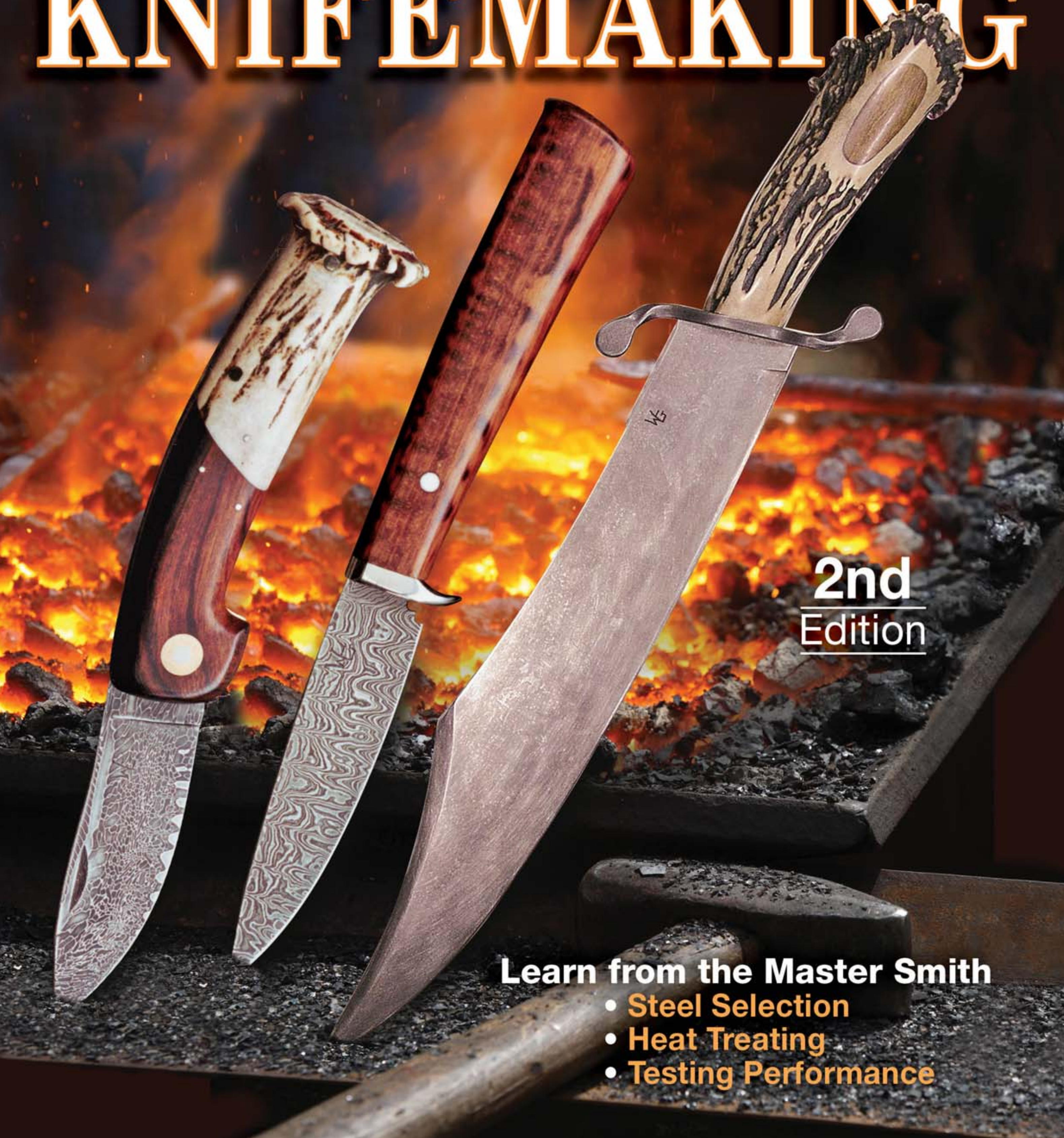
WAYNE GODDARD

The Wonder of KNIFEMAKING



2nd Edition

Learn from the Master Smith
- Steel Selection
- Heat Treating
- Testing Performance

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A Love Story With A Happy Ending

When I was 15 years old I fell in love with a tall blond girl named Phyllis. It wasn't long after that I told her I wanted to marry her when I grew up. My plan worked out really well, we celebrated our 50th anniversary in 2009 and we're still in love.

Right from the start back in 1963, Phyllis always supported my knife-making. My first injury was a cut hand from some plastic with broken edges. I didn't have a vise so I was holding the plastic in my left hand, portable drill in the right hand, and the plastic spun on the bit. When I came home from work the next day Phyllis presented me with a new vise from Sears. It wasn't very big but it was all we could afford. It served me well until I found a larger one, used and cheap. I still use the Sears vise as a "vise-in-a-vise" (see Chapter 6).

In 1973, when it came time for me to make knives as a full-time business, Phyllis made it possible by working full-time so that our family had health insurance and money for groceries. She may not have done any of the physical work on the knives, but by enabling me she was a full partner and we grew into a full-time business. I would not have survived the shift to full-time status without her.

Thank you, Honey.

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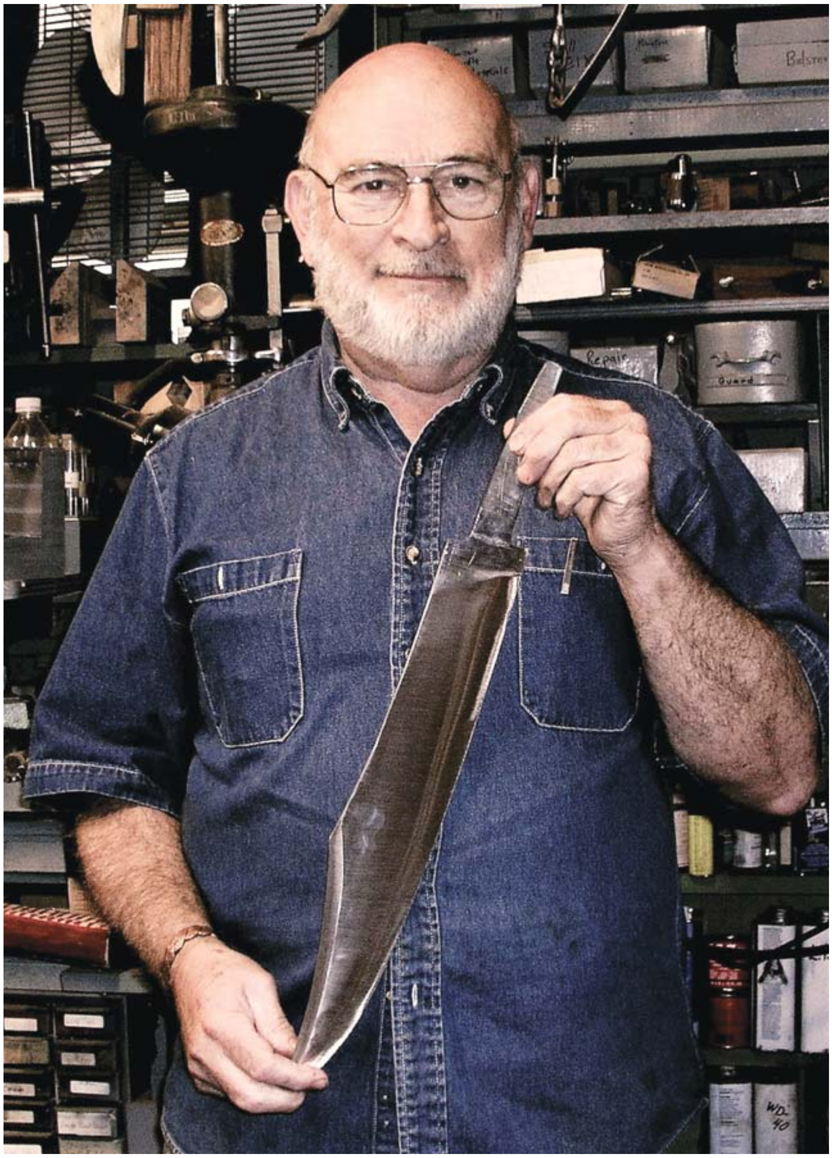


Welcome to *The Wonder of Knifemaking 2nd Edition*. The original *The Wonder of Knifemaking* was based on nine years of my writing for *BLADE Magazine*. That first book contained what I considered a "best of" the material I had in print. It was a mix of questions and answers, BLADE Workshop features, single issue articles and other articles that were part of a series.

When publisher Krause asked me to do a second edition, I spent some time trying to find out the difference between a revision and a second edition. (I had done a revised edition of *The $50 Knife Shop* and made up my own rules for it.) So, now you have the second edition of *The Wonder of Knifemaking* in your hands. You will find the color pictures are many times more interesting than the original black and white. You will find some material from the first edition along with new and revised material and also some story telling. I've had a lot of interesting experiences in my career as a knifemaker and I don't mind sharing them. I tried to stuff it with information that you are not apt to find with Google.

Some readers have talked with me on the phone, written letters to the BLADE Q&A, exchanged e-mails or talked to me at shows. Your questions, comments, and sometimes complaints are what keep me going as a writer. Keep it coming!

Wayne Goddard

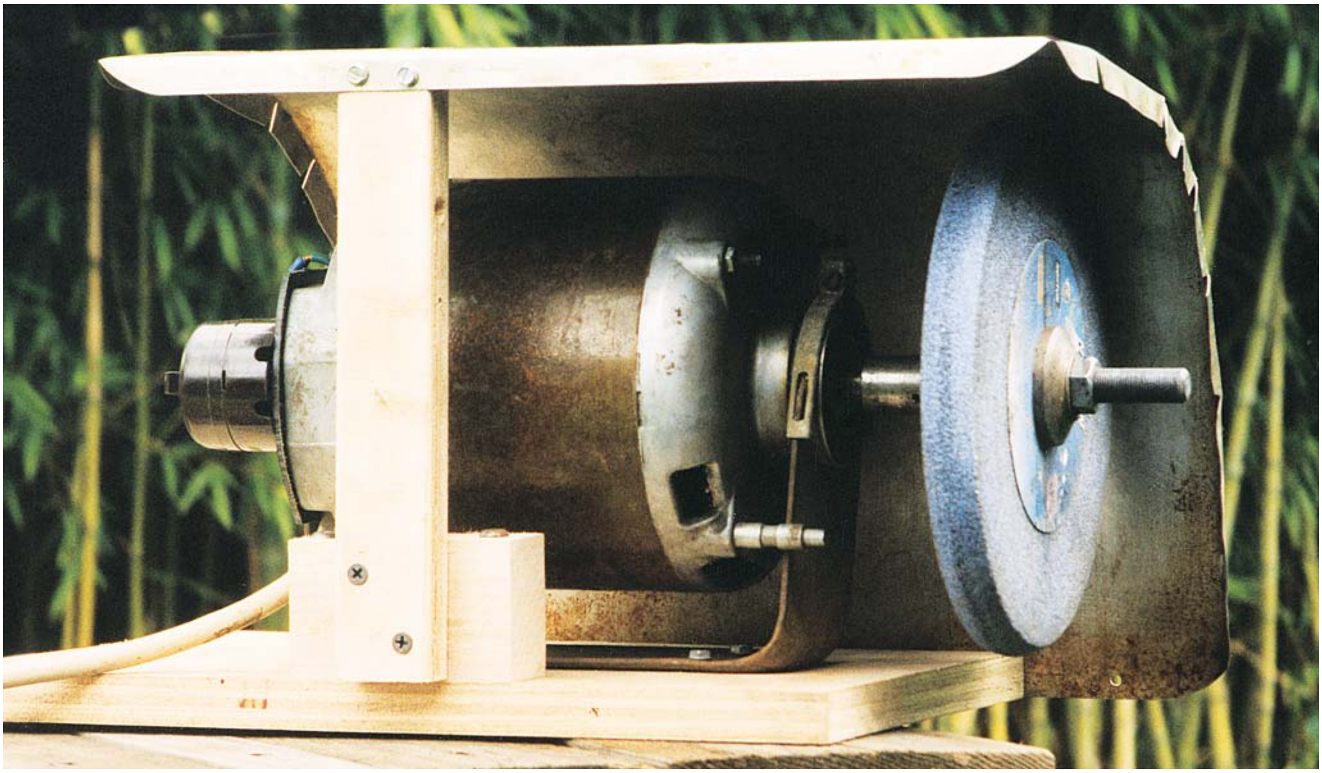
So, You Want To Make Knives

Way back in 1956 I made a few knives in the high school wood working shop in Gooding, Idaho. Our teacher was in WW2 and had some Japanese swords which he'd brought home. He would cut up the blades and rework them into hunting knives. With the thought that I too could make a knife, I got some old beet topping knives at a secondhand store. It was all stock removal from flame cut blanks and I made some clubby-looking butcher type knives. It's amazing how much knifemaking can be done with only a grinding wheel and disc sander. I likely would not have tried to make a knife with next to nothing if I had known about the equipment found in the average maker's shop.

Fast forward to 1959. At Army National Guard summer camp at Gowen Field in Boise, Idaho, I was the Battalion Supply Sergeant. One day I needed a knife to open a pile of boxes. The problem was that I had recently lost my pocketknife. The supply room was in a large warehouse building and no one was there to lend me a knife. I wasn't going to get the boxes opened sitting around, so I locked up the supply room, jumped in my jeep and headed for the company mess hall. They were short on knives and couldn't spare one. The head cook told me there was a broken butcher knife in the garbage. Someone else had scrounged the main part of the blade, but I could see making the couple inches of remaining blade into something that would work to open boxes.

Off I went to the truck repair shop, where I used the largest double-end grinding wheel machine I had ever seen to grind through wood and one rivet and expose enough steel to get a knife that was half blade and half handle. It wasn't much of a knife, but it got me through the box-opening party. After I set up the $50 knife shop in 1963, the ugly little knife got some disc sanding, hand finishing and buffing. I've always kept it in a safe place as a reminder of one of the first tiny steps on my long journey as a knifemaker.

The large ugly knife is a beet topping knife, the little ugly knife is the box opener made from a broken butcher knife.



Front view of the Good News/Bad News grinder, GNBN for short. The good news is that it only cost $5 to put together. It is a very good replica of the original made in 1963. The 1998 version of the grinder had a state-of-the-art Norton ceramic grit wheel, which made the grinding go much faster. The wheel was worn out on a saw sharpening machine, and just the right diameter for the washing machine motor grinder. The bad news is that it's not much of a grinder compared to a $2,000 belt grinder.

Over the next four years I tried to rework everything from kitchen knives to bayonets. I had a three-inch grinding wheel on an arbor that fit a Black and Decker 1/4-inch drill a friend had given me. The main thing I accomplished was to waste my time. All that time I collected knives, read about knives and tried, mostly unsuccessfully, to repair broken folding knives.

My first shop

An old-time blacksmith gave me a formula for using an oven-tempered lathe rasp to make a knife. In 1963 I found a lathe rasp. Then I needed a grinder, so I built one. It wasn't much of a machine, but it worked well enough to grind out my first knife and quite a few more. It consisted of a 1/3 hp -1750 rpm Westinghouse washing machine motor, a grinding wheel adapter and wheel from Sears, a plywood base and an old cookie sheet for a guard.

My first shop was the sun porch of the apartment we lived in. I had a bookcase with the grinder on it and an old wooden chair without a back. I'd hold the blades down on the chair with one hand and the drill/disc machine in the other hand. Yes, I sanded my hand several times.

The first knife I made gave me a tremendous amount of satisfaction. I finished it on a Friday and drove around town on Saturday to show it to all my friends. I didn't know at the time, but that knife got me started on what turned out to be my life's work.

There were those who liked that knife well enough to ask me to make one like it for them. The guard is steel from an old rusty wrench, the handle slabs are Oregon myrtlewood and I made the rivets out of 1/4-inch bolts. I ground it out carefully from a lathe rasp, just like the formula said. I tempered it at 375 degrees F in the kitchen oven. Careful grinding was necessary to keep the edge from being softened from overheating. (The edge-holding ability of most carbon and carbon alloy steels can be ruined by careless grinding with wheels or belts.) The grinding wheel marks were smoothed with the disk attachment on an electric drill. Back then, my idea of a fine finish was somewhere between 60 and 80 grit.

That first knife never did sell; it seemed that everyone wanted the "improved" workmanship of the subsequent models. By the end of that first year I decided it would be a good one to keep. I figure it is pure luck that I still have it, and I'm glad I do. That knife helps me prove some points with new or want-to-be makers. It shows that a knife can be made with a five-dollar grinder and an electric drill. That ugly knife clearly shows that I had no real, natural-born talent for knifemaking. I've seen a lot of makers who start out but don't go very far with it. The missing ingredient is a passion for knives. Years of hard work and practice will get a maker a lot closer to success than any talent they may have at the start.

The first six years, the only knifemakers I was acquainted with learned most of what they knew from me. They figured out some new and different ways to do things, and I would usually try their method if it looked like a better way to do things. I had very little money to purchase equipment and I wouldn't have known what to get anyway. I made knives the only way I could figure to get the job done. This may not the best way to get started, but I've never regretted it. I've always been thankful for the things I learned by doing it the hard way. I learned to solve problems on my own, and that included how to make most of my own equipment. This primitive beginning makes me grateful for all the tools I have to work with today.

I've been in my present location for 41 years. When we moved in, all of my equipment fit on a four-foot square homemade table that I bought at a thrift store. I had a grinding wheel mounted on a ball bearing arbor for roughing out the blades; it was a big improvement over the grinder made from the washing machine motor. I smoothed out the marks from the grinder with a disk sanding attachment on an electric drill. A washing machine motor turned my buffing wheel. A second electric drill mounted in a drill press adapter furnished a crude but workable method to

The knife on the left is the first knife I made from scratch. I used an oven-tempered lathe rasp for the blade, steel for the guard and myrtlewood for the handle. The knife at the right with the maple burl handle is the project knife I made in 2005 for a chapter I wrote for *BLADE's Guide to Making Knives*.

drill holes. Everything else was done with a small vise, coping saw, carpenter-type wood saw, metal cutting hacksaw, files, sandpaper and sharpening stones.

The Good News grinder is set up here with a table so it can be used as an abrasive saw. That's something a $2,000 belt grinder can't do.

That was 1970 and I had made several hundred knives by then. A few of those early knives are in my collection, and they aren't too bad if you consider the tools I had to work with. I first started using a belt grinder in 1972, and it was one I made out of junk parts. It didn't work very well but it was a big improvement over the sanding attachment on the electric drill.

When we bought the house, it was the first place we lived that had a double garage. I remember telling my wife Phyllis that I would keep the knifemaking stuff in one half and she could keep her car in the other half. That lasted about six months, and by 1975 the whole garage was closed in as a shop. You could say that our vehicles have suffered through the winter weather of Oregon ever since and the knifemaking business is to blame.

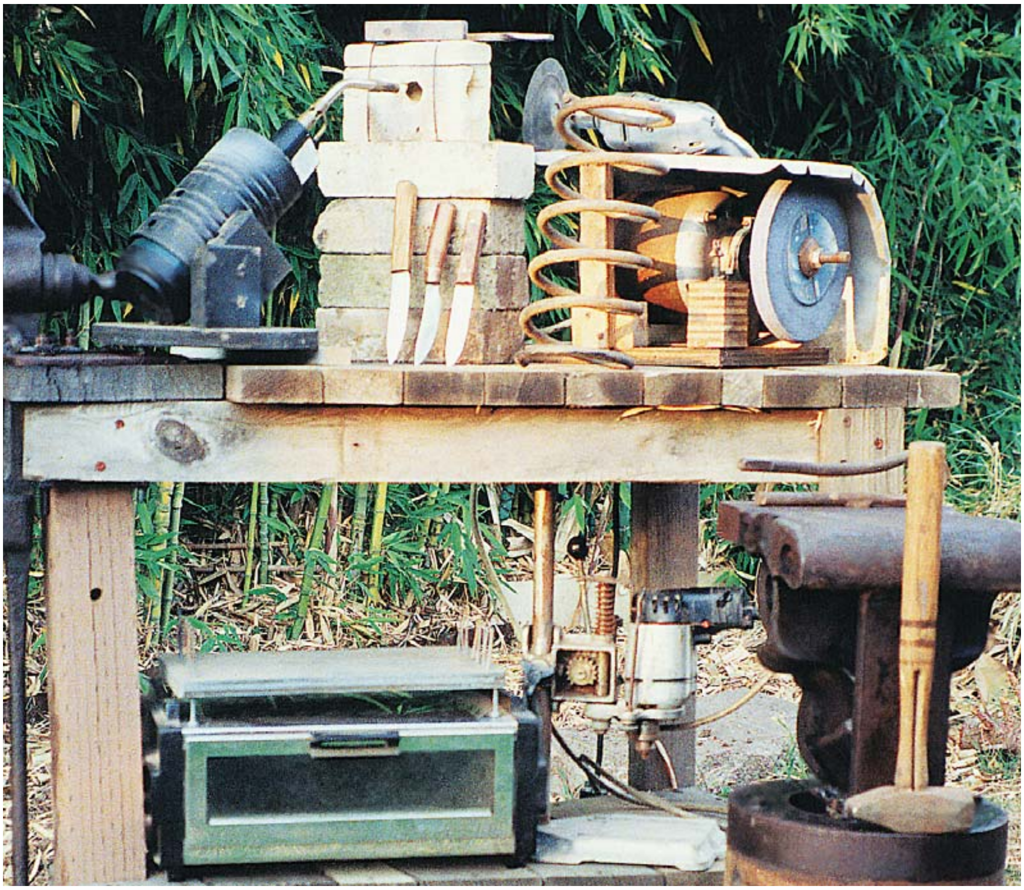
Keep it simple

It was my rebellion against "high tech" that led to the *BLADE® Magazine* series "The $50 Knife Shop." The purpose was to present knifemaking with simple tools and methods. This is in stark contrast to the headlong rush toward complicated (and often expensive) that is quite normal for tools in the handmade knife shop of today.

I tell my students that if they can't learn to do it with simple equipment, they may not ever do it long enough with fancy equipment to get good at it. I've often heard new makers say that their knives would be better if they had better equipment. I have also watched their frustration level raise when they finally get better equipment and find it still takes many hours of practice to get the skill necessary to do good work.

Every so often the phone rings and it's someone who wants to get started making knives. When I'm not too busy I invite them out to see my shop and get acquainted. I remember one young man who walked in, took one look around at all my equipment and said words to this effect, "I won't be able to make knives, I can't afford all this stuff!" I told him that it could be done with much less equipment and even described to him the meager equipment I had when I moved here. I explained that it took me over thirty-five years to accumulate all that I had. He would not be convinced. He was going to have a lot of equipment or none at all; a simple start was not for him.

This is the backyard $50 Knife Shop.



That experience, and others where the shortage of tools and information hindered people from getting started, reinforced my desire to teach knifemaking on a very basic level. This led to experiments in the use of primitive methods. It might be considered unusal to accomplish something in such a primitive manner. A simple start is not for everyone; it is for rugged and inventive individuals, like those that gave rise to the phrase "Yankee Ingenuity." The most important ingredient for success with simple methods is the sincere desire to do it. I like to call it having a severe case of the want-to.

Perhaps the most sensible part about a simple beginning is that, as the skill level increases, more and better equipment that allows higher production can be obtained. I've seen many new makers frustrated by having good equipment but no skill to go with it. It would be like giving a three-year old kid a Stradivarius violin and then expecting to hear something that sounds good. On the other hand, you can give a master violinist almost any old fiddle and they can make sweet music with it.

The most important ingredient for success with simple methods is the sincere desire to do it.

Getting started and paying your dues

The skills necessary to produce knives with superior workmanship, strength and cutting ability are learned with much practice. Books, videos, classes and machinery are only a starting point. I recently did some calculations and came up with the following: Let's say it takes the beginner 10 hours to make a knife, and assume they will have to make at least 100 knives to become efficient. It will take an investment of 1,000 hours to learn the fundamentals. Assuming that their time is worth $20 per hour, it means an investment in hour/dollar of $20,000. A pretty good set of knifemaking machinery can be purchased for less than $4,000. What I'm getting at is this; a wise person will consider both the investments in time and money necessary to learn the skills of knifemaking.

After months of anticipation and burning the midnight oil, the wondering if I was doing the right thing was over. Phyllis and I were finally on our way to our first knife show; it was the summer of 1972. It was a long drive from Eugene, Oregon, to Kansas City, but the '67 T-Bird ran smooth and fast (until the transmission went out in Wichita on the way home).

The Knifemakers' Guild was having their show in conjunction with the Missouri Valley Gun Collectors Association. It was the third time the Guild had gotten together and the first time they had a separate room exclusively for their show. A business meeting was scheduled before the show to decide on rules for admission into the Guild. I was more than a little nervous wondering if they would let me in. They did, as a probationary member. In 1974 I was accepted as a voting member. I stayed in the Guild for 25 years, but quit paying my dues when I no longer had anything to offer them. (It is my belief that we should not join an organization for what we think it will do for us, but for what we can bring to it.)

Feedback from the field

The most rewarding part of writing about knifemaking is hearing from those it has helped. Tim Pollock had no place to set up his knifemaking equipment, so he set it up in his attic.

Here's how Tim explained it: "It was tough going from two incomes to one. That's when I saw your book advertised (The $50 Knife Shop) and started making knives. I've never enjoyed anything more! Everyone always said I was a workaholic. I've always worked more than one job at a time, and making knives helps keep me sane. I love it!"

The "T-1" Skinning Knife by Tim Pollock; heated in a gas forge, the blade is goop quenched 1095, triple tempered.

That show in 1972 was small by today's standards, but all the big names of the period were there. There were approximately 40 tables, and before the show was over I was acquainted with almost everyone. My records show that we sold three knives for a total of $150. That's not much when compared to sales at the shows today, but it brings me to the first – and what I think is the most important – reason for the new maker to go to shows.

Reason #1: Part of paying your dues is spending the money to attend knife shows. You might work really hard getting ready for the show and not make enough money to cover your expenses. That doesn't mean the show isn't a success. The contacts that you make will almost always be worth far more than the dollars you get for your knives.

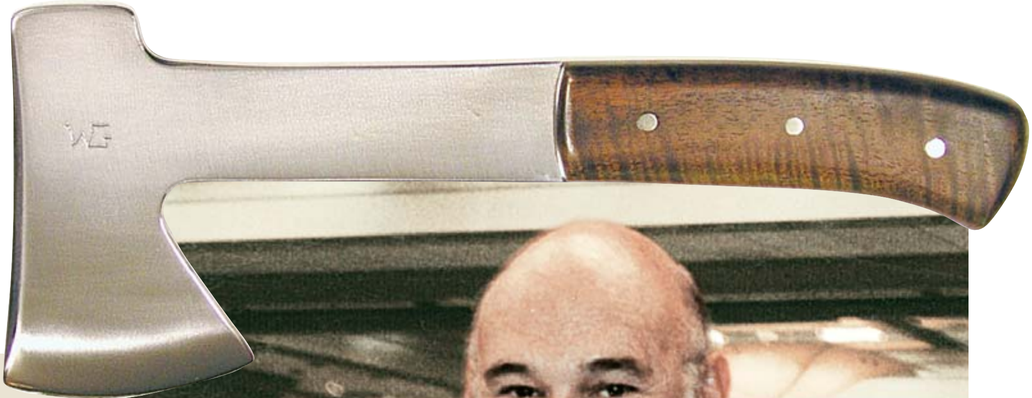
For example, at that 1972 Guild Show I met Sid Latham, Al Mar and Butch and Rita Winter. Sid was working on an article about hunting axes for *Field and Stream Magazine*. Because I was one of half a dozen makers who had hunting axes at the show, I was included in the article, which came out in the May 1974 issue. I had become a full-time maker in May of 1973 and already had a backlog of several months. My backlog was out several years by the time all the orders came in from that article. You heard it right, two years work from one article! Sid also included me in his book *Knives and Knifemakers* (Winchester Press, 1973). That book is in most large libraries and I still get calls every so often from people who read it.

One of the knives we sold was a Nessmuk style hunting knife, which Butch and Rita Winter added to their collection of Guild Member Knives. That knife was photographed and appeared in the Bates and Schippers book, *The Custom Knife* (1973).

Even though that show in 1972 was seemingly not a success from the financial standpoint, the long term benefits of exposure in articles and books was extremely valuable.

Reason #2: Gain and maintain perspective about your work and the rest of the trade. Before the 1972 Guild Show I had seen very little of the best work that was being done at that time. It was all there for me to see, and by the time the show was over I knew exactly what I needed to do to improve my knives. Also, I started to get a clear picture of a specialty that I wanted to pursue: folding knives.

The tips, techniques and inspiration gained from the makers was well worth the cost of the trip. Remember, at that time there were no magazines or books telling how it was done. In the early 70s, if you were going to learn new stuff it was either



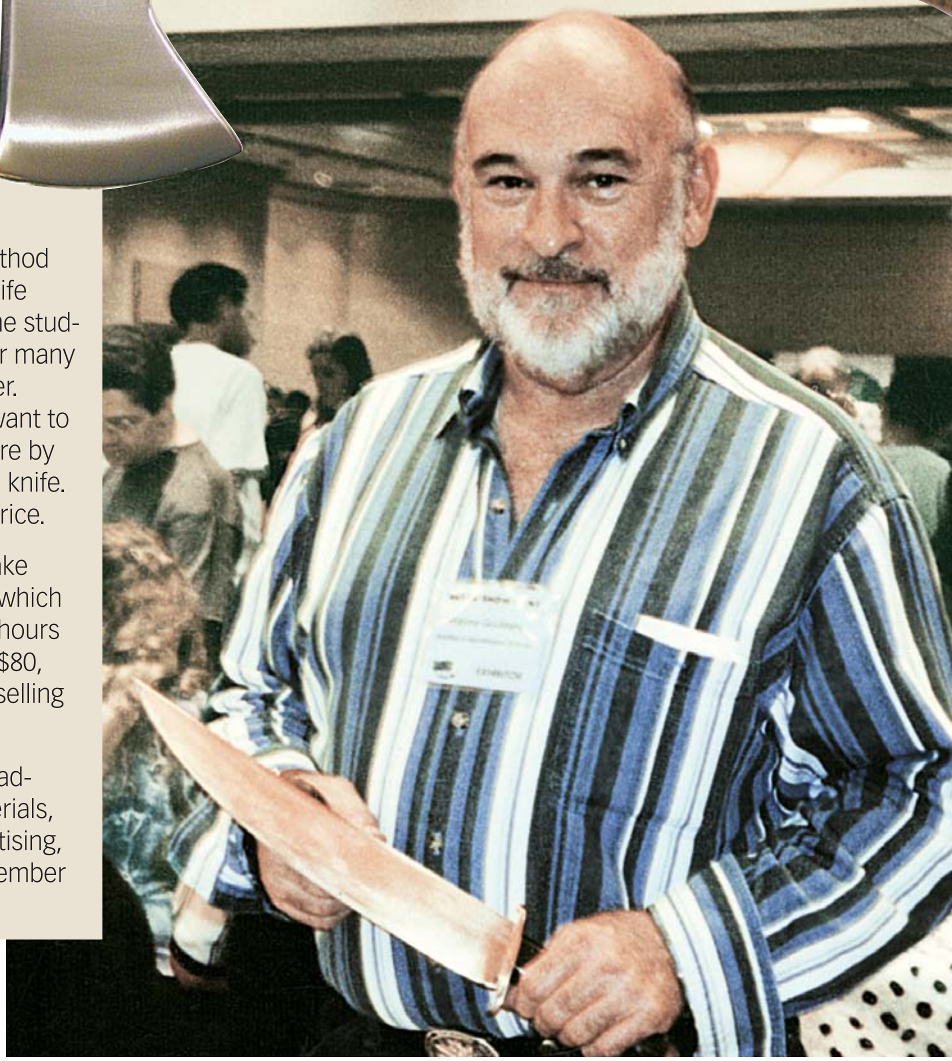
Hunter-style axe similar to the one that was in the *Field and Stream* article. This one was made in 1964 and refurbished with new fiddleback walnut handle slabs in 1973.

