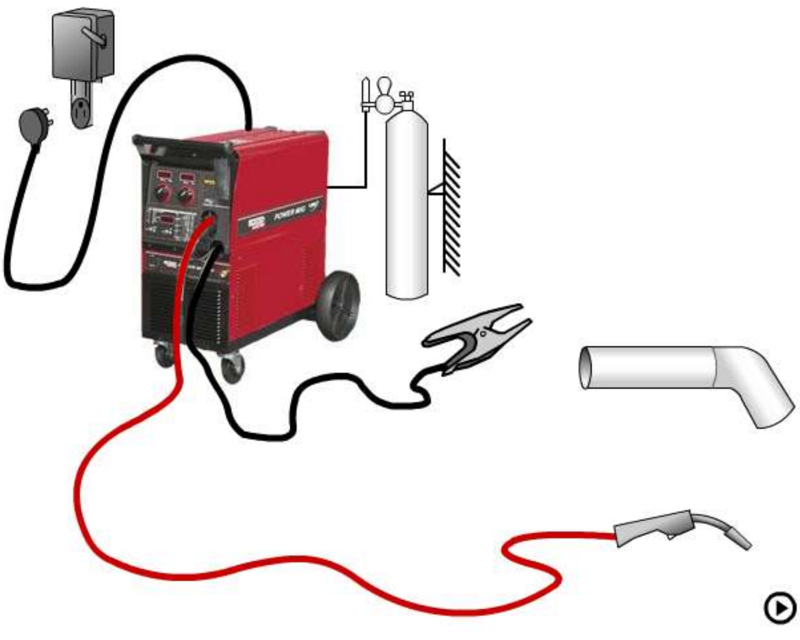
HANDOUT FOR
MECHANICAL ENGINEERING DEPARTMENT

GMAW (MIG/MAG) WELDING



Presented By
STC/NBQ/NFR

INTRODUCTION:

Gas Metal Arc Welding (**GMAW**) is commonly referred to as MIG welding (Metal Inert Gas welding). It is also referred to as MAG welding (Manual Metal Arc Welding). The basic principle of MIG Welding is, an arc is maintained between the end of the bare wire electrode and the work piece where the heat source required to melt the parent metal is obtained. The arc melts the end of the electrode wire, which is transferred to the molten weld pool. For a given wire material and diameter, the arc current is determined by the wire feed rate. The arc and the weld pool is shielded from the atmospheric contamination by an externally supplied shield gas. Metal Inert Gas (MIG) welding is a 'flat' arc process (constant) voltage. The required voltage is selected by adjusting the voltage control knobs provided at the power source. The process itself can be manual, partly mechanized, fully mechanized or automatic.

PRINCIPLE OF MIG WELDING:

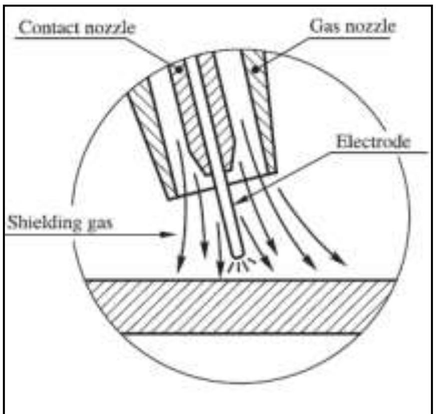
- With semi-automatic MIG welding, the electrode wire is fed through a welding gun controlled by the operator. The operator starts the arc and controls the puddle. In automatic MIG welding, a robot or automated machine makes the weld.
- An arc digs into the base metal much like water from a nozzle on a garden hose digs into the earth. (The flow of the water is like welding current and water pressure is similar to voltage)
- Molten metal forms a molten pool or crater and tends to flow away from the arc while cooling and solidifying.
- A continuous even flow of shielding gas is needed to protect the molten weld metal from atmospheric contaminants such as oxygen and nitrogen. The shielding gas comes from a gas cylinder and flows through the gun and cable assembly, through the gas nozzle, and into the welding zone.

GMAW Definition:

- “GMAW” stands for Gas Metal Arc Welding .
- GMAW is commonly referred to as MIG or Metal Inert Gas welding
- During the GMAW process, a solid metal wire is fed through a welding gun and becomes the filler material
- Instead of a flux, a shielding gas is used to protect the molten puddle from the atmosphere which results in a weld without slag .

