

# **METAL SHOP MANUAL**

**Equipment Policies & Procedures**



# About this Manual

This manual provides information about the School of Art Metal Shop at the University of Tennessee, Knoxville. It is required reading for all who have been approved to use the shop. This manual is not an exhaustive resource, but is instead designed to provide basic information and policies that encourage a culture of safety in the sculpture facilities. This handbook is written and maintained by the 3D Shop Technician.

*This copy was last updated: Spring 2020 by Casey Fletcher*

## Safety

The Metal Shop is a comprehensive metal fabrication facility. Every tool and machine carries its own inherent dangers and it is imperative that you are aware of the safety hazards involved with each process. Knowing this helps to protect yourself and those working around you. Momentary lapses of attention or reason can affect you or your classmates for life, so please: Pay attention, be alert, follow instructions, ask for help. Follow these guidelines to help UTK Sculpture maintain the safest creative environment possible:

- Know the locations of emergency exits, fire extinguishers, first aid kits and eyewash stations.

In case of emergency follow these steps:

- Move away from any danger.
- Call 911 or University Police at (865)974-3111
- If possible, stay in a safe area to provide information to emergency personnel when they arrive.
- Notify shop technician, professor or office staff as soon as possible.

## Shop Attire

From the time you enter the shop you should be wearing proper Personal Protective Equipment (PPE) and appropriate shop attire. Each individual tool has its own requirements and restrictions, so begin with these general guidelines:

- Eye protection: Required upon entering the shop. Please wear at all times.
- Face Shield: Required for many processes involving cutting or grinding.
- Ear Protection: Required for most cutting and grinding processes, highly recommended for the duration of your time in the shop.
- Shoes: Closed-toe shoes are required for shop entry. Stronger boots are highly recommended to prevent injury from falling heavy objects.
- Clothes: No synthetic fibers are allowed while working in the shop. Denim, leather or other non-synthetic pants are required. Shorts, skirts and leggings are not allowed. Shirts with long sleeves must be able to be rolled up securely. Remember **Cotton burns off, synthetic melts on.**

**METAL SHOP POLICIES**

# General Shop Safety and Etiquette

- Report all respiratory and/or health issues to your professor at the beginning of the semester.
- Do not use the shop if you are under the influence of any substance or medication that might impair your abilities or if you feel overly tired or emotionally distressed.
- Be mindful of those working around you. Warn them if you are going to be welding or using a loud tool. Never distract someone who is using a power tool. Offer a helping hand if you see a student struggling.
- Keep your workspace organized and free from debris/tripping hazards/flammable materials.
- Do not remove machine guards and do not tamper with the safety gear, or the lock mechanism of the tools and machinery.
- Do not attempt to make any repairs to equipment or tools. Report all defects to the shop tech, monitor on duty or your professor.
- Always unplug tools when changing out blades, discs, bits, etc.
- Never hesitate to ask for help if you are unsure of a process, tool, machine etc. It is always better to ask!

# Shop Access

Only students who are currently enrolled in a sculpture class are allowed access to the Metal Shop. These students must complete safety training on the equipment they wish to use. Undergraduate sculpture majors only have access to the shop during posted open studio hours unless arrangements have been made with shop technician. Sculpture graduate students have 24 hour access to the metal shop **as long as there are two (2) or more graduate students working together in the shop.**

Project proposal forms may be filled out by students outside of the sculpture area who wish to use the shop equipment. Projects like these will be approved at the discretion of the shop technician.

# Cleanliness

The Metal Shop is a shared workspace and must be kept clean and organized. Part of maintaining a culture of safety is to keep the space *operationally clean*, this means that sharp edges, tripping hazards, toxic substances, and other hazards should be stored correctly. When cleaning up ask yourself: How would I prepare this space for a visit from a child?

Keeping the space *formally clean* is also important. Always clean up your area immediately after you finish working. Clean debris off of tools you have used and put them away in their proper places. Participation is required in the group clean up at the end of each semester.

# Storage

Storage in the metal shop is extremely limited. Storage is first reserved for any sculpture class that is currently doing a project involving the metal shop. Some horizontal storage is provided for longer steel stock and sheet metal. Any raw materials stored in the shop must have your name and the date clearly visible. In-progress project storage must be approved by the shop technician. Projects are expected to be removed no later than 1 week after critique date unless otherwise specified.

# Tool Checkout

Certain tools may be checked out by sculpture students, majors and graduate students for a maximum of 48 hours. See the shop technician or monitor to fill out the tool checkout form.

# Material Purchases

The shop technician keeps a limited amount of steel stock and sheet metal that is available for purchase by students. Some materials are provided as a part of class lab fees. If you are unsure about what is included in your lab fees, ask the shop technician. If you wish to purchase steel from the school, or order any other special materials, see the shop technician. Failure to pay for materials on your tab at the end of each semester will result in suspended shop access until all debts are settled.

# Shop Equipment & Safe Use Procedures

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# Shear / Brake / Press

## Required PPE: Safety Glasses, Ear Protection, Gloves

The shear/brake/press is a multi-use machine that is used for either cutting, bending or forming sheet metal. Only use this machine for sheet metal that is 3/16" thick or less! Never use bar stock, angle iron, rod or anything thicker than 3/16"!



## Before You Begin

- Ensure that your work area is organized and that you have on the correct PPE and shop attire. Make sure those working around you know you will be using the machine and have on proper PPE.
- Visually inspect the machine and cord for any defective parts. Report defects to shop tech, monitors, or instructor. Do not attempt to repair any part of the machine yourself.

## Set up

- Decide which function you need to perform and set the levers accordingly. Levers are located around the right side of the machine near the floor. (Operation Selection Diagram)
- When adjusting, move lever 1 first and then lever 2.
- Use clamping arm to secure metal for cutting or bending.
- DO NOT place hands, arms, or other body parts in way of the clamping, shearing, bending, or pressing components.

## Shear: Operating Instructions

- Set levers 1 and then 2 pointing to the right
- Insert your material into the shear to the far right, and line up your material to be cut with the upper and lower blades.
- Press the ON button on the control box. Clamp the material securely by pressing the CLAMP DOWN button until the clamp is secure.
- Press the SHEAR DOWN button and hold until the material is fully cut.
- Bring the clamp up by pressing the CLAMP UP button until your metal is free. Then bring the shear up by pressing the SHEAR UP button until the cutting arm is fully raised.
- When you are finished, press the OFF button, turn off the lamp and swing the control arm into position above the machine.

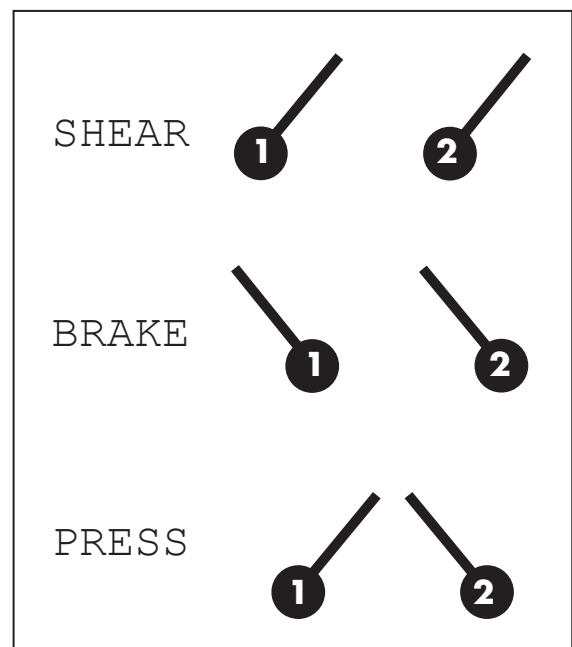
## Press: Operating Instructions

- Set lever 1 pointing to the right and then lever 2 pointing to the left.
- Select which die you would like to use and have technician assist you in assembling the press.
- Press the ON button. Use the SHEAR DOWN button to drop the press and the SHEAR UP button to bring it back up.

## Brake: Operating Instructions

- Set lever 1 and then lever 2 pointing to the left
- Insert your material into the center of the brake, and line up your mark with the clamp and brake
- Press the ON button. Clamp your material securely by depressing the CLAMP DOWN button until the clamping arm is fully engaged. Be sure to double check your alignment and adjust if necessary
- Stand to the side of the machine and press/hold the BENDER UP button until you have reached your desired bend. Press the BENDER DOWN button until the bending arm is fully dropped.
- Press the CLAMP UP button to release your material. Press the OFF button, turn off the lamp and swing the control arm into position above the machine.

