standard Specification for Aluminum and Aluminum-Alloy Rivet and Cold-Heading Wire and Rods*

B 429/B 429M-10e1 *Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube*