Introduction to Bladesmithing

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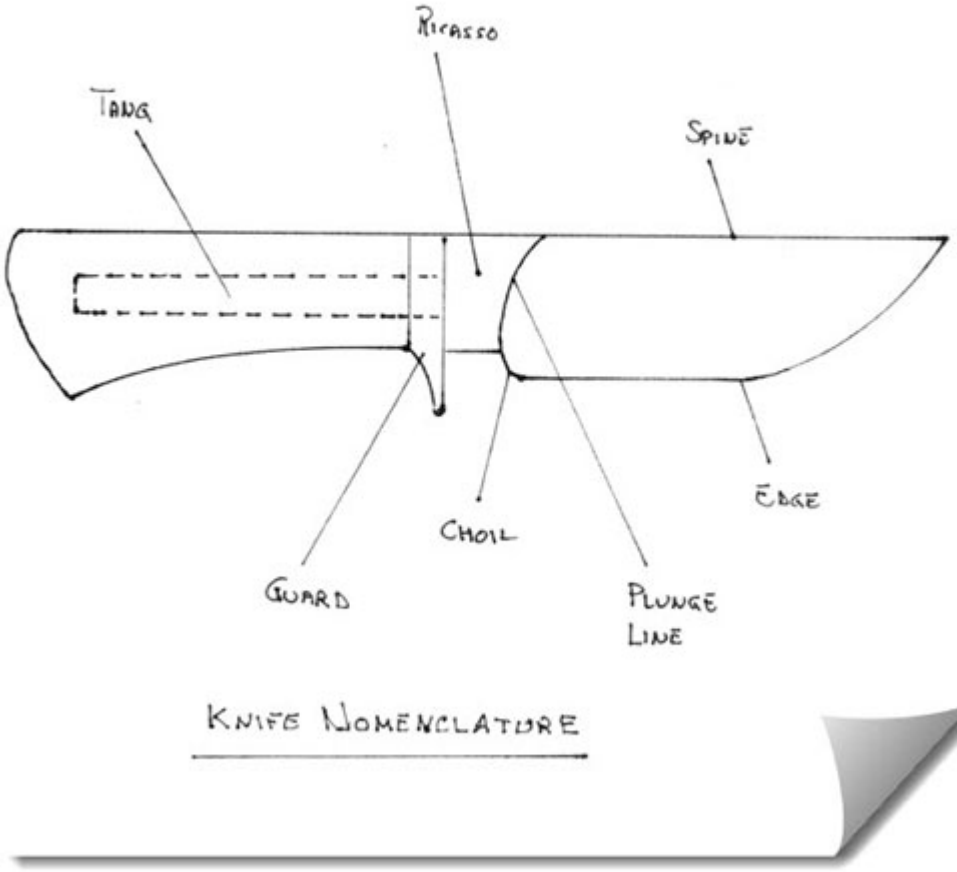
INTRODUCTION

This document was developed to provide a set of basic guidelines for those interested in building a forged knife with a hidden tang handle. Although there is no substitute for working experience, this document should offer insight into each of the major processes of bladesmithing. As with most endeavors, there is more than one approach that will yield excellent results. The methods outlined herein represent an approach tempered by experience and proven in the shop, but there are certainly other methods that work as well.

WEAR SAFETY GLASSES AT ALL TIMES WHEN WORKING IN YOUR SHOP. WEAR A RESPIRATOR WHENEVER USING A GRINDER, EVEN WHEN GRINDING FOR SHORT PERIODS. WHEN FORGING AND GRINDING, WEAR EAR PROTECTION.

The information contained within this document describes the following processes in detail:

- ❑ Forging the Blade
- ❑ Normalizing and Annealing
- ❑ Grinding the Blade
- ❑ Heat Treating
- ❑ Sharpening the Edge
- ❑ Testing the Blade
- ❑ Building the Guard and Handle



KNIFE NOMENCLATURE

FORGING THE BLADE

WEAR SAFETY GLASSES AND EAR PROTECTION WHILE FORGING

- Select appropriate steel. Limit your steel options to a few and learn their characteristics well. In my experience the best steels are 5160 for larger knives (bowies), 1084 for smaller knives (hunters) and 1084/15N20 combination for Damascus. 1084 is very versatile steel and can be used in almost every case when making knives. For swords, most bladesmiths use 1080, which water quenches and shows a hamon well. Purchase your steel in bar form from reputable bladesmith supply dealers to insure the quality and composition of the product. Most dealers will also provide information on steel analysis, hardening temperatures and tempering heats with resulting Rockwell hardness.

- The following method of forging will deliver excellent results and will satisfy most blade forging situations. The best way to forge is to hammer in one spot on the anvil and move the steel under the hammer to hit the desired spot on the blade. Lock the end of the steel bar into your hip with your free hand and move your hip slightly backward or forward to move the blade under the hammer.

- Grind off the points of both corners at the end of the steel bar that is to become the point of the blade. (This is helpful but not necessary. If you don't grind off the corners, when forging them down use high striking force – otherwise the end of the bar will curve into a 'U' shape.)

- Keep the steel at an appropriate temperature during forging operations – usually in the red to early orange range – ideally in the neighborhood of 1400 to 1800 degrees F. Try to start forging at the higher end of temperature and as you proceed keep dropping the temperature till you finish forging at the lower end (i.e. start in the orange range and end in the red range).

- During all forging operations, work both sides of the blade an even number of hammer blows.

- Avoid hammering where the ricasso is likely to be. This area will ideally have no hammer marks to be corrected during grinding. During forging of the blade, keep the ricasso area beyond the edge of the anvil to avoid any chance of the ricasso being distorted.

- Forge the point first by heating just the first couple of inches of the bar. Hold the bar vertically against the forward edge of the anvil with the bar slightly tilted up lengthwise and forge the tip of the bar hammering toward you to begin to establish the point. Work both edges of the bar to establish the point. Once the point is formed, place the bar flat on the anvil and draw out the distal taper from the tip to about one-third the length of the blade. (The distal taper is the taper seen when looking down the spine of the blade from back to tip).

- Establish the length of the blade by measuring back from the tip and hammering the blade edge on the edge of the anvil closest to you to draw it down to delineate the termination of the rear edge of the blade (this spot is called the choil).

- Forge the blade edge, working both sides of the blade an even number of blows. To draw down the blade edge and narrow it, start forging at the very edge of the blade through the entire length, on both sides, and as you make additional passes forge up toward the spine of the blade. While forging the edge, the blade is likely to curl up. As this occurs correct it – otherwise the curve will grow too large to correct easily.

- ❑ Refine the point of the blade to establish style – dropped point, clipped, etc.

- ❑ Throughout forging, check for twists and straightness – correct periodically during the forging process in order to keep distortions to a minimum. Distortions can be identified by laying the blade on a flat anvil. Do this for both sides of the edge and spine and correct any problems.

- ❑ Once the blade has been forged to shape, determine where the ricasso ends and the tang begins. Use a fuller to compress the tang behind the ricasso and to establish the width of the ricasso and the start of the tang.

- ❑ Heat the steel bar and use a cut off to cut the bar approximately two inches behind fuller marks (or use a chop saw). This steel will be forged out to make the tang.

- ❑ Forge the tang by drawing the tang back from the fuller mark. As the tang is being drawn out, taper the tang by reducing the size of the tang in both width and height. The tang should be at least three-quarters of the length of the handle, and should be dropped according to the style of knife.

- ❑ If necessary, use a flattening hammer in the ricasso area to flatten out the high spots created by the fullering tool when starting the tang. Be careful that the sides of the ricasso remain flat and parallel to each other.

- ❑ Perform a final inspection for distortions and make any straightening adjustments. Use light hammer blows in this process. This inspection can be enhanced by first profiling the blade edge and spine on the grinder, which will highlight any distortions.

- ❑ Other tips:

  - A wooden hammer is useful in taking out blade distortions during final inspection/straightening since it will not leave marks in the steel.

  - Mark the side of your anvil near the face with inches to help in measuring blade and tang size.

  - Hang a heavy weight on the horn of your anvil to greatly reduce the ringing that occurs when forging. This can also be accomplished by affixing a large magnet to the side of the anvil.

NORMALIZING AND ANNEALING

Once the blade is forged it must be normalized. This is the first of several heat-treating steps necessary during the construction of the blade. Much has been written about heat-treating blades – it is an interesting and somewhat complex subject. In this document, I describe the necessary heat-treating steps without getting into too much detail – however if they are followed they will produce a blade that performs well, is easily sharpened and holds an edge. More detailed information on heat-treating a blade is available from several sources – one I would recommend can be found at http://www.dfoggknives.com/hardening.htm

- ❑ Normalizing

  - Normalizing a blade after forging is necessary – it relieves stress and shrinks the steel grains to consistent size.

- This operation should be performed two to three times after forging is completed.

- Uniformly heat the forged blade to approximately 100 degrees above critical (non-magnetic) temperature (where you see no shadow in the heated blade) and allow to air cool. The best way to air cool is to use a rack to hold the blade vertical on its spine while it cools. Laying the blade flat on a surface is likely to allow one side to cool quicker than the other and may lead to warping.

- ❑ Annealing

  - Annealing further shrinks the grains of the steel and softens it, making the steel easier to grind and hand finish.

  - This operation is performed once, although some bladesmiths do not anneal at all – apparently without poor results.

  - Uniformly heat the forged blade to a dull red color.

  - Once heated, submerge the blade in a bucket of vermiculite, lime or ashes and allow it to slowly cool to room temperature – six to twelve hours. I use a fifty-gallon metal barrel filled with vermiculite and place red hot pieces of scrap bar steel in the vermiculite just before I heat the blade. Once the blade is heated to proper temperature, I place it into the vermiculite as well, taking care that it is equal distant from and not too close to the hot scrap bars. This will hold the heat longer and allow the blade to cool as slowly as possible.

GRINDING THE BLADE

WEAR SAFETY GLASSES, EAR PROTECTION AND A RESPIRATOR DURING ALL GRINDING STEPS

- ❑ Remove the forging scale from the blade. This should be done with an angle grinder or on a grinding wheel with a used 36-grit belt. The intention is not to remove every bit of scale, but to clean most of it off so that the scale won't dull the fresh belt when you begin grinding the flats. (Some of the scale is extremely hard – 75 – 80 Rockwell). I do all grinding of forged blades with the flat platen grinder attachment. I begin grinding all blades except very small blades with a 36-grit belt. For very small blades I start with a 60-grit belt. For the following discussion, assume we are using 36-grit belt until a change in grit is called for. For the initial grinding, we continue with a used belt.

- ❑ NOTE: Grinding well is not easily learned – it has taken me years of grinding to reach a point where I am satisfied with my skills. Don Fogg taught me an approach that greatly improved my grinding ability. When holding the blade, lock your elbows into your waist and do not move your arms when grinding. Instead, bring your entire body forward to bring the blade to the belt, and shift your weight slightly from one foot to the other to move the blade lengthwise against the belt. Your hands are only used to influence the tilt of the blade into the belt – i.e. whether you grind the edge or higher on the blade. This approach will greatly improve your control of blade contact with the belt.

- ❑ Have a bucket of water nearby to dip the blade and cool it off as the blade temperature rises due to grinding.

- ❑ Profile the blade along both the edge and spine until very close to final dimensions.

- ❑ Profile the tang so that it tapers in both dimensions from ricasso to the end of the tang. If the tang is not perfectly aligned along the lines of the blade (a straight line from blade tip to end of tang with no bending of the tang to either side), now is the time to correct this. The rear of the ricasso will be perfected in later steps – at this point leave about a quarter of an inch excess ricasso length toward the rear. When grinding the sides of the tang, start at the ricasso and grind off enough of the side of the tang so that it is about one-thirty second of an inch below the side of the ricasso – then continue grinding to the end of tang, tapering from the ricasso to the end of tang. Once the tang is ground, it will not be touched again so be certain to get it right now.

- ❑ At this point, I change to a new belt. The ricasso must be cleaned up and flattened first. Hold the blade by the end of the tang point down against belt with contact being made in ricasso area – grind both sides of ricasso flat and parallel. You should constantly check during this process to insure that the ricasso is being ground with both sides parallel to each other on both vertical and horizontal planes. Remember that where you put pressure on the ricasso to force the opposite side into the belt is where more steel will be ground off. I place my thumb against the ricasso and push it into the belt – if I need to take a bit more off the spine side of the ricasso then I place my thumb closer to the spine edge of the ricasso.

- ❑ Grind the blade bevels

  - NOTE: it is important to constantly check that the shape and positioning of the plunge line on both sides of the ricasso are exact. Check the following throughout grinding and adjust appropriately: angle of the plunge line on the side of the blade, termination point and centering of plunge line at bottom of ricasso, termination point and shape of curve of plunge line at spine of blade.

  - NOTE: To get perfect plunge lines, some bladesmiths place a shoulder guide on the ricasso where they want the plunge line and then use a chain saw file to cut the plunge line between the end of the blade and the ricasso.

  - All grinding of the blade is done with the blade edge up, and proceeds from plunge line to tip.

  - In grinding the blade, the blade is held at the spine of the tip with one hand and by the tang with the other hand, with the thumb on the ricasso. The placement and pressure of the thumb on the ricasso, either the top or bottom of the ricasso, can be used to control which part of the blade (edge or spine) is more directly in contact with the grinding belt, and therefore having more material removed.

  - Hold the blade edge up with the grinding belt contacting the edge first. Establish the break point (plunge line) between the ricasso and blade, and grind in a continuous movement from ricasso to point.

  - Work the second side of blade as well, frequently changing sides so that the progress of the grind from edge to spine is made on both sides equally.

  - Work the grind progressing from edge to spine over several grinding passes.

  - Plan to leave the edge about one-eighth inch thick at conclusion of grinding.

  - To some degree, the shape of the plunge line and diameter of its curve at the spine is influenced by how much of the belt is extending over the edge of the flat platen. You'll need to experiment with this to understand the dynamics of belt overhang – but in most cases about one-eight inch will provide good results.

- Once the blade is ground to shape, change to the next higher grit belt to clean up the grind. From this point forward, higher grit belts are used primarily to subtly refine the face of the blade and remove the deeper grind marks of previous more course grits. Blade shaping is accomplished primarily with the lowest level grit only. I usually grind with the following grit sequence: 35, 60, 120, and 240. As you go to finer belts, reduce the speed of the belt. Higher speeds should be used for course grits only.

- Once you have cleaned up the blade sides through the grit sequence noted above, grind the spine and edge lightly to clean up the courser grit lines as well. Machine grinding is now complete.

- At this point, refine the blade by hand sanding with sandpaper and a hard sanding block. CONTINUE TO WEAR A RESPIRATOR DURING THE SANDING PROCESS. Start by sanding with the same grit of the last belt or one grit size lower. Initial sanding should be done lengthwise on the blade (since machine grinding is vertical). Continue alternating direction each time you change to a finer grit size – this will allow you to see if you have eliminated the courser scratches of the previous grit (which is necessary) before moving on to a finer grit. This process will use grits up to 400-grit. If the 400-grit sanding was done vertically, a final sanding with 400-grit should be done lengthwise. At this point all parts of the blade from tip through ricasso, spine and edge should be cleanly sanded to 400-grit with no lower level grit lines remaining, and the blade sides should be flat.

- The plunge line corner presents a challenge to sand cleanly. I usually use sandpaper backed with a Doctor's wooden tongue depressor (available at CVS). This must be done with the appropriate grit sandpaper each time you change grit size when sanding the sides of the blade.

- The area where the ricasso meets the tang needs to be squared off and the tang lowered no more than a sixteenth of an inch below the shoulder on each side of the ricasso so that the guard fits tightly against the back of the ricasso. I usually size the ricasso between one-half to three-quarters of an inch, depending on the size of the blade. Using a shoulder-filing fixture available at www.riversidemachine.net, finish the shoulders of the ricasso with files. A round file should be used on the narrow edges where the tang meets the ricasso and a square file on the broad side edges of the tang. Once completed, sand the ricasso lightly with 400-grit paper to clean off any burrs.

- If using a name stamp to mark the blade, stamp the name on the ricasso. Most bladesmiths strike the name on the left side ricasso. Before stamping, once again inspect that the ricasso is square and parallel – if it isn't the stamp will not make a uniform impression in the ricasso. If necessary, return to the grinder and correct the ricasso (at this point a major problem to correct since if one side of the ricasso is ground, it will probably either change the centering of the blade edge on the ricasso and/or change the shape of the plunge line where it meets the spine of the blade). An alternative is to block up the blade so that the ricasso face is parallel both vertically and horizontally to the face of the name stamp before you strike it. This will result in a uniform stamp impression, but still leave you with a poorly formed ricasso. Once the name is stamped, that face of the ricasso will have to be sanded with 400-grit again to remove the raised portion of the name impression.

HEAT-TREATING

WEAR SAFETY GLASSES DURING THIS PROCESS

- ❑ Prior to heat-treating, insure that all grind lines go in a tip-to-tang direction, including the edge and spine. It is not necessary to hand-sand the tang, which will be hidden inside handle.
- ❑ Heat-treating consists of several steps, normalize, harden the edge, temper and draw the spine. Within each of these major steps are several alternative approaches.
- ❑ NORMALIZE – to remove any stress built up in the metal during grinding it is safest to normalize the blade two to three times (as done after forging) before hardening.
- ❑ HARDEN THE EDGE– there are two approaches, edge quenching and full quenching. I prefer Chevron Quenching Oil as quenching medium.
  - Edge Quench
    - Set up the edge quenching trough. This is usually a container long enough to hold the blade and deep enough to place an adjustable platform within it. The container should be filled with enough quenching oil to cover the adjustable platform. Adjust the platform so that when blade is placed on platform, the blade edge will have about one-quarter to one-third of the height of the blade submerged under the quenching oil.
    - Heat the quenching oil to 120 to 160 degrees.
    - Heat the edge (bottom third) of the blade to ten to fifteen degrees above critical temperature with an acetylene torch. To do this properly, you must first heat the ricasso so that it doesn't act as a heat sink when heating the edge
    - Once the edge is at the proper temperature, immediately quench the edge of the blade by placing it tip down on the platform and quickly rocking it back so that the entire blade edge is quenched. with the edge submerged one-quarter to one-third of the blade height in the quenching oil.
    - Keep the blade in oil until blade temperature has dropped to at least 350 degrees.
  - Full Quench
    - The full quench usually uses a vertical quench tank (made from a metal pipe with the bottom welded to a plate to close it off and act as a base).
    - Heat the quenching oil to 120 to 160 degrees.
    - Using a torch or gas forge, heat entire blade to ten to fifteen degrees over critical temperature. If a gas forge, be careful not to overheat the blade.
    - When the entire blade has reached critical temperature, grasp with tongs and quench point first into the vertical quenching tank.

- Keep in oil until the blade temperature has dropped to at least 350 degrees.

– NOTES:

- Edge quenching may be more appropriate for larger knives since it will result in a more flexible and resilient blade (cutting edge is hard but spine is soft).

- In hardening a Damascus blade, use a full vertical quench otherwise the pattern colors will vary between the hard edge and softer spine.

- Check the hardness of the edge with a sharp file. If hardened properly, the file should slide over the edge without cutting in.

- Occasionally a blade may warp during hardening. Immediately after taking the blade out of the quenching oil, check the blade for straightness. If you have minor bending, you have about a five-minute window to attempt to straighten it. While the blade is still hot, with gloved hands force the blade back to straight.

❑ <u>TEMPER</u>

Tempering is done to remove brittleness from the blade. It is good practice to temper for two hours, two to three times, and to temper regardless of hardening approach. Tempering should be done as soon as possible after hardening (within one hour if possible) since the blade is susceptible to damage in the hardened state.

– This describes how to temper in a heat treatment oven (preferred due to accuracy of temperature). A kitchen oven can also be used but there is a risk that temperatures within the oven will vary outside of the acceptable range during the process. Tempering can also be accomplished with a torch but it is very difficult to gauge temperatures accurately.

– Heat Treatment Oven

- Set the oven to the proper temperature (each steel has a different tempering temperature which can usually be provided by the manufacturer, but generally in the range of 350 to 450 degrees) and preheat oven. Examples follow that will typically result in a Rockwell hardness of 58 to 60:

  - 5160: 375 – 400 degrees

  - 1084: 425 to 475 degrees

  - Damascus – set for the primary steel in the Damascus steel as above – usually 1084 steel

– Place the blade in the oven resting on its spine.

– Hold at tempering heat a minimum of two hours.

– At end of two hours remove the blade from the oven allow it to air cool.

– Repeat for total of two or three times.

- ❑ DRAW THE SPINE

  The purpose of drawing the spine is to soften the tang, ricasso and spine of the blade so that the blade will flex without breaking. As heat is applied in the following steps, be sure to apply it evenly to both sides otherwise warping may occur. Always direct the flame toward the tang of the blade, never toward the tip. Never bring the steel to red hot, as this can air-harden the steel and create a brittle spot. Dull, dull red might be seen once in a while, but it's a lot safer not to allow even this to occur.

  - Lightly sand the blade and tang to clean up the metal so that temperature (color) change during drawing is obvious.

  - Heat the tang and ricasso, moving the torch from the end of the tang into the ricasso so that the steel turns color, first purple and blue, then to gray. The gray color indicates that the proper drawing temperature has been reached, and you should be able to observe it working its way from the end of the tang to the ricasso as you apply heat.

  - In applying heat to the ricasso, be sure that the heat does not run to the blade edge, as it will reduce the edge hardness. If necessary, wet the edge of the blade with a wet rag to keep it cool.

  - Drawing the back of the blade will require that the hardness of the edge be protected from the heat. To accomplish this, the edge should be immersed in water for about one-quarter to one-half inch throughout the drawing process. (An angle iron drawing tank serves this purpose well. Make one out of a three foot section of two – three inch angle iron with caps welded over the ends to insure that it is watertight. Fill the trough with enough water to protect the blade edge from the drawing heat.)

  - With the edge submerged in water, heat and draw the back of the blade as indicated above for the tang. (You will probably have to rock the blade in the water trough to submerge the tip and insure that it retains hardness.)

  - Allow the blade to air dry and clean with fine grit sandpaper.

STRAIGHTEN THE BLADE

WEAR SAFETY GLASSES DURING THIS PROCESS

Occasionally the blade will warp or bend during heat-treating. If this has occurred, the application of heat and force will straighten the blade. Force alone will not remove the bend/warp, heat must be applied.

Put the blade in a vise with the bend outside the vise. If a sharp bend, put the bend close to the vise; if a long bend, but the bend further away from the vise. For larger bends, this process may have to be repeated several times, moving down the blade addressing different sections of the bend each time.

- ❑ Insure that water is available, both for quenching (a cup of water) and for protecting the edge from heat (a wet cloth).

- ❑ The blade must be clean so that you can see the heat move through the steel as it is applied.

- ❑ Heat along the spine where the bend has occurred. Bring heat to a gray color being careful that color does not run to the edge. Use the wet cloth to protect the edge if necessary.

- ❑ Apply heat to both sides of blade, but put a little more on the inside of bend.

- ❑ When heated to a gray color, force the blade straight (overcompensate a bit) by applying pressure and while holding blade in this position, quench with a cup of water along length of curve.

REGRIND AND FINISH BLADE

WEAR SAFETY GLASSES, EAR PROTECTION AND A RESPIRATOR DURING ALL GRINDING STEPS

At this point the edge is still one-eighth to three-sixteenth of an inch thick and there may be some warping in the blade edge due to the heat-treating process. As a result we must again grind the blade to refine and reduce the edge width prior to sharpening. This process will use the same belt sizes as the initial grind (but increasing grinding grits up to 400-grit) and is very similar to the grinding process described earlier except as follows:

- Reduce the belt speed at all stages of grinding

- Start grinding at one grit higher than the lowest grit initially used.

- Instead of ending grinding at 240-grit, add an additional grinding pass with a 400-grit belt.

- ❑ At this stage, grinding should be done with bare hands to sense if the blade begins to heat up. If it gets too hot there is risk that the edge will lose its hardness. As heat buildup is sensed, dip the blade in water to keep temperatures down.

- ❑ Grind the side of the blade keeping the edge straight and centered in comparison to the ricasso and reduce the edge down to about one thirty-second of an inch. Feather the edge into the side leaving the side straight from edge to spine.

- ❑ Once grinding is complete, the blade must be refined to higher levels of grit by hand sanding, as described earlier. Start again at 400-grit and proceed using the following grit sizes – 600, 1,000, and perhaps 2,500.

- ❑ For a satin finish, hand sand through grit size 1,000. On the final passes, sand in continuous strokes from plunge line to tip until there are no swirl marks. Wrap 600-grit over a thin steel edge and drag the edge in one continuous stroke from plunge line through tip of blade resulting in a satin finish. Do the ricasso area and spine of the blade using the same process.

- ❑ For a mirror finish, finish through grit size 2,500 and then polish with paste polish (Mothers Aluminum and Magnesium paste, Flitz paste, and/or diamond embedded paste wax).

SHARPEN THE EDGE

WEAR SAFETY GLASSES, EAR PROTECTION AND A RESPIRATOR DURING ALL GRINDING STEPS

- ❑ Note: Sharpening the edge at this point results in the handle and guard work being done with a sharp blade. Those processes can thus be very dangerous and will require your undivided attention to avoid injury.

- ❑ While sharpening the edge hold the corners at the bottom of the plunge line with your finger tips to protect them from being hit by the belt.

- ❑ In sharpening, use the slack portion of the belt – in a flat platen setup this would be the area of the belt before the top wheel immediately leading to the platen area.

- ❑ Use a 240 or 400-grit belt.

- ❑ With the edge facing you, with minimal pressure apply the edge of the blade to the belt close to the front wheel. As you do this, rock the edge slowly back and forth on the belt working your way from edge near ricasso to tip. When the tip is reached, rotate blade so that curved edge of tip remains flat against belt. In rocking the edge, only the edge and about a quarter of an inch of the blade contact the belt. Be sure to watch for heat buildup – avoid drawing the hardness from the edge by getting it too hot. Use a sharp belt and frequently dip the blade in water. Try performing this step without gloves to be able to more readily detect heat buildup. Alternate sides of the edge during this process so that the edge remains centered on the blade.

- ❑ Continue, progressing on the belt from near the front wheel up to center of slack area. This will provide a gentle curve in the blade from slightly above the edge and down to the edge.

- ❑ This should be continued until edge geometry is close to sharp.

- ❑ For the final pass, sweep the blade the full length until you get a small burr on the edge the full length of the blade. This requires only light pressure – the burr can be seen in direct light. If you can't get a burr, either the edge is too hard or you haven't yet gotten edge geometry fine enough in previous steps.

- ❑ Once the burr is present, change belts to a very high grit or synthetic belt and give the edge a final pass to remove the 400-grit lines.

- ❑ The final sharpening of the blade is done on a fine grit stone (a Norton fine grit India stone and/or a black ceramic stone).

  - Wet the stone with either WD-40 or Tap Magic – these fluids float the metal crystals off the stone and keep the grit open.

  - Using light pressure, with blade about 20 to 22 degrees against the stone, pass the blade against the stone to knock off the burr and sharpen.

  - As final step, lightly strop the blade on flat leather to give the edge a final finish.

TEST THE BLADE

WEAR SAFETY GLASSES WHILE TESTING THE BLADE

Test the blade to determine that it meets performance requirements. Install a temporary handle and guard on the blade. The journeyman test (cut hair, free-hanging one-inch hemp rope, two 2x4s, and cut hair again) should indicate the quality of the blade for heavier knives (hunters, bowies, etc.) For finer knives such as filet or butcher knives, try whittling the 2x4 in two, rather than chopping. Think about what the blade will be used for, ask what the worst treatment the blade will receive in the hands of the owner and adjust the test accordingly. Holding a piece of magazine paper vertically and slicing down with the blade is a good indicator of sharpness and will also make any small chips or dull spots in the blade obvious.

Edge geometry and tempering will determine the cutting characteristics of the blade. If the edge is too blunt, the blade won't bite well. If it's too thin, it will chip or roll when you chop with it. If you do get edge damage and the geometry's right, it may be that the blade isn't tempered correctly. If the blade edge chips, it may be too hard and if it rolls it may be too soft. Determine what issues exist through the testing process, determine the cause, and correct your grinding or heat-treating method.

Once the blade has been satisfactorily tested, wrap it in tape to cover the sharp edge during the following processes.

BUILD THE GUARD

- ❑ BEST INSTRUCTION on handles and guards is the book Handles and Guards by Joe Keeslar – available at American Bladesmith. A very worthwhile investment. Otherwise follow below:
- ❑ Select the guard material and cut a rectangular piece a bit oversized.
- ❑ Measure the tang width closest to the ricasso – this will be the size of the guard slot.
- ❑ Choose a drill bit just under the size of the width of the tang. Mark the guard material so that the slot is positioned appropriately. Use a punch to create a 'V' along the line you want to drill. This will keep the drill centered correctly when starting the holes. Drill holes the length of the slot just smaller than the size of the tang. Webbing between the holes will remain.
- ❑ File between holes with a round file to remove the remaining webbing (again undersized) or use jewelers saw to cut the webbing out.
- ❑ Slowly file the slot larger, checking frequently for tang fit. Slide the guard up the tang to check fit. Since the tang is tapered toward the end your fit will be tighter the closer to the ricasso you are. As you approach the ricasso end of the tang, check more frequently. The objective is to have the slot sized for a tight fit at the point when the guard is placed on the tang against the back of the ricasso. Upon final fit, the joint between the guard and ricasso should be almost invisible. Also, if fitted correctly, the face of the guard should be exactly perpendicular to the sides of the ricasso. If not, your filing of the top of the ricasso was probably not square. This is a common problem if the sides of the ricasso are not perfectly

parallel on both planes – the result is that the shoulder-filing guide will not fit perfectly flat against the ricasso and the filing of the ricasso shoulders will not be properly aligned.

- ❑ Once the slot is at the correct size, shape the profile of the guard by rounding the corners and shaping the finger stop extension with files or on the grinder. The sides of the guard can remain rough ground and a bit oversize until the handle is affixed.

- ❑ Polish the face of the guard to final polish.

- ❑ Sand the back of the guard smooth. The face and back of the guard should be perfectly parallel on all planes after this sanding.

- ❑ If the guard fit is tight enough, use JB Weld to fasten the guard to the tang/ricasso. Use a guard compression device available at www.riversidemachine.net to hold the guard tightly against the ricasso while the JB Weld hardens. After the guard is placed on the tang with JB Weld, allow the JB Weld to dry for one or two minutes then remove the excess JB Weld on the face of the tang with a pointed Popsicle stick and Q-tip dipped in acetone.

BUILD THE HANDLE

WEAR SAFETY GLASSES, EAR PROTECTION AND A RESPIRATOR DURING ALL GRINDING STEPS

- ❑ The following describes how to make a hidden tang handle. Handles for an average blade (4 – 6 inches) are usually four to four and one-half inches in length. For longer blades (9 – 11 inches) the handle is usually five to five and one-half inches. For a hidden tang handle, the tang should be at least three-quarters of the length of the handle. Measure the tang, and if necessary shorten it to meet the above recommendation.

- ❑ Select the handle material. Wood handle material is usually available through knife supply vendors and come in blocks one and one-half inches square by five inches long.

- ❑ Check both ends of the block to insure that they are perpendicular to the sides and parallel to each other on all planes – if not, use your grinder to square them off perfectly.

- ❑ With the guard on the tang and abutting the ricasso, hold the tang against the side of the block while the end of block is pressed hard against the back of the guard. While doing this, position the top of the guard so that it about one-eighth inch below the side of the block.

- ❑ Trace the outline of the tang on the block. This outline will also be useful now and later as a guide of where the guard resides within the handle during shaping the handle on the grinder.

- ❑ On the guard end of the wood block extend the tang lines across the top of the block using a small square. Draw a line down center of the top of the block going through the center of both extended tang lines. The portion of this line that lies between the two extended tang lines is where you will drill a hole in the block to fit the tang.

- ❑ Secure the block of wood vertically in a drill press vise. With a long drill bit in the chuck (assuming a drill press is used) align the drill against the outline of the tang on the side of the wood block. If the tang

line and drill bit do not align correctly, the wood block will have to be tilted in the vise with a small wedge to align the proposed hole with the drill bit.

- ❑ Select a drill bit that is a little larger than the width of the tang. Drill the tang hole in the block. Remember to drill the hole only about one-quarter inch deeper than the length of the tang (with guard on) traced on the side of the block. I usually start with a short drill to insure straight holes and then move to a drill long enough to reach the bottom of the hole depth.

- ❑ When the tang holes are drilled webbing will remain between them. Clean out the webbing with a modified wood rasp (filed down so that it will fit into the hole).

- ❑ When completed correctly, the tang should fit into the hole and the wood block should abut the back of the guard perfectly flat in all planes with no space showing between them anywhere. This may require further modifications to the tang hole and is usually done with a wood file.

- ❑ Once the block fits correctly, draw a line on one side of the block outlining how you want the profile of the handle to appear. The top of the edge of the handle abutting the guard should be very close to the height of the top of the ricasso (but not below it) when the knife is finished, and the bottom edge of the handle should align with the bottom edge of the ricasso (but not above it).

- ❑ Using a band saw cut off the bottom piece of the handle (that part beginning at the bottom side of the guard and curving back toward the rear of the handle) about one-eighth of an inch below the line you just drew. Again, be sure the remaining handle is oversized from what you envision the finished handle to be. Cutting this piece off will make it much easier to use the grinder to shape the handle when the guard is a traditional finger protector guard. Do not cut off the back of the block – it must be square for the next operation.

- ❑ Epoxy the handle onto the tang. Since the tang was last ground with a very course grit, there is plenty of variation to the tang surface for the epoxy to grip – no further pins are necessary to bind the handle to the tang unless for decorative purposes. Use a modified carpenter's one-handed bar clamp available at Home Depot to assist in clamping the handle to the blade. Modify this clamp by cutting a slot in the forward plastic grip piece so that the blade will fit in the slot, the slot will push against the front of the guard, and the rear grip piece will push against the back of the wooden handle block. Fill the tang hole with epoxy, put a small amount of epoxy on the top of the handle block where the guard will abut, and insert the blade. Excess epoxy will bleed out so be prepared to wipe it up. Once you have put the blade tang into the tang hole in the wooden handle block, place the knife in the bar clamp and tighten it to insure that the block rests tightly against the back of the guard while the epoxy hardens. Check to see that the back of the guard abuts with the wood block perfectly.

- ❑ Once assembled and bonded together, the handle must be shaped. This is done with the grinder fitted with a round wheel and a 36-grit belt. Using the grinder shape the handle to approximately ninety to ninety-five percent of final shape. During this process you will reach the point where you will be grinding the sides and top of the guard and the handle simultaneously – which will insure a perfect transition from guard to handle.

- ❑ As you are shaping the handle, frequently check the handle alignment against both the spine and edge of the blade to insure that the handle is aligned with the lines of the blade and guard. When looking down the edge of the blade to the rear of the handle, an imaginary straight line should be formed from the tip of the blade edge through the bottom point of the guard and on to the apex at the bottom rear of the handle. A similar imaginary line should be formed when sighting down the spine of the blade. While

checking these alignments, also check that both sides of the handle protrude an equal distance from these imaginary center lines.

- ❑ Once finished with the grinder, do final sanding by hand with sandpaper strips moving from 120, 240, and 400-grit up to 600-grit. To facilitate holding the knife, purchase a Riverside Moran Vise at www.riversidemachine.net. At the same time, finish the sides of the guard with the sandpaper strips being sure that the transition from guard to wooden handle is invisible to sight and touch. If a mirror finish is desired on the guard, proceed to polish the sides of the guard and the back of the finger guard separately with 1000 and 2000-grit paper. When finished wax the handle with gun stock wax, check it again for any grind marks that might have been missed, correct them, and polish the handle on a buffer using wood polishing compound. Protect the blade and guard with Renaissance Wax or a light coat of thin oil (3-in-One works well).

- ❑ Once complete, your knife is finished!

MISCELLANEOUS

- ❑ Test to determine if stock is mild steel (which is not appropriate for knife blades): heat to critical temperature, oil quench, and then try to break end off. Mild steel will bend and not break, whereas carbon steel will break off clean.

- ❑ Grinding belts – keep humidity free otherwise performance suffers. Accomplish this by putting them in a closet with a 25 watt bulb continuously on.

- ❑ Various steel combinations for damascus blade:

  - Best combination is 1084 and 15N20. It provides great blade characteristics, excellent welding ease and distinguished pattern visibility. This combination alone might meet all your needs in making Damascus steel.

  - 1018 or 1095 and O1

  - 1075 and 15N20

  - 5160 and L6

  - O1 and A36

  - O1 and L6 or 15N20

- ❑ Handles

  Wood – For unstabilized wood only: to get the smoothest finish, after shaping wipe with a wet cloth and expose to a heated but turned off forge. This will raise the wood pores that should then be sanded. Do this several times for best finish.

- ❑ Other

- Anneal non-ferrous alloys – to anneal non-ferrous alloys such as brass rods for attaching handles, heat to a dull red and water quench.
- When inspecting the blade for scratches, be sure that it is done under both incandescent and florescent lighting as each shows up flaws differently.

❑ Equipment – necessary to have

- Forge
- Hammers
- Tongs
- Various hand files
- Hand metal saw
- Variable speed grinder and various grit paper
- Vise
- Anvil
- Leather apron and gloves
- Quench tank
- Annealing bin with vermiculite or lime
- Torch, tanks, cart
- Drill press, bits
- Magnet, mounted on a rod for testing for critical temperatures
- Flat block of marble or granite for flat sanding

❑ Nice to have

- Trip hammer
- Electric metal saw
- Chop saw
- Temper oven
- Milling machine
- Press (for Damascus)

IRIDESCENT COLOR RANGES

Degrees F	Color
1200	dull red
1400	red
1500	cherry red
1600	full cherry red
1800	orange (cutoff point for forging most tool steels)
1900	orange yellow
2000	yellow
2200	full yellow
2400	light yellow

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