XI. Tables

Table 1

Types of Tungsten Electrodes				
AWS Classification	**Type of Tungsten (Alloy)**	**Color Code**	**Available Finish***	**Remarks**
EWP	Pure	Green	Cleaned and ground	Provides good arc stability for AC welding. Reasonably good resistance to contamination. Lowest current carrying capacity. Least expensive. Maintains a clean balled end.
EWCe-2	Ceria CeO_2 1.8% to 2.2%	Orange	Cleaned and ground	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life. Possible nonradioactive replacement for thoria.
EWLa-1	Lanthana La_2O_3 0.9% to 1.2%	Black	Cleaned and ground	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life, high current capacity. Possible nonradioactive replacement for thoria.
EWLa-1.5	Lanthana La_2O_3 1.3% to 1.7%	Gold	Cleaned and ground	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life, high current capacity. Possible nonradioactive replacement for thoria.
EWLa-2	Lanthana La_2O_3 1.8% to 2.2%	Blue	Cleaned and ground	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life, high current capacity. Possible nonradioactive replacement for thoria.
EWTh-1	Thoria ThO_2 0.8% to 1.2%	Yellow	Cleaned and ground	Easier arc starting. Higher current capacity. Greater arc stability. High resistance to weld pool contamination. Difficult to maintain balled end on AC.
EWTh-2	Thoria ThO_2 1.7% to 2.2%	Red	Cleaned and ground	Easier arc starting. Higher current capacity. Greater arc stability. High resistance to weld pool contamination. Difficult to maintain balled end on AC.
EWZr-1	Zirconia ZrO_2 0.15% to 0.40%	Brown	Cleaned and ground	Excellent for AC welding due to favorable retention of balled end, high resistance to contamination, and good arc starting. Preferred when tungsten contamination of weld is intolerable.
EWG	Specify	Gray		Contains other rare earths or a combination of oxides.

*Clean finish designates electrodes that are chemically cleaned and etched. Ground finish designates electrodes with a centerless ground finish to provide maximum smoothness and consistency.

Centerless ground tungsten electrodes are used where minimum resistance loss at the collet-electrode contact point is desired.

Table 2

Typical Current Ranges for Tungsten Electrodes*						
		Direct Current, DC	Alternating Current, AC			
		DCEN	70% Penetration		(50/50) Balanced Wave A	
Tungsten Diameter	Gas Cup Inside Diameter	Ceriated Thoriated Lanthanated	Pure	Ceriated Thoriated Lanthanated	Pure	Ceriated Thoriated Lanthanated
.040	#5 (3/8 in)	15 – 80	20 – 60	15 – 80	10 – 30	20 – 60
.060 (1/16 in)	#5 (3/8 in)	70 – 150	50 – 100	70 – 150	30 – 80	60 – 120
.093 (3/32 in)	#8 (1/2 in)	150 – 250	100 – 160	140 – 235	0 – 130	100 – 180
.125 (1/8 in)	#8 (1/2 in)	250 – 400	150 – 200	225 – 325	100 – 180	160 – 250

*All values are based on the use of Argon as a shielding gas. Other current values may be employed depending on the shielding gas, type of equipment, and application.
DCEN = Direct Current Electrode Negative (Straight Polarity)

Table 3

Recommended Types of Current, Tungsten Electrodes and Shielding Gases for Welding Different Metals[1]				
Types of Metal	**Thickness**	**Type of Current**	**Electrode[2]**	**Shielding Gas**
Aluminum	All	AC	Pure or zirconium	Argon or argon-helium
	All	AC Advanced Squarewave	Lanthanated, cerium thoriated	Argon or argon-helium
	over 1/4"	DCEN	Lanthanated, cerium thoriated	100% Helium
Copper, copper alloys	All	DCEN	Lanthanated, cerium thoriated	Helium
Magnesium alloys	All	AC	Pure or zirconium	Argon
	All	AC Advanced Squarewave	Lanthanated, cerium thoriated	Argon
Nickel, nickel alloys	All	DCEN	Lanthanated, cerium thoriated	Argon, argon-helium, argon-hydrogen (5% max)
Plain carbon, low-alloy steels	All	DCEN	Lanthanated, cerium thoriated	Argon or argon-helium
Stainless steel	All	DCEN	Lanthanated, cerium thoriated	Argon or argon-helium
Titanium, zirconium, hafnium[3]	All	DCEN	Lanthanated, cerium thoriated	Argon
Refractory Metals[3]	All	DCEN	Lanthanated, cerium thoriated	Argon

[1]These recommendations are general guidelines based on methods commonly used in industry.
[2]Where thoriated electrodes are recommended, lanthanated, ceriated or rare earth containing electrodes should be used.
[3]A glove box is often required to prevent atmospheric contamination.