Operation Selection Diagram





# DeWalt Chop Saw

## **Required PPE: Full Face Shield and safety glasses, Ear Protection**




The chop saw is used to cut mild steel only! It is best suited for round stock larger than 1/4", square tube and angle iron 1/2" or larger and channel stock 1/2" or larger. Check with the tech, monitor or instructor to make sure this tool is appropriate for your project.



## **Before You Begin**

- Ensure that your work area is organized and that you have on the correct PPE and shop attire. Make sure those working around you know you will be using the machine and have on proper PPE.
- Visually inspect the machine and cord for any defective parts. Report defects to shop tech, monitors, or instructor. Do not attempt to repair any part of the machine yourself.

## **Set up**

- Measure and clearly mark the area to be cut. Check the orientation of your stock to ensure that it can be securely clamped in the saw's vice. Never support steel stock with your hands while cutting, always use the vice! Also, make sure your stock is oriented so the least amount of surface area is in contact with the blade (i.e. on angle iron the angle should be facing up like this  not like this  or this  )
- Set the vice to whatever angle you need for your cut. Check the alignment of the blade on your material by lowering it with your hand away from the trigger. Take into account the thickness of the blade in your measurement.
- Once you have fully considered the safety and accuracy of the cut, you are ready to begin.

**SHOP EQUIPMENT & SAFE USE PROCEDURES**



# Operating Instructions

- Ensure that your stock is sitting flat on the table and is securely fastened within the vice.
- Take a comfortable stance in front of the saw, making sure that your hands and limbs are out of the marked hazardous areas.
- Press in the trigger on the handle and listen to the saw to make sure it has reached full power.
- Lower the blade gradually into the material. Despite the name “Chop Saw” you should never use a chopping motion to go into your steel, this can severely damage the blade and cause harm to self and others.
- Apply steady pressure to guide the blade through the material. The chop saw blade is actually an abrasive disk that is grinding through the steel so it will take some time. Never force the blade to cut faster than it wants to.
- Once you are all the way through your material, release the trigger and pull the saw up to its original position. Never reach under the blade for your material while the blade is still spinning.
- Unclamp your steel from the vice and be especially careful with the ends that have been cut as they are very hot and very sharp. Take care to prevent others from accidentally grabbing or running into your cut pieces.
- To clean up edges of material we suggest using an angle grinder, followed by the disk or belt sander and/or a file. For a cleaner edge, try using the horizontal bandsaw or Doringer Cold Saw
- Always clean up after you are finished working in the chop saw area and report any issues with the machine to the tech, monitor or your instructor.




# Horizontal Band Saw

## Required PPE: Safety glasses, ear protection

The horizontal band saw provides a cleaner cut than the chop saw, and due to its guides and stops is particularly useful for cutting multiple pieces of identical length.



## Set Up & Operation

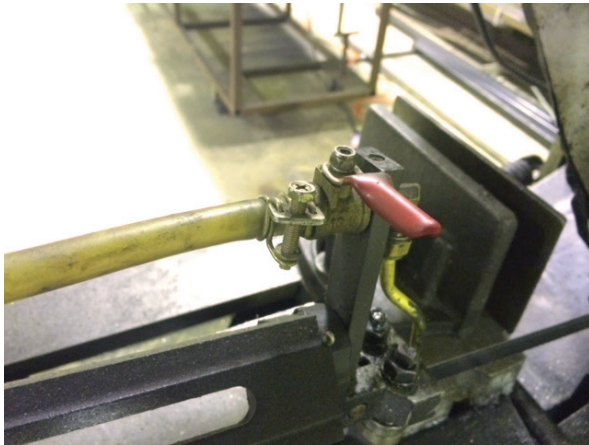
- Measure and clearly mark the area to be cut. Check the orientation of your stock to ensure that it can be securely clamped in the saw's vice. Never support steel stock with your hands while cutting, always use the vice! Also, make sure your stock is oriented so the least amount of surface area is in contact with the blade (i.e. on angle iron the angle should be facing up like this  not like this  or this  )
- Make all necessary adjustments before using the machine (if you have not been trained to do adjustments, please ask your technician for help):
  - Blade speed adjustment
  - Width adjustment
  - Angle adjustment
  - Hydraulic drop speed adjustment
- On the Control Box, flip the black knob to "ON." This indicates that the coolant pump will turn on when the blade is turned on.
- Insert your material into the clamp and line up your cut mark with the blade. Tighten the clamp and ensure that your material is steady and supported.

## Before You Begin

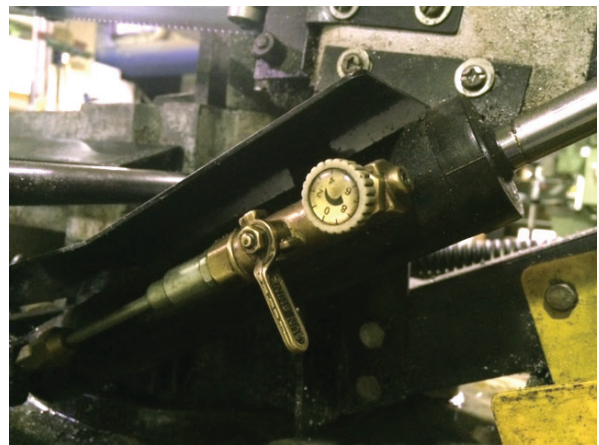
- Ensure that your work area is organized and that you have on the correct PPE and shop attire. Make sure those working around you know you will be using the machine and have on proper PPE.
- Visually inspect the machine and cord for any defective parts. Report defects to shop tech, monitors, or instructor. Do not attempt to repair any part of the machine yourself.

**SHOP EQUIPMENT & SAFE USE PROCEDURES**

- Take a comfortable stance in front of the machine and press the white ON button.
- Adjust the flow of the coolant being released onto the blade by turning the coolant valve slowly in line with the hose. It should come out as a slow trickle, just enough to coat the blade.



Coolant Valve (Closed)



Hydraulic Valve (Closed)

- Release the hydraulic arm by flipping the lever out of line with the hydraulic. Keep a close eye on the speed of the blade as it lowers into your material. This is a very SLOW process. The movement of the blade down toward your work should be barely detectable. Trying to cut too fast will damage the blade and machine.
- Stand by the band saw and watch as it makes the entire cut, do not walk away or get distracted. The blade will shut off on its own when the cut is complete.
- In case of emergency, the red button will instantly stop the machine
- If the blade stops suddenly, it is likely that it has come off track. If this happens immediately turn off the machine. Notify the tech or the shop monitor.
- The saw will automatically stop when at its lowest point. Once the machine has stopped, raise the arm and lock the hydraulic lever. Turn pump off and close coolant valve.
- Unclamp and remove your material and unplug the machine. Clean up the machine and work area after each use.

# Doringer Cold Saw




## **Required PPE: Safety glasses, full face shield, ear protection**

The cold saw is used to cut new mild steel only! Must not be used for scrap or welded pieces. It is best suited for round stock larger than 1/4", square tube and angle iron 1/2" or larger and channel stock 1/2" or larger. Check with the tech, monitor or instructor to make sure this tool is appropriate for your project.

## **Before You Begin**

- Ensure that your work area is organized and that you have on the correct PPE and shop attire. Make sure those working around you know you will be using the machine and have on proper PPE.
- Visually inspect the machine and cord for any defective parts. Report defects to shop tech, monitors, or instructor. Do not attempt to repair any part of the machine yourself.

## **Set Up & Operation**

- Measure and clearly mark the area to be cut. Check the orientation of your stock to ensure that it can be securely clamped in the saw's vice. Never support steel stock with your hands while cutting, always use the vice! Also, make sure your stock is oriented so the least amount of surface area is in contact with the blade (i.e. on angle iron the angle should be facing up like this  not like this  or this  )
- Set the vice to whatever angle you need for your cut. Check the alignment of the blade on your material by lowering it with your hand away from the trigger. Take into account the thickness of the blade in your measurement.
- Once you have fully considered the safety and accuracy of the cut, you are ready to begin.
- Ensure that your stock is sitting flat on the table and is securely fastened within the vice. If cutting down longer stock use supports to be sure the metal is level and won't bind when cutting.
- Take a comfortable stance in front of the saw, making sure that your hands and limbs are out of the marked hazardous areas.
- Activate and adjust the fluid, turn on saw and allow blade to come up to full speed.
- Lower the blade gradually into the material. Let the saw do the work, while applying gentle and steady pressure, move the handle downward to complete the cut. Never force the blade.
- Once you are all the way through your material, allow the handle to return to its original position and turn the saw off. Never reach under the blade for your material while the blade is still spinning.
- Unclamp your steel from the vice and be especially careful with the ends that have been cut as they could be sharp.
- Always clean up after you are finished working on the cold saw, reset saw to 0° if angle was changed, wipe down the bed of the saw and be sure the floor is dry.

