TIG Welding for Dummies®

Miller Electric Special Edition

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Welcome to *TIG Welding For Dummies*, Miller Electric Special Edition! In this book, we tell you all about the innovative process of TIG (Tungsten Inert Gas) welding, also known as GTAW (Gas Tungsten Arc Welding). Along the way, we cover the get-in, get-out information you need to know: basics of the process, info about equipment and peripherals, safety tips, and the different types of joints and welds you may run across.

**About This Book**

So that we can draw your attention to new terms and define them for you, we put these terms in italic typeface.

**Foolish Assumptions**

We assume that you are either new to welding or, at the very least, new to TIG welding. For that reason, we cover the basic concepts of TIG welding and how it differs from other welding processes that you may (or may not) be familiar with.

**How This Book Is Organized**

This book is divided into six chapters that hit the highlights of the TIG welding process.

- **Chapter 1: Getting to Know TIG Welding.** In this chapter, we cover the basics and background of TIG welding: current, polarity, and arc starting methods. We also cover the pros and cons of the TIG process compared to other arc-welding processes.

- **Chapter 2: Gearing Up: TIG Welding Equipment.** This chapter covers the major equipment you need: welding machines, torch, coolants, and remote controls.
Chapter 3: Choosing Electrodes and Consumable Materials. This chapter goes into detail on electrodes and consumables used in the TIG welding process, such as shielding gas and filler metal.

Chapter 4: Putting Safety First. Chapter 4 shows you how to avoid the hazards that go with the territory, like electrical shock, flash burn, and fumes.

Chapter 5: Preparing to Weld. This chapter covers preparation: getting the power source, joint, and base metals ready for welding.

Chapter 6: Selecting Joints and Welds. At last, you’re ready to weld, and this chapter delves into the topic. We cover the different types of joints and welds and their uses.

The Icons Used in This Book

Like all books in the For Dummies series, this one uses icons to draw your attention to important points.

Keep an eye out for this icon: It indicates a clever or useful bit of info you’ll need.

This icon indicates a hazardous situation, which if not avoided, could result in death or serious injury.

When you see this icon, you find a fact that you want to file away in your brain for future reference.

This icon denotes interesting, but not necessarily crucial, technical information that you may want to skip over if you’re so inclined.

Where to Get Started

Get started anywhere you like! Begin at Chapter 1 and read the book straight through if you feel like you need a real overview of the TIG welding process. Otherwise, flip to the chapter that interests you most and jump in!
Chapter 1

Getting to Know TIG Welding

In This Chapter

- Discovering the uses of TIG welding
- Understanding alternating and direct current
- Starting the arc

Are you a complete beginner to welding? Or do you wonder how TIG welding differs from the other types of welding you’re familiar with? If so, look no further: In this chapter, we give you the lowdown on TIG welding: its advantages and disadvantages, how it works, and how it compares to other types of welding.

Discovering TIG Welding

Arc welding uses an electrical power supply to create an arc between an electrode and the base material. TIG welding (TIG stands for Tungsten Inert Gas) is the more commonly used name for the Gas Tungsten Arc Welding (GTAW) process and is one of many types of arc welding. The necessary heat for TIG welding is produced by an electric arc that is maintained between a non-consumable tungsten electrode and the part to be welded. Non-consumable means that the tungsten will not melt to become part of the weld pool.

The molten metal and the tungsten electrode are both shielded from the atmosphere by a blanket of inert gas fed through the TIG torch. Inert gas is inactive, or deficient in active chemical properties. The shielding gas blankets the
weld and excludes the active properties in the surrounding air, which keeps impurities out of the final weld. The shielding gas doesn’t burn, add, or take anything from the metal. Inert gases such as argon and helium are the most commonly used for TIG welding. These gases possess no odor and are transparent, giving the welder maximum visibility of the arc. The TIG welding process, shown in Figure 1-1, can produce temperatures of up to 35,000°F/19,426°C. The torch contributes heat only to the work piece. If filler metal is required to make the weld, you can add it manually in the same manner as you would in the oxyacetylene welding process.

![Diagram of TIG welding process](image)

**Figure 1-1:** The TIG welding process.

**Advantages of the TIG Welding Process**

The biggest advantage of the TIG welding process is that it will weld more kinds of metals and metal alloys than other arc-welding processes. You can use TIG to weld most metals, including stainless steel, nickel alloys, titanium, aluminum, magnesium, copper, brass, bronze, and even gold. You can also use TIG welding to weld dissimilar metals to one another, such as copper to brass and stainless to mild steel. In the next sections, we look at a few more advantages of the TIG welding process.
Concentrated arc

TIG welding has a concentrated arc, which permits pin-point control of heat applied to the work piece, resulting in a narrow heat-affected zone. The heat-affected zone is where the base metal has undergone a change due to the superheating of the arc, followed by fast cooling. The heat-affected zone is where the welded joint is weakest and is the area along the edge of a weld that would be expected to break under a destructive test. A narrow heat-affected zone is the result that is typically desired. TIG welding is great for producing a narrow heat-affected zone. A high concentration of heat is an advantage when you’re working with metals with high heat conductivity such as aluminum and copper.

No slag

Unlike some other types of welding, flux is not needed; therefore, no slag is produced to obscure the welder’s vision of the molten weld pool. The finished weld has no slag to be removed between passes. Entrapment of slag in multiple pass welds is seldom seen.

No sparks or spatter

In the TIG welding process, no metal is transferred across the arc. You have no molten globules of spatter to contend with and no sparks are produced, as long as the material being welded is free of contaminants. When welding in DC (direct current) polarity, the TIG welding arc is quiet, without the usual cracks, pops, and buzzing of Shielded Metal Arc Welding (SMAW, or stick) and Gas Metal Arc Welding (GMAW or MIG). Generally, the only time noise is a factor is while welding on alternating current (AC) with the TIG process. AC does produce a buzzing sound.

No smoke or fumes

The TIG process itself does not produce smoke or fumes. If the base metal being welded contains coatings or elements (such as lead, zinc, nickel, or copper) that produce fumes, these must be contended with as in any fusion-welding
process done on these materials. If the base metal contains oil, grease, paint, or other contaminants, smoke and fumes are produced as the heat of the arc burns them away. To avoid this, be sure to clean the base metal before you begin welding.

**Disadvantages of the TIG Welding Process**

Here’s a list of the disadvantages you can encounter with TIG welding.

- The main disadvantage of the TIG welding process is the *low filler metal deposition rate*, which refers to how much filler you can place in a period of time.
- Another disadvantage is that the hand-eye coordination necessary to accomplish the weld is difficult to learn and requires a great deal of practice to become proficient.
- Also, arc rays produced by the process tend to be brighter than those produced by stick and MIG welding. This situation is primarily due to the absence of visible fumes and smoke created by these other welding processes.

To avoid the hazards of the bright UV rays, be sure to follow the safety procedures we outline in Chapter 4: Take care to protect your skin with the proper clothing and protect your eyes with the correct lens. Also, concentrations of shielding gas may build up and displace oxygen in confined spaces, so make sure that the areas you’re welding in are ventilated properly.

**Getting the Gist of TIG Welding**

The two most basic parameters of welding are the amount of current in the circuit and the amount of voltage pushing it. Current and voltage are further defined as follows:

- **Current**: The number of electrons flowing past a given point in one second, measured in amperes (amps).
- **Voltage**: The amount of pressure induced in the circuit to produce current flow, measured in voltage (volts).
TIG welding is typically done with Direct Current Electrode Negative (DCEN) polarity, and in alternating current (AC). Welding with DCEN polarity is typically used for welding steel, stainless steel, copper, and most other materials that are weldable. AC is typically used for welding aluminum and magnesium.

**Alternating Current**

Alternating current (AC), as shown in Figure 1-2, is an electrical current that has both positive and negative half-cycles. These current cycles don't occur simultaneously, but alternately, thus the term *alternating current*. Current flows in one direction during one half of the cycle and reverses direction for the other half. The half cycles are called the *positive half* and the *negative half* of the complete AC cycle. Together, this "hill" (positive half) and "valley" (negative half) represent one cycle of alternating current.

![AC Cycle Diagram](image)

**Figure 1-2**: Alternating current.

Alternating current is used while welding aluminum and magnesium. An AC sine wave (refer to Figure 1-2) is a graphical representation of alternating current.
Squarewave AC

Some TIG welding power sources, due to refinements of electronics, have the ability to rapidly make the transition between the positive and negative half-cycles of alternating current. When you’re welding with AC, the faster you can transition between the two polarities (EN and EP) and the more time you spend at their maximum values, the more effective the machine is. The miracle of modern electronic circuitry now makes it possible to make this transition almost instantaneously. The effective use of the energy stored in magnetic fields results in waveforms that are relatively square. Note: Waveforms aren’t truly square due to electrical inefficiencies in the Squarewave power source. However, the Advanced Squarewave TIG welding power source has improved efficiencies and can produce a nearly perfect squarewave.

Frequency

The rate at which alternating current makes a complete cycle is termed frequency. Figure 1-3 illustrates a couple of different frequencies. Electrical power in the United States is delivered as 60 cycles per second frequency, or to use the proper terminology, 60 hertz (Hz). This means that 120 times per second the current changes to positive, then negative. The power input to an AC welding machine and other electrical equipment in the United States today is 60 Hz power. Outside of North America and the United States, 50 Hz power is more commonly used. The operating frequency that we refer to here isn’t the same as high frequency that’s used to start, and stabilize, the welding arc.

Frequency has a big effect on the performance of the welding arc. Increasing the frequency of an AC wave will narrow your arc cone and make the arc more focused. This more focused arc translates into more control of the welding puddle.
Direct Current

Direct current (DC) is an electrical current that flows in one direction only. Direct current can be compared to water flowing through a pipe in one direction. Most welding power sources are capable of welding with direct current output. They accomplish this with internal circuitry that changes or rectifies the AC into DC.
Aligning the Poles: Discovering Polarity

With DC, welding can be done on electrode negative or electrode positive (which is rarely used for TIG). These two options cause a change in the electrical charge that the electrode has and changes the direction that the electrons are flowing in the welding circuit. This positive or negative charge is referred to as polarity. If you use a negative electrode while welding, you get a negative polarity.

