Choosing Tungsten Electrodes

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Weld Like a Pro
An ARC-ZONE.COM
Product Selection Guide

General

Introduction

Tungsten is an ideal material for Plasma Arc Welding (PAW) and Tungsten Inert Gas / Gas Tungsten Arc Welding (TIG / GTAW) welding electrodes. Tungsten or wolfram (hence the chemical symbol W) is a very dense gray metal. In fact, its name comes from the term "heavy rock" in Nordic languages. It has several physical characteristics that make it very desirable in industrial applications. Tungsten has the highest melting point (3,422 °C, 6,192 °F) of any pure metal and has the second highest melting point of all elements. It also has the highest tensile strength and lowest thermal expansion of any pure metal. Tungsten is also a good electrical conductor.

In 2000, the world production of tungsten concentrates was 37,400 metric tons. China and Russia are the biggest producers of tungsten by far, followed by Austria, Bolivia, Peru, and Portugal. Australia, Brazil, Canada, France, Japan, Sweden, South Korea, Thailand, and the United States have largely exhausted their known deposits. Deposited in narrow veins, tungsten is usually mined underground rather than from open pits. The ore is crushed and milled to release the tungsten mineral.

In addition to welding, tungsten has a wide variety of industrial uses, especially in cemented carbides (hard metals). Applications include metal wires and contacts for lighting, electrical, electronic, heating, and of course welding applications. Tungsten is also used for armaments (high density penetrators), turbine blades, weights, heat sinks, tool steel, wear resistant coatings, and high-temperature lubricants. The high melting temperature and conduction of tungsten make it outstanding for PAW and GTAW welding electrodes. In normal use, tungsten electrodes are not consumed by the welding process, though some burn-off wear occurs. Electrodes come in clean or ground finishes. Great for heat conduction, ground electrodes have a polished surface and are ground to a uniform size. Electrodes are available from 3" to 24" in length with diameters running from .02" to .25".

Choosing Tungsten Electrodes

When choosing a tungsten electrode's composition, diameter, and tip shape, you should consider:

- The amperage range needed
- The shape and thickness of the welded metal
- The type of welded metal
- The type of welding power source including wave type and output frequencies
- Whether you plan to use AC or DC current

Tungsten Electrodes Alloys

Advantages

While pure tungsten is a good material for electrodes, tungsten rare-earth alloys perform even better. Benefits include:

- Better current capacity, including low-current performance
- Improved point maintenance rather than balling, producing a narrower arc cone with less wandering
- Longer service life

Classifications

Both the International Organization for Standardization (ISO) and the American Welding Society (AWS) have standardized tungsten electrodes in ISO 6848 and AWS A5.12 respectively. The electrodes are classified and color coded by the type and quantity of alloying elements added to the tungsten (see table).

The color appears as a dab of paint on the end of the electrode. The most common types in the U.S. are:

- 1.5% lanthanated tungsten
- 2% ceriated tungsten
- 2% thoriated tungsten
- Pure tungsten
- Rare-earth hybrid tungsten

No matter what alloy you choose, the most important factor is electrode quality. Quality manufacturers test their electrodes for chemical content, density, grain size, length, diameter, straightness, and roughness.

Type of Tungsten Electrodes				
Alloy	AWS Color	AWS Class	ISO Color	ISO Class
None (pure tungsten)	Green	EWP	Green	WP
2% cerium oxide	Orange	EWCe-2	Gray	WC20
1% lanthanum oxide	Black	EWLa-1	Black	WL10
1.5% lanthanum oxide	Gold	EWLa-1.5	Gold	WL15
2% lanthanum oxide	Blue	EWLa-2	Sky-blue	WL20
1% thorium oxide	Yellow	EWTh-1	Yellow	WT10
2% thorium oxide	Red	EWTh-2	Red	WT20
3% thorium oxide			Violet	WT30
4% thorium oxide			Orange	WT40
2% yttrium oxide			Blue	WY20
0.3% zirconium oxide	Brown	EWZr-1	Brown	WZ3
0.8% zirconium oxide			White	WZ8
Rare earth hybrid	Gray	EWG		

Best Uses for Tungsten Alloy Electrodes		
Alloy	AC	DC
None (pure tungsten)	yes	no
Cerium oxide	no high current	no
Lanthanum oxide	yes	yes
Thorium oxide	specialty uses only	yes (top choice for high current)
Yttrium oxide	yes	yes
Zirconium oxide	yes (top choice)	no
Rare earth hybrid	yes	yes

Poorly manufactured tungsten electrodes can present a host of problems including:

- Bends, especially in 1/16" diameter and smaller electrodes, which cause arc performance issues
- Flaking color-coding paint, which can make electrode identification difficult or can contaminate the weld
- Inconsistent diameter, which causes fitting issues with collets
- Inconsistent finish, such as spotty texture and uneven grinding, which causes arc performance issues
- Inconsistent rare-earth dopant distribution, which causes arc performance issues

Pure Tungsten Electrodes

Electrodes made with pure tungsten (WP or EWP) are general purpose budget models (the WP stands for wolfram pure and the E stands for electrode). Pure tungsten is harder to start and maintain a stable arc. It also suffers from high burn-off resulting in a shortened service life. Pure tungsten electrodes are color coded green (both ASW and ISO). These electrodes form a balled tip when heated and have good arc stability for AC balanced-wave welding, especially on aluminum and magnesium. Pure tungsten electrodes are not recommended for DC welding.

Cerium-Oxide Tungsten Electrodes

Electrodes with cerium oxide (ceria) added (WC or EWCe) offer improved arc stability and starting while reducing burn off when compared to pure tungsten electrodes. A 2% cerium oxide alloy is considered a universal moderate-current tungsten electrode. Cerium Oxide Tungsten electrodes are especially good for low-amperage applications, DC orbital tube, pipe, thin sheets, and small parts. Like thoriated tungsten, these electrodes are good for DC welding on carbon steel, stainless steel, nickel, and titanium. In fact, welders often have difficulty discerning any performance difference between ceriated and thoriated tungsten electrodes. Unlike thoriated ones, ceriated tungsten electrodes are not recommended for higher amperages because the oxide will migrate to the tip of the electrode causing arc quality issues. 2% cerium-oxide tungsten electrodes are color coded orange (ASW) or gray (ISO).

Lanthanum-Oxide Tungsten Electrodes

Electrodes with lanthanum oxide (lanthana) added (WL or EWLa) provide similar benefits to cerium oxide, namely improved arc stability and starting while reducing burn off when compared to pure tungsten electrodes. A 1–2% lanthanum oxide alloy is considered a universal tungsten electrode. With similar conductivity characteristics to 2% thoriated tungsten, 1.5% lanthanated tungsten is a good replacement for thoriated tungsten electrodes when the latter is not dictated by code. Lanthanated tungsten electrodes with a pointed end work well for DC negative electrode and AC square-wave power sources. Electrodes with ball-shaped ends work well with AC sine wave power sources. 1% lanthanum-oxide tungsten electrodes are color coded black (ASW and ISO), and 1.5% are color coded gold (ASW and ISO).

Rare-Earth Hybrid Tungsten Electrodes

In addition to the standard alloys, there are many proprietary alloy blends created by manufacturers. In the AWS system, those are designated as EWG.

Yttrium-Oxide Tungsten Electrodes

Electrodes with yttrium oxide added (WY) provide similar benefits to cerium oxide. 2% yttrium-oxide tungsten electrodes are color coded blue (ISO only). Yttrium is sometimes used in proprietary "rare earth" blends.

Zirconium-Oxide Tungsten Electrodes

Electrodes with zirconium oxide (zirconia) added (WZ or EWZr) improve arc stability, starting, and current capacity. They are a top choice for AC welding because they combine the stable arc and balled end typical of pure tungsten with the current capacity and starting characteristics of thoriated tungsten. These electrodes are used radiographic-quality applications with minimum tungsten contamination. .3% zirconium-oxide tungsten electrodes are color coded brown (ASW and ISO), and .8% is color coded white (ISO only).

Thorium-Oxide Tungsten Electrodes

Electrodes with thorium oxide (thoria) added (WT or EWTh) are usually intended for DC applications. They provide similar benefits to the other alloys but can withstand even higher temperatures, depositing less tungsten into the weld puddle. Thorium oxide has fallen out of favor because it is radioactive with the attendant health concerns, especially when grinding an electrode. Alloys with a higher concentration of lanthanum oxide provide similar benefits; however, some codes still specifically call for thorium alloys. Thoriated electrodes are primarily used for DC welding on carbon steel, stainless steel, nickel, and titanium; however, they are also used for specialty AC welding, such as thin-gauge aluminum and materials less than 0.060 inches thick. Thoriated tungsten is especially good at maintaining its sharpened edge, which is essential for thin materials. Thoriated tungsten electrodes are recommended for higher amperages because the oxide will not migrate to the tip of the electrode, causing arc quality issues. 1% thorium-oxide tungsten electrodes are color coded yellow (ASW and ISO), and 2% are color coded red (ASW and ISO). 3% and 4% are color coded violet and orange respectively (ISO only).

Choosing Electrode Sizes

Lengths

Tungsten electrodes come in lengths of 3″, 6″, 7″, 12″, 18″, and 24″ with 7″ being the most common in the U.S. and 6″ (152 mm) the most common in Europe. For automated TIG / GTAW and PAW applications, electrodes are often custom cut and ground to minimize variables.

Diameters

Electrode diameter is determined by the smallest diameter that can handle the amperage that you require. A smaller diameter means greater control and a more focused arc in addition to simply saving money. Rare-earth tungsten alloys increase the current capacity over pure tungsten electrodes. Similarly modern power sources have also increased the current capacity all electrodes. The following charts provide some amperage guidelines:

DCEN (DC Straight Polarity) Tungsten-Electrode Current Capacities	
Electrode Diameter	Pure and Rare-Earth Tungsten Electrodes (Amperes)
0.010” (0.25 mm)	Up to 15
.020” (0.50 mm)	5–20
.040” (1.0 mm)	15–80
0.060” (1/16” or 1.6 mm)	70–150
0.093” (3/32” or 2.4 mm)	150–250
0.125” (1/16” or 1.6 mm)	250–400
0.156” (5/32” or 4.0 mm)	400–500
0.187” (3/16” or 4.8 mm)	500–750
0.250” (1/4” or 6.4 mm)	750–1000

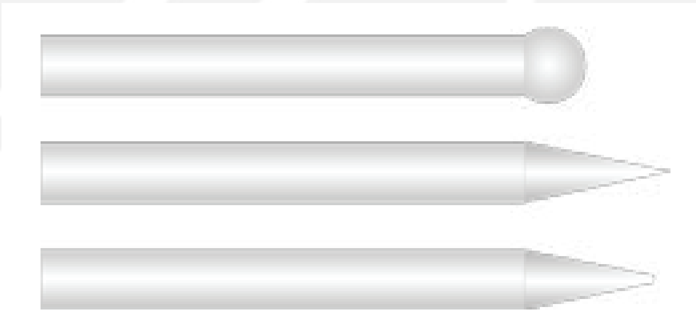
DCPN (DC Reverse Polarity) Tungsten-Electrode Current Capacities	
Electrode Diameter	Pure and Rare-Earth Tungsten Electrodes (Amperes)
0.010” (0.25 mm)	N/A
.020” (0.50 mm)	N/A
.040” (1.0 mm)	N/A
0.060” (1/16” or 1.6 mm)	10–20
0.093” (3/32” or 2.4 mm)	15–30
0.125” (1/16” or 1.6 mm)	25–40
0.156” (5/32” or 4.0 mm)	40–55
0.187” (3/16” or 4.8 mm)	55–80
0.250” (1/4” or 6.4 mm)	80–125