MIG/MAG Welding:

Generally **Gas Metal Arc Welding** or welding with shielding gas, as it is often called, is a welding arc process which utilizes the heat of an electric arc established between a continuoually feeded wire and the workpiece. During this process the wire will melt and the weld metal is transferred to the workpiece.

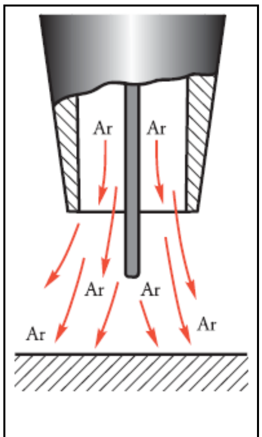


Shielding gas nozzle

The weld pool is always protected by a shield of gas in order to protect both the melting wire and the weld pool from the oxygen and

nitrogen in the air. If these gases enter into the shielding gas atmosphere,
it may cause porosities in the weld. Exterior disturbances such as draugths from open doors and windows may cause the shielding gas to blow away. Also ventilating air currents may influence on the welding place and the shielding gas.

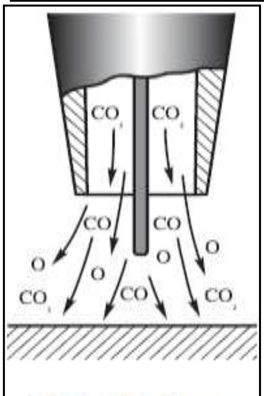
The shielding gas is usually divided into two sub methods according to the applied type of shielding gas.



Argon shielding gas

MIG Welding:

MIG welding is welding in an atmosphere of inert gas, which means welding with a shielding gas that does not react with other substances. Inert gases are for instance argon and helium of which argon is more used within the European region. Usually, the process is called MIG welding even when the inert gas is mixed with small quantities of O2, CO2, H2 or similar substances.



CO2 shielding gas

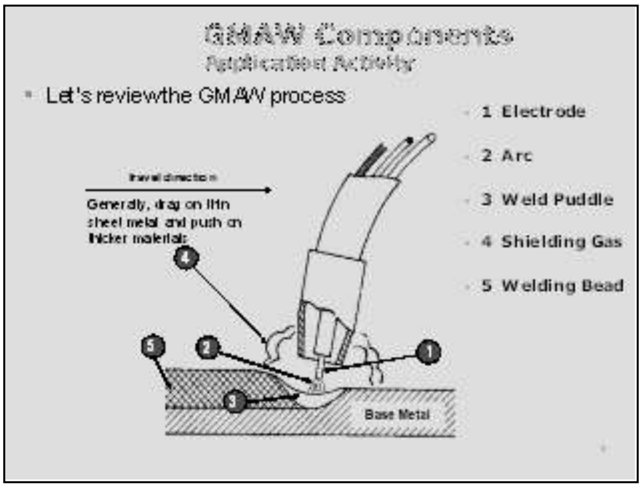
MAG Welding:

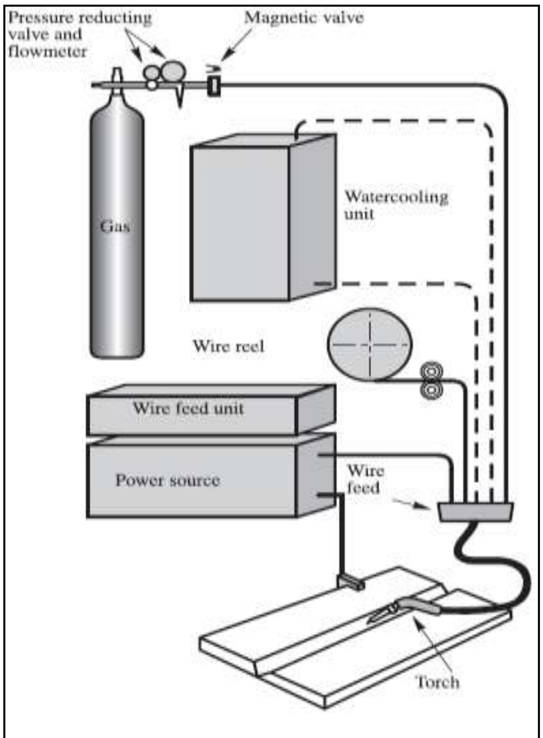
MAG welding is welding in an atmosphere of reacting gases, or as it is also called: shielded by an active gas. This means that the gas is separated in the arc and to a smaller or larger extent reacts with the weld pool. CO2 is mainly used as shielding gas which is why the process is also known as CO2 welding.