Establishing a selling price for your knives

I am often asked about the method used to establish a price for knife work. I base my method on time studies and operating expense over many years spent as a full-time maker. Multiply the hourly wage you want to make by four. Multiply that figure by the hands-on hours spent on a knife. That answer gives the selling price.

For example: If you want to make $20 per hour, multiply $20 x 4, which equals $80. If it takes you four hours to make the knife, multiply 4 x $80, which equals $320. This is the selling price for the knife.

This formula should allow you adequate income to pay for materials, insurance, maintenance, advertising, show expense and more. Remember to pay your taxes.



I never pass up the opportunity to get my picture taken holding one of the Bowie knives I create. This was at a BLADE Show West in California.

work it out yourself or find a maker to show you. My desire to teach and share comes out of those early years. I will ever be grateful to Bob Loveless, Lloyd Hale, Gil Hibben, Corbet Sigman and Bob Ogg, who were the main sources of my inspiration and at the same time totally unselfish and free with information.

Reason #3: The variety of customers is a broad base for your business. My personal observations seem to show that the most successful makers combine sales from advertising and shows to gain the broad base necessary to keep busy. The internet has changed things a lot; these days it just may be possible to keep busy full time with only a web page.

Reason #4: It offers a market for “show-” or “art-”type knives that would not sell in your hometown. I get to do what I want when getting ready for a show, and it’s usually more fun than working to the strict instructions that come with a custom order. I make knives for a show as if I was making them for myself. As such, they are more of a true expression of my art than turning out standard models. Leading up to a show, a peculiar design festering in my mind has a chance to come into reality.

Most knife shows have some type of competition for knifemakers, and I take it seriously. Working on a knife for a competition inspires me to do my best work and not worry about whether the knife will sell or not. The quality of the fit and finish becomes the motivation for the work. I do my best work when it becomes a labor of love and all thought of money is set aside.

Reason #5: You get to see this country, and maybe others. Phyllis and I were talking one day about our knife business and she mentioned that we got to see much of our great country just from going to knife shows. We cherish our memories of New York City, Orlando, Dallas, Kansas City, Atlanta, Los Angeles, San Francisco, Knoxville and Paris, France.

Reason #6: To sell knives is the lowest priority on my list of reasons. We all want to sell knives at the shows, but it sometimes takes a few shows or years for a maker to figure out what sells and what does not. Instant success is not possible for most of us. Do not give up after a few shows; those who are successful never gave up on their ideas and dreams.

Insider tips

A couple of tips about shows. These are not reasons for going to shows, rather secrets that I will share to help you have a successful show.

Lay out a good variety of styles, sizes and price ranges. Sales are always better when you have a good variety. If you have a whole table full of hunting knives, there will be nothing for the buyer of miniatures, axes, Bowies, fighters, camp knives, folders and etc.

A young maker called me discouraged when he couldn't get into knife shows because of a waiting list. He wanted to get publicity in magazines so he could sell more knives. I advised him to get on the waiting list like everyone else does. I should have suggested that he donate a knife to a magazine to use in a contest give-away. That's a sure way to get a picture of his knife in print. I told him to get good quality photos made and send them to the major knife publications. I suggested that he consider starting a knifemakers club.

Developing a unique style

Developing a style of your own includes having good designs. There are so many knifemakers today that it might be difficult to come up with something unique. That doesn't mean you shouldn't try.

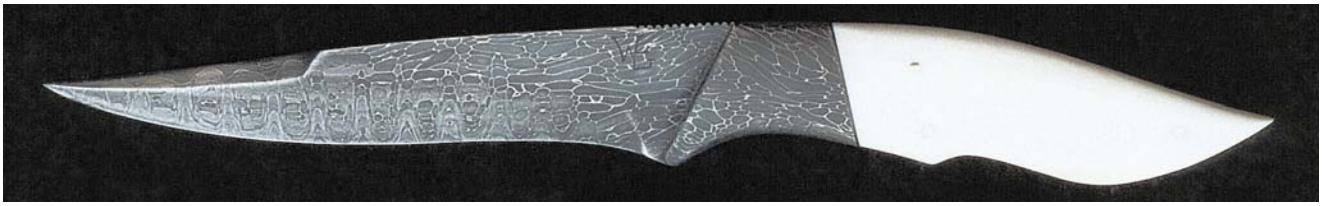
I wanted to see what Webster's New Collegiate Dictionary had to say about style. I got down to the fourth definition before it applied to this chapter: "distinctive or characteristic mode of presentation, construction or execution in any art, employment or product, especially in any fine art; also quality which gives distinctive character and excellence to artistic expression." I like that definition; that Webster fellow had a real smooth way with words.

Did you notice the phrase "especially in any fine art" in the previous paragraph? I won't try to define fine art, but I will take a shot at defining an art knife. A knife that is not intended to do real work should be considered an exercise in art by the maker. Can a working knife be artistic? Certainly, as long as the design elements do not interfere with the usability of the knife.

It was easy to sell knives in the '60s, mostly because my customers hadn't seen the best of what was being made. Everything I made seemed to look good to my customers. Hardly anyone I knew had ever seen a handmade knife or one that was well designed.

I got to see a lot of well-made and beautifully designed knives at my first Knifemakers' Guild Show in 1972. I came home from there and got serious on my workmanship and designs.

My style didn't develop much until I went into knifemaking full time in 1973. There was something about making a lot of knives that sped up my design "smarts." It's hard to explain the evolution of my patterns, but it went something like this: I'd make one or more of a pattern and usually nothing seemed like it needed changing.



At the Paris show we got to meet Patrice Palsky, designer of this beautiful boot knife. It has a wire damascus blade with an integral bolster and ivory handle.

My version of a picture of the Eiffel Tower, taken while at the 1994 Paris Knife Show.

My wife of 51 years, Phyllis, is the brains behind our outfit and the one who made it possible for me to be a knifemaker. This is Phyllis at the Paris Show in 1994.

A time always came when I looked at a pattern or a finished knife and some part of it looked too fat, too thin, too curved or too straight. I'd make a change, usually going too far. As I progressed, changes previously done in fractions of an inch changed to the width of a pencil line. I can't explain how I decided what needed changing other than it just didn't look right. I can see how my style developed when I look at old photos. Learning which shapes and curves would work together on a knife was the bonus that came with developing a style of my own.

Making knives to a customer's drawing was a valuable experience. A few of them taught me about good design. Most of the customer ideas weren't too efficient when it came to what a working knife should be. Some of the customers figured that out by themselves and came back for a design of mine that was proven to be a good working knife. A design of mine that's an example of "distinctive" is the Odin's Claw folder from 1973. It started with a drawing from the customer. I immediately saw the potential it would have after making several changes. It was a tactical folder before the knife world had the term for it.

It was from the occasional good design that I learned the most. All of this was an important part of my development as a designer. When I got to the point where I had confidence in my designs, I would often talk a customer out of his impractical idea in favor of one of mine that I knew would work.

In 1969 I was standing in front of a Ka-Bar knife display case in a discount store. It was the style that sat on the floor and probably had the whole Ka-Bar line of knives in it. The sign said "Closing Out 50% off." I asked a gentleman who was also looking which one he was going to get. We got to talking and he was interested to find out I was a knifemaker. I gave him a business card and not too long after that he called to see if I would help him with a knife he was working on. This led to a friendship with Maynard Meadows that has lasted over 40 years. He is responsible for what I call the Traditional Hunter. It's basically a smaller, modernized version of the hundreds-of-years-old butchers legging knife. It has been the only style of hunting knife I offer ever since 1979.

When it came to handle thickness, length, shape and such, it seemed that I had to make several knives that didn't work to figure out what did work. When I made a knife that didn't feel or look appropriate, I wouldn't make another one like it. There's a lot to be said for using one's own knives to do some real work.

I see many knives being sold as hunting knives that have square corners on a too-thick or too-thin handle. Blades are often too wide or too thick and of a clumsy shape. Most such knives wouldn't be made the way they are if the maker had actually ever done any work with them. Part of my style is to round everything off real well, and I suppose I do that because I remember the blisters I got using one of my knives that had a thin handle with square corners.

Your life experience, background and motivation will influence the style you develop. These factors determine if you make real or make-believe knives. I define a make-believe knife as one that's designed on paper and made without any evolution as a working tool. My opinion is that most lasting designs evolve and aren't necessarily the result of an original idea.

I realize that probably 90 percent of handmade knives will never be used for serious work. You may be able to make a good living turning out knives that are all fangs, claws, reptile parts and buggy eyeballs. There's a market for that and you'll not need to worry about the knife holding an edge, being balanced or having proper edge geometry.

You might consider what the market share is for different types of knives. I went through an issue of *BLADE* magazine and classified every knife shown in one of six categories. The following figures show what type knives are being featured in articles and advertisements, but may not be a true indication of what is actually being sold: tactical (folder and fixed)-108; sport /hunting (folder and fixed)-31; elegant

Having fun after dinner at the 1996 BLADE Show in Atlanta. Left to right: Barry Gallagher, Ed Schempp, Mike Draper, Josh Smith, Lisa Smith, Phyllis and Wayne Goddard, Wade Colter and Rick Dunkerley. History was made twice that day. Josh Smith became the youngest and Audra Draper the first lady to gain Journeyman Smith status in the American Bladesmith Society. *(Photo by Audra Draper)*

When it comes to distinctive style, it's hard to beat an Ed Fowler knife. His Long Yearling has a high-performance blade, distinctive guard and one-of-a-kind sheep horn handle.

There are craftsmen and there are artists. JD Smith is a true artist as this one-of-a-kind knife shows. From the tip of the Wootz Pattern Hammer Steel blade to the end of the handle, it is unique in the world.

folding knives-30; traditional (folder and fixed)-29; bowies-22; and art/daggers-16.

A famous French aircraft designer made a statement that went something like this. "A perfect design is achieved when everything that isn't essential is removed." That can apply to knives. I recently critiqued knives for several new makers. In the first case, I told the maker that there wasn't one thing that I understood about his two knives. I asked the other maker to explain some elements of his design, which he could not do. He had educated himself by looking at pictures of knives and then adopting curves, lines and such for which there was no realistic reason.

The world we live in is beautiful because our creator made all of nature with curves of all types. Think about it, how many straight lines do you see in trees, shrubs and flowers? Curve every element of your knives, round the corners, make them user-friendly. Think about how the overall lines of the knife meet at the junction of handle and blade. Don't stick a big square of metal there and expect the eyes of the beholder to enjoy the overall look of the knife.

I keep a loose-leaf notebook titled, "The Good, Bad and Ugly." A collection of photographs and pictures from magazines and catalogs, it's my textbook for teaching design. A picture is worth a thousand words and it's easy to point out distinctive styles as well as good and bad designs. Start a book that contains your drawings and ideas. Include pictures of knives you like and then figure out why you like them. Keep the ugly knives in it too, just so you'll remember not to make them. Good luck with developing your unique style.

Pitfalls for the knifemaker

It isn't enough to have some good designs, use the best materials and to know how to make a good knife. It does not depend on having a specific type or brand of belt grinder. It takes physical as well as business skills to succeed as a knifemaker. Some of these are only learned by trial and error and with the passage of time.

The owner of a cutlery shop had been in business about a year. He sold a lot of my knives and a lot of other handmade knives too. He told me, "What most knifemakers need is some business training." I told him that it might hurt his business because once we knew how to run a successful business we would quickly look for another more profitable trade. When asked why I make knives, I've been known to answer, "Because I can't help myself." The knives are trapped inside of me, my reality is getting them out.

My love of making folding knives using antler crowns led me to develop a unique folding knife design. The average crown has too much curve to split and leave enough to make a full sized handle. The problem is solved by making a long and wider bolster. The bolster shape creates a guard against slipping up onto the blade. Metal made it too heavy, so I made a few out of Micarta but settled on wood. You'll notice the same guard shape on my Spyderco Clipit design.

There are a number of pitfalls for the new or experienced maker. The knifemaker who avoids the most pitfalls has the best chance for success. I made some of these mistakes myself, so I write from first-hand knowledge. Some common pitfalls and possible solutions follow.

Unrealistic rates

An unrealistic shop rate can lead to poor wages. To cover overhead for a one-man operation, the per hour shop rate needs to be higher than that of job shops that employ many workers. The knifemaker working alone is the head janitor, maintenance foreman, production manager, bookkeeper, delivery person, and in their spare time they make knives. Over many years, I doubt that I average five hours a day hands-on time making knives. The rest of the day is taken up with other necessary duties and it's rare to get only eight hours total. That means that the value of a knife made in one day will have to equal the hourly wage you expect, plus pay all expenses necessary to keep the business going. That is how a shop rate is calculated and it's a necessary thing to have figured out if there is to be money coming in equal to the wages plus expenses.

When I look at knives made by a maker that I am unfamiliar with I can usually tell from the prices if the maker does it as a part time job. The knives will usually be priced for less than they could afford to sell them for if they were doing it for their sole support. I have rarely overestimated the time and materials necessary to complete the one-of-a-kind custom knife. I have adopted the policy of telling the customer that it will be no less, but no more than so many dollars. This is the only way I have been consistently able to be profitable on the custom, one-of-a-kind orders.

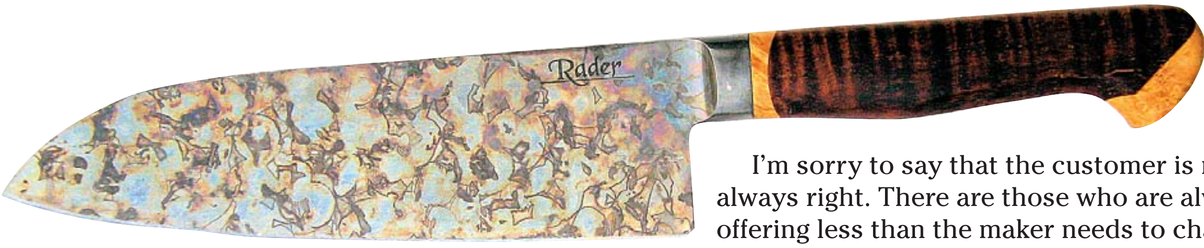
"A perfect design is achieved when everything that isn't essential is removed."

Don't gamble with trades

Do not take things in trade for knives that have to be made in the future. This can be worse than abusing a credit card. Play it safe and if you make trades, do it only for knives that you already have finished. This will keep you from getting in the deep hole that I've seen more than one maker get into.

Be realistic about your skill level

Don't try to work beyond your skill level. There have been times when I could not deliver knives on time because I got talked into trying a project that was beyond my skill level. When a knife project goes bad it is hard on the both the nerves and one's patience. If you have a deposit on the project it puts on extra pressure that isn't needed.



From my kitchen, a distinctive cook's knife by Michael Rader. His unique and original handle details set it apart from all others. I've used the knife for several years and the mustard patina keeps the blade looking like new.

I'm sorry to say that the customer is not always right. There are those who are always offering less than the maker needs to charge. Others are bullies that want delivery ahead of other work you have lined up. One customer offered me $50 to get quick delivery on a knife. He was quite upset when I told him I would to it if he wrote to all those on my waiting list and satisfactorily explained why I should do it. I no longer take orders because of age and health reasons. I do keep a waiting list of who wants what. I let them know when I have a finished knife that fits the bill.

Taking deposits

General advice; don't do it unless you are very careful. I quit taking deposits with new orders many years ago and it was one of the best things I ever did. When I made a set of steak knives that required $900 in handle materials (select pearl, ivory and sambar stag), I got a materials deposit on that order.

Don't overpromise

Avoid promising out more work than can be actually done. This often comes from getting publicity, which usually brings in more work than can be reasonably scheduled. There is a certain amount of security in having a backlog of orders. The down side is the added responsibility to keep to a delivery schedule and also to manage any money taken in as deposits.

Get some business training

Most of us knifemakers, if we knew anything about doing business at the start of our knifemaking careers, would probably have gone into some other line of work. I started out without any real plan other than to make knives. I had made knives on a part time basis from 1963 to 1973 and by then Phyllis and I both felt that the thing to do was give full-time knifemaking a try. We had her income from a full-time job to fall back on while the knife business got going, and we needed it.

My plan was to make knives and not much thought was put into any other aspect of entering the new business. The knives that were inside of me were trying to get out and making them was the only way to relieve the problem. From the business standpoint, that may not be the best reason to start an enterprise. From the practical application standpoint it is a good reason. The headaches that come with the bookkeeping end of the business were far from my mind.

Success will come quickly and easily for only a few. To most others, including myself, it means working long hours with not much pay. I read this somewhere, "no one ever mastered anything in 40 hours a week." When it comes to knifemaking, I agree. The desire to create knives is what kept me going even when my ego and pocketbook were as flat as they could be. I am a knifemaker because there is nothing else that I wanted to do for the last 47 years. This is the best reason I have for what I do.

This picture is a reminder to make cute little knives. They are very saleable, low budget items and much overlooked by some who need to make sales. This cute little knife from my collection was made by my friend Richard Veatch.

The 5160 Club of Oregon

Part of being successful in your knifemaking efforts may depend on your relationship with other makers. “Two heads are better than one,” has been true many times for me. I think the popular term is “networking.” I didn’t have any local competition for the first five years or so. First one, and then another friend got started making knives. Having other knives to compare my knives to was about the best thing that could have happened to speed my progression as a maker. The computer age has brought the four corners of the world and placed it all in living color on my desktop. You will be somewhat handicapped if you do it on your own without a local friendship/network, or without the internet. For me, one of the best things about being a knifemaker is the friendships that are formed with knifemakers, collectors and dealers.

In the fall of 2008 local maker Jeff Crowner suggested that we start a knifemakers club that would be mostly a performance-oriented group. He talked it over with me and decided it was a good idea. The club would set up a testing program for blades that would set requirements at a higher level than the present, commonly accepted standards. Both stock removal and forged blades would be tested. It would be a regional group, where people could test within local units without having to go clear across the country. Performance first, fit and finish second. It would not be “forged versus stock removal.” It would be a test of heat treatments and edge/blade geometry. The result was the 5160 Club. (5160 chromium steel was our choice for the 10-inch long test knives.)

We’ve been having a lot of fun for almost two years now. We have monthly meetings at the local Woodcraft store. Those of you who live in the Eugene, Oregon, area are welcome to check out our meetings. We usually have about 20 people there. We have three or four “big” activities each year that have included demonstrating at a local festival, or just getting together at someone’s place with a certain theme. We had a forge-welding party at Lynn Moore’s shop. Another time we had a get-together at Jeff’s shop where we did water-hardened blades with a clay back.

We had a great get-together at Jim Jordan’s place in May of 2010. The theme for the day was to show off our portable outfits and to see if we could finish some all-steel knives. I thought I was getting there early but Mike Johnson was already there and set up. Guess what? His early start paid off, he won the contest. My outfit sets up on one of the older style WorkMate tables made by Black & Decker. There were a total of seven portable outfits set up and there were lots of mini demonstrations going on. Some of the new members got to hammer some hot steel and at least one got his first forging lesson. It was a fun time. Jim and his wife had a great lunch for us and they said we can come back next spring and do it again.

The 5160 Club has never got much into what the original concept was. We’ve done some testing and mostly we have been having fun with sharing our knowledge

Yes, *The Wonder of Knifemaking* is required reading for the Eugene 5160 Club.

and making knives. A typical meeting will have a guest speaker or members will bring a demonstration or talk about a recent project. We always have show and tell and have seen an awesome variety of knives. Most knifemakers have a knife collection of some sort and we learn from looking at knives.

The knifemaker who avoids the most pitfalls has the best chance for success.

A lesson in perspective

I wanted to make a version of a Scagel knife that I saw in a magazine. The photo was about three inches long; the knife I wanted to make would be nearly 14 inches long. I took the magazine page to a copy shop and started making enlargements until I got the blade the size I wanted. At this point the handle was nearly seven inches long. That was about 15 to 20 percent longer than it should have been. It was then that I realized that the handle was closer to the camera than the blade. That put the perspective of the knife out of proportion to the real knife. In the small picture the perspective was not noticeable, but it had to be reckoned with when enlarged to full size.

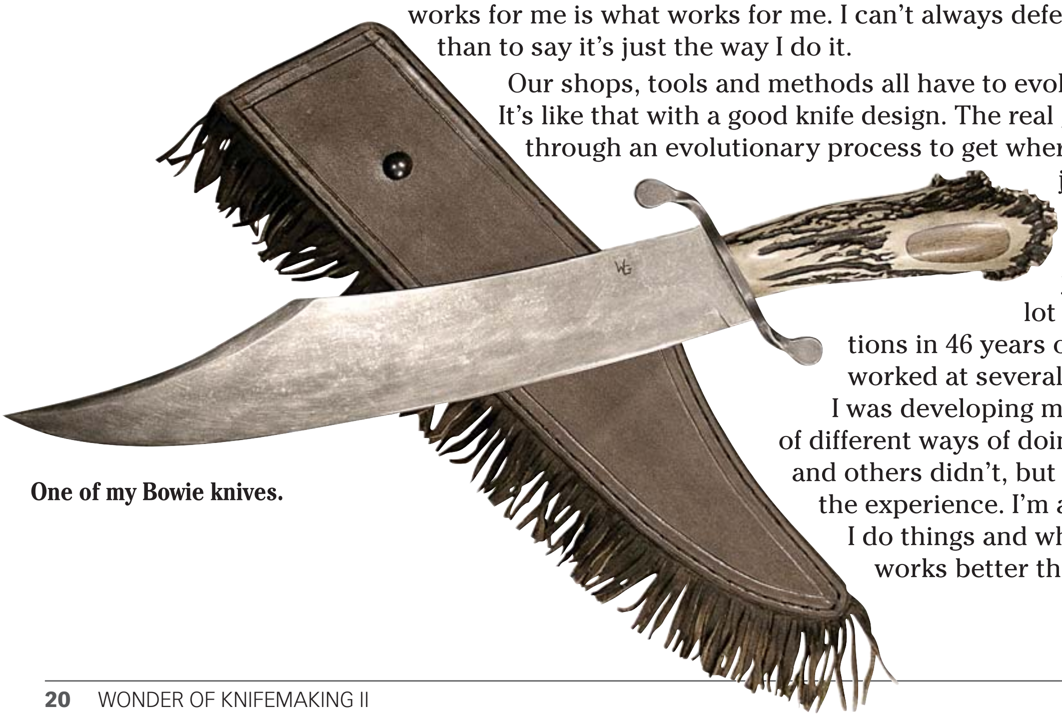
I surely can't see things from another's perspective because I haven't walked a mile in their shoes. I believe this causes many of the honest differences of opinion that are a part of life. I not only can't see an issue from the other side but my foolish pride will usually get me in an argument simply because I want to be right about my position. I'm so busy being right that I often don't hear the valid points that shoot down my argument. I once saw a sign that said: "What I said wasn't what I meant, and what you heard was not what I said." I've been there and done that. Most of us have filters that are quite efficient at blocking out things we do not to want to hear. We can't possibly have the whole picture on an issue when our filters are grinding away at it.

This applies to the methods and processes that are part of knifemaking. I don't always remember the exact instructions. I find it nearly impossible to do anything exactly the way I am told. I always think I can improve on it in some small way. That is why the things I present here may or may not work for another. Even if a method is followed exactly, differences in materials or equipment will give different results.

One of the more interesting things about knifemakers is that we do things in a lot of different ways and still get the job done. Many of the processes necessary to make a finished knife are quite complicated. If one step is omitted or done out of order the results may not be what was expected. When I say what works for me it doesn't mean that I am trying to get anyone to change the way they do it. What works for me is what works for me. I can't always defend my position other than to say it's just the way I do it.

Our shops, tools and methods all have to evolve in their own time. It's like that with a good knife design. The real good ones have gone through an evolutionary process to get where they are; they didn't just jump off of a drawing board one day.

My knifemaking journey has taken me a lot a lot of different directions in 46 years of grinding and forging. I worked at several different specialties as I was developing my skills. I have tried lots of different ways of doing things. Some worked and others didn't, but I always learned from the experience. I'm always changing the way I do things and what I end up with always works better than what I started with.



One of my Bowie knives.

CHAPTER 2

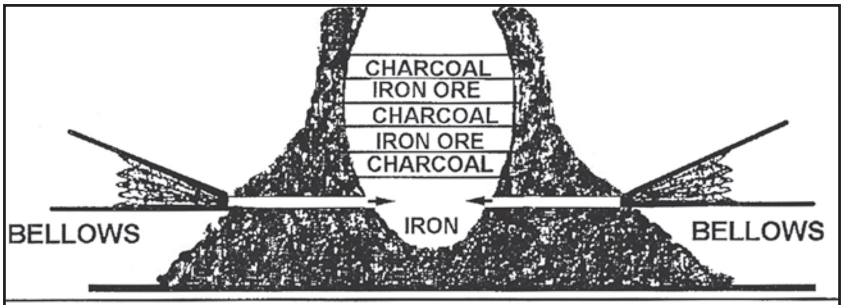
The Mystery And Magic Of Steel

We can only speculate about how ancient man first made iron, and then how from the iron he formed knives and tools. The methods used are understood today because many ancient iron-making furnaces have been excavated; a few of which had the “bloom” intact. The bloom is the end product of reducing the natural iron ore by use of fire. The bloom is also called sponge iron because of its resemblance to a natural sponge. Somewhere along the way they figured out that they could make the iron harder by certain treatments.

According to Genesis 4:22, Tubal Cain was “an instructor of every artificer in brass and iron.” This means that mankind has been working iron for about 6,000 years. An iron blade, probably 5,000 years old, was found in one of the pyramids of Egypt. I read somewhere that the Earth’s crust is seven percent iron. There are places where you can pick up relatively pure iron ore off the ground. Iron meteorites were also used by early ironworkers.

Sometimes iron is in the form of black sand, which was a favorite source for the sword makers of Japan. Once the iron ore or black sand was collected, charcoal for fuel and a source of forced air was all that was needed. That is where the bellows came in, and bellows of animal skins are quite ancient. The Oriental method was to use an air pump, either round or square. Both methods would supply enough air to heat the charcoal fire to a temperature sufficient to reduce the ore into an impure form of iron. The earliest smelters may have been simple pits in the ground with

Shear steel, double shear steel and cast steel markings on knives from the 1800s.



Cross-section view of a primitive iron-making furnace.

Close up of the "damascus" pattern that shows up in old shear steel when etched. This blade was made from a large old circular saw.

clay tubes for the air supply. Later the smelters evolved into larger-capacity furnaces made of earth and clay.

The cross-section drawing gives a general idea of a furnace built of earth with a clay liner. The furnace would first be fired with charcoal to warm it up and then alternating layers of charcoal and ore were laid up and burned out. After several hours, smelting was complete. Some sources say the earliest furnaces were not tapped but that the bloom would be removed after it had cooled down. In some cases this meant tearing down the furnace. The bloom was a porous, metallic mass that was primarily iron but with some parts containing carbon in varying amounts.

I have a video of contemporary African steel makers that shows this process. The furnace is built into a hillside. In the most primitive of operations the bloom is forged out at a temperature that we would call a welding heat. They use a large rock for an anvil and another rock swung by a strong man as the power hammer that forges the bloom into a rough bar. The rough bar is forged out, folded and forged enough times at the welding heat to solidify and homogenize the iron. The narrator on the video says that this method has been in use for at least the last 1,700 years.

A later development consisted of breaking up the bloom and sorting the pieces according to the apparent grain size or hardness, then using the different parts for varying things. The process we know as pattern welding may have started when it was discovered that some of the layers created in the folding process were of a different appearance than the others. This would have been the result of welding together bars made out of material from different parts of the bloom.

The charcoal or coal fire can be reducing, oxidizing or neutral. The oxidizing fire has an excess of oxygen; this type fire will cause the surface of the steel to form scale and gradually be consumed. When there is an excess of carbon, iron has the capacity to absorb it at the right temperature. When iron absorbs enough carbon to cause it to harden, it becomes known as steel. It only takes one percent of carbon by weight to make high-carbon steel out of iron. The folding and welding process in the right type of fire would have given the iron enough carbon to become steel. This is probably what led the ancients to figure out how to make steel from iron.

Only in the last several hundred years it was discovered that carbon alloying with iron causes it to harden when quenched into water from a "cherry red" heat. Along the way it was discovered that iron could be "steeled;" this we call carburizing. When iron is heated with different organic materials containing carbon, such as horn or hoof trimmings, leather filings, charcoal or leaves, it absorbs carbon and becomes steel. Over a number of hours the iron absorbs the carbon that remains as the organic material burns up. This led to the making of blister steel, shear steel and cast steel.

Somewhere in history it was discovered that some forms of iron were harder than others. It was only a matter of time before it was possible to narrow the variables and produce blades that had comparatively good edge-holding ability.

The ancient method of "steeling" an iron bar left it with an outer shell that hardened in water, with the core remaining anywhere from soft to springy. Carburizing would be the modern terminology for steeling. During the process of forge-welding small bars of steeled iron together to make a larger bar, the material was refined and the carbon was diffused more equally through the bar. Welding together bars of dissimilar carbon content most likely led to the discovery of the layered look after etching, and the eventual development of pattern welded steel.