Unbalanced Wave AC Tungsten-Electrode Current Capacities		
Electrode Diameter	Pure Tungsten Electrodes (Amperes)	Rare-Earth Tungsten Electrodes (Amperes)
0.010” (0.25 mm)	Up to 15	Up to 15
.020” (0.50 mm)	5–15	5–20
.040” (1.0 mm)	10–60	15–80
0.060” (1/16” or 1.6 mm)	50–100	70–150
0.093” (3/32” or 2.4 mm)	100–160	140–235
0.125” (1/16” or 1.6 mm)	150–210	225–325
0.156” (5/32” or 4.0 mm)	200–275	300–400
0.187” (3/16” or 4.8 mm)	250–350	400–500
0.250” (1/4” or 6.4 mm)	325–450	500–630

Balanced Wave AC Tungsten-Electrode Current Capacities		
Electrode Diameter	Pure Tungsten Electrodes (Amperes)	Rare-Earth Tungsten Electrodes (Amperes)
0.010” (0.25 mm)	Up to 15	Up to 15
.020” (0.50 mm)	10–20	5–20
.040” (1.0 mm)	20–30	20–60
0.060” (1/16” or 1.6 mm)	30–80	60–120
0.093”		
(3/32” or 2.4 mm)	60–130	100–180
0.125” (1/16” or 1.6 mm)	100–180	160–250
0.156” (5/32” or 4.0 mm)	160–240	200–320
0.187” (3/16” or 4.8 mm)	190–300	290–390
0.250” (1/4” or 6.4 mm)	250–400	340–325

Choosing and Preparing Electrode Tips

Once you’ve chosen the smallest diameter electrode of the correct alloy that can handle your current requirements, the next step is choosing and preparing the correct tip for the electrode. You have three choices: balled, pointed, or truncated.



Ball, pointed, and truncated tips.

Balled Tips

Balled tips are for AC power sources using sine or conventional square wave technology. Pure and zirconiated tungsten are the best alloy choices for balled tips. The ball appears naturally on the electrode when you apply the correct current for the electrode’s diameter. In proper use, the balled end shouldn’t exceed 1.5 times the electrode’s diameter. For instance, the ball on a 1/8” electrode should not exceed 3/16”. If the ball gets bigger than that, the arc will lose stability, and the ball may fall off, contaminating the weld.

Pointed and Truncated Tips

Pointed and truncated tips are best for DC and modern advanced AC welding. A tip provides more control over the arc and makes for easier starting but it also must carry more current over a smaller mass without melting. That is why the higher current capacity of the rare-earth alloys is desirable.

Properly preparing a pointed or truncated tip is critical to performance and a quality arc. You need a grinding wheel that's specifically designed for this purpose. We have a separate Technical Focus Sheet, Grind-ing Tungsten Electrodes with Diamond Wheels, on that topic.

In general, you should grind the electrodes parallel to their length, not at a 90˚ angle. That is, the grinding marks should run the length of the electrode, which minimizes ridges that might encourage arc wander-ing. The taper should be 2 to 2.5 times the electrode's diameter. For instance, a 1/8" diameter electrode should have a taper between 1/4" and 5/16" long.

A pointed tip transfers current in a focused arch that helps prevent distortion in thin metals (0.005" to 0.040"); however, a pointed tip cannot handle high current applications—the tip will melt and drop off, contaminating the weld puddle. For higher power applications, a slightly truncated (flattened) tip is best. To truncate the tip, create a pointed tip first and then grind a 0.01" to 0.03" flat area on the end. For this purpose, you can grind at a 90˚ angle.

About ARC-ZONE.com

Jim Watson

Jim is CEO and founder of Arc-Zone.com. He is a master fabricator with years of hands-on experience in his own shop and also as a winning motorcycle racer, car builder, and chief mechanic for a top motor-sports team. He also has extensive experience in manufacturing, technical sales, and product development. Before launching Arc-Zone.com, he held leadership positions in some of the most respected com-panies in the welding industry.

Arc-Zone.com

Under Jim's direction, Arc-Zone.com has led the industry in product innovation and online sales and service, becoming the world's leading supplier of high-quality, high-performance welding and metal working tools and accessories.

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