The Blacksmith
Notes for the basic blacksmithing class, Jeep's Forge

- Blacksmith ranked second in importance to those engaged in various branches of agriculture.
- Town fathers realized the importance of encouraging smith craft. It was a necessity. Many even made special land grants to those who could work irons.
- Early blacksmiths were well paid.
- Style of the American blacksmith- simple, direct, utilitarian, little embellishment
- In 1664 used nails were still being salvaged by burning down buildings. Eight boys could produce 25,000 nails in a week
- 1607- James Read, a blacksmith, -colonist in Jamestown. Case in May of that year.
- Early on, little research has been done into the early American blacksmith, as they were so common. There has been a general lack of interest in the products of the blacksmith. Few pieces were marked, so the object and the maker have fallen into obscurity. As of late, several blacksmiths have studied the pieces found and laying around in museums to the point that they have figures out they were made and what the purpose was.

Training through apprenticeship

- To his father
  - Lived at home
  - Learned trade
  - Rudiments of reading, writing and arithmetic.
  - Keeping accounts and religion

- Traditional apprenticeship
  - 9 years
  - 12- 21st birthday
  - others are the same as if he were living with his father

Journeymen blacksmiths

- A book on eighteenth and nineteenth century trade secrets was nonexistent. All of the information was passed through word of mouth, except for: Mechanick exercises on the Doctrine of Handy Works, by Joseph Moxon, London. 1703

Blacksmith worked:

- Charcaoal iron- Charcoal used to fuel to furnace that produces the iron. All charcoal iron was not of the same quality. Some factors were:
  - Quality of ore mined
  - Skill with which the iron was extracted from the ore
- The best iron was made in Sweden. Some iron was such poor quality worked by the blacksmith before it could be used.

Early American Blacksmithing up to 1850

1585- Raleigh expedition discovers iron ore on Roanoke Island, North Carolina

1608- Bog ore exported to England from Jamestown. Jamestown had great forests necessary for the production or iron, as the Middle Ages; method of smelting with charcoal was still being used.

1685- Saugus, Mass. The first operation iron works in the New World.

1621- Falling Creek, Va. The first iron works were attempted, but never went into production, due to an Indian attack.

- By the mid eighteenth century the iron industry in the New World was firmly established.
- The English government tried to inhibit the production of iron because of competition
- There is little in American wrought iron that one might claim as distinctly American. Nothing indigenous or novel in design and execution.
- The European traditions were transported into a new environment.
- The Dutch settlers in New York and New Jersey left their imprint on household hardware.
- English style of smithing is found in all 13 colonies.
- Pennsylvanian German towns exhibit their German influence.
- French style can be seen in Northern New York, Vermont, and New Hampshire.
- Early American wrought iron is therefore a sort of smorgasbord effect, with a variety of influences, with the British influence most seen, with a dash of French, Italian, Spanish, Dutch, and German.

History

- Today's blacksmith's methods and techniques are not different form that of their ancient ancestors
- Romans- Vulcan. God who caught Venus and her lover Ares in a net of iron. Made weapons for the Gods of Olympus.
- Osiris of Egypt
- Thor of Norse mythology
- The Iron age began about 1200 BC. It was used by the ancient Egyptians 9000 years ago
- Europeans did not have the technology to use until the Middle Ages. Iron became more important than copper and brass when the iron cannon has invented.
- Iron remained unknown in the New world until Columbus landed in 1492.
- European blacksmiths were extremely ornate in their work. Grill work was their greatest accomplishment.

Early American Ironwork

- The style of the colonial American blacksmith was simple, direct, and utilitarian.
- Jamestown had plentiful land and a nail shortage. The burning of houses to retrieve the nails was forbidden by law in 1644.
- Eight boys were said to be able to produce 25,000nails in a week, provided that they had enough iron bars.
- By the 19^{th} and 20^{th} centuries, blacksmithing lost its importance because of the industrial revolution

Welding

- Iron filing combines with the flux serve two purposes:
  - As the iron approaches the welding temperature the iron filings burn first, preventing the pieces form oxidizing.
  - When hammering the pieces together the filings are forced out of the scarf faces carrying away the scale of the flux.
- Flux – serves two purposes
  - Combines with the scale of lowers the melting point.
  - After the scare melts, it forms a liquid barrier preventing oxidation.
- Use flux sparingly
  - Too much will cause more scale formation by attracting oxygen.
  - If too much flux is in the weld, and not completely forced out, it will form a barrier, preventing the two pieces from joining.
- Ingredients of Flux- clean sand and borax
  - 4 pints sand
  - 1 pint borax
  - This will produce general flux
  - Or store bought Borax soap powder

FLUX FOR HIGH CARBON STEELS: 50% ANHYDROUS BORAX, 25% BORIC ACID, 25% SILICA SAND
A REDUCING FIRE IS NECESSARY FOR WELDING.