Blister steel was a later development where iron was carburized in large quantities. The surface of the carburized bars formed blisters during the process, thus the name. Blister steel was used for some tools; however, a higher grade of material was made as follows:

Bars of blister steel were stacked, forge-welded together, drawn out, sheared into smaller pieces, restacked and forge-welded once more. The finished product of this process was called shear steel. When the shearing, restacking and forge-welding was repeated, it was called double shear steel. When forged, finished and etched, old shear steel saw blades make beautiful knives. The pattern is a subdued layer look with a few surprise squiggles, and a very clear and sharp temper line.

Sheffield owes its fame as a steel-making center to Benjamin Huntsman, a clock-maker from Dorchester, England. In 1740 he was searching for better quality steel for his springs and pendulums. He discovered that shear steel, when melted in a crucible and cast into ingots, made steel that was much more uniform in composition than blister steel or shear steel. Steel made by the new process was called crucible or cast steel. Another type of crucible steel was made by melting wrought iron with charcoal and fluxes. The modern version of Wootz steel is made by melting in a crucible a pure form of iron and with a suitable source of carbon.

It is interesting to note that the new material did not find acceptance by the Sheffield cutlers, who claimed that it was hard to forge. After the French cutlers began to use it, their Sheffield counterparts began to realize its value as a blade material. Crucible cast steel was the highest quality material for knives in its day, but it would be no match for steel made by modern methods

What is steel and what do certain elements add to it?

Steel in its simplest form consists of iron, carbon and manganese. Steels containing only these three alloying elements are known as carbon steels. When a particular steel type contains more than these three elements it is classed as an alloy steel or tool steel. Tool steels are special-purpose alloy steels and have their own classification system. Carbon and alloy steels are classed by a number designation system: 1084, 1095, 5160, 52100, etc. Tool steels have a letter prefix: A-2, D-2, W-l, 0-1, etc.

The most important alloying elements in carbon and carbon alloy steels used for knives are carbon, chromium and vanadium. All steels contain manganese (Mn). However, manganese is not considered effective as an alloy element until added in an amount over .40 percent. Manganese is in all steels because it is necessary to make the steel sound when first cast into the ingot. Manganese also makes the steel easier to hot roll or forge.

The effect of a specific alloying element on steel is rather complicated because of the ability of one alloy element to boost the value of the other alloy elements in the steel. The value of a particular element when used alone may be five, yet when combined with one or more elements may be eight or more. The accompanying chart shows the common alloy elements used in knife steel and their effects on the steel.

Carbon (C) makes the steel hard. The more carbon steel has, the harder the steel (the hardness giving it the ability to hold an edge).

Chromium (Cr) is a strong carbide former and improves the steel's ability to be hardened. The hard carbides formed promote wear-resistance. When the chromium content is 13 percent or more, the steel can be classified as stainless.

Vanadium (V) is also a strong carbide former when found with chromium in

50100-B and 6150. The only real difference between W-l and W-2 (see the Steel Specification Chart) is the .20 percent vanadium in W-2. After working with these two steels, I can verify the positive effect of a little vanadium in a steel type.

Practically all tool steels contain small percentages of silicon (Si), .10 to .30 percent, and for much the same reasons that manganese is used. As an alloy element silicon is almost always used with manganese, molybdenum or chromium.

Nickel (Ni) increases the steel's toughness. It is found in L-6 (sometimes used for saws) and in amounts up to 2.75 percent in other saw steels. The strongest blades I have tested were made of saw steel, bearing witness to the usefulness of nickel as a toughening element.

With tungsten (W), the "W" stands for wolfram (an alternative name still used for tungsten). Tungsten increases wear-resistance somewhat in high-carbon steel when added to the extent of 1.50 percent. Four percent tungsten in 1.30 percent carbon steel causes the steel to be so abrasive-resistant in the hardened state that it is very difficult to grind. When added in amounts of 12 to 20 percent with chromium or in an amount of six percent with molybdenum, tungsten gives the steel the property of red hardness. (These steels are known as high-speed steels.) The red hardness is important in cutting tools that have high operating speeds. The heat generated at these speeds would draw the hardness out of carbon steel cutting tools. Few makers work with high-speed steel because it is so expensive and difficult to work. High-speed steels make an excellent knife where cutting ability is important and strength is secondary.

The last alloy element we will consider is molybdenum (Mo). It imparts somewhat the same properties as chromium and tungsten. It gives the air-hardening steels, such as A-2, the ability to harden in air. In large amounts and in conjunction with chromium, it imparts secondary hardening characteristics to the 154-CM/ATS-34 family.

The steel detective: Chromium vanadium steel

It was a big, thick leaf out of a truck spring that I bought at a yard sale many years ago. It was obviously new because it still had paint and symbols on it and was much too clean to have ever been under a truck. When I got ready to work it, I split it into four pieces with the oxygen/acetylene torch.

My plan was to forge one piece of it into a Bowie knife with a 15-inch blade. As I started forging I realized that it was harder to forge than if it were the 5160 I usually use for large knives. At first I thought it was because of the 3/8-inch thickness, but as I worked it down at the edge it was still harder to forge than 5160. I was beginning to think that it was not 5160 as I assumed it would be.

After the finish forging, normalizing and annealing, I ground it to prepare it for heat treatment. For heat treatment I heated the blade in my homemade gas forge. I used a magnet to judge the low end of the critical temperature, let the temperature climb a bit more and did an edge quench in my "goop." (Goddard's Goop is a mixture of paraffin, cooking grease and dirty hydraulic oil.)

As soon as it was cool enough to handle with bare hands I took it out of the goop. I immediately knew it was not 5160 because of the appearance. Blades come out of the edge quench with a distinct color difference between the hard edge and soft back. Edge-quenching of 5160 results in very little difference in appearance between the soft and hard parts of the blade. This blade had an absolutely clear visible line, as distinct as I have ever seen, and the edge portion was extremely hard.

After the clean-up grind prior to tempering, it showed a sharp and distinct temper line. The steel had a slight yellow tint to it; that's different than 5160. It took a higher than normal temper to get it to what I thought was right for a Bowie style. It was somewhat difficult to finish too, compared to 5160. I was now totally convinced that the blade was something other than 5160.

I finished that Bowie Knife with a Scagle-style handle and wrought iron guard. I

Wootz cakes and billets made by Al Pendray. The cake at the right has been cut in half to show the crystalline structure.

COMMON TOOL STEELS									
	C	Mn	Si	Cr	Ni	Mo	Co	V	W
W-1	1.00	.35	.35	/	/	/	/	/	/
W-2	1.00	.35	.35	/	/	/	/	.20	/
W-4	1.10	.30	.50	/	/	/	.25	/	/
W-5	1.10	.30	.25	.60	/	/	/	/	/
W-7	1.00	.30	.30	/	/	/	.50	.20	/
O-1	.90	1.60	/	.50	/	/	/	/	.50
O-2	.90	1.60	/	/	/	.30	/	/	/
O-6	1.45	1.00	1.25	/	/	.25	/	/	/
O-7	1.25	.35	.35	.60	/	.20	/	/	1.75
A-2	1.0	/	/	5.00	/	1.00	/	/	/
D-2	1.50	.40	/	12.00	/	.80	/	.90	/
D-3	2.25	.35	.25	12.00	/	/	/	.20	/
D-5	1.40	.30	.60	13.00	.50	/	3.30	/	/
D-6	2.00	.80	.35	12.00	/	/	/	/	1.2
D-7	2.35	/	/	12.00	/	1.0	/	4.00	/
L-3	1.00	/	/	1.5	/	/	/	.20	/
L-6	.70	/	/	.75	1.50	.25	/	/	/

Table of common tool steel types.

had it at the SOFA (Southern Ohio Forge and Anvil) Blacksmith Conference in the fall of 1998. I told the participants at my demonstration the whole story of working the steel. I said that I wasn't sure what the steel was because it was different than anything I had ever worked. One of the participants said he had experience with heavy truck springs and to him my steel sounded like 6150.

W-2 is more difficult to work than W-1, and the only difference is a small percentage of vanadium. That same degree of difference is what I found with 6150, and its small percentage of vanadium when compared to 5160 which has only carbon and chromium as alloy content.

All of the following steels either have been or are still used for springs: 4161, 50B60, 5160, 6150, 8660 and 9260. To determine if what I have in the large spring is actually 6150, the next step in this steel detective project is to purchase some 6150. I want to know what I'm working with, and from it I'll make a couple of hunting size test knives. Then we can compare them to some made out of the remaining spring that the Bowie came out of.

CARBON AND CARBON ALLOY STEELS		
STEEL TYPE	Number	Example
Plain Carbon Steels	10XX	1095
Manganese Steels	13XX	1350
Nickel Steels	2XXX	2340
Nickel Chromium Steels	3XXX	3150
Molybdenum Steels	4XXX	4140
Chromium Steels Low Chromium Medium Chromium	5XXX 51XX 52XX	50100-B 5160 52100
Chromium Vanadium Steels	6XXX	6150
Silicon Manganese Steels	9XXX	9160

Table of carbon and carbon alloy steel types. The first number is the classification, the last two the carbon content. For example, 1095 has .95 carbon.

STEEL TYPE	C	Mn	Si	Cr	Ni	Mo	V
4161 Chromium-molybdenum	.50	.80	.30	1.00	/	.20	/
50B60 Boron Steel 0.0005 minimum boron	.60	.90	.30	.80	/	/	/
5160 Low chromium	.60	.80	/	.80	/	/	/
6150 chromium-vanadium	.50	.80	/	.90	/	/	.18
8660 Nickel-chromium-molybdenum	.60	.80	.30	.60	.60	.20	/
9260 Silicon-manganese	.60	.80	2.00	/	/	/	/

A comparison of spring steel types.

Working with files and saw steel

Most modern flat files are one percent simple carbon steel. I have a large supply of older files marked Nicholson/Black Diamond. These files tested out at 1.25 percent carbon and make excellent knives. To gain superior strength, it is necessary to grind away the teeth from the edges, corners and sides that will make the edge. This eliminates stress risers that can cause cracking in the quenching process or unexpected failure while in use. Some rasps and files are not suitable for knives because they are made of a low carbon steel that has been case hardened.

It is easy to determine if a file or rasp is made of high carbon steel. Simply bring it up to the hardening temperature, quench it in warm oil and then see if it breaks like glass. If it stays springy, it is usually case hardened and not suitable for knifemaking. Before putting any labor into a new source of steel, it is imperative that you do a quench test to make sure it will harden.

I've seen old and new knives made from files that were broken, and the breaks were always running through a stress riser where a file tooth was not removed prior to quenching. Often you will notice a dark area at one side of the break that is exactly where the crack started when it was quenched. The elimination of stress risers applies to all types of steel. My experience is that the strength of blades is always dependent on the absence of stress risers, and that means removing most or all of the teeth from the surface of a file by grinding them off.

I decided to do a new forging experiment with a file to see if I was wrong about grinding some of the teeth off a file before forging on it. I forged a four-inch-long blade on the end of one of my favorite Nicholson/Black Diamond files. When the forged-to-shape blade was finished, the teeth were almost untouched along most of the spine and the sides within half an inch of the back. The teeth remnants decreased in the areas where the sides were forged to create the wedge shape of the blade. Enough teeth were left at the edge so that it needed to be ground to a depth of approximately .015 of an inch to clean them up. This is within the range of normal grinding to clean up after forging. With a little more grinding as security and with a correct heat treat, the blade would make a good knife. The only problem areas on my experimental blade were along the spine and on the sides of the blade. These are still stress risers and should be eliminated to make a first-class blade.

Before putting any labor into a new source of steel, it is imperative that you do a quench test to make sure it will harden.

My experiment convinced me that it is necessary to grind the teeth off the corners, edges and most of the sides that will make the edge. They're going to have to be ground off after forging anyway. Why take a chance on a tooth that can't be seen from being forged into the edge? Great care should be taken to eliminate every possible factor that might cause the blade to fail.

I have made several thousand knives from band and circle saw steel. (I just happened to be working for a saw manufacturer when I started making knives.) Saw blades are made from a variety of steel types. However, most are of the "Special Purpose `L´ classification." "L" steels make some of the strongest knives I have tested. The carbon content varies from medium to high with varying percentages of alloy elements.

Most saw steel is fairly high in nickel content (1.50 to 2.75 percent – see chart). In order to make good knives of saw blades, it is necessary to work out by trial and error a hardening and tempering method for each individual blade. If you have a large saw, it is wise to use it up before you start on another. If you mix and match heat-treat batches from different saws, you might not get consistent results. When an effective formula for heat treating is worked out and you start with a good, quality saw blade, the results can be excellent. I passed my journeyman smith requirements for the ABS with a blade made from a circular saw. It didn't crack and returned to nearly straight from the 90-degree flex test.

I use a magnet to judge the hardening and annealing temperature of files and saws. Heat the blade slowly and uniformly, occasionally touching it with the magnet. When the blade becomes nonmagnetic, it is an indication of the low end of the critical temperature. Let the blade climb another 50 degrees F and quench in warm oil. To anneal files or saws, heat to nonmagnetic and place them, while still hot, into a container of vermiculite for a slow cool. Vermiculite, also sold as Zonolite, is available at garden supply stores and places that sell firebricks and other refractory materials. Wood ashes, if kept dry and warm, will work for annealing.

I like to recycle materials as much as the next person. However, I teach my students to buy new bar stock and learn to work with one steel until it is mastered. 1084 and 5160 will run less than a dollar per knife. You will usually have to buy a whole bar and that will run $25 to $45, depending on the thickness and width. It is the labor that makes knives cost what they do. Steel is cheap, buy good stuff.

Knives made from horseshoe rasps

Some horseshoe rasps are case hardened and, as such, will not make good knives. The first thing to do is a quench test to see if it is made out of high carbon steel. Heat one end of the rasp to approximately red-orange (nonmagnetic) and quench in water. Put the very tip in a vise and then flex to see if it breaks clean. If it breaks like glass it is has the right stuff in it to make a good knife.

After shaping the blade, heat treat as follows: Judge the hardening temperature with a magnet. Heat slowly and uniformly to where the magnet no longer is attracted by the blade. Let the temperature climb just a little bit more, then quench in oil that has been warmed to 130 degrees F. Remove the blade from the oil when it has cooled enough to handle with bare hands. Clean the blade down to bare metal by sanding. Place in an oven that has been heated to 400 degrees. Leave for at least an hour and a half, then remove the blade but keep the oven on. When the blade reaches room temperature place it back in the oven for another temper of the same time as the first. The blade is then ready for finishing.

Stainless steel

A quick test for stainless is to use the type of cold-blue solution used to touch up firearms. Clean the part to be tested and apply a drop of the cold-blue solution. An immediate color reaction rules out the part being stainless steel. Check it with a magnet. If it attracts the magnet it may be martensitic stainless, which can be hardened by quenching. If the stainless is nonmagnetic it is most likely an austenitic stainless and that means it cannot be heat-treated. Not too common is ferritic stainless. It is magnetic but not hardenable by heat-treatment. It is used in high-temperature applications where strength is not the most important factor.

Safety note: Always wear a full face mask or safety glasses and heavy leather gloves when flexing knife blades.

Stainless Steel Used for Knives

Identifying the steel used in handmade knives is more cut and dried than for commercial knives. Most makers of handmade knives know what their steel is and can tell you a number or name that the steel manufacturer calls it. Furthermore, the maker usually knows the alloy content and can explain the advantages of why he or she used this particular steel for a certain application. It is much different with commercially manufactured knives. When it comes to the higher quality knives being manufactured in 2010, it is unusual that manufacturers state exactly what type of steel is in any particular model. Some even advertise exclusive steel, which seems silly to me. I guess they figure that the competition isn't smart enough to have a $50 chemical test done in order to find out what the steel is.

It is interesting to look at the way a lot of factory-made knives are advertised by mail order firms. One could form the opinion that they either don't know exactly what the steel is or don't care to share this information with the potential customer. I made a list of how the stainless steels were described in some of the most recent mail order cutlery catalogs that come in the mail. By the time I was finished with two catalogs it was clear to me that it was not a priority with these folks to inform the reader with accurate information about the steel types used.

The first steel listed was Sandvik 12C27. The catalog stated exactly what the steel was and I appreciate that. This is a very excellent stainless steel made in Sweden.

The rest of the stainless steels were described, in order as found, as follows: Strong stainless steel, 440-C, mirror-polished stainless steel, 440-C high carbon steel. Many were just listed as stainless steel, 440, high carbon martensitic, 440 stainless, 440-B, 440-B modified, 440-A, T80, ATS-34, G-2 and AUS-6.

Let's do some guesswork.... Strong stainless steel could mean that they do not know what it is, but they have tested it and it is strong! Perhaps the mirror-polished isn't as strong and the best thing they could say about it was that it was mirror-polished! 440-C is always high carbon and always martensitic, (that means it is hardenable). The one listed 440 could be 440-A, 440-B or 440-C, but which is it?

The ones listed as 420, 440-A and 440-B, are cut and dried. The one referred to as "Surgical Steel" is probably 420, high carbon, martensitic, strong and mirror-polished steel. XT80 is a new one to me and I haven't a clue as to what is in it. ATS-34 is an old standard.

Stainless Steel

Chromium is the element that makes stainless steel highly resistant to pitting and staining. The folks who make steel decided that 13 percent chromium is necessary to make steel stainless in what they call "normal use". Stainless steel does not become "stainless" until it is properly heat teated.

	C	Mn	Si	Cr	Ni	Mo	Co	V	W
STEEL TYPE									
440-C	1.20	1.00	1.00	18.00	/	.75	/	/	/
425 Modified	.54	.35	.35	13.5	/	1.00	/	/	/
CPM 420-V	2.20	/	/	13.00	/	1.0	/	9.00	/
CPM 440-V	2.20	.50	.50	17.5	/	.50	/	5.75	/
440-XH Stainless D-2	1.60	.50	.40	16.00	.35	.80	/	.45	/
ATS-34	1.03	.25	.41	13.75	/	3.56	/	/	/
ATS-55	1.00	.50	.40	14.00	/	.60	.40	/	/
BG-42	1.15	.50	.30	14.50	/	4.00	/	1.20	/
CRB-7® Alloy	1.10	0.40	0.30	14.00	/	2.00	/	1.00	/
Elmax Uddeholm	1.70	.03	.08	18.00	/	.75	/	3.00	/
RS-30	1.12	.50	1.0	14.0	/	.55	/	.25	/
RS-30	1.12	.50	1.0	14.0	/	.55	/	.25	/
MBS-26	1.00	.40	.65	15.0	/	.25	/	/	/
G-2	.90	.37	.60	15.50	/	.30	/	/	/
12C27	.58	.35	/	14.00	/	/	/	/	/
AEB-L	.65	.65	.4	12.8	/	/	/	/	/
AUS-6	.65	1.00	1.00	14.5	.49	/	/	.25	/
AUS-8	.75	1.00	1.00	14.5	.49	.3	/	.25	/
D-2 (Almost stainless)	1.50	.40	/	12.00	/	.80	/	.90	/

I've included D-2 to show how to close to being stainless steel it is. A few brands of D-2 have more chromium than the 12 percent listed on the chart. When properly heat treated and given a nice finish it will not stain in normal use.

Surgical Steel

I've not been able to find a steel company that makes a specific steel called surgical steel or even surgical stainless steel. In the past, I have seen at least four different steel types referred to as either surgical stainless or stainless surgical steel. My collection of steel catalogs turned up two different steel types that have surgical and dental instruments listed as applications. The first is Crucible Specialty Metals 440-A. Other typical applications listed for it are bearings, cutlery, seaming rolls and valve parts. The second steel type is Armco 420; applications listed for it are cutlery, surgical and dental instruments, scissors, tapes and straight edges.

I went from my steel catalogs to the Internet and Google. Keywords searched were surgical stainless and stainless steel. I found a strange and curious mix of products made of "surgical stainless." Even more interesting to me was that both

D-2 Specification Sheet

Tool steel type D-2 has been around forever (at least since WW1) and from recent questions about heat treating and forging it, there may be a resurgence in usage. It is one of my favorite steels for making hard working, stock removal knives. There are a lot of scrap planer blades around and these can be utilized in the hard stage, which is how I work them. They can be forged or annealed and worked with normal stock removal methods. D-2 is available from many steel manufacturers and most knifemaker supply companies.

	C	Mn	Si	Cr	Ni	Mo	Co	V	W
O-1	.90	1.60	/	.50	/	/	/	/	.50
A-2	1.0	/	/	5.00	/	1.00	/	/	/
D-2	1.50	.40	/	12.00	/	.80	/	.90	/
ATS-34	1.03	.25	.41	13.75	/	3.56	/	/	/

Preheat Temp	Austenitizing Temperature	Hold Time	Quench	Freeze Treatment	Tempering Temperature
1400-1475 Preheating is recommended to decrease the possibility of cracking or warping.	1825-1875	15-45 min	Air	-250 F 4-8 hours	Two hours two times 300 61-63 Rc 400 60-62 Rc 500 59-60 Rc 600 58-60 Rc 700 57-59 Rc 800-900 57-59 Rc

Annealing: Hold for two hours at 1600-1650 cool in the furnace at 50 F per hour below 1200 F then air cool.

HOLD TIME: Most of the useful alloy content of tool steels exists as microscopic carbide particles in the soft matrix of the annealed steel. These carbide particles must be at least partially dissolved into the matrix of the steel during the hold time at the austenitizing or hardening temperature.

CRYOGENIC TREATMENT: D2 is likely to have retained austenite after quenching. By cooling the steel to sub-zero temperatures, retained austenite may be transformed to martensite. In the past, freeze treatments were done between tempering cycles. Recent experimentation indicates that continual cooling from the austenitizing temperature to -250 f does the best job of transforming any austenite. New martensite is similar to the as-quenched martensite, and must be tempered to relieve the stresses created during it's formation.

TEMPERING: D-2 should be tempered at least 2 times for a minimum of 2 hours for each temper. All tool steels should be allowed to cool completely to room temperature between tempers.

FORGING: Heat slowly and uniformly to 2,000-2,100 F
Do not forge below 1700 F
Cool slowly from the forging temperature. (this does not anneal it)
D-2 must be annealed as per the instructions above for correct hardening results.

heat-treated and non-heat-treatable stainless products were being made of "surgical stainless." One company had Surgical Stainless Steel medical alert tags (316L). I found all of the following to be made of it: pots and pans, the genuine Ginsu® knives, kitchen utensils, handles for silverware, thermos bottles, miscellaneous jewelry items (including objects worn in pierced body parts), broadheads (steel arrowheads), and refrigerators. Most of the products I found were not identified by the actual type of stainless of which they were made.

I also found knives made of 420-J2 surgical stainless steel. One advertisement listed the alloy content of 420-J2 and it is identical to standard 420 as made by the steel suppliers from whom I have catalog sheets. As it turns out, J2 is a designation for the Japanese steel mill that produces the stainless steel used by that manufacturer. After my research was done I had worked myself into a circle and ended up back where I started with my collection of surgical stainless types. What I have to assume from this is that there seems to be no standard for surgical stainless.

As for alloy content, chromium and nickel are the elements that make steels stainless. Type 304 is an austenitic stainless and, among other things, that means it is nonmagnetic in the annealed condition and cannot be heat treated. The combination of 18 percent chromium and eight percent nickel make it a very good form of stainless for anything used in food preparation or surgical trays and appliances. Type 304 is sometimes called 18-8, the numbers coming from the percentages of the major alloying elements. 440-A and 420 are martensitic stainless steels and that means they can be heat treated. They are the stainless steels of which real surgical cutting-type tools are made.

There is one more group of stainless steels known as ferritic, which includes 405, 430, 430F and 446. They are magnetic but not hardenable by heat treatment. They are used in high-temperature applications where strength is not the most important factor.

The Old Favorite D-2

I call D-2 "The Old Favorite" because it has been around for a long time. I can't find the reference to it but I remember reading somewhere that it was developed during World War I in an attempt to find an alternative to High Speed Steel.

When properly heat treated, D-2 will make about as good a knife as could be wanted. A quick survey of the steels used by makers listed in *Knives '99* shows approximately 40 percent of the makers listed as using D-2 for at least part of their production. (The survey counted only those who list what steels they use.)

The "D" series tool steels are classed as Cold Work Tool Steels– high carbon, high chromium. All D-2 is not created equal; my 1969 "Guide To Tooling Materials" shows 51 versions. In '69, some steel makers put a little nickel and cobalt in their D-2. Others left out the silicon but added to the molybdenum. D-2 is made in a free-machining grade with the addition of sulfur. The free-machining grade does not polish well and hence is not as suitable for knives as the standard grade.

From the standpoint of the alloy content D-2 looks a lot like 154-CM/ATS-34. It would seem that D-2 with it's higher carbon content and .90 vanadium would have better edge-holding ability when compared to ATS-34 and 154-CM. My comparisons, which were done at a hardness of 60-61 Rc, indicate that there is not enough difference to notice.

Thirteen percent chromium is considered to make a steel type stainless by industry standards. D-2, which can have from 11 to 13 percent chromium when properly hardened and given a good finish, is very stain resistant. D-2, as well as all hardenable grades of stainless steel, loses stain resistance when not fully hardened. In normal use, I have not found it to rust or stain.

I use Ohio Knife Co. D-2 planer blades to make hunting knives. (See the chemical test results.) Note the additional carbon and vanadium, plus the nickel and tungsten which are not in most D-2 steels. I had been using OK-6 (Ohio Knife Co D-2) for over 20 years not knowing that it had the extra goodies in it.

With my brass-rod edge-deflection test, D-2 shows more strength at the working hardness of 60 Rc than 154-CM/ATS-34. I attribute this to the lesser amount of chromium and the addition of the vanadium. 154-CM and ATS-34 have a lot more molybdenum, which theoretically should give them more strength and toughness. The bottom line: When comparing the grain size, D-2 has a much finer grain, and a fine grain always means more strength.

One disadvantage of working D-2, at least in my planer blades, is that it does not take a shiny finish easily. It has a distinct orange-peel texture when overworked on soft buffs. I usually put a shiny satin finish on a working knife and call it good.

For many years it was puzzling to me why some makers and writers did not like D-2. The mystery was solved when I determined that their conclusions were reached using knives that were defectively heat treated. The hardening temperature of 1825-1875 degrees F is critical. When overheated, the blade will not be as hard as it should be. It does require a 20-minute soak time at the hardening temperature prior to air cooling.

I had a customer who did not like D-2 and I could never figure out exactly why. His favorite steel was 154-CM. When he asked me to develop a prototype design in a hurry and had not specified the steel type; I made it from the D-2 planer blade stock. He liked the way it performed and was very surprised when told it was D-2.

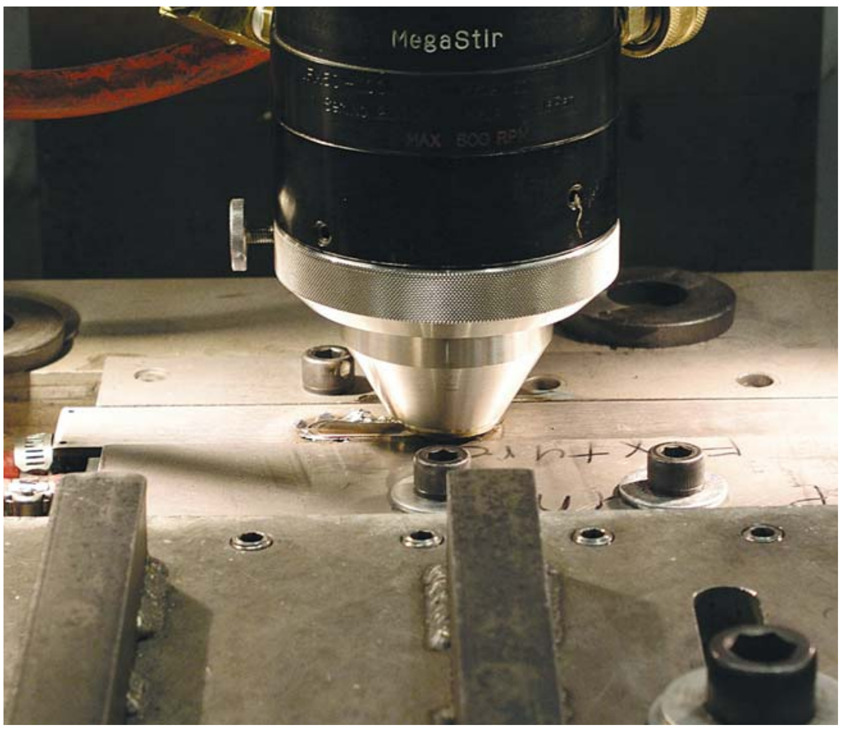
I needed a quick knife for the free-hanging rope cutting contest at the 1999 Oregon Knife Show. I used a large, new, Spear and Jackson (Sheffield steel) D-2 planer blade and ground out a straight-edged blade. The size limit of the blade for the contest was 12x2 inches, so I made my blade to the limit. It was as thin at the edge as any hunting knife I ever made. We started out with one rope at a time and worked our way up. I was able to complete a cut on six at a time which was good for third place. This knife is too thin to cut anything harder than rope so I am regrinding it with a thicker edge and will reshape it into a camp knife.

