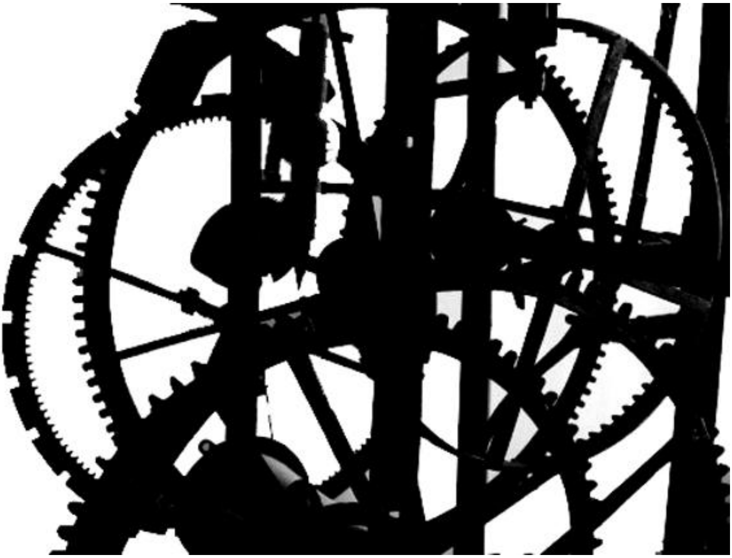
Jack Waygood's



'Workshop Handbook'

Submitted to

Hereford & Ludlow College of Technology

Design & Forgework Skills

October 2014

Contents

Blacksmithing

Throughout history we can see how blacksmith's have constantly adapted their lines of work to survive and how associations and traditions were forged. It brings to question the contemporary blacksmith and his or her place in our post modern world.

Within society there is general confusion and uncertainty towards blacksmiths, ye olde village smithy who shod the horse and the term 'a dying Art' should now be seen as a thing of the past. Today there are many smiths challenging the shadows and despite the crafts hardship as a minority, with perceived competition from industry, there is increasing general interest.

In the last thirty years BABA and the work of devout blacksmiths have faced the challenge of regenerating the craft; their efforts have and continue to elevate the Blacksmiths profile in many different ways.

There are now many different routes to learn the skills and more and more blacksmiths interested in pushing the process forwards, using great experimentation and creativity. The number of colleges teaching blacksmithing has risen and the apprenticeship schemes are on the way. Fellow smiths share advice and help one another; this bond happens internationally, even if they don't speak the same language they can speak using the language of the hammer and anvil. At a Forge-in you can expect blacksmiths from all over the world, for many journeymen it's a good opportunity for networking, planning where to travel and work. A truly dedicated smith won't go hungry.

The fundamentals of blacksmithing process haven't changed, forging is the core element and smiths create all kinds of things ranging from public art and sculpture, architectural, domestic, functional and non functional, hardware and garden ornaments... the list goes on. The craft holds the freedom of infinite variation, the smith can create something using the hands, heart and soul.

In these times I believe people are starting to move away from a disposable nature and looking more towards sustainability and quality. Perhaps the reason blacksmithing hasn't been recognised in the greater craft community is subject to time;

when other crafts such as ceramics and textiles started to be recognised in contemporary art and design, blacksmithing was still in demand as a rural trade. Maybe now the area society placed ceramics and textiles in is the long awaited direction for the blacksmith.

In this handbook I have referenced material given to me over my five years training on the Artist Blacksmithing (BAhons) and the advanced course 'Design and forge work skills'. For the purpose of my assessment, the academic work is in my words, the additional content is simply aiding the use of this handbook for personal use only.

My gratitude and appreciation goes to the blacksmiths teaching at HCA and HLC with special thanks to Adrian Legge and Paul Allen whom I'm constantly learning from.

Design

All the creations in the forge are at some point designed, it's another attribute the smith if they learn to skilfully communicate how they generate visual ideas and interests. It is as important, if not more important than the practical making.

The way in which designs are created can be personal and there is no right or wrong way of going about it. The aim is to get the best resolution in the parameters of a project. Thinking outside of the box and going with the gut isn't always successful. The Blacksmiths approach can generally be categorized into three main areas Literal, Abstract and Conceptual. This is down to the individual and by no means is there approach better or worse than someone who works differently. A method for getting started is to lay out some guidelines, record, analyse and develop designs and ideas.

- Start by gathering imagery making considered decisions / Primary and secondary resources
- Analyse, compare and contrast, find out what your drawn to, reasons you like something, reasons you don't. Look at patterns, details, forms, textures, materials etc..
- Start drawing from your imagery; try to understand what you want from it and how to portray it in an abstract or literal manner. Take something from the observation and communicate it, use sketches to make gestures/make samples of it on the forge/plastercine/maquettes etc..
- From your samples and drawings you can explore the boundaries and aim to refine the defining characteristics of your style.

Build a collection of visual elements to develop your own aesthetic style. It can be argued that when making with our hands your own personal style happens naturally anyway and it does. We are constantly influenced by the stuff we see around us but by practicing to control the visual part of the objects we make takes real skill. Also being traditionally trained in blacksmithing will teach you the basic principles of construction.

These skills are transferable and can be applied to making your own designs from the process above.

Designing an object from your research takes care of the 'artist block' but there are still important considerations to make.

- **Do a scaled drawing of the object (if the object is intended to be view at a distance it will appear smaller) - Exact size of stock bar and fixings?**

Consider all the elevations and make a scaled model if necessary

- **Proportions - Do the elements flow and are they consistent**
- **Internal or exterior ironwork? Transportation, will it need assembling on site?**
- **Where is it going to be placed? Health and safety www.HSE.gov.uk/ security risk, can it be climbed.**
- **Building regulations? www.planningportal.com**
- **Assembling – make it easy for yourself, do you have tooling already for certain sized holes, collars, rivets etc..**
- **Finish – this is very important and should be introduced early on with the design development.**

Notes:

Design Development
Drawing Samples
Factors To Consider
Important Design Evaluations

This chart can be used as a basic overview of tools and equipment in a forge, what they are used for and the potential hazards and maintenance involved.

Tools & Equipment	**Guide Maintenance Risk Assessment**
Anvil	**The assessment for a good Anvil is to listen for a clear and sharp ringing when worked on. A dull sound could mean it is too soft or has flaws. When forging the anvil should work for you, by bouncing the hammer back after every swing.** **To set the anvil, rest your arms by your side and see that your knuckles meet the face. Use a metal stand or a stump of elm or oak. The anvil and stand need to be solid and positioned efficiently.** ❖ **The Anvil will get hot when worked on** ❖ **Can cause pain if walked into or fallen upon** ❖ **Visual check** ❖ **Very rarely maintenance is necessary in dressing the Anvil; ideally it should have a perfectly smooth face and Bick with a variety of radiuses edges.**

<u>Solid Fuel Forge & Gas Forge's</u>	**Various types of solid fuel and gas forges are used in blacksmithing. A standard side blast forge with an electric snail fan is capable of most forging operations, designed for processes such as fire welding and localizing heats. The open hearth allows you to heat large objects and use the bed as a workstation. The gas forge works differently, it can give long heats on multiple bars and is useful for maintaining the temperature on a handful of rivets or collars. Often quite small they are handy portable forge.** **You can build both forges yourself and customise them to your needs.** ❖ **Any electrical appliance should have an annual PAT test** ❖ **Gas equipment should be replaced every five years** ❖ **Make visual checks on the gas forge, is the lining ok, does the regulator work?** ❖ **If you can smell gas check the connections with spray. Replace the PTFE** ❖ **Make visual checks on the solid fuel forge, keep the front and back boshes full, check for rust, Keep it**

	tidy and sweep it down. Remove clinkers. ❖ **Fire, hot metal, hot coke, sparks; boiling water and hot ash can cause injury. Correct PPE must be worn.**
<u>Tongs</u> **<u>Pliers/Fire Tongs/Anvil Tongs</u>**	**Tongs are designed for different jobs and there are three main families. Pliers have uses such as scrolling up, bending and opening and shutting collars. Most Anvil tongs are made to hold a particular section and have a rein length from 370mm-600mm.** **Fire tongs are considerably bigger and have much longer reins. Designed for industrial uses.**
➢ **Flat Bits**	**Closed mouth, holds flats/sheets/plates. MS.WI**
➢ **Hollow Bits**	**Or Round bit, holds rounds. MS.WI**
➢ **Square Hollow Bits**	**Or Diamond hollow bits, holds square and round. MS.WI.**
➢ **Universal Bits**	**Useful for holding square and round bars at 90’ MS.WI.Spring steel**
➢ **Bolt Tongs**	**Used for holding shapes with the same principle as a bolt. Different swaged nibs. MS.WI.Spring steel.**
➢ **Rivet Tongs**	**For gripping rivets. Case hardened.**
➢ **Side Hollow Bits**	**Used for holding shapes that needs to pass through the jaws. Make them weighty to increase the grip.**

