Introduction to Blacksmithing

Orange County Blacksmiths Guild
a Part of the Heritage Museum
of Orange County

3 April 15 Edition

Outline of Basic Blacksmith Class

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1.0 Introduction

1.1 History

The history of blacksmithing is as detailed, varied and complex as the history of humanity itself. Basic blacksmithing is thought to stretch back to the Egyptians some 5,000 years ago that used the iron found in meteorites to hammer decorative beads. A very brief timeline is presented below:

- Around 2,800 BC Egyptians use meteoric iron to make decorative beads
- Around 1,500 BC the European Hittites begin smelting iron.
- Around 450 BC, the use of iron moves all over Europe.
- Around 350 BC, China starts to produce steel.
- Around 150 BC, steel production begins in Europe.
- Around 1200 AD, Crusades are on going and Islamic Armies make swords from Wootz Steel. Has a devastating effect on the Crusading armies.
- Around 1350 AD, powerful blast furnaces are developed and are able to produce cast-iron and then steel.
- Around 1500 to 1700 AD blacksmithing spreads across Europe
- Around the mid-1700's European settlers move to North America and take the craft of blacksmithing with them.
- Blacksmithing allows the settlement of the "New World"

1.2 The "Craft"

It is very important that you understand that this shop exists to pass along the craft of blacksmithing. Our objective with this class, and everything else we do, is that you understand the basics of the craft and then, through your learning process, gain as much knowledge as you can. Consequently, we are not here to teach you how to make knives, spears, swords, axes, hatchets, arrow points or any other weapon you can think of. We are here to teach you a process that is over 4,000 years old and a process that, up until 40 years ago, was a dying craft. When you have learned the basics, we welcome the opportunity to see your ability in weapons production, tool production or anything artistic.

1.3 Shop Safety

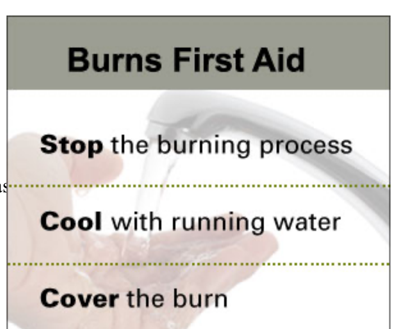
Metal temperatures in the shop can exceed 2500°F. At these temperatures you can suffer a 3rd degree burn in seconds, set fire to clothing, burn the shop to the ground potentially killing people in the process. We take this very seriously and you need to as well. Make sure that you are following the rules listed below. Failure to comply with them could result in your removal from the shop.

1.3.1 Clothing and Accessories

- Safety glasses are required – make sure you have impact resistant lenses with side shields. If someone is in the shop without eye protection, please instruct him or her to leave the shop or assist them in getting safety glasses (extra glasses are located in the small lockers on the back wall of the shop).
- Wear natural fiber clothing (cotton). Synthetic clothing will adhere to your skin when it comes into contact with anything hot enough to melt the fabric.
- Hearing protection is not required, but strongly recommended.
- Steel-toed boots are also not required, but highly recommended.

1.3.2 Burns or Injuries

- If you receive a burn, immediately immerse the burn in one of the orange buckets or slack tubs nearest you.



- Do not wait to feel it, if you think you have touched something hot, soak the burn ASAP. This will draw the heat out of the burn the fastest way possible.
- The first aid kit is immediately on your left as you enter the shop through the double doors.
- Make sure to tell your instructor about the burn.
- If you see someone who has been burned make sure others know.

1.3.3 Working in the Shop

- NEVER PICK UP A PIECE OF METAL BEFORE CHECKING TO SEE IF IT IS HOT (hover the back of your hand over the metal to check for heat)
- Note locations of fire extinguishers, slack tubs, water buckets, exit doors, and first aid kit.
- Be mindful that HEAT TRANSFERS to the objects you are working with. For example, the end of your tongs are going to heat up while working, if your working hot metal in the post vice it will also heat up, anything that comes in contact with hot metal is going to get dangerously hot. If someone comes into your work area let them know something is hot (e.g. post vice, tools) before they touch them.
- Watch for others moving around in the shop.
- If you have hot metal and you are moving from one place to another with the metal (i.e. forge to the post vise, forge to vermiculite), look around you and move safely. If you are coming close to someone that looks like they are moving something hot, yield to them and watch around you.
- If the shop is crowded, it is best to not walk around with hot metal at all.
- The nearest clean water is in the bathrooms.