Friction Forged®, Mysterious Metallurgy

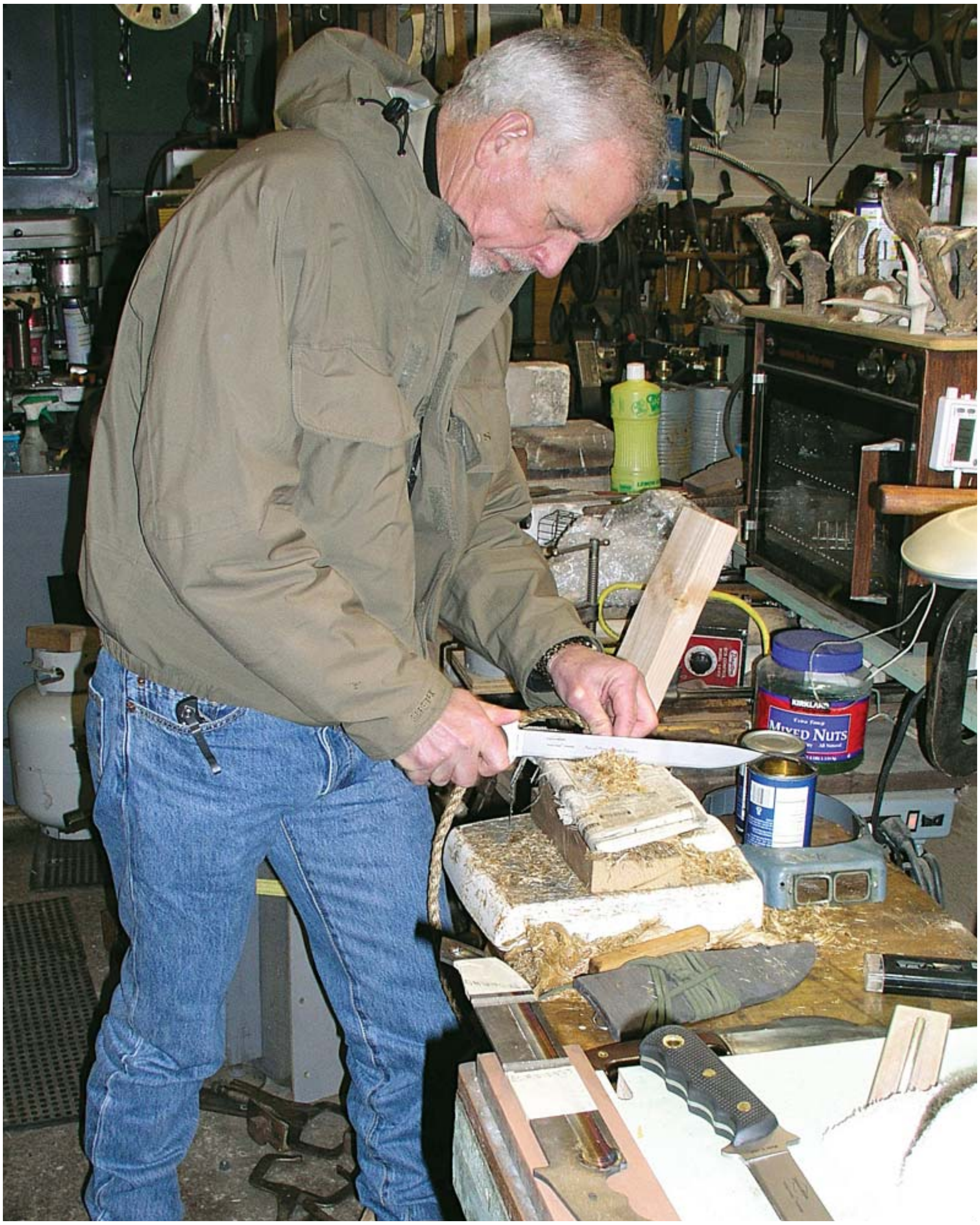
One of the first installments of a steel series I wrote for *BLADE Magazine* was titled "The Old Favorite Steel: D2" (February 1992). All these years after it was originally developed, it is most likely the most common steel used for tool and die making. Also, a high percentage of planer blades are made of it. It is very popular for handmade knives and some makers specialize in knives made of D2.

My old favorite is now available in a new "form" that has some unusual attributes as a result of a process called Friction Forging®. I first heard about this new material approximately four years ago when I received an e-mail from Charles Allen, owner of Knives of Alaska. He told me he was experimenting with a new forging process and asked if I would be interested in testing it when it was ready for market. I answered in the affirmative and then got to work thinking about what exactly friction forging might be and how it would be accomplished. As it turns out, I didn't have a clue.

The Friction Forged® stirring tool, called a probe, is made of PCBN, (polycrystalline cubic boron nitride). It has to withstand over 300 rpm with up to 10,000 lbs of down pressure. The only thing in the universe that is harder is diamond.



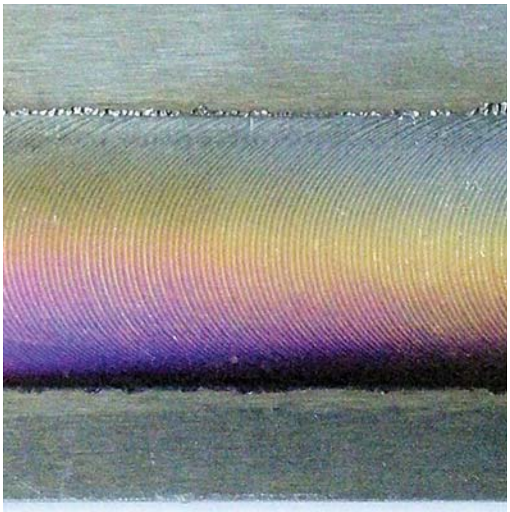
Here is the probe performing its forging duties.



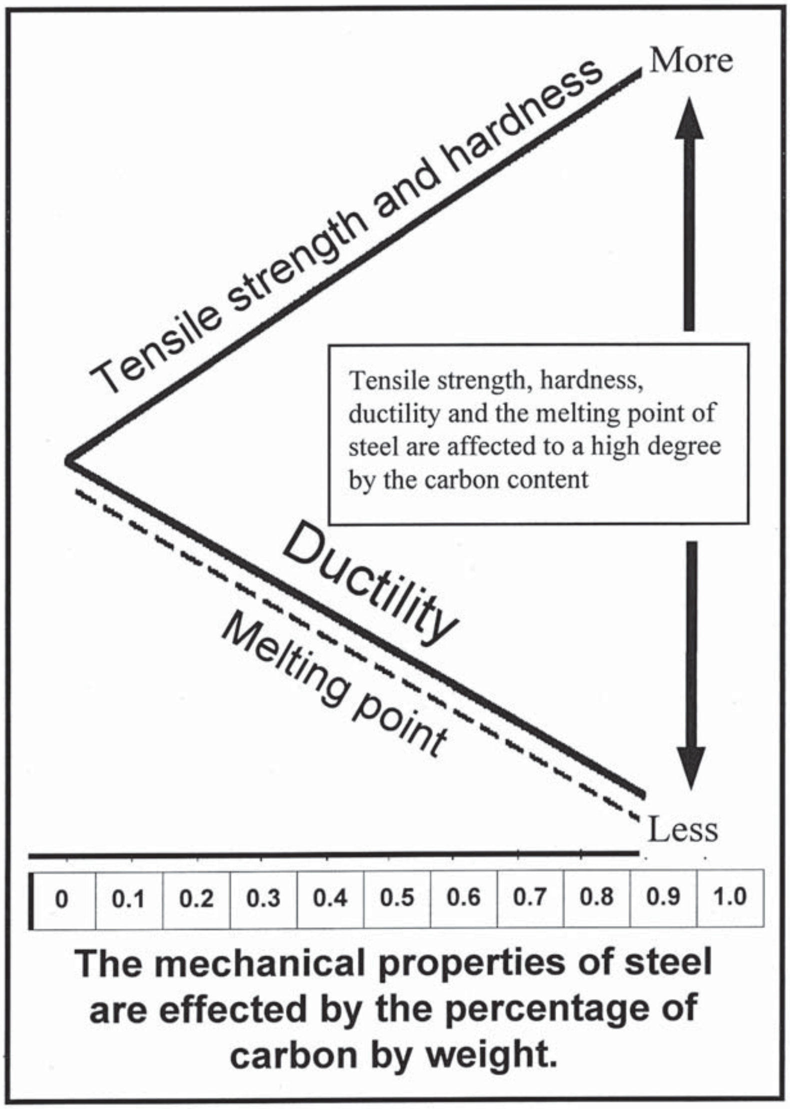
Charles Allen is doing his 100 cuts. Just out of camera shot are Chuck Karwan and I waiting to make our 100 cuts.

The day of testing arrived on a chilly spring morning in 2007. Charles Allen, his wife Jody and gun and knife writer Chuck Karwan were at my shop for some knife testing with a friction forged blade. The edge holding test procedure we used is what I've worked out over the last 35-plus years. After checking the edge to be sure that it was truly sharp, (no wire edge), Charles, Chuck and I took turns cutting with the Friction Forged® D2. All together we made 300 slicing cuts on ½-inch hemp rope. That same batch of rope had dulled the next best knife I ever tested at less than a hundred cuts. The Friction Forged test blade had shown very little decrease in cutting ability at 100 cuts; Chuck and I were starting to get the idea that we were testing something special. I think Charles already knew what the blade was going to do. All I saw on his face was a look of satisfaction. In my opinion, "The Old Favorite D2" has been reinvented in a most satisfactory way.

The object in slicing rope is to compare a test blade to a blade of known value. It's necessary to have a stopping point with the cutting; we chose to use the point where the edge no longer bites into the rope. The key to the test procedure is monitoring the pressure required to make a slicing cut. This is done by placing the rope



This close-up shows the forged zone on a blade blank.



on a cutting platform that is mounted on a scale. Test knives are made that have the same general shape, blade length and thickness at the spine and edge. In the comparison test it is essential to have all things equal. The test knife blades are one inch wide and 1/8-inch thick; flat ground down to an edge that is .020-inch thick, or less. The flat is kept on the edge all through the assembly and finishing of the knife. The last operation in making a knife is the sharpening. The sharpening bevel of approximately 15 degrees per side is established on a medium grit abrasive belt, then refined with the Norton India/Crystalon combination stone. The India (fine aluminum oxide) is used for the final edge with the wire edge being worked off with fine passes at an angle of about 30 degrees. The resulting edge will shave hair and yet will bite into the rope.

When cutting rope most knives quickly start requiring more pressure to make the cut. By 25 cuts the pressure starts increasing. Standard heat treated D2 will show a pressure of approximately 35 lbs at around 45 cuts on the ½-inch rope. This is the point where the edge loses its ability to bite into the rope and where it will no longer shave hair. Once again, the Friction Forged® D2 cut 300 slicing cuts before the pressure measured 35 lbs.

Charles was curious to see how the stock removal Friction Forged® blade would do in a test similar to the ABS performance test. He cut a free hanging one-inch rope multiple times, chopped a 2x4 in half several times and then flexed the blade to approximately 115 degrees without any damage to the edge.

The heat in the patented Friction Forged® process is created by a stirring tool (probe) made of PCBN (polycrystalline cubic boron nitride). The PCBN forging tool has a hardness that is second only to diamond. No other material has the strength and heat resistance to handle the stirring and compression of the metal required by the Friction Forged® process. The computer controlled PCBN probe penetrates the steel while rotating and creates frictional heating and stirring of the metal while it is in the plastic state.

The stirring of the metal at the forging heat in conjunction with the pressure and a carefully controlled cooling rate creates a unique form of the original material. The chromium carbides in standard D2 are quite large and "blocky." In the Friction Forged® form they are much smaller and distributed throughout the matrix of the steel. The Friction Forged® material has been transformed into a new form of D2 that makes the edge portion of the blade. The Friction Forged® D2 has an ultra fine grain size: .05 micron compared to 5 micron in standard D2. The ultra-fine grain imparts sufficient toughness to make a working hunting knife at an edge hardness of 66-68Rc.

The Friction Forged® edge isn't made of truly magic material, but as far as I'm concerned it comes close. The combination of technologies that came together to produce the Friction Forged® edge on a D2 blade is truly amazing. I have found no other steel that can be sharpened to such a keen edge that will cut rope for as many cuts.

Steel for a sword

When it comes to the type of flexible strength that a real sword needs, stainless would not be the best choice. I would recommend 5160, either stock removal or forged. It has what is required for taking a "good beating." When enough chromium is put in steel to make it stainless, there is a subsequent weakening of the grain boundaries. As a blade is flexed, the inside of the bend is put under compression while the outside curve is under tension. On the molecular level, the grain boundaries are trying to pull apart. The more a blade is stressed, the weaker the boundaries become. Microscopic cracks start across the grains and grow with the flexing. When enough of the cracks line up the blade will break.

My choice of 5160 chromium spring steel is based on tests of blades that are not over 12 inches long. My opinion is based on my own test procedures of what I call the combat-quality blade. Forged or stock removal, it wouldn't matter to me. The strength of the sword would depend on the excellent choice of steel and the proper heat treatment.

In my opinion, any sword that is the same hardness all the way through will break at some point of deflection. (I was assuming that it had enough hardness to be an effective cutting tool.) A blade could be made with a spring temper all the way through that would be very tough and unbreakable. Regardless of the flexible strength, it would have poor cutting ability and would be prone to bending from rough use.

When properly done, a 10-inch blade of 5160 with a hard edge and a soft back will flex 90 degrees without the edge cracking. The blade should return to around a 10- to 20-degree bend, which can be straightened without the edge cracking. My students and myself consistently make such blades. The 5160 will give up some edge-holding ability to the higher carbon blades, but the extra strength is worth it. These opinions are based on knife-sized blades but I believe they translate well enough to apply to sword blades.

The real secret to the success of the Japanese sword was in the selective heat treatment. In the best swords, the steel was very pure and refined; however, the heat treatment had to be just right to turn that superior steel into a combat-quality blade. The best Japanese sword blades were of a composite construction, and then selectively hardened. The edge was very hard and brittle with a carbon content that was ultra-high by today's standards. The back was a medium carbon steel and was soft, the center was springy.

The Metallurgy Of Knife Steels

As a metal cools from the liquid phase, there is a point where one spot becomes cool enough to solidify and form one unit cell. As the metal continues to cool, branches begin to form on the single cell. Eventually colonies of cells form and, when completely cooled, the colonies form boundaries which are visible with magnification. The individual colony of cells is called a grain. The term “crystal” usually refers to a colony but may be a single grain. A single grain or crystal of iron that is .10 inch in size contains 10^{18} iron atoms. A dendrite is a full-grown grain.

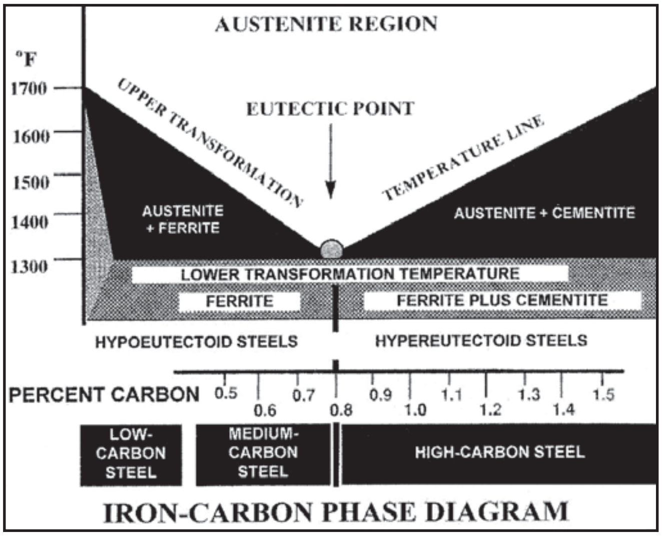
It would be proper to think of the finished knife blade as a mosaic of innumerable crystals. When we do this it gives us greater respect for the changes caused by the heat and pressure cycles. If we abuse the blade material, it can cause damage that results in a defective blade. Even if the blade is not outright defective, it will be inadequate when compared to one treated with proper respect. Blade steel is becoming more like a living thing to me as I gain a better understanding about the internal structure and the processes it takes to make a superior blade. The most desirable property in a finished blade is proper working hardness for the intended purpose. At the same time, we want a fine grain (crystal) structure that assures us a strong blade. This is achieved only by proper heat treating.

Steel recrystallized many times during the processes of rolling and annealing that brought it to us in the finished state as bar stock. Those of us who heat our steel to the plastic stage and then hammer it into shape put it through the recrystallization process many times. The final crystal size is determined largely by the last time through the recrystallization process during the quench. To a lesser degree the size and stressed condition of the crystal structure prior to heat treating has an effect on the finished grain size.

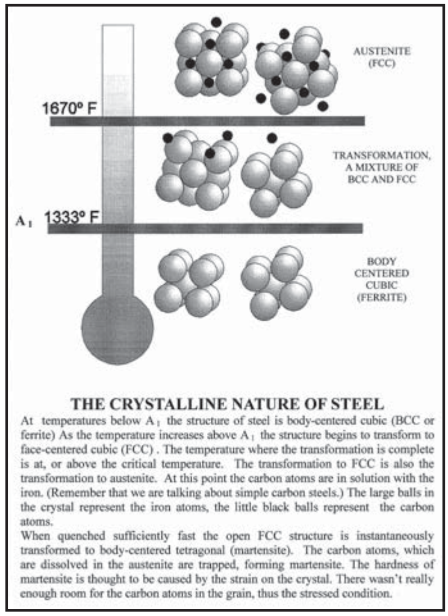
In the simplest terms possible, heat treating proceeds like this for simple carbon and most carbon alloy steels. Each steel type has a unique time-temperature sequence of heating, then cooling and then reheating again. The proper time and temperature sequence will result in a blade of great strength and excellent cutting ability.

When the steel is heated to a certain point and then cooled rapidly by quenching in oil, it becomes very hard and brittle. (An exception to this would be air-hardening steels.) When heated to a temperature of around 300 degrees F the hard and brittle steel starts to soften. This is called tempering and all blades need it to some degree. When heated to around 374 to 425 degrees F it becomes suitable for a knife. If heated to around 700 degrees F it is suitable for a spring. If cooled very slowly from the hardening temperature the steel becomes soft and malleable. Industry as we know it could not exist without the certainty that steel can be heat treated to a specific and suitable hardness for specific applications.

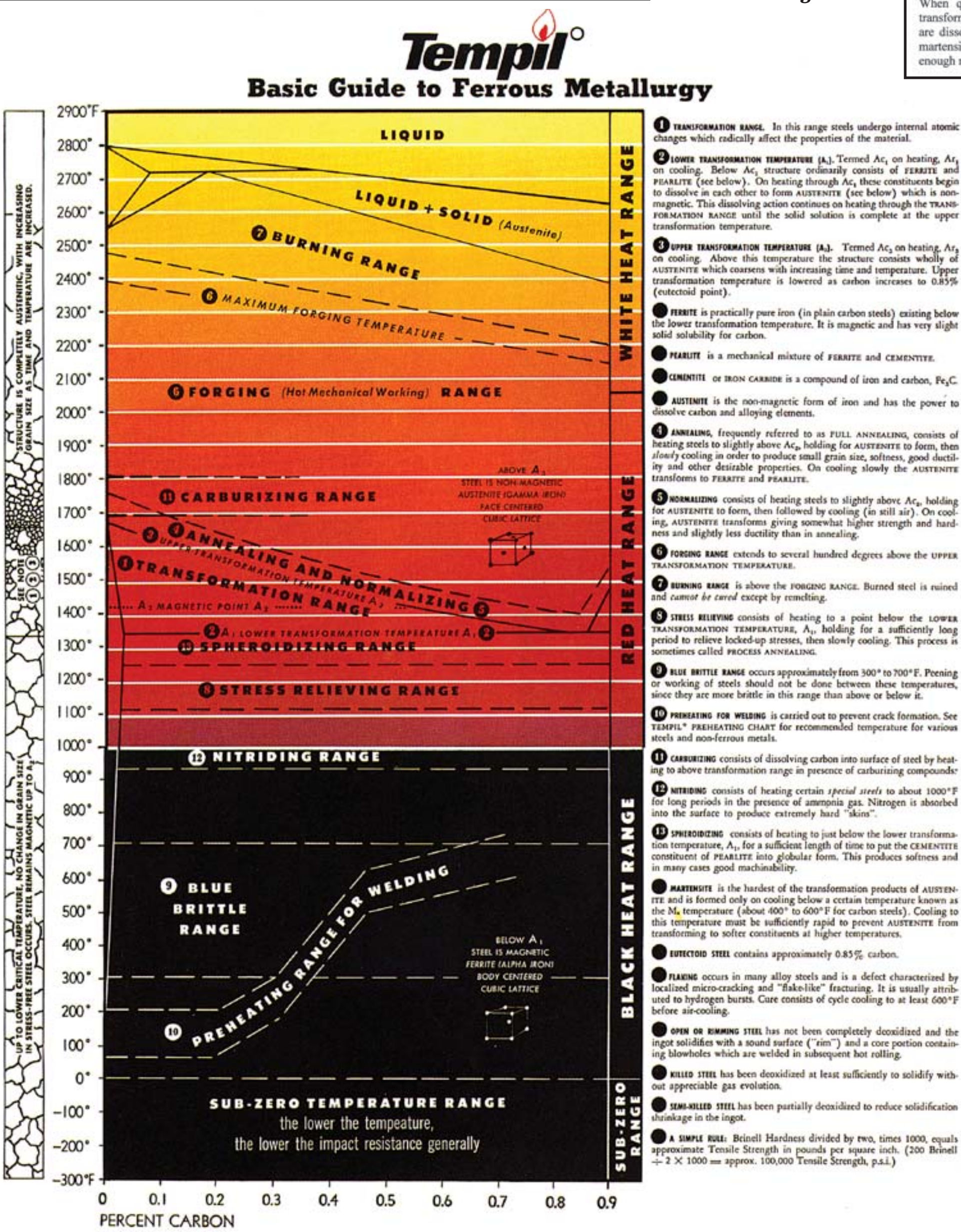
Steel is useful not only because it is can be hard, but because it can also be soft or anywhere in between. When heated to a certain point and cooled sufficiently fast



The crystalline nature of steel.



Once more, pay attention to the changes in temperature required as the carbon content changes.



Tempil° Basic Guide to Ferrous Metallurgy courtesy of TEMPIL, an ITW Company

There is a whole big lesson in metallurgy in this chart. Notice the extent to which carbon content affects the transformation temperature.

it becomes very hard, brittle and full of stress. Tempering is heating the hardened steel to a lower temperature. There is a specific temperature for each steel type that makes it durable yet hard enough to hold an edge. Annealing is a heat treating process that results in steel being in the softest condition possible; then it can be more easily shaped by milling, turning, grinding, press forming and etc.

It is important to not only have the correct degree of hardness, but in the case of a knife blade it is essential to have a fine grain structure. A knife blade that has a fine grain structure will always show superior strength to one of the same hardness that has a coarse grain. Blades fail because of poor quality heat treating; it's usually not the fault of the steel itself. Poor steel with good heat treating will make a superior blade when compared to one made of good steel with bad heat treating.

In my opinion there is too much emphasis put on steel types and not enough on proper heat treating practice. The proper heat treating for the intended use of the knife is the single most important characteristic of a quality knife. Proper temperature controls during the hardening and tempering operations insure that the blade will have a fine grain and the proper balance of not too hard or too soft. To accomplish this, it is necessary to know the temperatures required for the specific steel type as well as how to accurately regulate the heat source used for hardening and tempering.

Throughout the ages the hardening and tempering methods for steel have been either kept secret or made to be seen as magic or mystical. The actual molecular and physical changes that take place during heat treatment have only been well understood in the last hundred years.

Sixteenth century writer Vannoccio Biringuccio advanced the following theory of the hardening of steel: "When the pores of the steel have been well dilated and softened by the strong fire, and the heat has been driven out of them by the violence of the coldness of the water, these pores shrink and the steel is converted into a hard material which, because of the hardness, is brittle." A previous owner of the book where I found that had scribbled in the margin "Good grief!" I agree, but even though we know how to make steel hard and we can identify the hard form under the microscope, to the best of my knowledge it is still not understood exactly why the steel is hard. There will be more about that as this lesson progresses.

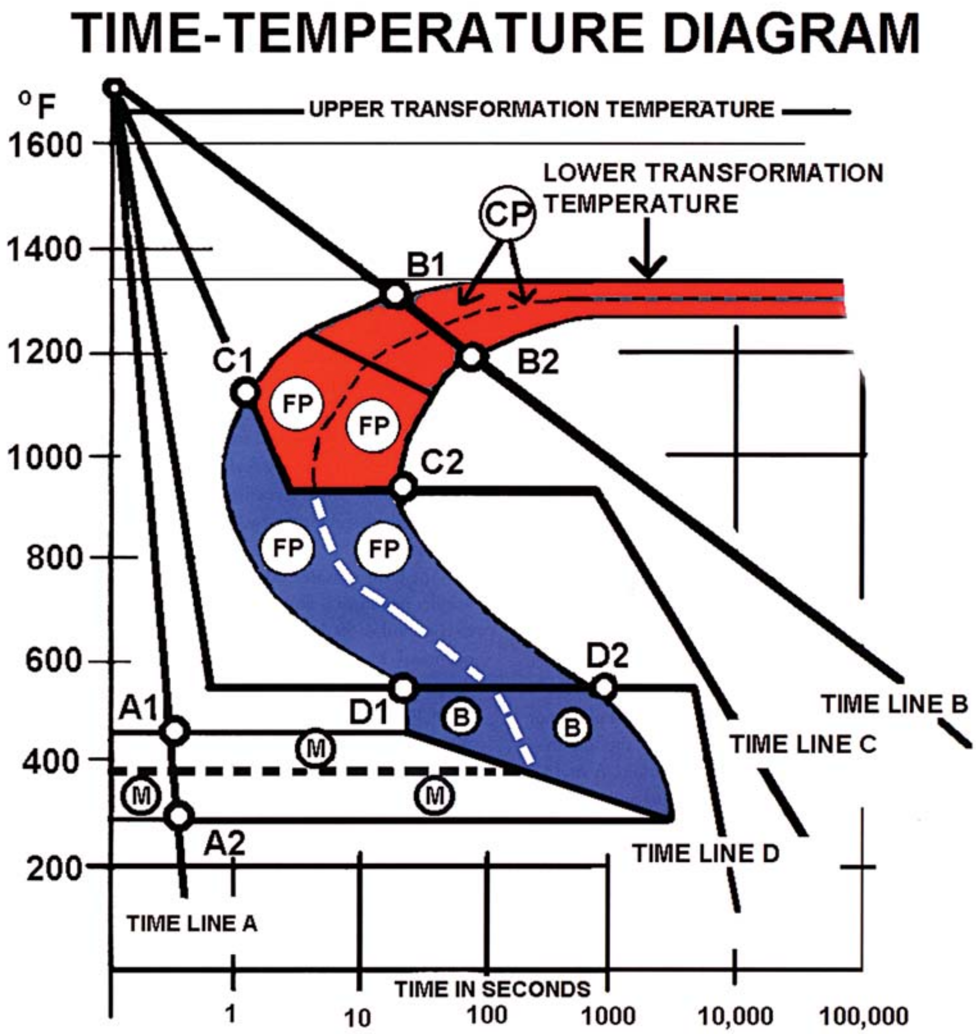
It seems to me that most of the books on metallurgy are written on a theoretical level and I have difficulty understanding them. It was after I found several books that were written on a more practical level that I began to grasp the fundamentals. I hope to present only what theory is necessary to present simply and clearly the fundamentals of metallurgy, and heat treating theory as it applies to knives. In order to do this I have modified some of the standard charts and diagrams in order to make them more understandable.

There is too much emphasis put on steel types and not enough on proper heat treating practice.

There are three elements to any heat treating process: heating, cooling and time. A little difference in temperature can have a big effect on the results. The element of time is less important, but is always the combination of time and temperature that is necessary to accomplish the transformations that give the desired results. Each steel type has its own unique combination of time-temperature cycles that will result in a blade of superior strength and cutting ability. These cycles can be charted and shown in a graphical manner and as such are known as isothermal transformation diagrams.

The Iron-Carbon diagram is the starting point for understanding the heat treating of steel. It shows the relation of carbon content to the transformation temperature.

When steel is heated above the transformation temperature, it takes an internal form known as austenite. Austenite is the nonmagnetic form of iron and has the power to dissolve carbon and alloying elements. The eutectoid point is where the upper transformation temperature line, the lower transformation temperature line and the 0.8 percent carbon pearlitic lines meet.



The time-temperature chart shows the effect of four different cooling rates as timelines A, B, C and D. Each steel type has its own unique "nose" curve which is determined by quenching sample pieces of the steel type at different cooling rates. In order for steel to become fully hard it must be cooled fast enough to miss the nose of the curve as in timeline A. This timeline results in martensite which is the hardest transformation product of steel. Martensite has to be tempered to make a serviceable blade.

Timeline B is the slowest cooling and results in the soft structure coarse pearlite. Coarse pearlite is a combination of coarse pearlite, coarse ferrite and coarse cementite.

Timeline C causes the steel to have the structure fine pearlite.

Timeline D causes the steel to transform to banite. Banite is more ductile than martensite and is a good compromise between the softer structures ferrite, cementite, or pearlite and the hard and brittle martensite.

Breaking the tips off of knife blades is not a total waste of good material.

The two triangular blue areas on each side of the eutectoid point make up the temperature transfer range. This is where the action is. On the rising heat the low temperature structure of ferrite, pearlite, cementite or martensite is transformed to austenite. On the falling heat, depending on the speed of cooling, austenite is transformed to martensite, ferrite, pearlite or cementite.

Martensite is the hardest of the transformation products of austenite and is formed only on cooling below a certain temperature known as the ms temperature (about 400 to 600 degrees F for carbon steels). Cooling to this temperature must be sufficiently rapid to prevent austenite from transforming to softer constituents at higher temperatures. 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. Cementite or iron carbide (fe3c) is a compound of iron and carbon.

Note the following on the iron-carbon phase diagram.

1. The lower transformation temperature remains the same regardless of the carbon content.

2. The upper transformation temperature changes with the carbon content.

3. Below the lower transformation line the structure of hypoeutectoid steel is ferrite.

4. Below the lower transformation line the structure of hypereutectoid steel is a mixture of ferrite and cementite.

5. The crystal structure of ferrite is Body Centered-Cubic (BCC). The BCC crystal is a tightly packed arrangement of atoms.

6.The crystal structure of austenite is Face-Centered Cubic (FCC).

7.The mixtures of austenite + ferrite and austenite + cementite exist on the rising heat in the area between the lower and upper transformation temperatures.

As the ferrite crystal is heated above the lower transformation temperature (approximately 1333 degrees), it opens up and begins the transformation to BCC. When carbon is present the carbon atoms slip between the iron atoms and form a solid solution of iron and carbon (Austenite). (See diagram.) When Austenite is cooled rapidly it transforms to martensite. If austenite is cooled at a rate slower than necessary to form martensite it transforms into a variety of structures dependent of a specific rate of cooling.

Carbon atoms trapped in the iron put strain on the lattice structure of the crystal. The stressed condition of the crystal is thought to cause the extreme hardness of martensite.

Proper heat treating for a stock removal knife blade starts with the blade in the annealed condition. When annealed the steel responds to the transformation temperatures in a consistent manner. Bar stock that is purchased for making stock removal knives is usually HRA (Hot rolled and annealed) and as such is in the proper condition to go into the heat treating operations. Those who forge blades must normalize and anneal, or normalize only, to prepare their blades to get them ready to respond properly to the subsequent heat treatment.

