	Stick (SMAW)	MIG (GMAW)	TIG (GTAW)	Plasma (PAC)
Overview	Stick/Arc or SMAW (Shielded Metal Arc Welding) is one of the oldest and most popular welding methods and was popularized between WWI and WWII. It offers the user excellent portability and is popular in outside work, field repair construction, pipe welding, and maintenance and repair welding.	MIG welding was developed fairly early but early issues limited its use until after WWII. MIG welding became the dominant welding process by 1970's and is preferred by DIY'ers up to Heavy Industrial. Fast, economical, and easy to learn.	TIG welding was initially developed for aircraft and aerospace applications where precise and high quality welds are required. It is the most complicated of the common welding processes. It requires a high-skill level, knowledge and coordination. It is primarily used on aluminum, stainless, and magnesium. Industries that commonly use TIG: aerospace, tool and die, chemical processing, power plants, food processing, custom motorcycle and race car applications.	Plasma cutting is used for fine/intricate cutting of steel and other metals of varying thicknesses. It is a versatile process, and is used in applications like HVAC, construction, fabrication, artwork, and many more. Plasma cutting uses compressed air and an electrical arc to cut. It is a very easy process to learn and is great for precise cuts. One downfall is that it is generally limited to ~1" max cutting capacity.
Shielding (Gas)	External shielding gas is not used but rather the flux on the electrode acts as the shielding for the welding puddle and helps stabilize the arc. Different electrodes and flux types provide different arc characteristics and have unique attributes designed for certain applications.	Initial shielding gases used were Inert or Non-reactive gases like Argon or Helium. While Argon is still common, various mixed gases are the most popular. The shielding gas protects the puddle from atmospheric contamination and provides arc stability.	Initial shielding gas used was Helium. Now, the typical gas used for aluminum, titanium, or magnesium is Argon, an inert (non-reactive) gas. The shielding gas protects the puddle from atmospheric contamination and provides arc stability.	External shielding gas is not used. Instead compressed air or nitrogen is supplied for cutting.
Popular Filler Metals (Steel Only)	E6010 - Deep penetrating rod primarily used for root (1st) passes on steel pipe.	Solid (ER70S-6) - Most common for welding indoors as minimal cleanup is required. Shielding gas required.	Solid (ER70S-3) - Most common for welding steel.	N/A
	E6011 - A general purpose rod for steel. OK for most jobs but not great for any one application.	FC No Gas (E71T-GS) - A tubular wire with flux on the inside that provides shielding so no external shielding as is needed.	Solid (ER70S-2) - Sometimes used and has a little better deoxidizing capability	
	E6013 - A general purpose rod for steel. Good for out-of-position (vertical or horizontal) welding and thinner materials.	FC Gas (E71T-11) - A tubular wire with flux but also requires shielding gas. Common for outdoor construction and repair welding,	Solid (ER70S-) - Sometimes used and "wets out" better than ER70S-3.	
	E7014 - A general purpose rod for steel. Known for nice bead profile and east to strike.	Metal Core - Developed as a higher productivity alternative to Solid wire, it has higher fume generation rates and long term popularity is being debated. It also requires shielding gas.		
	E7018 - Provides nice bead profile on critical steel welds where cracking is a concern. Used heavily in fabrication, repair, and construction			
Base Metals (Welded by Process)	Steel, Stainless Steel, Cast Steel & Cast Iron, Brass & Copper, Tool Steel, Aluminum (non-critical)	Steel, Stainless Steel, Cast Steel & Cast Iron (sometimes), Brass & Copper, Aluminum	Aluminum, Stainless, Titanium, Magnesium, Steel, Cast Steel, Tool Steels	Any electrically conductive metal.