1.3.4 Power Tools

- Do not use ANY power tools in the shop until you have been trained on the tool. Each tool has its own idiosyncrasies and can be dangerous if you are not aware of them. Power hammers especially fall into this category.

2. The Forge

2.1 Types of Fuel

2.1.1 Coal

Coke

Lignite

Bituminous

Anthracite

- With any coal, the goal is to make coke and the coke is the fuel for the forge. Coke is produced when coal is exposed to high heat and the volatiles burn out of the coal and leave primarily carbon behind. This changes the coal from a solid rock appearance to a more pumice appearance.

- There are three main types of coal – lignite, bituminous, and anthracite.

- Lignite is the worst type of coal for blacksmithing due to the high amount of non-burnable metals and high sulfur content. Produces a lot of "clinker".

- Some controversy exists about bituminous or anthracite being the "best" coal for the blacksmith's forge. Most tend to agree that bituminous is the best because it burns cleanly, most impurities burn off and it has a low sulfur content. We currently use Pennsylvania bituminous in our shop.

- Anthracite can also serve well as a forge fuel source as it has some of the same properties of bituminous except it tends to burn a bit cleaner and gives off more heat (BTU) per volume. The drawback is that anthracite makes small pieces of coke (unlike bituminous), which tend to fly out of the forge. This can be mitigated with proper airflow control.

2.1.2 Propane

- Propane is used in a forge designed to burn only this fuel because it burns without smoke and produces forgeable heat. This fuel source is used when air quality issues (for you or neighbors) are a driving force. Propane can be advantages over a coal forge in that it can provide a large even heat, allows you to work on small items that could get lost in the coal; however, propane is more expensive than coal for equal heat.

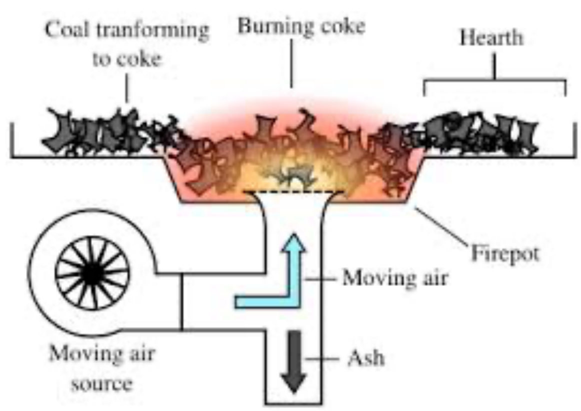
2.1.3 Oxygen & Acetylene/Propane

- Cutting torches that use an oxygen and acetylene mixture will produce forgeable heat. It can be used on small scale in a garage and provides for versatility in a home shop. Propane is sometimes used to replace acetylene as propane will not produce carbon "floates" in low oxygen high fuel mixture conditions. As with propane alone, this method can be quite expensive compared to other forms of fuel for blacksmithing.

2.2 Controlling the "Hot Spot"

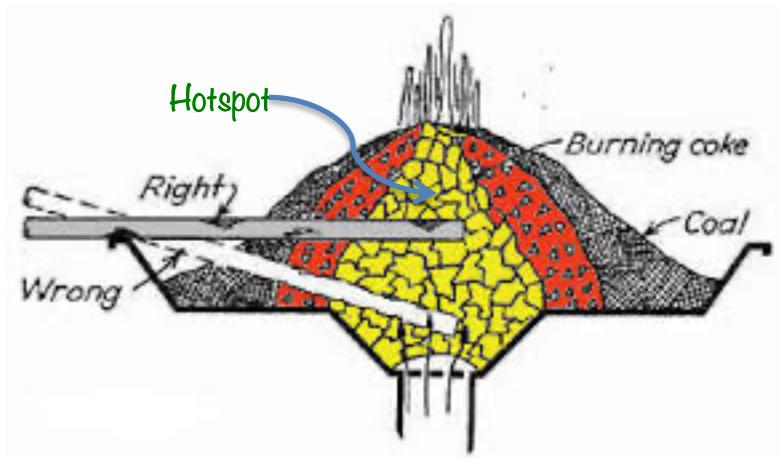
2.2.1 Anatomy of the Forge

- There are many types of forges that can be made and used for blacksmithing. We are going to concentrate on the parts of the forge and the types of forges you will be using in the shop. Below is a general diagram of a forge and the "firepot".



2.2.2 Fire Maintenance

- Maintaining heat in the forge is something of an art and has to be done by paying special attention to your forge's "hotspot". This is the part of the burning coal that is hot enough to bring your metal to a temperature that it can be smithed. The hotspot will be where there is sufficient oxygen to maintain it.



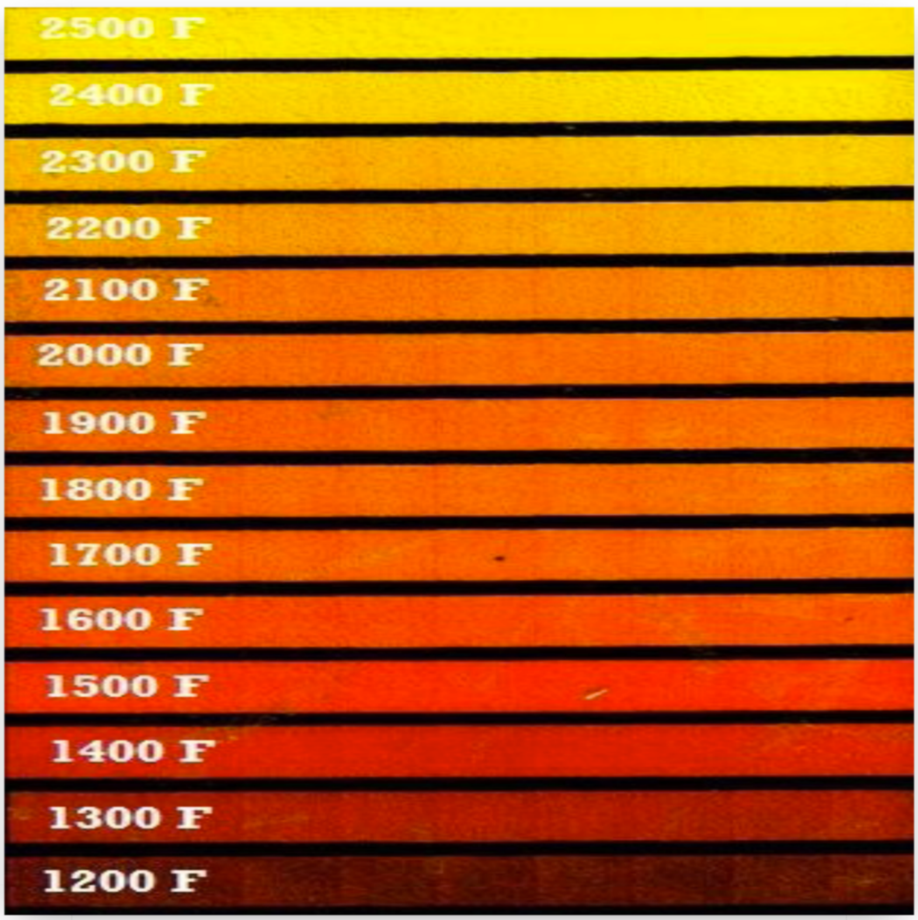
- The hotspot will move with oxygen concentrations. If you slow down airflow it will sink down, conversely; if you speed up airflow the hotspot will rise.
- As you burn the coke it will convert to clinker and drop to the bottom of the firepot. The clinker will not yield its heat as readily as coke and it will build up at the base of the firepot reducing airflow. If you notice that your hotspot is not where it was and even with increase oxygen flow the hotspot does not rise, you will need to crank the clinker breaker and drop the clinker out of the ash port. This will increase airflow and heat in the forge. **Be aware that when you do this, you will get significantly more heat generated much quicker and the possibility of burning your work increases significantly.**

2.2.3 Metal Temperature Control (colors)

- Temperature of the forge, and consequently your metal, is determined by the color of your heated metal. It is not an exact science, but knowing the colors will help you tremendously to know when the metal can be moved the most efficiently. Ultimately, the type of metal/steel you use will dictate the correct working temperature.