A quick metallurgy lesson from the school of hard knocks

In 1983 I started testing my selectively heat treated blades with the 90 degree flex test. These were a mixture of damascus and forged. Some of those first test blades broke between 45 and 90 degrees and the fracture showed a medium to coarse grain. I had read just enough metallurgy to realize that a coarse grain usually meant that the blade was overheated going into the quenchant. I had heard of using a magnet to test for the hardening temperature but had never tried it. I started using it and no longer had broken blades. The magnet taught me that I could not judge the hardening temperature by eye. Breaking the tips off of knife blades is not a total waste of good material... that's where I get the material for those little friction folder blades!

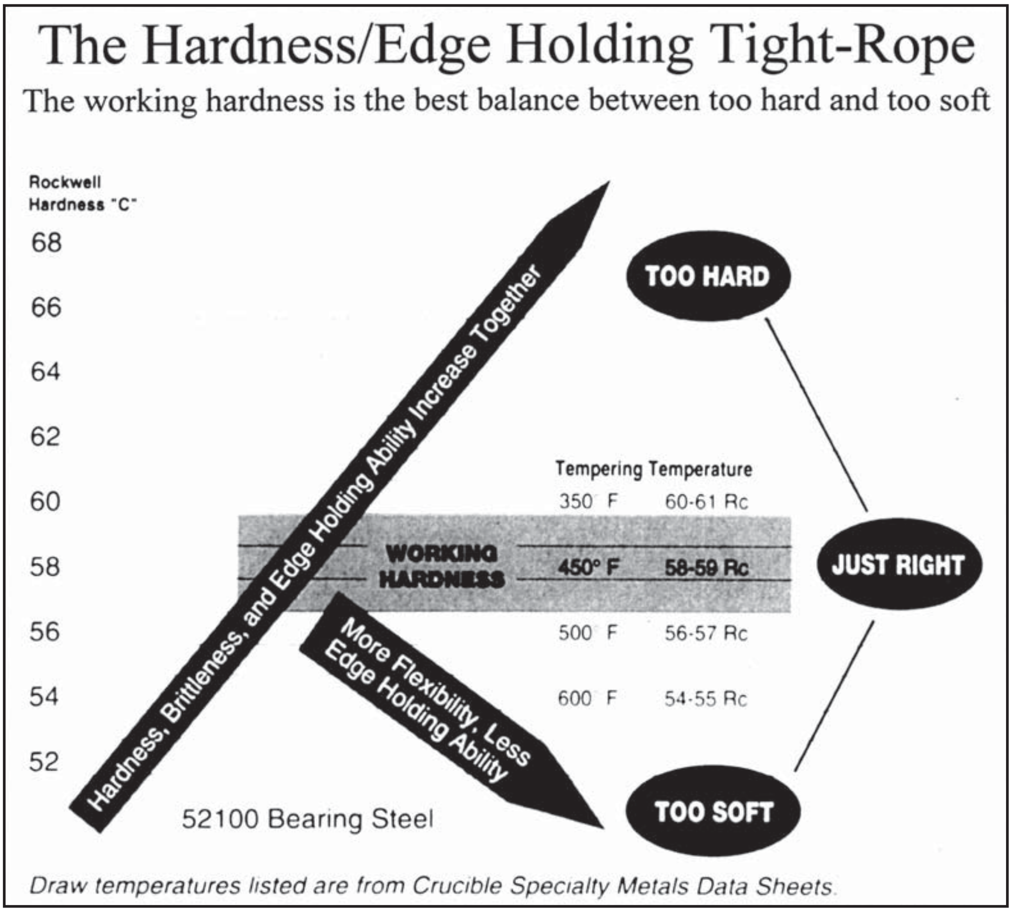
An interesting thing happened about that same time. I was ready to test two heat treated blades that I had forged from Nicholson Black Diamond files. I had judged the hardening temperature by eye on the first blade. The second blade was hardened using a magnet. I had gotten them mixed up and did not know which one was which. I tried them with a file and one seemed a little harder than the other was. I'm still not sure why I did it but I hit the two blades together edge to edge. One blade notched the other with little damage to itself. This was puzzling because the blade that was notched seemed to be the harder of the two. I broke off the tips of the two blades and studied the grain size. The notched blade showed a medium to coarse grain and the undamaged one had a nice fine grain. Learn to think of the heat treating process as necessary to end up with a fine grain in the knife blade that at the same time is hardened and tempered to perfection.

Heat Treating Knife Blades

All blades are not created equal. Variance in heat treatment causes discrepancies in performance. A blade that chips in normal use is not worth much as a working tool. The same is true if a blade does not have the full potential of edge-holding ability that is typical of that specific steel type. When a blade fails, the blame often falls on the steel. Usually the heat treatment is at fault. Proper heat treating for the intended use of the knife is the most important part in the making of a knife.

Heat treating, the real secret to blade performance

I once read the following in a magazine article: "I've had D-2 that stained like O-1, was too hard, was too soft, and in effect D-2 has shown me more variation than



The tightrope between too hard and too soft.

Here is an example of complete mastery of blade heat treating. Back in 2000, Audra Draper passed the American Bladesmith Society requirements for Master Smith. Her damascus blade cut a free hanging one-inch rope, chopped a 2x4 in half twice and then survived the 90-degree flex test. She went on to pass the Board of Judges workmanship and design inspection at BLADE Show in Atlanta. She was the first female to earn the Master Smith rating. Audra's husband Mike passed his Journeyman Smith requirements the same day. (Leather gloves and a face mask are required for the test, this picture was posed.)

any steel I have worked with." Why would an experienced knife user find this much variation in a most excellent steel type? I find D-2 to give absolutely consistent and superior results. My opinion is that the variances found were not the fault of the steel but could be traced to differences in heat treating of the individual knives. The one that stained like O-1 may not have been D-2 and that would not be the first time that a maker mixed up his steels or that a writer got confused.

Heat treating methods used by knifemakers vary quite a lot. From studying the performance of many blades produced by a variety of methods, I have come to believe that using a specific method is not as important as getting good results with another method. In other words, any method can be misapplied.

Why settle for the common denominator when the ultimate blade material is out there just waiting to be discovered? Ed Fowler's experiments with 52100 ball bearing steel and Al Pendray's search for the steel known as Wootz point out the advantage of taking a steel type as far as is possible. With help from some really bright metallurgists, Charles Allen brought Friction Forged® D-2 to the knife world. They brought together several state-of-the-art processes and created a totally new form of D-2 tool steel.

There seems to be too much emphasis on specific steel types and not enough thought put into the effectiveness of the heat treating. A question I hear a lot is, "what is the best steel?" My typical reply is that it depends on the heat treatment. In the past I have made the statement that I believed a large percentage of the commercial and handmade knives were not heat treated to their full potential. I'm happy to say that quality of heat treating is improving. Many commercial companies are making blade performance a priority. Better steel with improved heat treat is bringing commercial knives closer to the performance level of handmade knives. This is a nice change from the tendency of the commercial knifemakers to choose a steel type because it was easy to work.

In the simplest terms possible, heat treating proceeds like this for simple carbon and most carbon alloy steels. Each steel type has a unique time-temperature sequence of heating, then cooling and then reheating again. The proper time and temperature sequence will result in a blade of great strength and cutting ability. When the simple high-carbon steel is heated to a certain point and then cooled rapidly by quenching in oil it becomes very hard and brittle. When heated to a temperature of around 300 degrees F the hard and brittle steel starts to soften. When heated to around 374 to 425 degrees F it becomes suitable for a knife. If heated to around 700 degrees F it is then suitable for a spring. If cooled very slowly from the hardening temperature the steel becomes soft and malleable. Industry as we know it could not exist without the certainty that steel can be heat treated to a specific and suitable hardness for specific applications.

The quench: Oil hardening

White, billowing, smelly clouds of smoke mixed with split tongues of flame swirl from a bubbling pot. There's no witch here with pointed hat, broom and black cat, but an old guy with a white beard wearing a dirty, wrinkled shop hat. He squints through the smoke and flame, watching for the boiling to subside. Something very hot hangs down on a wire into the bubbling oil.

The old guy sticks a scarred, callused finger into the oil, gently feeling for the last of the heat to exit the blade. At last, he pulls the blade from the oil and attacks the edge with a file. This produces a loud noise but has no effect on the glass-hard blade. A look of satisfaction spreads across the old guy's face as he unceremoniously dumps the blade in a box full of sawdust. He gives the blade a thorough rubdown with a stiff wire brush to remove excess oil and sawdust. Coarse abrasive paper is used to remove the dirty black scale and then the blade is put into a small oven for tempering to the exact degree of hardness. The quench may not always be exciting, but it is always the process that imparts life and usefulness to a fine blade.

Most knife steels are oil-hardening, and almost any kind of warm oil will work. I have used all of the following: used motor oil, used and dirty automatic transmission fluid mixed with motor oil, cooking fat saved from the kitchen, old heat-treating oil, and many mixtures of the above. Always warm to a minimum of 130 degrees F for whatever oil you are using for the quench. Cold oil does not suck the heat out of the blade like warm oil will.

Quench oil is usually of a mineral type with additives to give it desirable properties, and is generally rated as fast, medium or slow. The worst thing is to have an oil that is too fast for the steel type, which can cause cracked or broken blades during the quench. On the other hand, if the oil is too slow, the steel may not get as hard as it should. Two common quenchants used for knives are Texaco Type A and Brownells Tough Quench.

Goddard's Rule of Heat Treating is: "Never quench any blade in water unless it did not get fully hard in an oil quench."

I do most of my quenching in a substance that has become known as "Goddard's

This blade is getting an edge quench in goop.

Goop." It is about one-third of each of the following: paraffin, cooking grease from the kitchen and dirty hydraulic fluid. It works great and everything quenched in it gets very hard. At room temperature it is a solid, and I like that. I developed it to have a quenchant that I could haul cross-country while teaching and demonstrating without worrying about spilling it. The only disadvantage is that it flames up, but I have learned to deal with that. The ingredients can be paraffin, lard and canola oil from the grocery store. It needs to be solid enough that it can't be dented with a finger tip.

I happened to come across an old recipe for a quenchant that sounds similar to Goddard's Goop. It is as follows: "For tools requiring a hard, tough edge, two-thirds tallow and one-third beeswax and a little saltpeter. Quench the edge and draw to a light straw color. I haven't tried the saltpeter, it is claimed to add nitrogen to the steel and that would make the blade harder and more flexible.

The purpose of the quench is to get the blade as hard as possible. Blades will never perform up to their full potential if full hardness in not reached in the quench. Blades fresh out of the quench should be too hard to file and the appearance of the grain when broken should be silky. The hardest blade can then be tempered back to exactly the correct working hardness.

Goddard's Rule of Heat Treating is: "Never quench any blade in water unless it did not get fully hard in an oil quench." I learned about water quenching the hard way in 1982 after I forge welded my first blade made of wire rope. I assumed wrongly that the basic 1085 steel that the cable was made of would safely harden in water. (I had never quenched anything in water.) That beautiful hunting knife blade that I had welded up with much excitement and sweat broke into four pieces as soon as it hit the water.

Overheating can also cause cracking of the quenched blade. Looking back on that experience I believe that the blade of wire rope may have been overheated. At that time I had not yet learned that I could not judge the hardening temperature by eye, testing taught me that. "The College of Hard Knocks" and making comparisons between different steels and methods just happens to be the way I have learned almost everything I know about working steel into knife blades.

After the quench, test it.

ABS School student Bill Nease forgot to check his newly hardened test knife blade after he quenched it. One stroke with a dull file would have told him if it had gotten hard or not. He selectively tempered it, installed a temporary handle, sharpened the blade and made a successful cut on a free-hanging, one-inch rope. (This is a test of sharpness, it shows nothing else about what will make a good knife.) The next test is to chop a 2x4 in half twice and the blade must still have the ability to shave hair. After chopping part way into the 2x4, the edge of Bill's test blade bent

ABS School student Bill Nease made blade-lore history by cutting the one-inch rope with a knife made of mild steel. However, the edge rolled over when he started on the 2x4 chopping. That was when we found out he got into the wrong steel pile. This event proved my opinion that cutting the free hanging rope is only a test of sharpness; it has little to do with the overall quality of the blade.

over. After some simple testing and detective work, I determined that the blade had been forged from mild steel. Mild steel was at the school for the making of pattern welded damascus. It was an honest mistake getting a piece of mild steel to forge a blade from. I did the same thing that same week, but caught my error when the material seemed too soft under the hammer.

My number one blade-making rule: Test every blade you quench for hardness. The quench should be such that the blade achieves the maximum hardness possible. Moreover, the appearance of the grain when broken should be silky. Breaking a sample piece of quenched steel and comparing the grain size with known samples will show if the quench temperature was correct. Would you rather assume that it was heat treated properly or break a sample strip of the hardened steel and observe the grain size. Fully hardened steel will exhibit a fine and silky grain and that indicates that the quench temperature was correct. When a blade is overheated going into the quench it will have a coarse grain. Coarse-grained steel will be hard enough to hold an edge but will be weaker than it should be.

The blade as quenched is too hard to be durable. It must be tempered so that it is neither too hard nor too soft. That's what is known as the working hardness. When the blade is too hard, it may chip out or break in use. If it's too soft, it will not hold an edge. The hardness that is correct for a specific steel type and application is something that should be worked out by trial and error and not left up to chance. Even in failure there is always some thing to be learned. Bill Nease accidentally proved that the free-hanging rope cut is only a test of the sharpness of the blade and has nothing to do with the quality of the steel or heat treating.

Tempering and selective heat treatments

The purpose of the quench is to get the blade as hard as possible and then temper it correctly. Anything else and the full potential of the blade will not be reached. A file test or Rockwell test is an essential part of the heat treating procedure. How accurate is a test with a file? I am convinced that I can consistently judge the hardness of a piece of steel to within one point on the Rockwell C scale by using a file. I have sample pieces of steel, each one a different hardness and I compare the effect of the file on the just-quenched blade with the sample pieces. I use the triangular files used to sharpen saws. The files are quite hard (64 Rc). A difference in hardness of two points is quite obvious; one point is barely discernible.

My number one blade-making rule: Test every blade you quench for hardness.

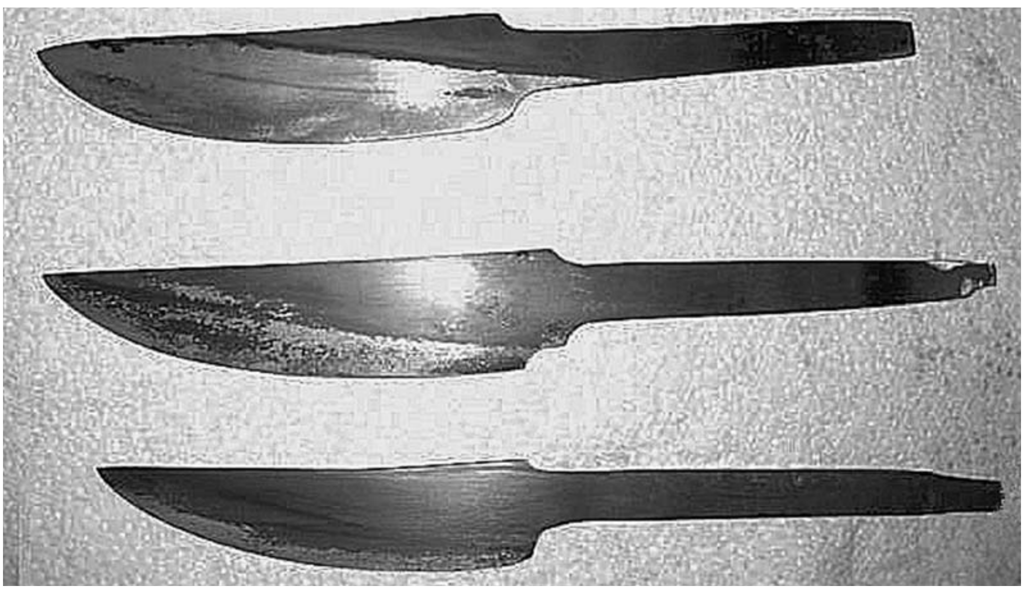
Reality Check

I was tested on my skill with a file when I gave a talk and demonstration to a metallurgy class at a local community college. The students were very impressed with the ability of a blade to flex 90 degrees without breaking. I told them it was the selective hardening and tempering that resulted in a blade with a hard edge, springy center and a soft back. One of the students asked what the hardness difference was between the edge and the back. I told him that the edge was 60-61 Rc, the center was 54 Rc and the back was 48 Rc. The instructor suggested that we go to the lab and check the blade. The hardness tested out just as I had said in the different zones on the blade (within one point). I hadn't tested that blade before but it was a steel type that I had used many times. I had my hardening-tempering formula worked out for that steel and I had tested enough blades to know what the results would be. That's the way it works.

When the blade comes out of the tempering furnace for the last time, the quality of the blade is pretty well set. Every time and temperature cycle that it experienced has had an effect, and the effect could be either good or bad. It is the maker's responsibility to determine if what he/she did was worthwhile. Testing blades will show very quickly where all weak spots are in the methods used for heat treating.

Selective hardening and tempering techniques

Most blades, commercial and handmade, are fully hardened and tempered. Not to say there is anything wrong with fully hardened blades, this method serves the



Three test blades that have been edge quenched at different depths. The blade at the top has too much hard part, the whole blade might as well have been hardened. The blade in the middle could use a little more soft back but isn't too bad. The bottom blade has the correct proportions of hard and soft. Note the appearance of the hardened part, the black layer of scale explodes in the quench.

world of knives very well. However, a blade with enough hardness to hold an edge that is fully hard will break at some point. I'll discuss and explain a variety of selective hardening and tempering techniques.

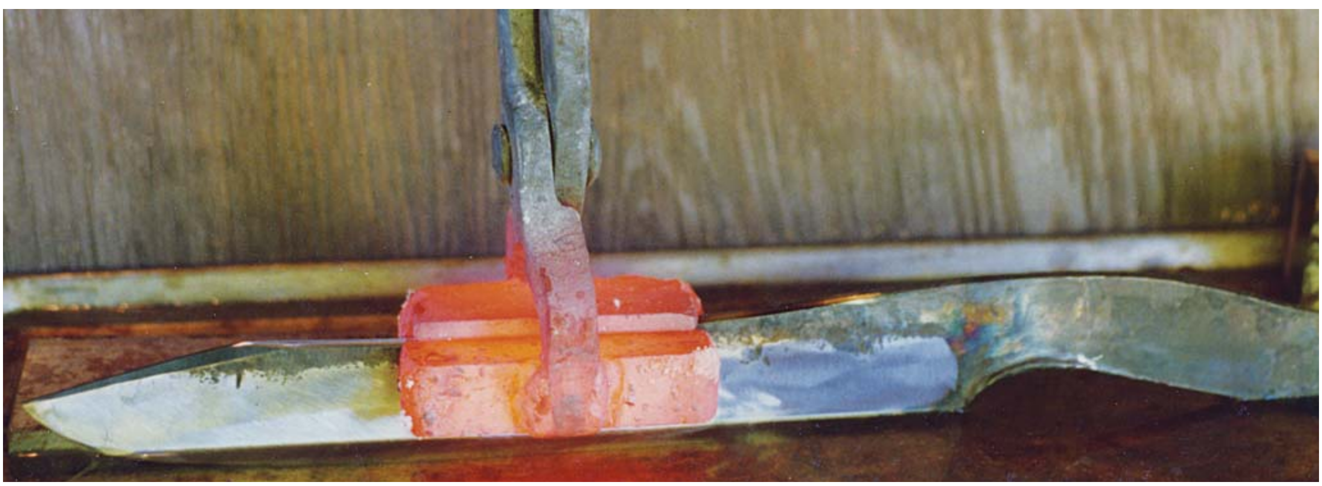
What appears to me as the oldest method is to fully harden the blade and then temper the back to spring hardness or slightly more (45-50Rc). I'll call these blades, soft backed or selective tempered. When done properly the blades will not break. Selective Tempering (soft back draw): The whole blade is quenched and then the back is given a blue color temper with the oxygen / acetylene torch. With practice it is possible to get an even selective temper down to the desired straw color at the edge. It is always wise to give the whole blade a one hour oven temper. Steels like O-1 and 52100 need an hour at the tempering temperature.

"Master of The Torch" Ed Fowler heating the edge of a blade. I'll bet it's made of ball bearing steel and will be edge quenched.

Another method and probably more popular is edge hardening, also called edge quenching, in which the differential hardness is developed in the quench. In my opinion it is easier to learn, and it has been easier for my students to master. The whole blade is heated and then quenched edge down in a pan of oil. A block of steel or aluminum is placed in the pan to regulate the depth that the edge will penetrate into the oil. Some makers use an adjustable platform to regulate the depth of the edge when quenched.

After comparing both methods, I have come to prefer edge quenching for the majority of blades that I make. It works especially well on thin, narrow blades. Edge quenching eliminates some of the variables that cause problems when heating the back of the blade with a torch. The whole blade is most often tempered to the working hardness desired, and selective hardening or tempering is capable of making a

The heat tongs are getting hot in the small heat treating forge. The heating surfaces are one-inch square and four inches long, that amount of orange hot steel is necessary to get a soft back draw on a large knife.



The heat tongs in action, the edge of the blade is kept in water to keep it from being over-tempered.

blade that will not break. The soft-back draw is used to soften the back of a blade while leaving the edge hard. Most usually the blade is fully hardened and tempered and then the back of the blade is softened sufficiently to eliminate breaking. When properly done it will give a blade the optimum in edge-holding ability and, at the same time, very good total blade strength. This is done by heating the back of the blade either with a torch or with special tongs that have been heated. The quick heating of the back is necessary so that the edge does not have time to become heated enough to soften it.

Another method of softening the back on a fully hardened blade is with heat tongs. I use this on large knives, and it is especially useful to soften the back on a fully hard completed knife. The photos pretty much tell the story.

The "goop" quench

I was fortunate to spend time with old time blacksmith Al Bart at the conferences of The Northwest Blacksmith Association. His wisdom came from years of practical experience added onto what had been passed down to him from generations of smiths. One of the things he told me was that he preferred to quench cutting tools in bacon grease. His opinion was that it made them good and hard and perhaps added some good qualities to the items quenched. Because bacon grease has salt in it Al figured it was giving a faster quench than plain grease.

Cutting tools need to be made as hard as is possible in the quench and then be tempered back for strength combined with edge holding ability. If a quenchant cools the blade too slowly, something less than maximum hardness will be achieved.

I started my experiments with grease quenching in 1984. I saved up a lot of fat from the kitchen, put it in an old coffee urn and started using it for quenching. It worked great in getting everything hard. It was exciting to use because it made a great deal of smoke and fire. It got rancid in time, and it was a problem to keep the neighborhood animals out of it. I reasoned that if it were harder, then it perhaps would not get rancid. About that time I bought a huge box of junk candles at a yard sale so I started mixing the grease with an equal part of candle wax. The candle wax was a mix of mostly paraffin with some beeswax in it. The improved goop didn't get rancid and the animals evidently didn't like the taste of it because they left it alone. I've improved the goop recipe by adding about 1/4 by volume of dirty hydraulic fluid. I like the way it works even better now and use it instead of oil for everything except double-edged blades, which require a tip down, straight-in quenchant container.

The goop stays semi-solid and that makes it very portable. It's difficult hauling oil around to demonstrations so having a quench medium that will not spill works out good. My traveling outfit is a 2x9x14-inch cake pan. For traveling it sets on its end in a five-gallon bucket with a thin piece of plywood for a lid. I surround it with hammers, tongs and steel, then I'm off for a day of fun. The one I use in the smithy is a stainless steel pan from a restaurant hot table; it's about 4x10x20 inches. It's just long enough to get a 12-inch blade, full tang, bowie or camp knife in by going corner to corner. I can do up to a 15-inch long narrow tang blade in the big pan.

The goop quench needs no preheating for an edge quench on small blades. The photo on page 44 shows a four-inch blade going into the solid goop. When doing blades 10 inches and longer I will heat a piece of scrap steel and quench it so as to create a groove of melted goop. The groove makes it possible to get the whole long blade cooled fast enough to completely harden. I usually have some small blades to do first, and at those times it is not necessary to preheat a slot big enough for a long blade. The goop burns quite nicely when overheated so caution is needed. Keep a lid handy to smother any fire that starts.

Keep a lid handy to smother any fire that starts.

After any quench, don't assume that a blade got hard; try every blade with a file to make sure it got hard. I use the triangular files used for sharpening saws. When too dull to sharpen saws they are just right for hardness testing and you can usually get them free from a saw shop.

The goop quench makes a lot of smoke but my smithy is open air so it's not a problem. I would not recommend using it in an enclosed space without some major ventilation being available. The advantage of commercial heat treat oil is the low flash point and small amount of smoke compared to most types of oil.

How to harden a dagger

When different areas of a blade are not the same types of structure they will not react to the etching process in the same way. The differences may be in the grain size or a difference in hardness. Either way, the cause is usually from uneven heating in the normalizing, annealing or hardening phases.

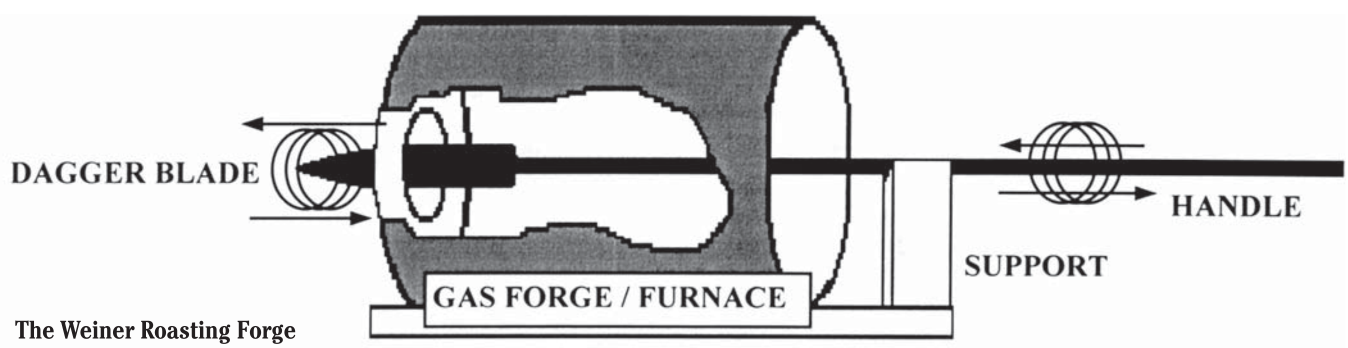
A dagger blade is very different in cross section from a single-edge knife. Because of the thickness of the center rib in relation to the edge it is easy to overheat the edge. My opinion is that the edge of the dagger blade was overheated going into the quenching oil. I would suggest that the blade be annealed and hardened again. Take care that you get an even heat and see if the blade etches out more even.

It is undesirable for the thin sections of a blade to go above the hardening temperature and then drop back when the rest of the blade catches up. The overheated sections will have a more coarse grain and there will be unequal stresses in the blade from the uneven heating. It is always best to heat slow and easy and quench the blade on the rising heat.

It is important to have the heat source for hardening running not too much hotter than the hardening temperature of the blade. This allows a slow even rise to the quenching temperature without overheating the thinnest sections of the blade. The fact that the edge of a double-edged blade comes up to temperature before the center can be used to your advantage. You can use it to make a selectively hardened blade, assuming that the evenness of the pattern is not important. I call it the "Wiener Roasting" System.

Here is how I do it. The heat source is a homemade gas furnace with a hole in the back end large enough to stick the point of the dagger blade through. The blade is welded onto a handle so that it is centered and balanced. It is necessary to be able to spin the blade and at the same time move the point through the opening in the back so that it does not overheat. The fire is regulated so that it is much hotter than the normal hardening fire. This is necessary to bring the edge up to temperature before the center rib absorbs enough heat to harden. It is wise to practice on a dummy blade to refine the technique. (Any new hardening system should be practiced.)

You will have to work fast and not make any wrong moves. When the edge is up to the hardening temperature the blade is quickly stuck point first into the quenchant. Take care to go straight in and you'll have less chance for a warped blade. If you can't get the edge hot enough to harden before the center of the blade comes up to temperature it means you do not have the furnace running hot enough.



The Weiner Roasting Forge

What hardness is best for a knife?

I was selling cutlery door-to-door in 1959 when I met an old time blacksmith who told me something like the following. "You can make a pretty good knife out of a lathe rasp. First, draw some of the hardness out of it by tempering it in an oven to a straw color, then just grind it out real careful so as not to get it hot enough to change the color of the steel." It took me a few years to find a worn out lathe rasp. I tempered it in the kitchen oven to a dark straw color and then ground it carefully to shape. I finished it up with a steel guard and a Myrtlewood handle. It didn't take a lot of knowledge about metallurgy or heat treating to get me started.

The year was 1963 and that was the start of my career as a knifemaker. It was a good knife, I used it to dress and skin several deer that I shot with a muzzle loader. I still have it and I like looking at it once in a while to help me remember how far I've traveled on my journey.

I went to work for a saw manufacturer at the same time I was finishing up that first knife. There were piles of scrap saw steel available, so I started using it. Those saw steel knife blades were heated to the hardening temperature in the large salt "pot" that was used to harden the saws we made. The pot, as we called it, was three feet in diameter and three feet deep; the molten salt in it ran at 1,475 degrees F. The saws to be hardened were suspended on hook type hangers and suspended into the orange-hot salt. At that temperature the salt was transparent enough so that the room temperature steel, when put into the pot, was visible until it reached the temperature of the salt. After sufficient soak time in the molten salt the saw blades were quenched in oil, cleaned up and then tempered to a hardness of around 44 Rc. If I remember right the tempering temperature was 750 degrees F.

I had no idea what the correct hardness for a hunting knife should be. I borrowed all the knives I could get from friends and the people that were in the two different gun clubs that I belonged to. With the knives I had a list of which knives they liked or disliked and why. It was a mixture of knives of all ages and quality. I did Rockwell tests on all the knives and compared the hardness with the list of likes and dislikes. The hardness of the knives that were best liked for edge holding

This is the color spectrum formed by oxidization of the steel surface on a carbon steel knife blade that has had a soft back draw. The oxide color is a true indication of the temperature reached in that portion of the blade. Another steel type would show a different color spectrum. An interesting exercise is to heat your oven up to 450 degrees F, insert three pieces of freshly ground steel; one of simple carbon steel, one of 5160 and one of whatever stainless steel you have on hand. After a minimum of 45 minutes, turn off the oven, let it cool down with the door shut and inspect the pieces once they are at room temperature.