**SHOP EQUIPMENT & SAFE USE PROCEDURES**

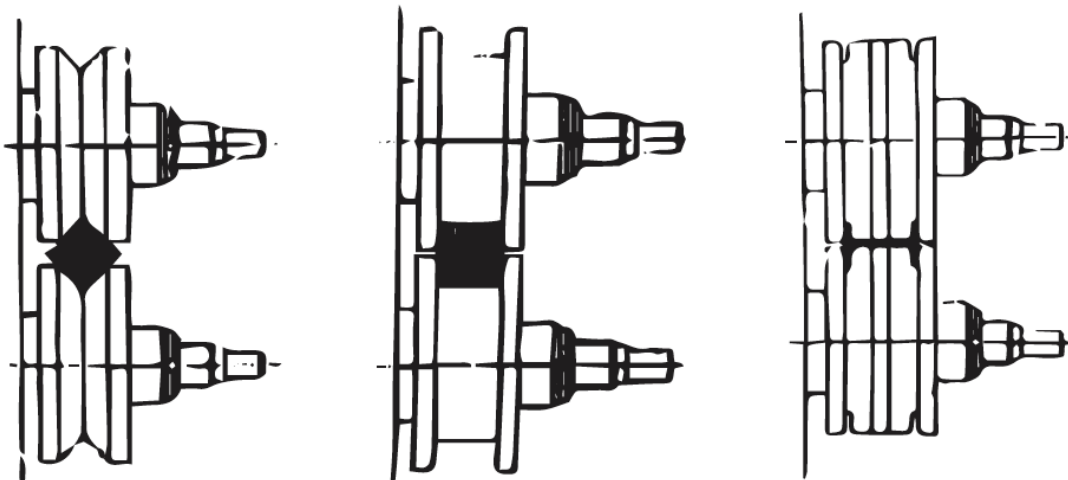
# Tube & Roll Bender

## Required PPE: Safety glasses, gloves (optional)

The metal tube roller is used to bend rod, angle iron, square, rectangular and flat steel stock. For each type of stock there is a different die configuration. Ask your shop tech before beginning to check that the machine is properly set up for your specific type of material.

## Before You Begin

- Ensure that your work area is organized and that you have on the correct PPE and shop attire. Make sure those working around you know you will be using the machine and have on proper PPE.
- Visually inspect the machine and cord for any defective parts. Report defects to shop tech, monitors, or instructor. Do not attempt to repair any part of the machine yourself.
- Ensure that you are working with the correct die configuration for the type of steel stock you are bending. (see illustration below)
- To find the distance needed between the top and bottom rolls, place a sample of the material to be bent between the rolls. The groove of the upper roll should be 2-4mm larger than the thickness of the material you are bending.





# Tube & Roll Bender

(Continued)

## Set Up & Operation

- It is always a good idea to do a test bend with scrap material, to figure out how many passes you need to make to achieve your desired radius. Also, you can make a to-scale drawing of your desired bend to check your material against as you go.
- Place your material between the two lower rollers and the upper roller.
- Rotate the hand-lever and move the upper roller down until it makes contact with the material's profile.
- Press the foot pedal the corresponds to the desired direction of the bend.
- The bending diameter is adjusted by positioning the upper roller at the desired depth.
- Continue rolling the material back and forth, lowering the middle roller little by little to achieve a tighter and tighter radius.
- Make sure that your material stays in line with the slanted bars on the face of the machine by applying steady forward pressure on your metal. Otherwise, you material will be formed in a spiral.
- With the emergency stop button, the operator can easily stop the roll rotation if the material begins to deform or for safety reasons.
- Always be very mindful of your hands in relation to the rollers. Ask for help if rolling longer stock.

**SHOP EQUIPMENT & SAFE USE PROCEDURES**

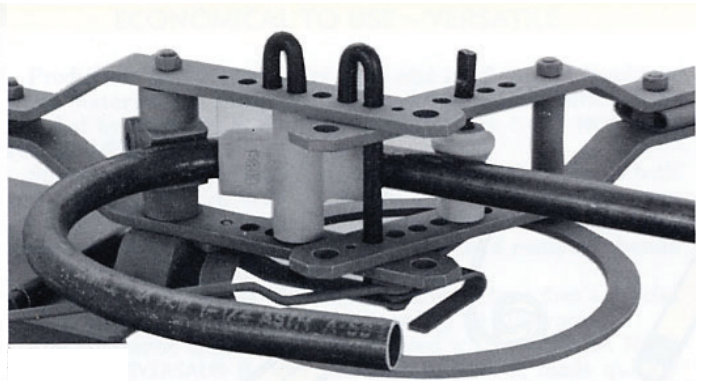
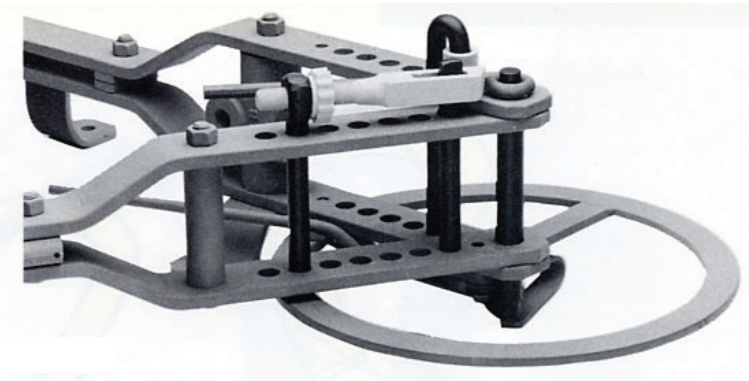
# Hossfeld Bender

## **Required PPE: Safety glasses, gloves (optional)**

The Hossfeld Bender is used to bend a variety of steel stocks including rod, angle iron, square, rectangular and flat steel stock. The type of stock and radius of the bend will determine your die configuration. Use caution when assembling pins, parts are extremely heavy and can easily fall on feet.

## **Set Up & Operation**

- Ensure that your work area is organized and that you have on the correct PPE and shop attire. Make sure those working around you know you will be using the bender.
- Determine the type of bend you would like to make and the material you are using and double check with the shop technician about the appropriate die configuration.
- Draw out a to-scale plan for your bend so that you can measure the increments in which to move your material and so that you have something to check your bend against as you work.
- Set up your configuration of dies. Insert your material into the space between your dies. Bend gradually at first moving along even increments and checking your material against your diagram for accuracy.





# Sheet Metal Roller

## **Required PPE: Safety glasses, ear protection**

The sheet metal roller is used to gradually and evenly form sheet metal into curves.

This machine may not be for sheet metal thicker than 3/16" or for any round rod, angle iron, tubing or dimensional steel of any kind.

## **Set Up & Operation**

- Raise the top roller so that material easily slides between the upper and lower rollers.
- With the middle of your material in the rollers, use the knobs on the left and right of roller to set your initial radius. Set them equal to one another.
- Roll the material back and forth using the foot pedal, adjusting the two sides of the roller in tandem until the desired radius is achieved.
- Dial the top roller down gradually, making sure both sides stay at an even height. The thicker the material the smaller the increments you should use.
- When cutting your material, take into account that there will be a section (6"-10") on both ends of your material that will never pass through the rollers and will remain flat unless curved by hand before rolling the material.
- To make a full cylinder you will need the assistance of the shop technician, monitor, or your instructor.
- To remove your material, simply raise the top roller until material slides out freely.

# Plasma Cutter

**Required PPE: Shaded eye protection #8 or #9 level, gloves, flame resistant jacket**

The Plasma cutter superheats inert gas (air) and blows it at high speed through a nozzle at the metal that is being cut. An arc is simultaneously formed between the conductive metal and the electrode tip, turning some of the gas into plasma and allowing the user to make quick and precise cuts through various thicknesses of metal.

## Before You Begin

- Ensure that your work area is organized and that you have on the correct PPE and shop attire.
- Make sure those working around you know you will be using the machine and have on proper PPE as well.
- Inspect the torch tip, electrode and shield cup and replace worn items.
- Make sure your metal is free of excessive rust, all paint, etc.
- Check gas/air pressure at the compressor or bottle gauge.
- Set the amperage control according to the thickness of the metal you are cutting and check the air pressure settings according to your metal's thickness.
- Place the ground clamp close to (but not within 3 inches of) the cut, and place the clamp on the work piece itself when possible. Check for any loose connections between the work cable and the clamp.
- Find a good starting position with a comfortable stance holding the tip at a 90 degree angle to your work. Relax - don't hold the torch too firmly or your hand will shake more.
- If cutting a straight line, it is best to set up a straight edge with another piece of metal clamped to the table.
- Place the drag shield on the edge of the base metal, or hold the correct standoff distance (typically 1/8 in.). Direct the arc straight down.
- To make a full cylinder you will need the assistance of the shop technician, monitor, or your instructor.
- To remove your material, simply raise the top roller until material slides out freely.