MIG/MAG WELDING EQUIPMENT:

Welding equipment for MIG/MAG welding consists of the following components:

- A shielding gas system with control
- A power source
- A wire feed unit
- A complete welding torch
- A reel of welding wire
- Gas cylinders with pressure-reducing valve and flow meter





Welding Methods

GMAW Circuit:

- Three things happen when the GMAW gun trigger is pulled:
  - The wire electrode begins to feed .
  - The circuit becomes electrically 'hot'.
  - Current flows from the power source through the gun cable, gun, contact tip to the wire and across the arc. On the other side of the arc, current flows through the base metal to the work cable and back to the power source . ***Shielding gas flows through the gun and out the nozzle*** .

This process utilizes a direct current electrical power supply with the **electrode positive (DCEP).** The positive electrode attracts electrons flowing in the circuit; these electrons act to melt the electrode wire. The welding current is varied by changing the wire feed speed. Higher wire feed speeds produce higher welding currents. The arc length can be varied by changing the voltage setting. Higher voltages produce longer arc lengths.

1 – Electrode:

A GMAW electrode is:

◦ A metal wire Fed through the gun by the wire feeder Measured by its diameter .

2 – Arc:

An electric arc occurs in the gas filled space between the electrode wire and the work piece .

3 - Weld Puddle:

- As the wire electrode and work piece heat up and melt, they form a pool of molten material called a weld puddle .
- This is what the welder watches and manipulates while welding .

4 - Shielding Gas:

- GMAW welding requires a shielding gas to protect the weld puddle .
- Shielding gas is usually CO2, argon, or a mixture of both .

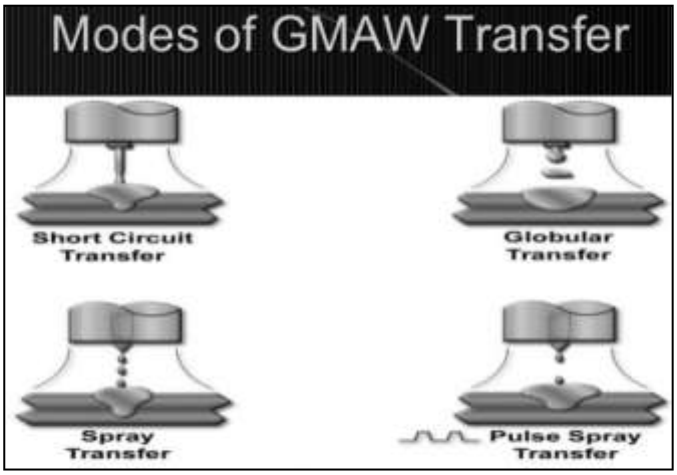
5 - Solidified Weld Metal:

- The welder "lays a bead" of molten metal that quickly solidifies into a weld
- The resulting weld is slag free

METAL TRANSFER ACROSS THE ARC:

The weld metal transfer from the electrode to the work is classified into four different types

1. Short circuiting,
2. Globular,
3. Pulsed spray and
4. Spray transfer.



Principle of Material Transfer:

MIG/MAG welding is performed in two ways depending on the transfer of the metal; either **Spray transfer welding** or **Dip transfer welding**.

At spray transfer welding the voltage and current intensity are relatively high in relation to the diameter of the electrode. The material transfers as a lot of droplets which are flung from the arc like turbulent jets into the weld groove.

The mode of weld metal transfer is determined by the following:

- Welding current
- Electrode size
- Electrode composition
- Electrode stick out (Extension)
- Shielding gas

Short circuiting transfer characteristics:

At low current and voltages, short circuit transfer occurs. The weld is a shallow penetrating weld with low heat input. Using GMAW in this mode allows welding in all positions since the weld puddle is so small. In comparison to the other three modes of transfer, this method is slowest (low productivity). Used primarily for sheet metal applications. This mode produces large amounts of spatter if welding variables are not optimized. This mode is also known as short arc or dip transfer.

Globular transfer characteristics:

This mode of transfer is obtained at intermediate current and voltage levels or at high current and voltage levels with 100% CO_2 shielding gas. Has higher heat input and penetration than short circuit transfer. Larger weld pool makes it more difficult to weld in over-head position. It produces significant amounts of spatter.