Steel Type	440-C	ATS-34 154-CM	CPM T440-V	D-2
Preheat	Not necessary for blade size pieces	None	1550º-1600ºF, then transfer to a furnace	No preheat
Hardening Temperature and soak time	1850º-1900º F	1975ºF 40 minute soak at temperature	at 1850º-2050ºF Soak 10-30 minutes depending on the section size and hardening temperature. (Lower temperatures require longer soak times.)	1800-1875F soak 20 minutes DON'T OVERHEAT
Quenching medium	Air or Oil	Argon or rapid air	Air or Oil	Air
Hardness as quenched	59Rc	1900ºF 62Rc 1950ºF 60Rc 2000ºF 54Rc * ***see footnote***	Air @ 2050ºF 61Rc Oil @ 2050ºF 63 Rc Air @ 1950ºF 59Rc Oil @ 1950ºF 60Rc Air @ 1850ºF 54Rc Oil @ 1850ºF 57Rc	63-64
Tempering Temperature and Freeze treatment sequence.	212º F 59Rc 400º 56Rc	(As per Paul Bos) Freeze after quench -220º for 6-8 hours followed by two tempers of two hours @ 950º	Freeze treating should be performed between the first and second tempers.	450º F 59Rc
Spring temper hardness	50Rc 1150º F	50Rc 1050º F	50Rc 1100º F	50Rc
Working hardness	56-58Rc	58-60Rc	58-60Rc	59-61Rc
Annealing	For maximum softness soak at 1650ºF for six hours followed by a furnace cool. Cycle anneal by heating to 1600ºF, hold for two hours, cool to 1300ºF, hold for four hours, then cool in air.	For maximum softness, soak at 1650ºF for six hours, followed by a slow furnace cool. Cycle anneal by heating to 1600ºF, hold for two hours, cool to 1300ºF, hold for four hours. Then cool in air	Heat uniformly to 1625-1650ºF and hold for two hours, cool slowly with the furnace at a maximum rate of 25ºF per hour to at least 1200ºF, then air cool	Heat uniformly to 1550-1660F and cool slowly at a rate of not more than 20F per hour until the furnace is black. Turn off furnace and let cool naturally.

ability and strength were 56-57 Rc. From this I formed an opinion that the correct hardness for carbon alloy steel hunting knives should be 56-58 Rc. This was in the days before I ever dreamed about using stainless steel for knives. Because of the alloy content, and with proper heat treating, stainless knives of ATS-34 can have adequate strength at 60 Rc.

Edge-holding ability is almost entirely dependent on a relatively high hardness. I would estimate that 95 percent of handmade knives are between 56-61 Rc. The specific alloy elements in some types of steel will allow them to have more strength than other types at the same hardness. The intended use for the knife will determine the maximum hardness that will be acceptable.

Hunting-size knife blades will have adequate strength at 59-60 Rc when made of D-2 or 154CM/ATS-34. 440C is brittle at 60 Rc, so it is usually given a hardness of 56-57 Rc. When D-2 or 154CM/ATS-34 are drawn back to 56 Rc, neither will cut any longer than 440C at the same hardness. A knife with a hardness of 52 Rc will have almost no cutting ability, but it will be extremely strong.

Each steel type will have a hardness where adequate strength and edge-holding ability are at the optimum. This hardness is referred to as the "working hardness." Steel types that can be differentially hardened and tempered can have a hardness of 60-61 Rc at the edge, 54 Rc at the mid point and 47 Rc or less at the back.

My tests show a decrease of up to 20 percent in edge-holding ability when the hardness is decreased by two points. When tested at the same hardness, there is very little difference in the edge holding ability of the majority of steels being used for knives. Certain alloying elements will allow one steel to have a higher working hardness than another will. Most of the gain in edge-holding ability is dependent on the higher hardness, which was possible because of the gain in strength due to the specific alloys. The alloys themselves do not usually cause the increase in edge-holding ability.

Heat treating stainless steel

Heat Treating ATS-34

The optimum hardness for a hunting type knife of ATS-34 is 59-60RC. In my opinion, it is a waste of good material to make knives out of this material with blades under 59 Rc. When the hardness is decreased by two points, my endurance cutting tests show a decrease of 15-20 percent. ATS-34 is an excellent steel and has a very good reputation at hardness levels of around 59-60 Rc. The alloy content allows it to have good strength at this hardness.

There are those who believe the high temperature temper cycle used by Paul Bos results in less strength. I don't agree with that. Paul has done my heat treating of ATS-34 for many years and I find no fault with it. All theory aside, his blades speak for themselves.

I have presented the two methods so that you can compare and form your own conclusions. Let me know your test results if you get a chance to try both methods.

Heat treating 440-C

Quench hardened parts should always be tempered to relieve stresses set up by the quench. Quenched and untempered parts can develop cracks that will cause failure at some future time. Knife blades are tempered to give them the required hardness to be serviceable; stress relieving comes for free with the tempering process. The general rule is to temper as soon as possible. I'd guess that a double temper for two hours each time would be good. A six to eight hour freeze between the temper cycles will give you an improvement in edge holding ability and perhaps one point of hardness. The retained austenite will be transformed by the temper and freeze cycles. Your blades are gaining hardness as retained austenite transforms to martensite, but this is not the way to do it. As the retained austenite transforms it is untempered martensite and as such full of stresses that have to be

A toaster oven in the knife shop will help keep peace in the family.

The knife shop toaster oven. Note the plywood shelf on top, the finish nails hold blades backside down for air cooling between tempers.

relieved by the subsequent temper cycle. A good working hardness for 440-C is 56-58. Your tempering temperature of 450 degrees F would get you on the low side for hardness.

The finished hardness at any specific tempering temperature will depend on the as-quenched hardness. I don't heat treat stainless steel, so I have to go to the books or follow what Bos recommends. Crucible Specialty Metals data sheets gives the following tempering temperatures and the expected hardness for 440-C.

The toaster oven for tempering blades

The toaster oven is used for tempering carbon alloy and damascus blades. I send my stainless blades to Bos because I don't believe it is time- or dollar-efficient to do it myself. I expect 100 percent of the potential performance of the blade, and I get it with the blades he does. That includes the proper sub-zero freeze treatments that I believe are essential for stainless blades.

The last 10-plus years or so I've been using a Farberware convection oven for tempering carbon and carbon alloy steels. (That is anything up to 550F.) Like it's predecessor, it is also from a thrift store and cost me $5. It has a larger capacity and, since the heat source is outside the chamber, the heat is very uniform.

I made a good investment in a Sunbeam digital kitchen thermometer. It is very accurate and the price was less than $20. I had four of the standard old style thermometers in the oven and was testing them against the Sunbeam. They all read something different and the average of the old style readings was close to the digital. I drilled a hole for the flex probe so I could get the thermocouple in the center of the oven.

A toaster oven in the knife shop will help keep peace in the family. I tempered knives in the kitchen oven for almost 20 years. It was hard to get all the oil off of the blades and there was usually some smell of smoke in the house during tempering. I finally figured out I could do it in a toaster oven kept in the shop.

Just about any of them will work but the larger and heavier they are, the more accurate they are. Hotpoint made the toaster oven I mentioned. The internal chamber measures approximately eight by 12 inches. I bought it at an as-is thrift store for less than a dollar. It worked fine, but was very dirty. Some cook figured it was easier to give it away than clean it up. The gunk makes it just right for knife work. It's real nice not to have to worry about messing up your shop oven. Any oven that will give a uniform temperature over the range from 325 - 500 degrees F will work.

There are three modifications to the toaster oven:

1. I added a thin plate of stainless steel to the bottom rack, it works as a deflector or diffuser. The bottom element is quite close to the one rack when it is in the middle of the oven. The stainless plate is under the blades and evens out the radiant heat from the element. The diffuser plate is also bent up at a right angle at the front, which will prevent round items from rolling off onto the element. (I occasionally temper drills, counter bores, punches and chisels that I have made.) Inside the oven you can see a blade holder that supports a blade, or blades edge up. I don't like laying them flat in the toaster oven. The Farberware convection heats more evenly so the blades are laid down flat in it.

2. A good quality oven thermometer is mounted to the rack as a visual indicator of the temperature. Or get a digital one as mentioned above.

3. In order to make it possible to do larger blades than would fit completely inside the oven, I cut a slot in one end that will accept the blades of two or three knives. The slot is placed as near as possible to the front so as to give the most room to get a long blade in the oven.

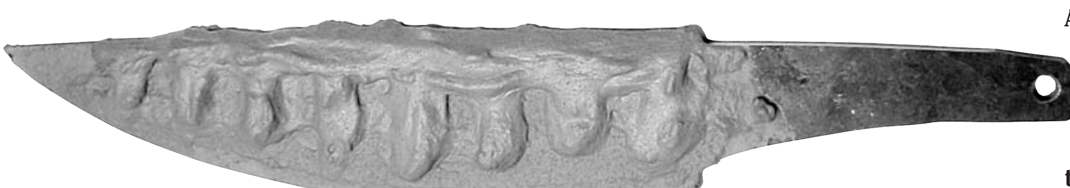
Clay back hardening

We must give the Japanese sword makers credit for this method which is gaining in popularity. Heat resistant clay is applied to the back of the blade. I had good luck with Parker or Chimney Sweep brand furnace cement that I got in the stove repair department in a large home improvement type store.

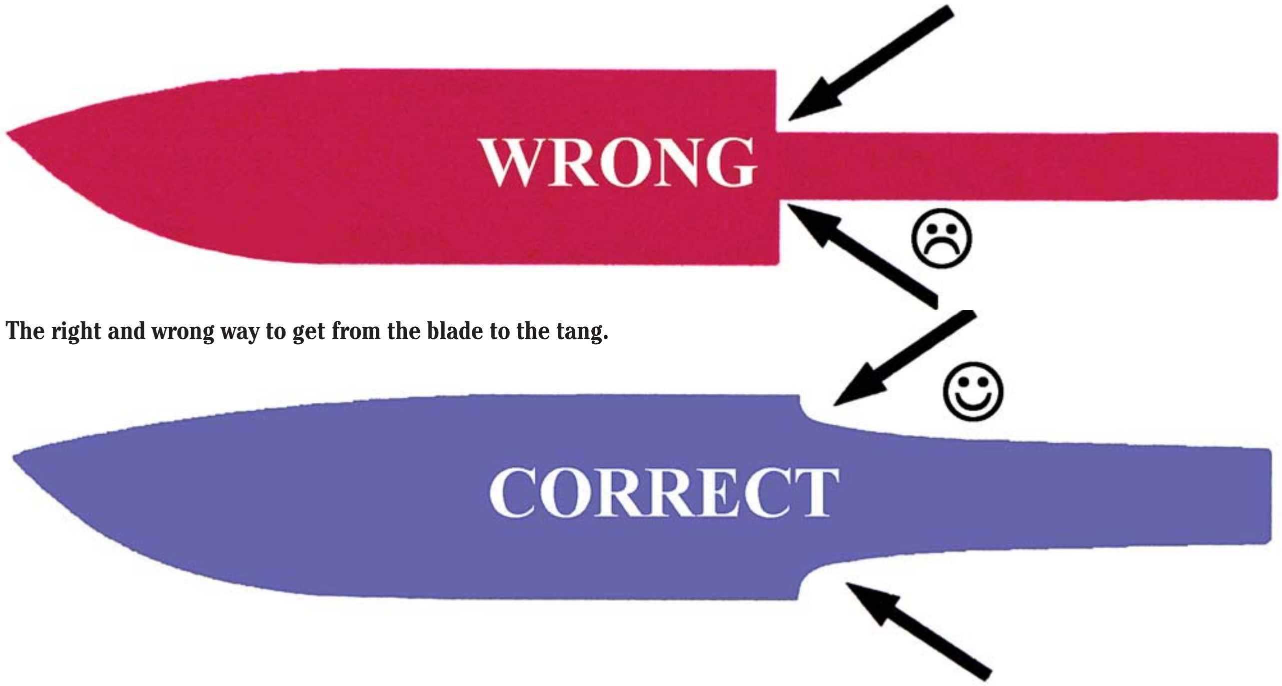
I make sure the fire clay is not too stiff, not too runny. Put a little in a container and add a little water and mix well. If there are chunks of harder stuff in your clay it will be hard to get good detail. I use a wood tongue depressor to mix and apply the clay. A thin coat is applied to the whole blade and then lines of clay are applied at a right angle from the edge. These lines need to line up with the ones on the other side. A final thick layer goes over the back of the blade and down about 25 percent of the width of the blade. The blade in the photo was quickly done but might still make a beautiful blade.

Once the coating is on the whole blade, it is heated and fully quenched. The coating on the back of the blade slows the cooling rate so that some of the coated area does not harden. For this method to be successful it is imperative to bring the edge up to the hardening temperature sufficiently fast so that the clay coated area does not have a chance to come up to the hardening temperature.

When I first tried to harden a blade with clay coating on the back the whole blade got hard. It was a long tanto blade that I forged from 1095 bar stock. I was working in a real slow and mellow hard coke fire. Because the fire was not hot enough it took me too long to bring the blade up to the hardening temperature. The clay coating came up to the hardening temperature at the same time as the edge. Quite naturally, the whole blade got hard. After being annealed the back of the blade was once again coated with fire clay. It was put back in a very hot fire and successfully hardened and tempered. It showed a nice temper line with a soft back.



A blade with clay applied, ready for the quench. You will need to practice with different patterns, thickness and steel types to see what works best for you.



The right and wrong way to get from the blade to the tang.

Eliminating stress risers

A knife blade ready for the quench should be free of stress risers. A stress riser on a blade would be any sharp change in contour, a surface defect or even a coarse grinding mark on the surface. The classic stress riser that has caused many knives to break is a square corner where the tang meets the blade. The knife breaks at the junction of tang and blade where the two lines meet at 90 degrees. (See the drawing.) The break started with a small crack that was caused by the stress of the quench. This junction should have a nice smooth radius which will spread out the stress created in the quench.

I see many knives were made from files and rasps that have marks showing where there are remnants of the teeth left. So-called “buckskinner” knives are often made that have hammer marks left on the surface. The hammer marks usually show remnants of scale that was hammered into the surface. These defects and irregularities are all stress risers where microscopic cracks can form during the quench. These stress risers may lead to failure of an otherwise good blade.

When a blade fails because of a stress riser there is almost always a discolored area visible that shows where the crack started in the quench. At a recent demonstration – teaching day at Fort Vancouver – one of the participants brought a drawknife that he had forged and heat treated. It had warped quite badly in the quench and I thought I would straighten it for him. I gave it a soft back temper using heat tongs and proceeded to try to straighten it. It broke in half with very little pressure. The break crossed a medium sized hammer mark that had fire scale in the bottom. There was a dark line spreading out from the bottom of the dent, proof positive that the crack that caused the blade to break started in the quench. The break showed a nice fine grain and such a blade will usually not fail when given a soft back temper.

The blade had been quenched back first into the oil. This puts the back under compression and the edge in tension. In my opinion this is exactly backwards to gain the maximum strength in a blade.

Practice is recommended

Knifemakers rarely get the same results with the same steel type. My “goop” or oil-quench oil may be slower or faster acting and used at a different temperature than another maker using the same steel. This can result in the as-quenched hardness of my blades being slightly different, which requires a different tempering time and temperature. There are dissimilarities in steel, too. Different melts of the same type won't respond exactly the same to identical heat treatment. A few years ago the formula I used for 5160 at home wouldn't work at the ABS School with 5160 from a different source.

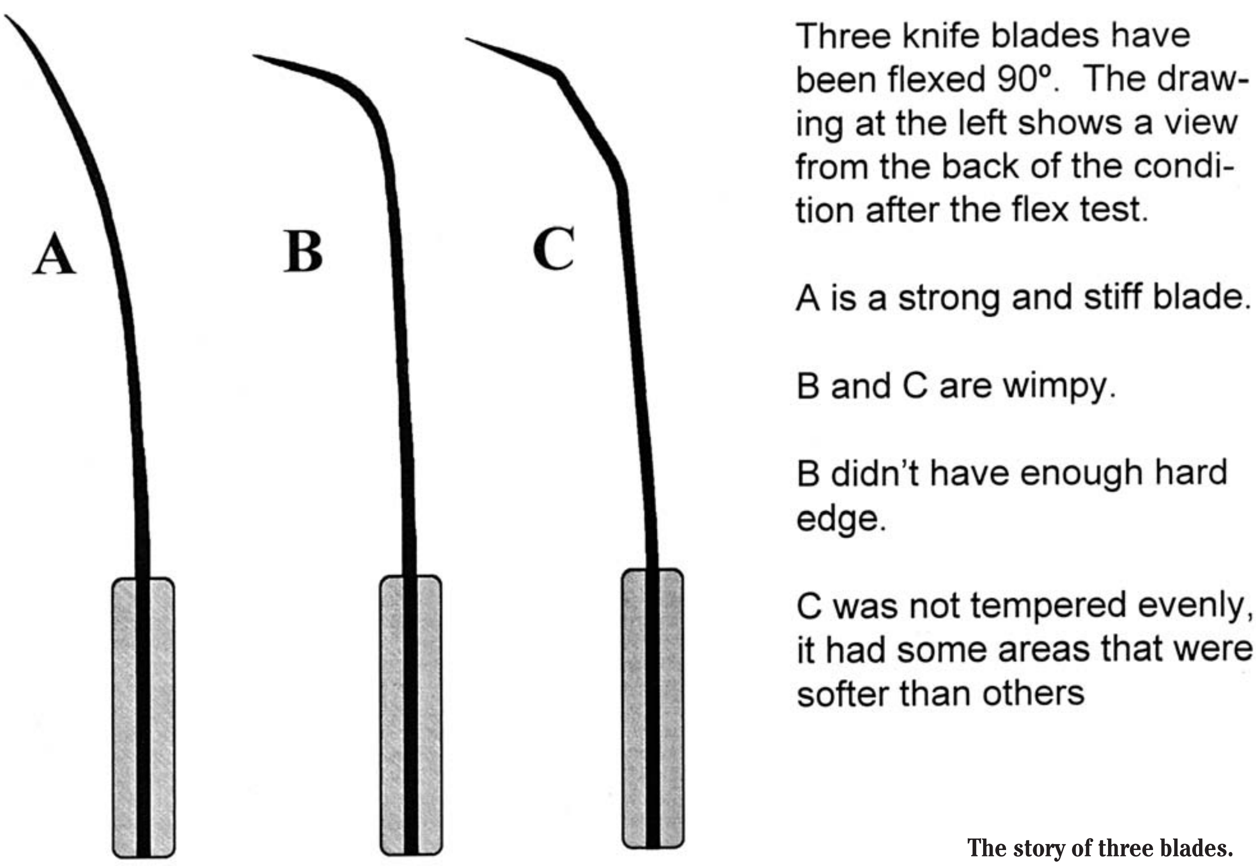
The effectiveness of these methods will depend on the condition of the grain structure going into the quench. It was assumed that proper thermal treatments brought the blade up to and through the quenching operation with a fine grain size.

A superior blade is the result doing everything right, never from doing most of it right. It comes down to knowing the material on an intimate basis. This knowledge can only be learned from having worked out by trial and error every little detail in the heat treating process.

A superior blade is the result doing everything right, never from doing most of it right.

The effectiveness of these methods depends on the condition of the grain structure going into the quench. It was assumed that proper thermal treatments brought the blade up to and through the quenching operation with a fine grain size. Steel is interesting to study because it keeps an internal record of its treatment, both good and bad. I have never seen a broken test blade that had a fine grain in the back portion of the blade. Some broken blades are coarse grained, others do not have a real coarse grain but are what I would describe as questionable. I define questionable grain size as, "other than fine." Questionable and large grain structure in the back portion of a blade is usually the result of improper normalizing and annealing of forged blades. A coarse grain in the edge portion of the blade is usually caused by overheating of the blade for the quench.

Something to think about has to do with working with coal or gas. More applicants who burn coal fail the flex test, and it is evident by the appearance of the grain size that the blade was overheated. Hardening out of a gas forge is something I can only say good things about. Coal has the potential to melt the steel or perhaps it only got hot enough to damage the grain boundaries. Either way the blade is no good.



The story of three blades.

Handles, Blades, Guards And Tangs

Plasma cutting blade blanks

Plasma cutters are a most excellent way to cut out blades. There is no real damage done except for an air-hardened, extremely hard skin at the edge of the cut out blank. Although the hard skin is very thin, it would have to be ground off as soon as possible. Leaving the hard, untempered material at the edge could cause a crack to start. My own experiments with plasma cut blanks showed that the skin at the cut edge was so hard that a file would not touch it, and it would surely ruin a band saw blade.

A nice assortment of junkyard materials, everything from old wrought iron to nearly new 50-pound coil springs made of 5160.

Caution: Scrap steel

I have a few words of caution regarding using scrap steel to make knives. First of all, new steel is relatively inexpensive. Five dollars worth of 1084 or 5160 will make one or two knives, depending on the blade length. Scrap steel is not worth using unless you have a large enough quantity from the same source to make it worthwhile to spend the time learning to work it.

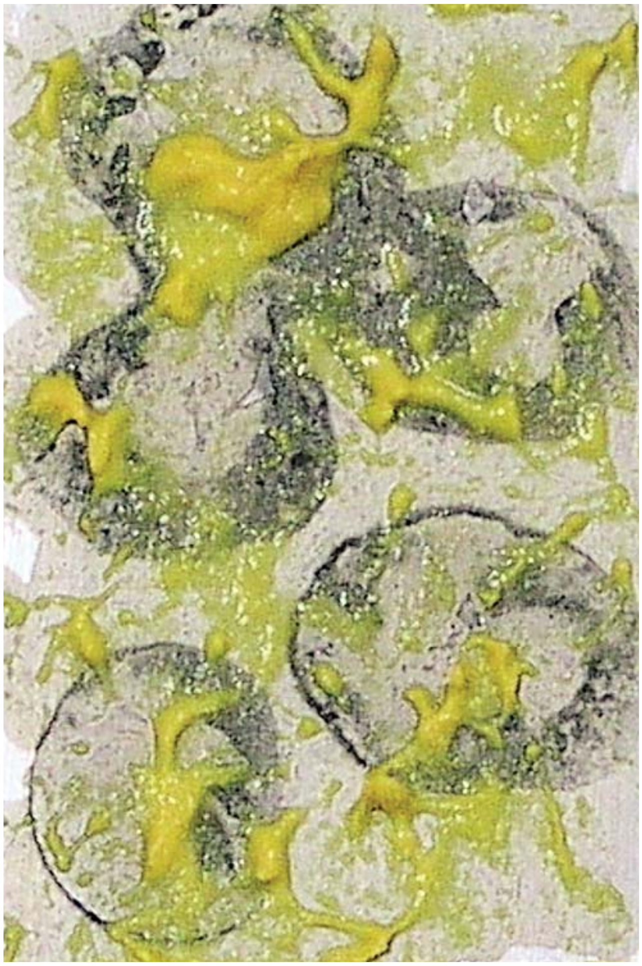
On the other hand, purchasing new steel does not guarantee a first class finished product. There are probably just as many defective knives made of new steel as there are from recycled sources. The bottom line is that the heat treatment has to be correct for the steel type and intended use of the knife.

The one exception in the scrap steel category is the material in large circular saws. When they have nickel in them I find them highly desirable for large, rough use knives. Many are very similar in alloy content to the tool steel L6. It is difficult to find wide, yet thinner new steel for the large bowies I make. Saw steel solves the problem in most cases.

The mustard patina

When properly done, a mustard finish gives a hard oxide layer of protection to a carbon or carbon alloy (non stainless) blade. I've kept knives with the mustard patina around for a year or more and never wiped them off and they don't pick up the normal finger prints or spit pits. (A spit pit is caused when someone talks while looking at a knife and the blade is put away without cleaning.)

Mustard application #1: The spacing is important, it shouldn't be nice and even.



Mustard application #2: Place the mustard dollop randomly over the first layer.

Very few things in knifemaking go well the first time you try them.

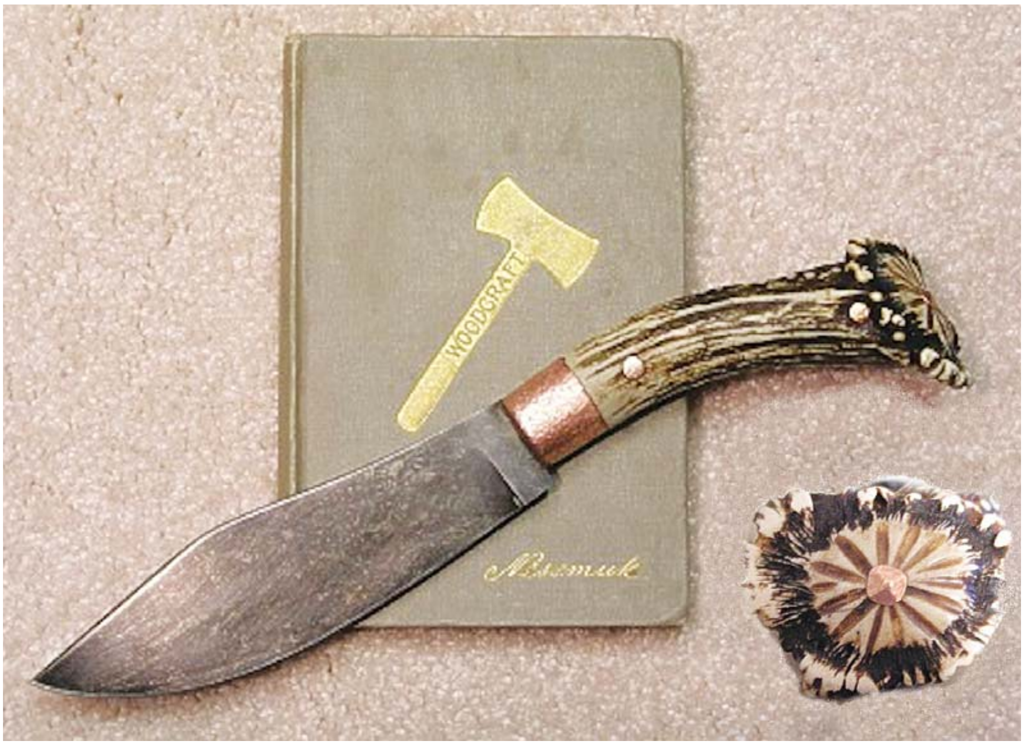
Common prepared mustard works fine, it's the vinegar and salt in the mustard that makes the color. I mixed dry mustard with water and nothing happened when applied to a blade. Vinegar by itself turns the blade black when a drop is applied with a cotton swab. The texture of the prepared mustard is necessary to create the interesting random pattern on the blade. I am often asked if Grey Poupon mustard works. I recently tested it and the only difference I found is that it is more "runny" and I don't recommend it. I bought a jar of mustard at a dollar store and it was so runny that the dollops turned into little round puddles; the camouflage, old knife look is replaced by a bunch of circles. I don't mind saying that Albertson's brand is what I use. It has the proper consistency to make nice dollops.

The mustard finish looks and works best as a protective coating when the blade is hand finished to at least 600 grit. Apply the mustard to the clean blade by placing little pats with the ball of your index finger. Like the photo shows, bare areas are left between the pats. Once the both sides of the blade are covered, allow the mustard to dry.

Depending on the temperature and humidity, it will take two to four hours. The blade will be rusty looking when the mustardizing has had time to do its work. Wash the blade with warm water and clean with 00000 steel wool (or the finest you can find). I find that three or four treatments are necessary to get a uniform and complete coverage of the oxide layer. Use subsequent treatments to fill in any bare or light colored spots that remain.

For a more primitive looking patina, work the blade down to 400 grit and use a hand stone to create swirls and any type of irregular pattern with it. Then do the mustard finish and

The final finish after application #3.



I made this Nessmuk style hunting knife with a mustard patina on the blade. The copper ferrule is stippled to give it a used appearance. The inset shows one way to make the button more interesting.

you'll have an old looking blade. I will sometimes give a finished mustardized blade a dip in water that has cold blue solution added to it. Just a quick one minute or so, you don't want to hide the mustard pattern. Please do understand that it is good to practice on a scrap blade. Very few things in knifemaking go well the first time you try them.

After the final rinse and steel wool cleaning, let the blade dry and apply a coat of vegetable oil or other edible oil. Let it set for an hour or so, then wipe off and the knife is ready for action.

Grinding blades

After 47 years it is less frustrating but not easy for me to grind good blades. Repetition does help build skill, but for me it takes great concentration at the same time. With your own two hands you will stick the blade against the belt and grind where you didn't want to remove anything. All I can say is, "Just don't do it."

Here are some things that have helped me.

1. Use sharp belts and keep the blade cool. A good idea is a metal bucket of water under the grinder that will catch the spark pattern coming off the blade.

2. Use good lighting that comes in from both sides of the belt.

3. Experiment with the height of the grinder so that you can work without neck and arm strain.

4. If you have been standing up to grind, try sitting on a stool, this works out well for some makers.

5. Start a light cut and go the full length of the blade before looking at it.

6. Practice. When I was a kid I took piano lessons for a while. My teacher was always telling me that practice didn't make perfect, but perfect practice makes perfect.

Save your finger tips with a grinding aid made from an old screwdriver. It not only saves the fingertips, but gives more leverage to push the steel into the belt when profile grinding.

Tips and techniques for long blade grinding

Clean up the flats in the guard area using a horizontal 6x48-inch Craftsman belt sander. Use an eight-inch-long grinding magnet to hold the blade. Once I get the flats established, I go to a 2x72-inch belt grinder to take off 80 percent of the material to form the bevels. At this time I'm not too worried about making sure it is really straight. When I go back to the platen on the 6x48, I've got nearly 18 inches of abrasive to contact the blade.

I bought the 6x48 machine used and had in mind using it primarily for woodworking. An 18-inch damascus blade was giving me trouble with my 2x72 belt grinder. I decided to try the wide belt machine and it worked so well that I've utilized it on long blades ever since. The platen of the wide belt sander is at approximately waist level, making it quite easy to swing the whole length of a long blade over the grinding surface. Using the grinding magnet to hold the blade is essential. Because the blade is in the horizontal position, it sort of floats over the platen.

The longest blade I have done was a full-tang wire Damascus blade, including the tang, that was nearly 26 inches long. I've done half a dozen other blades that run from 15 to 18 inches. I would not want to be without the 6x48 for grinding long blades.