Color	Estimated Temperature °F	Estimated Temperature °C
Yellow/White*	>2370	>1300
Yellow*	1820-2000	1000-1100
Orange**	1740-1830	950-1000
Light Red**	1560-1650	850-900
Bright Red	1500-1560	800-850
Deep Bright Red	1300-1380	700-750
Deep Red	1020-1200	550-650
Dull Red (barely visible)	930-1020	500-550

*welding heat
**forge heat

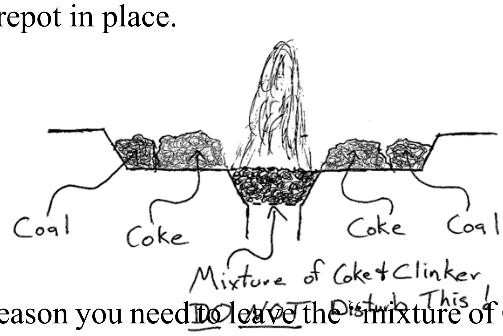


Varying colors and their corresponding temperatures

Colors of heat to look for in the metal when forging.

2.2.4 Shutting the Forge Down

- Shutting down the forge is NOT walking away from the forge when you are done for the day. There is a process to shutting down the forge that is as important as firing up the forge.
- You should have coke left over from working the forge and it should be around the periphery of the hotspot. If you have used most of your coke, you should make more prior to shutting the forge so that the next person that uses the forge has coke to start their fire. When you have sufficient coke in your forge you are ready to shut the forge down.
- Pull the coal back from the pile and stack it away from the fire separating the coal from coke. Once you have establish a linear stack of coal, pull the coke back lining up against the coal but taking great care not to mix the two. You will do this on both sides of the firepot. The coke you have been using immediately on top of the firepot will be pulled back as well when the coke is pulled back, but make sure that you level off the firepot leaving all coke that was in the firepot in place.



- The reason you need to leave the "mixture of Coke & Clinker" alone is so that no clinker is mixed with your coal or coke piles. This will contaminate the piles and would need to be picked out by the next person that uses the forge. Walking up to a forge where clinker has been mixed with coke is very frustrating because extracting the clinker from the coke is a tedious process.

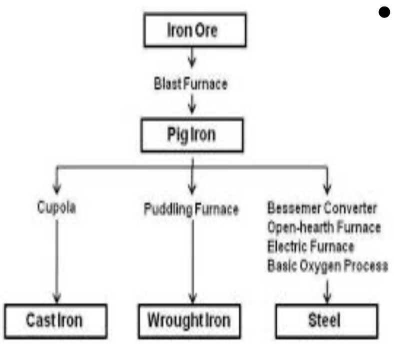
2.3 Forge Welding (brief introduction)

- Forge welding is one of the coolest things a blacksmith learns to do. It is also by far one of the more frustrating things a blacksmith can do. Modern welding basically fuses metal together by heating the ends to be joined and adding metal to weld the pieces together (this means you have surficial metal joined to metal at the location of the weld only). Forge welding will actually fuse two pieces of metal together into one piece through the entirety of the joined metal. Getting proficient at this requires patience, practice, and more patience. When you get to the point where you can weld well, it will have been worth all the work it took to get there (and it WILL take work to get there).

3. Metal

3.1 Iron

3.1.1 Pig Iron



Iron and Steel Products

- Iron is basically ore pulled from the Earth and then heated to extract impurities from the ore to make iron. The process of heating iron ore from a blast furnace produces "pig iron" (the name is derived from the early smelting operations that commented on the shape of the liquid coming from the furnace taking the shape of suckling pigs as it spilled out on to the ground). This form of iron has limited use due to its brittle nature (because of impurities like iron carbide and sulfur found in it) and is used primarily to make steel.

