DIAMOND GROUND PRODUCTS

TUNGSTEN GUIDEBOOK

GUIDE BOOK FOR THE PROPER SELECTION AND PREPARATION OF TUNGSTEN ELECTRODES FOR ARC WELDING

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This "guidebook for the proper selection and preparation of tungsten electrodes for arc welding" is an effort to provide information for use by welders in various industries.

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Guidebook For The Proper Selection and Preparation Of Tungsten Electrodes for Arc Welding

I. Scope/ Introduction

This specification Booklet is intended to assist welders in selecting and preparing one of the most important and frequently overlooked welding process variables: *the electrode*. Welders can spend thousands of dollars on welding equipment, but if they do not select and prepare their electrodes with this less expensive process component properly, then their welding results can be poor, inconsistent, or problematic. This guide will help eliminate this variable as a concern in your welding and make it an asset.

This information applies only to the selection and preparation of electrodes for Gas Tungsten Arc Welding (GTAW), also known as Tungsten Inert Gas (TIG) welding, and Plasma Arc Welding (PAW). The different types of GTAW and PAW welding that this applies to includes but is not limited to Orbital Tube and Pipe Welding, Automatic/Mechanized TIG Welding, "Micro-TIG," Automatic/Mechanized Plasma Welding, "Micro-Plasma," and Manual Arc Welding. The section of this booklet that describes the proper electrode grinding techniques is dedicated almost entirely to direct current welding, since electrodes for alternating current welding are usually balled and not ground.

The industries that this type of welding applies to includes, but is not limited to, Aerospace, Semiconductor, Biotechnology/Pharmaceutical, Tube Producers, Contractors, Automotive, Fitting and Valve Manufacturers, Industrial, Nuclear, and Specialty Gases.

The technical details of TIG and PLASMA arc welding are that an electric arc is transferred from a tungsten electrode to a work piece. Typically, to initiate the arc high voltage is used to break down and ionize the shielding gas between the electrode and the work piece. Current is then transferred from the electrode to the work to create an electric arc. The tungsten electrode serves as the terminal for the electric arc and fuses together either with or without filler material. Although there are different methods of arc initiation, high voltage arc starting will be referred to in most cases throughout this guidebook.

Tungsten electrode geometry has an affect on the arc shape (thereby affecting the weld bead size and shape), the weld penetration, and point longevity of the electrode. The electrode's geometry is thus a welding variable that should be monitored during weld procedure development. In addition, proper electrode grinding procedures and equipment should be used in order to ensure that electrodes are dimensionally correct. Finally, different tungsten materials poses different characteristics in arc start ability, electrode life, and contamination resistance. This makes the selection of the proper material for your application an important variable in welding performance. The proper preparation of your electrodes in each of these areas will provide the benefits of consistent welding with optimum performance.

II. The Proper Tungsten

Selecting the proper tungsten material for your specific application is dependent on the type of welding you are doing, the composition of the material you are welding, your amperage level, and many other factors. The following section is a guideline to understanding the different options available and will highlight some of the accepted standards. Recommendations are made for different applications that are believed to be reliable information from industry end users and tungsten manufacturers. However, the best way to determine which tungsten material is best suited for your particular application is through testing. Because of the number of process variables, it is very difficult to generalize about which tungsten is best for every application. Testing is crucial.

A. The Basics

Diameters and Lengths – Tungsten Electrodes are available in a variety of standard diameters and lengths. The most commonly used diameters are:

U.S. Customary Measurements	Metric Measurements
.040"	1.0 mm
1/16" (.062" and .060")	1.6 mm

3/32" (.093")	2.4 mm
1/8" (.125")	3.2 mm
5/32" (.156")	4.0 mm
3/16" (.188")	4.8 mm

In addition to these sizes, some manufacturers also offer .020" (0.5mm) and ¼" (6.4 mm) tungsten. The most common length is 7.00" (175 mm). Tungsten is normally sold in boxes of 10 pieces.

Current Ranges- The following chart is reprinted courtesy of the American Welding Society. The chart shows the general current ranges for tungsten using Direct Current and Alternating Current. ***All values listed are based on using argon as the shielding gas. Different electrode materials will vary slightly from these guidelines. Use of other gases will also change the recommended currents.*** **Use this chart as a general guide. Also keep in mind that for a given amount of amperage, larger diameter electrodes will last longer, but will be harder to arc start. Excessive current will cause the electrode to melt and drop off. Insufficient current will lead to unstable arc.**

Recommended Tungsten Electrodes for Various Welding Currents

Electrode diameter			Direct current, a		Alternating current, a	
			Straight polarity	Reverse polarity	Unbalanced wave	Balanced wave
In.	mm.		DCEN	DCEP		
.020"	.050		5-20		5-15	10-20
.040"	1.0		15-80		10-60	20-30
1/16"	1.6		70-150	10-20	50-100	30-80
3/32"	2.4		150-250	15-30	100-160	60-130
1/8"	3.2		250-400	25-40	150-210	100-180
5/32"	4.0		400-500	40-55	200-275	160-240
3/16"	4.8		500-750	55-80	250-350	190-300
¼"	6.4		750-1100	80-125	325-450	325-450

International Color Coding Chart- The material type of each tungsten is easily identified by checking the color of the paint strip that is applied to one end of each stick of tungsten. The color codes are different in the United States, Europe, and Japan. Since those three geographic areas include most of the market share for tungsten sold, all three color codes have been included in the chart below.