Spray and pulsed spray transfer characteristics:

Spray is achieved at higher welding currents and voltages with argon or Helium based shielding gas (over 80% Ar). This high-heat-input, deep-penetrating weld limits the application to the flat position. This mode produces little or no spatter and is known for the high deposition rate (higher productivity). Pulsing the current where spray transfer occurs allows for better control for out of position welding.

POWER SOURCE:

Only **Direct Current DCEP (Reverse Polarity - DCRP**) source is used for MIG welding process. A power source with a flat characteristic is almost used for Metal Inert Gas Welding process as it offers several advantages e.g., latitude in setting the welding condition and self-regulated arc besides it also meets the special requirements of dip transfer welding. Power sources incorporate output characteristics designed to optimize the arc performance for a given welding process. For MIG, the output characteristics fall into two main categories:

1. **constant current**
2. **constant voltage**

The important advantage of flat characteristic power source is its ability to produce self-regulated arc. Self-regulated arc means maintaining the arc length constant. With a constant potential power source, change in arc voltage will have marked effects on current. Thus if the arc length is reduced from the set value, there will be an increase in current resulting in faster burn off rate and the arc length will be adjusted back to its original value .

In other hand, increase in arc length from a set value would increase the arc voltage resulting in less current and a low burn off rate. The arc length would be restored to the original length. Self-adjustment will operate successfully only when the change in current produced by voltage fluctuations is sufficiently large to produce a large alteration in burn off, and rapid response rate and correction that the disturbance cannot beat. Current density is defined as the current employed with a particular electrode diameter divided by its current carrying cross-sectional area. If the wire feed speed is low, then the current density will be low, and vice versa. Lower current density applied to a given electrode is associated with the short-circuit mode of metal transfer. Higher current density is associated with the higher energy modes of metal transfer: globular, axial spray transfer or the more advanced pulsed spray metal transfer.

SHIELDING GASES:

The shielding gas is supplied in cylinders of various dimensions and with a pressure of up to 150 kg/cm2. The gas cylinder is fitted with a pressure reducing valve in order to decrease the high pressure inside the cylinder to a lower and less dangerous working pressure, before the gas flows into the hoses. After the pressure reducing valve (in connection with it) is a flow meter indicating the gas consumption, usually in litres per minute. The welding machine is equipped with a solenoid valve which controls the gas supply.

The primary purpose of shielding gas is to protect the molten weld metal from contamination by the oxygen and nitrogen in air. The type of shielding gas used has a major influence on the weld quality. Only inert gases and their mixtures are utilized for welding. The required purity of the gases must be guaranteed.

- MAG welding + Reactive shielding gasses (oxygen, nitrogen, carbon dioxide & hydrogen)
- MIG welding + Inert shielding gasses (Argon & Helium)

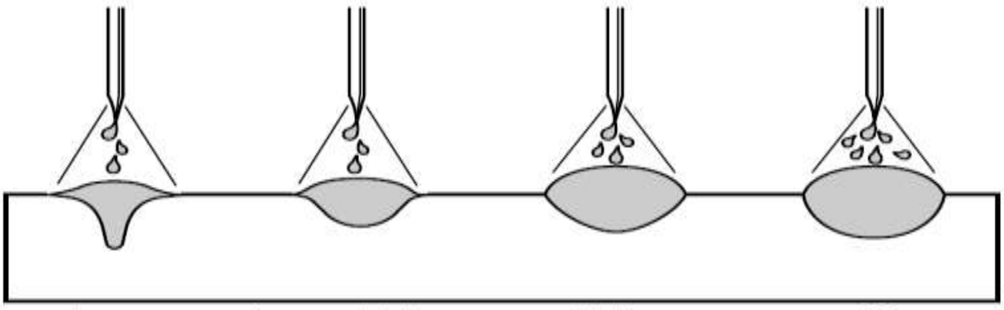
The primary shielding gasses used are:

- Argon
- Argon – 95% to 5% Oxygen
- Argon – 75% to 25% CO_2
- Argon/Helium
- CO_2 is also used in its pure form in some MIG welding processes. However, in some applications the presence of CO_2 in the shielding gas may adversely affect the mechanical properties of the weld.

Although pure inert gas protects metal at any temperature from reaction with constituents of air, they are not suitable for all welding applications. Controlled quantity of reactive gas mixes with inert gas improves the arc action and metal transfer characteristics when welding the steel, but such mixtures are not used for the reactive metals. The heavier a gas, the more effective it is for gas shielding. Helium is very light, argon is about 10 times heavier than helium and about 30% heavier than air.