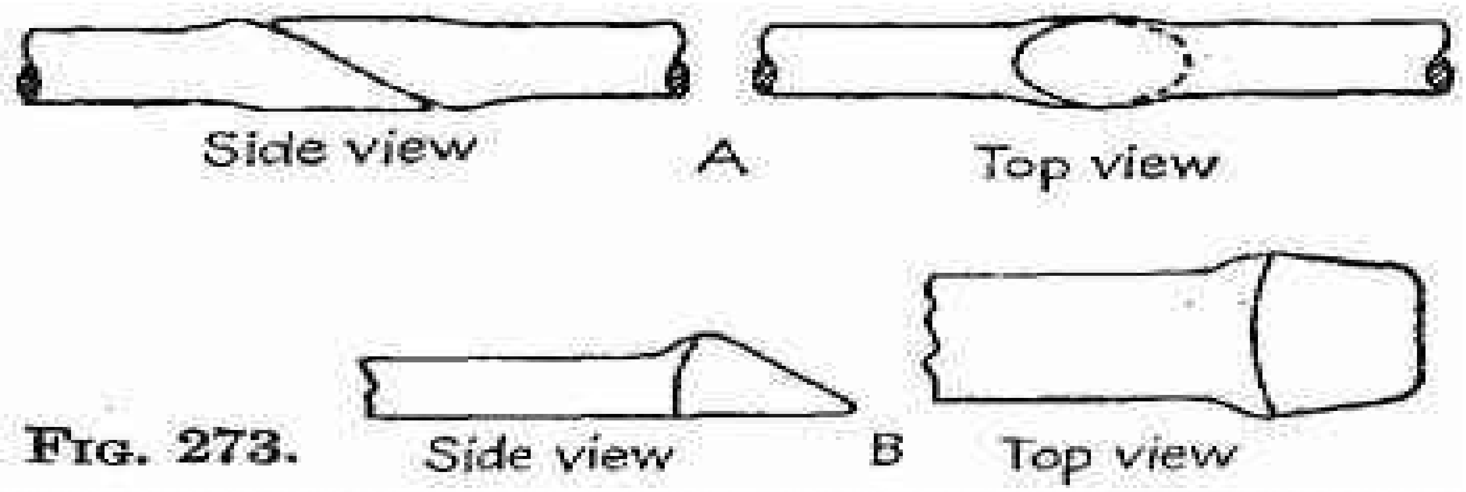


Fig. 273.

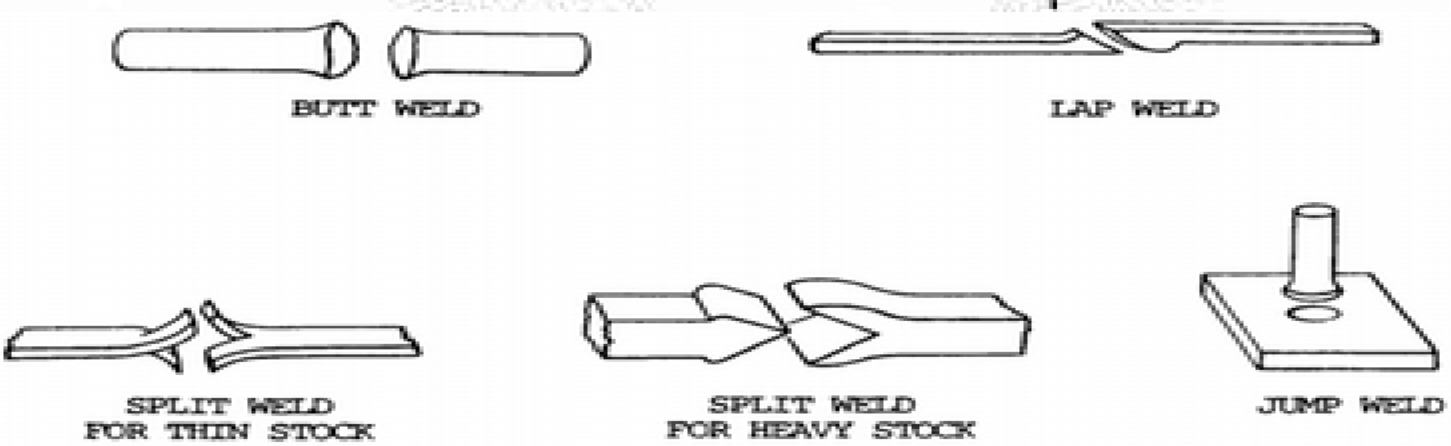
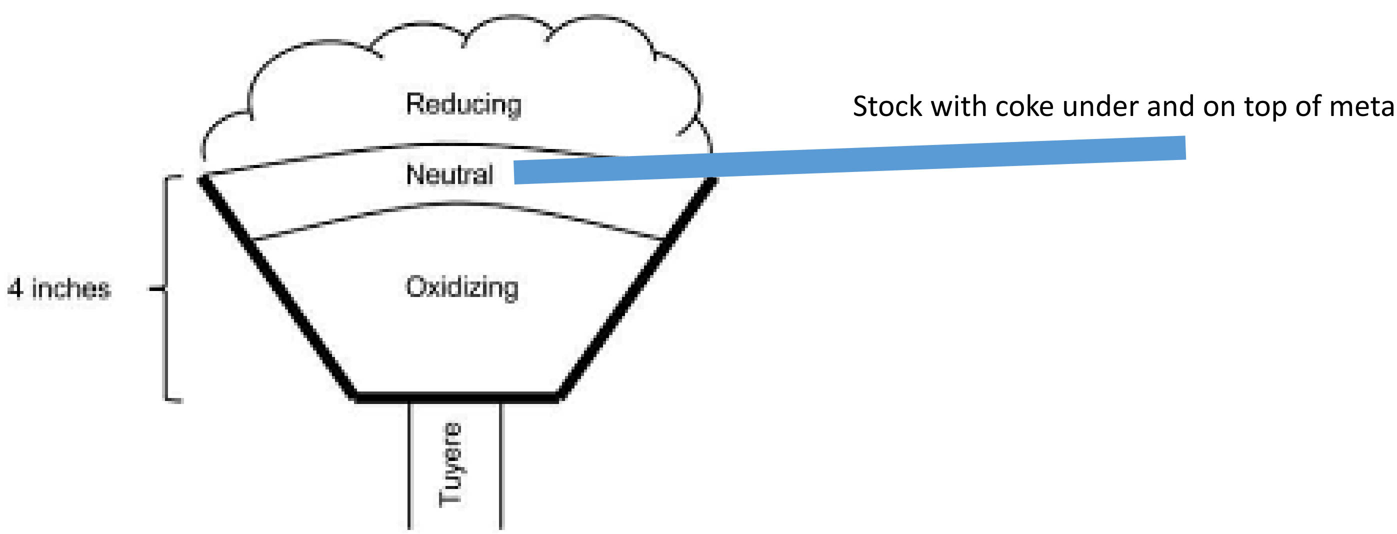
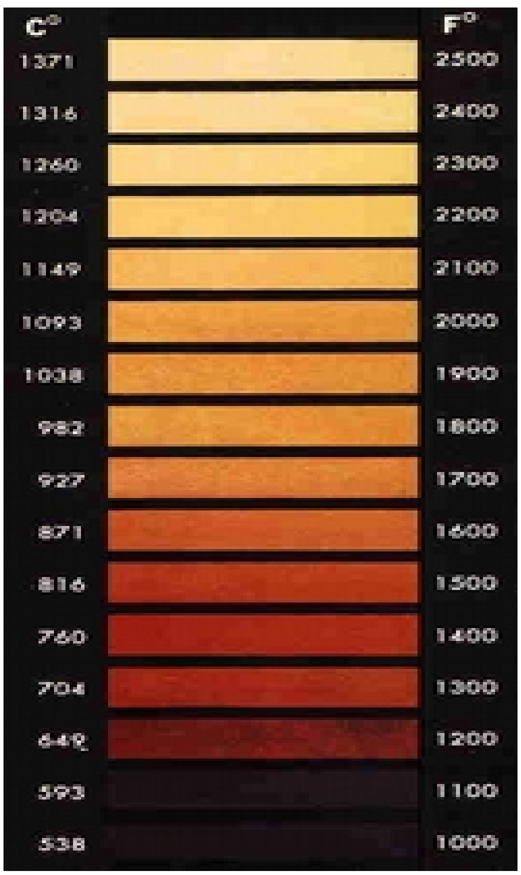


Figure 12-48. Forge welds.



<u>Iron</u>

Blacksmith, is named after the black metal, iron.
When iron is heated it oxidizes forming layers of black scale.
At orange heat 1,740℉ scale will fall off.
Light cherry 1,550℉ scale adheres and iron remains black.
For every heat, you lost 1% of the total weight of the iron, use as few heats as possible.
Iron in its natural state is in the form of iron oxide.
Pig iron is the iron that is extracted by means of a chemical process of the blast furnace.
All other iron products come from pig iron.
Cast Iron – mixing the pig iron with other grades if iron and steel depending upon its future use.
Wrought Iron – Worked with large hammers to combine slag with the iron. The amount of siliceous slag in wrought iron varies from 1-3% by weight. This slag gives wrought iron its fibrous character.
Wrought iron is resistant to corrosion because of the purity of iron and because of the slag.
Work at yellow heat 2,100 – 2,200℉
Weld at white heat 2,500℉



2000°F	Bright yellow	1093°C
1900°F	Dark yellow	1038°C
1800°F	Orange yellow	982°C
1700°F	Orange	927°C
1600°F	Orange red	871°C
1500°F	Bright red	816°C
1400°F	Red	760°C
1300°F	Medium red	704°C
1200°F	Dull red	649°C
1100°F	Slight red	593°C
1000°F	Very slight red, mostly grey	538°C
0800°F	Dark grey	427°C
0575°F	Blue	302°C
0540°F	Dark Purple	282°C
0520°F	Purple	271°C
0500°F	Brown/Purple	260°C
0480°F	Brown	249°C
0465°F	Dark Straw	241°C
0445°F	Light Straw	229°C
0390°F	Faint Straw	199°C

Steel

Steel is a combination of Iron and carbon

Plus – manganese, phosphorus, sulfur, silicone, and other alloys.

Carbon major alloy of iron amount of carbon from trace – 1.7% or 170 points of carbon (A point is 0.01%)

A 1% carbon steel would have 100 pts. Of carbon

Mild or low carbon steel	1- 40 points
High carbon steel	40-60 pts.
Spring steel	70 – 80 pts.
Tool steel	80 – 170 pts.

Hot Rolled Steel

Hot rolled steel has been roll-pressed at high temperatures (over 1,700˚F), which is above the re-crystallization temperature for most steels. This makes the steel easier to form, and also results in products that are easier to work with.

To process hot rolled steel, manufacturers start with a large, rectangular billet. The billet gets heated and sent for pre-processing, where it is flattened into a large roll. From there, it is kept at a high temperature, and the glowing white-hot steel is run through a series of compression rollers to achieve its finished dimensions. For sheet metal, manufacturers spin the rolled steel into coils and leave it to cool. For other forms, such as bars and plates, materials are sectioned and packaged.

Steel shrinks slightly as it cools. Because hot rolled steel is cooled after processing, there is less control over its final shape, making it less suitable for precision applications. Hot rolled steel is often used when minutely specific dimensions aren't crucial—in railroad tracks and construction projects, for example.

Hot rolled steel can often be identified by the following characteristics:

• Scaled surfaces, the remnants of cooling from extreme temperatures.

• Slightly rounded edges and corners for bar and plate products (due to shrinkage and less precise finishing).

• Slight distortions, where cooling may leave slightly trapezoidal forms rather than perfectly squared angles.

Hot rolled steel typically requires much less processing than cold rolled steel, which makes it a lot less expensive. Hot rolled steel is also allowed to cool at room temperature, so it's essentially normalized, meaning it's free from internal stresses that can arise during quenching or work-hardening processes.

Hot rolled steel is ideal where dimensional tolerances aren't as important as overall material strength, and where surface finish isn't a key concern. If surface finish is a concern, scaling can be removed by grinding, sand blasting, or acid-bath pickling. Once scaling is removed, various brush or mirror finishes can be applied. Descaled steel also offers a better surface for painting and other surface coatings.

Cold Rolled Steel

Cold rolled steel is essentially hot rolled steel that has gone through more processing. To get cold rolled steel, manufacturers generally take cooled-down hot rolled steel and roll it more to get more exact dimensions and better surface qualities.

But the term "rolled" is often used to describe a range of finishing processes such as turning, grinding, and polishing, each of which modifies existing hot rolled stock into more refined products. Technically, "cold rolled" applies only to sheets that undergo compression between rollers. But forms like bars or tubes are "drawn," not rolled. So hot rolled bars and tubes, once cooled, are processed into what are called "cold finished" tubes and bars.

Cold rolled steel can often be identified by the following characteristics:
• More finished surfaces with closer tolerances.
• Smooth surfaces that are often oily to the touch.
• Bars are true and square, and often have well-defined edges and corners.
• Tubes have better concentric uniformity and straightness.

With better surface characteristics than hot rolled steel, it's no surprise that cold rolled steel is often used for more technically precise applications or where aesthetics are important. But, due to the additional processing for cold finished products, they come at a higher price.

In terms of their physical characteristics, cold worked treatments can also create internal stresses within the material. In other words, fabricating cold worked steel—whether by cutting, grinding, or welding it—can release tensions and lead to unpredictable warping.

Depending on what you're looking to build, different types of materials each have their own benefits and drawbacks. For unique projects or one-off productions, prefabricated steel materials can provide the building blocks for any structural configuration imaginable.

For projects where you'll be manufacturing many units, casting is another option that can save time in machining and assembly. Cast parts can be made to almost any form in a range of quality materials.

Tool steel

Tool steel is a type of carbon alloy steel that is well-matched for tool manufacturing, such as hand tools or machine dies. Its hardness, resistance to abrasion and ability to retain shape at increased temperatures are the key properties of this material. Tool steel is typically used in a heat treated condition which provides increased hardness. Several grades have additional resistance to corrosion due to added chemical properties such as vanadium. Also, with certain grades the manganese content is restricted in order to minimize the potential of cracking while water quenching. Other grades offer various methods other than water to quench the material, such as oil. The choice of Tool Steel grade depends on a number of factors. For example:

Is sharp cutting required?

Does the tool have to withstand impact loading (axes, hammers, picks, etc.)?

Is abrasion resistance an important criteria?

What type of heat treating is needed?

Tool Steel Grades

Water Hardening (W-Grades)

This is basically a high carbon steel. While it generally has a lower cost it cannot be used where high temperatures are involved. This steel can achieve a high hardness, but it is rather brittle when compared to other tool steels. All W-Grade tool steels must be must be water quenched, which can lead to increased warping and cracking.

Typical applications of W-Grade tool steel include Cold Heading,Cutting tools and knives, Embossing, Reamers and Cutlery.

Air Hardening (A-Grades)

This is a very versatile, all-purpose tool steel that is characterized by low distortion factor during heat treatment, due to the increased chromium content. This tool steel has good machinability and a balance of wear resistance and toughness.

Typical applications of A-Grade tool steel include Arbors, Cams, Die Bending, Blanking, Coining, Embossing, Cold Forming, Lamination, Cold Swaging, Cold Trimming, Gages, Chipper Knives, Cold Shear knives, Woodworking Knives, Lathe Center Knives.

D Type (D-Grades)
This is a high carbon, high chromium (air hardening) tool steel. It was formulated to combine both the abrasion resistance and air-hardening characteristics. Common applications for these tool steels include forging dies, die-casting die blocks, and drawing dies.
Typical Applications of D-Grade tool steel include Burnishing Tools, File Cutting, Paper Cutters, Die Bending, Blanking, Coining, Cold Heading Die Inserts, Embossing, Cold Extrusion, Cold Forming, Lamination, Cold Swaging, Thread Roll, Cold Trimming, Wire Drawing, Gages, Paper Knives, Rotary Slitters, Cold Shear Knives, Woodworking Knives, Knurling tools and Lathe Center Knives.

Oil Hardening (O-Grades)
This is a general purpose tool steel. It has good abrasion resistance and toughness for a wide range of applications.
Typical applications of O-Grade tool steel include Arbors, Bushing, Chasers (Thread Cutting), Collets, Die Blanking, Cold Forming, Cold Trimming, Drill Bushing, Gages, Knurling Tools.
Shock resisting types (S-Grades)
This type of tool steel has been designed to resist shock at low or high temperatures (E.g. Jackhammer bits). Its low carbon content is required to achieve the necessary toughness. This group of metals has high impact toughness, but a low abrasion resistance.
Typical applications of S-Grade tool steel include Battering Tools, Boiler-Shop Tools, Chisel Blacksmiths, Chisel Cold Working, Chisel Hot Working, Chuck Jaws, Clutch Parts, Collets, Cold Gripper, Hot Gripper, Cold Swaging, Hot Swaging, Hot Trimming, Chipper Knives, Cold Shear and Hot Shear.
Hot-Working (H-Grades)
This tool steel group is used to cut material at high temperatures. The H-Group has added strength and hardness for prolonged exposure to elevated temperatures. They are low in carbon and moderately high in additional alloys.
Typical applications of H-Grade tool steel include Cold Heading Die Casings, Die Casting Dies and Cores for Zinc and Aluminum, Hot Extrusion for Aluminum and Magnesium, Hot Forging, Hot Gripper, Hot Swaging, Hot Trimming, Dummy Blocks (Hot Extrusion), and Hot Shear Knives.
Tool steel is commonly used to make tools because of its hardness, resistance to abrasion and ability to withstand high pressures.

Metallurgy of Blacksmithing:
Forging process is possible because iron becomes plastic.
Structure of iron and its alloys is called crystalline.
When iron is heated the crystals expand and the bond between them become weaker. Metal becomes like plastic.
Generally – Higher the heat easier to form the metal.
Crystals of the iron assemble together into groups called grains.
The higher the heat the larger the grains.
Welding greatly increases grain size, the weld is then hammered or refined or annealed to break up the coarse grain.
Metal cooled rapidly, carbon is trapped inside the crystal.
Metal in high stressed condition.
Steel in the stressed state is hardening.
Removing stress is tempering.
Removing all stress is annealing.

PRODUCTS OF THE BLACKSMITH:

The products depended on the ace and time period that he worked.

There was a total lack of horseshoeing in the eighteenth and early nineteenth centuries.

The agricultural community did not need to waste its iron on horses, as the roads were largely unpaved.

There was a constantly changing pattern of work for blacksmiths in the eighteenth and nineteenth centuries.

18th century: Smiths had mostly a large variety of small items. A great deal of time was spent on repair and replacement work. He made many of his own tools and objects for the hearth.

Some examples are: Cranes (for the fireplace), irons, trammels, tongs, shovels, trivets, small game spits, skillets, toasters, skewers, and holders. Most items were primarily functional.

Tools for the farm were produced by the blacksmith, as well as architectural hardware: Long strap hinges.

<u>BLACKSMITHING:</u>

Fire, fuel, and heat

Blacksmith coal – bituminous soft coal with a low sulfur and phosphorus content low in inorganic material which contribute to ash.

Composed of lumps the size of 1st joint of your little finger plus fines.

Coal breaks down the following proportions

	Carbon	high	55-65%
Will	Moisture	low	2.5-3%
Not	Ash	low	3-8%
Burn	Sulfur	low	1-2%
	Volatility	high	30-40%
	B.T.U.		13,500 – 14,500

Soft coal contains high content of volatile substances which produce a smoky fire in early stages but assist in binding coal so it converts to coke.

It is estimated that it takes 3ft. of peat to make a seam of bituminous coal 1ft. thick.

Peat goes through the following stages to form coal.

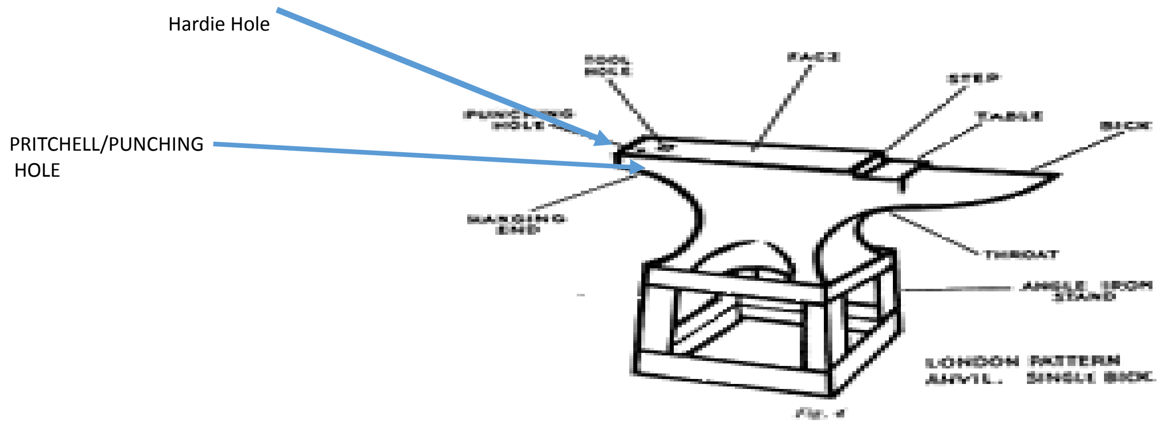
Peat brown coal - ignite - sub bituminous - bituminous - semi anthracite – anthracite bituminous coal will break apart in your hand.

Charcoal- First fuel used in Blacksmiths, used today if needed for a low temp and clean fire.

3 Aims in Managing the Fire:

1. Keep the fire as small as possible – purpose of the fire is to heat metal nothing more.
2. To prevent the fire from burning hollow the heat of the fire must be in the middle. Fire below and above the piece of metal being heated. Blast of air will produce oxidizing.
3. To defeat clinkers- produced by the combination of oxygen in the blast with impurities don't use more blast than necessary.

The Anvil



#100-#140 best for average use.
Forged anvil will be more alive than a cast anvil
Numbers on the side indicate the weight. Based on an old system

First numbers indicate the full hundred weight (112 lbs)
Second number indicates ¼ of the 112 pounds (28 lbs)
Third number represents actual pounds
Example: #112 – 112/28/2 – 142 lbs.

Forge – the "oven." Heat source for bringing the iron to a workable temperature.
Slag Tub – tub of water used to cool the iron. Was believed to have curative power. Don't cool tool steel in slag tub.
Tuyere – (blow pipe) controls the size and the character of the fire by its shape and the amount of air allowed to the fire.
Side blast tuyere used in the 17th and 18th centuries

Tuyere opening	3/4" x 1" x 1-3/8"
Depth of fire box	4" x 5" x 6"
Diameter of supply pipe	1-3/4" x 2" x 2- ½"

Hammers:

Cross peen:

Straight peen:

ie

Ball peen:

Smith redresses the face, so as not to mar the iron. File off the rough edges of hammer.
Sledges
Hand Sledges: 5-10 lbs.
Swing Sledges: 10-20 lbs.

Tongs – extension of the blacksmiths hand. Many were custom made for a particular job.

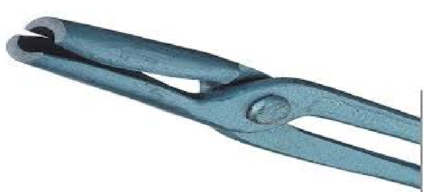
Pick up tongs: Used to pick up tools or small pieces of iron.

Flat tongs: Bit is flattened to hold flat pieces of iron.

Box tongs: For holding square iron. Has a lip on the inside to keep the iron from slipping out.

Round bit tongs: Curved bit. Used for holding round iron.

Hollow bit tongs: Has a hollow area at the end to hold a round piece with a swell (Such as a bolt.



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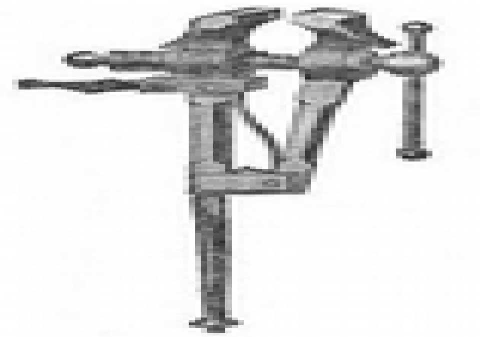
Pincer's tongs: For holding a piece of round area off of the main body

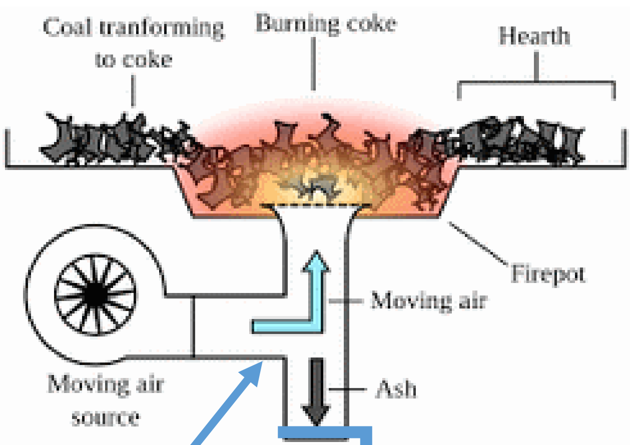
Vise – Third hand of a blacksmith. (Post, box, stake, and leg vises)



Hardies- Fit into the hardie hole of the anvil or chuck it up into the vise.

Fullers: Similar to swage. Top has a wooden handle and bottom has a plug for the hardie hole. Used in pairs.
Swage lock: Iron with precut forms 70-80 lbs. Used to turn square stock round. Bowls, spoons, ect shaped on a swage.
Top swages: wooden handle. Rounded cup. Paired with a bottom swage, which fits into the hardie hole.
Flatter: Used to finish the surface and remove any hammer marks.
Set Hammer: Smaller than a flatter. Has a sharp edge to get into corners, shoulder, ect. Used like a hammer.
Punches: Used to punch holes. (round, square, and oval)
Bolster: A base placed under the iron when you are punching a hole. Prevents the hole from splaying. May use interchangeably with a nail header.
Nail Header: Flat pieces of iron with holes in various sizes. Used to hold the shaft of a nail in place while the head is being shaped. Held over the Pritchell hole.
Twisting Wrenches: Provides balance and leverage for twisting iron.
Drift: Used to open or form a hole.
Mandrill: Used to form circular shapes and rings. It is cone – shaped to allow a variety of diameters.
Beak: Small mandrill which is horizontal (as compared to the vertical mandrill), And fits into the hardie hole. Used to make small rings.
Saddle: Used over the face of the anvil while cutting. Prevents scarrign the face.
Heading Tool: Used for nail and bolt heads.
Chisels: Same used as a hardie, except it has a wooden handle to protect the hands from the heat of the piece being cut.

FIRE:



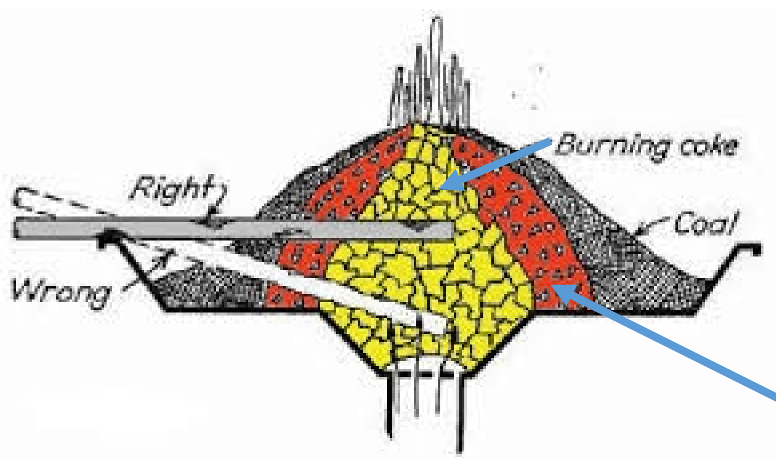
Ash dump door

Tuyere pipe

Reducing: consumes all the oxygen from the blast. It is a compact bed of coals and coke. The sides are well banked and formed, so that the heat is reflected inward, making a hotter more desirable fire.

Oxidizing: An excess of oxygen usually hollow with a layer of coals and clinkers it is impossible to weld at the fire, difficult to heat metal.

Neutral: Scale forms 1% of metal weight is loss.



Coal turning into Coke done by adding water to the coal allowing it cook slowly.

FORGING PROCEDURES:

Drawing Out: Stretching or lengthening a piece of steel by forging. Draw out square, and then round out the corners, if desired.

Flattening: Heating a bar and flattening one side, and then the other.

Bending: Bending hot iron over the anvil, horn, or vise. Wrought iron is bent in the direction of the grain, but mild steel can be bent in any direction.

Upsetting: Thickens or bulges a piece of metal. Can be done on the ends or in the middle.

Twisting: Usually done for decorative purposes. This can only be done to metal with square corners. Twists can be single, double, multiple, or reverse. When twisting, the hottest part of the metal will twist the easiest.

Splitting: Process of hot cutting iron in its major dimension. Heat to a welding heat. (White Hot) Begin with cold chisel, then hot cut along the score marks made.

Punching and Drifting: The process of punching a hole in metal. The drift is used to finish a hole. When punching a deep hole, one can put a few grains of coal dust onto the part being punched to prevent the tool from sticking. When punching a delicate hold, a bolster may be useful to help support the metal, and keep it from distorting.
Hot cutting on a hardie: Used hot handle. Metal is cut at yellow heat.

JOINING TECHNIQUES:

Collaring: A collar is round of flat piece that is bent around 2 or more pieces of iron to join them.
Wrapping: Serves same function as collaring, but made with two or more turns of the iron bar. Wrap begins as a collar, then ends wrapped around the iron.
Mortise and Tenon: One bar forged to a round or square tenon. (Square tenon will prevent turning) This tenon is pushed through a hole called mortise. The tenon should be long enough to upset the end into a rivet head.
Riveting: Joining two or more pieces of iron together with a rivet shank.
Forge weld: Method of joining iron or steel to each other while in a plastic state, Pressing together clean metal surfaces under the application of heat and pressure of hammer blows. The flux cleans the metal.

Wrought iron is the easiest to weld. The higher the carbon content of the steel, the harder it is to weld.
Flux is amplified at red heat: Flus will combine with the oxide skin layer and scale to yield a low melting point. (This compound of flux and scale will be squeezed out during hammering.) Surround metal with coke when it looks wet it's ready to weld.