Material	United States	Europe	Japan
4% Thoriated	(*)	Orange	(*)
2% Thoriated	Red	Red	Red
2% Lanthanated	Blue (+)	(*)	Yellow-Green
1.5% Lanthanated	Gold (+)	(*)	(*)
1% Lanthanated	Black	Black	Black
2% Ceriated	Orange	Grey	Grey
1% Zirconiated	Brown	White	(*)
Pure Tungsten	Green	Green	Green

(*) not standardized

(+) pending 1997 revision to the ANSI/AWS A5.12 will add standardization.

Standards – The three main areas where tungsten is manufactured and used are America, Europe, and Japan. Each area has a written standard for tungsten electrodes, which dictate the dimensions, packaging, and manufacturing standards that must be adhered to. If particular tungsten falls within those standards it does not necessarily mean that it was manufactured by a high quality manufacturer (as you will see later in the section on Manufacturing Variables). It only means that you claim to conform to the content requirements, the packaging rules, etc. The American standard is known as ANSI/AWS A5.12, the European as ISO 6848, and the Japanese as JIS.

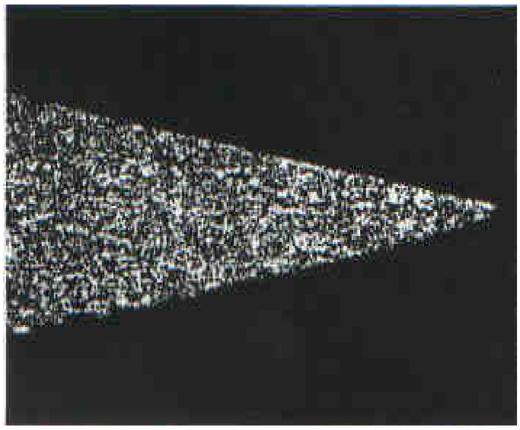
B. Determinants of Tungsten Performance

In most applications, welders use tungsten, which contains an emission enhancing oxide such as Thorium, Cerium, or Lanthanum. These oxides naturally migrate from inside the tungsten to the heat at the point of the electrode, give off their oxide element in the arc, and leave a film of the metal alloy on the tip. This causes the electrode to have a different temperature at the tip based on the work function of that element. The oxides that are emitted at the tip serve to improve arc starting and stability. They also

cause the electrode to provide the same level emission as pure tungsten at much lower temperatures. Lower temperatures improve the longevity of the tungsten and keep the grains within the tungsten smaller for improved arc stability. Thus, oxides are a very important part of tungsten. Each of the available oxides has different physical characteristics that affect tungsten performance. In addition to the oxide's characteristics, the techniques used in manufacturing the tungsten also determine the tungsten performance. All of the determinants of tungsten performance are discussed below.

1) Manufacturing Variables

Grain Size and Structure- The picture below shows the molecular structure of the inside of a point of tungsten and how it is divided into smaller groups called grains. These are very important because it is primarily along the boundaries, or borders, of these grains that the oxides migrate to the tip. It is much easier for the oxides to migrate from inside the tungsten to the tip on the grain boundaries than it is for them to migrate within the crystallized grains. In manufacturing the tungsten, the smaller the size of the grains, the better the oxides will migrate to the tip because this produces more paths for oxides to use. Therefore, the smaller the grains, the better the migration of the oxides to the tip. It is a very difficult process in manufacturing to minimize the size of the grains while maximizing the consistency of the oxide distribution and maintaining the proper quantity of oxides. This is one of the reasons why there are differences in the performance of tungsten produced by different manufacturers.



During the extreme temperatures of welding, the grains have a tendency to combine with larger neighboring grains to form one large grain. This is called grain growth. If a continuous flow of oxides at the grain boundaries is maintained, this serves to surround the grains and pin down the size of the grains and keep them from combining. Thus, oxides are grain growth inhibitors (they also promote electron emission, which will be discussed later in the section on work functions). When tungsten runs out of oxides in any area, the grains combine readily and the tungsten is reduced to poor performance because of the lack of avenues for oxides to move to the surface. In the example in the picture above, notice how this 2% Lanthanated electrode still has a very small grain structure even after one hour of welding time at 180 amps on a 1/16" electrode. As will be explained in this guidebook, this is due to quality manufacturing by this tungsten manufacturer and the oxide properties of
2% Lanthanated tungsten.