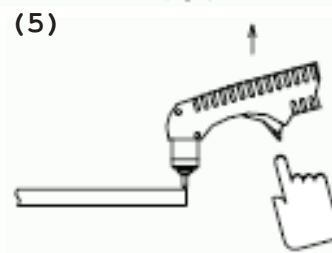
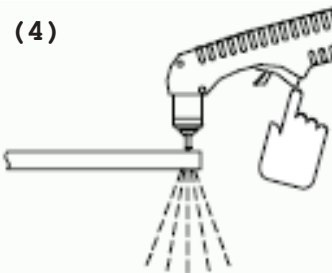
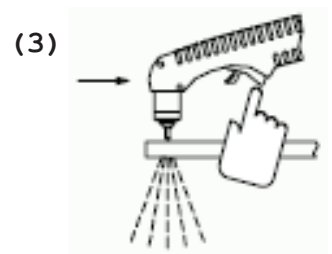
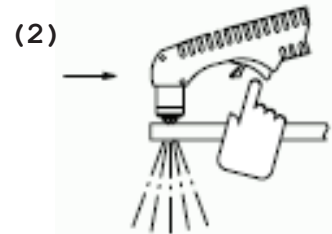
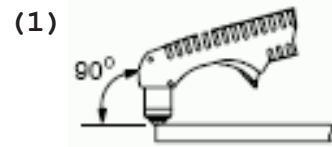


# Plasma Cutter

(Continued)

## Operation

- The arc starts immediately when trigger is pressed.
- Raise the trigger lock, press the trigger and the pilot arc starts immediately.
- Once the cutting arc starts, begin to slowly move the torch across the metal.
- Adjust your speed so sparks go thru metal and out bottom of cut. Thinner - faster, thicker - slower.
- If the sparks are not visible at the bottom of the plate, the arc is not penetrating the metal. This can be caused by moving the torch too quickly, insufficient amperage or directing the plasma stream at an angle (not straight down). Insufficient grounding can also cause this problem.
- At the end of a cut, angle the torch slightly towards the final edge or pause briefly before releasing trigger to completely sever the metal.
- Traveling at the right speed produces a very clean cut with less dross on the bottom of the cut. If the travel speed is too slow, the material you are cutting may become hot and accumulate more slag. To minimize slag, increase travel speed or reduce amperage (for an indication of how fast to move the torch, refer to the machine's cutting speed graph or check the speed for a rated cut).
- Bleed the air out of the line, turn off the machine, clean your area.



**SHOP EQUIPMENT & SAFE USE PROCEDURES**

# Gas Forge

## **Required PPE: Eye protection/face shield, gloves, flame resistant jacket**

The Gas Forge works to evenly heat a variety of steel stock to a high enough temperature to be smithed with the power hammer, an anvil or other tools. The metal can be manipulated in a number of interesting ways with far more ease than if it were cold.

## Set Up & Operation

- Ensure that you are wearing the proper PPE and have adequate tools set up for handling your hot metal.
- Open front door of the forge before attempting to light.
- Set fuel pressure guage to 10lbs. Normal operating range is from 6lbs to 15 lbs pressure.
- Open ball valve and you will hear fuel entering the combustion chamber. Immediately push the red button on the quick light until it lights. If the gas fails to ignite after two or three snaps of the quick light, shut off the gas supply immediately by turning the ball valve to the off position and check with shop technician.
- Adjust the flame by adjusting the burners (see shop tech). Once a strong blue flame is achieved and the hot spot on the floor of the unit has no shadows visible, a peak flame performance has been achieved.
- Set your metal in the forge where it can be easily retrieved. When retrieving objects from a hot forge, approach from the side or bottom (a little practice will help with this skill). The unit will heat objects to forging temperature with the door open, but it will take longer.



- Propane gas has a strong odor. Never continue to run the forge if the smell of propane gas is present. Shut the unit off and check all connections for leaks with soapy water. See shop technician
- Always bleed the gas and air lines and clean up after use.

# Blu Power Hammer

**Required PPE:** Eye protection/face shield, ear protection gloves, flame resistant jacket

The Big Blue forging hammer is a powerful pneumatic hammer used for smithing hot metals into various shapes and textures. This machine has interchangeable dies to assist with a large range of hammering styles.

## Set Up & Operation

- This machine is not intended to be used with cold metals. See instructions for the gas forge to learn one way to get your metal to right temperature for forging.
- Determine the die configuration that is best for your project. NEVER run the hammer with the dies removed. Do not attempt to change the dies unless you have been trained to do so. Consult the shop tech.
- Slowly turn the ON/OFF valve to the ON position. Remember that the hammer is dangerous when the air is ON, even though it is not moving.
- Experiment first with the hammer control and speed to gain a good feel for how to control the machine.
- Ensure that your material is long enough to maintain a good grip and safe distance from the hammer. Use tongs to hold onto smaller pieces of metal. Be aware of those around you and the hot parts of the metal.
- Introduce hot metal to the machine and depress to foot pedal to activate the hammer. Practice working between the movement of your metal and the speed of the hammer. There are many different techniques for acheiving your desired look and YouTube is a great resource for blacksmithing demos.
- Always manitain a solid, comfortable stance while using the machine and ensure that your tongs, or whatever you are holding the metal with, have a secure grip.
- Always clean up your area after use.



**SHOP EQUIPMENT & SAFE USE PROCEDURES**

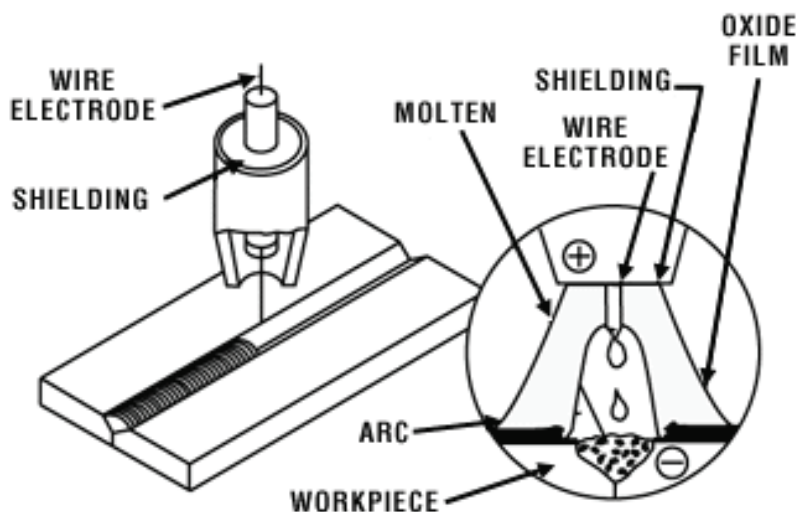
# MIG WELDER

## Required PPE: Welding hood, gloves, flame resistant jacket

MIG welding is a way of permanently fusing separate pieces of steel. During the MIG welding process, the wire melts within the arc and becomes deposited as filler material. The shielding gas, an Argon/CO2 mix, prevents atmospheric contamination and protects the weld during solidification. The shielding gas also assists with stabilizing the arc, which provides a smooth transfer of metal from the weld wire to the molten weld pool.

## Before You Begin

- Plug in the welder, check cords for any signs of damage.
- Turn on gas with valve on top, adjust gas flow with valve on pressure gauge (in=more/ out=less) to 15 CFH (cubic feet per hour)
- Adjust wire speed and voltage according to the thickness of your metal. (see chart inside welder)
- Find a place for your ground clamp either on your work or on a metal table where you are working
- Secure your work with magnets, vices, jigs, etc.
- Make sure you have a clean work area free of extraneous or flammable objects. Ensure that those around you know you will be welding and are not vulnerable to the brightness of the arc.





# MIG Welder

(Continued)

## Operation

- Prepare your material! A clean, tight, stable joint will be the most successful.