➢ **Duck Bills**	**Traditionally used by the wheelwright for holding a tyre.**
➢ **Box Jaw Bits**	**Or lugged tongs for greater support holding flats and squares. MS.WI**
➢ **Pickup Tongs**	**Or dandy tongs used by the dandy man or striker as general support. WI.MS.316SS**
➢ **Scroll Pliers**	**For scrolling up and tweaking. Need to be made strong, case hardened. WI.MS.Spring steel.316SS.Titanium.**
➢ **Bow Pliers**	**Used for bending and tweaking shapes with the same principle as a bolt. Need to be made strong, case hardened. WI.MS.Spring steel.316SS.Titanium.**
➢ **Angle Tongs**	**Used to hold angle iron. MS.WI**
➢ **T Angle Tongs**	**Used to hold T bars. MS.WI**
➢ **Shingling Tongs**	**Used to hold short pieces that have been jumped up under a hammer. MS.WI**
➢ **Pipe Tongs**	**Used for holding pipe. Quenching hot pipe spits boiling water which can be very painful. MS.WI** ❖ **Look after your tongs by checking they work well and re-setting them if necessary.**
<u>Hand Hammers & Mallets</u>	**The smith uses different pattern hand hammers weighing from 1 1/2LB to 3LB.**
➢ **Ball-Pein**	**Commonly used as the main forging hammer. The pein can be used where you need accuracy and minimal contact making it Ideal for riveting**
➢ **Cross-Pein**	**Designed for spreading material**

	cross ways and general forging.	
➢ 5LB Hammer	The hard face can be used for forging and the soft face for use on striker tools.	
➢ Turning Hammer	The farriers hammer, quite a different technique is used to whip the blows.	
➢ Ball Faced Hammer	Useful for dishing, riveting and bending without leaving marks.	
➢ Sledge Hammer	A useful sledge hammer weighs from 7lb to 16lb and is used by the striker.	
➢ Leafing Hammer	Used for decorative leaf work.	
➢ Raw Hide, Copper Faced & Lead Mallets	Good for straightening out twists without knocking the edges off. Mallets are ideal for bending without marking the surface. ❖ A shaft made from ash or hickory is ideal. To treat the handle and wedge, soak in raw linseed oil over night. ❖ The face of the hammer and any additions should be dressed correctly. ❖ Make visual checks before using a hammer. ❖ Cracks or a loose head can be dangerous.	
<u>**Hot Cutting Tools**</u>	Hot Hardies, hot chisels and hot sets can be made straight or curved and ground in different ways. The versions	All cutting tools need to be dressed correctly to be efficient. Any tool used with a striking end must be free of mushrooming. Hardening and tempering if

	designed for cutting cold metal have no less than a 60’angle and are hardened and tempered. EN9	required. Keep a constant eye on their condition and fix any problems straight away.
➢ **Hardies**	Fit in the hardy hole on the anvil and are used for cutting hot metal. The angle of the cutting edge is ground as sharp as you can get away with.	
➢ **Chisels**		Use a cutting plate
➢ **HotSet**	Held in the hand with a striking end to be hit with a hammer. A hot set has a wooden or rodded handle and is used with a striker or under a power hammer.	

<table>
<tr>
<td><u>Fullers</u>

➢ Fullers

➢ Cheese Fuller

➢ Butchers</td>
<td>Fullers are convex and form a corrugated impression. They have rodded or wooden handles.
Fullers should be stocked in various sizes.
Wider and more circular with rounded edges.
Used for notching and making tenon's.</td>
<td>❖ All fullering tools need to be dressed correctly to be efficient.

Any tool used with a striking end must be free of mushrooming.

Keep a constant eye on their condition and fix problems straight away.</td>
</tr>
<tr>
<td><u>Anvil Tools</u></td>
<td colspan="2">These tools fit in the hardy or pritchle hole and fulfil a variety of tasks.

❖ Bottom swage
❖ Bottom fuller
❖ Anvil forks
❖ Rivet snap
❖ Saddle
❖ Bolsters
❖ Anvil bick
❖ Hardies
❖ Mandrils</td>
</tr>
<tr>
<td><u>Fire Tools</u></td>
<td colspan="2">The forge is equipped with various tools to manage the fire. Clinker is frequently cleaned out with a poker and shovel and to</td>
</tr>
</table>

	stop the fire getting low, it's built back up using a rake. Another useful fire tool is a watering can, a rodded bean tin works well, used for cooling down around the fire and compacting the bed it's also used for localising heats on hot metal. ❖ **Fire tools work well and are kept on the hearth.**
Monkeys	**This tool looks like a punch and is made to fit different sections. Mainly used to secure joining elements before riveting or dressing the shoulders on a tenneon.** ❖ **These tools heat up if used on hot metal.** ❖ **A rack for all different sizes can be made as illustrated.**
Hold fast	**Works by striking the tool into the pritchal hole allowing the arm to be used as a clamp on the anvil.** ❖ **Spend time making these tools good and they will last a long time.**
Blacksmiths Helper	**Is an anvil tool used where two sides are to be forged single handily. Operations such as double set downs, even cut offs, stamping and fullering.** ❖ **Unsecure tooling can be dangerous.**

	❖ **Avoid using to cold because it will wreck the dressing on the tools.** ❖ **Remove any mushrooming** ❖ **Organised storage.**
<u>Bolster Plates and Heading Tools</u>	**Heading and rivet snaps work by passing a shank through the hole and shouldering the required amount for the head. Bolster plates are versatile and can be used in the same way, mainly used for drifting holes.** ❖ **Organised storage, these tools save time.**
<u>Mandrils</u>	**A mandril is a tool used to form shapes around. The cone mandril varies in size up to about 2.5M and is used to shape rings and circular forms. Smaller cone mandrills can be made for the Anvil. Square mandrils are used for making collars, the designs can be very simple as illustrated.** ❖ **Considered positioning for large mandrills.** ❖ **Heat is transferred when hot bars are formed on a mandril.**
<u>Swage</u> ➢ **Swage Block** ➢ **Top and bottom Swage**	**The swage block has various concaved grooves around all four sides; the face also has various shapes and sized holes. It can be used lying down or standing up.** **Top swages are rodded or shafted with a wooden handle, used in conjunction with a bottom swage which gets placed in the hardy**

➢ **V Swage**	**hole. There used to swage sections round.** **These swages have a variety of shaped grooves allowing different sections to be forged.** **.** ❖ **Its handy to have the block mounted at anvil height as it doubles up as a support for long lengths. The original cast iron stands are ideal.** ❖ **Move the block using a heavy bar for leverage, wearing the correct PPE.** ❖ **Considered storage space and organisation makes the tooling efficient.**
➢ **Flatter** ➢ **Set Hammer**	**For smoothing out hammer marks and finishing after forging. Wooden handle or rodded.** **Used for dressing corners and making sets or notches. Often ground with two sharp edges and two radiused for versatility.**
➢ **Spring Fuller** ➢ **Spring Swage**	**Spring tools allow single-handed use at the anvil or on the power hammer. The design incorporates guides to keep the nibs inline as illustrated.** ❖ **Take time making them and they will last a long time.** ❖ **case harden the nibs**
<u>Punches</u> ➢ **Tapered Punches Round/Square/Slot**	**Punches are used for punching holes in hot metal. There designed to be held in the hand**

	with a striking end to be hit with a hammer or can be handled and used with a striker or under the power hammer. They can be made to any given shape, the most common are listed. ❖ Punches can bend and may need redressing. ❖ Keep an eye on them and grind any mushrooming. ❖ Hardened and tempered EN9	
<u>Twisting Wrenches</u>	**A common twisting wrench is made from flat bar with a punched hole in the middle. They can be made to fit the section being twisted.**	**Tooling like this can save time, make a good job of them and keep them by the vice.** **visual check for cracks and bends**
<u>Drifts</u>	**Once a hole is punched it can be drifted to give a more accurate size.**	**Grind away mushrooming and keep them straight and true.**

Bending Forks	A dog wrench or scroll dog can be used with bending forks for all kinds of bending operations.	Maintain the smooth forks to avoid leaving marks on a hot bar. Case hardened or made from spring steel.
Dog Wrench		
Workbench	The bench is generally used for laying out, fixing and assembling , arc welding and finishing. It should be level and sturdy. A 3M x 5M and no less than 10mm Steel top that you can work around is ideal. The bench can also be used as storage space. It's essential to have shelving and racking in the workshop.	Work areas are kept organised by having tools in the right place and working efficiently. The bench gets hot if you put forgings down or use it for gas or welding. Good housekeeping reduces the hazards. Be sure of what you place at a height and the weight capacity of the storage.

<u>**Files**</u>	**Filing requires different sizes shapes and degrees of coarseness. They are used on cold normalised metal, Good for creating details or filing sections that are impractical to forge. Needle files are used for very fine work, for reducing or shaping hot metal the bastrard side of the rasp is very effective.** **All files can be cleaned to maintain the depth of cut and should have a good secure handle. Keep hold of old files and reuse them for their tool steel.** ❖ **Don't use without a handle** ❖ **Files only cut in one direction and should be sharp.**	
<u>**Bench Shears**</u>	**'Bench shears' are used for cutting sheet metal, larger 'shear cutters' can be used to crop hot or cold bars. They work like scissors, the leverage**	**There is a guard on the blades and the handle is locked and made visible when not in use.** **Understand the blades limits, keep it sharp and don't cut forged or hardened metal.** **Frequently oil moving parts.**

	from the handle open and close the hardened blades.	

<u>Vice's and Clamps</u> ➢ **Leg Vice**	**The smith will need a good leg vice, designed for gripping, twisting and upsetting, when struck the force travels down the leg dampening the blow this protects the screw thread and allows for heavy work. Position the leg vice close to the forge with plenty of space to work around it. It should be set so that the height of the jaws meet the elbow.** ❖ **Every so often the spring or wedges may come loose, be sure to tighten them up.** ❖ **Spray the vice with WD40 avoid using grease because dirt and filings can mix in and become abrasive.** ❖ **When not in use, nothing should be left in the jaws and the arm wants to be left in the down position.**
➢ **Bench Vice**	**For general bench work, Filing, grinding and welding. The jaws remain parallel and are grooved for extra grip. Some of these vices can swivel 360' and have an anvil face for chipping of welds.**
➢ **Mole Grips/G-clamps/carver clamps**	**A variety of clamps is useful. Mole grips are good for welding operations and general use. G-clamps and carver clamps work**

	well for fixing and assemberling. ❖ Place the clamps where there mostly used and keep returning them. ❖ Vices and clamps can get hot.	
<u>Blacksmiths Helper</u>	**Stands are used as supports around the workshop. The height can be adjusted and they should be robust and easy to move about.**	**Be sure stands are secure when in use. Keep them stood up and out of the way when not in use.**
<u>Measuring Devices and Marking Out</u>	**Measuring needs to be accurate for the best possible result.**	
➢ **Rulers and Tape Measures**	**Brass rulers don't discolour on hot metal. Tapes are useful on long lengths or cold material.**	**Accurate measuring should be made after the scuffed end.**
➢ **Calipers**	**Can be used for Internal and external measurments**	**Useful for multi pull measuring.**
➢ **Set Square**	**Used for measuring 90' angles**	**Useful to have a variety of sizes**
➢ **Spirit Level**	**Checking surface level**	

➢ **Chalk** ➢ **Centre Punch** ➢ **Dividers** ➢ **Centre Finder** ➢ **Engineer Blue** ➢ **Scribes** ➢ **Wire**	**Calcium carbonate or French chalk is hard and ideal for marking out.** **For demarcation of a point.** **Work like a compass for marking an arc.** **For marking the centre of circles** **Useful for highlighting marks on metal.** **For faint line markings.** **Handy when measuring curves.**	**Magnetic Levels and laser levels are very handy.** **Keep the edge sharp and hard.**
<u>Power Hammers</u>	**Power hammers go back to the advent of water power, beginning with Tilt, helve and drop hammers. The mechanical hammers came next. Modern hammers are mostly pneumatic. Operation controls and forging results vary from hammer to hammer. There basic function is**	**Use a hammer that suits your work. There a vital part of most business and it might be a good idea to have a backup. This is where smaller mechanical hammers are useful as they can be easily fixed. Be sure to understand**

	to forge metal under controlled powerful blows.	**all the ins and outs of your hammer. Treat this tool with respect.**
<u>Saws</u> • **Band Saw** • **Donkey Saw** • **Chop Saw** • **Hack Saw** • **Junior Hack Saw** • **Fret Saw** **Hydraulic Press**	**A band saw is a powerful continues blade, it can be set with a drop rate and self cooling systems.** **Donkey saws an older machine that works by dropping a reciprocating blade.** **A chop saw has a large cutting disc attached to a pivot arm anchored to a metal base.** **A hack saw has fine teeth and is used by hand; the smaller version is a junior hacksaw.** **A fret saw can be useful in sheet work where the deep frame allows you to cut into the sheet.**	**Saws work best when sharp.**

<u>Angle Grinders, Bench Grinders.</u>	**A bench grinder is stationary and powers an abrasive wheel, mostly used for sharpening. Angle grinders can have a number of different attachments cutting and grinding are its main use, cup brushes also come in quite handy. Battery operate ones make them very useful for site work.**	**Grinding should be done in a well ventilated are and with the correct PPE. Injuries from grinders can be quite nasty. Use decent quality consumables**
<u>Plasma Cutter</u>	**Plasma cutting is a process that uses a high velocity jet of ionized gas that is delivered from a constricting orifice. The high velocity ionized gas, that is, the plasma, conducts electricity from the torch of the plasma cutter to the work piece. The plasma heats the work piece, melting the material.**	**Replace the electrode when worn more than 1/16th of an inch Clean air**
Belt Linisher	**Or a grinding linisher is used to improve the flatness of a material or to polish the**	**Belt will need changing as they become bold and can break.**

	surface	
Cropper	**A cropper can refer to bench shears, bolt croppers and hydraulic cropper. All are designed for cutting metal**	**Hydraulic croppers also have a nibbler used for small shearing jobs.**
Welders	**MMA is manual metal arc welding process that uses consumable electrodes. Its used for welding cast iron and steels. It has the benefit on site, being easily portable and doesn't require shielding gas.** **MIG stands for metal inert gas, and is regarded easier to use than MMA. It can be used for brazing and aluminium welding as well as steel.** **TIG welding stands for tungsten inert gas. It's the most recent welder and has a variety of weld functions.**	**All welding produces toxic fumes** **Skin should be covered to protect from UV rays.**

Pillar Drill	**Also known as a drill press is a stationary drill. Can be used for cutting accurate holes.**	**Correct PPE Keep oiled and use cutting fluid.**
Milling and Lathes	**Milling machines can carve out complex shapes on a vertical and horizontal plane. Lathes have a horizontally drive that are used in conjunction with cutting tools.**	**Don't put your finger where you wouldn't put your cock (or boob)**
Scrap Bin	**The system for scrap is resourceful and considered. A palletized oil drum can be easily lifted onto a trailer. Where a larger bin is needed lifting points are incorporate for assistance of a forklift.**	**Make them robust and located in a convenient place. The bin has a maximum limit and doesn't have scrap overhanging or left around it.**
Clinker Bin	**A steel bin with a lid serves the purpose well. Clinker can be used as hardcore or disposed of at the tip. Cinder paths were quite sort after by rich Victorian women.**	**Clinker can be a slip hazard.**

Fly Press	**Very useful in a forge, It's an older metalworking tool that can perform on hot or cold work. If the tooling is up to scratch this tool can save allot of time in batch production.**	**Fly presses don't need much maintenance. Keep the shaft well lubricated. The weight arms need to be left in a position where they won't move.**
Gas Torch	**Sometimes called a gas axe used for cutting, bending and welding operations. The torch is connected to oxygen and a gas such as propane or acetylene, you can use the regulators to get the desired amount of pressure for the flame.**	**Bottles need to be leak tested and shut of completely over night. Acetylene needs thought out storage.**

Tool Maintenance For Your Workshop

Organisation name:

Tools	Maintenance requirement?	How often to make checks?	Do you need to do anything else to manage this?	Action by when?	Done
Hammers	Dressing, keep the faces polished and smooth. Soak in linseed oil once in awhile to maintain the shaft quality.	Have a butchers hook when using the hammer.	Store in a dry place		
Punches	Dressing, grind off mushrooming. Keep cutting tools sharpened to the required edge. Hot punches need to be straight and true. Hardening and tempering if required.	Constantly, keep an eye on the condition of these tools and sort them out straight away if there's a problem.	Make it simple by having a grinder easily accessible.		
Tongs	Look after them by re setting straitening them if they bend.	If they don't hold the work sort them out.	Make them well and out of a suitable material		

Tools	**Maintenance requirement?**	**How often to make checks?**	**Do you need to do anything else to manage this?**	**Action by when?**	**Done**
Donkey saw	**Annual PAT test. Check coolant. Check blade. Visual check ,Oil moving parts, remove swarf and off cuts.**	**Before use and when it becomes slow to cut.**	**Have new blades and coolant in stock.**		
Lathe	**Annual PAT test. visual check, Oil moving parts, Keep it tidy remove swarf**	**Before every use.**			
'Blacker C' power hammer	**Annual PAT test, visual check, oil moving parts, Keep it tidy**	**Before every use. Oil Once a day.**			
Forge	**Annual PAT test. Sweep the hood, Clean out the clinkers. Fill the front and back boshes.**	**When every in use.**	**Keep a bucket handy.**		

Tools	**Maintenance requirement?**	**How often to make checks?**	**Do you need to do anything else to manage this?**	**Action by when?**	**Done**
Anvil	**Visual check**				
Leg vice	**Grease or oil, Visual check, makes sure it's good and sturdy.**				
Hacksaw	**Change Blades**	**When it's not cutting easily**	**Have blades in stock**		
guillotine	**Oiled and sharp.**	**When it's not cutting easily.**			

Tools	**Maintenance requirement?**	**How often to make checks?**	**Do you need to do anything else to manage this?**	**Action by when?**	**Done**

Tools	**Maintenance requirement?**	**How often to make checks?**	**Do you need to do anything else to manage this?**	**Action by when?**	**Done**

Tools	**Maintenance requirement?**	**How often to make checks?**	**Do you need to do anything else to manage this?**	**Action by when?**	**Done**

Health and safety policy

This is the statement of general policy and arrangements for:	**Name of organisation**
Overall and final responsibility for health and safety is that of:	**Name of employer**
Day-to-day responsibility for ensuring this policy is put into practice is delegated to:	

Statement of general policy	**Responsibility of** ***(Name / Title)***	**Action / Arrangements** ***(Customise to meet your own situation)***
To prevent accidents and cases of work-related ill health and provide adequate control of health and safety risks arising from work activities		**Identifying the hazards in my Forge and implementing the appropriate controls.**

To provide adequate training to ensure employees are competent to do their work		**N/A for Self-Employed**
To engage and consult with employees on day-to-day health and safety conditions and provide advice and supervision on occupational health		**N/A for Self-Employed**
To implement emergency procedures - evacuation in case of fire or other significant incident. You can find help with your fire risk assessment at:		**Identifying the hazards and making a fire risk assessment.**
To maintain safe and healthy working conditions, provide and maintain plant, equipment and machinery, and ensure safe storage / use of substances		**Being sure to have tidy workstations and maintaining equipment to a high standard. COSHH Risk assessment.**

Health and safety law poster is displayed:					
First-aid box and accident book are located: **Accidents and ill health at work reported under RIDDOR: (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations)**					
Signed: (Employer)		**Date:**			
Subject to review, monitoring and revision by:		**Every:**	**Month**		

Risk assessment

All employers must conduct a risk assessment. Employers with five or more employees have to record the significant findings of their risk assessment.

Organisation name:

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
Slips and trips	Staff and visitors may be injured if	We carry out general good housekeeping.		Me		

What are the hazards?	**Who might be harmed and how?**	**What are you already doing?**	**Do you need to do anything else to manage this risk?**	**Action by whom?**	**Action by when?**	**Done**
	they trip over objects or slip on spillages	**All areas are well lit. There are no trailing leads or cables. Staffs keeps work areas clear, deliveries stored immediately, forge is swept**				

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
		each evening.				
Storage at height	Staff and visitors may be injured if an object were to fall from the rack	Being sure to place objects securely on the rack. There are no loose or over hanging items.	Additional safety use of bungee cords to secure objects to the shelf.	Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
Extraction	Staff could be electrocuted	PPE. All electrical equipment is PAT tested once a year. Visual checks before use.		Me		
Donkey saw	Staff and Visitors may be	PPE. PAT test. Visual check. Cutting fluid is	Safety stops to be installed.	Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
	injured by, sharp blades, spillages and moving parts.	toped up. Moving parts have had the correct maintenance. Appropriate knowledge of the tool.				
Lathe	Staff and Visitors	PPE. PAT test. Visual check.	Safety stop to be	Me		

What are the hazards?	**Who might be harmed and how?**	**What are you already doing?**	**Do you need to do anything else to manage this risk?**	**Action by whom?**	**Action by when?**	**Done**
	may be injured by moving parts, electrical default, swarf and breakages.	**Moving parts have had the correct maintenance. Swarf is removed and drill bits and tooling put away after every use. The key is never left in the**	**installed**			

What are the hazards?	**Who might be harmed and how?**	**What are you already doing?**	**Do you need to do anything else to manage this risk?**	**Action by whom?**	**Action by when?**	**Done**
		chuck. Appropriate knowledge of the tool.				
'Blacker' power hammer	**Staff and visitors may be injured by moving parts and hot**	**PPE. PAT test. Visual check. Moving parts have the correct maintenance.**	**A cage can be installed to block off moving parts.**	**Me**		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
	metal.	No obstructions and good housekeeping. Appropriate knowledge of the tool.				
Forge	Staff and visitors may be injured	PPE. PAT test. Visual check. Blower is		Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
	by fire. Hot metal, hot coke, sparks, boiling water, hot ash.	caged off. Good understanding of how to work the forge. Boshes are always toped up. Workstation kept tidy.				

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
Anvil	Staff and visitors could injure themselves by walking into the anvil or touching it when hot.	It is in a clear space and mounted on a very solid base.		Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
Leg vice	Staff and visitors could be harmed by walking into the vice touching when hot or getting trapped in the jaws.	The vice is solidly mounted and in a clear position. I keep the handle in line with the post when not in use. HOT can be written on the jaws if		Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
		necessary.				
Tool rack	Staff and visitors could be injured if not used sensibly. Sharp tools heavy tools	PPE. The rack is kept organized and is secure.		Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
	etc..					
Storage / Filing cabinet	Staff and visitors could be injured if they get there hand caught in	The storage is heavy and secure.		Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
	the draw					
Layout bench	Staff and visitors could be injured if they walk into the bench.	Keeping the bench tidy.		Me		

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when?	Done
guillotine	Staff and visitors could be injured by the blade and long handle.	The long handle is locked after use and a wooden wedge placed in the jaw.		Me		

Employers with five or more employees must have a written health and safety policy and risk assessment.

It is important you discuss your assessment and proposed actions with staff or their representatives.

You should review your risk assessment if you think it might no longer be valid, eg following an accident in the workplace, or if there are any significant changes to the hazards in your workplace, such as new equipment or work activities.

For further information and to view our example risk assessments go to http://www.hse.gov.uk/risk/casestudies/

Combined risk assessment and policy template published by the Health and Safety Executive 11/11

The Forge Fire

The three fundamental rules of forging are, the smith must be able to hold it, heat it and hit it. If you can do all three your laughing! Fire management is important because without the correct heat you can't work effectively or efficiently. Fire requires the presence of all three of these elements, fuel, heat - the temperature at which fuels ignite (the flash point) and oxygen. There are three states of a forge fire: reducing, neutral and oxidizing. The reducing fire is built like a mole hill to the required size; it's formed this way to reflect the heat inwards. All the oxygen from the blast is consumed making it a hot and efficient fire. An oxidizing fire starts to hollow out and clinker up, it's impossible to weld on and hard to get a good heat. A neutral fire consumes less oxygen than a reducing fire and scale will form.

Diagram of a forge hearth

Evaluation of Fuels

Overview

A fundamental component to the smithy is fuel. There are various types that can be used including, coke, coal, charcoal and gas. Whatever the chosen fuel, ultimately the smith must be able to reach fire welding temperature.

The first fuel to be used by primitive man was discovery of charcoal. Charcoal is made by heating wood or other organic material with the absence of oxygen, what's left is effectively a form of pure carbon. It could be used on the forges and furnaces reaching a high enough temperature to smelt iron. For a long time Forest kilns were used to produce large amounts of charcoal for the Iron industries.

When coal was used for smelting the sulphur content caused problems that made the Iron 'cold short' (brittle at a low temperature). At the time when the Industrial Revolution was just around the corner there was increasing demand for more fuel and charcoal making was having devastating effects on the woodlands.

In 1709 Abraham Darby was the first person to make cast iron using a coke fired blast furnace at his foundry in Iron Bridge. His breakthrough would lead to coke becoming a replacement fuel for the iron industries. Producing coke involved a similar process two charcoaling wood. Coal would be mined from the ground and burnt in heaps, reducing the oils liquid and gases and driving of the sulphur the end product is coke, dark grey in colour with high carbon content with few impurities.

The Differences

***Charcoal* can be cost effective option for a smith if the resources are available. Hardwoods are preferable for forging and can be charcoaled in a large oil drum or forest kiln. The amount of charcoal you need depends on the forge you use. Most motor powered snail fans will blow the fuel out of the hearth or burn it very quickly on a low blast. Because is charcoal light its better**

suited to bellows or a hand cranked blower. When used efficiently it burns clean and produces hardly any clinker. Another advantage is the last resort readily available at petrol stations. Charcoal is a good fuel for fairs and market demonstrations, it doesn't weigh allot which can be a benefit in terms of transport and people can see that you produced your fuel in a sustainable way.

Bituminous Coal **is cheaper than coke and pound for pound takes less to fire the forge and produce ironwork than charcoal. A coal fire produces big flames that can spread quickly, it also produces soot and smoke and it radiates heat a great deal hotter than charcoal or coke. In the fire clusters of coke are formed and need breaking up, it will also form clinker that will need removing. The nature of the fuel needs consideration when using it on the forge. I worked in Italy using coal on a bottom blast forge. The fire was contained between two thick cast iron walls (as illustrated) and you had a tool for damping down the coal with a wet rag. The system worked very well for managing the size of the fire and controlling the heat. It also had quite a low hood and drop down walls to prevent the amount dirt getting out into the workshop.**

A disadvantage to coal can be the effort required in maintain and controlling the fire. Also don't use coal with a high level of sulphur present because the metal will become 'cold short'. The added dirt and soot can also be hazardous to your health and unwelcomed at shows with customers wearing clean clothes.

Coke **is already refined from coal; it produces less soot and has fewer impurities. Ideal for a standard side blast forge with an electric fan, fire welding temperatures are easily reached and the fire can be easily controlled. Different sized beans can be purchased, smaller ones designed for very delicate work. A disadvantage in the UK is the price of coke keeps increasing. It can also be said that the quality of coke varies, occasionally its awful stuff that produces loads of ash and clinker. On the whole it's the fuel of choice but cheaper alternatives need to be test if we are to replace this expensive habit.**

Gas **for heating metal has many advantages such as being quicker and cleaner to operate. It's much easier to control and doesn't give off dangerous smoke or fumes.**

Blacksmithing Metallurgy

The structure of Iron and its alloys is crystalline, held together by strong metallic bonds. The crystals can only be seen under a microscope, to the naked eye they are described as grains, effectively groups of crystals assembled together. Fine grains indicate a refined condition that is hardened and strong, the bond between large coarse grains is weaker. When heating steel slowly or by reaching a high temperature the crystals will expand becoming course, this is called grain growth, at a welding temperature 'giant grain growth' occurs and carbon leaches from the surface. The hotter the metal is worked the easier it will move. Forging breaks up the large grain structure refining and making them smaller, this improves the strength however If forging stops before cooling the grains will start to grow again. Above 1350^{0}C mild steel burns it can also burn at lower temperatures caused by an exothermic reaction where oxidisation is present. Any sort of burning destroys the grain structure.

Heating Steel (Iron/carbon phase diagram)

At room temperature mild steel has a normal grain structure; each grain consists of ferrite and pearlite atoms with few impurities.

Ferrite is practically **pure iron** (in plain carbon steels) existing below the lower transformation temperature. It is magnetic and has very slight, solid solubility for carbon.

Pearlite is a mechanical mixture of Ferrite and Cementite existing as alternate laminated layers.

Cementite or **Iron Carbride** is a compound of iron and carbon, Fe3C.

The more carbon in steel basically means its more Pearlite and less Ferrite.

Steel will heated up at a uniformed rate until it reaches the **Transformation Range.** In this range steels undergo internal atomic changes, which radically affect the properties of the material. Forging is made possible because at this point iron starts to develop a plastic state. The temperature pauses for a while then slowly rises to the Upper Transformation Temperature then continues to rise at its original rate.

723^0 is the lower transformation temperature LTT and the grain structure will start to change. The Pearlite changes to Austenite directly while the Ferrite transformation is gradual till Upper transformation temperature UTT is reached.

Lower Transformation Temperature Below lower transformation temperature structure ordinarily consists of FERRITE and PEARLITE. On heating through LTT these constituents begin to dissolve in each other to form AUSTENITE, which is nonmagnetic. This dissolving action continues on heating through the TRANSFORMATION RANGE until the solid solution is complete at the upper transformation temperature.

Upper Transformation Temperature Above this temperature the structure consists wholly of **Austenite,** which coarsens with increasing time and temperature (grain growth). Upper transformation temperature is lowered as carbon increases to 0.8% (eutectoid point).

The critical temperature is found by using a magnet on the steel, as soon as a full transformation of grain structure becomes Austenite the magnet won't attract, this is the critical temp.

The more carbon in the steel the quicker it transforms into Austenite before the Eutectic point. After the Eutectic point Pearlite transforms straight to Austenite & Cementite at the lower transformation temperature and the more carbon the longer it takes to transform into Austenite

Controlling the grain structure through heat treatment

Re crystallisation If the grains become large, long or deformed reheat to the UTT, at approximately 450^{0}C small new grains stat to form, once the heat is maintained eventually the whole structure through dissolving will consist of small grains again.

Annealing Process of heating steels to slightly above UTT and holding for Austenite to form, then slowly cooling in order to produce a fine grain structure which is ductile, easily worked and softens the meterial. On cooling slowly the grains have longer to reassemble, the Austenite transforms back to ferrite and pearlite.

Normalising (normal grain size) Process of heating steels to slightly above UTT holding for Austenite to form then followed by cooling (in still air). On cooling, Austenite transforms back to ferrite and pearlite giving somewhat higher tensile strength and hardness and slightly less ductility than annealing.

Work hardening may be desired to add strength to the material its achieved cold working, care must be taken increasing the hardness.

Cold working compresses and stretches the grain structure reducing the malleability and ductility. Excessive working will cause brittleness and fractures.

Blue Brittle Range Occurs approximately from 150^{0}C to 350^{0}C. Excessive work should be avoided in this range since it is more brittle than above and below it.

Martensite is the hardest of the transformation products of Austenite and is formed only on rapid cooling from just above UTT to room temperature (for plain carbon steels). Cooling to this temperature must be sufficiently rapid to prevent Austenite from transforming to softer constituents at higher temperatures.

Eutectoid Steel contains approximately 0.8% carbon, structure is all pearlite.

Hardening and Tempering is an advantage of steel its made possible because of the carbon content. The smith can choose the appropriate steel and heat treatment for tasks such as tool making where certain qualities may be desired.

If the crystalline structure of iron was arranged as Body-centred cubic crystals imagine it transforming at the critical temperature into face-centred cubic crystal.

The rearrangement means the face centred cubic crystal has space in its centre because it's expanded. Carbon atoms are smaller than iron atoms. So when carbon is present, it moves to the centre of the iron crystals. Cooled slowly and the carbon moves back to its previous state outside the iron crystal. However if the metal is rapidly quenched the carbon gets trapped inside the iron crystal. It creates stresses and in turn produces a harder more brittle structure. If grain structure has been allowed to grow it will be frozen in its enlarged state.

Hardening in practice the appropriate quenching medium and temper colour are chosen for the task. (see: Quenching Mediums and Tempering Colours for Steel). Take a slow even heat approximately 30mm on the edge or face to be hardened. Bring it up to the critical temperature and quench half the heated length immediately, takes care to move the steel around in the water to avoid stress lines and bubbles forming on the surface. It's best to quench on a rising heat and as close to the critical temperature as possible because the larger the grain becomes the weaker the outcome. The quenched end should be cool enough to touch.

Tempering to remove the brittleness and set correct degree of hardness (toughness) for the steels intended use. Quickly put a shine on the quenched point using a grindstone, hold the steel vertically to allow the heat from behind the quench to draw upwards. Observe the temper colours as they move towards warming the cold tip. When the required colour reaches the end, quench the steel out fully, freezing the temper. Test the steel on some scrap if it's too soft or to hard re harden or re temper as necessary.

Tips Getting the right medium and speed for the quench are essential to getting the right hardness. Another important factor is the mass and volume of the object being hardened. If it's a big piece of metal it will cool slower when quenched reducing the hardness, however choosing steel alloyed with the desired physical property is maintained anyway. Harden ability is increased by the following alloys vanadium, molybdenum, tungsten, chromium, manganese and silicon. When tempering act quick getting the heat to draw up the polished surface, keep away from anything cold that will act as a heat sink. Be sure there's heat behind the quench but not too much that it sends the colours up rapidly or is quenched above the UTT.
Note incorrectly hardening or tempering can result it shattering!

Quenching Medium	Process
10% Brine Solution **Fast Quench**	**Take 1Litre of water add salt until it stops dissolving then add 9litres of fresh water to give you a 10% solution.**
Cold Water	**Used for most hardening operations. Move slightly up and down through the water to avoid bends and waterline cracks.**
Oil's	**A slow quench giving more tensile strength but less hardness.**
Air	**Normal state of hardness**

Case Hardening is handy for low carbon steels that receive minimal effect form hardening and tempering. It gives properties of a hard shell and soft core. When steel is heated above its critical temperature it can absorb a degree of carbon when in contact with a carbonaceous material. The carbon fuses to the surface forming a very hard skin, this is called carburizing. Case hardening compound 'hardenite' is available for this process. To use the steel is heated up to its UTT then put into a pot of the compound and left to soak until the LTT. Its then reheated to the UTT and quenched in water. You can mix it up your own casehardening compound.

Testing for hardness can be estimated by the smith by using a file or rasp, if the teeth slip, this indicates the surface is hard. Visual checks are also used, in the case of a hammer head the face should be smooth any indentations indicate it's soft.

Forging Heats

Incandescent heat colour is dependent on the ambient light conditions. Bright or direct sunlight can cause confusion (and may result in burning the metal) so forging should be carried out in a semi

Room Temperature $18^{0}C$	Normalised material can be cold worked mainly for forming operations, also work harden material.
Warm Heat $200^{0}C$	For setting up springs without loosing the temper. Melting wax for finishing.
Black Heat $550^{0}C$	No heat colour visible but in darkness a faint red can be seen. Hammer finish smoothing out (planershing) and oil blacking.
Dull Red $700^{0}C$ (Lowest temp for carbon steel)	Finishing once forging and refining is complete. the hammer is worked firmly over the section with overlapping blows compressing the grain structure
Cherry Red $780^{0}C$	Light forging operations can be carried out at this heat particularly bending. Steel becomes non-magnetic.
Bright Red $900^{0}C$	Scale will approx form and can be freely cleaned from the surface of the steel.
Orange $1000^{0}C$ (Highest temp for carbon steel)	Mild steel forges quite easily. Maximum heat for carbon steel, above this temperature the properties rapidly deteriorate.
Yellow $1150^{0}C$ **Bright Yellow $1250^{0}C$**	All forging operations should be carried out at this heat or above. Drawing down, upsetting, cutting and punching.
White Welding Range **$1300^{0}C$ - $1375^{0}C$**	Light welding heat on mild steel looks slippery and wet on the surface and emits tiny sparks. A Full welding heat is a brilliant incandescent white with sparks and dripping molten metal.
Burning Range $1450^{0}C$ +	Mild steel will burn at this heat emitting a lot of larger sparks and destroying the structure. Wrought Iron welds at this heat.

Properties of Iron & Steel

Brittleness - is the property of breaking without much permanent distortion. It may be due to brittleness of the grain boundaries or the crystals themselves. Also associated with 'red and cold shortness'.

Ductility - a metal is ductile when it can be drawn out in tension without breaking. A ductile metal must be both strong and plastic.

Elasticity - the elasticity of a metal is its power of returning to its original shape after deformation. The elastic limit of a metal is the force, which it can take before permanent distortion takes place.

Hardness - the hardness of a metal is its agility to withstand scratching, wear and abrasion, indentation by harder bodies, marking by file etc.

The Brinell hardness of a metal is found by pressing a hard ball onto the surface of the metal. The hardness number is found by dividing the load on the ball by the surface area of the impression.

Malleability - this is the property of permanently extending in all directions without rupture by pressing, hammering, rolling etc. it requires that the metal shall be plastic but not so dependent on strength, e.g., lead plasticity similar to malleability involves permanent distortion without rupture. It is the complete opposite to elasticity. Plasticity is necessary for forging, and metals may be rendered plastic by heating them.

Strength - the strength of a metal is its ability to resist the application of a force without rupture. In service a metal may have to resist tensile. Compressive and shear forces. The strength of a metal is found by loading it in a testing machine. The ultimate strength is the load necessary to fracture 1 sq. inch of cross section of the material. The tenacity is the ultimate strength in tension. Ultimate strength and tenacity are always expressed in pounds or tons per square inch or NEWTONS for S.I. Units.

Toughness - is the amount of energy a material can absorb before fracture. A test of toughness of a material is to nick it, place in a vice and hammer it until it bends or breaks.

Tempering Colours for Steel

Colours emerge when heating polished steel; they are an affect of oxidisation, as the temperature increases the colours will deepen. In terms of heat treatment the colours are used as a measure of temperature. Tempering steel reduces the hardness to achieve the desired quality; this will depend on the alloys, carbon content and also the speed that it is quenched.

Oxide colour	Application
Yellow **210°C**	Dies, drills, lathe tools.
Light Straw **227°C 440°F**	Cutting edges of knives, planning tools, Wood Chisels and Reamers. Small Case Hardened parts.
Straw **238°C 460°F**	Carbon steel milling cutters, large cutting or turning tools. Slotting tools and small punches or dies.
Dark Straw **249°C 480°F**	Drills, small taps, profile cutters, screwing dies and hammers.
Orange/Brown **260°C 500°F**	Press dies, shears and woodcutting tools, punches, rivet snaps.
Light Purple **274°C 525°F**	Chisels, large punches, hardies, Axes, pressing dies and cutlery.
Purple **282°C 540°F**	Saws, screw drivers, drifts, large dies and heavy chisels.
Blue **293°C 560°F**	Springs or portions of tools to be locally tempered to give maximum resilience. Cold chisels.

Metals used in the forge

The word Blacksmithing came from the process of smiting black metal. This was true in the making of decorative wrought ironwork which was a black material forged by hand. In the golden age decorative wrought iron was alive in the 18th century. Today the term can be used by fabricators who use it as an advertising tool.

Wrought Iron was made in a reverberatory furnace designed to cause a reaction that de-carburizes and removed the impurities from pig iron. The wrought Iron would then be rolled to size and graded. The product was known as 'puddle bars' and came in increasing quality merchant bars, 'best best' and then ultimately 'triple best'. The Wrought Ironworks is the last place in the UK were you can buy recycled wrought iron, its mainly used in restoration.

Mild steel is the most common material used by blacksmiths today. Its has a carbon content of no more than 0.25% it also contains manganese, sulphur, phosphorous and silicon in minute amounts. Its widely available in a range of shapes and sizes and is relatively cheap. Also available as 'bright' basically mild steel that has been pickled then cold rolled to give a crisp bright work hardened finish. Mild steel can be worked cold or at low temperatures, it can be fire welded and is quite forgiving. Although in appearance similar to wrought iron it's quite different to work and is generally regarded better suited to forging.

Blacksmiths will occasionally used Non ferrous materials such as copper, brass and bronze. All three are forgeable and can give additional qualities to the work. There can be problems with contamination and research is necessary before joining different metals together.

Plain carbon steel is a term given to steels harder than mild without any other elements such as chromium, tungsten, vanadium and molybdenum that are used in specialist steels.

Medium carbon steel is sometimes referred to as tool steel its ideal for hardening and tempering most tools used by blacksmiths. It has a carbon content of between 0.25 and 0.60% . The forging range is narrower than mild steel 700'c – 1150'c, any hotter and the qualities deteriorate. It should always be normalised after forging.

High carbon steels are used for making taps and dies, blades for planning and drills that sort of thing. Very hard with toughness but brittle when neglected. Its carbon content is between 0.60 to 1.5%. The higher the carbon content the narrow the band of forging temperature.

Stainless steel is popular for high quality exterior work. Its alloys chromium and nickel give good corrosion resistance. When finishing its usually pickled or electro polished, this restores the stainless properties, if un treated it become susceptible to corrosion. Stainless steel is often non magnetic the forgeable grades are 304 and 316. It’s hard to forge and has a short working time.

Alloy steels are for specialist requirements in mechanical and civil engineering, some are forgeable others are not. The elements used are chromium, tungsten, vanadium, molybdenum and manganese.

Production Faults

Production Fault	**Cause of the fault**	**How to repair the fault**	**Preventing the fault**
Waterline Cracks	This is caused by oxygen bubbles building up on the surface of a quenched tool. Occurs mainly because of shrinkage or spot heating.	The crack is a weakness to the material and cannot be passed for anything structural or where it's a risk.	Quenching in running or slow moving water.
Mushrooming	Mushrooming Is caused by work hardening the striking end of a	Mushrooming should be cut off or ground back.	Constant maintenance can be prevented by using softer tools two

	tool through use.		strike with.
Galling	Caused by folding	Grinding or filing can remove galling depending on the depth of the fold.	'Toothpaste' method of forging, When drawing out push the inner core out.
Burns	Burning is an affect of oxidization, It will occur when there is an excess of unconsumed oxygen, i.e. a low oxidising fire or heating to melting point in a forge where oxygen is present etc.	The carbon is destroyed by burning and the fault can run very deep. Ultimately the material should be scraped unless it is possible to save minor burns by rasping and re-forging.	Work on fire management .
Skin creep	Skin creep is where material	Depending on the degree of fault, it might be possible to	Use considered blows with the hammer and

	folds over and the layer is trapped causing a weakness.	open it back out or fire weld it in.	keep your eye on the metal.
Draw filing	Using a rasp on hot metal leaves teeth marks on the surface, If designed as a punch or a drift the texture will cause drag.	Remove the teeth marks by forging or filing.	
Structural Fracture	Or internal cracking can be the cause of working material too cold. excessive compressing and stretching the grain causes	The crack is a weakness to the material and cannot be passed for anything structural or where it's a risk.	Avoid forging in the blue brittle range.

	brittleness and fractures.		
Oxygen Crack	Hard thin material can shatter like a mosaic	Mostly un repairable.	Keep the heat in there and don't hit it cold.

Identification of metals

There are a number of methods used to identify metals. Simple examination of its weight, colour, surface finish and weather its magnetic or not can tell us allot. Another useful method is the spark test. By grinding the metal we can gain an approximation of the carbon content, we can also find out the general type of alloy steel were dealing with. This takes experience and time but to help its a good idea to make a spark tester. Simply gather metals that you already know what they are then use them to compare the material you're trying to identify.

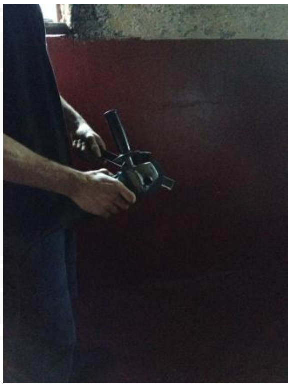
This test was carried out under the same lighting conditions and with the same amount of pressure applied from an angle grinder. For a more accurate test use a bench grinder as this will increase the control.

Mild Steel : A long train of bright orange, yellow and white sparks that burst and feather at the ends.

EN9 (medium carbon steel : Medium length streaks the same colours as MS with bursts and feather at the ends.

Wrought Iron : Short train of straight orange sparks that burst with no feathers.

Stainless steel : Very short straight lined orange spark.



H13 (tool steel) : Shorter length sparks than EN9 Same colours with bursts and little feathering.

Aluminium, copper and brass have no sparks and are advised not to be ground.

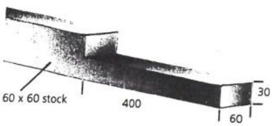
Stock estimation

Calculations for forging stock section to a specified size.

Terry Clark

I was given this information by Will Maguire, a young Australian smith. It is a very simple method of calculating the length of stock of one cross section needed to forge a particular length of a smaller cross section. I have explained this to several smiths who found it easy to remember. There are many other ways of calculating, but this works for me.

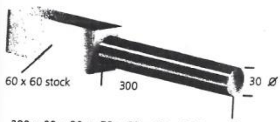
Get a calculator and have a go.



400 x 60 x 30 ÷ 60 ÷ 60 = 200mm of stock needed

Calculations for forging a size required out of a stock item. Using this format makes it straightforward to work out how much material you need.

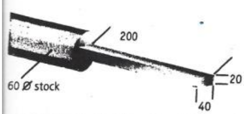
You multiply the length x width x thickness, then divide it by the stock size width & thickness, as shown in the opposite diagram.



300 x 30 x 30 x .78 ÷ 60 ÷ 60 = 58.5mm of stock needed

In this diagram, we are forging round out of square. You need to treat the round initially in the calculations as a square. You multiply the length x width x thickness, eg. it would be 300 x 30 x 30 then use .78 which will convert the square to round. Then the calculations will be 300 x 30 x 30 x .78

Then divide by the stock size, in this case ÷ 60 ÷ 60, as shown in the opposite diagram.



200 x 40 x 20 ÷ 60 ÷ 60 ÷ .78 = 56.98mm of stock needed

In this diagram the stock size is round, so you are using the .78 on the divide side, e.g. the forged area is calculated first, as in 200 x 40 x 20 then again treat the round as square, using the .78 to convert it to round.

If you find this of interest, I have more information on tapers and cones.

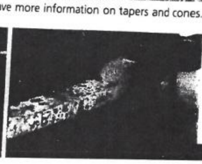
Why .78 ?

Because the area of a circle (say 20mm round) is .78 of the area of a 20 x 20 square bar.

Formula for calculating volumes of forgings:

volume of forging (x .78 if round)

end area of stock (x .78 if round)



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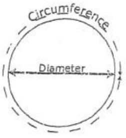
UNWELDED EYES / RINGS

NAME

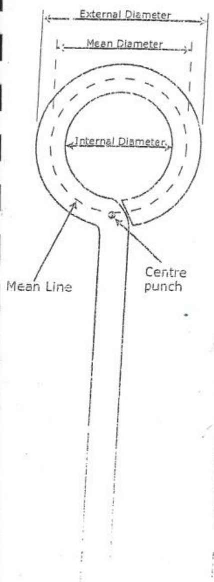
When making an unwelded eye or ring, you must first calculate the amount of stock material needed to produce it.

When bending:

- The material on the inside will shorten due to upsetting.
- The material on the outside will lengthen due to stretching.
- The length of material in the centre (the mean line) will be unchanged and is the true length needed



- The **diameter** of a circle is the length of a straight line through the centre of the circle.
- The **circumference** of a circle is the length all the way around it.
- The length of material needed to produce the ring or eye is the circumference - **along the mean line.**
- **We have to know the mean diameter to calculate the mean circumference.**



You can find the mean diameter by adding on half the thickness of the stock material on each side.
This is the same as adding the internal diameter to one thickness of the stock material. **Look at the diagram opposite.**

- To find any circumference, use the formula $\pi \times D$

  $\pi = 3.142$ and D = Diameter

Multiply the mean diameter by π, (3.142) to get the mean circumference.

EXAMPLE:

An eye with an internal diameter of 30mm made from 10mm round.

Internal diameter	Stock thickness	Mean diameter	Length needed (Mean diameter X 3.142)
30mm	10mm	40mm	126mm

Do this calculation for eyes made from 8mm round bar.

Internal diameter	Stock thickness	Mean diameter	Length needed (Mean diameter X 3.142)
[illegible]			
[illegible]			
[illegible]			

Metric Imperial Conversion Chart

Into Metric

If you know	Multiply by	To Get
Length		
inches	2.54	centimeters
foot	30	centimeters
yards	0.91	meters
miles	1.6	kilometers
Area		
sq. inches	6.5	sq. centimeters
sq. feet	0.09	sq. meters
sq. yards	0.8	sq. meters
sq. miles	2.6	sq. kilometers
Mass (Weight)		
ounces	28	grams
pounds	0.45	kilograms
short ton	0.9	metric ton

Into Imperial

If you know	Multiply by	To Get
Length		
Millimetres	0.04	inches
centimeters	0.4	inches
meters	3.3	feet
kilometers	0.62	miles
Mass (weight)		
grams	0.035	ounces
kilograms	2.2	pounds
metric tons	1.1	short tons

Estimate Price List of Steel and Coke

Monckton 18mm x 10mm coke beans.

1 Bag 25KG £10.50 (inc vat) Collect

20 Bags ½ Tonne £197.00 (inc vat) Collect

40 Bags 1Tonne £410.55 (inc vat) Collect

A forge will burn on estimate £1.60 worth of coke an hour.

ROUND/SQUARE/REINFORCING BAR. CHANNEL

ROUND	P/M		SQUARE	P/M
6	.22		6	.28
8	.40		8	.50
10	.62		10	.79
12	.89		12	1.13
16	1.58		16	2.01
20	2.47		20	3.14
22	2.98		22	3.80
25	3.85		25	4.91
30	5.55		30	7.07
32	6.31		35	9.62
35	7.55		40	2.60
40	9.86		45	5.90
45	12.5		50	9.60
50	15.4			
REINFORCING			**CHANNEL**	
10	.90		50X25	4.46
12	1.00		76X38	6.70
16	1.80		100X50	10.20
20	2.70		125X65	14.80
			150X75	17.90
CHS			150X90	23.90
21.3 X 3.2	1.43		180X75	20.30
26.9 X 2.5	1.67		180X90	26.10
26.9 X 3.2	1.87		200X75	23.40
33.7 X 2.6	1.99		200X90	29.70
33.7 X 3	2.27		230X75	25.70
42.4 X 2	2.15		230X90	32.20
42.4 X 2.5	2.55			
42.4 X 3	2.91			
48.3 X 2.5	2.75			
48.3 X 3	3.35			
60.3 X 3	4.24			
60.3 X 4	5.55			
76.1 X 3	5.41			
76.1 X 4	7.11			
88.9 X 3.2	6.76			
88.9 X 4	8.38			

Flats

	price/metre		price/metre
10x3	.24	75x10	5.89
13x3	.31	75x12	7.07
13x5	.47	80x6	3.77
13x6	.61	80x8	5.02
16x3	.38	80x10	6.28
16x5	.63	80x12	7.54
16x6	.75	90x6	4.24
20x3	.47	90x8	5.65
20x5	.78	90x10	7.07
20x6	.94	90x12	8.48
25x3	.59	100x5	3.93
25x5	.98	100x6	4.71
25x6	1.18	100x8	6.28
25x8	1.57	100x10	7.85
25x10	1.96	100x12	9.42
30x3	.71	120x6	5.65
30x5	1.18	120x8	7.54
30x6	1.41	120x10	9.42
30x8	1.88	120x12	11.30
30x10	2.36	120x15	14.10
40x3	.94	130x6	6.12
40x5	1.57	130x8	8.16
40x6	1.88	130x10	10.20
40x8	2.51	130x12	12.20
40x10	3.14	150x6	7.10
40x12	3.77	150x8	9.42
50x3	1.18	150x10	11.80
50x6	2.36	150x12	14.10
50x8	3.14	150x15	17.70
50x10	3.93	160x20	25.10
50x12	4.71	180x12	16.96
60x6	2.83	180x15	21.20
60x8	3.77	180x20	28.26
60x10	4.71	200x6	9.42
60x12	5.65	200x8	12.56
65x6	3.06	200x10	15.70
65x8	4.08	200x12	18.84
65x10	5.10	200x15	23.55
65x12	6.12	200x20	31.40
70x6	3.30	250x10	19.63
70x8	4.40	250x12	23.55
70x10	5.50	300x6	14.13
70x12	6.59	300x8	18.84
75x6	3.53	300x10	23.55
75x8	4.71	300x12	28.26

Site Work

Here is a list of considerations to make before you go on site.

- **Be aware of health and safety.**
- **You might need to arrange parking.**
- **Keep everything locked and beware of thieves.**
- **Check for power, check for lighting.**
- **Do you need site screens for welding?**
- **Know who you're talking to, deal with the contractor.**
- **CE markings.**
- **Structural regulations.**
- **Transport and Packaging (is the work going to be damaged?)**
- **Do you need to hire Lifting, crane, scissor lift?**
- **Do you need Straps, sling and hooks, wooden wedges, trolley jack?**
- **Site box – Fill with a check list of everything you need, cleaning kit for once the work is finished. Dust sheets and hardboard.**
- **2x1 plywood for frame building – gate measuring.**
- **Do you need to hire a stone mason or carpenter?**
- **Dose the site have security overnight?**
- **Are there any environmental issues?**
- **How do you dispose of waste, is it toxic?**
- **Be aware of what you drill or cut, are there any hidden cables or pipes.**
- **Working at a height or depth.**
- **Dose the weather effect what you're doing, such as leading in? Let the customer know.**
- **PPE.**
- **Snagging.**

Working drawings for a customer shouldn't be considered for anything less than a £500 job. You should include a charge for your drawing and time.

When invoicing a customer you should write the following statement at the bottom. – All my work remains the property of MR ….. until the full payment is made, failure of payment within __ days will result in the retrieval of my goods.

For gallery or shop work write a contract. State your terms and conditions which can vary. All work remains the property of the artist until payment is received in full. Any damaged work is the liability of the gallery. All work must be packaged to the best of the gallery's ability. When sending work attach a price list and contract, be sure to confirm the agreement of the terms and conditions.

On invoice you can add your terms of copyright. If you sell the work and feel you still want ownership over the design, state that you keep the physical copyright. In most cases you can state the physical copyright is released when sold.

On your contract you should also add in snagging, which is a sort of warranty. It states the period of time you're happy to return if something goes wrong inclusive to the payment. You can also offer a maintenance service every 5years or so.

When dealing with a customer or contractor have everything in writing, if you have to take notes or you're communicating over the phone, re write the discussions up in full. With your information then consult the customer in person – it is my understanding that 'as follows' is agreed and sign. Keep all paperwork.

If your uncertain about potential risks such as drilling out metal from stone work, consult the contractor that you can't guarantee the removal will be successful. Have this in righting so if it does go pear shaped your back is covered. When working on old

buildings that may not be square and level be certain that going with what looks right is right and ok with the contractor.

Pricing your work

Estimate the length of time you will need to make the item.

This can be worked out per heat, assembly and finish.

Hourly rate based on your overheads - £30.00 average

Additional costs

- **Fuel and Materials**
- **Possible travel contribution**
- **Charge for hidden costs**
- **Time on site**
- **Consumable fixings**
- **Finishes**
- **Posting work**

Then add on 30%