Oxide Distribution and Size – Perhaps one of the most important variables in the performance of the tungsten is the oxide distribution. This is also the most obvious factor in determining whether or not a tungsten manufacturer is a high quality producer. It is extremely important for the oxides to be dispersed within the tungsten in a homogeneous manner. As discussed above, if there are any areas with little or no oxides, the grains will easily combine under heat and restrict the flow of oxides to the point. Even though there may be plenty of oxides within the tungsten, if they cannot travel to the point and emit the oxide, the performance of the tungsten will be restricted. On the other hand, if too many are clumped together in one area, bottlenecks will occur to prevent the oxides from getting to the point. Finally, the selection of the raw material oxides to use in manufacturing is also important. Higher quality oxides are smaller in size, which allows them to migrate to the tip easier.

2) Physical Characteristics of Different Oxides

Electron Work Function (eV) – The work function is the energy needed to remove an electron from an atom and is measured in electron volts (eV). The lower the work function of an electrode, the lower the voltage necessary to strike an arc, thus the easier the arc starts. The oxides added to a tungsten serve to promote the electron emission by lowering the work function of the tungsten. Below is a list of different oxides and metals and their respective work functions. The oxide work function is important because the lower the eV for the oxide, the easier it will start. The metal work function is important, because upon emitting an oxide the metal is left as a film on the tip. The lower the eV of the metal at the tip, the lower the temperature will be at the tip which will decrease grain growth and provide a constant flow of oxides and longer service life.

Material	Oxide eV	Metal eV

Lanthanum	2.5	3.3
Thorium	2.6	3.35
Cerium	3.2	2.84
Pure Tungsten	No oxide present	4.5

For each type of oxide, the more of an oxide added to tungsten by the manufacturer, the lower the work function that tungsten will have and thus the better it will arc start. For example, ABC Tungsten Manufacturer makes both 2% Lanthanated and 1% Lanthanated tungsten using the same manufacturing process. 2% Lanthanated will have a lower work function because of a higher volume of oxides and thus the arc will start better.

It is difficult to compare different types of electrodes without testing because of the different properties of the oxides. However, another issue that is important is the density of the oxide. All of the oxides have different densities and thus a 2% by weight thorium, cerium, or lanthanum electrode will all have different amounts of oxides by volume. The following is a list clarifying this:

Material	Density (g/cm3)	Volume % of 2% by weight electrode
Lanthanum	6.15	5.7
Thorium	11.72	3.8
Cerium	6.65	5.2

Therefore, even though they all have 2% by weight of the oxides, 2% Lanthanated tungsten has a significantly higher volume of oxides than 2% Thoriated tungsten to feed to the tip. Warning: even if electrodes are the same type, you can not compare electrodes of different manufacturers using only the work function and volume of oxides because this comparison would not take into account the important manufacturing variables such as grain size and structure of the oxide size and distribution. Therefore, the work function and oxide density numbers should only be used as a general guide. Testing is always the best way to determine which tungsten will be best for you.

Migration and Evaporation Rates- The migration rate, or diffusion rate as it is often called, is the rate at which each of the different oxides naturally travels from inside the tungsten to the heat at the tip of the electrode. The evaporation rate is the rate at which the oxides separate from their metal component and are emitted at the tip of the electrode once they finish migrating there. The optimum-performing electrode is one, which has a balance of good migration and evaporation rates. If the migration rate is slower than the evaporation rate, then there will be an inadequate amount of oxides arriving at the tip to maintain a consistent arc and the tungsten may be reduced to the performance level of pure tungsten. This is due to an inadequate replenishment of oxides from inside the tungsten to the surface. If the evaporation rate is slower than the migration rate, the oxides will be crowded at the point. If both of the rates are very high, welding properties at the beginning of welding will be great, but all of the oxides may be used up quickly. As mentioned earlier, the migration of oxides to the surface does not only depend on the physical properties of the oxide but also the manufacturing techniques used (i.e. oxide distribution, grain size, and structure).

C. The Different Oxide Types

Below is a list of the common oxide types and some of their general characteristics. Once again, testing is the only way to determine which tungsten will optimize your welding performance.

1) Thoriated - This has been the most commonly used type of tungsten for a long time and thus is the standard that is used for comparison to other tungsten. However, since it is a low-level radioactive hazard many users have switched to other alternatives. Regarding the radioactivity, thorium is an alpha emitter but when it is enclosed in a tungsten matrix the risks are negligible. Thus holding a stick of Thoriated tungsten in your hand should not pose a great threat unless a welder has open cuts on their skin. Thoriated tungsten should not get in contact with open cuts or wounds. The more significant danger to welders can occur when thorium oxide gets into the lungs. This can happen from the exposure to vapors during welding or from ingestion of material/dust in the manufacture and grinding of the tungsten. Therefore, precautions should be taken when welding and use of an exhaust system should be implemented to remove the grinding dust from the work area when grinding tungsten. Proper disposal in an environmentally friendly way is also a responsibility. There are discussions under way in Europe about eliminating the use of thorium there altogether because of these problems. Please research this subject yourself to get a complete understanding. Notwithstanding these issues, 2% Thoriated tungsten is still the most commonly used tungsten in America and is a good general use tungsten. It has

one of the lowest work functions, and it performs well when overloaded with extra amperage. However, it does not hold its point as well as some other non-radioactive tungsten that have been introduced. This tungsten is used primarily for DC welding and may split if used for AC welding.

2) <u>Ceriated</u> - Ceriated tungsten was introduced as the first non-radioactive alternative to Thoriated tungsten. 2% Ceriated tungsten is how it is most commonly offered and it is readily available. It is known to be especially good for DC welding with low amperage because it starts very easily at low amps and usually requires about 10% less amps than Thoriated material to operate. Thus it is most popular material used for orbital tube and pipe welding and is also commonly used for welding very small parts. Cerium also has the highest migration rate so it has the best delivery of oxides to the tip at the beginning of use. This gives it good welding properties at the beginning but later you have fewer oxides to surround the grains so you get grain growth (i.e. grains combining) and a significantly reduced migration rate. However, at lower amperages it should last longer than Thoriated tungsten. Because of its properties, it would generally be good for short welding cycles and also where a specific number of welds are called for and then the electrode is to be replaced. Higher amperage applications are best left to Thoriated or Lanthanated material. This tungsten is used primarily for DC welding and may split if used for AC welding.

3) <u>Lanthanated</u> - In Europe and Japan, this has been the most popular alternative to 2% Thoriated tungsten for most applications. It is available as 2%, 1.5%, and 1% Lanthanated tungsten. Lanthanum Trioxide has the lowest work function of any if the materials thus it usually starts easiest and has the lowest temperature at the tip, which resists grain growth and promotes longer service life. Testing of 2% Lanthanated material showed that it offers much longer life than Thoriated if not overloaded and better arc starting in most applications. It is also especially good at (a) resisting the "Thermal shock" of pulsing, (b) welding in situations where there are numerous re-ignitions with a short weld cycle, and (c) resistance to contamination. Welders with tube mill applications have been especially satisfied with this material because its longer life reduces down time. Also, as a general rule it will probably require about 15% less amps to start and sustain low current arcs. The Lanthanum in this tungsten is a "rare earth" material and is not radioactive. It has not been as heavily marketed and used in the United States as in Europe or Japan, however Diamond Ground Products, Inc. has been offering this material since 1993. This tungsten is primarily used for DC welding, but will also show good results for AC welding.

4) <u>Zirconiated</u> - This material is most commonly used for AC welding because it balls up well in AC welding and has a more stable arc than pure tungsten. It also resists contamination well in AC welding. Finally, while it has better current carrying and arc starting characteristics than pure tungsten, on the whole it is the worst non-radioactive tungsten from a performance standpoint.

5) <u>Pure Tungsten</u> - This material has a very high work function thus it is more difficult to start and produce a stable arc than other materials. Also, because of the high work function, the temperature at the tip is higher and grain growth occurs. This leads to an unstable arc, starting difficulty, and a shorter service life. This material is only used for AC welding; however; better alternatives are available.

6) <u>Other Options</u> - In addition to the materials listed above, there are other less common materials, such as 1% Thoriated, 4% Thoriated, 2% Yttriated, and also mixes of different oxides in the same tungsten. Diamond Ground Products, Inc. introduced tungsten called TRI MIX™, which combines three non-radioactive materials into one tungsten. The goal was to make the best possible tungsten by balancing the migration and evaporation rates, while keeping the work function down. It starts and re-ignites very well and offers a particularly excellent service life in welding situations where welding cycles of at least 15 minutes are used. Technical studies in Japan have shown that mixed tungsten is very successful in optimizing welding and thus it is expected that more of this type of product will become available in the U.S. market. The Japanese and European markets are already recognizing the benefits of combining three non-radioactive oxides into one electrode.

D. Conclusion on The Proper Tungsten

The best way to determine which tungsten material is best for your application and whether or not a particular manufacturer produces a high quality tungsten is to perform a series of tests for your particular application. When testing you should document the following properties of the different tungsten:

1. Ease of Ignition (i.e. arc starting)
    a. Ease of first arc start

b. Ease of re-ignition of same tip after previous use(s)

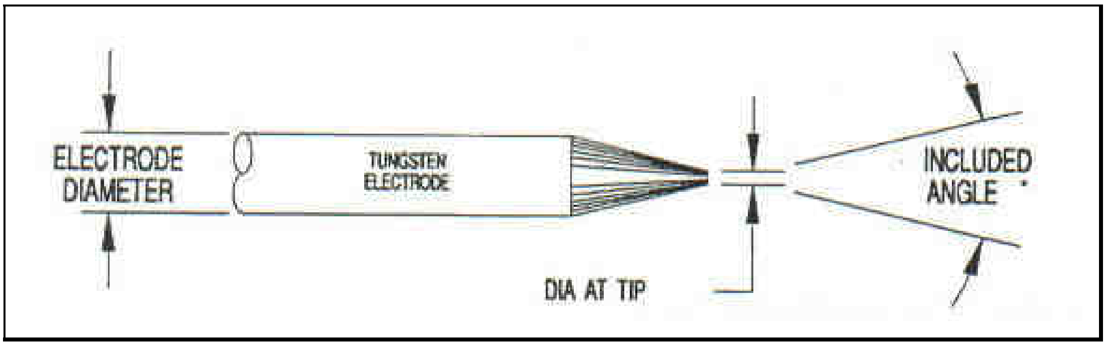
2. Service Life
   a. Maximum number of ignitions
   b. Retention of tip geometry during use
3. Quality of Welds
   a. Arc shape
   b. Arc stability
   c. Quality of welding joint
   d. Depth of weld pool

After some trial and error you will likely discover that you can make improvements to your weld process and lower your costs by utilizing materials that last longer and improve arc starting. In addition, reduced down time in replacing and preparing new electrodes is a substantial savings to consider.

III. The Proper Preparation

A. The Proper Electrode Geometry

Selecting the proper electrode geometry for your particular application is an important consideration in the arc welding process. Tungsten electrodes may be used with a variety of tip geometries. In AC welding, pure or Zirconiated tungsten electrodes are usually used and are melted to form a balled end. This section of the guidebook is dedicated to grinding electrodes for DC welding. The complete geometry for DC welding is comprised of the electrode diameter, the included angle (a.k.a. taper) and the tip (flat) diameter. In addition, the surface finish of the grind is also important.



Your choice of geometry will always be a compromise that will effect the following results: shorter to longer electrode life, easier to more difficult arc starting, deeper to shallower weld penetration, and wider to narrower arc shape (and thus bead shape and size as well). No matter which geometry you select, it is very important that you consistently use the same geometry once a successful welding procedure is established. Electrode configuration is a welding variable that should be tested while welding procedures are being developed, noted as a critical process variable for the weld procedure, and held close tolerances for all subsequent welds.

Electrode Diameter- The welding equipment manufacturer's recommendations are almost always the best way to choose which diameter electrode to use. There are also guidelines published by the American Welding Society, which are duplicated in the Current Ranges chart on page 3 of this guidebook. You will notice that larger diameters can accommodate higher amperages. In addition, if you have chosen the amperage you will weld with and are deciding between two different diameters of electrodes, keep in mind that larger diameter electrodes will last longer than smaller ones, but smaller ones will be easier to arc start. If higher current levels than those that are recommended for a given electrode size are used it will cause the tungsten to deteriorate or breakdown more rapidly. With the erosion of the tip, the probability of tungsten particles falling into the weld pool and defecting the weld much greater. If the current used is too low for a specific electrode diameter, arc instability can occur.

For a given level of current, direct current with the electrode positive requires a much larger diameter because the tip is not cooled by the evaporation of electrons but heated by their impact and thus will become hot and subject to erosion. In fact, an electrode used with DCEP can handle approximately on 10% of the current that it could with the electrode negative. With AC welding, the tip is cooled during the electrode negative cycle and heated when positive. Thus, an electrode on AC can handle the current somewhere between the capacity of an electrode on DCEN and DCEP and about 50% less than that of DCEN.

Electrode Tip/Flat- The shape of the tungsten electrode tip is an important process variable in precision arc welding. A good selection of tip/flat size will balance the need for several advantages. The bigger the flat the more likely arc wander will occur and the more difficult it will be to arc start. However, by increasing the flat to the maximum level that still allows you to start and eliminate arc wonder, you will improve the weld penetration and increase the electrode life by using the larger flat. Some welders still grind electrodes to a sharp point, which makes arc starting easier. However, they risk decreased welding performance from melting at the tip and the possibility of the point falling off in the weld pool. In situations where very low amperage is used or short weld cycles are used (i.e. one second or less) a pointed electrode is desirable, however, outside of these applications it would be beneficial to consider preparing a flat at the end of the electrode. Please refer to your welding equipment manufacturer's recommendations as a starting point for your testing or use the chart below. During the welding operation, the accurately ground tip of a tungsten electrode is at a temperature in excess of 3000°C (5500° F). Without a correct and consistent diameter flat at the tip of the tungsten electrode the following problems can occur:

- Pointed electrode tip drops into weld pool creating weld defect
- Reduction in electrode life
- Arc instability
- Change in arc voltage from one electrode to another due to inconsistent tip shape

Electrode Diameter		General Tip Recommendations
.020"	(0.5mm)	0- .005"
.040"	(1.0mm)	0- .020"
1/16"	(1.6mm)	0- .030"
3/32"	(2.4mm)	.005"- .030"
1/8"	(3.2mm)	.010"- .040"
5/32"	(4.0mm)	.010"- .050"
3/16"	(4.8mm)	.010"- .060"
¼"	(6.4mm)	.010"- .070"

Electrode Included Angle/Taper- Electrodes for DC welding should be ground longitudinally and concentrically with diamond wheels to a specific included angle in conjunction with the tip/flat preparation. Different angles produce different arc shapes and offer different weld penetration capabilities. In general, blunter electrodes that have a larger included angle:

- Last Longer
- Have better weld penetration
- Have a narrower arc shape
- Can handle more amperage without eroding

Sharper electrodes with smaller included angle:

- Offer less arc weld
- Have a wider arc
- Have a more consistent arc

Larger tungsten diameters and higher currents are normally paired with larger tapers in the 25° to 45° range to increase electrode service life and provide a more stable arc. More pointed tips in the 10° to 25° range are used for lower current. The angles listed above are the included angle.

Electrode Angle Surface Finish- The smoothness of the finish on the prepared tip of the electrode will determine some of the characteristics of the welding process. In general, points should be ground as fine as possible to improve welding properties and increase the service life of the electrode. Electrodes that are ground too coarse result in unstable arcs. A standard finish of around 20 RMS, which would still show the longitudinally ground lines to the naked eye, is an all-purpose, quality finish for any application. A high-polished, or mirror-like finish of approximately 6-8 RMS, where few or no lines can be seen, is better for the longevity of the electrode because without any grit to the electrode surface, it is much less likely for contamination to "stick" to the electrode point and thus less erosion takes place. However, for welding power supplies that do not have strong arc starting characteristics, a finish of approximately 20 RMS is better because the longitudinally ground lines will help steadily lead the electrons to the extreme point of the electrode which assists in arc starting. The issue of longitudinal grinding will be covered in greater detail later. Some manufacturers of pre-ground welding electrodes provide coarser finishes in the 30 to 40 RMS ranges, which do not last long, provide unstable arcs, and tend to be too gritty for extended, effective arc starting.

Typical Manufacturers' Recommended Geometries – Many manufacturers have already done testing to determine which electrode geometry is the most beneficial for their equipment in various applications and make this information readily available. Where this testing has not been done, or if this information is not readily available, Diamond Ground Products, Inc. or other industry experts are the best source for this information.

Tolerances Required for Different Applications- Many welding applications are deemed highly critical and require strict tolerances on the length, taper, and flat, in addition to a high polished finish. These applications include orbital tube welding for high purity, pharmaceutical, and aerospace applications, as well as fitting manufacturing and many others. Basic guidelines for tolerances in these applications are ±. 002" for the length, ±½° for the taper, and ± 002" for the tip/flat. Where applications require electrodes to be manufactured to these extreme tolerances it is necessary to use equipment such as an optical comparator, microscope, and micrometer in addition to the precision tungsten electrode grinder, which is required for almost all applications. Other applications will often call for their own specific tolerances. Where not specified, keep reasonable tolerances for the type of work being performed and remain as consistent as possible.

B. The Proper Equipment

In most applications, it is very important that a dedicated, custom tungsten electrode grinder is used. This is because other grinding equipment that may be available at a typical facility either do not offer the means for proper longitudinal diamond grinding or consistency of preparation from one electrode to the next. Because of this, they will take up too much of a welder's costly time to produce an electrode that may not weld or for very long. In addition, a non-dedicated machine will be contaminated with foreign material because it is used for grinding parts other than tungsten. This will contaminate the electrode and cause welding problems.

In order to efficiently produce consistent and repeatable electrodes and welds, please use the following questions for requirements a precision tungsten electrode grinder should meet:

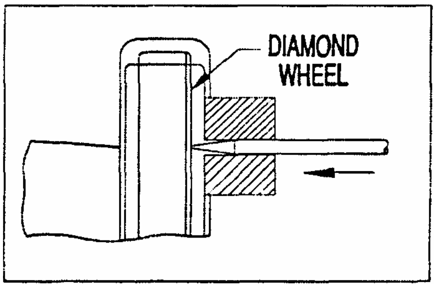
- Does it grind longitudinally? *A necessity.*
- Does it incorporate a diamond-grinding wheel? *Also a necessity.*
- How many electrodes can a typical diamond grinding wheel make before requiring replacement? *The more the better. This also varies based on operator use.*
- If a cutting apparatus is needed, does it offer a diamond-cutting wheel with measurement apparatus? *Notching the electrode and hand breaking is not acceptable* (see page)
- How short can the electrode be cut? *Match this to your needs.*
- What is the surface finish to the electrode after grinding? *20 RMS is fine for most uses, finer finishes are even better.*
- How quickly does it take to flat, grind, and cut a typical electrode? *A .040" diameter electrode should not take more than 60 seconds after setup.*
- What is the process for <u>setup</u> to flat, grind, and cut different electrode diameters, angles, flats, and lengths? *It should sound simple and direct otherwise it will take too long and become cumbersome.*
- What is the process the equipment operator needs to follow to complete one electrode? *It should not be complex so that all welders can repeat the process and produce the same electrode.*
- What tolerances can a typical operator expect to produce for the angle, length, and flat? *Match these to your needs.*
- Are accessories such as vacuum dust collection, on site carrying case, a wide variety of collets, etc. readily available? Is support readily available? What is the warranty? *Match these to your needs.*
- How expensive is it? *Expect to pay quite a bit more than a standard bench grinder, but a good tungsten grinder will pay for itself over time with saved welding time, saved electrode preparation time, and improved welds.*

C. Proper Grinding and Cutting Techniques

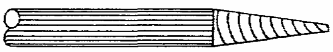
Tungsten electrodes are the crucial electrical carrier in the welding process and must be ground and cut properly. Improperly prepared electrodes can lead to arc wander, splitting, shedding, welding inconsistencies, or expensive mistakes. Properly ground and cut electrodes can improve arc starting and stability.

When grinding and cutting always use diamond wheels. While tungsten is a very hard material, the surface of a diamond wheel is harder and this makes for smooth grinding. Grinding without diamond wheels, such as aluminum oxide wheels, can lead to jagged edges, imperfections, or poor surface finishes not visible to the eye that will contribute to weld inconsistency and weld defects. Also, welders should avoid contact of the electrode with the weld pool. If this does happen, make sure you cut off the contaminated portion of the tip and regrind the electrode from the beginning.

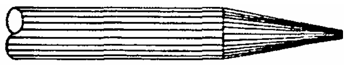
Tip/Flat Preparation - Depending on your welding process, you may be preparing a flat from a new electrode or from a previously used end of an electrode. When preparing a used electrode, if the end you will be grinding is exceedingly contaminated than you should cut off this old tip first before preparing the flat. The figure below illustrates how to recondition an electrode with minimal contamination. This procedure would also work with a new electrode or an electrode with the contamination cut off. You simply push the electrode at exactly a 90° angle to the side of the wheel. There should be an apparatus to hold the tungsten so that the angle is maintained.



Taper Grinding – The most important element of proper taper grinding is that the electrode must be ground longitudinally (lengthwise). Grinding electrode tips crosswise has a negative effect on the stability and formation of the arc at the electrode tip. Tungsten electrodes are manufactured with the molecular structure of the grain running lengthwise and thus grinding crosswise is "grinding against the grain." More importantly, electrons flow at a greater density on the surface of the electrode. If electrodes are ground or polished crosswise the electrons have to jump across the grinding marks. The arc begins before the tip, spreads out, and usually wanders. The tungsten electrode becomes overheated and wears out quicker. By grinding longitudinally with the grain, the electrons are led steadily, with less difficulty to the extreme tip of the tungsten electrode. The arc starts straight and remains narrow, concentrated, and stable. The electrode is subjected to less Thermal shock, and therefore lasts longer.

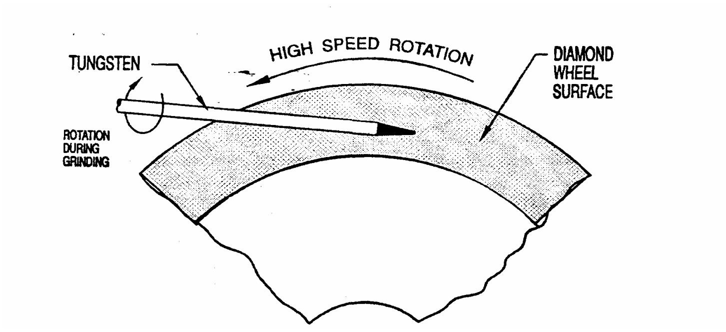


WRONG: crosswise grind marks restrict welding Current, cause arc wander, risk inclusions.



RIGHT: lengthwise grind marks don't restrict Current. Mirror finish is even better.

For the best possible arc stability, diamond grinding of tungsten electrodes should be done with the length of the electrode at a 90° angle to the axis of the grinding wheel (see figure below). The diamond-grinding wheel should not be used for grinding anything other than tungsten to ensure that the wheel and thus the tungsten tip will not become contaminated during the grinding operation and then transfer that foreign material to the weld.