When TIG welding, the welder has three choices of welding-current type and polarity. These choices are

- **Direct current electrode negative** (DCEN, or straight polarity)
- **Direct current electrode positive** (DCEP, or reverse polarity)
- **Alternating current** (AC), which is actually a combination of both electrode negative and electrode positive polarity

Each of these current types has its applications, its advantages, and its disadvantages, which we cover in the next few sections. Taking a look at each type and its uses helps you to select the best current type for your job.

**Direct current electrode negative**

Direct Current Electrode Negative (DCEN) is also sometimes called straight polarity. DCEN is used while welding steel, stainless steel, copper, titanium, gold, and pretty much any other material that can be welded with the exceptions of aluminum and magnesium, which are welded using AC.

The torch is connected to the negative terminal of the power source and the work lead is connected to the positive terminal. Power sources with polarity switches have the output terminals marked electrode and work.

When the arc is established while welding in DCEN, electrons flow from the negative electrode to the positive work piece. In
a DCEN arc, approximately 70 percent of the heat generated by the arc occurs in the work piece — thus you can use a smaller electrode, as well as a smaller gas cup and reduced gas flow. The more concentrated arc allows for faster travel speeds. This concentrated arc also accounts for the deep penetration when using DCEN for TIG welding.

**Direct current electrode positive**

Direct Current Electrode Positive (DCEP) is also known as reverse polarity. Welding is not typically done with DCEP. When using this polarity, the electron flow is still from negative to positive; however, the electrode is now the positive side of the arc and the work is the negative side. About 70 percent of the heat of the arc is focused on the positive side of the welding arc. On DCEP, 70 percent of the heat is focused directly on the tungsten, which creates a large ball on the tungsten. For welding with DCEP, a very large tungsten is typically needed. Between the large tungsten and the nature of a DCEP arc, the arc can be very erratic and quick to wander — which is the main reason that this polarity is typically undesirable for TIG welding.

The arc, though erratic, does create a cleaning effect for welding on aluminum and magnesium.

**Alternating current**

To weld aluminum, the best combination is the good penetration of electrode negative plus the cleaning action of electrode positive. To obtain the advantages of both polarities, use alternating current to weld aluminum.

During a complete cycle of alternating current, there is theoretically one half-cycle of electrode negative and one half-cycle of electrode positive. Therefore, during every cycle, there is a time when the work is positive and the electrode is negative, and a time when the work is negative and the electrode is positive; in theory, the half-cycles of alternating current sine wave arc are of equal time and magnitude.
AC is used while welding aluminum and magnesium. The main reason why AC works so well for aluminum and magnesium is that both materials have a thin layer of protection called an oxide layer. This oxide layer has a melting temperature of about 3700 °F. Aluminum and magnesium melt at about 1200 °F. In order to break through this oxide layer, the electrode positive side of an AC waveform has a cleaning effect that lifts this oxide off the surface. This is why when welding aluminum on DCEN, the weld looks so dirty. DCEN does not have the cleaning portion of DCEP to help lift this oxide layer off the surface.

Getting to Know Arc Starting Methods

TIG welding uses a non-consumable electrode, which means that the electrode doesn’t melt to become part of the weld pool. Because this tungsten electrode isn’t compatible with the metals being welded (unless you happen to be welding tungsten), it requires some unique arc-starting and arc-stabilizing methods. We cover these methods in the next few sections.

High frequency

High frequency, shown in Figure 1-4, is a high voltage/low amperage charge generated at a very high cycle or frequency rate. Frequency rates of up to approximately 1 million cycles, or Hz, are typical. High frequency is used for two main purposes. The first purpose is starting the welding arc. This arc-starting method makes it possible to start welding without your tungsten making contact with the material being welded. High frequency ionizes the shielding gas used in this process and provides a good path for the current to follow. The path between the electrode and the work becomes much more conducive to the flow of electrons, and the arc literally jumps the gap between the electrode and the work piece. Touching the tungsten to the work can contaminate the work as well as the tungsten. High frequency can be used to start the arc without making contact with the work, eliminating this possible chance of contamination.
High frequency is also used to stabilize the welding arc. When welding on AC, your amperage is positive and negative alternately. At the point that the amperage switches negative to positive, the arc becomes very unstable. If high frequency is used continuously, the arc is much more stable. Without high frequency, it is very common for the arc to experience an outage (the arc will extinguish).

High frequency falls under the control of the Federal Communication Commission (FCC) and can cause interference problems with all types of electrical and electronic devices if the welding machine is not properly installed.

**Lift-Arc**

The Lift-Arc arc-starting method is often mistaken with scratch start (see the following section). Scratch start and Lift-Arc are not the same thing. The Lift-Arc arc-starting method allows the tungsten to be placed in direct contact with the metal to be welded. As the tungsten is lifted off the part, the arc is established. This is sometimes referred to as *touch start*. Little if any contamination is possible due to special power-source circuitry. After the arc is established, the power-source circuitry switches from the Lift-Arc mode to the weld power mode, and welding can begin.
Scratch start

The scratch-start method of starting an arc is not generally considered appropriate as it can easily lead to contamination in the weld area. Scratch start is typically used when doing TIG DC welding on a power source designed for stick welding only. These machines are not equipped with an arc starter, so the only way to start the arc is by direct contact of the tungsten electrode with the metal. This is done at full weld power level and generally results in contamination of the electrode and or weld pool. The scratch-start method, as the name implies, is accomplished much like scratching or striking the arc, as would be done with stick welding.
Chapter 2

Gearing Up: TIG Welding Equipment

In This Chapter
- Deciding on the right machine
- Choosing the sources of power
- Discovering duty cycles
- Working through different phases
- Cooling the torch
- Taking in the joy of remote controls

Before you can start welding, you have to gear up with the right equipment. You have decisions to make about everything from the welding machine itself to peripherals like torches and coolers. In this chapter, we tell you everything you have to know about selecting the right equipment to get you started.

Choosing the Right Welding Machine

With the many types of welding machines available, you have to take a lot of factors into consideration in order to make sure that you're using the right machine for the job. You have to determine the range of amperage (amps) needed for a particular process and select a welding machine to meet those needs. Rated output of the welding machine is also an important consideration. Remember, the output must be within a proper duty-cycle range. A duty cycle is the time for which you can use a specific machine.
You often can do light welding (with low output requirements of about 200 amps or less) with single-phase welding machines. Duty cycles are often in the 60 percent or less range. (For more on how duty cycles are measured, flip ahead to the “Understanding Duty Cycles” section later in this chapter.) These single-phase welding machines are especially suited for shops and garages where only single-phase power is available.

Some of these smaller single-phase machines may be capable of using 115 volt AC primary power. Other machines may use 230 volt or higher primary power.

Larger DC TIG welding machines used for heavy-plate, structural-fabrication, and high-production welding generally need three-phase AC input power. Most industrial locations are supplied with three-phase power because it provides the most efficient use of the electrical distribution system — and it's required by many electric motors and other industrial electrical equipment.

These large DC TIG welding machines often have capacities of more than 200 amps, and often have 100 percent duty cycles.

So that you can best understand the arc welding power source and its requirements, we start at the arc and work back to the wall receptacle.

The TIG welding process requires the welder to maintain a consistent arc length. Any variation in arc length affects the voltage. The longer the arc, the higher the voltage — and the shorter the arc, the lower the voltage. As the arc is moved across the part being welded, the welder will have difficulty maintaining the arc length and the voltage will change. This change in arc length/voltage causes inconsistencies in the final weld bead.

**Keeping Current: Constant Current Power Sources**

Arc-welding power sources are classified in terms of their output characteristics with regard to voltage and amperage. They can be constant current (CC), constant voltage (CV), or both. A constant-current machine, the kind used in TIG
welding, maintains close to a constant-current flow in the weld circuit no matter how much the voltage (arc length) varies.

Processes like TIG and Shielded Metal Arc Welding (SMAW), also known as stick welding, require the welder, not the equipment, to maintain the arc length. A constant-voltage power source maintains voltage close to a preset value no matter how much current is used in the process. This type of power source is used in Gas Metal Arc Welding (GMAW), also known as Metal Inert Gas (MIG) welding. Processes like MIG and Flux Cored Arc Welding (FCAW) utilize the equipment to help maintain a specific arc length.

You'll notice that in both cases we say that these machines maintain current and voltage values close to preset values respectively. Be aware, however, that the values will vary slightly because no power source is perfectly efficient.

The volt-amp curve shown in Figure 2-1 is indicative of those curves seen in TIG-welding power sources. The sloping line on the constant-current graph represents the output of a magnetic amplifier power source. Because of this sloping characteristic, these power sources are often referred to as droopers.

![Figure 2-1: Volt amp curve of a CC power source.](image)

Figure 2-2 is an example of a basic DC power source for TIG welding. The single-phase high voltage, low amperage is applied to the main transformer. The transformer transforms this high voltage to low voltage and at the same time transforms the low amperage to high amperage for welding. It does
not affect the frequency, which is 60 Hz in and 60 Hz out. This low voltage, high amperage is now rectified from AC to DC in the rectifier.

Rectification produces a fairly rough DC current unlike the power provided by a battery. A filter is used to smooth and stabilize the output for a more consistent arc. The filtered DC is now supplied to the TIG torch. Line frequency (the frequency at which electricity is sent over power lines, which is 60 Hz) power sources tend to be large and very heavy. Their arc performance is slow and sluggish, which eliminates them from being used for advanced wave shaping or pulsing.

True constant-current power sources are an advantage in that the current that is set is what's delivered to the welding arc. These electronically controlled power sources are more desirable than the older-style power sources and have applications in both manual and automatic welding. The current settings are very accurate, and welds are very repeatable. The electronically controlled and inverter-type power sources have special circuits that maintain their output very consistently. This is accomplished with a closed-loop feedback circuit. This circuit compares the output current going to the arc against what has been set on the machine. Think of a car with the cruise control on: If the car goes up and down a hill, the speed is maintained without input from the driver. In that same fashion, if the welder raises and lowers the arc, the amperage is maintained.

This ability to maintain a consistent output is also helpful for line-voltage compensation. By law, power companies must supply a consistent voltage. However, power companies are allowed a range, which can be as much as plus or minus 10 percent of the nominal voltage. If the primary voltage to a non-compensated TIG-welding power source changed up
to 10 percent, the power going into the arc can fluctuate from 10 to 20 percent. With a line-voltage-compensated machine, a plus or minus fluctuation of up to 10 percent on the primary will only have a plus or minus 2 percent change in the arc, thus creating a very consistent weld. Most electronically controlled power sources can also be used to provide pulsed welding current. Due to the fast response time and great control over the current level setting that electronically controlled power sources offer, two different heat levels pose no difficulty for these types of power sources.

Electronically controlled power sources can also be remotely controlled, and these controls can be very small and compact. The remote controls are small enough to be mounted directly on the torch or built into the torch handle. However, design limitations can make them more difficult to operate, and may take more time to learn and get used to than simpler control designs.

**Becoming Familiar with the Inverter Power Source**

Inverter power sources were first conceived of in the 1940s, but weren't successfully marketed until the 1970s. Instead of operating at a line frequency input power of 50 or 60 Hz, inverters boost the frequency to as much as 1,000 times that of the input frequency. This allows for a drastic reduction in the number of transformer coil turns and a reduced coil area, resulting in a machine much smaller and lighter in weight than a conventional transformer-rectifier power source.

Another major advantage of this type of machine is its primary power requirements. Some inverters can be used on either three-phase or single-phase input power, and either 50 or 60 Hz. This is because the incoming primary power is rectified and converted to the extent that it's not a critical factor. This is an advantage because you can use this type of machine in both an industrial setting (three-phase) and in the home (single-phase). This type of machine can also be used internationally because many other countries use 50 Hz line frequency. (Welders in the U.S. use 60 Hz.)
Inverter machines can run on single- or three-phase power, which we cover in the next section. As Figure 2-3 illustrates, the first thing the inverter does is rectify the high-voltage, low-amperage AC into DC. The DC current is then filtered and fed to the inverter's high-speed switching devices. Just like a light switch, the switching devices turn the power on and off. These devices can switch at a very fast rate, up to 50,000 times per second. This high-voltage, low-amperage, fast DC switching looks like AC to the transformer, which is many times smaller than a 60 Hz transformer. The transformer steps the voltage down and increases the amperage for welding.

This low voltage, high amperage is filtered for improved DC arc-welding performance or converted to AC through the electronic polarity control. The AC or DC power is then provided to the TIG torch. This AC is fully adjustable.

![Image of inverter power source block diagram]

**Figure 2-3**: An inverter power source block diagram.

**Understanding Duty Cycles**

As mentioned earlier in this chapter, duty cycle is of prime importance in the selection of a welding machine. The duty cycle of a welding power source is the actual operating time you can use it at its rated load, without exceeding the temperature limits of the insulation in the component parts.

The duty cycle in the United States is based on a 10-minute time period. Simply stated, if a power source is rated at a 50 percent duty cycle and it is operated at its rated output for
5 minutes, the power source must be allowed to cool for 5 minutes before operating again. The duty cycle is not cumulative. For example, a power source with a 50 percent duty cycle cannot be operated for 30 minutes then allowed to cool for 30 minutes. This violates the 10-minute rule. Read on.

The 10-minute rule states that no matter what the duty-cycle rating is, it’s measured over a 10-minute time period. The preceding example uses 50 percent for a given output (say, 150 amps). The amount of welding time required for the overall project you’re working on doesn’t matter; the machine can only weld continuously for 5 minutes at 150 amps. The machine must remain idle then to cool for 5 minutes or it will overheat. So, if a given project takes 30 minutes of welding time and the machine can only weld for 5 minutes at a time, the overall job will take 60 minutes using 150 amps. However, that same machine may have a 100 percent duty cycle, but at a lower amperage (say 80 amps). Then, by using only 80 amps, the welder can weld continuously for 30 minutes without overheating the machine.

A machine rated at 50 percent should not be operated at the maximum for 5 minutes and then shut off. The cooling fan must be allowed to operate and cool the internal components, otherwise the machine may incur damage.

A power source with a 100 percent duty cycle may be operated at or below its rated output continuously. However, if the machine is operated above its rated output for a period of time, it no longer has a 100 percent duty cycle.

**Knowing It’s Just a Phase:**
**Single- or Three-Phase**

DC welding machines normally require either single-phase or three-phase power. Three-phase power sources are quite popular in the welding industry because, generally speaking, a three-phase machine will deliver a smoother arc than a single-phase machine.
Most AC/DC TIG machines operate from single-phase power. Some power sources can be powered by either single-phase or three-phase power. These are usually inverter-type power sources.

**Single-phase input connections**

AC and AC/DC transformer power sources operate from single-phase primary power. DC power sources may be either single or three-phase. Check the nameplate, literature, or owner's manual to find out for sure what power your machine will require.

With single-phase power, you have two current-carrying conductors and a ground wire that are connected to the terminal board of the power source.

**Three-phase input connections**

Many industrial DC welding power sources for TIG welding utilize three-phase primary power. Three-phase DC power exhibits very smooth arc characteristics because there are three separate sine wave traces within the same time span (1/60th of a second) as the single-phase sine wave trace. A typical example of a three-phase rectified output is shown in Figure 2-4.

Primary power is connected to the input of a three-phase power source using three current-carrying conductors and a ground wire. The power source also has three current-carrying terminals and a ground terminal connection.

If a three-phase inverter power source is connected to a single-phase line, the output rating will be reduced. Check the power source's specification for details.
Getting Your Input: Input Voltage

Most power sources are equipped with an input terminal board. This board is for the proper connection of the power source to the line voltage being supplied. This must be properly connected or severe damage can occur to the welding equipment. If the power source is moved from location to location with different input voltages, you'll have to relink this board. Certain power sources are equipped with devices that detect the input voltage and automatically set the equipment for proper operation.

Two common types of input boards are Auto-Link and Auto-Line. Auto-Link uses a sensing circuit to mechanically relink the primary to the transformer as needed, whereas Auto-Line electronically — on a sliding scale — constantly monitors and maintains the appropriate voltage to the transformer.
Keeping Your Cool: Torch Cooling Methods

When welding with the TIG process, the majority of heat goes into the arc; however, a significant amount of heat is retained in the torch. Consequently, some means must be provided to cool the torch. Torches used for TIG welding may be either water- or air-cooled.

High production or high amperage torches are usually water-cooled, whereas lighter duty torches for low amperage applications may be air-cooled.

These low-amperage torches require no additional cooling other than the surrounding air. The higher amperage versions are less flexible and harder to manipulate than water-cooled torches. The power cable must be heavier than the cable in water-cooled torches, and may be wound around the gas-carrying hose or located inside the gas hose to provide additional cooling. The water-cooled torch is designed so that water is circulated through the torch that’s cooling it and the power cable.

Carrying a Torch: Components, That Is

You need to think about several torch components, which are

✔ Collet body: The collet body screws into the torch body. It is replaceable and is changed to accommodate various size tungstens and their respective collets.

✔ Collet: The collet holds the welding electrode in the torch and is usually made of copper or a copper alloy. The collet’s grip on the electrode is secured when the torch cap is tightened in place. Good electrical contact between the collet and tungsten electrode is essential for good current transfer.
Gas lenses: A gas lens is a device that replaces the normal collet body. The lens attaches to the torch body and is used to reduce turbulence and produce a longer undisturbed flow of shielding gas. A gas lens allows the welder to move the nozzle further away from the joint, allowing increased visibility of the arc. A much larger diameter nozzle can be used, which produces a large blanket of shielding gas. This can be very useful in welding material such as titanium. The gas lens also enables the welder to reach joints with limited access, such as inside corners.

Nozzles: Gas nozzles, or cups as they are better known, are made of various types of heat-resistant materials in different shapes, diameters, and lengths. The nozzles are either screwed into the torch head or pushed into place. Nozzles can be made of ceramic, metal, metal-jacketed ceramic, glass, or other materials.

Ceramic nozzles are the most popular, but are easily broken and must be replaced often. Nozzles used for automatic applications and high-amperage situations often use a water-cooled metal design.

Gas nozzles or cups must be large enough to provide adequate shielding-gas coverage to the weld pool and surrounding area. A nozzle of a given size allows only a given amount of gas to flow before the flow becomes turbulent. When this occurs, the effectiveness of the shielding is reduced, and nozzle size must then be increased to restore an effective non-turbulent flow of gas.

Not Just for Couch Potatoes: Remote Control

Sometimes a welding task requires the welder to place a weld in a location where he cannot access the controls on the power source. The welder may need to control the amount of current being used. Extra amperage may be required at the beginning of the weld to establish a weld pool more quickly on cold metal — or when making long welds on materials such as aluminum, where weld current must be gradually reduced because of the arc pre-heating the work.
Most welding machines designed primarily for TIG welding provide remote control capability. The remote control capabilities usually include output and current control. Generally, output and current control are located as separate switches on the machine's front panel and can be operated independently if desired. By using a remote control device, the welder can safely get to a location away from the power source, activate the power source and its systems (such as the gas flow, arc starter, and so on), and vary the amperage levels as desired.

Remote output gives the welder control of open circuit voltage (OCV), which is present at the output studs of the power source with no load attached. Once a torch is connected to the output, the electrode would be continuously energized if it were not for the output control. The remote output's primary job then is to interrupt the weld circuit until the welder is prepared to start the arc.

When remote control is activated, the current-control switch on the power source works in conjunction with the main current control. If the main current control is set at 50 percent, the maximum output current available through the remote device is 50 percent. To obtain full machine output current through the remote device, the main current control must be set at 100 percent. Understanding this relationship allows the welder to fine tune the remote control device for the work being done.

The most popular of the remote output and current controls is the foot-pedal type. This type operates much the same as the gas pedal in an automobile: The more the pedal is depressed, the more the current flows. Another type that affords greater mobility is the finger-tip control. The finger-tip control mounts on the torch.
Chapter 3

Choosing Electrodes and Consumable Materials

In This Chapter

- Selecting an electrode
- Understanding the types of electrodes
- Prepping electrodes for use
- Working with shielding gas
- Using a filler metal

From electrodes to shielding gas to filler metal, TIG welding requires a number of consumable materials. In this chapter, we cover what you need to know to get started.

All about Tungsten Electrodes

Electrodes made of tungsten and tungsten alloys are secured within the TIG welding torch to carry current to the welding arc. Tungsten is preferred for this process because it has one of the highest melting points of all metals.

The tungsten electrode establishes and maintains the arc. This electrode is said to be non-consumable because it isn’t melted and included in the weld pool. In fact, you must take great care so that the tungsten doesn’t contact the weld pool in any way, thereby causing a contaminated, faulty weld — a defect known as a tungsten inclusion.
Tungsten electrodes for TIG welding come in a variety of sizes and lengths. They may be composed of pure tungsten, or a combination of tungsten and other elements and oxides.

The American Welding Society (AWS) identifies many electrode classifications as they do for filler metal specifications. The classification code is pretty easy to decipher once you know what the different letters and numbers mean. For example, the classification for a ceriated tungsten electrode is EWCe-2. The letter E in the classification is the designation for electrode. The W is the designation for the chemical element tungsten.

Additional letters in a code designate the alloying element used in the particular electrode. The letter P designates a pure tungsten electrode with no intentionally added alloying elements. The letters Ce, La, Th, or Zr designate tungsten electrodes alloyed with cerium, lanthanum, thorium, or zirconium, respectively.

The numbers 1, 1.5, or 2 behind the alloy element indicate the approximate percentage of the alloy addition. So, using our EWCe-2 example, this code indicates a tungsten electrode alloyed with 2 percent cerium.

**Note:** There is one other electrode designation: EWG. The letter G indicates a “general” classification for those tungsten electrodes that do not fit within the other categories. Obviously, two electrodes bearing the same G classification could be quite different, so the AWS requires that a manufacturer identify on the label the type and content of any alloy additions.

Electrodes are color-coded for ease of identification. Exercise care when working with these electrodes so that the color-coding is kept intact.

**Choosing a Tungsten Electrode**

You can use several different types of tungsten electrodes in TIG welding, and each has its strengths and weaknesses. In the next few sections, we give you a run-down on the most commonly used tungsten electrodes.
One of the main considerations of the tungsten diameter is the welding current. The welding current is determined by several factors, including base metal type and thickness, joint design, fit-up, position, shielding gas, type of torch, and other job quality specifications.

An electrode of a given diameter has its greatest current-carrying capacity with Direct Current Electrode Negative (DCEN), less with alternating current, and the least with Direct Current Electrode Positive (DCEP).

The Three Main Types of Electrodes

Tungsten electrodes come in several different types, however the three main types are

- Pure (EWP)
- Ceriated (EWCe-2)
- Thoriated (EWTh-2)

We take a look at each of these main three types of tungsten electrodes in the following sections.

**EWP (100 percent Tungsten, Green)**

EWP electrodes are unalloyed, “pure” tungsten with a minimum of 99.5 percent tungsten. These electrodes are designated with a green band of paint around one end of the electrode. Pure tungsten is typically used with a conventional (non-inverter) type power source. Pure tungsten provides good arc stability when using AC current, with either balanced wave or unbalanced wave and continuous high-frequency stabilization. Pure tungsten electrodes are preferred for AC sine wave welding of aluminum and magnesium because they provide good arc stability with both argon and helium shielding gas. Because of their inability to carry very much heat, the pure tungsten electrode forms a balled end.
**EWCe-2 (2 percent Cerium, Orange)**

EWCe-2 electrodes are alloyed with about 2 percent cerium, which is a non-radioactive material and the most abundant of the rare earth elements. These electrodes are designated with an orange paint band. Ceriated tungsten has better starting characteristic and a higher current-carrying capacity than pure tungsten. These electrodes are all-purpose and operate successfully with AC or DC electrode negative. Ceriated tungsten is typically recommended with all inverter type power sources in both AC and DCEN.

**EWTh-2 (2 percent Thoria, Red)**

EWTh-2 electrodes are alloyed with 2 percent thoria and are designated with a red band of paint. These are very commonly used electrodes and were the first to show better arc performance over pure tungsten for DC welding. However, thoria is a low-level radioactive material, so its vapors, grinding dust, and disposal raise health, safety, and environmental concerns. *Note:* Be sure to properly dispose of any grinding dust in an environmentally safe way.

The thoriated electrodes are usually preferred for direct current applications. In many DC applications, the electrode is ground to a taper or pointed.

The thoriated electrode retains the desired shape in those applications in which the pure tungsten would melt back and form the ball end. The thoria content in the electrode is responsible for increasing the life of this type over the pure tungsten, EWP.

**Preparing Electrodes for AC Sine Wave and Conventional Squarewave**

After you’ve selected the proper size and type of electrode, how you prepare and maintain the electrode determines its
performance and life. Many misconceptions exist about tungsten electrodes and their correct use. In this section, we tell you what you need to know to make common-sense decisions about tungsten electrodes.

Always wear proper face, hand, and body protection when preparing tungsten electrodes.

Electrodes that will be used with AC sine wave or conventional squarewave current will form a balled end. The diameter of the end should not exceed the diameter of the electrode by more than 1.5 times. As an example, a \( \frac{1}{8} '' \) electrode should only form a \( \frac{1}{6} '' \) diameter end. If the end becomes larger than this because of excessive current, it may drop off and contaminate the weld. For improved arc focus, set the balance control to maximum penetration and try a ceriated or thoriated tungsten with a modified point.

**Preparation of Electrodes for DC**

**Electrode Negative Use (Pointed)**

With DCEN, most of the weld energy is provided by electrode negative, so very little heating effect occurs on the tungsten, and a sharp, pointed tungsten is generally preferred. Figure 3-1 shows the preferred shapes for balled ends and the various types of points used with the DC and AC wave-shaped power sources.

Pointing of electrodes is a hotly discussed topic: Many theories and opinions exist on the degree of the point. Your application will determine how you should prepare your tungsten. A common practice in pointing electrodes is to grind the taper length for a distance of 2 to 2 \( \frac{1}{2} \) times the electrode diameter for use on DC and usually to a sharp needle point, then slightly blunted (see top of Figure 3-2). Using this rule for a \( \frac{1}{8} '' \) electrode, the ground surface would be \( \frac{1}{4} '' \) to \( \frac{3}{8} '' \) long.
Tungsten is harder than most grinding wheels, therefore it is chipped away rather than cut away. The grinding surface should be made of some extremely hard material like diamond or borazon. The grinding marks should run lengthwise with the point (see middle and bottom of Figure 3-2). If the grinding is done on a coarse stone and the grinding marks are concentric with the electrode, there are a series of ridges on the surface of the ground area that may melt off and float across the arc. If the stone used for grinding is not clean, contaminating particles can be lodged in the grinding crevices and dislodge during welding, ending up in the weld. **Note:** The grinding wheel used on tungsten electrodes should not be used for any other material.

*Figure 3-1: Three main tip preparations (L to R): Tapered w/point, Tapered w/land, and Balled.*
Chapter 3: Choosing Electrodes and Consumable Materials

1. Tungsten Electrode
2. Tapered End
Grind end of tungsten on fine grit, hard abrasive wheel before welding. Do not use wheel for other jobs or tungsten can become contaminated causing lower weld quality.

Ideal Tungsten Preparation – Stable Arc
1. Stable Arc
2. Flat
3. Grinding Wheel
4. Straight Ground

Wrong Tungsten Preparation – Wandering Arc
1. Arc Wander
2. Point
3. Grinding Wheel
4. Radial Ground

Figure 3-2: Proper tungsten grind pattern and technique.
The surface of the tungsten after it has been used should be shiny and bright. If the surface appears dull, an excess of current is indicated. If it appears blue to purple or blackened, the shielding gas is insufficient, which may be caused from insufficient gas flow, gas contamination, or insufficient post-flow. This condition means that the surrounding atmosphere oxidized the electrode while it was still hot, and it is now contaminated. Continuing to weld with this condition will result in the oxide flaking off and ending up in the weld deposit. A general rule for post-flow is one second for each ten amperes of welding current. This is normally adequate to protect the tungsten and weld pool until they both cool below their oxidizing temperature.

Contamination of the electrode can occur for several reasons besides a lack of post-flow shielding gas.

- The most common form of contamination is contact between electrode and weld pool, or electrode and filler rod.
- Loss of shielding gas or contamination of the shielding gas due to leaking connections or damaged hoses also causes electrode contamination.
- Excessive gas-flow rates and nozzles that are dirty, chipped, or broken cause turbulence of the shielding gas. This draws air into the arc area, which also causes contamination.

An electrode that has been contaminated by contact with the pool or filler rod will have a deposit of the metal on it. Grind the electrode to remove the contamination. Use good grinding techniques, as improper techniques can cause problems or injury. Breaking off the contaminated tungsten is generally not recommended as it may cause a jagged end or split or bend the electrode. A properly prepared tungsten reduces or eliminates arc wandering, splitting, and weld-quality inconsistencies.

**Shields Up, Captain:**

**Shielding Gas**

All arc welding processes utilize some method to protect the molten weld pool from the atmosphere. Without this protection,
the molten metal reacts with gases in the atmosphere and produces porosity (bubbles) in the weld bead, which greatly reduces weld strength.

The importance of atmospheric shielding is reflected in the fact that all arc-welding processes take their names from the method used to provide the shielding: Gas Tungsten Arc, Gas Metal Arc, Submerged Arc, Shielded Metal Arc, Flux Cored, and so on.

Two inert gases are primarily used for shielding purposes for TIG: argon and helium. Shielding gases must be of high purity for welding applications: at a level of 99.995 percent.

Although the primary function of the gas is to protect the weld pool from the atmosphere, the type of gas used has an influence on the characteristics and behavior of the arc and the resultant weld bead. Argon, after leaving the torch nozzle, tends to form a blanket over the weld, whereas helium tends to rise rapidly from the arc area. In order to obtain equivalent shielding, flow rates for helium are usually two to three times those of argon.

**Argon**

Argon is obtained as a byproduct in the manufacturing of oxygen. The earth’s atmosphere is composed of .9 percent argon, 78.0 percent nitrogen, 21.0 percent oxygen, and .1 percent other rare gases. Looking at these percentages, you can see that many cubic feet of air must be processed in order to obtain a cylinder of argon. The price of argon may vary widely depending on locality and volume purchased.

Argon provides excellent arc stability and cleaning action even at low amperages. Argon is the most commonly used inert gas for all TIG welding applications.

**Helium**

Unlike argon, helium has high thermal conductivity. Due to this higher thermal conductivity, the arc column expands, reducing current density in the arc. The arc column becomes wider and more flared out than the arc column with argon shielding gas. Figure 3-3 illustrates the two arc columns. The more flared out the arc column, the more the work surface
area is heated. The heat at the center of the arc, while using helium, is very hot — which results in a deeper penetrating arc. In Figure 3-3, note the wider arc and deeper penetration produced by the helium shielding gas.

Helium produces a higher arc voltage than argon does. Because the total power is a product of voltage and amperage, it’s apparent that more heat energy is available with helium. Helium or argon/helium mixtures are desirable on thick material and where high travel speeds are desired. Typical argon/helium mixtures are 75/25 and 50/50, argon, helium.

Figure 3-3: A representation of the effects on the arc and bead produced by argon and helium shielding gases.

### Going with the Flow: Flow Rate

The correct flow rate for shielding gas is an adequate amount to shield the molten weld pool and protect the tungsten electrode. Any greater amount than this is wasted. The correct flow rate in cubic feet per hour (CFH) is influenced by many variables. Generally speaking, when the welding current, nozzle diameter, or electrode stickout is increased, the flow rate should be increased. When welding in the AC mode, the current reversals have a disturbing effect on the shielding gas, and flow should be increased by 25 percent. And, of course, when welding in a drafty situation, you want to double the flow rate. When welding corner or edge joints, excessive flow rates can cause air entrapment. In this situation, you can improve the effectiveness of the shielding gas by reducing the gas flow by about 25 percent. A good starting point is approximately 15 to 20 CFH.
The purpose of both pre-flow and post-flow is to prevent contamination of both the weld pool and the tungsten electrode by the surrounding atmosphere.

When the torch is not in use, air will enter the system through the nozzle. Moisture in the air can condense inside the nozzle and gas hose, causing hydrogen contamination during initial stages of the weld. The shielding gas pre-flow clears the air and moisture from the torch and prevents this contamination.

Post-flow works a little differently. Immediately after the welding arc is extinguished, the weld bead, filler rod, and tungsten electrode remain hot enough to cause a chemical reaction with oxygen in the atmosphere. The result of this oxidization is quite obvious when it occurs because the oxidation causes the weld bead, filler rod, and tungsten to turn black. Proper post-flow prevents oxidization from occurring by shielding the hot electrode and weld area while the puddle solidifies.

A tungsten that has discolored because of oxidization must be properly removed from the torch and replaced. Refer to the owner’s manual for instructions on how to do so.

### Selecting a Filler Metal

The TIG welding tungsten electrode is a non-consumable electrode and therefore does not become part of the weld — as do stick welding or MIG welding electrodes, which melt and become filler metal that adds to the weld volume. This non-consumable electrode is advantageous on thin materials (usually narrower than \(\frac{3}{16}\)") where the TIG weld fuses the edges of the base materials together. This fusion is referred to as an "autogenous" weld (no filler) and is common on thin metal butt, lap, and flange joints.

Welds on thicker metals (about \(\frac{3}{8}\)" and up), beveled joints, and poor fit-up joints may need filler wire added to the weld pool for proper fusion and weld strength. You usually do this by hand-feeding the filler wire into the pool. The filler rod diameter should be approximately the same as the electrode diameter. You want to keep the hot end of the filler rod in the blanket of shielding gas and/or post-flow until it has cooled below its oxidation temperature.
Automated TIG welding uses a wire feeder to automatically feed a continuous wire into the weld pool as the weld proceeds along the joint.

**Shapes of filler metals**

The most common filler material for TIG welding takes the form of 36" straight rods that are fed by one hand while the other hand manipulates the torch. These rods usually come in 10 or 50 pound boxes or tubes and often have the wire type on a tag or stamped into the side of each piece of filler rod. TIG welding is preferred for critical work that is generally done to a code and approved welding procedures. To maintain control, the filler metal must be identifiable.

Also used to a lesser degree are flattened rods. These rods are preferred by some welders who feel it is easier to feed the rods because of their shapes.

Another type of filler material is coiled wire for automated TIG welding. This would be the same wire used on a given material for the MIG welding process.

**Steel**

Carbon steel filler rods come in seven designations. A typical designation is ER70S-6 for TIG. In this example, the ER means that you can use the filler for either TIG or MIG welding. If the designation lacked the R, it would signify a continuous electrode to be used with MIG welding only. No designation exists for a filler rod using just the R: the designation will always be ER. The 70 stands for the welded tensile strength, measured in thousands of pounds per square inch. S stands for “Solid” electrode as opposed to a tubular or hollow wire such as that used in the Flux Cored welding process. The 6 refers to the chemical percentages within the rod’s composition. In other words, the number at the end of the description refers to the classification of wire being used.

**Stainless steel**

Many more stainless steel designations exist than steel designations. A typical classification of a stainless rod would be ER308. The ER, as it is in steel, stands for either continuous
electrode, or electrode rod. The 308 designates a specific stainless steel chemical composition. These numbers are often used to match the filler rod to specific compositions of base metals being welded.

Certain types of stainless steel rods may have letters or numbers after the three digits, such as L, meaning low carbon content, or Si, meaning high silicon content. Sometimes a manufacturer’s brand name may use ELC instead of L to mean Extra Low Carbon, or HiSil instead of Si meaning High Silicon Content.

**Aluminum**

Aluminum filler rods have approximately 12 designations. A common all-purpose rod is ER4043. The ER designates electrode or rod, and the 4043 designates a specific chemical composition. ER4043 is used with many aluminum base metals, but be sure to always consult electrode wire manufacturers for the proper filler to use in critical welds.
As in any welding process, in TIG welding, safety precautions are very important. Be sure that you understand all the information relating to the safe operation of the welding equipment and the welding process before you begin work. A careless welder who doesn’t observe simple rules can cause a hazardous situation for everyone in the area. The process of arc welding creates several hazards that must be guarded against: everything from electrical shock to fumes to eye injuries. In this chapter, we take a look at the most common hazards and how to guard against them.

Be sure to review the instruction manuals that come with each piece of welding equipment for important safety information. This chapter contains general safety information, but does not take the place of reviewing the instruction manual for the specific equipment that you’re working with.

Common sense is the most important tool a welder can bring to the welding area. Horseplay or practical jokes have no place in the working area. (Save practical jokes for the appropriate time and place, like your Aunt Susie’s wedding reception or your cousin Dave’s graduation speech.)
TIG welding is an electrical welding process, which means that a TIG welding machine puts out electrical energy. Always install a welding machine according to the manufacturer’s recommendation and in accordance with the National Electrical Code and local code requirements.

As a welder, you must always be concerned about the possibility of electrical shock. Electricity will always take the path of least resistance. If a proper secondary circuit exists, the current will follow that path. However, if poor connections, bare spots on cables, or wet conditions exist, the possibility of electrical shock is a real hazard.

Never weld while standing in water. If you’re working in wet conditions, take the following precautions:

- Stand on a dry board or a dry rubber mat when welding.
- Do not place the welding equipment in water.
- Keep gloves and shoes dry. Even perspiration can lower your body’s resistance to electrical shock.

Although the majority of welding is done in the direct current (DC) mode, welding power is most often obtained from the local power company out of an AC wall socket.

If the welding machine is “hard wired” directly to the wall rather than using a plug and wall socket, you must shut off the primary power to the machine at the fuse box if work needs to be done on any part of the welding equipment. Also, remember to shut off the primary power at the fuse box when the machine is idle for long periods of time.

Note: Always use caution when installing any welding equipment. Improper connections can lead to an electrically “hot” welding machine case, which could result in a severe shock to anyone who touches it.
Primary wiring should only be done by a qualified electrician who is absolutely sure of the electrical codes in a given area. Before any primary power is connected to welding equipment, be sure to read the equipment’s operation manual and follow its instructions to the letter.

**Avoiding Fumes**

As with most welding processes, the heat of the arc and the molten pool in TIG welding generate fumes. Because TIG does not typically use flux or produce slag, we highly recommend that the material being welded is clean.

The flux on a stick electrode or in a flux-cored wire has several functions, one of which is to clean the base material. If the base material isn’t clean, the weld can become defective.

Compared to other arc-welding processes like stick- or flux-cored welding, few fumes are produced. However, the base metals being welded may contain coatings or elements such as lead, zinc, copper, nickel, and so on, that may produce hazardous fumes. These fumes may create health hazards, especially for the lungs. Exhaust hoods or booths can remove fumes from a particular area. Ozone can also be produced as the ultraviolet light emitted by the arc hits the oxygen in the surrounding area, producing a very distinctive, pungent odor.

When welding, keep your head and helmet out of the fumes rising off the workpiece.

Be sure that proper ventilation is supplied, especially in a confined space. Because TIG welding is a gas-shielded process, you must take care not to extract too much air from the arc area, which would disturb the process. Be careful that the device used to pull the welding fumes from the area isn’t so close or so strong that it pulls the shielding gas away from the weld. This leaves the molten puddle exposed to the air, which results in a defective weld.
Being Wary of Arc Rays

The electric arc used in TIG welding creates several hazards, including infrared and ultraviolet rays. The light and rays can produce a burn similar to sunburn. The arc rays, however, are more severe than sunburn because the welder is so close to the source. These rays can quickly burn any exposed skin.

To protect yourself from the rays, you must wear proper safety gear while welding. A welding arc produces ultraviolet rays as well as very high temperatures in the area near the arc. If you weld without protection, you risk a chance of flash burn, which causes redness of the skin and can produce a painful burning and itching in your eyes.

Proper clothing

The clothing recommended for TIG welding is a tightly woven long sleeve shirt, leather gloves, pants that cover the legs completely, and a pair of closed-toe shoes that will protect your feet.

To prevent fires, be sure that all the protective equipment you use is free of oil, grease, or anything else that is flammable.