Blade finishes

Polished blades

The reflections from the surface of a buffed and mirror-finished blade can cause a visible distortion of the lines, and the actual surfaces are usually not kept as flat and true. Reflections from the surface of a mirror-polished blade make it difficult to photograph. Many years ago I made a large double-edged Bolo-style knife that was buffed to perfection. To photograph it I stood it upright against a background. When I got the pictures back there was a perfect image of the camera, tripod and myself; all perfectly reflected from the center of the blade. The reflection was almost more interesting than the knife.

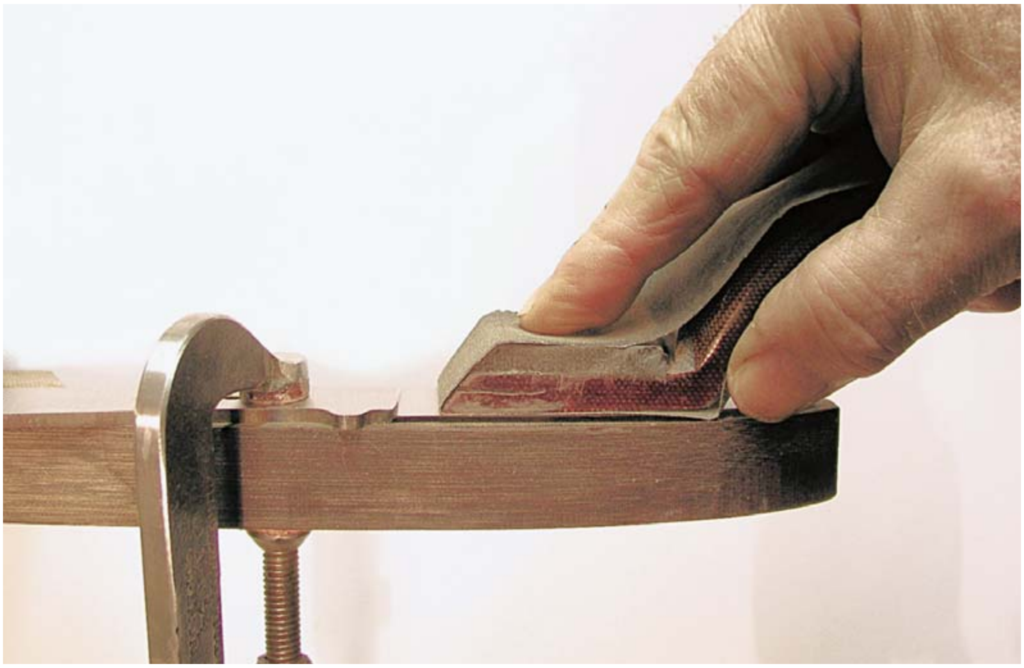
Blades that are not stainless steel benefit from a high polish because the surface is smoother and more resistant to rust and staining. I rarely mirror polish because I prefer the appearance and practicality of a satin or hand-rubbed finish. They don't show every little scratch like a mirror-polished blade and are very easy to touch up. Many years of dealing with well-used and sometimes abused knives have taught me the disadvantages of a high polish.

I made a lot of stock-removal, highly polished blades back in the 70s. I often saw how traumatic it was to a customer when a shiny blade was accidentally scratched. I was in the shop one evening about 9:30 when I got a call from a local customer. While sharpening his mirror-finished 154-CM blade he had slipped off the stone and put an ugly scrape down the side of the blade. He was very upset with himself and said he wouldn't be able to sleep until it was fixed. I had him bring it over and I refinished it with a satin finish. The customer went home with a blade he wasn't afraid to sharpen and use. That was about the time I started putting a satin finish on most all of my working knife blades. When making knives for the collector market it is probably desirable to learn to mirror polish blades, or else refine hand rubbing to a high degree. For working knives though, I'd stick to finishes that are easy to touch up or redo.

The hand rubbed finish

A close look at the surface of a finely finished Japanese sword blade reveals a lot of information about its construction, age and quality. Perfection in the polish makes the grain structure of the steel clearly visible. It has always amazed me that such a high degree of blade finishing was accomplished without the use of belt grinders and buffing wheels. The whole process is done by hand using natural stones and abrasives.

The high degree of finish allowed the sword smith to see if his blade was free of visible defects. The finish made the grain structure visible, and that revealed whether the heat treatment was correct. The fine finish also allowed the purchaser to see the quality of his purchase. It was only natural that a high degree of polish became one of the characteristics of a quality blade.



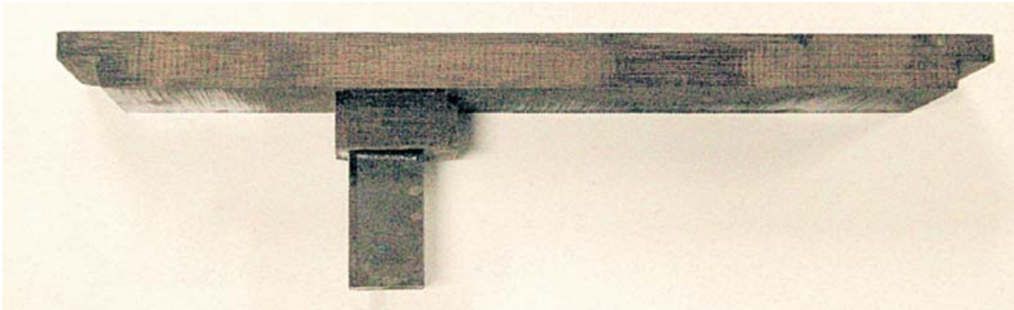
This old style push stick is used for hand rubbing.

Hand-finishing, when well done, results in a crisp and clean definition of the surfaces that gives a more true appearance than a mirror finish does. The reflections from the surface of a buffed and mirror-finished blade can cause a visible distortion of the lines and the actual surfaces are usually not kept as flat and true.

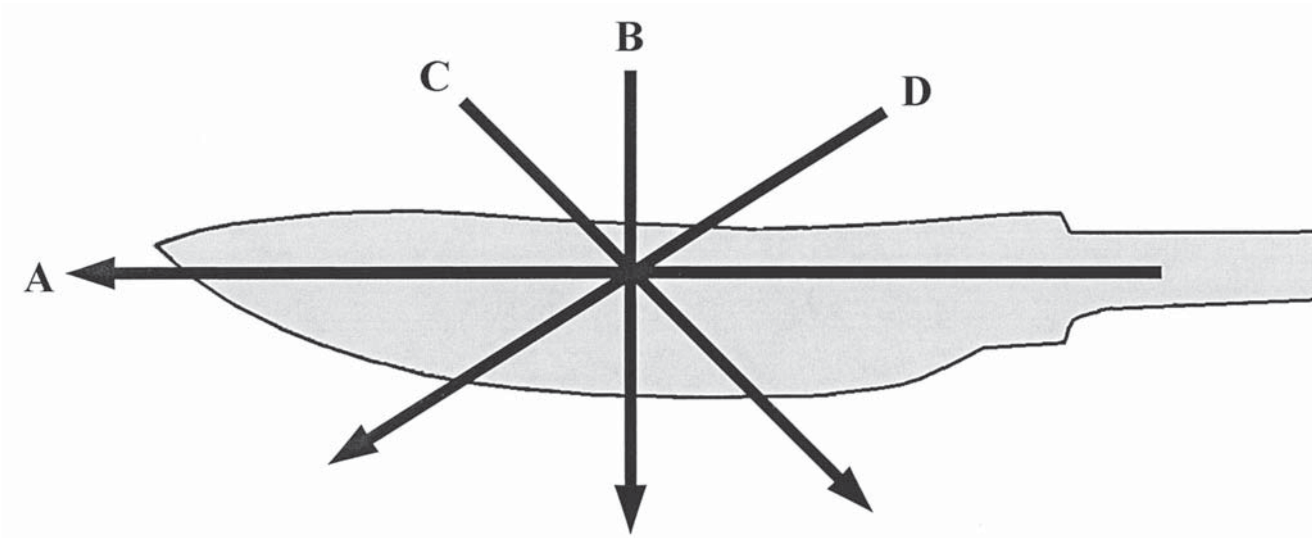
I use what I call a quick-rubbed finish on many forged blades. It's quick because the strokes are all lengthwise with the blade. The quick-rubbed finish results in a nice, although not perfect, finish because there are usually some coarser lines under the final finish.

The new and improved hand rubbing platform.

For many years I used what I call a push stick for hand rubbing. The push stick backs up the abrasive paper as I rub it on the blade, which is held by a clamp. I've been trying out a new system and it is working out very well. In the new system, the abrasive paper is stationary and I rub the blade on it. When I thought about it, it dawned on me that the Japanese sword makers rub the blade on the stone. Very interesting! I fold a standard sheet of wet or dry paper in half lengthwise and slice it in half with whatever blade is handy, cutting from the inside of the fold. The half sheet is folded in half lengthwise and that is the size I made the holder. The holder is 3/4-inch Micarta with a hole for a machine screw to hold it to the work bench. The ends have a step so that the small size spring clips will work to hold the abrasive paper tightly.



Detail view of the hand rubbing platform.



This drawing shows the proper sequence for hand finishing. The scratch pattern from the belt will be in direction "B" and the first rub will be lengthwise "A."

The blade to be hand finished is taken down to anywhere from 300 to 600 grit before the hand finishing starts. I stop at 320. Whatever the final belt grit size, the hand finishing would start by dropping back one grit-size to start.

The hand-rubbing process may be accomplished by alternating directions "A" and "B" only (see diagram). If you were doing it all by hand, the sequence would be as follows: "A" would be 100 grit, "B" would be 200, back to "A" for 300, "B" would be 400, and so on until the desired degree of finish is achieved. To further refine, you can also use the final steps "C" and "D." With the quick-rub method, all the work is done in direction "A."

The final step is always in direction "A" with all the strokes starting at the tang and going towards the point. Use a fresh section of paper for each stroke to get the finest finish. Use silicon carbide wet or dry paper. Some makers use water and some use it dry. Dry is always best for the final steps. Grit sizes are rounded off to the nearest hundred-something; use whatever you can get.

The satin finish

One distinction between a hand-rubbed finish and the satin or brushed finish is the direction the scratch pattern runs. The satin finish shows its pattern at a 90-degree angle to the edge and is usually not much finer than 300- or 400-grit with light buffing. A hand-rubbed finish has the scratch pattern running parallel with the cutting edge and is usually taken to a much finer degree of finish.

Here's how I do my version of a satin finish. Get the blade down to a half-dull, 240-grit finish or, if you prefer, use a sharp 320 belt. The blade can be flat-, convex- or hollow-ground. Carefully buff the blade with No. SF (satin finishing) 300 (grit) compound. I use the compound on a 10-inch sewn muslin wheel that runs 1,750 rpm. It takes practice to get a uniform scratch pattern. At this point, the surface will be fairly open and not too smooth. Once you have a uniform finish, buff the blade lightly with a medium cutting compound. Easy does it with this step, once or twice down each side is enough. Finish the blade by buffing lightly once or twice down each side with a finish compound like RCH Green Chrome. Over-buffing with the final finish compound will wipe out the scratch pattern that sets up the satin finish. The result will be a shiny blade. The finish buffing is done on the 10-inch sewn muslin wheel at 1,750 rpm. With practice you will be able to get a nice satin finish that is not too shiny.

Once the acid flux residue works out and eats into the blade, it is hard to fix the damage.

Satin finishing compound is a water-based glue product that is also called greaseless compound. It is applied to the wheel while it is turning. The wheel is left running and the glue hardens. I turn the buffer on, then turn it off and apply the compound as the wheel runs down. Not too much is required. If the compound is applied in a thick layer, when it hardens the buff acts more like a grinding wheel and it will not make a satin finish. These compounds are available from most knifemaker supply companies.

Sand-blasted finishes

Heavy sand blasting with coarse sand will blend in some scratches. Fine or dull sand will have less effect on the surface finish. It will depend somewhat on the visual effect that you want for the blade. Glass beads are used for a very fine finish. A tactical folder might look better with a fine satin finish lightly blasted. A rough and ready survival knife might look just fine with a 120- or 220-grit belt finish with a heavy blast job. Some makers also use sand or beads on Micarta and TeroTough-type laminated handle materials.

Soldering the guard

I've been asked what causes corrosion like rusting and sometimes pitting at the joint where the guard or bolsters are soldered to the blade. How can it be fixed?

The problem is caused when acid-type flux is trapped in the solder joint. The neutralizing and cleaning process was not efficient in killing the acid flux. The flux eventually eats its way out and can nearly ruin a blade if not caught in the early stages. A fine line of rust is usually the first indication of the problem and pitting follows if the acid is not completely neutralized. Once the acid flux residue works out and eats into the blade, it is hard to fix the damage.

There are several things to try that may eliminate the problem. The first is to improve the soldering method so that pockets or bubbles of trapped flux are eliminated. The second is to use a multiple-step neutralizing process. A final solution may be to use an acid-free flux.

For many years I had no problems with soldered joints. After soldering I would wash the soldered parts in warm water and then let them soak in a warm soda water solution for several hours. This was followed by a clear-water rinse. In the last three or four years I have noticed that this process does not seem to work as well. I am of the opinion that something has changed in the flux that makes it more difficult to neutralize. It is interesting to me that when I first noticed the problem it wasn't long before I started hearing and seeing about the same thing on other knives.

There are acid-free fluxes available that may be more suitable than what is furnished with the silver-bearing, lead-free solder commonly used in knife work. The method used for soldering guards may be trapping flux in the joint. Many makers put the blade point up and apply the solder to the blade side of the guard. This pushes the solder and flux into the joint and usually results in too much solder being used. When too much solder is used it takes more heat and also makes the cleaning of the joint more difficult. With this method the temperature may not be sufficiently hot to cause 100 percent solder flow through the joint, and that may trap flux in the joint.

I believe a more trouble-free method is to lay the blade down on a jig made of insulating material. The guard should be fitted very close because the solder will not hide a poor fit. Slowly heat the blade/guard area while applying some liquid flux. This etches the surface of the blade and prepares it for the solder. Apply a small amount of the paste solder or a few snippets of stick solder to the area of the guard on the handle side. If you feed stick solder into the heated joint, I can almost guarantee that there will be too much used. Too much heat will destroy the action of the flux, resulting in a poor bond. If the flux turns black and the solder won't flow, then you will know that you have too much heat. Pull back the torch flame every so often. Just watch and wait for the solder to flow.

If you feed stick solder into the heated joint, I can almost guarantee that there will be too much used.

This method assures the whole guard area is up to temperature or else the solder will not flow through the joint. Use only enough heat to cause the solder to flow. Too much heat can actually cause the solder to boil and that can cause bubbles in the joint. These bubbles will usually have flux in them. Capillary action will draw the solder through the joint, toward the heat source. Turn the blade "other side up" occasionally during heating. Use a piece of stainless wire that is slightly sharpened and polished to help the solder flow completely around the joint. While still liquefied, wipe the excess solder off with a flux brush or a piece of leather.

Never use a file on a solder joint. If you do you will surely leave a mark on the blade or guard. Use a sharpened copper or brass rod as you would use an engraving tool and scrape out the excess solder. There will not be much cleanup once you master the above method. Use 600-grit backed up by a piece of stiff leather to polish the surface of the blade and guard, then buff.

Make yourself a "dummy" blade to practice on, then practice until you have mastered the process.

Handles

Gluing handle slabs on a full tang knife

Make sure that the handle material is dry and flat and let it cure under clamp pressure for 24 hours. I use riveted pins to hold my handles in place, therefore the epoxy is actually more of a seal than an adhesive. If I were to decide to put knives together where I needed an adhesive to hold them together I would perhaps look for another product.

There is one more factor to consider with slab-type handles. I use vulcanized fiber spacer material between the slab and tang, and it isn't just for looks. This is the spacer material sold by knifemaker supply companies. The spacer acts as a shock absorber as well as an expansion / contraction buffer. Natural materials that aren't stabilized or sealed against moisture will expand and contract with the seasons of the year. Without this material in the glue line the handle slabs are prone to work loose.

Wood for handles

Recently there has been talk that wood is "dead" as a handle material. I can't agree entirely with that statement. There is a lot of ugly wood being put on knives, and that market may be dead. I will agree that stag, ivory and pearl are desirable and probably help sell knives in the collector market. If the dealers in collectible

This bowie handle was made from bamboo that grows in my back yard. It is different, beautiful and fairly rare. Who says wood is dead!!

knives don't want knives with wood handles that is fine and good. Back in the real world, many knifemakers keep busy making working knives as part or perhaps all of their production. Wood and Micarta® are very appropriate for working knives.

I see a lot of wood handles that look cheap, and that won't help sell a knife. Quality wood will help sell knives when everything else about the knife "works." My personal preference has been totally warped by having a supply of really good desert ironwood and snakewood. I can't visualize most of the fixed blade knives I want to make with any other wood on them.

If you think that you can't afford select, rare and beautiful wood, you need an attitude adjustment and it goes like this. Buying good wood or other material is an investment that helps guarantee that you will be paid well for the labor you put in a knife. In the end, the customer pays for the wood, and they pay gladly for high quality material.

The stag doctor

With each passing year I get more enthused about making something useful out of what otherwise would end up in a landfill. That's why I chose an ugly, sun-bleached, and cracked piece of elk antler for the handle of the friction folder I made for the Blade Workshop series.

There was a time when I would not have considered it as usable material. The year is 2010 and we're running out of a lot of stuff, so let's all make the most out of what we have to work with.

It's said that you can't judge a book by its cover. If we judge a piece of material only from the outward appearance we can miss a beautiful handle waiting to be brought out by the appropriate method. The surface of this antler looked like rotten chalk, but underneath it had the appearance of antique ivory. Here is how I made the reject elk antler into usable handle material.

The usable part of the antler does not include the soft core. If you choose to leave some of the core exposed, it should be sealed and all holes filled with super glue. If left unsealed, it will quickly rot out when exposed to working knife conditions. Elk antler is superior to deer antler because it is white under the colored crust. The colored layer is usually shallow but occasionally runs deeper. A mature bull elk will grow antlers with the darkest and deepest colors. The texture of the antler from these bulls is also the best looking of all. The solid part of deer antler runs from light shades of gray to brown. An old deer antler that has been exposed to the sun can be a real nice white color.

Antler for slabs should be split and stored in a very dry place until completely cured. Antler rounds are cut to length and have a hole drilled through. The crown pieces are left alone to dry out. I use a heated storage locker to keep my materials dry. It's a big wood box with shelves made of pegboard to allow air circulation. The heat source is a 100 W light bulb in the bottom that runs on a thermostat set at 75 degrees. A space at the bottom of the door lets air in to circulate; another space at the top lets the warm air out.

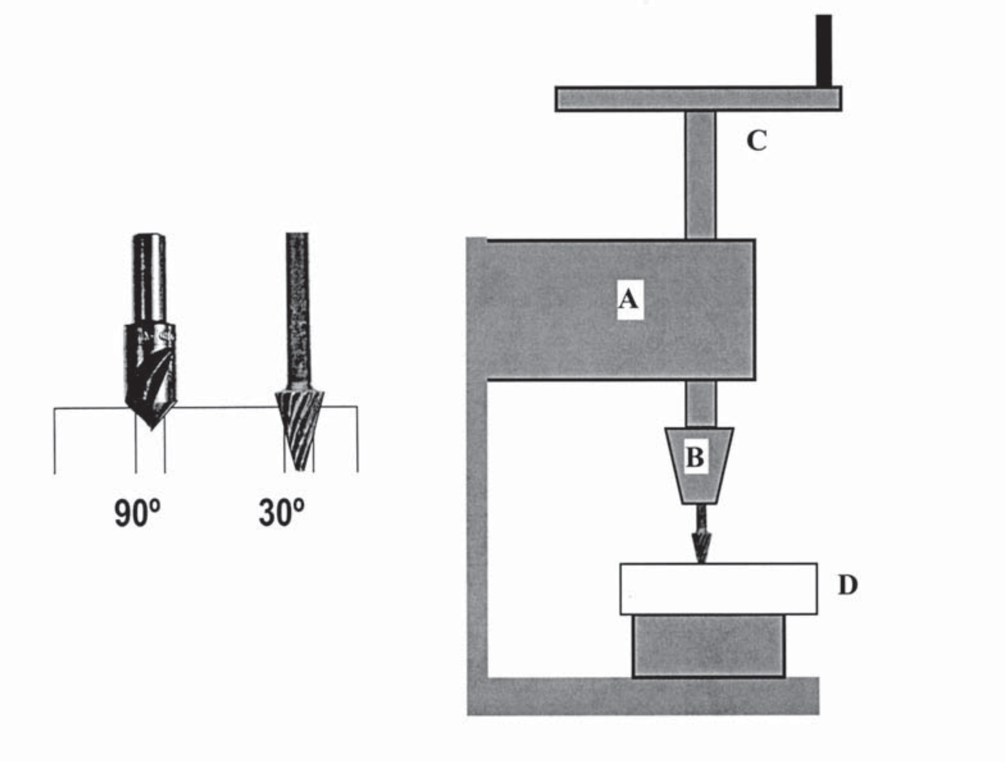
When selecting material for slab type handles, any cracks should not go completely through the slab. Use a belt sander and work material close to the finished size. Use dye to color the whole surface of the handle piece. (Practice on a small piece of scrap from the antler you want to use to see what happens.) Be sure to get the dye in the cracks and allow it to thoroughly dry. Depending on the density of the antler material, the dye may only fill the cracks. Other times the antler is more porous and some color will go into all or other parts of the surface.

My favorite dye for antler is potassium permanganate crystals dissolved in water. The potassium permanganate dye gives the most natural brown color of any dye I've found. Water-base dye may not penetrate as deeply as leather dye and that's good for this application. Brown leather dye has the tendency to appear somewhat red when applied to stag.

After the dye has dried, fill the cracks with super glue. Also seal the inside of the handle slab with the glue. When the glue is dry, sand to the final shape and fit to the knife.

Material for pins

I purchase 90 percent of my pin material from a local welding supply store. I use nickel-alloy and bronze brazing rod and stainless steel TIG welding rod. Most of the knifemaker supply companies sell wire for pins. Wire will come in gauge size or by



The drawing at the left illustrates that the recess made by a standard 90 degree countersink is shallow in comparison to one made with the 30 degree mounted point. In normal use a mounted point is motorized and used for carving. For this application it is turned by hand using a homemade fixture similiar to a hand tapper. See the drawing at the right. "A" is a bushing type arbor which is mounted to a steel frame; the shaft is free floating. "B" is a chuck to hold the mounted point. "C" is the hand crank. "D" is the work being countersunk.

standard fraction sizes. I purchase the gauge size wire from the different knifemaker supply firms for use in repairing old knives. Most commercial knives use gauge size wire rather than fractional. It is important to have drill bits to match the diameter of the pin stock you want to use. It's not much fun to discover you have holes in the tang of a hardened blade with no pin stock to fit.

It was in 1955 and High School Arts and Crafts class where I learned to use copper harness rivets for leatherwork. When I made my first knives in shop class I didn't have harness rivets long enough so I used welding wire that I riveted on each side of the handle. In 1963, when I started making knives to sell, I continued to use pins.

I use a 30-degree recess for riveting with pin stock because it gives a deeper head, and thus is stronger.

I purchase high-speed steel drill bits from several local firms. They are nothing fancy, just whatever brand they have in stock. There are three systems of drill sizes: letter, number and fraction. Between the three systems I can usually find a drill the correct size. When I buy pin stock I usually get enough to last several years. I use a micrometer to measure the exact diameter and then make sure that I have the right drills for it. I use drills that are approximately .002 inch oversize. That figures out like this: for pin size 1/32 inch, use #67; 1/16 inch, use #52; 3/32 inch, use #41; 1/8 inch, #30; 5/32, use #21; and for ¼ inch, use letter size F. After I sharpen a drill bit I usually drill a test hole to make sure it is not cutting oversize.

The Tang

"Out of sight, out of mind", is not the way to think of your knife tang. The strength of the knife tang is often overlooked when the tang is thought of as a design element. After seeing many knives and a couple of swords that had their handles broken off, I've formed some strong opinions about how a tang should be constructed. Broken tangs can result from any of the following; defective heat treatment (either too hard or too soft… spring temper is good), not being large enough, stress risers, handle material too weak for the intended purpose, or air space between the tang and handle material.

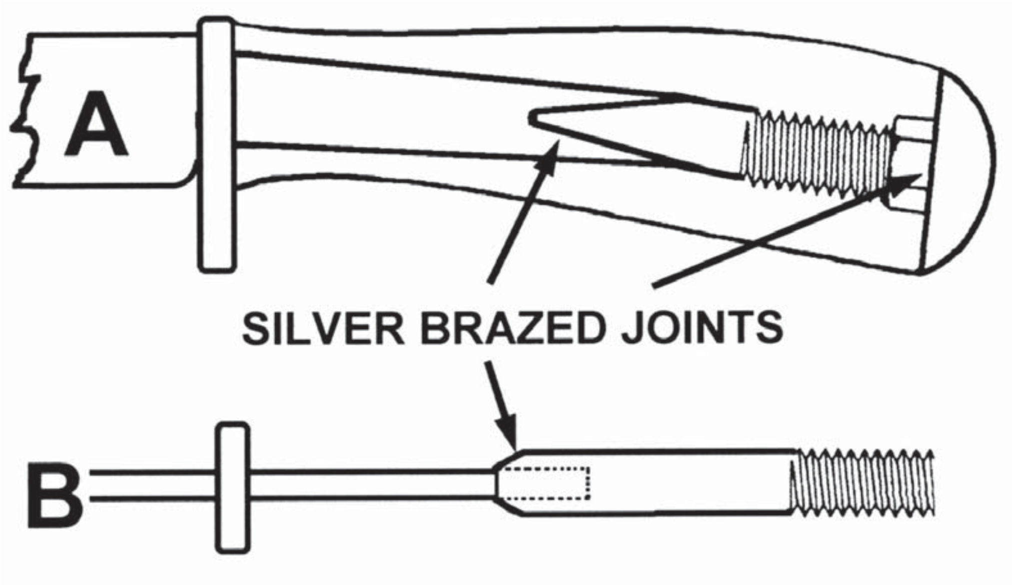
Troubleshooting

When a handle breaks at the junction of the blade and guard it is usually because of a stress riser. It's an accident waiting to happen when the junction of tang and blade is square. This corner should have as large a radius as is feasible. When the tang breaks up inside the handle it was either too small or too hard. See the comments below concerning handles made of spacers. When a spacer-type handle is constructed it is imperative that the tang be of the utmost strength. I've worked out a formula for tang size that gives the maximum strength.

The practice of arc or gas welding tangs is very popular, but I don't recommend it unless the tang is thoroughly tested before the knife is assembled. Most welds are somewhere between 80 percent and 90 percent the strength of the surrounding material. The trouble with arc welding is that the grain structure in the areas around the weld is left extremely coarse from the heat required to make the weld. My own experience with arc welded joints was most unfavorable with blades made of 52100. Arc welding creates a very large and weak grain structure in the weld zone. This steel has the tendency to air harden and I never could get the strength I wanted in the tang.

I prefer a silver-brazed joint because the joint is always stronger than the surrounding material. The heat involved is much less when properly done and therefore the grain enlargement found with arc or gas welding is not present. I learned to silver-braze many years ago when I worked in the saw manufacturing and repair business. My first job was silver-brazing carbide bits into saws and cutters of all descriptions.

Three ways to do a tang extension.



Narrow tang versus full tang

Several years ago Steve Shackleford, editor of *BLADE* Magazine®, asked me to participate in a point-counterpoint article on the subject of full-tang versus narrow-tang knife construction. I remember telling him that the only way I would do it was if I could argue for both sides. I have used both methods for 36 years because neither method by itself is most suitable for the many styles of knives I make.

Most of the opinions I've seen in print that advocate one method or the other missed two points that I consider the most important of all. Those points are these: the simplicity of tools required to make the narrow tang, and the strength and durability of the narrow tang when it is properly constructed. My opinions were formed from how well the different methods held up on knives I've made and from what I've observed about other knives, both newly made and old.

The majority of knives throughout history have had narrow tangs. The many advantages of that method became clear from my experiments with primitive knifemaking methods. Probably most important is the frugality of blade material. It takes almost twice as much steel to make a full-tang knife as it does to make one with a narrow tang. Narrow-tang construction has always been common because few tools were required. The narrow tang is contained within the handle material so there is less metal to be finished when compared to a full tang.

A handle made of stacked spacers is weak in as much as the handle itself does not have much strength against breaking in the transverse section. The strength of the handle will depend totally on the tang. As an example of this, recently there was a discussion on the Internet about a sword with a broken handle. A photo of the broken handle showed a round tang that, in my opinion, was much too small for the diameter of the handle. The tang appeared to be approximately 25 percent of the diameter of the handle. The handle separated at a place where the tang should have been rectangular and at least 80 percent the width of the handle. The handle of bronze, bone and marble spacers had little actual strength against sideways pressure.

There is no doubt in my mind that there are fewer things to go wrong with a properly constructed narrow-tang knife.

The tang that supports a spacer-type handle for sword or a knife that will receive rough use should be of the maximum size and strength. In my opinion a sword handle should be of one-piece construction, and a fairly strong piece of material at that.

I recommended the following sequence for a narrow-tang knife with a ferrule: First, solder the guard to the blade. Use a 430 degree F, lead-free soft silver solder. Then fit the handle into the ferrule, using epoxy or super glue to hold it together. Then use epoxy to join the handle-ferrule assembly to the tang.

There are several ways to attach the butt cap so that the tang does not have to go through it. The method I use is to silver-braze a nut to the underside of the butt cap. The nut/butt cap assembly threads onto the end of the tang and when tightened it draws the whole handle up tight. In my opinion, this is the strongest way to assemble a narrow-tang knife. A method I use on small knives is to silver braze a large wood screw to the butt cap. The butt cap with the screw attached is then screwed and glued into the handle. A good silver solder job would probably hold the screw to the pommel cap on light duty knives, but I wouldn't trust it on a heavy use knife like the Bowie style. I've also seen several knives where the butt cap was simply epoxied on and it eventually fell off.

The combat quality blade

Another factor to consider is the fact that the narrow-tang knife is more of a sealed unit than where slab handles are affixed to the full tang. There is no doubt in my mind that there are fewer things to go wrong with a properly constructed narrow-tang knife.

When the guard is fitted onto the tang and a stub tang is silver brazed or welded, a gain in strength is made. For example, if the blade is 1/4-inch thick and the tang is threaded, the end of the tang is 1/4-inch. If a stub tang is added it can be as large as is needed for strength.