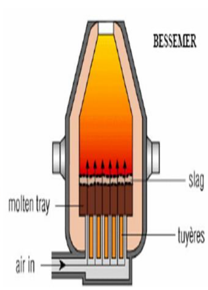
3.1.2 Cast Iron

- This form of iron is made when pig iron is refined again to remove impurities. Cast iron has a higher carbon content (> 2%) and is more ductile (shapeable) than pig iron. It was historically used to produce industrial items by melting the metal and pouring the liquid iron into castings. Early on when cast iron was used, it was difficult to control the alloys, contaminants, and carbon content in the metal as it was processed. Consequently, cast iron eventually was processed an additional time to make wrought iron. For our purposes, cast iron is not forgeable.

3.1.3 Wrought Iron

- When the technology for "puddling" (specialize furnaces) became available, the process of making wrought iron from cast iron (and pig iron) became more common. The puddling process allowed for the control of oxygen and carbon content in the metal as it was processed. This allowed for a stronger more ductile type of iron that was used on such structures as the Eiffel Tower and Statue of Liberty. Unfortunately, the smelting process was such that only relatively small quantities could be made at any one time. Wrought iron has a green color similar to wood and requires specific forging techniques. Currently, true wrought iron is found primarily in very old recycled metal. Today's use of the term "wrought iron" refers more to a decorative style than metallurgic properties of the materials used.

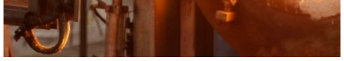
3.2 Steel



- With the discovery of the "Bessemer" process, iron could now be smelted and the carbon content could very accurately be controlled. Consequently, iron was now processed into high grades of steel that could be made to accurate tensile strengths and ductility. By controlling carbon content, various types of steel could be produced. The following table shows the type of steel and the carbon content associated with it:

Stainless Steel	Less than 0.3%
Mild Steel	Not exceeding 0.3%
Medium Carbon Steel (aka Carbon steel)	Between 0.3% and 0.6%
High Carbon Steel	Over 0.6%

- As you can see, types of steel are mainly delineated by the carbon content. In general, the higher the carbon the harder the steel. This would be a good place to make sure you know the difference between "hard" and "tough" steel. If a metal is considered hard, then it takes a lot of energy to change its shape. If a metal is considered tough, it takes a lot of energy to get it to break. In general, hard metals are not tough, and tough metals are not hard. Think of it this way. Glass is hard but not tough. Rope is tough but not hard.

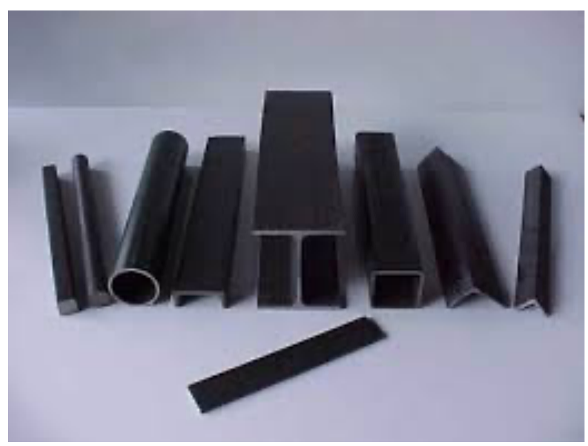


In general, it takes a lot of energy to change the shape of glass, but takes little energy to break it (e.g. a glass bottle). In the case of rope, it takes very little energy to change the shape, but a lot of energy to get it to break (e.g. a tow rope).

- Please be advised that the above information about pig, wrought, cast and steel is accurate, but it is a simplification of the history of these metals. This was done to give you an overview of how iron has been used historically and how steel is now made from iron. For more information all you need do is type any of the names of these metals in an online search engine and get ready to be inundated with information.

3.3 Shapes of Steel (round and square stock)

- The blacksmith will use mostly mild steel due to cost and ductile properties of the metal. Mild steel can come in a variety of shapes and sizes. In the shop you will primarily be using flat stock, round stock and square stock. Not surprisingly, the name of the stock is the shape of the stock. Each of these shapes will have different diameters, thickness, widths etc. The images below will give you some idea of the variety of the shapes in which steel is produced.