Eye protection

Always use eye protection for welding. As standard practice, wear safety glasses — even under the welding hood — at all times during welding. Never look at the welding arc with unprotected eyes. A short exposure to the arc, which sometimes occurs accidentally, may cause flash burn to your eyes. Usually, this injury isn’t permanent but may be painful for a short time after exposure. The feeling is similar to having sand in your eyes, without all the fun of a trip to the beach first. Sometimes four to eight hours may pass before a painful sensation in the eyes develops. Mild cases of flash burn can sometimes be treated, but continued exposure to flash burn can cause permanent eye damage.

Because the TIG welding process produces so little smoke, the arc can appear very bright even if you’re wearing a welding hood. For this reason, you should wear a welding hood while
welding. Welding lenses are not simply colored glass, but are special lenses that screen out almost 100 percent of the infrared and ultraviolet rays.

Lenses are manufactured in various shades designated by a shade number, and the higher the shade number, the darker the lens. The choice of a shade may vary depending on a person's sensitivity of eyesight and the welding variables.

Generally speaking, the current that you use determines the shade of the lens needed. The higher the current, the darker the shade lens should be. You can get the welding helmet equipped with an electronic lens that automatically lightens and darkens as required. You can find safety rules related to eye protection in the AWS-approved ANSI Z49.1 booklet, *Safety in Welding and Cutting*.

**Securing the Welding Environment**

The TIG welding process can create light, heat, and fumes. In addition to wearing protective clothing, you (the welder) must take other precautions as well.

Be aware that the light given off from welding may bother other workers in the area. You can use permanent booths or portable partitions to contain the light rays in one area.

Be aware also that the heat given off during welding is capable of setting flammable materials on fire. Therefore, welding should not be done in areas containing flammable gases, vapors, liquids, or in dusty locations where explosions are a possibility.

Many injuries have resulted from welding done on containers that have previously held combustible materials. Acceptable methods of cleaning such containers before welding are outlined in the American Welding Society’s booklet, AWS A6.0, *Safe Practices for Welding and Cutting Containers That Have Held Combustibles*. Never attempt to weld such containers without first reviewing and implementing the safety procedures outlined in this booklet.
Safely Handling Cylinders

Regardless of a cylinder’s content, you must handle any pressurized cylinder at all times with great care. Shielding gases such as carbon dioxide, argon, and helium are nonflammable and non-explosive. A broken valve, however, releases extremely high pressures, which could cause the cylinder to be hurled about at hazardously high speeds. Think of a child’s balloon: If a balloon is blown up and then released, the jet force of air escaping causes the balloon to fly about rapidly and erratically. The same is true if a cylinder valve breaks off. The weight of the cylinder and the extremely high pressure could easily cause a very damaging and possibly fatal accident.

Keep cylinders securely fastened at all times. Chains are usually used to secure a cylinder to a wall or cylinder cart. When moving or storing a cylinder, fasten a threaded protector cap to the top of the cylinder. This cap protects the valve system should it be bumped or the cylinder dropped. Use a cylinder cart whenever you have to move a cylinder.

Be sure to keep excess heat of any kind away from cylinders. Never weld on any cylinder. When a cylinder is exposed to too much heat, the pressure inside the cylinder increases. To prevent the excess pressure that can cause the cylinder to explode, the cylinder valve is equipped with a safety nut and bursting disc.

Do not hang welding torches and other cables on or near cylinders. A torch near a cylinder could cause an arc against the cylinder wall or valve assembly, possibly resulting in a weakened cylinder or even a rupture.
Before you start the arc, you need to make certain basic preparations, like making sure to read and follow all equipment labels and owner’s manuals carefully. These preparations also include getting the base metal ready and setting up the machine and its controls. In this chapter, we show you how to get ready to weld, including how to prepare each of the commonly welded base materials.

Getting the Power Source Ready

Figure 5-1 illustrates the front panel of a typical AC/DC machine designed for TIG welding. Keep in mind that not all power sources will have all the features or controls of this machine. Depending on the make and model of your machine, the controls and switches mentioned in the following information may be found in locations other than the front panel. The various controls each have a specific function and the operator changes them as the application changes.
Figure 5-1: The front panel of a typical AC/DC TIG welding machine.

**Power switch**

When the switch is in the “on” position, voltage is applied to the control circuit. A light or an LED meter will indicate that the power is on. Before activating the “On” switch, make certain the electrode is not in contact with the work lead or any portion of the work circuit! If this happens, the machine could begin welding prematurely and cause a potential danger.

**SMAW/GTAW mode switch**

The SMAW/GTAW switch should be set for the particular process that you’re using: either SMAW or GTAW. The machine will disable the functions that aren’t required by the process being used. For example, the gas solenoid valves will not be active in the SMAW mode because they’re only required for TIG welding.
**Amperage control panel/remote switch**

When you’re using a remote control device (foot pedal/fingertip control), the panel/remote switch on the front panel needs to be in the Remote position. When you’re controlling amperage from the front panel of the machine, you must have the switch in the Panel position.

**Weld current control or amperage control**

The weld current or amperage control sets the output current of the machine when no remote current device is being used. With a remote device attached, the control provides a percentage of total output.

For example, if the machine is set at 50 percent of the capable amperage, the remote device at full output delivers 50 percent of the machine’s available current.

**Remote amperage control receptacle**

The remote amperage control receptacle is provided for connecting a remote hand control or a remote foot control. This feature allows you to have amperage control while welding at a work station that is a long distance from the power source. With the foot or fingertip control, you can vary the amperage as you progress along a joint. This is particularly helpful when you’re starting on a cold workpiece. You can increase amperage to establish a weld pool quickly, and as the material heats up, you can decrease the amperage. When coming to the end of a joint, you can further decrease the amperage to taper off and “crater out.”
AC/DC polarity (material selector) switch

The AC/DC polarity switch allows you to select Direct Current Electrode Negative (DCEN) for welding material such as mild steel, stainless steel, chromoly, and so on, or alternating current (AC) for materials like aluminum and magnesium.

Preparing the Weld Joint

Many TIG welding problems, or supposed problems, are a direct result of a welder using improper methods to prepare the joint. Chief among these methods is the improper use of grinding wheels to prepare joints.

Grinding wheels should be clean and dedicated exclusively to the material being welded. If grinding is the method that you choose, using a sanding disc on your grinder is generally a good choice for preparing a joint to be welded.

Cleaning

The cleaning process is as critical if not more critical than welding itself as far as the TIG process is considered.

When getting ready to weld, you must remove oil, grease, dirt, paint, marking crayon, and corrosion from the joint edges and metal surfaces to a distance of about \( \frac{3}{4} \)" on both sides of the joint. Their presence during welding may lead to arc instability and contaminated welds. If you make a weld with any of these contaminants present, the result could be a weld bead with pores, cracks, or inclusions.

Any of these results could lead to a possible weld failure in the future.

You can clean by using a mechanical method such as sanding discs, wire brushes, and files. Chemical cleaning, which includes degreasers or deoxidizers, is also an option. You also can use a combination of mechanical and chemical cleaning methods. When cleaning aluminum or stainless steel, use a stainless steel wire brush.
Use the abrasive wheels and wire brushes only on one specific type of material. For example, if you use a wire brush on rusty steel and then on aluminum, the brush you use can carry contaminants from one piece to another. The vigorous brushing can impregnate the contaminants carried in the brush into the aluminum. The same is true of abrasive wheels.

Sometimes, a welding operator can transfer contaminants from dirty welding gloves onto the filler rod and consequently into the weld area. This is why it is critical to have gloves that are fairly clean while TIG welding.

**Preheating**

Preheating, if needed, is typically dictated by the thickness of the material to be welded. When welding on thicker material, preheating may be needed to establish a puddle to make welding possible.

Preheating is most often done with an oxyacetylene torch. However, when you use this method, you must take care that localized overheating doesn't occur, and that the base metal (especially aluminum) is not contaminated with combustible by-products of the oxy-fuel process. Other methods of preheating include induction coils and heating ovens.

**Preparing Mild Steel for Welding**

Low carbon steels, commonly referred to as mild steels, are readily welded by the TIG-welding process. Mild steel should always be mechanically cleaned prior to welding. Rust, paint, oil, and grease, or any surface contaminants, should be removed. Hot-rolled products such as angle iron, plate, and pipe may contain a heavy mill scale. For best results, remove any scale or coatings prior to welding.

Mild steels are available in many different alloys and types. The familiar structural shapes, plates, and hot-rolled sheet metal are usually comprised of what is termed *semi-killed steel*. This term means that the steel has been partially deoxidized during manufacture. The steel, however, still contains some oxygen, and this oxygen can cause problems when welding. These problems occur in the form of bubbles in the weld.
pool and possibly in the finished weld bead. *Killed steel* has had more oxygen removed in its manufacture and presents less of a problem when welding.

A filler wire containing sufficient silicon and manganese, added as deoxidizers, is necessary for TIG-welding mild steel. Lower-grade filler rods used for the oxyacetylene welding of many hot-rolled products are not suitable for making high-quality TIG welds.

When working with mild steel, direct current electrode negative is recommended, with a high-frequency, or Lift-Arc start. You should use a 2-percent ceriated or 2-percent thoriated tungsten with point or taper on the electrode.

**Preparing Stainless Steel for Welding**

*Stainless steel* is the common term for chromium-nickel alloyed steel. You can find both magnetic and non-magnetic types of stainless steel. You also can find many types of alloys, and each type possesses its own properties of corrosion resistance and strength. Check with the manufacturer when you’re in doubt about the specific properties of an alloy.

When welding stainless steel, you need to first thoroughly clean it. Protective paper or plastic coatings are applied to many stainless steels to keep the material clean. Foreign material may cause porosity in welds and *carburization* (uniting with carbon) of the surface, which lessens the corrosion-resisting properties.

If you clean the surface with a wire brush, be sure to use a stainless steel wire brush, dedicated to this material, to prevent iron pickup on the stainless surfaces. As with other welding procedures, use clean and dry filler metal and take proper precautions to prevent contamination during welding.

Stainless steels are considered readily weldable. Normally the welding does not adversely affect the strength or ductility of the deposit, parent metal, or fusion zone. Tungsten type and preparation should be the same as previously noted for mild steel. When welding stainless steel, be sure that the filler material is compatible. The heat conductivity of stainless steels is
about 50 percent less than mild steel with a high rate of thermal expansion. This increases the tendency for distortion on thin sections.