Table 4

AWS Specifications for Filler Metals, Shielding Gases and Electrodes Suitable for Gas Tungsten Arc Welding	
Specification Number	**Title**
A 5.7	Copper and Copper Alloy Bare Welding Rods and Electrodes
A 5.9	Stainless Steel Bare Welding Rods and Electrodes
A 5.10	Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes
A 5.12	Tungsten and Tungsten Alloy Electrodes
A 5.13	Surfacing Welding Rods and Electrodes
A 5.14	Nickel and Nickel Alloy Bare Welding Rods and Electrodes
A 5.16	Titanium and Titanium Alloy Bare Welding Rods and Electrodes
A 5.18	Carbon Steel Filler Metals for Gas Shielded Arc Welding
A 5.19	Magnesium-Alloy Welding Rods and Bare Electrodes
A 5.21	Composite Surfacing Welding Rods and Electrodes
A 5.24	Zirconium and Zirconium Alloy Bare Welding Rods and Electrodes
A 5.28	Low Alloy Steel Filler Metal for Gas Shielded Arc Welding
A 5.30	Consumable Inserts
A 5.32	Welding Shielding Gases

Table 5

Welding Position Designations
Plate Welds
Groove Welds
1G Flat position 2G Horizontal position 3G Vertical position 4G Overhead position
Fillet Welds
1F Flat position 2F Horizontal position 3F Vertical position 4F Overhead position
Pipe Welds
Groove Welds
1G Flat position, pipe axis horizontal and rotated 2G Horizontal position, pipe axis vertical 5G Multiple positions, (overhead, vertical and flat) pipe axis horizontal and is not rotated (fixed) 6G Multiple positions, (overhead, vertical and horizontal) pipe axis in inclined 45° from horizontal and is not rotated (fixed) 6GR Multiple positions, (overhead, vertical and horizontal) pipe axis in inclined 45° from horizontal and is not rotated (fixed), with restriction ring
Fillet Welds
1F Flat position, pipe axis is 45° from the horizontal and the pipe is rotated 2F Horizontal position, pipe axis is vertical 2FR Horizontal position, weld pipe axis is horizontal and the pipe is rotated 4F Overhead position, pipe axis is vertical 5F Multiple positions, (overhead, vertical and horizontal) pipe axis is horizontal and is not rotated 6F Multiple positions, (overhead, vertical and flat) pipe axis is 45° from horizontal and is not rotated

Table 6

Welding Process Comparison Based on Quality and Economics			
	All Positions		
Applications	**GTAW**	**GMAW**	**SMAW**
Carbon steel plate (over 3/16")	G	E	E
Carbon steel sheet (to 3/16")	E	E	G
Carbon steel structural	F	F	E
Carbon steel pipe — 3" IPS and under	E	F	F
Carbon steel pipe — over 4" IPS	G	G	G
Stainless steel plate (over 3/16")	G	E	G
Stainless steel sheet (to 3/16")	E	G	F
Stainless steel pipe — 3" IPS and under	E	F	F
Stainless steel pipe — over 4" IPS	G	G	F
Aluminum plate (over 3/16")	G	E	NR
Aluminum sheet (to 3/16")	E	G	NR
Aluminum structural	E	G	NR
Aluminum pipe — 3" IPS and under	E	NR	NR
Aluminum pipe ” over 4" IPS	E	F	NR
Nickel and nickel alloy sheet	E	F	F
Nickel and nickel alloy tubing	E	NR	NR
Nickel and nickel alloy pipe — 3" IPS and under	E	F	NR
Nickel and nickel alloy pipe — over 4" IPS	E	F	NR
Reflective metals, titanium — sheet, tubing, and pipe	E	NR	NR
Refractory metals, TA and Cb — sheet, tubing	E	NR	NR

GTAW — Gas Tungsten Arc (TIG)
GMAW — Gas Metal Arc (MIG)
SMAW — Shielded Metal Arc (Stick)

E — Excellent
G — Good
F — Fair
NR — Not recommended on basis of cost, usability, or quality.

Table 7

Cost Information			
Weld Process	**Approximate Equipment Cost**	**Average Gas and Power Cost Per Hour**	**Relative Labor Cost**
GTAW	$1,500 – 10,000	7.00	Medium
GMAW	$2,000 – 10,000	8.00	Low
SMAW	$500 – 2,000	1.50	Low/Medium