The reactive gas are not generally used alone for arc shielding, carbon dioxide can be used alone or mixed with an inert gas for welding many carbon and low alloy steels. Oxygen is used in small quantity with one of the inert gasses – usually Argon. Nitrogen is used occasionally but is mixed with argon, as a shielding gas to weld copper. The most extensive use of nitrogen is in Europe, where helium is relatively unavailable.

PENETRATION PATTERN FOR VARIOUS SHIELDING GASSES:



The shielding gas, used for atmospheric shielding, affects the type of metal transfer in the process, the penetration depth, and the bead shape. The ionization potential of the gas is the ability of the gas to give up electrons and is the characteristic which determines the plasma characteristics of the arc. The ionization potential (IP) of the gas can have an effect on welding characteristics such as Arc heat, stability, & starting.

- Helium with high Ionization potential inhibits spray transfer in steels
- CO_2 with moderate Ionization potential also has limited spray transfer
- Argon with low IP promotes the Spray mode particularly at higher currents.

Surface tension of the weld pool and metal droplets are also effected by the type of shielding gas. Surface tension affects:

- the Drop size
- Puddle flow, and
- Spatter.

WELDING VARIABLES AND PARAMETERS:

1. **Electrode extension** - affects the amperage. Stick out length should be 10 - 15 mm.
2. **Inductance** - smoothes the arc characteristic. Also called the choke. If it is Set low it gives excess penetration and if set high, no penetration.
3. **Wire feed speed** - amperage. Controls fusion and penetration.

4. **Travel speed** - controls depth of penetration.
5. **Gas flow rate** - protects weld from atmosphere.
6. **Voltage** - set on the welding machine and controls the arc length.
7. **Tilt angle** - back or fore hand should be not greater than 15° from the perpendicular.
8. The welding position and type of weld are further variables to be considered.

MIG Welder Machine Set-UP, Preparation and a Basic Overview of Settings:

Before setting up your machine you need to prepare and research a few things before squeezing the trigger to striking an arc. MIG welding is a semi-automated process that does not require the world's most skilled welder. Most of the weld quality relies on MIG welder settings or machine set-up and proper preparation.

Before setting up your machine, you need to get the answers to:

- What Type of Metal Will I Be Welding?
- What is the Metal Thickness That I Will Be Welding?
- How Will I Prepare the Joint?
- Do I Have The Right Gas and Electrode/Filler Wire?
- How is the Welder Set-Up?
- Where Can I Find a MIG Welder Setting Chart or Whom Can I ask for Advice!

What Type of Metal Will I Be Welding?

The type of metal that will be welded has a big impact on the machine setting, electrodes and gasses that will be used. Different metals have different melting temperatures and hold that heat differently. When setting up you MIG welder you need to know exactly what type of metal you are going to weld. There is no single setting that works on every metal type. The three most commonly MIG welded metals are:

- Carbon Steel/Commonly Designated as A 36 Grade
- Stainless Steel/Nickel Based Alloys
- Aluminum/Non Ferrous Metals

What is the Metal Thickness That I Will Be Welding?

The thickness of the metal has a major impact on the machine settings. When it comes to other processes like Stick or TIG welding you can use almost the same setting for a variety of metal thicknesses. For example you can weld ¼ inch thick plate with the same setting used to weld a 1" inch thick plate and so on. Now MIG welding on the other hand does not work this way! The heat settings vary greatly depending on the metal thickness. The biggest danger from a weld quality stand point comes from using too low of a heat setting. For example; in the Nuclear Power Plant building industry, MIG welding is almost banned. This happened because in the past there were many welders who did not use enough heat and ended up welding joints that did not penetrate at all. The weld looks fine but a few taps with a hammer and the joint falls apart.

Even a proper spot weld would be a lot stronger! MIG welding too cold will put in the weld, but it is only laying on the surface of the joint. To cold of a weld is as useful as duct taping the joint.

How Will I Prepare the Joint?

Machine set-up only works right if you have a properly set-up joint. Ideally you want all rust, paint, oils, dirt's and mill scale removed from the weld area. This is done for three reasons:

- The first is a clean joint produces a clean weld.
- The second is that the machine settings will vary between dirty joints and clean one.
- Finally a dirty joint will spatter and spit increases the chances of you getting burns or starting a fire.