Cutting to Length - One of the most overlooked areas of tungsten electrode preparation is the cutting operation or contaminated tip removal. Contaminated tungsten electrode tips are a common problem that confront TIG welders. A contaminated electrode produces an erratic arc and a dirty, contaminated weld. The best way to ensure that all contamination is removed from the tip is to cut off that part of tungsten. Regrinding the tip when contaminated may not remove all of the contamination and can deposit the contamination on the grinding wheel, only to be picked up again in future grinding.

Because tungsten is a very hard material, proper cutting involves using a diamond-cutting wheel for consistent, clean cuts. Many welders cut their tungsten incorrectly using one of the following methods:

a) **For .040" and 1/16" diameter electrodes using wire cutters or hands to break electrodes.**
b) **For 3/32" or 1/8" diameter electrodes using two pairs of pliers and a twisting motion or notching the electrode on the grinding wheel and then breaking the electrode by hand or with pliers**
c) **For electrodes larger than 1/8" diameter using a sharp hammer blown to the electrode on a sharp metal edge or notching the electrode on a grinding wheel and then hitting with a hammer on a sharp metal edge.**

All of these methods risk safety and weld problems. You can splinter or shatter the electrode and not notice it. When using a fractured electrode you can get arc instability, parts of the tungsten dropping into the weld pool creating a weld defect, or other problems. Also, if the tungsten shatters there is the risk of eye or hand injury. In any case, it is much easier to cut an electrode quickly and properly with the correct cutting apparatus designed specifically for how hard and brittle tungsten is.

The cutting apparatus should keep the tungsten rigidly secure on either side of the cut for stability and so that the cut is exactly at a 90° angle. Using a diamond cutting wheel will ensure that the cut will be clean and smooth and is void of fractures or splintering. Never use a silicon carbide wheel, which contaminates the tungsten. The apparatus should be quick and easy to use, have safety covers, and provide a scale to ensure the exact length is measured and cut.

IV. DGP Products That Meet Welders' Needs

Diamond Ground Products, Inc. specializes in maximizing the quality and consistence of one of the most frequently overlooked welding process variables: *the electrode*. Below is a description of the products we offer that can improve and maximize the efficiency of welding process.

A. The Proper Tungsten

Our factory is a "One-Stop-Shop" for all of your tungsten needs. We stock all the sizes of the most commonly used tungsten: 2% Thoriated, 2% Ceriated, 2% Lanthanated, and our trademarked multi-oxide blended tungsten called TRI-MIX™. In order to service all of your possible tungsten needs, we also offer 1% Lanthanated, 1½% Lanthanated, 1% Zirconated, and Pure tungsten with reasonable delivery times. Free evaluation samples are always available for welders to determine which type of tungsten will maximize their welding performance.

B. The Proper Precision Tungsten Electrode Grinders

To develop the first tungsten electrode grinder that actually meets the needs of welders, we worked closely with actual end users to learn what they wanted to accomplish and how they wanted to do it. The result of this project was an economical system for quick and easy preparation of tungsten electrodes for TIG and Plasma welding applications. This system makes up the core of all of our models (DGP-1, DGP-2, and DGP-3) to allow users to longitudinally diamond grind the angle (taper) and tip (flat) of the electrode. The DGP-2 and DGP-3 models have additional capabilities that allow users to quickly and easily diamond cut electrodes to correct lengths using either a stop/scale or a micrometer. All of these models are available with vacuum assisted dust collection units that include a tool cabinet and flexible spotlight. Adding a "-V2" to the end of the model number reflects this option. For example, the tungsten grinder pictured is the DGP-2-V2. There are also practical accessories available such as a tip/flat measurement gauge and a carrying case for transportation to a work site. Free samples electrodes ground on these machines are available upon request.

C. Properly Pre-Ground and Cut Electrodes

For applications like orbital welding, which require extreme tolerances, we offer Pre-ground Welding Electrodes that are cut, ground, and finished to the user's specifications. We adhere to tolerances of ±.002" on the length, ±½° on the included angle (taper), and ±.002" on the tip flat. We are the leading manufacturer of this product in the U.S. Please call or write for free evaluation samples in either our standard 20 RMS or our High Polished 6-8 RMS finishes.

V. Conclusion

This guidebook has attempted to assist the welder in determining which type of electrode material to use and how to properly prepare it. This will benefit the welder with improved weld quality and, in the long run, lower costs. Hopefully, it will also help avoid the headaches and problems that are sometimes difficult to solve when your welding application just isn't working as well as it could and you are not sure why. In addition, I hope that it will assist welders in avoiding the expense of having to discard improperly welded parts and start over.

If you have any questions about the topics discussed in this guidebook or any of the products that Diamond Ground Products Ltd. offers, please do not hesitate to call us at: +44 (0)1480 459706 or e-mail sales@diamondground.co.uk