3.4 Hot and Cold Rolled Steel

- When steel is shaped, it can be done so hot or cold. When the word hot is used in this case it means above 1700°F or above scaling (impurities formed on the surface of the metal) temperatures. Cold rolled, in general means below scaling temps, but typically means room temperature. The main difference is that hot rolled metal will not have the same measurement tolerances (preciseness) that cold rolled steel will have. Hot rolled will be cheaper to make because the metal will move easier, but when the metal cools it will not be the exact same measurement. Cold rolled does not have that issue, but it can be more expensive because it is a more involved process to make the desired shape.

4. Blacksmith Tools

4.1 Hammers

- There are many styles of hammers blacksmiths will use. Below are just a few of the styles of hammers you will see in the shop. It is impossible to know what style or weight of hammer you will prefer; as a result, you should try different hammers until you find one you like and then stick with if for a while.

4.2 Tongs

- Tongs, like hammers, are as varied as the techniques used by blacksmiths. To get you started we will help you select the tongs that will work best for your first project so you will get a little experience with tong selection. After that, if you want to have consistency in your technique, you should pick up your own pair of tongs (we can help you with that as well). Below are just a few of the types of tongs that you will see in the shop.


Flat Tongs


Vbit Tongs


Wolf Jaw Tongs

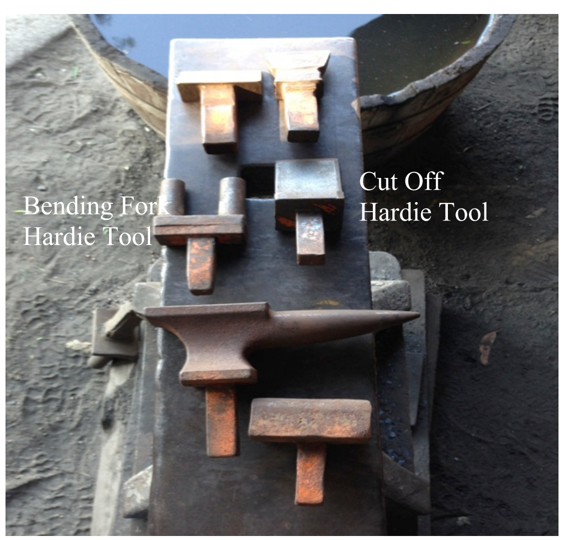
Variety of different tongs used for a variety of jobs.

4.3 Anvils

- Anvils, like tongs and hammers, are as varied as the history of blacksmithing (are you seeing a pattern). We have a wide variety of anvils in the shop in size, style and use. Below is an image of a London pattern anvil with a description of the parts. Knowing the parts of the anvil can be very beneficial if someone is trying to help you understand how to use the anvil to move metal.

4.4 Hardie Tools

- These are tools that are inserted into the hardie (square) hole and are used to cut and bend (among many other things) metal. These tools will be used as you work through different projects. Each anvil in the shop may have a different size hardie hole; consequently, there are varying sizes of hardie tools.



4.5 Chisels

- These are used to mark and cut metal as needed. They are available in a host of different lengths and sizes and are used on hot metal and cold.

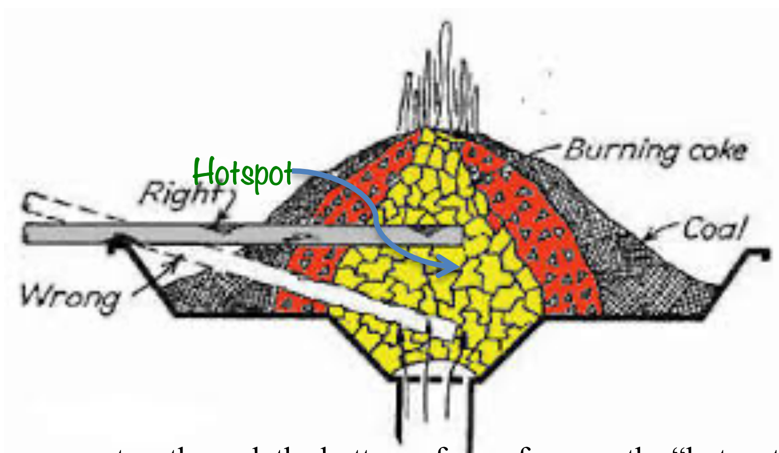
4.6 Top Tools

- Top tools are (as the name suggests) used on top of the metal and consist of a handle that you can hold with one hand while hammering the tool with the other hand. These tools can be used to cut, shape and drift metal.