Do I Have The Right Gas and Electrode/Filler Wire?:

A major part of setting up your machine is choosing the right gas and filler wire/electrode. This is an area that varies depending on all of the above factors and many more.

The three most commonly used gas/ electrode variations or combinations are:

- Carbon Steel – ER70s Electrode with a C25 Gas (75% Argon and 25% Carbon Dioxide)
- Stainless Steel – ER308L with a C2 Gas (98% Argon and 2% Carbon Dioxide)
- Aluminum – ER4043 with 100% Argon gas

How to Set-Up a MIG Welder?

There are three settings or controls that set the welder and those three are:

- Voltage
- Wire Feed Speed
- Gas Flow Rate/Gas Type or Mixture

These three settings are what control the heat of the weld and depending what gasses are used the transfer type too. If you are not familiar with transfer types then please read up on MIG Welder Transfer Types because they have a big affect on your settings and how you will be welding.

Voltage Settings and Polarity Type:

To start the voltage type used is almost always D/C electrode (+) positive. This means that the handle is the positive side of the circuit, or it may be said, the electricity flows from the metal in to the welding handle. This setting almost never changes and if you do need to change it then you need to unbolt the internal leads and flop them.

The voltage is the main heat setting that get's changed depending on the joint, metal thickness, gas type and position of the weld. It does most of the regulation and is most commonly used to change the welder's settings. The voltage setting varies depending on what size electrode is used, how thick the metal is and what type of gas is used. Since MIG welders are CV or Constant Voltage power sources, the voltage does not fluctuate very much when welding.

Wire Feed Speed:

The wire feed speed regulates how much or how fast the wire is feed into the weld joint. Wire feed speed is regulated in IPM (or) Inches Per Minute. The wire feed speed also serves another purpose for regulating the amperage. When Stick or TIG welding, the main setting is amperage, but it is the voltage that fluctuates depending on the arc length. With MIG it is the voltage setting that stays the same but the amperage is changing depending on the wire feed speed and electrode stick-out. Picture this; the faster the wire is feed into the joint, the better contact it has. The better contact, the more amperage gets through the wire and the higher the heat.

Gas Flow Rate/Gas Type or Mixture:

Finally the gas type and gas flow rate help regulate the transfer type. A high percentage of Argon or Helium added to a mix creates a hotter arc. The main goal of the gas setting is to provide enough gas to shield the weld area from the air. Gas flow rates are regulated in CFM or Cubic Feet Per Minute. This is an area that requires experimentation. In a shop setting a rate of 15 CFM may be enough, but a drafty area might require a rate of 50 CFM. Another thing to watch for is not to have the gas setting to high. A flow rate that is too fast can cause turbulence and suck in air to contaminate the weld. Having the right gas flow rate is a trial and error process that is ultimately a search for a happy medium of all settings in the current welding conditions.

Putting the Voltage, Wire Feed Speed and Gas Flow/Gas Type All Together:

Finally once these settings are all put together it produces the transfer type we wanted and it has enough heat to properly penetrate the metal without burning a hole through the joint. It is the result of trial and error that experimentation ultimately sets the machine just right to produce the weld we need, want or hope to make. That all sounds fine unless a welding engineer or procedure has done all of that work for you. If not, then it is time to look at the next section, MIG Welding Charts, Settings and Guides.

MIG Welding Charts, Setting Guides and Exact Answers:

Finally if you need some exact answers and guidance then you can read this! The manufactures of most welding machines include either a MIG welding chart inside of the machine or a guide to their machine settings. I do want to mention that two identical welding machines that are made by the same company at the same time never run the same. These are only guidelines and do change from machine to machine! Each machine is calibrated differently and that all depends on its use and who has serviced it.

MIG Welder Settings Charts, Guides and Tables for Steel, Stainless and Aluminum:

To start the pictures below are the manufactures recommended (Lincoln Welders and Miller Welding Equipment) voltage, wire feed speed settings and gas recommendations. After those pictures I have added a chart of my own settings (working on it) that are the happy medium of the manufactures recommendations. Just remember these are just guidelines and each machine runs differently. This is a game of trial and error that requires just that, trial and error! Test your settings on a piece of scrap metal that is very close to the thickness of the metal that you will be welding. It should also be set in the position that you will be welding in. If you take your time following these steps then you will have a much easier time welding.


Good Weld
Voltage to High
Voltage to Low
Too Fast
Too Slow