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.

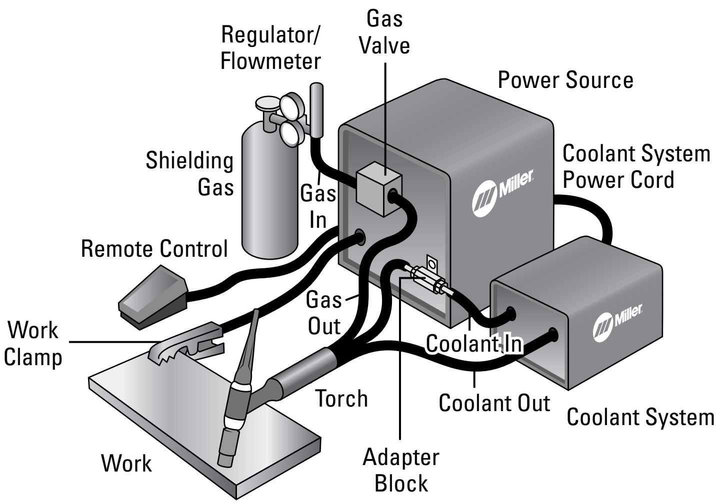

Figure 1-1: The TIG welding process.

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.

REMEMBER

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.

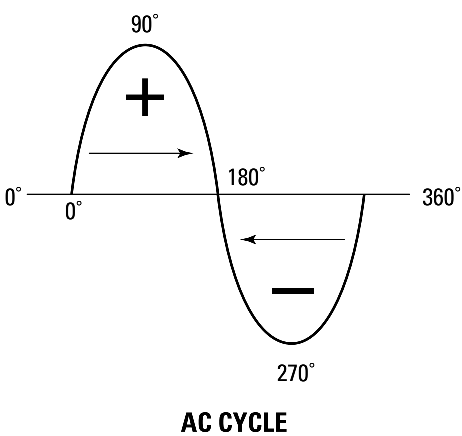

Figure 1-2: Alternating current.

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.

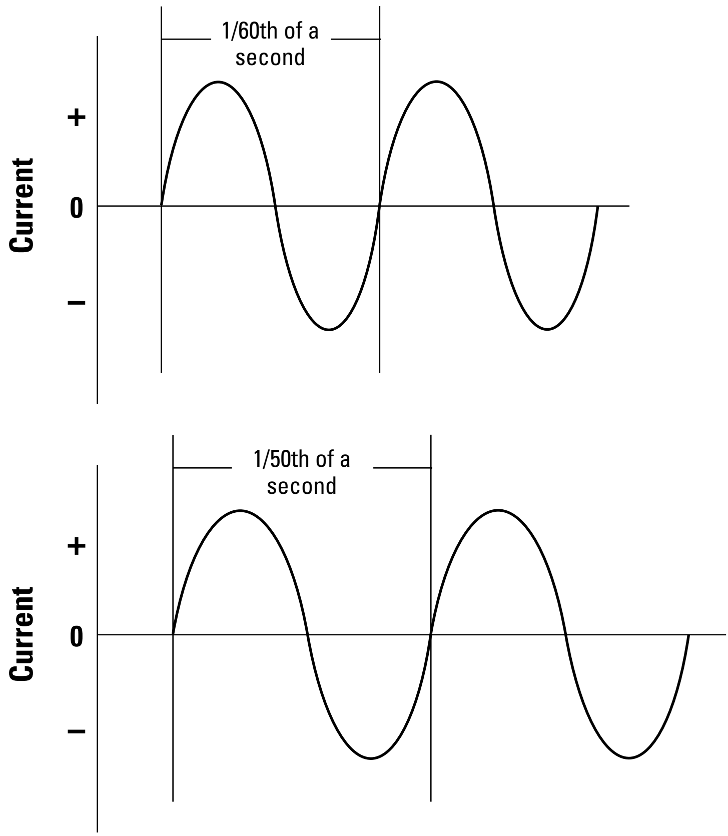

Figure 1-3: Various frequencies.

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.

TIP

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 peice. 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.

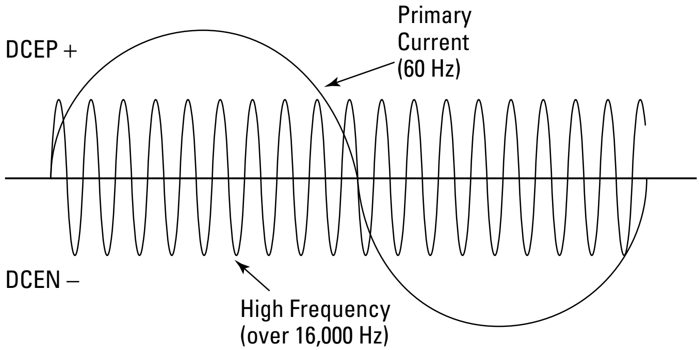

Figure 1-4: High frequency is used to stabilize and start the arc.

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).

TIP

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.