Consumables	Besides electrodes, the main consumable is occasional replacement of the ground or electrode cables.	Besides wire on spools, MIG welding requires more machine maintenance. Common consumables: Tips, Diffusers, Nozzles, Liners (Spring Steel – Steel) & (Teflon – Aluminum), Drive Rolls (V-groove – solid wire) & (U-groove – aluminum) & (Knurled – FC wires), Replacement guns or parts	Nozzle/Cup (Alumina or Lava style), Collet, collet body, gasket/insulator, gas lens, gas lens insulator. Other parts to supplement these common consumables: back caps, torch bodies, torch handles, power/gas/water cable set ups	Plasma cutting electrodes, swirl ring, nozzle, retaining cap, shield
Troubleshooting	**Arc Stability** – usually caused for poor electrode choice, damp or damaged electrode, wrong amperage, or grounding issues. **Cracking** – usually caused by improper procedure or poor electrode choice. **Arc Striking** – most use a "tap" or "scratch" start. Some electrodes are naturally more difficult to strike.	**Poor wire feeding** – the main cause of problems could be caused by tip, liner, drive rolls or feeder tension. **Arc stability** – improper wire feed speed or voltage settings, or gas leak is common.	**Arc Stability** – can be caused by many factors depending on the setup, base metal, and gas. Check the power supply for any issues (check for hot spots in the cable due to electrical resistance). Check gas connections are clean and secured tightly; ensure adequate type and amount of gas flowing from the torch (but not too much). Check polarities are correct for the application and machine setup. Double check parameters of the machine. TIG machine parameters can be finicky and finding the "sweet spot" often requires hours of practice.	**Poor Performance** - Dirty or moist air is number one problem with plasma cutting. A filter and dryer is recommended. Sometimes the consumables are installed incorrectly and the plasma cutter will not work if this happens.
Parameters	**Amperage** – this is the primary parameter and controls heat, penetration and shape of the weld. **"Hot Start"** – increases starting amperage to overcome electrode arc striking concerns. **"Dig" or "Arc Force"** – changes the standard voltage to amperage relationship and can affect electrode characteristics and penetration.	**Voltage** – controls the shape of the arc and transfer mode. Can also affect the bead profile. **Wire feed speed** – adjust voltage first and then fine tune the WFS. **Amperage** – directly affected by WFS and stickout. **Wire Feed System** – whenever there are welding issues it usually means there are problems with the wire feeding system. When troubleshooting wire feeding, start at the spool and work towards the tip. Make spool tension and drive roll tension is good. Check alignment of wire to inlet, wire drive rolls, and MIG gun. Check the liner, diffuser, and tip. Make sure drive rolls, and consumables are properly sized for MIG wire diameter.	**Amperage** – this is the primary parameter and controls heat, penetration and shape of the weld. **Frequency** – for AC the number of times current alternates between DCEP and DCEN in one second, measured in Hz. Standard US AC household frequency is 60Hz. Affects the arc shape. **Pulse** – output amperage cycles between base (lower) current and main (upper) current to provide more heat control. Pulsing affects the bead profile and pattern. Usually you set Pulses Per Second and/or % On Base Current. **Balance** – percent of time the current spends in DCEN. Household AC frequency spends 50% in DCEP and 50% DCEN. The more time (higher percent) spent in DCEN, the tighter the arc/less cleaning action/and reduction of tungsten balling. **Pre-/Post-Flow** – seconds of air flow programmed to occur before and after the weld. Helps with more shielding and tungsten cooling. **Ramp Up/Down** – aka slope control. Rise of Voltage over run of Amperage. Controls the rate of voltage increase/decrease at programmed amperage? **Crater Fill** – Adjusts the amperage at the end of the weld to fill the crater in the weld puddle.	**Amperage** – this is the primary parameter and controls the heat/penetration needed for the cutting capacity. Thicker materials need higher amperages. **Air Flow** – a good clean and dry air flow with plenty of volume is required. The air compressor needs to provide plenty of volume rather than high pressure.

	Steel	Stainless Steel	Tool Steel	Cast Steel or Cast Iron	Copper/Brass	Aluminum
Overview	Steel before WW1 was difficult to work with and crack sensitive. "Old" steel was usually joined with rivets or sometimes "Gas" (Oxy-Acetylene) welded. By WWII, steel chemistry had improved dramatically by controlling the content of carbon and other elements and now could easily be welded, often by "Arc" or "Stick" welding.	Stainless steel was developed by adding Chromium to steel so that a protective layer of chrome-oxide would be created instead of iron-oxide (rust). In addition to Chromium, Nickel is often added which can alter weldability, mechanical properties and corrosion resistance.	Tool steels are highly alloyed steel. They usually contain a significant amount of Carbon, Vanadium, Chromium, Tungsten, Molybdenum, and possibly some Cobalt or Boron. Each of the alloying elements creates carbides and/or very tight and hard microstructures that resist heat and abrasive wear.	Cast Steel and Cast Iron may look the same but from a welding standpoint, they are entirely different. Cast Iron can have as much as 10 times the Carbon content as Cast Steel. High Carbon contents create numerous issues with weldability. Cast parts are often found on complex machinery.	Brass or bronzes are essentially copper alloys and can be made of primarily copper with the addition of Tin, Zinc, Aluminum, Silicon, and Nickel. Copper Alloys are primarily used for corrosion resistance and their high thermal and electrical conductivity.	The aerospace industry was the main driver behind the various aluminum alloys that can be found today. Properly alloyed and heat treated aluminum can provide a higher strength to weight ratio than steel. While aluminum has benefits for certain applications it also has its challenges when welding and fabricating with it.
Types	There are literally 1000's of grades of steel but it's easiest to group them into 3 categories based on their carbon content. The higher the carbon, the stronger the steel, the more brittle, and more crack sensitive.	There are 100's of stainless steels and usually grouped by their microstructure (the way atoms align). Some stainless steels are easy to weld and some are close to impossible.	There are many types but usually grouped into Water Hardened, Cold Work, Shock Resistant, High Speed, and Hot Work types. There are specialty applications where Tungsten, Vanadium, and Boron types come in to play.	Cast Steel usually has a carbon content of less than 0.5% while Cast Iron can be 3-5% Carbon. There are certain types of wear resistant Cast Iron (White or Ni-hard) that are considered unweldable.	Typical classifications are: Pure Copper, Brass (Copper + Zinc), Aluminum Bronze, Silicon Bronze, Copper Nickel, and Nickel Silver alloys.	While there are many types, most aluminum can be classified as heat-treatable and non-heat-treatable. Heat-treatment precisely controls the heating and cooling of the base metal to optimize mechanical properties.
Popular Grades & Typical Welding Procedures	**Mild or Low "C" Steel** The majority of steel used and are consider "soft" or ductile and can easily be formed, drilled, cut, and welded. No special procedures required to weld.	**Austenitic** Most common, fairly easy to weld, and usually a 200 or 300 series number. They are non-magnetic to slightly magnetic. The key to welding these is keeping the base metal cool, usually under 400°F.	Tool steels are very difficult to weld and usually require high preheat along with a specific post-weld heat treatment. A special welding procedure is required with each type.	**Cast Steel** Common and easy to weld with steel electrodes or wire. Sometimes a little preheat of 200-300°F is used.	**Copper Alloys** are fairly easy to weld with the right procedure and filler metal. The main difficulty comes from overcoming the high thermal conductivity and either getting enough preheat to help with this problem or having enough welding heat input to get good fusion. Color match is often a concern which is always difficult but matching the base metal chemistry to the filler metal chemistry is usually a good bet. If you want one product to weld most copper alloys or bronzes, usually a Silicon Bronze or Aluminum Bronze filler metal is used. Stick and TIG welding along with "silver soldering" which is really silver brazing are all common joining methods.	While welding most types of aluminum is possible with MIG or TIG welding, it also comes with risks and challenges. Welding by its nature will alter the base metal mechanical properties and these needs to be understood and planned for. Since aluminum wire is softer than steel, MIG welding while faster than TIG welding has some challenges. When MIG welding aluminum a spool gun or push-pull gun is usually recommended along with Teflon liners and U shaped drive rolls. TIG welding also presents some challenges as the aluminum oxide layer will reflect heat so AC is recommended which will alter the polarity and help break up the oxide.
	Medium "C" Carbon Steel Construction grade steel is often borderline between low/medium carbon steel and often need special welding procedures to prevent cracking. HSLA (High Strength Low Alloy) steel also falls into this category and require specific filler metals and welding procedures to weld correctly. Often other elements like Chromium, Molybdenum, and Nickel are used to alloy (change physical properties). Typical pre-heat of 300-500°F are used.	**Martensitic** Used in special applications and designated by a 400 series number, they have better mechanical properties than Austenitic types but lower corrosion resistance. Martensitic SS are highly magnetic and very difficult to weld. Usually a moderate preheat of around 400°F is used when welding these along with a controlled cooling rate.		**Cast Iron** Difficult to weld and crack sensitive. A nickel base "cast iron" electrode is commonly used with a preheat of 600°F. A "Nickel 55" electrode is preferred for most repairs unless machinability is a factor and then"Nickel 99" is often used. Small stringer beads should be used with immediate peening, followed by a slow cool where the welded part is buried in sand or wrapped in welding blankets.		
	High "C" Carbon Steel Due to high hardness and resistance to abrasive or frictional wear, these steels are very difficult to weld and "Tool Steels" often fall into this category. Often highly alloyed with Chromium, Molybdenum, Nickel, Tungsten, Vanadium, and Boron. Typical pre-heat of 400-800°F are used.	**Ferritic** Used in special applications and designated by a 400 series number, they are often used where there is a combination of high heat and corrosion. Martensitic SS are highly magnetic and very difficult to weld. Minimized heat input when welding these is important along with a controlled cooling rate.		**White Cast Iron (Ni-hard)** A high carbon cast iron with chromium added to improve wear resistance. Often found in agriculture or sewage pump housings. Due to the high chromium content, chrome-carbide will be formed when welding which will create cracking problems.		
Abrasives	Brushes, flap discs, cutting and grinding wheels are often used for welding preparation or cleanup after welding.	Typical abrasives for steel can be used but make sure you use stainless steel wire brushes instead of steel as regular steel will contaminate the base material.	Because of the extreme wear resistance and hardness of tool steels, ceramic embedded abrasives are usually recommended.	Brushes, flap discs, cutting and grinding wheels are often used for welding preparation or cleanup after welding.	Brushes, flap discs, cutting and grinding wheels are often used for welding preparation or cleanup after welding. Do not use standard steel bristle brushes.	Since aluminum is soft it will often load of traditional abrasives. A specially designed abrasive is recommended. When wire brushing, use a brass bristle to prevent contamination.
Drilling	Depending on the hardness or type of steel that needs to be drilled will affect the type of drill bit used. High Speed – most often used for occasional mild steel drilling. Cobalt – used for medium carbon and alloyed steels. Carbide – used for the most difficult applications and high carbon steels.	Drilling austenitic or ferritic stainless steels is fairly easy with a quality drill bit but when drilling on martensitic base metals, make sure you have a top quality bit with extreme heat and wear resistance.	Carbide based tools and bits are recommended.	A cobalt based drill bit or carbide bit is recommended with slow speeds and caution. When drilling Cast Steel, a nice spiral will be formed and when drilling Cast Iron flakes or small chunks will occur. The drilling test often used to determine whether the material is cast iron or cast steel.	Drilling copper alloys is fairly straightforward and typical bits used for steel can also be used.	While you can easily drill aluminum, the aluminum can stick to the bit and cause damage to the bit, so a specially coated bit is recommended to prevent aluminum loading up on the bit.

General Welding Info

Welding Cable Chart

Amps	50’	75’	100’	150’
100	#4	#2	#2	#1
150	#2	#2	#1	2/0
200	#2	#1	2/0	3/0
250	#1	1/0	3/0	4/0
300	#1	2/0	3/0	
350	1/0	3/0	4/0	

General Amperage Ranges SMAW (Arc) Electrodes

1/16”	1.6 mm	30-40 Amps
5/64”	2.0 mm	50-65 Amps
3/32”	2.4 mm	60-100 Amps
1/8”	3.2 mm	85-140 Amps
5/32”	4.0 mm	130-180 Amps
3/16”	4.8 mm	150-250 Amps

Stainless and Nickel electrodes should be on the low side.

Welding vertical and on thinner materials should be on the low side.

Welding thicker materials should be on the high side.

Low amperages tend to cause electrode sticking while higher amperages tend to cause spatter.

Tungsten Recommendations

1.5-2% Lanthanated (La)	Most versatile tungsten (best overall)
1.5-2% Ceriated (Ce)	Solid performance for most applications
1-2% Thoriated (Th)	Performance OK but hazardous
Pure (P)	OK – but tungsten will ball up and not allow concentrated arc – good for older sine wave AC machines

Recommended Amperages for TIG

Tungsten Ø	DCEN (Th, La, Ce)	AC (La, Ce)	AC (Pure)
.040”	10-50 Amps	20-40 Amps	N/A
1/16”	40-120 Amps	30-110 Amps	30-90 Amps
3/32”	90-200 Amps	60-180 Amps	40-120 Amps
1/8”	150 Amps +	130 Amps +	100-200 Amps

Forney Welding Machine Ratings

	INPUT				OUTPUT			
	OCV	Frequency	Voltage	Amps	Duty Cycles			
270 MIG (#319)	18-45 V	60 Hz	230 V	40 A	30% 250 A 25.5 V	60% 200 A 24 V	100% 150 A 21.5 V	
242 DUAL MIG (#327)	18-45 V	60 Hz	230 V	40 A	35% 200 A 24 V	60% 155 A 21.7 V	100% 120 A 20 V	
201 MIG (#311)	19.5-38 V	60 Hz	230 V	30 A	10% 210 A 21 V	25% 130 A 20.5 V	100% 65 A 17.5 V	
190 MIG (#318)	30 V	60 Hz	230 V	20 A	15% 140 A 21 V	25% 120 A 20 V	60% 80 A 18 V	100% 60 A 17 V
140 MIG (#309)	32 V	60 Hz	120 V	20 A	20% 115 A 19.75 V	35% 90 A 18.5 V	60% 60 A 21 V	100% 55 A 16.75 V
190 MP (#324) ***MIG process***	60 V	60 Hz	230 V		20% 170 A 22.5 V	60% 100 A 19 V	100% 85 A 18.2 V	
MIG process	60 V	60 Hz	120 V		35% 120 A 20 V	60% 90 A 18.5 V	100% 75 A 18 V	
STICK process	80 V	60 Hz	230 V		20% 170 A 27 V	60% 100 A 24 V	100% 85 A 23.5 V	
STICK process	80 V	60 Hz	120 V		40% 100 A 24 V	60% 85 A 23.4 V	100% 65 A 22.6 V	
TIG process	9.5 V	60 Hz	230 V		20% 170 A 22.5 V	60% 100 A 19 V	100% 85 A 18.2 V	
TIG process	9.5 V	60 Hz	120 V		40% 110 A 14.4 V	60% 90 A 13.6 V	100% 70 A 12.8 V	
140 MP (#322) ***MIG process***	60 V	60 Hz	120 V		25% 90 A 18.5 V	60% 60 A 17 V	100% 45 A 16.2 V	
STICK process	60 v	60 Hz	120 V		35% 80 A 23.6 V	60% 60 A 22.4 V	100% 45 A 21.8 V	
TIG process	6.5 V	60 Hz	120 V		20% 100 A 14 V	60% 60 A 12.9 V	100% 45 A 21.8 V	
700 P (#303)	480 V	50/60 Hz	230 V		30% 40 A 96 V	60% 25 A 90 V	100% 20 A 88V	
	480 V	50/60 Hz	120 V		25% 30 A 92 V	100% 20 A 88 V		
325 P (#302)	310 V	60 Hz	120 V	24 A	50% 20 A 88 V			
250 P+ (#317)	310 V	60 Hz	120 V	16 A	25% 12 A 84.8 V			
220 ACDC TIG (#325) ***TIG AC process***	80 V	50/60 Hz	230 V		25% 200 A 18 V	60% 130 A 15.2 V	100% 95 A 13.8 V	
TIG DC process	90 V	50/60 Hz	230 V		35% 200 A 18 V	60% 140 A 15.6 V	100% 110 A 14.4V	
STICK process	70 V	50/60 Hz	230 V		35% 200 A 28 V	60% 140 A 25.6 V	100% 110 A 24.4 V	
220 ST (#326)	70 V	50/60 Hz	230 V		25% 200 A 28 V	60% 125 A 25 V	100% 95 A 23.8 V	
	70 V	50/60 Hz	120 V		40% 100 A 24 V	60% 80 A 23.2 V	100% 65 A 22.6 V	
235 ARC (#314) (AC = Bold)	DC = 63 V **AC = 72 V**	60 Hz	230 V		DC = 35% DC = 135 A DC = 21.5 V		**AC = 50%** **AC = 150 A** **AC = 26 V**	