When welding stainless, try to keep the heat input as low as possible. If the heat input is too much, a metallurgical change known as carbide precipitation can take place. If corrosion resistance is a big factor in the completed weld, be aware that some of the corrosion-resistance properties are lost in the weld and adjacent areas that are heated above 800° F to 1400° F on stainless steels. Keeping heat input to a minimum is necessary in this situation. The longer the work is within this critical temperature range, the greater the precipitation will be. Rapid cooling through the 800° F to 1400° F range helps keep this precipitation to a minimum.

The most common tungstens used for welding stainless steel are 2-percent thoriated and 2-percent ceriated. You'll want to prepare the tungsten as we discuss in Chapter 3. The filler metal that you choose must be of the same general analysis as the material being welded. A good example is stainless steel, which isn’t welded with mild steel filler because mild steel filler won’t have the same corrosion-resistant properties as the stainless does. If your filler metal selection isn’t compatible with your base material, failure can eventually occur.

**Preparing Aluminum for Welding**

The preparation of aluminum deserves more consideration than it is usually given. Aluminum is very susceptible to contaminants, which can cause considerable problems when welding. Aluminum has a surface oxide that must be removed during the welding process.

When the electrode is positive and the work is negative (reverse polarity or during one half of the AC cycle; refer to Chapter 1), the positively charged gas ions are attracted to the negative workpiece. These ions strike the surface with sufficient force to chip away at the brittle oxide, much like a miniature sandblasting operation. The electron flow from the work to the electrode lifts the loosened oxide, leaving clean base metal to be welded.
Do not rely on this cleaning action to do all the cleaning. You should also use the mechanical or chemical cleaning methods mentioned in the “Cleaning” section earlier in this chapter to remove anything from the material that will hinder proper fusion.

A problem sometimes occurs when only the side of the joint being welded is cleaned. Contamination from the backside or between butting edges can be drawn into the weld pool. Both sides of the joint should be cleaned if it contains foreign material.

Another frequent source of contamination is the filler metal. Aluminum filler wire and rod oxidizes just like the base metal. If the oxidation is severe enough, the rod must be cleaned prior to use. Stainless steel wool is good for cleaning filler wire and rod that is heavily oxidized.

Aluminum is a very good conductor of heat. The heat is rapidly conducted away from the arc area and spread over the workpiece. On small weldments, the entire part may heat up to the extent that you need to reduce amperage from its original setting while you are welding. Remote foot and fingertip amperage controls are useful in these situations.

A 2-percent ceriated tungsten electrode is recommended for aluminum. Grind the electrode to a point as you would if welding mild steel. However, after you’ve created a point, remove the tip by grinding a small land, or flat, on the end. The taper on the tungsten allows for a more focused arc, which is especially beneficial on thin base material. The flat on the end keeps the sharp point of your tungsten from breaking off and falling into the molten puddle. **Note:** This will cause contamination in your weld. The electrode stick-out beyond the cup may vary from approximately $\frac{3}{16}$" on butt joints to possibly $\frac{1}{2}$" in joints where it is difficult to position the torch. The normal recommended arc length (distance from your tungsten to the material) is approximately the same as the electrode diameter. (For proper tungsten preparation, refer to Chapter 3.)
Chapter 6

Selecting Joints and Welds

In This Chapter
- Getting familiar with types of joints
- Discovering fillet and groove welds
- Creating basic weld joints

A weld joint is the term used for the location where two or more pieces of metal are welded together. If your goal is a quality weld and cost-effective use of filler metal (and why wouldn’t it be?), joint design should be a prime consideration. The proper joint design depends on several factors, including material type, thickness, joint configuration, and strength required.

Often, a welder has little to do with how a particular joint is designed. However, a good welder should be familiar enough with joint design to carry out a welding job. In this chapter, we cover the ins and outs of the different types of joints and welds and their uses.

Getting to Know the Types of Joints

A proper joint design offers the required strength and the highest quality weld at the lowest cost. The joint design dictates what type of weld is required. Figure 6-1 shows the five basic weld joint designs, which are edge, butt, lap, corner, and T-joints.
The five basic joint designs are typically welded with the TIG process using either a groove or a fillet weld. *Groove* welds are those welds made into a prepared joint to get deeper penetration. When the edge or surface of joint members come together at a right angle to each other, the resulting weld, which is triangular in shape, is called a *fillet* weld. Fillet welds on lap or T-joints are commonly used in the welding industry. (We go into more detail on fillet and groove welds later in this chapter in the “Working with Fillet Welds” and “Using Groove Welds” sections.)

To prepare the joint, you must remove the base material (typically by grinding) and replace it with weld metal. Groove-welded joints are very efficient but take more time to make than a fillet-welded joint, primarily because they require some form of joint preparation. Fillet welds are made on joints that require no prep.
A few considerations of joint design are specific to TIG welding specifically. Naturally, the weld joint must be accessible to the TIG welding torch, allowing proper torch movements. Weld joints should not be narrow enough to restrict access of the gas cup.

In some cases, using a narrower gas cup or a gas lens with the electrode extending up to an inch beyond the gas cup will help improve access.

**Edge joints**

An *edge joint* occurs when the edges of parallel or nearly parallel members meet and are joined by a weld.

Edge joints are often used when the edges of the parts to be welded will not be subjected to great stresses. Edge joints are not recommended where impact or great stress may occur to one or both of the welded edges. If necessary, the joints can be altered by grinding, cutting, or machining the edges into a groove. The groove can be a square, beveled, V, J, or U. The main purpose of the groove is to allow proper penetration or depth of fusion, as shown in Figure 6-2.

![Diagram of joint penetration](image)

**Figure 6-2:** Depth of fusion and types of penetration.

*Complete joint penetration* refers to weld metal that extends completely through the groove and has complete fusion into the base metal. Partial joint penetration, which if not intended, is referred to as *incomplete joint penetration*.

**Butt joints**

A *butt joint* occurs when the surfaces of the members to be welded are in the same plane with their edges meeting.
Butt joints are often used to join pressure vessels, boilers, tanks, plate, pipe, tubing, or other applications where a smooth weld face is required. They generally require more welding skill than other joints. Butt joints have very good mechanical strength if they’re properly done. They can be expensive joints because a prepared groove is generally required to get the proper penetration and weld size. Getting the groove ready involves preparing the joint, removing material to open up the joint, and then welding to penetrate and fill the groove.

Distortion and residual stresses can be problems with butt joints.

Butt joints can be designed in various ways. They can be welded with or without a piece of metal or ceramic backing the joint, usually referred to as a backing bar or backing strip. The edges can be prepared into a groove that is square, beveled, V, J, or U shaped, as shown in Figure 6-3.

![Types of grooves. (A butt joint is used as an example.)](image)

Edges may be held tight together, or a small gap known as a root opening may be left between the edges. When speaking about groove joints, a few key features of the joint are referred to: the groove angle, groove face, root face, and root opening, shown in Figure 6-4. The groove angle is the total included angle of the joint. If two 37.5° bevels are brought together, they form a 75° V-groove. The groove face is the surface of the
metal in the groove, including the root face. The root face is sometimes called the land or flat spot at the bottom of the joint. The main purpose of the various grooves and root openings is to allow proper penetration and depth of fusion.

![Diagram of parts of a groove weld](image)

**Figure 6-4:** Parts of a groove weld. (A V-groove is shown as reference.)

If material thickness is less than approximately \( \frac{3}{8} \)" thick, square edges butted tight together, with no root opening can be used. (Aluminum usually requires a small root opening.)

Plate thicknesses of \( \frac{3}{8} \)" and greater generally require single or double V-groove and root openings for proper penetration and depth of fusion. The way the joint needs to be prepared before welding depends on the joint design and the equipment available to do the edge preparation. An oxy-fuel torch or plasma arc cutting/gouging is often used to cut a bevel-, J-, U-, or square-groove edge on steel plates. Aluminum is best prepared with mechanical cutting tools or the plasma arc cutting/gouging process.

**Lap joints**

Another joint design used a great deal in the welding industry is the lap joint.

*Lap joints* occur when the surfaces of joined members overlap one another. A lap joint has good mechanical properties, especially when it’s welded on both sides. The type of weld used on a lap joint is generally a fillet weld. The degree that
the members overlap is generally determined by the thickness of the plate. In other words, the thicker the plate, the more overlap that's required.

**Corner joints**

When members to be welded come together at about 90° and take the shape of an “L,” they are said to form a *corner joint*.

Welds made on the inside of the “L” are called *fillets*, and welds made on the outside of the “L” are called *groove welds*. Corner joints are easy to assemble and require little if any joint preparation. After welding, the welds are generally finished, meaning that they’re ground smooth to improve their appearance. When finishing a weld, you as the welder should make every effort to prevent overlap, high spots, low spots, and undercut. These problems can all mean more work because they result in additional grinding, rewelding, and regrinding.

Corner joints come in two main types: *open corner* (there’s a gap) and *closed corner* (edges are tight together). When you’re working on lighter gauge material, you may need to increase travel speed somewhat, especially on open corner joints where excessive *melt-through* (the weld puddle droops through the joint to the other side) is a possibility.

**T-joints**

A *T-joint* occurs when the surfaces of two members come together at approximately right angles, or 90°, and take the shape of a “T”. On this particular type of joint, a fillet weld is used.

T-joints possess good mechanical strength, especially when welded from both sides. They generally require little or no joint preparation and are easy to weld when the correct parameters are used. The edges of the T-joint may be left square only if a fillet weld is required. For groove welding, the edges may be altered by thermal cutting/gouging, machining, or grinding.
Working with Fillet Welds

Fillet welds are approximately triangular in cross-sectional shape and are made on members whose surfaces or edges are approximately $90^\circ$ to each other. Fillet welds can be as strong as or stronger than the base metal if the weld is the correct size and the proper welding techniques are used.

Figure 6-5 shows a cross section profile of the three types of fillet weld contours: flat, convex, and concave. (Contour is the shape of the face of the weld.)

The size of a convex fillet weld is generally the length of the leg referenced. Figure 6-6 shows a convex fillet weld and the terms associated with it.