5. Moving Metal

5.1 Using the Forge to Heat your Metal

- The diagram below speaks volumes about how you will use the forge as a heat source. Two major things to remember; 1) the more air you push into the forge the hotter the forge will get, 2) you can get the forge more than hot enough to completely burn your metal (sparks coming out of the forge is a telltale sign the metal is way too hot and is burning up). Oxygen is both a friend and enemy in the forge. It is needed to build and maintain the fire, but when the metal is at a "scaling" temperature (orange to red), oxygen is what causes the scaling. Additionally, the amount of oxygen when forge welding will dictate how strong the weld will be (too much makes the weld weak, too little and the forge will not get hot enough to weld.



- Oxygen enters through the bottom of your forge so the "hotspot" starts from the bottom and goes up. If you insert your metal towards the bottom of the hotspot and then apply oxygen, the point where the air enters the forge will be much hotter than points higher. Consequently, you want to insert your metal as you see in the diagram to avoid overheating your work. This will not be as critical as you get to know your forge (how much cranking is needed to keep the hotspot maintained, but not so much as to burn your work).

- Remember that this forge can get above 2,600°F and will melt just about anything you put in it if you are not careful. Just about everyone has burned work because they were not paying attention to how much air was being blown into the forge and the hotspot achieved a much higher temperature than was intended. Hopefully you can avoid this, but do not get too upset if it happens because it does most certainly happen.

- If you are working the forge with someone else, make sure that when you insert your metal into the forge that the person cranking stops for a moment until your metal has been placed. This will avoid a potential serious burn because when you insert your metal you will create a void that may allow air to blow out of the forge. Stopping (or slowing down) the cranking avoids hot coke being blown onto your arm or clothing. If you are the person cranking the blower, you must be considerate of the others at the forge (this is a safety issue as well as a courtesy).

5.2 Hammer Strikes

- Moving the metal with your hammer is one of the more enjoyable and frustrating things the blacksmith does. Here are things to remember as you are striking your metal. Technique is FAR MORE important than strength when it comes to using the hammer properly. If you understand that the contour of the face of your hammer moves the metal on your work, then you will understand that when the hammer strikes the metal the position of the hammer when it strikes will dictate which way the metal moves.

Imagine the rounded face of your hammer striking hot metal. The position of the face will dictate in which direction the metal will move. Your hand will dictate the position of the face of the hammer. This is where the craft comes alive. Your mind, in conjunction with your hand, will work together and, as you smith, your eyes will see what works and your mind will record that. Eventually, your muscle memory will take over and your hammer strikes will improve. This takes patience, practice, time and more patience.

- When you get metal hot it will move just like clay. The only difference is that you cannot touch the metal with your hands so you have to use tools. If you can imagine in your mind how to make an object in clay, then you can do it in metal.

5.3 Using the Anvil to Move your Metal

- This section could fill volumes and volumes of books, and a quick look at the blacksmithing literature would bear me out. However, this is a booklet with the objective of getting you started in blacksmithing so there is a lot we do not have to talk about (but a lot you have to learn). The best thing to remember is that the anvil is a hammer that does not move. If you want to move metal in a certain direction, think about the shapes available to you on the anvil and strike accordingly. This is where your instructor and time will be the most valuable tool you will have to learn.

- Now would be an excellent time to let you know that there is a tremendous number of books, internet websites, magazines and the list just keeps going on concerning the information available to help you figure out technique. Blue Moon Press is an excellent source for this information.

5.4 Project (Meat Turner)

Meat Turner

Material:
3/8" square (mild steel) hot rolled steel 24" long
Tools:
Hammer, anvil, turning wrench, vice, coal forge.

Drawing out steel - just as it sounds, making it longer, wider or both, but thinner. Here we will draw it out on four equal sides, to make a point, turning the piece as we work.

Round a square - start with the four sides, hammering the square edges, move the metal to make it eight sides, then hammer those edges to make it sixteen sided. By then it will be close round and can be finished.