Table 8

Guide for Shade Numbers				
Operation	**Electrode Size 1/32 in. (mm)**	**Arc Current (A)**	**Minimum Protective Shade**	**Suggested* Shade No. (Comfort)**
Shielded Metal Arc Welding	Less than 3 (2.5)	Less than 60	7	—
	3 – 5 (2.5 – 4)	60 – 160	8	10
	5 – 8 (4 – 6.4)	160 – 250	10	12
	More than 8 (6.4)	250 – 550	11	14
Gas Metal Arc Welding and Flux Cored Arc Welding		Less than 60	7	—
		60 – 160	10	11
		160 – 250	10	12
		250 – 550	10	14
Gas Tungsten Arc Welding		Less than 50	8	10
		50 – 150	8	12
		150 – 500	10	14
Air Carbon	(Light)	Less than 500	10	12
Arc Cutting	(Heavy)	500 – 1000	11	14
Plasma Arc Welding		Less than 20	6	6 to 8
		20 – 100	8	10
		100 – 400	10	12
		400 – 800	11	14
Plasma Arc Cutting	(Light)**	Less than 300	8	9
	(Medium)**	300 – 400	9	12
	(Heavy)**	400 – 800	10	14
Torch Brazing		—	—	3 or 4
Torch Soldering		—	—	2
Carbon Arc Welding		—	—	14
Plate thickness				
Gas Welding				
Light	Under 1/8"	Under 3.2 mm		4 or 5
Medium	1/8 to 1/2"	3.2 to 12.7 mm		5 or 6
Heavy	Over 1/2"	Over 12.7 mm		6 or 8
Oxygen Cutting				
Light	Under 1"	Under 25 mm		3 or 4
Medium	1 to 6"	25 to 150 mm		4 or 5
Heavy	Over 6"	Over 150 mm		5 or 6

*As a rule of thumb, start with a shade that is too dark to see the weld zone. Then go to a lighter shade which gives sufficient view of the weld zone without going below the minimum. In oxyfuel gas welding or cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light of the (spectrum) operation.

**These values apply where the actual arc is clearly seen. Experience has shown that lighter filters may be used when the arc is hidden by the workpiece.

Table 9

Conversion Table U.S. Customary Units to International System of Units (SI) — Metric System			
Property	**Convert From**	**To**	**Multiply By**
Measurement	Inches (in)	Millimeters (mm)	25.4
	Inches (in)	Meters (m)	0.0254
	Feet (ft)	Millimeters (mm)	304.8
	Feet (ft)	Meters (m)	0.3048
Area	in^2	mm^2	645.16
	in^2	m^2	0.000645
	ft^2	m^2	0.0929
Current Density	Amperes/in^2	Amperes/mm^2	0.00155
Deposition Rate	Pounds (lb)/hour (h)	Kilograms (kg)/hour (h)	0.0454
Flow Rate	ft^3/h	Litre/minute	0.472
Pressure, Tensile Strength	Pounds /sq in (psi)	Pascals (Pa)	6895.0
Travel Speed,	in/min	mm/s	0.423
Wire Feed Speed	in/min	cm/m	2.54
Weight, Mass	lb	Kg	0.454
Temperature	Fahrenheit (F˚), ^tF	Celsius (C˚) (centigrade)	$\frac{^tF - 32}{1.8}$
	Celsius (C˚) (centigrade), ^tc	Fahrenheit (F˚)	$^tc \times 1.8 + 32$
Impact Strength	ft lbs	Joules	1.356

Table 10

Control Symbols Found on GTAW Machines			
Functional Area	**Control**	**Wordage/Abbrev.**	**Symbol**
Power	ON	ON	
	OFF	OFF	
Polarity	Electrode Positive	Electrode Positive/DCEP	
	Electrode Negative	Electrode Negative/DCEN	
	Alternating Current	Alternating Current/AC	
Process	SMAW	Stick	
	GTAW	TIG	
Start Mode	Off	Off	
	Lift Arc	Lift Arc	
	HF Start Only	HF Start	
	HF Continuous	HF Cont.	
	Impulse	Impulse	
Output	On	On	
	Remote	Remote	
Trigger	Two Step Maintained	Standard/STD	
	Two Step Momentary	2T Trigger Hold/2T	
	Four Step Momentary	4T Trigger Hold/4T	
Amperage	Panel	Current Panel/A PNL	
	Remote	Current Remote/ARMT	
Gas	Preflow Time	Preflow	
	Postflow Time	Postflow	
	Gas Inlet	Gas In	
	Gas Outlet	Gas Out	
AC Waveshaping	Balance Phase Control	Balance/BAL	
	AC Frequency	Frequency/AC f	
	Maximum Cleaning	Maximum Cleaning/MAX CLEAN	
	Maximum Penetration	Maximum Penetration/MAX PEN	
	Electrode Positive Amperage	Electrode Positive Amperage/EP AMPS	
	Electrode Negative Amperage	Electrode Negative Amperage/EN AMPS	
Arc Force	Percentage Arc Force	DIG	
Sequencing	Initial Amperage	Initial Amperage/INITIAL A	
	Initial Time	Initial Time/INITIAL t	
	Initial Slope Time	Initial Slope	
	Spot Time	Spot Time/SPOT t	•••• t
	Weld Time	Weld Time/WELD t	None
	Final Slope	Final Slope	
	Final Amperage	Final Amperage/FINAL A	
	Final Time	Final Time/FINAL t	
Pulsing	Pulse Frequency	Pulses Per Seconds/PPS	
	Percent Peak Time	Peak Time/PK t	
	Percent Background Amperage	Background Amperage/BKGND A	
	Pulser	Pulser	
Coolant	Coolant Inlet	Coolant In	
	Coolant Outlet	Coolant Out	