Shielding Gas Recommendations

75/25	75% Argon/25% CO_2	Steel	Common for “short arc” welding on sheet metal and thin plate.
90/10	90% Argon/10% CO_2	Steel	Common for “spray” welding on thicker plate. (10-20% CO_2 will allow for spray transfer)
Argon	100% Argon	Aluminum	Typical gas used for aluminum, titanium, or magnesium. (Inert gas)
Helium	100% Helium	Aluminum	Original shielding gas used for TIG welding and why the term “Heli-arc” is still heard. Rarely used by itself, but usually added to Argon to create more heat and better penetration. (Inert gas)
Tri-mix (Stainless)	Helium/Argon/CO_2	Stainless	Originally developed for stainless steel and still common but expensive. This mix also has higher heat potential which sometimes is a negative.
98/2	98% Argon/2% CO_2	Stainless	A lower cost and often better performing gas mix for stainless.
Various Mixes	Argon/Helium/O_2/CO_2		There are numerous “mixes” available for specific applications that tout various benefits. Above are the most common.

Helpful MIG Conversions & Info

Standard	Metric	MIG Amperage Range	Typical Material Thickness	Typical Applications
.024”		<70A	<1/8”	Used for extremely thin materials or very low amperage DIY machines.
.030”	0.8 mm	50-150A	1/16”-3/8”	A versatile diameter especially for DIY or sheet metal work. Recommended for 120V machines.
.035”	0.9 mm	70A-200A	1/16”-1/2”	Arguable the most common and versatile diameter allows for sheet metal work up to fairly thick plate.
.045”	1.1mm	120A-400A	1/8”+	A popular choice for plate fabrication and welding.
1/16” (.062)	1.6mm	230-600A	3/8”+	Typically the largest common diameter for very thick plate and “heavy welding” applications.

		MIG Cons. (Below)	Dinse Size	Gun/Torch	Spool Gun	Ground & Stinger	TIG Torch	Foot Pedal
MIG Machines	125 FC	TW1*	N/A	85601	N/A	N/A	N/A	N/A
	140	TW1	N/A	85500	N/A	N/A	N/A	N/A
	190	TW1	N/A	85500	N/A	N/A	N/A	N/A
	210 QD	TW1	N/A	85508	85652	N/A	N/A	N/A
	210 Euro	TW2	N/A	85507	85651?	N/A	N/A	N/A
	242	TW2	50	85507	85651	85668(G)	N/A	N/A
	270	TW2	50	85507	85651	85668(G)	N/A	N/A
MP	140 MP	TW1	25	85500	85653	85667(G) 85669(S)	85654	85655
	190 MP	TW1	25	85500	85653		85654	85655
Stick/TIG	100 ST	N/A	25	N/A	N/A	85667(G) 85669(S)	85810 (9FV)	N/A
	220 ST	N/A	50	N/A	N/A	85668(G) 85670(S)	85812 (17FV)	N/A
	220 AC/DC TIG	N/A	50	N/A	N/A		85815 (26FV)	85671
	235 AC/DC	N/A	25	N/A	N/A	85667(G) 85669(S)	N/A	N/A
Plasma		**Electrode**	**Tip**	**Swirl Ring**	**O-ring**	**Shield Cup**	**Shield Cap**	**Kit**
	250P+	85755 (2)	85392	85393	85680	85394	N/A	85674
	325P	85755 (2)	85392 & 85393	85393	85680	85681	N/A	85675
	700P (Std)	85755 (2)	85678 & 85679	85393	85680	85681	N/A	85676
	700P (Max)	85755 (2)	85684	85393	85680	85685	85686	85677
MIG Consumables		**Tip**	**Diffuser**	**Nozzle**	**Steel Liner**	**Teflon Liner**		
	TW1*	60170(11-24) 60171(11-30) 60172(11-35) 60173(11-45)	85339(35-50)	85336(21-50) 85337(21-62)	N/A	N/A		
	TW1 (Red Trigger)				100202 (Binzel)	255-18-015 (Special)		
	TW1 (Black Trigger)				100356	100357		
	TW2	30179(14-30) 60175(14-35) 60168(14-45)	85341(52)	85335(22-50) 85335(22-62)	100356	100357		
Other	Plasma Circle Guide (85683) For all Plasma machines	Replacement Regulator (85662) For MIG and MP machines	Flowmeter USA (85664) For 220 AC/DC TIG	15” Gas Hose (85663) For all machines	PT40 (85688) For 302 & 317	PT40 Easy Fit (85687) For 303	242 KIT (334)	