Types of joints:



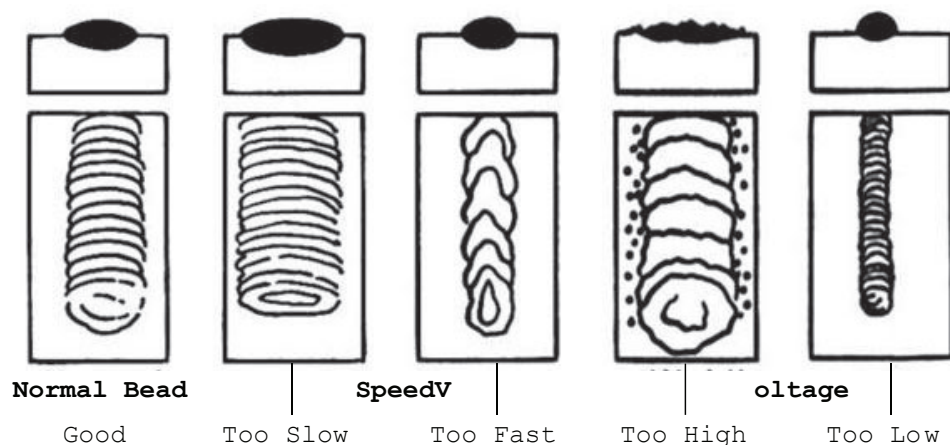
**Butt Joint**

**Lap Joint**

**T Joint**

**Corner Joint**

- Begin with your wire sticking 1/4 in out of the nozzle. If it is too long, trim with pliers. This is something you will get used to doing before each weld.
- Turn the welder on. Double check your settings and the ground clamp. Put your helmet down (use auto-darkening helmets if possible) and set up your welding position. It is best to rest your dominant hand on your non-dominant one for stability.
- Ensure that the wire is touching the spot where you would like to begin your weld. Pull the trigger to strike the arc and begin moving down your weld line immediately.
- The best way to move your weld (bead) down the line is with little “U” shapes, gently rocking the nozzle back and forth. Some also prefer to do small circles as you move down the line. Practice both to find your best method.
- The speed of your movement along with the voltage and wire speed all work together to create a successful weld. What your weld looks and sounds like is a good indication. Here are some things to look for:



**SHOP EQUIPMENT & SAFE USE PROCEDURES**



## Tips n' Tricks

- Test settings and techniques on scrap metal, not on final work.

- Butt joints can be stronger and the surface fully grinded away if you grind the edges of your metal so they are slightly beveled, giving the welding bead a groove to rest in, like this:



- Set up your welding spot with two pieces touching and place the tip of your wire before flipping helmet down to improve accuracy.

- Trim the end of your wire with pliers attached to welder. To begin, wire should be sticking approx. 1/8-1/4" out of nozzle.

- Keep the wire-feed hose as straight as possible when working, kinks and twists will ultimately jam the wire-feed.

- If the wire jams in the tip, gently try to pull it out with pliers, DO NOT HOLD DOWN TRIGGER, if it does not come out, ask for assistance

- Regularly dip your tip in nozzle dip when working for long periods, this keeps the tip from corroding and wire from sticking.

- Tack welds are great for temporarily holding pieces in place or to form a sheet of metal gradually over a curve.

- The sound of a good weld is a peaceful one, not too noisy or crackly, it should sound like bacon calmly frying, or white noise on a television.

- If your tip is sputtering/making skipping noises try lowering your voltage or increasing the wire speed. You may also be starting with the tip of your wire too long or too far away from your work.

- When welding two different thicknesses of metal together you should set the voltage for the thicker metal and practice moving more quickly on/off of the thinner part.

- Moving too slowly on a piece or having too high voltage may melt a hole through your metal. Practice practice practice!

# TIG Welder

## **Required PPE: Welding hood, gloves, flame resistant jacket**

TIG welding is a way of permanently fusing two separate pieces of steel. During the TIG welding process, the arc created by the heated tungsten electrode creates a molten pool between your two metals where filler rod is deposited to strengthen the weld. The shielding gas, Argon, prevents atmospheric contamination and protects the weld during solidification. The amperage (heat of the weld) is controlled with a foot pedal. The balance in TIG welding lies between the amperage, speed and rhythm of your weld.

## **Before You Begin**

- TIG welding involves the following consumable elements:

**Tungsten Electrode** - With an extremely high melting point (3410°C), Tungsten serves as an excellent metal conduit for the arc.

**TIG Filler Rod** - Contains higher percentage of metal and less coating than other filler rods (NO Oxy/Acetylene rods!)

**Shielding Gas** - Argon (mixed with other inert gases)

**Gun Consumables** - components of the gun, called collets, lock the electrode in place and must be the right size for the electrode diameter (1/8, 1/16, 3/32 etc. are etched into collet)

- Turn on gas with valve on top, adjust gas flow with valve on pressure gauge (in=more/out less) to the gas flow specified on the attached chart.

- Determine whether you will be using Negative Direct Current (DCEN) or Alternating Current (AC) utilizing the attached chart. This is first determined by the type of metal you are welding.

Determine the amperage setting utilizing the attached chart. This setting will be the maximum output when the foot pedal is pressed all the way down. The foot pedal allows for greater control and small adjustments.

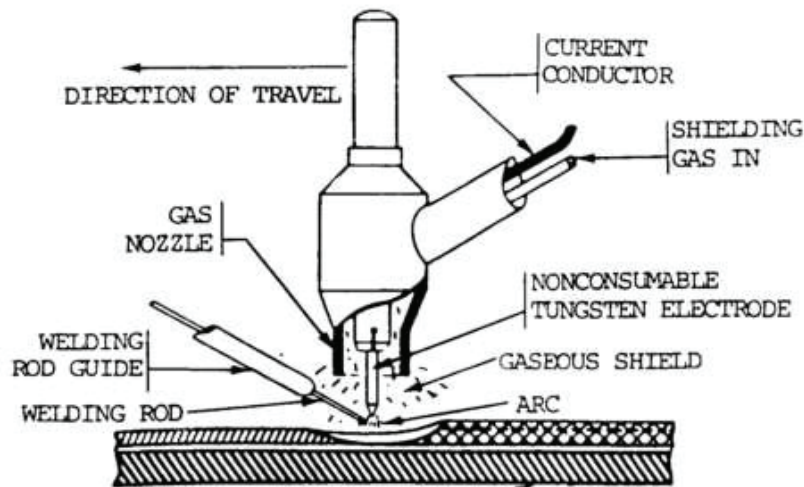
- Determine the type of electrode you will be using based on the current choice, amperage, type and thickness of metal. Utilize the attached charts.

- Ensure that the cooling water valve is open (different on each welder)

- The Tungsten electrode must be sharpened using the belt or disc sander. You must sharpen the tip so that the grooves formed by the sander are in line with the rod and not horizontal across the rod. The more pointed and even your electrode tip is, the more precise your arc will be. For thinner metal a very thin tip is advised, for thicker metal, you can flatten the top a bit like a lightly used pencil. Consult your instructor or shop tech to check your electrode tip.

**SHOP EQUIPMENT & SAFE USE PROCEDURES**

- Insert the electrode into the collet and tighten into place by turning the long end of the torch. The sharp, clean tip of your electrode should be sticking out 1/4" from the gas shield.
- Make sure you have a clean work area free of extraneous or flammable objects. Ensure that those around you know you will be welding and are not vulnerable to the brightness of the arc.
- Set up your grounding clamp and metals to be welded. Turn on the machine.



## Operation

- Make sure your hand is comfortable on the table/torch and you can reach the foot pedal.
- The torch should be tilted 10° in the direction you are moving (you should always be pushing your weld line, not pulling)
- Holding the tip of the electrode 1/8" away from your metal, strike your arc by pressing the foot pedal. Heat the metal in small circles, increasing your amperage with the pedal, until a visible pool of molten metal forms.
- Insert the filler rod into the metal pool, and begin to find a rhythm with your torch still moving in small circles while dabbing filler rod into the puddle. Keep the torch moving evenly down the weld line.
- Remember that the torch is heating the base metal and the puddle is what heats the rod. Do not dip the rod into the arc and do not dip the electrode tip into the puddle (will have to re-sharpen the electrode)
- Do not remove the electrode or filler rod until the weld has started to solidify. If you pull back too quickly you remove the gas shield and can compromise the weld.

# TIG Welder

(Continued)

## Tips n' Tricks

- If you are having trouble striking an arc, check to make sure your metal is clean. You may have to grind off excess rust or grease or use a wire brush to clean small areas.
- Always have a practice on scrap before you begin, TIG welding takes a lot of practice to get comfortable with the torch/filler rod rhythm.
- Ideally, torch angle should only be around 10 degrees or less. Too much torch angle will deflect the heat and melt the rod before you ever get it into the puddle. This causes the rod to ball up and blob into the puddle - not a pretty or strong weld.
- TIG welders often use specialty gloves with thinner fingers to allow for better control of the small filler rod.
- When welding thinner metal or aluminum, setting the amp ceiling to a higher setting will increase the range that you can control with the foot pedal and never have the foot pedal pressed all the way down. If you set the knob very low, then there is a smaller range of control

**SHOP EQUIPMENT & SAFE USE PROCEDURES**

## TIG Welding Charts (\*\*\*) indicates commonly used settings/elements)

TYPE OF TUNGSTEN	COLOR	USES AND PERFORMANCE
Pure	Green ***	Provides good arc stability for AC welding. Reasonably good resistance to contamination. Lowest current carrying capacity. Least expensive. Maintains a balled end.
Ceriated CeO <sub>2</sub> 1.8% to 2.2%	Orange	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life. Possible replacement for thoriated.
Thoriated ThO <sub>2</sub> 1.7% to 2.2%	Red ***	Easier arc starting. Higher current capacity. Greater arc stability. High resistance to weld pool contamination. Difficult to maintain balled end on AC.
Lanthanated La <sub>2</sub> O <sub>3</sub> 1.3% to 1.7%	Gold	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life, high current capacity. Possible replacement for thoriated.
Zirconiated ZrO <sub>2</sub> 0.15% to 0.40%	Brown	Excellent for AC welding due to favorable retention of balled end, high resistance to contamination, and good arc starting. Preferred when tungsten contamination of weld is intolerable.

Used for AC welding  
aluminum, bronze,  
stainless steel

Used for DCEN  
welding Mild Steel

Tungsten Diameter	Gas Cup (Inside Dia.)	*** Typical Current Range (Amps)				
		Direct Current, DC	Alternating Current, AC			
		DCEN	70% Penetration		(50/50) Balanced Wave AC	
		Ceriated Thoriated Lanthanated	Pure	Ceriated Thoriated Lanthanated	Pure	Ceriated Thoriated Lanthanated
.040	#5 (3/8 in)	15–80	20–60	15–80	10–30	20–60
.060 (1/16 in)	#5 (3/8 in)	70–150 ***	50–100	70–150	30–80	60–120
.093 (3/32 in)	#8 (1/2 in)	150–250 ***	100–160	140–235	60–130	100–180
.125 (1/8 in)	#8 (1/2 in)	250–400	150–200	225–325	100–180	160–250
All values are based on the use of Argon as a shielding gas. Other current values may be employed depending on the shielding gas, type of equipment, and application. DCEN = Direct Current Electrode Negative (Straight Polarity).						

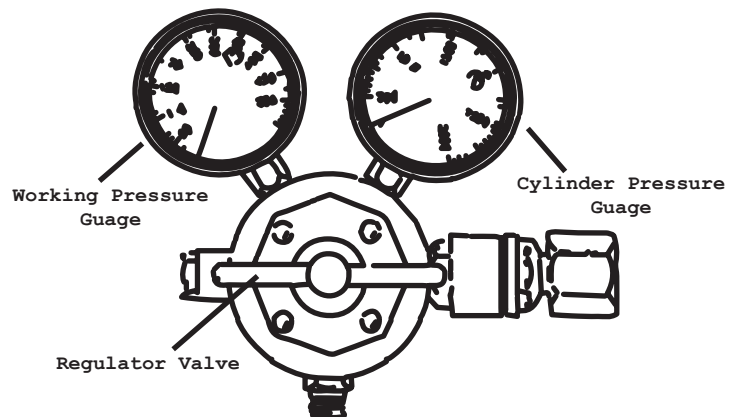
# OxyAcetylene Welder

**Required PPE: Gloves, tinted glasses #8 #9, flame resistant jacket**

The Oxy-Acetylene tanks and torches can be used for a range of metal fabrication processes. There are attachments for cutting, welding, heat patinas and forging. Learning the mechanics of Oxy-Acetylene processes can be a great introduction to more high-tech welders and cutters. Use great caution when moving the cart around, always check that the tanks are secured, never attempt to change out the tanks by yourself.

## Before You Begin

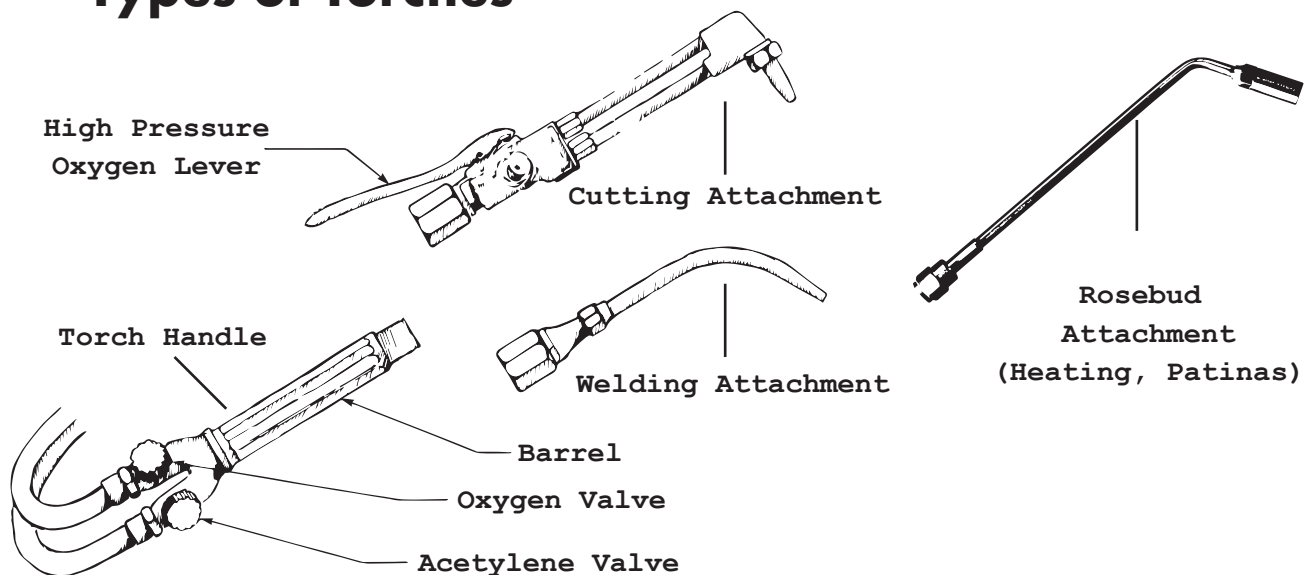
- Visually inspect the tanks and hoses for any damage. Ensure that you have an organized workspace free of flammable materials.
- Check that all of the valves are closed before opening the tanks. (See diagrams below for future references to parts of the torch)
- Open the valve on top of each gas cylinder. Open Oxygen (Green) tank all the way open, Acetylene (Red) tank only 1/2 turn. Turn the regulator valve (in = open) to the proper psi settings for your process, read from working pressure guage If you are unsure, start with lowest psi.
- Cutting:  
Oxygen - 20-35 psi  
Acetylene - 5-8 psi
- Welding:  
Oxygen - 8-15 psi  
Acetylene - 3-8 psi
- Rosebud Heating:  
Oxygen - 10-20 psi  
Acetylene - 5-8 psi



**SHOP EQUIPMENT & SAFE USE PROCEDURES**



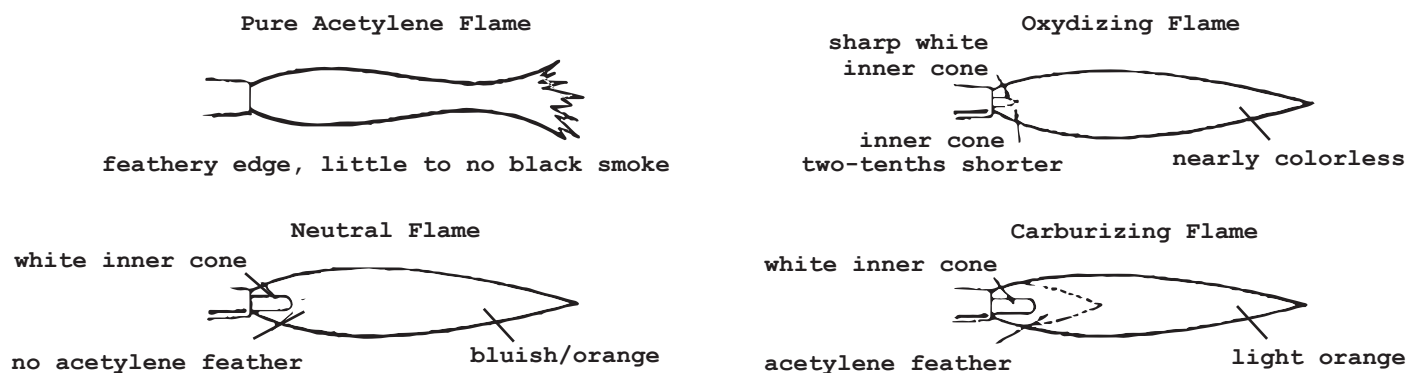
# Types of Torches



- Select the proper torch for your task. Ensure that all valves are closed when changing out torches. Hand-tighten torches, do not over-tighten. Open the valves on the regulator to begin the flow of gas to the torch. The valves on the torch handle should stay closed until you are ready to set your flame.