Quenching is cooling the metal quickly. We will use water in this projectin to cool the metal and allow us to continue working without the need of tongs. Quenching metal with a higher carbon content can cause damage to the metals structure. Quenching makes metal hard or more brittle, think about what will happen to the metal before you quench. Here we are using mild steel, and the project piece won't be jeoperized. Depending on the metal and its use, it may be better to just let it cool on the side of the forge. Their will be a time when a very slow cool ing is needed, called anealing.

Twisting metal brought to an orange heat can be moved in many ways. Turning (twisting) square stock creats an pleasing effect. Only the heated section will move. Have vice, and twisting wrench nearby to work quickly, not to loose your heat. Note the correct wrench size is needed for a **close** fit to the square stock. Make a "dry run" of your next step to help understand the process and be able to move quickly when metal is hot.

**" DON"T PUT YOUR METAL INTO THE FIRE,
UNLESS YOU KNOW WHAT YOU WILL DO WITH IT WHEN YOU TAKE IT OUT"**

Meat Hook

Handle:
Take either end to an bright orange heat **Draw** out a square point one, about seven inches long. Start at the end and work back to get length correct.

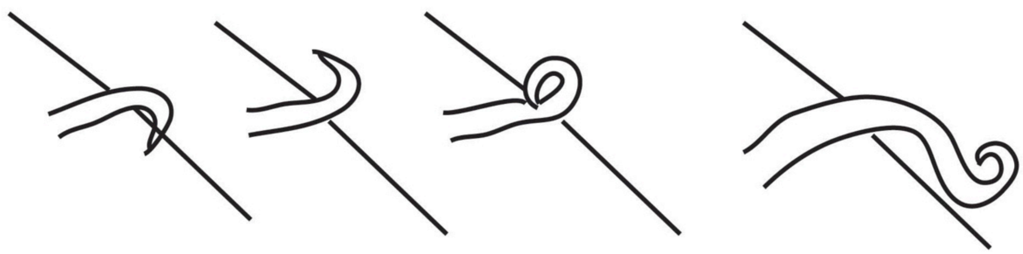
Round the square as was talked about earlier.

Heat first two inches or so, to bright orange being careful not to burn point, it is small and will heat the quickest. Over the farside, edge of the anvil, hammer the point down, to make a very small curve. Reheat end, turn curve facing up, toward you. Using short brisk strokes, push the metal back toward you, to create a small loop.

Take another heat, **quickly** quench only the small tip you just made, so it doesn't move anymore. With the loop just made, facing up, over the horn of the anvil, create a larger, two and a half inch or so, loop to make a round handle,

Look it over and make any adjustments..

Quench to allow working on other end.



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Meat Hook

Hook:
At the other end of the metal, heat to a bright orange **Draw** out a square point one, about three inches long. Start at the end and work back to get length correct.
Round the square as was talked about earlier

Measure about five inches from point and mark with soap stone. Heat and make about a two inch curve over the anvil's horn, to about a half circle. Remember that the smaller pointed end will heat much faster and will burn if not carefully watched. Heat to orange at the five inch mark, and hammer **fairly** sharp right angle over the rounded edge of anvil, (the square edge of the anvil, near the horn, has been rounded slightly, not a sharp corner, very difficult to show in a drawing.)

This will create the hook,
Clockwise is for right handers.
Counterclockwise fot the leftys.

Quench to allow working on a twist in the middle.

Twist:
Find the center and heat a five inch section to a good orange. Quickly, place metal in vice with hot end up, just above vice jaws, tighten vice. Place turning wrench at the upper end of the heat, turn wrench clockwise one complete revolution. While still a good heat, adjust twist to aligh hook end with handle end.

If piece bends a little (crooked) while twisting, quickly remove from the vice, place bent area in jaws of vice, horizontally, tighten vice to squeeze and straighten. Wire brush to clean scale. Quendh to cool .

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6.0 Blacksmithing Resources

6.1 Blacksmithing Tools:

- Blacksmith Supply (http://www.blacksmithsupply.com)
- Pieh Tool (http://www.piehtoolco.com)
- Centaur Forge (http://www.centaurforge.com)
- Blacksmith Depot (http://www.blacksmithsdepot.com)

6.2 Blacksmith Books and Literature:

- Blue Moon Press (http://www.bluemoonpress.org)

Notes: