W59-03
(Reaffirmed 2008)

Welded Steel Construction (Metal Arc Welding)

Update No. 1
W59-03
October 2004

Note: *General Instructions for CSA Standards are now called Updates. Please contact CSA Information Products Sales or visit* ***www.ShopCSA.ca*** *for information about the* ***CSA Standards Update Service****.*

Title: *Welded Steel Construction (Metal Arc Welding)* — originally published August 2003

The following revisions have been formally approved and are marked by the symbol delta (Δ) in the margin on the attached replacement pages:

Revised	Clauses 8.2.1.1, 10.5.3.1, Tables 11.1, 12.1, Figures 10.7 and 10.7, and Clause R3.6.1
New	None
Deleted	None

CSA W59-03 originally consisted of **312 pages** (xii preliminary and 300 text), each dated **August 2003**. It now consists of the following pages:

August 2003	i–xii, 1–68, 71–04, 107–122, 125–136, 139–156, 159–296, 299 and 300
October 2004	69, 70, 105–106, 123, 124, 137, 138, 157, 158, 297, and 298

- Update your copy by inserting these revised pages.
- Keep the pages you remove for reference.

8.1.5.2
Prior to acceptance of a weld subjected to radiographic inspection by the Contractor for the Owner, all of its radiographs, including any that show unacceptable quality prior to repair, and a report interpreting them, shall be submitted to the Engineer. (See radiographic test report sample, Appendix F, Figure F1.)

8.1.5.3
A full set of radiographs of welds subjected to radiographic inspection by the Contractor for the Owner, including any that show unacceptable quality prior to repair, shall be delivered to the Owner upon completion of the work. The Contractor's obligation to retain radiographs shall cease upon delivery of this full set to the Owner, or, in the event that delivery of the radiographs is not made, at the end of one full year after completion of the Contractor's work.

8.2 Ultrasonic Examination of Groove Welds

8.2.1 General

Δ **8.2.1.1**
The procedures and standards set forth in Clause 8.2 are to govern the ultrasonic examination of groove welds between the thicknesses of 8.0 mm and 200 mm (5/16 in and 8 in), inclusive, when such examination is required by the stipulation of Clause 7.4 of this Standard.

8.2.1.2
Variations in examination procedure, equipment, and acceptance standards not included in Clause 8.2 may be used upon agreement with the Engineer. Such variations include other thicknesses, weld geometries, transducer sizes, frequencies, couplant, etc.

8.2.1.3
Spot radiography is suggested to supplement ultrasonic examination of electroslag and electrogas butt welds in material 50 mm (2 in) and over in thickness to detect possible piping porosity.

8.2.2 Extent of Examination

8.2.2.1
Information furnished to the bidders shall clearly identify the extent of ultrasonic examination.

8.2.2.2
When complete examination is specified, the entire length of the weld in each designated joint shall be examined.

8.2.2.3
When spot examination is specified, the number of spots in each designated category of weld or the number required to be made in a stated length of weld shall be included in the information furnished to the bidders. Each spot examined shall cover at least 100 mm (4 in) of the weld length. When spot ultrasonic examination representative of a given unit length of weld shows defects, the defects shall be traced for repair and two additional spots shall be examined within the same unit length of weld to properly sample the remainder of the original unit length of weld. A defect condition in either of these spots shall result in the whole unit length of weld being examined ultrasonically.

8.2.3 Personnel Qualification
Personnel performing ultrasonic examination should be qualified as a Level 1, 2, or 3 Ultrasonic Operator in accordance with the pertinent requirements of CSA Standard W178.1 and CGSB Standard 48.9712. Level 1 Ultrasonic Personnel shall operate only under the direct supervision of Level 2 or 3 Ultrasonic Personnel.

8.2.4 Ultrasonic Equipment

8.2.4.1
The ultrasonic test instrument shall be of the pulse-echo type. It shall generate, receive, and present on a screen pulses in the frequency range of 1 to 5 MHz. The presentation on the screen shall be of the "video" type and characterized by a clean, crisp trace.

8.2.4.2
The horizontal linearity of the test instrument shall be within ±5% over the linear range, which shall include 90% of the sweep length presented on the screen for the longest sound path to be used. The horizontal linearity shall be measured by the techniques given in Section 6.2 of ASTM Standard E 317 except that the results may be tabulated rather than graphically presented.

8.2.4.3
Test instruments shall include internal stabilization so that, after warm-up, no variation in response greater than ±1 dB occurs with supply voltage changes within 15% of nominal or, in the case of battery-powered instruments, over the battery charge operating life. There shall be an alarm or meter to signal a drop in battery voltage before, or instrument shut-off due to, battery exhaustion.

8.2.4.4
The test instrument shall have a calibrated gain control (attenuator) adjustable in discrete 1 or 2 dB steps over a range of at least 60 dB. The accuracy of the gain control settings shall be within 1 dB and this accuracy shall be calibrated periodically as stated in Clause 8.2.6.1 by the techniques given in Section 6.3 of ASTM Standard E 317.

8.2.4.5
The dynamic range of the display of the instrument shall be such that a difference of 1 dB of amplitude can be easily detected on the screen.

8.2.4.6
Straight beam search unit transducers shall have an active area of not less than 323 mm^2 (1/2 square inch) and not more than 645 mm^2 (1 square inch). The transducer shall be round or square. Transducer frequency shall be 2 to 2.5 MHz. Transducers shall be capable of resolving the three reflections as described in Clause 8.2.10.1.3.

8.2.4.7
Angle beam search units shall consist of a transducer and an angle wedge as follows (the unit may comprise the two separate elements or be an integral unit):
(a) The transducer frequency shall be between 2 and 2.5 MHz, inclusive.
(b) The transducer crystal may vary in size from 12 to 26 mm (1/2 to 1 in) in width and from 12 to 21 mm (1/2 to 13/16 in) in height (see Figure 8.4).
(c) The search unit shall produce a sound beam in the material being tested within ±2° of the following proper angle: 70°, 60°, or 45°, as described in Clause 8.2.10.2.2.
(d) Each search unit shall be marked to indicate clearly the frequency of the transducer, nominal angle of refraction, and index point. The index point location procedure is described in Clause 8.2.10.2.1.
(e) Internal reflections from the search unit, with a screen presentation higher than the horizontal reference line, appearing on the screen to the right of the sound entry point, shall not occur beyond 13 mm (1/2 in) equivalent distance in steel when the sensitivity is set as follows: 20 dB more than that required to produce a maximized horizontal reference line height indication from the 1.5 mm (0.06 in) diameter hole in the International Institute of Welding (IIW) reference block (see Figure 8.5(a) and Figure 8.5(b)).

10.5.3 Procedures for Gas Metal Arc Welding with Single Electrodes

Δ **10.5.3.1**

The maximum size of a fillet weld made in one pass in either the flat or the horizontal position, shall be
(a) 6 mm (1/4 in) for 0.9 mm (0.035 in) electrode wire diameter;
(b) 8 mm (5/16 in) for 1.1/1.2 mm (0.045 in) electrode wire diameter; and
(c) 10 mm (3/8 in) for:
  (i) 1.3/1.4 mm (0.052 in) electrode wire diameter; and
  (ii) 1.6 mm (0.063 in) electrode wire diameter.

10.5.3.2

The minimum diameter of electrode wire shall be
(a) 0.9 mm (0.035 in) for fillet welds;
(b) 0.9 mm (0.035 in) for groove welds where base metal thickness does not exceed 12 mm (1/2 in);
(c) 1.1 mm (0.045 in) for groove welds where base metal thickness does not exceed 25 mm (1 in); and
(d) 1.3 mm (0.052 in) for groove welds where base metal thickness exceeds 25 mm (1 in).

10.5.3.3

The cross-sectional area of any single pass shall not exceed an area equivalent to the maximum-sized fillet weld for each of the electrode sizes as defined in Clause 10.5.3.1.
Note: *Single- and multiple-pass groove welds are normally welded using a forehand stringer pass technique.*

10.5.3.4

The mode of metal transfer across the arc shall be spray except for the root pass when it is removed to sound metal in preparation for welding the second side.

Table 10.1
Maximum Criteria for Prequalified Joints Using the Shielded Metal Arc Welding Process (SMAW)

(See Clauses 10.2.1 and 10.2.3.1.)

Maximum size of electrode	4 mm (5/32 in)	All passes in vertical fillet and groove welds
	5 mm (3/16 in)	All passes in overhead fillet and groove welds
		All passes in horizontal groove welds
		Root passes in grooves with backing where the root opening is less than 6 mm (1/4 in) in flat position
		Root passes in grooves without backing in flat position
	6 mm (1/4 in)	All passes in horizontal fillet welds
		Root passes for fillet in flat position
		Root passes in grooves with backing where the root opening is greater than 6 mm (1/4 in) in the flat position
	8 mm (5/16 in)	All passes subsequent to root passes for fillet and groove welds made in the flat position
Maximum thickness of layers	6 mm (1/4 in)	For root passes of groove welds with the minimum size being such as to prevent cracking
	5 mm (3/16 in)	For subsequent layers of welds made in any position
Maximum one-pass fillet	10 mm (3/8 in)	In the flat position
	8 mm (5/16 in)	In horizontal or overhead positions
	12 mm (1/2 in)	In the vertical position

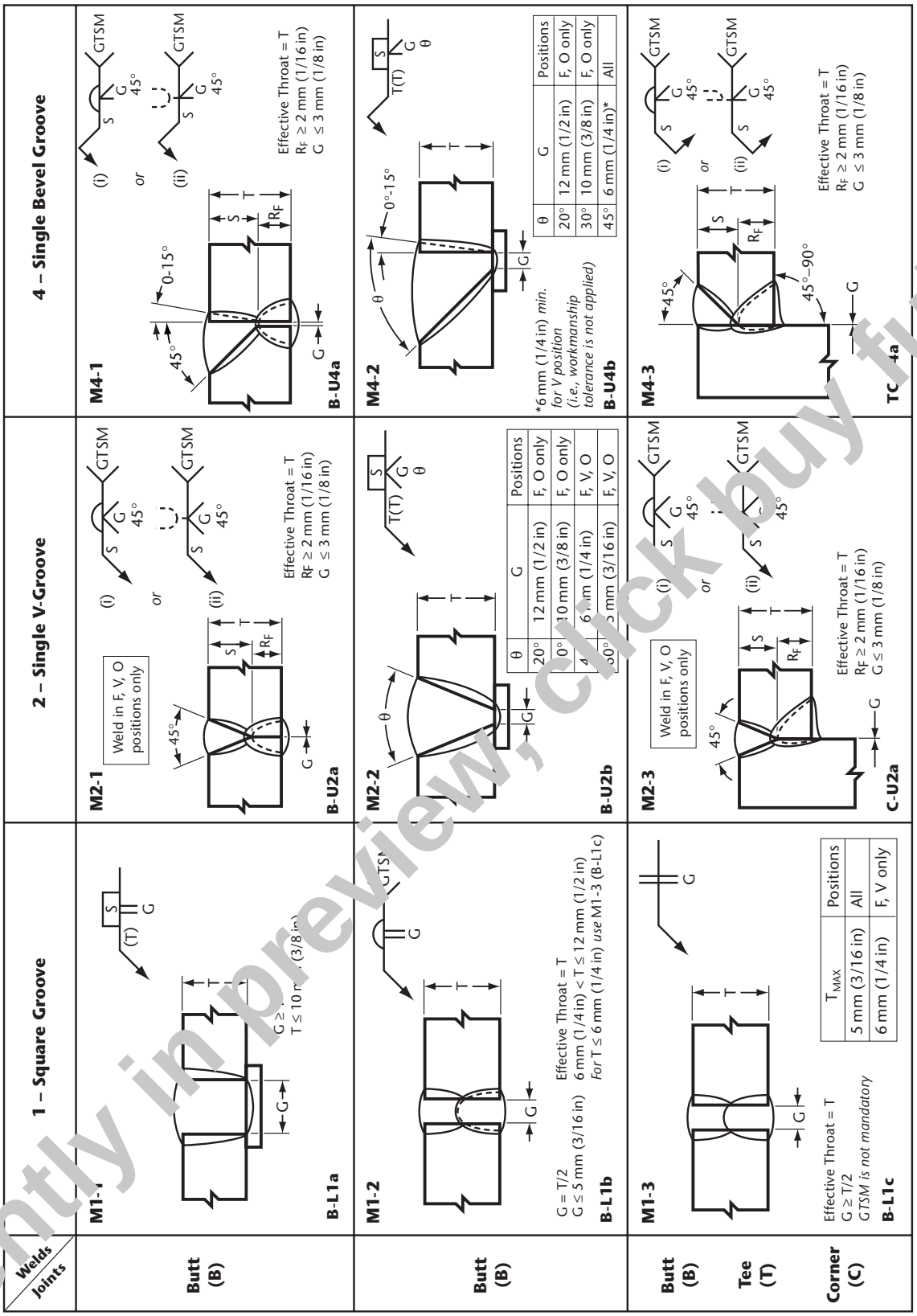
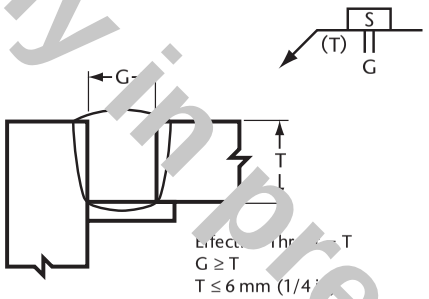
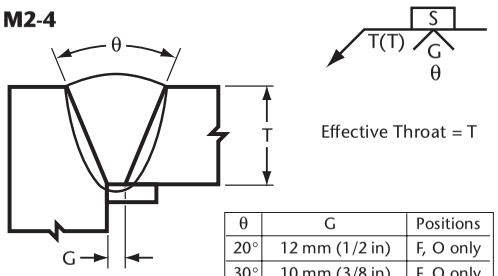
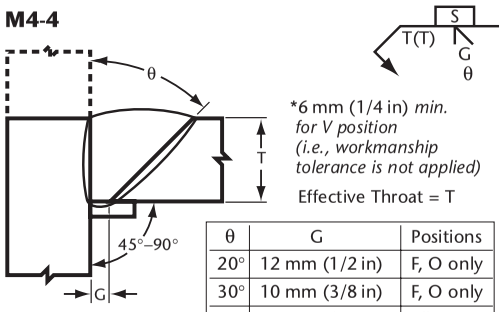
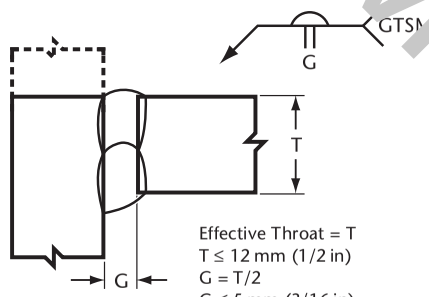
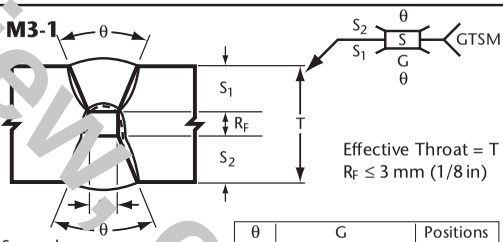
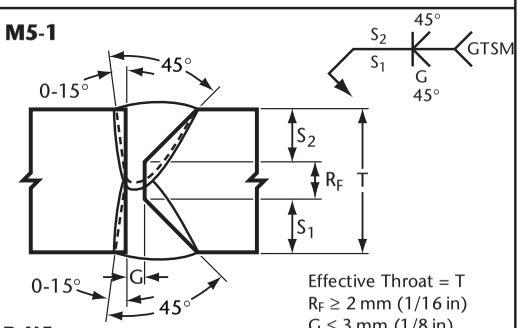
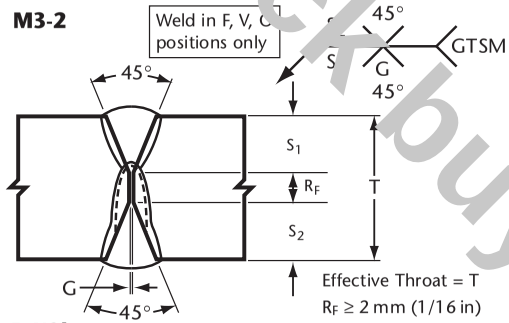
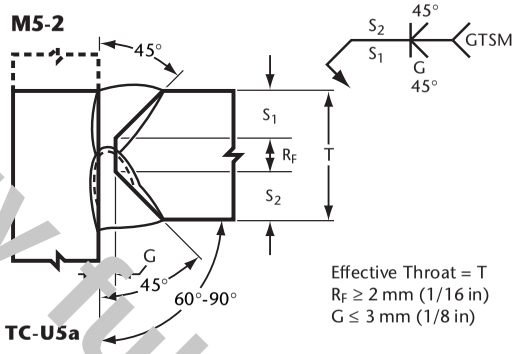
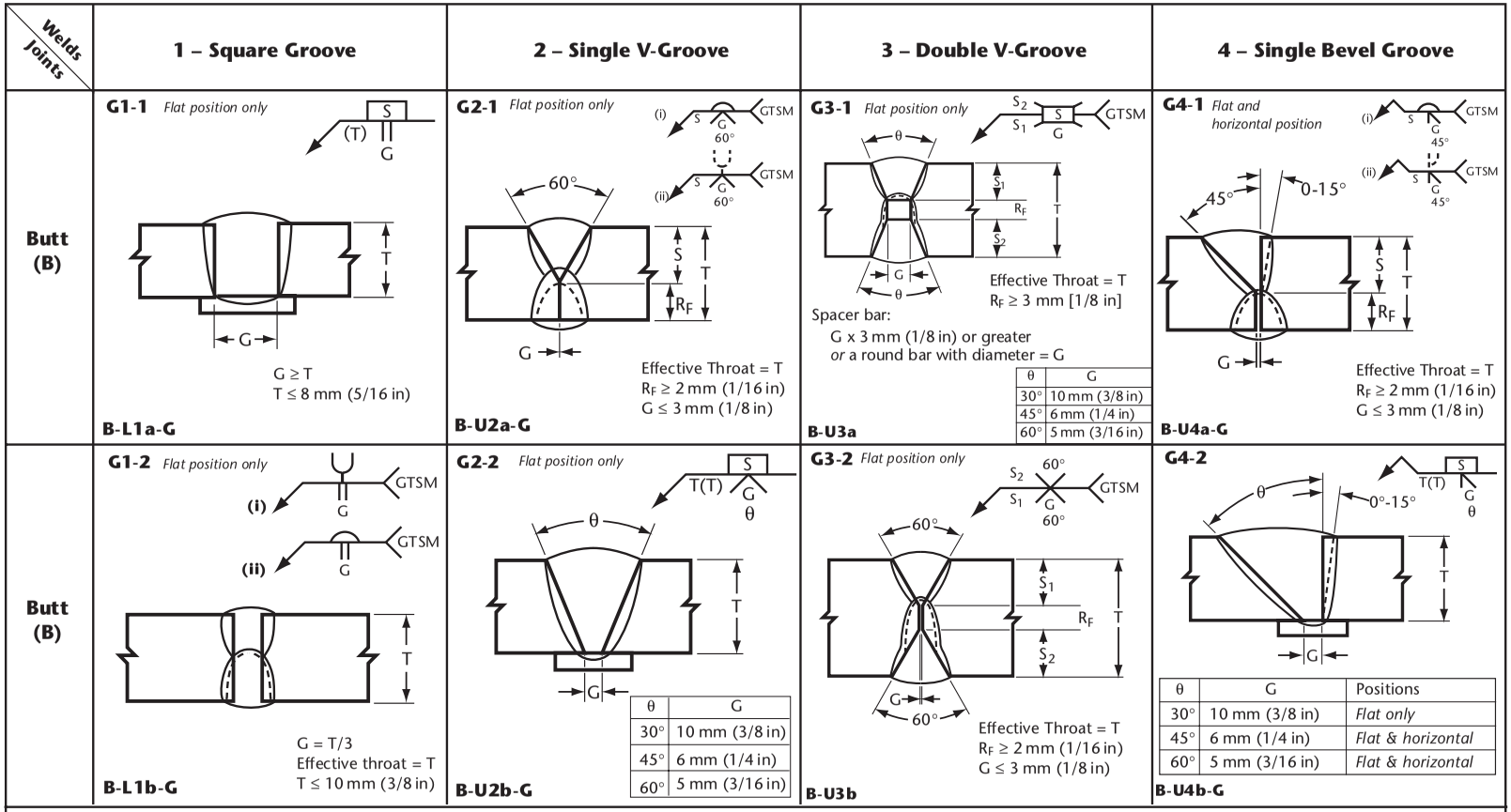


Figure 10.1
Prequalified Complete Joint Penetration Groove Welds for the Shielded Metal Arc Welding Process (SMAW) *(Continued)*
(See Clauses 10.1 and 10.2.1.)

Welds / Joints	1 – Square Groove (cont'd)	2 – Single V-Groove (cont'd) 3 – Double V-Groove	4 – Single Bevel Groove (cont'd) 5 – Double Bevel Groove
Tee (T) Corner (C)	**M1-4**  Effective Throat = T G ≥ T T ≤ 6 mm (1/4 in) **C-L1a**	**M2-4**  Effective Throat = T **C-U2b** θ: G: Positions 20°: 12 mm (1/2 in): F, O only 30°: 10 mm (3/8 in): F, O only 45°: 6 mm (1/4 in): F, V, O 60°: 5 mm (3/16 in): F, V, O	**M4-4**  *6 mm (1/4 in) *min. for V position (i.e., workmanship tolerance is not applied)* Effective Throat = T **TC-U4b** θ: G: Positions 20°: 12 mm (1/2 in): F, O only 30°: 10 mm (3/8 in): F, O only 45°: 6 mm (1/4 in)*: All
Butt (B) Tee (T) Corner (C)	**M1-5**  Effective Throat = T T ≤ 12 mm (1/2 in) G = T/2 G ≤ 5 mm (3/16 in) **TC-L1b**	**M3-1**  Effective Throat = T R_F ≤ 3 mm (1/8 in) Spacer bar: G x 3 mm (1/8 in) or greater *or* a round bar with diameter = G **B-U3a** θ: G: Positions 12 mm (1/2 in): F, O only 10 mm (3/8 in): F, O only 6 mm (1/4 in): F, V, O 5 mm (3/16 in): F, V, O	**M5-1**  Effective Throat = T R_F ≥ 2 mm (1/16 in) G ≤ 3 mm (1/8 in) **B-U5a**
Butt (B) Tee (T) Corner (C)	**Notes:** **(1)** *For all joints that show the GTSM reference on the welding symbol, gouging to sound metal prior to welding from the other side is mandatory. See Clause 5.1.4 for definition.* **(2)** *The groove in a joint may be reversed where more practical or necessary.* **(3)** *See Clauses 10.2.1 and 10.2.3.* **(4)** *For all joints with backing bars or spacers, the "S" in the welding symbol shall mean steel material in accordance with Clause 5.5.1.1.*	**M3-2**  Effective Throat = T R_F ≥ 2 mm (1/16 in) G ≤ 3 mm (1/8 in) **B-U3b**	**M5-2**  Effective Throat = T R_F ≥ 2 mm (1/16 in) G ≤ 3 mm (1/8 in) **TC-U5a**

(Continued)

Δ **Figure 10.1 (Continued)**
Prequalified Complete Joint Penetration Groove Welds for the Shielded Metal Arc Welding Process (SMAW)

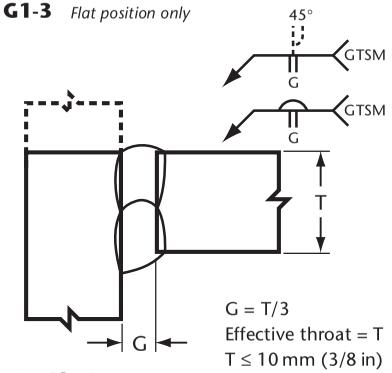
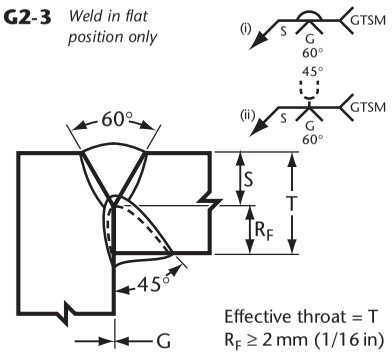
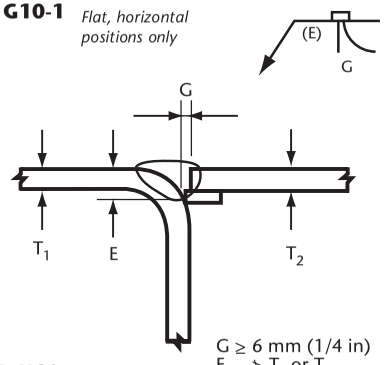
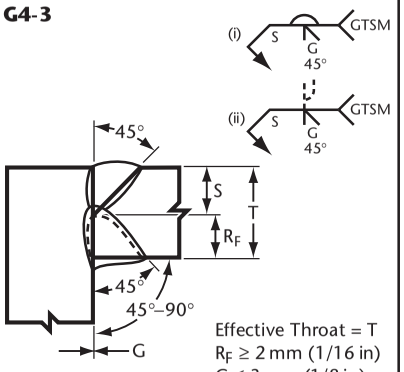
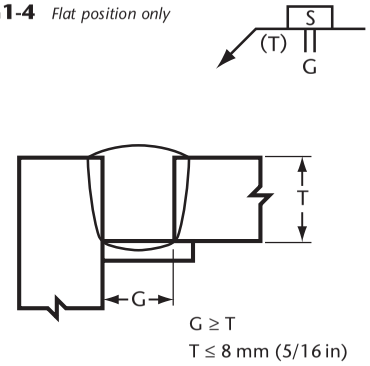
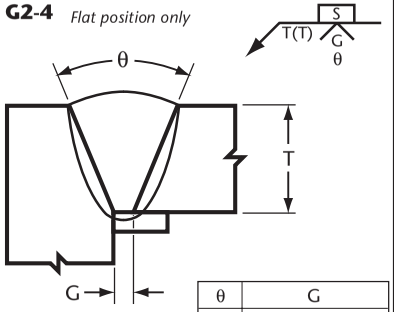
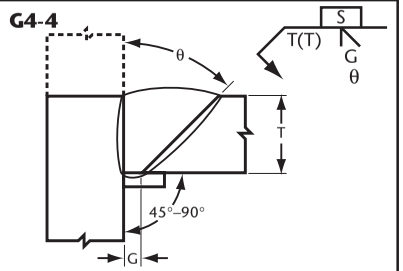


Notes:

(1) *For all joints that show the GTSM reference on the welding symbol, gouging to sound metal prior to welding the other side is mandatory. See Clause 5.1.4 for definition.*
(2) *The groove in a joint may be reversed where more practical or necessary.*
(3) *See Clauses 10.5.1 and 10.5.3.*
(4) *Backing material shall be specified in accordance with Clause 5.5.1.1.*

(Continued)

Figure 10.7
Prequalified Complete Joint Penetration Groove Welds for the Gas Metal Arc Welding Process (GMAW-SP) Spray Transfer Mode
(See Clause 10.5.1.)

Welds / Joints	1 – Square Groove (cont'd)	2 – Single V-Groove	10 – Single Flare Bevel Groove	4 – Single Bevel Groove
Butt (B) Tee (T) or Corner (C)	**G1-3** *Flat position only*  G = T/3 Effective throat = T T ≤ 10 mm (3/8 in) **TC-L1b-G**	**G2-3** *Weld in flat position only*  Effective throat = T R_F ≥ 2 mm (1/16 in) G ≤ 3 mm (1/8 in) **C-U2a-G**	**G10-1** *Flat, horizontal positions only*  G ≥ 6 mm (1/4 in) E_{max} ≯ T_1 or T_2 **B-U10**	**G4-3**  Effective Throat = T R_F ≥ 2 mm (1/16 in) G ≤ 3 mm (1/8 in) **TC-U4a-G**
Tee (T) or Corner (C)	**G1-4** *Flat position only*  G ≥ T T ≤ 8 mm (5/16 in) **C-L1a-G**	**G2-4** *Flat position only*  θ G 30° 10 mm (3/8 in) 45° 6 mm (1/4 in) 60° 5 mm (3/16 in) **C-U2b-G**	**Notes:** **(1)** *For all joints that show the GTSM reference on the welding symbol, gouging to sound metal prior to welding the other side is mandatory. See Clause 5.1.4 for definition.* **(2)** *The groove in a joint may be reversed where more practical or necessary.* **(3)** *See Clauses 10.5.1 and 10.5.3.* **(4)** *Backing material shall be specified in accordance with Clause 5.5.1.1.* **(5)** *For corner joints, see preferred preparation as shown in Figure 4.1.*	**G4-4**  θ G Positions 30° 10 mm (3/8 in) *Flat only* 45° 6 mm (1/4 in) *Flat & horizontal* 60° 5 mm (3/16 in) *Flat & horizontal* **TC-U4b-G**

(Continued)

Δ **Figure 10.7 (Continued)**
Prequalified Complete Joint Penetration Groove Welds for the Gas Metal Arc Welding Process (GMAW-SP) Spray Transfer Mode

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Table 11.1
Base Metals and Matching Electrode Classification for Statically Loaded Structures

(See Clauses 3.2.2, 5.2.1.1, 5.2.1.2, 5.2.1.4, 5.5.6.3.2, 5.5.6.3.3, 11.2, and 11.3.3.1.)

Note: *For mandatory use of low-hydrogen (SMAW) or FCAW and MCAW electrodes with diffusible hydrogen designators, see Clauses 5.2.2.2, 5.2.4.3, and Table 5.3.*

Base metal					CSA Standard W48 Electrode and electrode-flux classifications [1,2]				
					SMAW				
Steel group	Specified min. tensile strength of base metal, MPa (ksi)	CSA Standard G40.21	CSA Standard G40.21	ASTM	Carbon steel	Low-alloy steel	GMAW, MCAW[6]	FCAW, MCAW	SAW
1	Up to 400 incl. when F_y <250 (Up to 60 incl. when F_y <36)			A 36 [t >203 mm (8 in)] A 441 [Normalized t >102 mm (4 in)] A 500 Grade A A 515M Grades 380 & 415 A 516M Grades 380 & 415 A 1011 Grade 30/A 1011M Grade 205 A 1011 Grade 33/A 1011M Grade 230	E43XX E49XX	E49XX-X	ER49S-X	E43XT-X E49XT-X E43XC-X E49XC-X	F43XX-EXXX F49XX-EXXX
2	Up to 400 incl when $F_y \geq 250$ (Up to 60 incl. when $F_y \geq 36$)	260W 260WT 300W(HSS)	38W 38WT 44W(HSS)	A 36 [t≤203 mm (8 in)] A 441 [102 mm ≤ t ≤203 mm (8 in) or Normalized 38 mm (1-1/2 in) < t <102 mm (4 in)] A 500 Grade B A 501 A 572 Grade 42 A 1011 Grade 36/A 1011M Grade 250 A 1011 Grade 40/A 1011M Grade 275	E49XX	E49XX-X	ER49S-X	E49XT-X E43XT-X E49XC-X E43XC-X	F49XX-EXXX F43XX-EXXX
3	Over 400 to 480 inclusive (Over 60 to 70 inclusive)	300W 300WT 350W 350WT 350A[3] 350AT[3] 380W(HSS) 380WT(HSS)	44W 44WT 50W 50WT 50A[3] 50AT[3] 55W(HSS) 55WT(HSS)	A 242[3][4] A 441 [t ≤ 102 mm (4 in) or Normalized t ≤ 38 mm (1-1/2 in)] A 500 Grade C A 516M Grades 450 & 485 A 572 Grade 50 A 588[3] A 618 A 710 Grade A, Class 2 > 50 mm A 913 Grade 50 A 992/A 992M A 1011 Grade 45/A 1011M Grade 310 A 1011 Grade 50/A 1011M Grade 340 A 1011 Grade 55/A 1011M Grade 380	E49XX	E49XX-X	ER49S-X	E49XT-X E49XC-X	F49XX-EXXX

(Continued)

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Table 11.1 (Concluded)

Base metal					CSA Standard W48 Electrode and electrode-flux classifications (1,2)				
					SMAW				
Steel group	Specified min. tensile strength of base metal, MPa (ksi)	CSA Standard G40.21	CSA Standard G40.21	ASTM	Carbon steel	Low-alloy steel	GMAW, MCAW[6]	FCAW, MCAW	SAW
4	Over 480 to 550 inclusive Over 70 to 80 inclusive	400W 400WT 400A(3) 400AT(3)	60W 60WT 60A(3) 60AT(3)	A 572 Grades 60 & 65 A 710 Grade A, Class 2 ≤ 50 mm A 710 Grade A, Class 3 > 50 mm A 913 Grade 60, 65 A 1011 Grade 60/A 1011M Grade 410 A 1011 Grade 65/A 1011M Grade 450		E55XX-X	ER80S-XX E80C-XX	E8XTX-X E8XCX-X	F8XX-EXXX F8XX-ECXXX
5	Over 550 to 620 inclusive Over 80 to 90 inclusive	480W, 480WT 480A(3) 480AT(3)	70W, 70WT 70A(3) 70AT(3)	A 1011 Grade 70/A 1011M Grade 480		E62XX-X	ER90S-XX E90C-XX	E9XTX-X E9XCX-X	F9XX-EXXX F9XX-ECXXX
6	Over 620 to 700 inclusive Over 90 to 100 inclusive			A 514 [64 mm (2-1/2 in) < t < 152 mm (6 in)] A 1011 Grade 80/A 1011M Grade 550		E69XX-X	ER100S-XX	E10XTX-X E10XCX-X	F10X-EXX F10X-ECXXX
7	Over 700(5) Over 100(5)	700Q, 700QT	100Q, 100QT	A 514 [t < 64 mm(2-1/2 in)] A 517M		E76XX-X	ER110S-XX	E11XTX-X E11XCX-X	F11X-EXXX F11X-ECXXX
							A5.28	A5.29	A5.23
							AWS		

Notes:

(1) *For exceptions, see Tables 11.2(a) and 11.2(b).*

(2) *In case of exception under Note (1) for electrodes lower than matching, the value of X_u is that of the lower electrode classification; for electrodes higher than matching, the value of X_u is that of the matching electrode classification.*

(3) *For unpainted applications where the deposited weld metal shall have similar atmospheric corrosion resistance and/or similar colour characteristics to the base metal, the requirements of Clauses 5.2.1.4 and 5.2.1.5 shall apply.*

(4) *Only types with properties suitable for welding.*

(5) *Complete joint penetration groove welds made with the designated matching electrode classifications may not develop the specified minimum tensile strength of the base metal.*

(6) *Only when X_u >* 480 MPa *(70 ksi).*

12.5.4.3 Radiographic and Magnetic Particle Examination

Welds that are subject to radiographic or magnetic particle examination in addition to visual inspection shall have no cracks and shall be unacceptable if porosity or fusion-type defects exceed the following limits in size or frequency of occurrence:

(a) For welds subject to tensile stress under any conditions of loading, the greatest dimension of any porosity* or fusion-type defect† that is 2 mm (1/16 in) or larger in its greatest dimension shall not exceed the size indicated in Figure 12.5 under the dimension of defect "B", for the effective throat or weld size involved. The distance from any porosity or fusion-type defect described above to another such defect, to an edge, or to any intersecting weld shall not be less than the minimum clearance allowed, "C", indicated by Figure 12.5 for the size of defect under examination.

**Porosity signifies gas pockets and any similar generally globular-type voids.*

†*Fusion-type defect signifies slag inclusions, incomplete fusion, inadequate penetration, and similar generally elongated defects.*

(b) For welds subject to compressive stress only and specifically indicated as such in the design drawings, the greatest dimension of fusion-type defect that is 2 mm (1/16 in) or larger in greatest dimension shall not exceed the size "B", nor shall the space between adjacent defects be less than the minimum clearance allowed, "C", indicated by Figure 12.6 for the size of defect under examination.

(c) For welds subject to shear stress only, the greatest dimension of fusion-type defect that is 2 mm (1/16 in) or larger in greatest dimension shall not exceed the size "B", nor shall the space between adjacent defects be less than the minimum clearance allowed, "C", indicated by Figure 12.6 for the size of defect under examination.

(d) The limitations given by Figures 12.5 and 12.6 for 40 mm (1-1/2 in) joint or weld throat thickness shall apply to all joints or weld throats of greater thickness.

(e) Independent of the requirements of items (a), (b), and (c) the sum of the greatest dimensions of porosity and fusion-type defects less than 2 mm (1/16 in) in greatest dimension shall not exceed 10 mm (3/8 in) in any linear 25 mm (1 in) of weld.

12.5.4.4 Ultrasonic Examination

Welds that are subject to ultrasonic examination in addition to visual inspection shall have no cracks and shall also meet the following requirements:

(a) welds subject to tensile stress under any conditions of loading shall conform to the requirements of Table 12.5; and

(b) welds subject to compressive stress only and specifically indicated as such in the design drawings shall conform to the requirements of Table 11.3.

12.5.4.5 Liquid Penetrant Examination

Welds that are subject to liquid penetrant examination shall be evaluated on the basis of the requirements for visual inspection. The evaluation shall compare the physical size of the discontinuity with the acceptance standard defined for visual inspection.

12.5.4.6

When nondestructive examination is specified, the examination of welded joints subject to high restraint and/or joints of quenched and tempered steels shall be delayed as long as practicable and preferably not less than 48 h after completion of the welds.

12.5.5 Temporary Welds

Except with the express consent of the Engineer, there shall be no temporary welds in primary tension members and in tension flanges of beams or girders. When such temporary welds have been used, they shall be removed, ground smooth, and examined using magnetic particle or liquid penetrant inspection methods. Temporary welds at other locations shall be shown on shop drawings and shall be made with E49XX low-hydrogen electrodes or electrodes with diffusible hydrogen designators of H16 or less.

Δ

Table 12.1
Base Metals and Matching Electrode Classification for Cyclically Loaded Structures

(See Clauses 3.2.2, 5.2.1.1, 5.2.1.2, 5.2.1.4, 5.5.6.3.2, 12.2, and 12.3.3.)

Note: *For mandatory use of low-hydrogen (SMAW) or FCAW or MCAW electrodes with diffusible hydrogen designators, see Clauses 5.2.2.2 and 5.2.4.3 and Table 5.3.*

	Base metal				CSA Standard W48 Electrode and electrode-flux classification[1,2]				
					SMAW				
Steel group	Specified min. tensile strength of base metal, MPa (ksi)	CSA Standard G40.21	CSA Standard G40.21	ASTM	Carbon steel	Low-alloy steel	GMAW[6], MCAW[6]	FCAW, MCAW	SAW
1	Up to 400 incl. when F_y <250 (Up to 60 incl. when F_y <36)			A 36[4] [t>203 mm (8 in)] A 441[4] [Normalized t >102 mm (4 in)] A 500 Grade A A 515M Grades 380 & 415 A 516M Grades 380 & 415 A 1011 Grade 30/A 1011M Grade 205 A 1011 Grade 33/A 1011M Grade 230	E43XX E49XX		ER49S-X	E43XT-X E49XT-X E43XC-X E49XC-X	F43XX-EXXX F49XX-EXXX
2	Up to 400 incl. when $F_y \geq 250$ (Up to 60 incl. when $F_y \geq 36$)	260W[4] 260WT 300W(HSS)[4]	38W[4] 38WT 44W(HSS)[4]	A 36[4] [t≤203 mm (8 in)] A 441[4][102 mm ≤ t ≤203 mm (8 in) or Normalized 38 mm (1-1/2 in) < t < 102 mm (4 in)] A 500[4] Grade B A 501[4] A 572[4] Grade 42 A 1011 Grade 36/A 1011M Grade 250 A 1011 Grade 40/A 1011M Grade 275	E43XX E49XX	E49XX-X	ER49S-X	E49XT-X E43XT-X E49XC-X E43XC-X	F49XX-EXXX F43XX-EXXX
3	Over 400 to 480 inclusive (Over 60 to 70 inclusive)	300W[4] 300WT 350W[4] 350WT 350A[3] 350AT[3] 380W(HSS)[4] 380WT(HSS)[4]	44W[4] 44WT 50W[4] 50WT 50A[3] 50AT[3] 55W(HSS)[4] 55WT(HSS)[4]	A 441[4] [t ≤ 102 mm (4 in) or Normalized t ≤ 38 mm (1-1/2 in)] A 500 Grade C A 516M Grades 450 & 485 A 572[4] Grade 50 A 588[3] A 618[4] A 710 Grade A, Class 2>50 mm A 913 Grade 50 A 992/A 992M A 1011 Grade 45/A 1011M Grade 310 A 1011 Grade 50/A 1011M Grade 340 A 1011 Grade 55/A 1011M Grade 380	E49XX	E49XX-X	ER49S-X	E49XT-X E49XC-X	F49X-EXXX

(Continued)

Δ slag, and mill scale. The tip of the electrode must be kept sharp and clean. The tip shall be located horizontally 0.5 to 1.5 mm (0.02 to 0.06 in) from the weld toe (see Figure R8). Where toughness of the heat-affected zone may create problems, a modified technique using a second tempering pass may be used.

R3.7 Toe Grinding Plus Hammer Peening

R3.7.1

Toe grinding followed by hammer peening inhibits fatigue crack initiation and the rate of crack propagation. Thus, for critical joints, this combined treatment offers superior resistance to fatigue failure. The weld surface shall be checked visually and by magnetic particle for surface discontinuities prior to peening. During peening operations, visually check after each pass. (*References 4, 5, 8*.)

R3.8 Stress Range Increase

R3.8.1

The allowable stress range for cyclically loaded connections may be increased by a factor of 1.3 along the S-N design curve, which is equivalent to a factor of 2.2 on cycle life, for an S-N curve slope of approximately 1/3, when toe grinding, hammer peening, or TIG dressing is used. Note, however, that the effect of grinding and hammer peening is cumulative. A factor of 1.5 on the stress range may be allowed at high cycles ($N = 10^7$), but reduced to a factor of 1.0 (no benefit) at low cycles ($N = 10^4$). For nontubular joints, the improvement factor should not exceed the highest as-welded fatigue design category.

R4. References for Fatigue Enhancement

(1) Maddox, S.J. *Fatigue strength of welded structures*. Second Edition, 1992. Abington Publishing.
(2) Haagensen, P.J. IIW Doc. XII-WG2-22-93, *Recommendations for Grinding Welded Joints*. First Draft.
(3) Haagensen, P.J. IIW Doc. XIII-1510-93, *The Effect of Grinding and Peening on the Fatigue Strength of Welded T-Joints*.
(4) Haagensen, P.J. IIW Doc.XIII-1511-93, *Life Extension and Repair by Grinding and Peening*.
(5) *Improving the Fatigue Performance of Welded Joints*. TWI, Cambridge, England:
Maddox, S.J. Chapter 1, *An introduction to the fatigue of welded joints*.
Booth, G.S. Chapter 2, *A review of fatigue strength improvement techniques*.
Woodly, C.C. Chapter 4, *Practical applications of weld toe grinding*.
Haagensen, J. Chapter 5, *Effect of TIG dressing on fatigue performance and hardness of steel weldments*.
(6) Maddox, S.J. *International efforts on fatigue of welded construction*. Welding & Metal Fabrication, December 1992.
(7) Commission IIW Working Group 2 — *Improvement Techniques, Proposed IIW Specification for Weld Toe Improvement by Hammer Peening and Burr Grinding,* 1993.
(8) Takenouchi et al. IIW Doc. XIII-1509-93, *Fatigue Performances of Repairing welds with TIG-dressing for Fatigue Damaged Highway Bridges.*
(9) Welsch, W. *Peening Improves Fatigue Life*. Welding Design & Fabrication, October, 1990.
(10) *Connect*, No. 12. TWI, Cambridge (from AWS Welding Journal, February 12, 1991).
(11) CETIM/Centre technique des industries mécaniques. IIW Doc. XIII-WG2-10-91, *Improving the Fatigue Strength of Welded Joints by TIG or Plasma Dressing*.
(12) AWS D1.1/D1.1 M:2002.

Table R1
Relationship Between Plate Thickness and Burr Radius

Plate thickness, mm	Burr radius, mm	Plate thickness, in	Burr radius, in
< 20	5	<3/4	3/16
20 to 29	6	3/4 to 1-3/16	1/4
30 to 39	8	1-1/4 to 1-1/2	5/16
40 to 49	10	1-9/16 to 1-15/16	3/8
50 to 64	12	2 to 2-1/2	1/2
65 to 79	16	2-9/16 to 3-1/8	5/8
80 to 99	18	3-3/16 to 3-15/16	3/4
100 to 119	20	4 to 4-11/16	7/8
120 to 149	25	4-3/4 to 5-15/16	1
150 to 180	30	6 to 7-1/8	1-3/16

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DEDICATION

This edition of CSA Standard W59 is dedicated to the memory of JOSEPH T. BISKUP, P. Eng.,

a gentleman whose integrity and life-long devotion to structural welding in the areas of research, education, and the development and administration of welding standards, both nationally and internationally, combined with his exceptional work on this Standard over 32 years, have, for many, made his name synonymous with W59.

Joe took an active part in preparing virtually all CSA welding standards. His long-time participation in the AWS D1 Committee culminated in the unique situation of his being chair of both the AWS D1 and CSA W59 Committees from 1975 to 1981.

Preface

This is the eighth edition of CSA Standard W59, *Welded Steel Construction (Metal Arc Welding)*. It supersedes the previous editions published in 1989, 1984, 1982, 1977, 1970, 1946, and 1940. Unlike the 1989 edition, which was published separately in yard/pound (imperial) and SI (metric) versions, the 2003 edition consolidates the units. SI (metric) units govern in this eighth edition. Comparable approximate imperial units are provided in parentheses, where applicable, and are included only for information purposes. All text, tables, and figures in this edition have been completely reformatted electronically.

The following is a brief description of some of the most significant changes to the present W59 Standard.

The Scope of the Standard is covered in Clause 1. Changes to the Scope reflect the renaming of Clause 12 from Dynamically Loaded Structures to Cyclically Loaded Structures, to better reflect the emphasis of Clause 12 on the repetitive nature of structural loadings (fatigue) rather than the rate at which the loading is applied. Clause 1 acknowledges that provisions for metal-cored arc welding are now included in the Standard. Clause 1 also more clearly defines the application of the Standard, which is to base metals 3 mm and thicker. AWS D1.3 is recognized for welding thinner steels. Clause 1 also acknowledges the need for safety in welding, which is covered by other Standards.

In Clause 2, consumables manufactured to deposit weld metal having a specified maximum limit of diffusible hydrogen have been redefined as low hydrogen, instead of being referred to as basic. Two forms of engineering responsibility are also introduced: the Engineer responsible to the Contractor and the Engineer acting on behalf of the Purchaser or regulatory authority.

The qualification requirements for contractors performing work under this Standard have been moved to Clause 3 from Clause 6. Clause 3 also acknowledges that joints welded by either metal-cored arc or gas metal arc, in the spray transfer mode, can now be deemed as prequalified. Several steels have been added to the prequalified list.

In Clause 4, Design of Welded Connections, complete joint penetration groove welds are now designated as CJP and partial joint penetration groove welds as PJP. Fillet welds are now defined as having included angles between fusion faces of 60° to 135°. The section on flare welds has been completely rewritten and expanded significantly to cover flare bevel and flare V-groove welds in butt joints, and flare bevel groove welds in T-Joints. The concept of a flare bevel fillet weld is introduced. Minor changes have been introduced into the Section on plug and slot welds. A new clause dealing with skewed joints has been added.

Clause 5 has been reworded to reflect low hydrogen terminology and the inclusion of metal-cored arc welding. The section on storing and conditioning of electrodes has been rewritten. Information regarding beam copes and weld access holes is now included in the Standard along with special requirements for Group 4 and 5 shapes. The section on stud welding has been reworked.

Clause 6 has been left open, as the content was moved to Clause 3.

In Clause 7, CSA Standard W178.1, CSA Standard W178.2, and AWS QC1 are recognized.

In Clause 8, the radiographic portion has been rewritten, and procedures now include the use of hole type IQIs and wire type IQIs.

Clause 9, Strengthening and Repair of Existing Structures, has been completely rewritten. More emphasis has been placed on stress analysis, workmanship, and the need for a comprehensive work plan including inspection and documentation. Methods of fatigue life enhancement have been recognized.

In Clause 10, all the figures have been reviewed for consistency. A major inclusion is the prequalified joint geometries for the metal-cored arc welding process and the gas metal arc welding process, when using spray transfer. In addition, prequalified geometries have been included for various flare welds. Also, three previously qualified SMAW partial joint geometries have been deleted, M1-1P, M2-1P and M4-1P. The effective throats of two other SMAW partial joint geometries have been reduced M1-2P and M1-3P.

Clause 11, for statically loaded structures, has seen limited changes. The allowable stress method of design has been retained for this edition, but with no meaningful changes from the prior edition. Changes have only been made to the limit states design method. The strength of fillet welds can now be increased, depending upon the direction of loading. Partial penetration joints loaded in tension normal to the axis of the weld are no longer assumed to be loaded in shear.

The title of Clause 12 has been changed to Cyclically Loaded Structures — Design and Construction, to more accurately reflect the emphasis in the clause on the effects of cyclic and repetitive loadings (fatigue) on structures, rather than the rate at which the load is applied. The previous step-function allowable range of stress for various fatigue details has been replaced by a continuous equation. Fatigue is recognized as being load-induced or distortion-induced. The use of Miner's Rule is introduced for assessing cumulative damage from variable amplitude loading. Methods to enhance the fatigue resistance of welds are recognized. Additional fatigue detail categories have been added.

As CSA W59 contains no commentary, various nonmandatory appendices have been included to generate a better understanding of certain aspects of welded steel construction. The appendices of the previous edition of W59 have generally been reviewed for clarity.

Appendix H, which is a mandatory appendix dealing with the qualification of studs, has seen significant changes.

Appendix K has been modified to reflect only the results of research on arc spot welds.

Appendix L has been completely rewritten to reflect the importance of hollow structural sections in welded construction and the need for a better understanding of the design of their connections.

The previous Appendix N on weld capacities, loaded in shear has been deleted and replaced with an appendix providing a better understanding of the modes of metal transfer in gas metal arc welding, especially in light of the prequalification of joints using the spray transfer mode.

Appendix P has seen minor clarification changes regarding alternative preheat determination.

Appendix R has been added to provide a better understanding of the new equations dealing with the fatigue assessment of structures and the methods of fatigue life enhancement.

This Standard was prepared by the Technical Committee on Welding of Bridges, Buildings, and Machinery, under the jurisdiction of the Strategic Steering Committee on Welding and Structural Metals, and has been formally approved by the Technical Committee.

August 2003

Notes:

(1) *Use of the singular does not exclude the plural (and vice versa) when the sense allows.*

(2) *Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.*

(3) *This publication was developed by consensus, which is defined by* CSA Policy governing standardization — Code of good practice for standardization *as "substantial agreement. Consensus implies much more than a simple majority, but not necessarily unanimity". It is consistent with this definition that a member may be included in the Technical Committee list and yet not be in full agreement with all clauses of this publication.*

(4) *CSA Standards are subject to periodic review, and suggestions for their improvement will be referred to the appropriate committee.*

(5) *All enquiries regarding this Standard, including requests for interpretation, should be addressed to Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N6.*

Requests for interpretation should

(a) define the problem, making reference to the specific clause, and, where appropriate, include an illustrative sketch;

(b) provide an explanation of circumstances surrounding the actual field condition; and

(c) be phrased where possible to permit a specific "yes" or "no" answer.

Committee interpretations are processed in accordance with the CSA Directives and guidelines governing standardization *and are published in CSA's periodical* Info Update, *which is available on the CSA Web site at www.csa.ca.*

W59-03
Welded Steel Construction (Metal Arc Welding)

1. Scope

1.1
This Standard covers welding requirements for carbon and low-alloy welded steel construction, with the exception of those types listed in Clause 1.2.

Requirements that are essentially common to all such structures are covered in Clauses 1 to 10, while provisions applying specifically to statically loaded structures and to cyclically loaded structures are included in Clauses 11 and 12, respectively.

1.2
This Standard is not intended to apply to pressure vessels or to structures governed by special codes such as those of Lloyds, the American Petroleum Institute, the American Society of Mechanical Engineers, or the American Water Works Association. This Standard does not cover welding of stainless steel.
Note: *When welding stainless steel, other standards such as AWS D1.6 could be referenced.*

1.3
This Standard includes provisions for shielded metal arc welding (SMAW), submerged arc welding (SAW), gas metal arc welding (GMAW), flux-cored arc welding (FCAW), metal-cored arc welding (MCAW), electroslag welding (ESW), electrogas welding (EGW), and stud welding (SW) processes.

1.4
The provisions of this Standard are not intended for use with steels having a specified minimum yield strength over 700 MPa (100 000 psi).

1.5
This Standard applies to the welding of base metals 3 mm (1/8 in) and thicker. In cases where base metals less than 3 mm (1/8 in) thick are to be welded to base metals 3 mm (1/8 in) and thicker, the requirements of AWS D1.3 and this Standard apply. In the case of any conflict between AWS D1.3 and this Standard, the requirements of this Standard govern.
Note: *In cases where base metals less than* 3 mm *(1/8 in) thick are to be welded to base metals less than* 3 mm *(1/8 in), the requirements of AWS D1.3 may be appropriate.*

1.6
The values given in SI (metric) units are the standard. The values given in parentheses are for information only.

1.7
This Standard does not purport to address safety problems associated with welding and welding practices.
Note: *CSA Standard W117.2 addresses safety in welding, cutting, and allied processes, and should be followed in addition to any applicable workplace health and safety legislation in effect. It is the responsibility of the user of this Standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*