## Setting Your Flame

- Slightly open the Acetylene valve on the torch handle
- Use striker in front of torch tip to light Acetylene flame
- Increase Acetylene gas until the flame is turbulent and the black smoke is barely visible.
- Slowly open the Oxygen valve. (If you open too fast the flame will shut off and you will have to turn both gases off and begin again.) Adjust Oxygen until flame is Neutral (see below)
- If cutting, open Oxygen valve on torch and pull lever. Adjust cutting flame to Neutral (see below)





# OxyAcetylene Welder

(Continued)

## Cutting Procedure

- Ensure the you have the proper PPE and a clean and organized workspace. If others are working around you, alert them that you will be cutting.
- Set your flame to neutral. Test the high pressure Oxygen lever to check your neutral cutting flame as well.
- Begin preheating the spot where your cut will start by holding your torch with the blue portion of the flame at a 90 degree angle and about 1/8" above your metal. Move in small circles until the spot begins to glow.
- Gently depress the lever to release more oxygen (you may not need to go full-blast right away, this takes practice to find the right pressure)
- Allow the oxygen to push through the cut, adjust your angle in the direction of travel and continue cutting. In this process you should observe that you are literally pushing the molten metal through the cold metal.
- For thinner materials your angle will be very high - meaning you will have the flame close to parallel with the material. For thicker materials the torch will need to be kept almost perpendicular to the material.
- When you have completed your cut, turn off the oxygen first with the fine adjustment valve. Then turn off the acetylene at the handle.
- Your material will be very HOT. Do not leave unattended, use gloves or pliers when handling.
- The factors which must be balanced to achieve a good quality cut are:
  - Pressure Settings
  - Flame Settings
  - Speed of movement along the cut line
  - Angle of torch
  - Distance maintained from flame to material
  - Size of tip
- Practice on scrap metal until you feel comfortable.
- When you have finished, bleed the gas lines completely! Turn off the gas at the top of the tanks (not the regulator) and open the valves on the torch handle to let all of the gas out of the lines

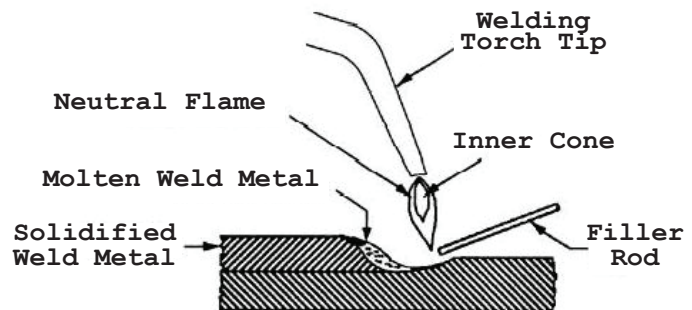
**SHOP EQUIPMENT & SAFE USE PROCEDURES**

# Welding Procedure

- Ensure the you have the proper PPE and a clean and organized space. If others are working around you, alert them that you'll be welding.
- Determine the thickness of filler rod that is appropriate for your project. If you are working with a long piece of filler rod, bend the end of it in so as not to poke those around you.
- Make sure that the two metals you are joining are clean, secured so they will not move, and are touching along the weld seam.
- Turn on the Acetylene, strike the torch, turn on Oxygen, set your flame to neutral.
- Use a circling or half moon motion between the two metals to begin preheating the spot at the beginning of your weld. The torch should be held 1/8" above your material. Make sure the motion stays even between the two pieces.
- Once you have a pool of molten metal, angle the torch slightly in the direction of travel while maintaining your motion between the two metals.

• Drip the filler rod into the pool and begin to find a rhythm between your movement along the weld seam, the drips of filler rod, and your small circular or half-moon motions.

• Maintain this rhythm all the way down your weld seam.



- If the pool is sparking excessively you may have the flame set too high or are moving too slowly. Sparks are a sign of overheating.
- If welding a long seam, always use tack welds (tiny one-spot welds) first along the seam to prevent warping.
- Your material will be very HOT. Do not leave unattended, use gloves or pliers when handling.
- Practice on scrap metal until you feel comfortable.
- When you have finished, bleed the gas lines completely! Turn off the gas at the top of the tanks (not the regulator) and open the valves on the torch handle to let all of the gas out of the lines.

# Arc (SMAW) Welder

## **Required PPE: Welding hood, gloves, flame resistant jacket**

Shielded Metal Arc welding is the process of joining two metal pieces using a flux covered electrode which is melted in an electric arc and becomes a fused part of the pieces being welded. This type of welding utilizes flux-coated welding rods and a simple, transformer type “cracker box” welding machine.



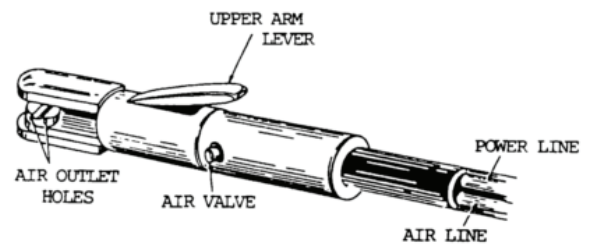
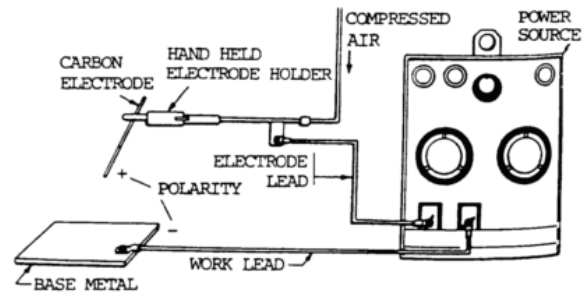
## **Before You Begin**

- Plug in the machine and inspect cords for any signs of damage.
- Ensure that you are wearing the proper PPE and that those working around you are protected from the brightness of the arc.
- Set up your materials to be welded. Remove any paint, grease, rust or any other substance that will interfere with you weld quality. The pieces should be touching along the desired weld seam and stabilized with clamps or magnets. Bevel your edges in toward each other if necessary to allow complete grinding of a weld.
- Find a suitable location for your ground clamp.
- Determine the correct amperage setting for your electrode and metal.(See Chart p. 32) As an example, 1/4 inch plate steel can be welded effectively using an E6011, 1/8 inch electrode, at between 80-100 amps.
- Place the electrode in the electrode holder (henceforth referred to as the stinger) making sure the conductive material of the stinger clamp is on the clean metal at the end of the electrode.