![Diagram of fillet welds (Flat, Convex, Concave)](image)

**Figure 6-5:** Fillet face contours.
For concave fillet welding, the size and leg are two different dimensions. The leg is the dimension from the weld toe to the start of the joint root; however, the actual size of a convex fillet weld, as shown in Figure 6-6, is measured as the largest triangle that can be inscribed within the weld profile. A special fillet weld gauge is used to measure concave fillet welds. If the weld is flat, the concave or convex fillet weld gauge can be used.

The general rule for fillet weld size is that the leg should be the same size as the thickness of the metals. If ¼" thick plate is being welded, a ¼" leg fillet is needed to properly join the members. The old saying, “If a little is good, a lot is better,” may be true in some cases, but not with fillet welds.

Consider again a ¼" thick plate. If a lot of weld would be better, think of ½ legs on the fillet. This would result in what is known as over-welding. This weld isn’t just twice as large as required, but its volume is three times what’s required. This wastes weld metal and the welder’s time, causes more distortion, and may even weaken the structure because of residual stress.

A weld or weld joint is no stronger than its weakest point. Even though you may think that a joint welded with a larger weld (one with longer legs) would be stronger, it won’t
support more stress than if the correct sized weld was used. It may even support less stress due to the additional residual stresses built up in the joint that is over-welded.

When metals of different thicknesses are to be joined, such as welding a \( \frac{3}{8} \)" thick plate onto a \( \frac{1}{2} \)" thick plate in the form of a T-joint, the rule for fillet weld size is that the size of the fillet weld leg should equal the thickness of the metal being welded. So, one would think that because there are two different thicknesses, the best weld results would be obtained by making an unequal leg fillet weld (that is, the fillet weld has a \( \frac{3}{8} \)" weld leg on the \( \frac{1}{2} \)" plate and a \( \frac{1}{2} \)" weld leg on the \( \frac{1}{2} \)" plate). However, consider the results of making the weld with an equal leg fillet. There would then be two choices: a \( \frac{1}{2} \)" fillet or a \( \frac{3}{8} \)" fillet. In this instance, the \( \frac{3}{8} \)" fillet would be the more practical because a weldment is no stronger than its weakest point. The extra welds in the \( \frac{3}{8} \)" fillet will also require more time, filler wire, and induce more heat into the metal, causing more residual stress.

**Using Groove Welds**

A groove weld is made in square, V, bevel, U, J, flare-V, or flare-bevel type grooves between workpieces. These are the most common type of grooves used in the TIG process. Each type of groove weld takes its name from the profile of the groove it uses. Review Figure 6-3 for typical grooves found on butt joints.

**Groove weld size**

When a weld is called for on a joint, the size of the weld is important to enable the joint to carry the load applied to it. In order to understand groove weld size, you have to first understand some of the terms applied to a typical groove, such as a V-groove joint — which we talk about in mere seconds. The groove angle, bevel angle, root face, and root opening are all illustrated back in Figure 6-4.

The groove weld size relates to how deep the weld fuses into the joint. The groove should be completely filled: Excess fill, called *weld reinforcement*, should be kept to a minimum. Any extra reinforcement decreases the strength of the joint by creating extra stresses at the weld toes.
Joint design for various types of groove welds can be expensive because some groove weld joints require more preparation than others. Therefore, be mindful of what types of preparation are necessary and what you can avoid.

**Square-groove**

You can make a *square-groove* weld with either a closed or an open groove. Usually, if the base metal is thin (such as thin sheet metal gauge thicknesses), a square groove weld can be used. Remember that the higher a gauge number, the thinner the material. If your base metal has a thickness of between $\frac{3}{8}''$ and $\frac{3}{4}''$, you want to weld both sides of an open-square-groove-weld to provide proper penetration into the groove. Usually, open-square-groove-welds are not made with groove openings of more than about $\frac{9}{16}''$. In cases where welding is done from only one side of the joint, you can use a temporary or permanent backup bar or strip. On critical welds, you can use a consumable insert.

These backings or inserts can ensure proper joint penetration, help avoid excessive melt-through, or provide a flush backing to the weld.

**V-groove**

*V-groove* weld designs require careful preparation, but for all the extra work involved, they are still quite popular. V-groove welds are usually made on medium to thicker metals, and are used quite often for pipe welding. These welds can be of excellent quality if they're properly completed.

The groove angle for a groove weld must be large enough for the torch to fit into the groove. The groove angle depends on metal thickness, desired electrode extension, and torch nozzle size. Usually V-groove welds are made on material thicker than $\frac{3}{8}''$ to $\frac{3}{4}''$. Adjusting the root face thickness can help control penetration.

Usually, the *root pass* (the first weld pass of a groove weld done at the bottom or *root* of the joint) of a weld without backing is done with some melt-through. Proper penetration and fusion of the root pass is necessary to avoid weld defects.
V-groove welds are often made on material up to about \( \frac{3}{8} \)" thickness, whereas double V-groove welds are normally made on thicker materials up to roughly \( \frac{3}{4} \)" in thickness. Double V-groove welds (V-grooves on both the top and bottom of the joint) on thicker materials can use less deposited weld metal and limit distortion in the weld, especially if a small root face of about \( \frac{1}{8} \)" is used on each member. Usually the weld passes on such a joint are made alternating from one side of the joint to the other, which helps to prevent distortion.

**Bevel-groove**

The bevel-groove weld requires preparation, but only one member must be beveled. The single bevel-groove can be used on material up to about \( \frac{3}{8} \)" in thickness, whereas double bevel-grooves are used on thicker material up to about \( \frac{3}{4} \)".

In most cases, up to \( \frac{1}{8} \)" root openings are used on single and double bevels.

A bevel-groove is sometimes used when welding in the horizontal position. Root faces up to about \( \frac{1}{8} \)" are normally used for either single or double bevel-grooves.

**U- and J-grooves**

On thicker materials, U- or J-grooves can provide good penetration. They do not use as much deposited weld metal as a V-groove or bevel-groove joint design. With thicker materials, the U- and J-grooves can be used with a smaller groove angle and still maintain proper fusion. A normal groove angle for either a U- or J-groove is about 20° to 25°. This also applies to the double U- and double J-grooves.

One disadvantage of U- and J-groove design is the difficulty of preparing the base material. Plasma gouging or special mechanical cutting tools are required for preparation of the J- or U-type design. V- or bevel-grooves are easier to prepare.

**Creating a Basic Weld Joint**

As a general rule, the arc length is normally one electrode diameter. However, when welding with direct current using a
pointed electrode, the arc length may be considerably less than the electrode diameter. The inside diameter of the gas cup should be at least three times the tungsten diameter to provide adequate shielding gas coverage. For example, if the tungsten is $\frac{1}{6}$" in diameter, the gas cup should be a minimum of $\frac{3}{6}$" diameter.

*Tungsten extension* is the distance the tungsten extends out beyond the gas cup of the torch. Electrode extension may vary from flush with the gas cup to no more than the inside diameter of the gas cup. The longer the extension, the more likely it will accidentally come into contact with the weld pool or the filler rod being fed in by the welder, or touch the side of a tight joint. A general rule is to start with an extension of one electrode diameter. Joints that make the root of the weld hard to reach require additional extension.

To start the arc, hold the torch vertical (90° from horizontal). After you start the arc, hold the electrode in place until the desired weld pool is established. Then tip the torch at a 75° angle from the horizontal so that the tungsten points in the direction of travel, and progressively move it along the joint, as shown in Figure 6-7.

*Figure 6-7: Proper torch and filler metal positioning.*
**Filler metal**

If you’re using filler metal, dip it into the leading edge of the pool using the heat from the molten puddle to melt the filler. Be sure to move the torch and filler rod progressively and smoothly so that the weld pool, the hot filler rod end, and the solidifying weld are not exposed to air that will contaminate the weld metal area or heat-affected zone. Use a large shielding gas envelope to prevent exposure to air.

The filler rod is usually held at about a 15° angle to the surface of the work and slowly fed into the molten pool (refer to Figure 6-7). Alternatively, you can dip it in and withdraw it from the weld pool repeatedly to control the amount of filler rod added. During welding, do not remove the hot end of the filler rod from the protection of the inert gas shield. When you turn the arc off, make sure that the postflow of shielding gas not only shields the solidifying weld pool but also the electrode and the hot end of the filler rod.

**Butt weld**

When welding a butt joint, be sure to center the weld pool on the adjoining edges. When finishing a butt weld, you can decrease the torch angle to aid in filling the crater in the bead at the end of the joint. Add enough filler metal to avoid an unfilled crater: Cracks often begin in a crater and continue through the bead.

Utilizing an amperage control device (either a foot pedal or torch-mounted hand control; refer to Chapter 5) is useful during the finishing of a bead. You can use it to lower amperage to decrease pool size as you add filler metal.

**Lap joint**

In a lap joint, the pool is formed so that the edge of the overlapping piece and the flat surface of the second piece flow together. Because the edge becomes molten before the flat surface, it is important not to angle your torch toward the edge too much. If too much heat is directed toward the edge, it will also tend to burn back or undercut. You can control this by dipping the filler rod next to the edge as it tries to melt away.
T-joint

A T-joint involves a similar situation as a lap joint: An edge and a flat surface are to be joined together. The edge will heat up and melt sooner than the flat surface. Angling the torch more toward the flat surface directs more heat onto it. The electrode may need to be extended further beyond the cup than in the previously mentioned butt and lap welds in order to hold a short arc. The filler rod should be dipped so it is deposited where the edge is melting away. Correct torch angle and placement of filler rod prevent undercutting. Again, the crater should be filled to avoid excessive concavity.

Corner joint

When welding a corner joint, melt both edges of the adjoining pieces and keep the pool on the joint centerline. When adding filler metal, be sure to use sufficient deposit to create a convex bead. A flat bead or concave deposit results in a throat thickness less than the metal thickness. On thin materials, the corner joint design lends itself to autogenous welding, which is fusion welding without the addition of filler rod. Good fit-up is required for autogenous welding.

Edge joint

As mentioned earlier in the chapter, edge joints are often used on thin material and when the members to be welded won’t be subjected to great stresses. Because of this, an autogenous weld can be used on this joint as well. Or, if additional reinforcement is desired, filler metal can be added with the same procedure mentioned in the “Butt weld” section.