**SHOP EQUIPMENT & SAFE USE PROCEDURES**

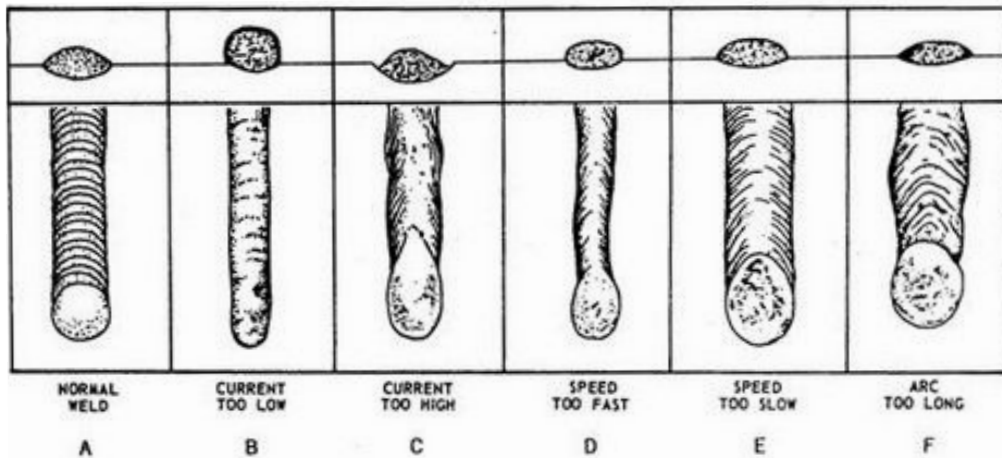
# Welding Procedure

- Turn the welder on and double check your surrounding work area.
- Hold the stinger in your dominant hand by the insulated handle, with the rod in a position so that striking the tip of it against the plate you are welding will be as natural a movement as possible.
- You may want to practice moving the electrode along the weld metal to get the feel of it before turning the power on, but never strike an electric arc without protecting your eyes.
- Select the point where you wish to begin your weld. Position the tip of the rod close to it, then drop the welding hood into place. You want to tap the tip of the electrode against the metal to complete the electrical circuit, then instantaneously pull it back a little bit, to create an electric arc between the electrode tip and the metal being welded.
- Another way to strike an arc is like striking a match. This arc gap, or airspace, creates a great deal of resistance in the electrical circuit, which is what produces the arc flame or plasma and heat needed to liquefy the electrode and the metal adjacent to the weld area.
- Strike the electrode against the surface of the metal, pulling it back slightly when you see an electric arc occur. This takes a great deal of practice, since different electrode diameters and welding amperages require a different gap between the tip of the electrode and the work piece, but if you can hold the gap steady, a continuous electric arc will occur from the electrode to the work piece. In general, the arc gap should be no greater than the electrode diameter.
- Practice steadying the arc by holding the electrode about 1/8 to 3/16 of an inch from the work piece, then begin moving along the path you want to weld. As you move the electrode, the metal will be melting away, filling the pool of molten metal and building your weld.
- Practice traveling across the path of your weld with the electrode until you can keep a consistent arc, moving at a consistent speed, and in line with the path you want to weld. The electrode is moved in a sideways motion as it is drawn along the weld path, either in a zig-zag, curved, or figure eight motion.



# Arc (SMAW) Welder

(Continued)



- Clean your finished weld. After you have finished welding, you may want to remove the slag and clean up your weld, either to allow paint to bond better, or simply for cosmetic reasons. Chip off the slag and wire brush the weld to remove any foreign material and remaining slag. A clean weld, particularly after grinding flat, is easier to examine to see if pitting, puddling, or other defects have occurred while welding.

- Never lay a new bead over existing slag, as this material will melt in the arc plasma and bubble through the new layer of metal you are placing, resulting in a weak and dirty weld.

- Clean up your work area and neatly wind up all of the cords on the welder. As you practice take notes for yourself about the feel of different electrodes, amperages, etc.

ELECTRODE	AC	DC*	POSITION	PENETRATION	USAGE
6010	NO	EP	ALL	DEEP	MIN. PREP, ROUGH, HIGH SPATTER
6011	YES	EP	ALL	DEEP	
6013	YES	EP, EN	ALL	LOW	GENERAL, EASY
7014	YES	EP, EN	ALL	MED	SMOOTH, EASY, FAST
7018	YES	EP	ALL	LOW	LOW HYDROGEN, STRONG
7018AC	YES	EP	ALL	LOW	
7024	YES	EP, EN	FLAT HORIZ FILLET	LOW	SMOOTH, EASY, FASTER
NI-CI	YES	EP	ALL	LOW	CAST IRON
308L	YES	EP	ALL	LOW	STAINLESS
*EP = ELECTRODE POSITIVE (REVERSE POLARITY) *EN = ELECTRODE NEGATIVE (STRAIGHT POLARITY)					

**SHOP EQUIPMENT & SAFE USE PROCEDURES**



# Drill Press

## Required PPE: Eye Protection, Ear Protection

The drill press allows for accurate drilling at a 90 degree angle. When drilling metal it is important to use a sharp drill bit and a lot of oil on the bit and hole itself. Never drill material that is not securely clamped to the table of the drill press.

## Operation

- Consult the technician if you are unsure of the appropriate speed setting for your drilling diameter. Do not attempt to change the speed settings unless you have been trained to do so. Always unplug the machine before making adjustments.
- Insert your drill bit (not past the shank) into the chuck and tighten with the chuck key.
- Adjust the height of the table by loosening the lever on the back and turning the crank on the right. Make sure to re-tighten table after making adjustments.
- Use a pointed metal punch and hammer to set a small indentation exactly where you want to drill to keep the drill bit from “walking”.
- Clamp your material securely to the table. Use a piece of scrap wood beneath your hole if needed to avoid drilling into the table. If you are drilling into a long piece of stock, make sure the longest end is to the left of the table so if it comes unclamped it will spin toward the wall and not toward you.
- Use plenty of oil to lubricate the metal in the spot you are drilling.
- Drill a small pilot hole for holes 1/4” and greater
- Never slam or force the drill bit through the material, let it do the work. If it seems to be struggling, add more oil. Be Patient.
- Sweep up your area after you are finished.



# Pedestal Grinder

## **Required PPE: Eye protection, Face Shield, Ear Protection**

The pedestal grinder has two wheels of different sanding grit that are used to grind away flashing, sharpen tools, etc. This grinder removes more material faster than the disk or belt sanders. The bench grinder should never be used for aluminum.

## **Operation**

- Ensure that you have a clear work area and are wearing the proper PPE
- Check to make sure that the ledge where you rest your material is 1/4" or less away from the grinding wheel. Alert the shop technician if it is not.
- Turn on the machine and allow it to reach maximum speed before introducing your material.
- Grind your material either level with the platform or at a slightly downward angle. An upward angle will cause the material to kick back. If your material is angled too far it will cause the piece to jam between the platform and the wheel.
- Always insert your material gently into the wheel and apply pressure as you work. Too much pressure will damage the machine.
- Keep material moving back and forth on the wheel to avoid forming a groove in any one spot and to improve the lifespan of the wheel.



- When grinding small pieces use pliers or vice grips to hold onto it. The metal will heat up as you grind it and it will become too hot to hold. Also, you do not want your hands anywhere near the grinding wheels.
- When you are finished, turn off the machine and sweep up the floor around your work area.

**SHOP EQUIPMENT & SAFE USE PROCEDURES**



# Wheel / Belt Sander

## **Required PPE: Eye protection, Face Shield, Ear Protection**

The disk and belt sander are used for fine sanding of metals after larger burs have been ground away with pedestal grinder or an angle grinder.

## **Operation**

- Ensure that you have a clear work area and are wearing the proper PPE
- Inspect the disc/belt for tears, report any defects to the shop technician.
- Use bench grinder or angle grinder first to grind away sharp burs to avoid tearing the disc/belt.
- Turn on the machine and allow it to reach maximum speed before introducing your material.
- Grind your material either level with the platform or at a slightly downward angle. An upward angle will cause the material to kick back. If your material is angled too far it will cause the piece to jam between the platform and the wheel.
- With the disc sander, always keep your material to the left of the center of the wheel. The wheel spins counter-clockwise and will kick your piece up if you place it on the right side.
- Keep your material moving (to the left of center) in order to wear down the disc/belt evenly and not just in one spot.
- When grinding small pieces use pliers or vice grips to hold onto it. The metal will heat up as you grind it and it will become too hot to hold. Also, you do not want your hands anywhere near disc or belt.



- When you are finished, turn off the machine and sweep up the floor around your work area.
- When grinding small pieces use pliers or vice grips to hold onto it. The metal will heat up as you grind it and it will become too hot to hold. Also, you do not want your hands anywhere near the grinding wheels.
- When you are finished, turn off the machine and sweep up the floor around your work area.

# Angle Grinder

**Required PPE: Eye protection, Face Shield, Ear Protection, FORM FITTING gloves**

The angle grinder is a portable and versatile tool used for grinding and cutting metal. There are also attachments available for wood carving. There is a **SERIOUS** danger of kickback with this tool, if you are unsure of the safety of your task ask the shop tech or your instructor.

## Operation

- Determine the appropriate backing pad, guard, nut, washer, disc and/or wheel for your project. **DO NOT** use cut off wheels for grinding or vice versa.
- Never change discs or make any adjustments to the grinder while it is plugged in.
- Secure all wheels with the right size wrench using the locking button on the top of the grinder.
- Make sure your metal is totally secured to the table or vice before grinding or cutting. Practice your approach with the grinder off to make sure you can have a comfortable stance and are out of the way of the sparks generated. If the cut feels awkward, it is unsafe.
- All grinding should be done within 1 inch of the edge of the disc, not the center. Keep the material between 1 and 3 o'clock on the wheel to avoid kickback. You should hold the grinder at a slight angle to the material, about 15 degrees.
- When cutting, keep the wheel at a 90 degree angle to your metal and maintain a straight cut. Keep the material between 1 and 3 o'clock on the cut off wheel. **DO NOT** attempt to make curved cuts.
- The cut off wheel should be used at no more than 1/4" depth. Any deeper and you risk serious kickback.
- When you turn off the grinder wait until the wheel comes to a complete stop before setting it down.



**SHOP EQUIPMENT & SAFE USE PROCEDURES**