There should be no air space between a handle and the tang. If the handle can move on the tang then the tang is not supported and can be bent. The strongest handle construction is where a through-bolt is used with either a threaded pommel cap or a nut on the end to draw everything up tight.

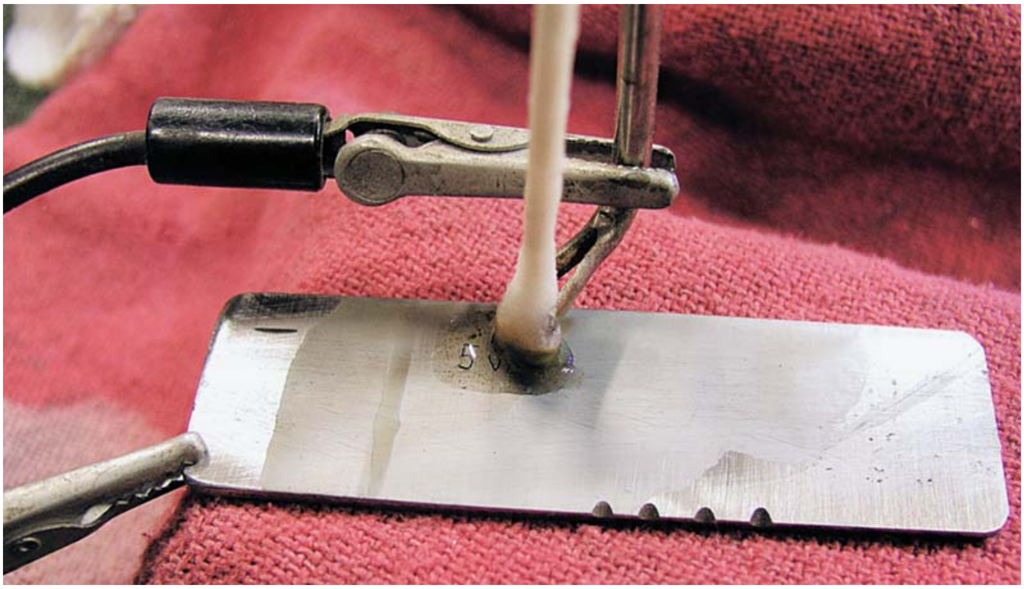
Logo etching

I learned about salt water etching with direct current in 1973. I was selling my knives at an open-air craft market and a patron stopped to look. He asked how I put my logo on the blades and I explained that I applied a wax mixture to the blade with a hot iron, then scratched my logo through the wax and then applied acid to etch the mark. He told me that instead of using acid I should use salt water and a 6-volt battery. I have to admit it was a couple of years before I tried it.

I always had to mix the acid a little different to get consistent results with the variety of steels I was working with. The acid mix that worked on one type of steel would not work that well on another and the acid wouldn't touch Stellite at all. Salt water and good quality direct current will etch every metal I've tried, including Stellite 6K, copper, brass and nickel-silver. I haven't tried it on titanium.

The wax mixture is applied to the clean blade with a hot iron. When the wax cools, scratch the logo into it and then treat with the saltwater etchant. It took me awhile to get it working smoothly but I have now been using this process for more than 30 years.

The complete etching outfit. Salt water and good quality direct current will etch every metal I've tried.



Detail view of the swab holder.

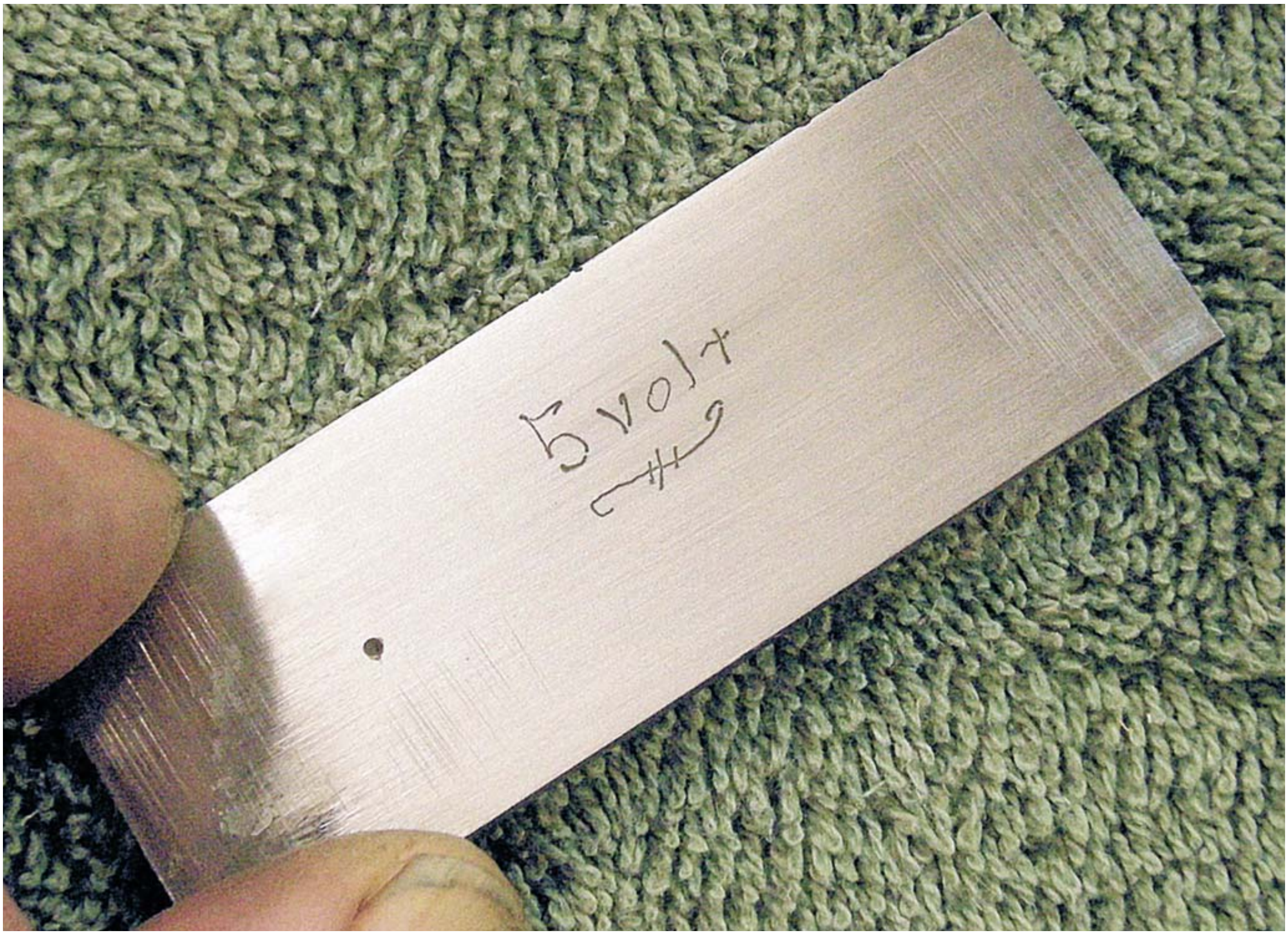
It takes a real good source of 5-6-volt direct current. A variable voltage power supply for electronic work will work; mine is from Radio Shack. Toy transformers and battery eliminators for radios and such won't work too well because the direct current they put out is not a pure form. A power supply from an obsolete computer will work very well. The one I used for these pictures is only 5V but it worked just fine. Most of those that I've modified put out two different voltages with 6V being the lowest. Just test the output leads and use the ones that are 5-6V.

I mix my salt-water etchant in an old-style half-ounce India-ink bottle. However much salt you can get between the tip of your finger and the end of your thumb is all that is necessary, too much salt in the water and the etch gets uneven and may even eat the wax away. Oregon has good water, but if your tap water doesn't work, try the distilled variety.

The negative wire goes to a holder that grabs a Q-tip® cotton swab by the end. (Cotton swab means Q-tip®, that's important because the cheap ones won't work very well.) Here is how to make the holder for the cotton swab. You need a small steel rod, not over 5/32 of an inch in diameter and five or six inches long. Stainless steel would be good. Ask for 5/32-inch stainless TIG wire at your local welding supply store. (TIG wire is also good to use for pin stock for holding handles on knives.) Cut a slot in the end of the rod and pry it apart just far enough so that it will grip the cotton swab by the cotton covered end. Leave about half of the cotton part sticking out and pull the cotton out to make it fluffy. Make a holder for the rod so you can adjust it so that the fluffy end of the cotton swab will just contact the knife blade.

My resist is beeswax and microcrystalline wax, about 50/50. Apply it with a hot iron. It will take some practice to apply a nice even layer of wax. It can easily be either too thick or too thin; practice is the key to make this process work. Polycrystalline or microcrystalline wax is used in the lost-wax casting process. My jewelry making instructor got me five pounds back when I started with this type of etching and I'm still using from that batch because a little of the wax mix goes a long way.

The reason for the mixture of wax is so it will be consistent in hardness over a wider temperature range. The wax can be either too hard or too soft; it needs to be workable. When too hard it will lift off with the stylus tool you use to scratch the logo into the wax. When too soft, the voltage can melt it. Keep the resist free of lint and dust; they will cause the etchant to eat holes wherever the contaminant is. The stylus tool needs to have a well-polished ball end on it so it does not dig into the blade; it needs to slide on the surface. A fine tip is used for small delicate logos like on a miniature. A wider tip will make a bolder mark for the larger knives.



A successful etch test.

The positive is put on the blade with an alligator clamp with the negative going to the swab holder. I use the dropper from the ink bottle to put a little puddle of the etchant on the blade. The cotton swab is soaked with salt water and lowered down till it just rests in the puddle. Be careful not to jam the cotton swab into the wax; you can ruin the mark. The 6-volts DC is then applied; etch for five minutes to start.

Too much voltage will melt the wax, or it may eat holes in the resist. The results of that happening are awful because it looks like the logo was shot with a tiny little shotgun. The only fix is to regrind and finish the blade. I use tap water because it works. I wear my OptiVISOR full time in the shop and this is good for checking to see if the etch is getting started correctly.

The versatility of the size and styles that are possible make it valuable for me. This is a great way to mark blades but not easy to learn. Practice a lot before you try it on a finished blade and stick with it until you get it figured out.

Cardboard sheaths

The minimal storage sheath

I've seen a couple of cut fingers caused by a sharp blade that was wrapped in a paper towel or piece of cloth. It takes only a minute or two to fold up a temporary sheath of cardboard that will protect the owner from the knife. And, it will protect the edge and point in case the knife is dropped accidentally. Cut a piece of cardboard that is at least an inch longer than the blade and make it wide enough to fold around the blade two times. A couple of wraps of masking tape will hold it together. With a little practice you will be able to make the first fold at just the right place so that the blade will fit snuggly in place. It will not be that safe if it is loose enough to slide out of the sheath.

A cardboard sheath for a working knife

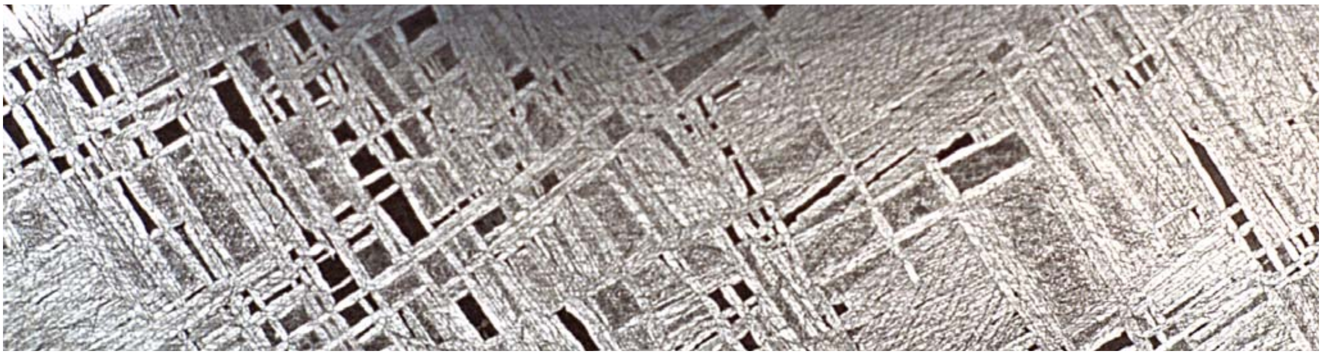
The black sheath in the picture is eighteen years old. It has served its purpose well protecting the knife which was made from a Senegalese machete. The front and back panels are cut out of heavy single layer cardboard. The spacer was cut out of yew, a not too hard, not too soft wood. The cardboard was coated with a layer of contact cement and allowed to dry, the intent being to make it somewhat waterproof.

Three cardboard sheaths

The inside surfaces were then given a layer of the cloth tape from a dollar store. The button stud was riveted in place with a piece of bandsaw steel backing up the riveted end. The spacer was glued to the front and back panels and then drilled for a series of little brass nails spaced about an inch apart. The outer edge of the sheath was smoothed up and the corners slightly rounded with sandpaper. The sheath then got a double wrap of the cloth tape. A piece of thin leather was glued into the throat of the sheath to give it a better grip on the thin blade. The cardboard sheath with the camouflage tape wrap was made by the same method.

The ugly knife made from the machete was a total wreck when found for 50 cents at a yard sale. The blade had large nicks, the tip was broken off and the handle ready to fall off. While cleaning up the blade on the belt grinder I determined it was a pretty good piece of steel. I wired, riveted and glued the handle together, "fancied" up the blade with some jewelling and then gave it a soft back draw. It's quite a good cutting knife and more than adequate as a camp knife. Making a cardboard sheath for it seemed like a really good idea.

The collector furnished meteorite parts for the custom project.



Polished and etched to show the Widmanstatten pattern.

My most unusual handle job

When the customer asked me if I could work with meteorites, I said yes. It was a plain question but I went down the wrong trail with my reply. I started explaining how I had forge welded a billet containing meteorite material and made several knives out of it. The customer explained that a pattern welded blade was not what he wanted. He went on to tell me about the Widmanstatten pattern that would be destroyed by the welding process. That was the start of my education about meteorites.

The Widmanstatten pattern develops in nickel/iron meteorites. The cooling rate of 20 degrees C per million years allows for large grains to grow in the meteorite. The grain comes out by etching the polished material. He wanted two knives made out of one meteorite slab. I told him it sounded like a fun and interesting project and we came to a price for two matching knives with presentation cases. My quote covered only the labor, the collector was responsible for purchasing the materials. Being a meteorite collector he knew the sources for slabs of the necessary material.

The iron nickel slab came first, and I went to work on an overall design. Let me tell you, I was nervous slicing the $800 slab in half with a thin wheel abrasive saw. Once I had the handle design worked out the collector purchased the stony meteorite pieces. There was none available that were large enough to do one side of the handle. I worked out the mosaic pattern to utilize the shape of the available pieces.

The nickel iron slab came from a meteorite found in Africa, the stony meteorite pieces for the handles came from Australia. The odd shaped stony meteorite pieces were a challenge to cut and fit. That is why each of the four handle slabs has a different pattern. The shiny lines between the handle pieces are nickel silver. The stony meteorite pieces were shaped with a thin blade diamond wet saw and finished with lapidary wheels and discs. The handles were fabricated in one piece with the meteorite blades epoxied in place.

One knife is completed, the other ready for the stony meteorite slabs. Note the silver brazed tang extension.

The irregular shape of the backs of the blades shows the skin of the meteorite with its natural recesses. This is a feature that is highly valued by meteorite collectors. If you find a smooth rusty metallic object it is probably not a nickel iron meteorite. If it had a lot of dents and recesses it could be a meteorite. The thumb shaped dents are formed by the burning during the entrance to the Earth's atmosphere.

The meteorite material for the two welded blades were fragments from Canyon Diablo. I forged a long spoon on the end of a large file, filled it with fragments and did a forge weld. Talk about ugly, the fragments just kind of pushed into the file, displacing it but welding where the meteorite touched the steel. The nickel in the meteorite material made it harder to forge, however the folding and welding evened it out. After folding and welding a couple of times I put a piece of bandsaw steel in the middle and folded it about six or eight more times. It came out pretty good but would not have had much of a pattern without the piece of bandsaw mixed in.

Two finished knives. At the start I let the collector know that the blades would have very little ability to hold an edge. He said that if they were capable of opening a letter that would be good enough, and they did.

Wayne's Shop

My shop is usually a mess of unprocessed junk, stuff that needs fixing and incomplete projects. I could write a book entitled, "Confessions of a Tinkerer." It would be about all the things I played with while I should have been making knives. And, I've never gotten into the habit of putting small tools away. I clean my workbench when it gets so I can't find the stuff I need. I've been "messy" all my life and don't defend it, it's the way I am and at the age of 72 I'm probably not going to change.

Several years ago I did some calculations to figure out how many hours I had spent in my present shop. We have lived in the current location for 40 years. I've been a full time maker for 37 of those years. I had two different short-term, part time jobs times that rarely kept me from getting in at least a 30-hour week in the shop. The bottom line is an estimated of 95,000+ hours. That has given me lots of time to fill every nook and cranny with something or other.

I set up this shop (double garage) in the early 70s and the smartest thing I did was make islands to put the power tools on. There was one heavy eight-foot bench

Open the door to the shop from the house, look a bit to the left and you will see the indoor forging area and heat treat central. The anvil is made out of two short pieces of rail with the bottom side up. The vise on the base at the right of the anvil is called "The Anvil Buddy". His jaws are at the correct height to hold a long piece on the anvil, real handy when working alone.

with a vise and work station on either end. It was built at standing height, so my forearms are parallel with the floor when grasping whatever tool is being used. The double garage door with southern exposure made the garage/shop hot in summer and cold in the winter. In 1975 I had a student for two weeks and, to my good fortune, he turned out to be a carpenter. On the weekend we closed in the garage and it became a shop.

I've been "messy" all my life. At the age of 72, I'm probably not going to change.

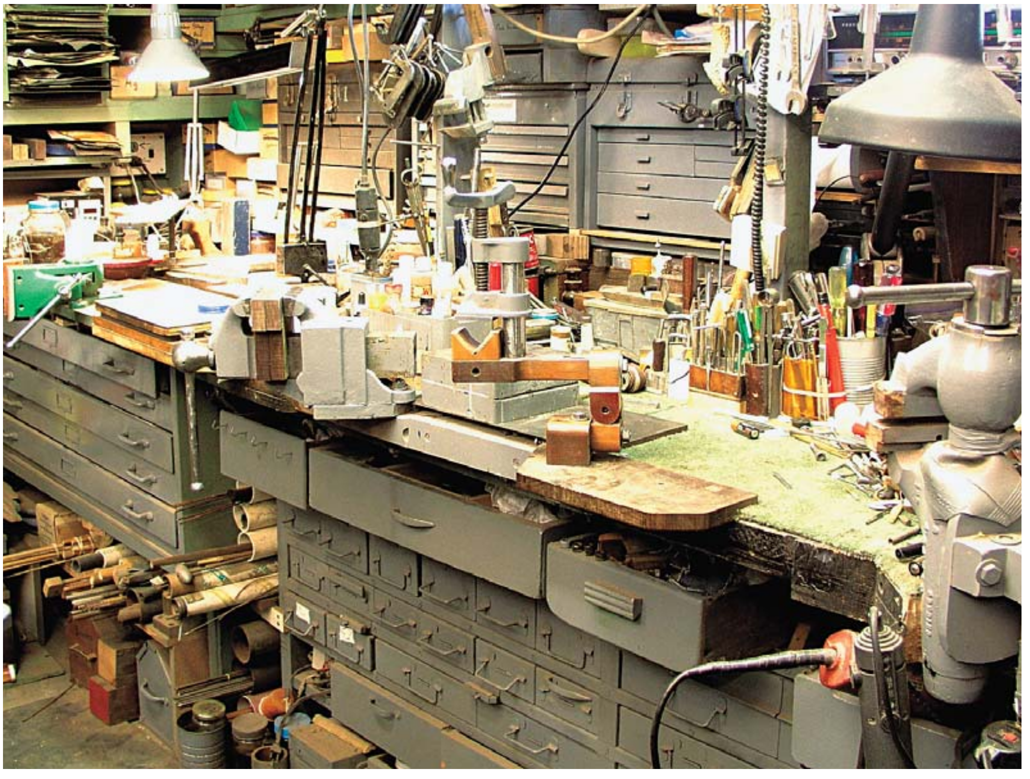
My shop has gone through two fairly complicated remodeling projects and half a dozen minor shuffles which became necessary as I added equipment. The first remodel was in 1982. I had just gotten set up to do investment casting, lapidary, and doing some silversmithing when I dove into making damascus steel. I got a chance to sell the largest item, a centrifuge. That space was filled by an anvil, the post vise was on a movable stand and the hard-coke forge on the back wall. A hood and blower was installed and I had the indoor forging area.

I had the stand-up bench from 1971 till about 1993. It was not against a wall where it would be more space efficient. My knees were getting so that I couldn't stand up for long periods of time. I needed a bench that was lower so I could sit on a shop stool. There was also the issue that as I added new equipment it had to go where there was space, not necessarily where it should be.

So, I tore my shop completely apart and made a sit-down bench that is also not a bad height to stand up at for not too long. I use a roll-around stool that I made by bolting an old time steel stool of the right height to a base with heavy duty swivel casters on it. The floor in front of the bench has artificial track surface on it, just about the ultimate stuff to stand on all day. I'm five feet 10 inches tall, the stool is 30 inches, the bench top 37 inches. Since I got both of my knee joints replaced in 1996 I don't sit as much.

Tools for the knife shop

You'll need a drill press, and it doesn't need to be large or fancy to get you started. You may want to make folders some day and then you will find out if you need a better machine. An imported one will do to start. Sears has a cute little drill press that is often on sale, and it's a solid looking little machine.



On this rare day, my workbench was halfway clean. Can you find the three vises and one makeshift clamping device? The horizontal Wilton is at the right. Note the Micarta attachment at the front of the bench. Various work holders are mounted to it via three threaded positions.

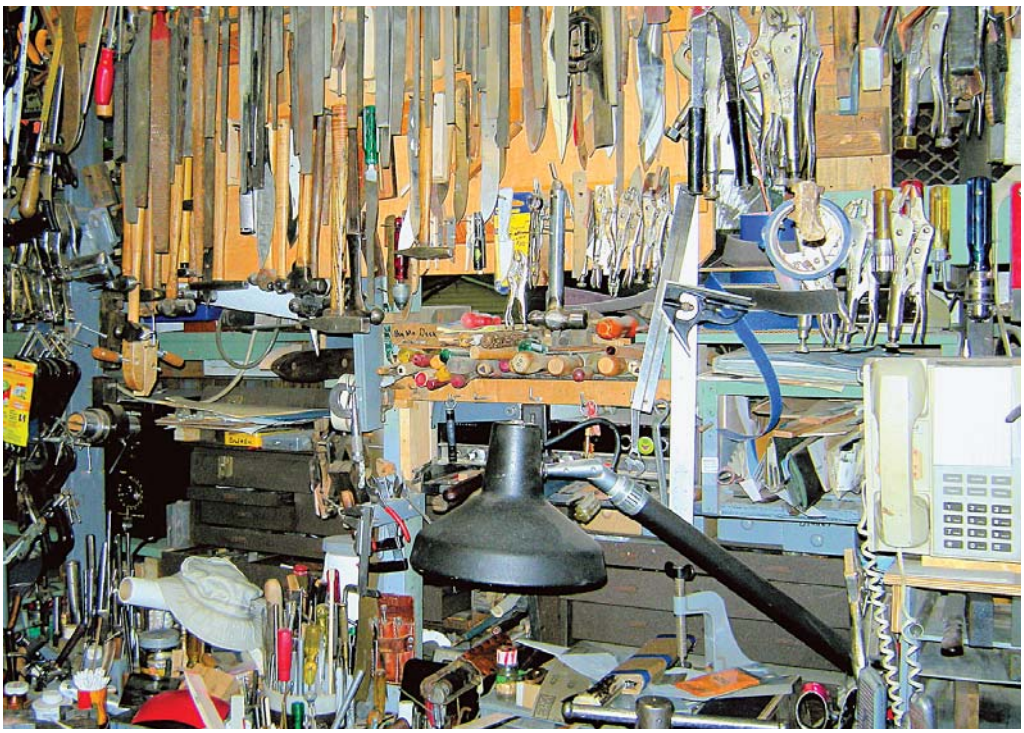
You'll need a band saw for wood. Same rule here, an imported one will do. What I've learned about the imported machines is that they are fragile. They can't be beat on with wrenches and such, the pot-metal parts need a gentle touch in order to make them last. The older American-made machines have steel or aluminum parts that will stand heavier duty work.

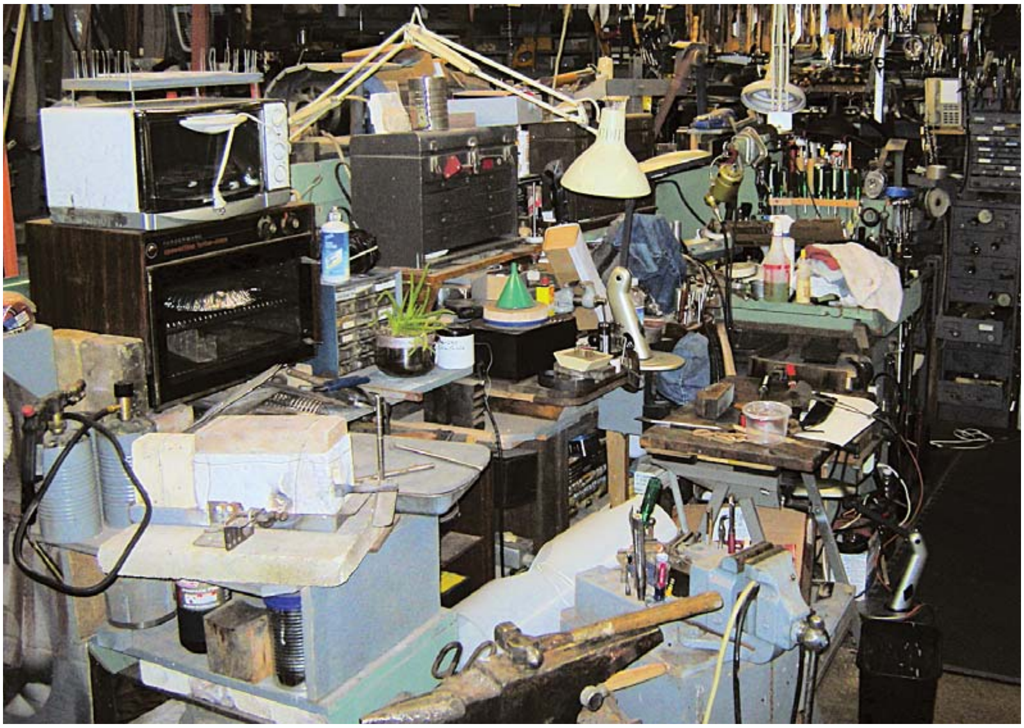
There are metal cutting saws for brass, aluminum and such softer metals. What cuts the nonferrous metals won't work for steel (ferrous). Before you buy a new saw, see what the instruction book says. The latest variable speed saws may run slow enough to do steel and, sped up and with the right blade, also do wood, Micarta and nonferrous metals. Information from a Wilton catalog says it will work for wood 3390 SFM (surface feet per minute), metal 39 to 278 SFM. I'd guess that my steel-only saw runs at no more than 80-100 SFM, with the fine tooth bi-metal blades. The old Delta wood/brass/Micarta saw at no more than 300 SFM.

I have one of the import flip/flop saws that are for metal only and it's the one for cutting nice and even steel for a damascus billet or 45-degree angle parts for building a machine. I didn't have a metal cutting bandsaw for the first 30 years. I would rough cut blades out of saw steel and other alloy steel with a torch. The torch won't work on stainless so I used abrasive cut-off wheels on a bench grinder that was set up to work as a saw. I've got a 14-inch abrasive chop saw that cuts bar stock to get it ready for the forge or for the doubling welds on damascus billets.

There are many types of metal cutting blades. The coarse tooth ones I use on my wood/Micarta/ brass/nickel silver saw has eight teeth per inch and that won't do steel. When I first tried to cut brass with it all it did was tear the teeth out. I jerry-rigged a jack-shaft to slow it down and experimented with the pulleys until it worked on wood/Micarta/ brass/nickel silver. Once more, it's not for steel, it's for nonferrous metals. The ones for steel have fine teeth and run as slow as you can make them go. I use half-inch-wide blades for everything, I like the extra strength. I can't cut the fine details but I don't need to. The last couple of years I've had a small three wheel bandsaw that takes the thin, narrow blades. It is more efficient for cutting out handle materials because of the narrower kerf and smaller turning radius. Often two handles can be cut out of one piece that would take two with the larger saw.

I call it the "Hanging Wall," and it is loaded.





This more up-to-date photo of the indoor forging area shows a different anvil in my shop. It's an 80# Hay-Budden.

This is the Porter Cable Porta Band. It has a variable speed motor and is quite the space-saving tool.

I've added a Porter Cable Porta Band to my collection of saws. I have it mounted to my welding table for cutting steel and all the soft metals. I made a mount for it that bolts to the saw through two of the screw holes that hold it together. The mount has a bolt hole which serves to fasten it to the bench top. It can be held in a vise too, a very handy saw to have. The very real advantage to the portable band saws is the space they save, and I'm out of space.

You'll need a double ended bench grinder set up with an abrasive cut off wheel on one end. A fine grit stone for sharpening drill bits and such is on the other end. You'll also need a buffer, a slow one with 10-inch stitched wheels (1450 rpm) will do fine.

For an air compressor, a little pancake type would do just fine unless you are going to run air tools or a sandblast cabinet.

Nicholson files are the best I've found. I use the eight-inch ones which I buy new at the discount store. Most of my other files come from junk stores or yard sales. I sharpen a lot of them by etching them in ferric chloride. As long as they are not chipped, they come out as good as new.

I use an OptiVisor with a 2X lens

Most of my good deals on tools come from those who don't stick with a hobby.

for all close fitting. The more powerful ones have a working range that is too close for most work. My dad was looking at one of my fancy folding knives one day and said something like, "I don't know how you make things fit so good." I had him put the OptiVisor on and then look at the knife again. He could see some little bitty things that didn't fit perfectly and then he understood that fitting it so it looks nearly perfect with the OptiVisor makes it look really good to the naked eye.

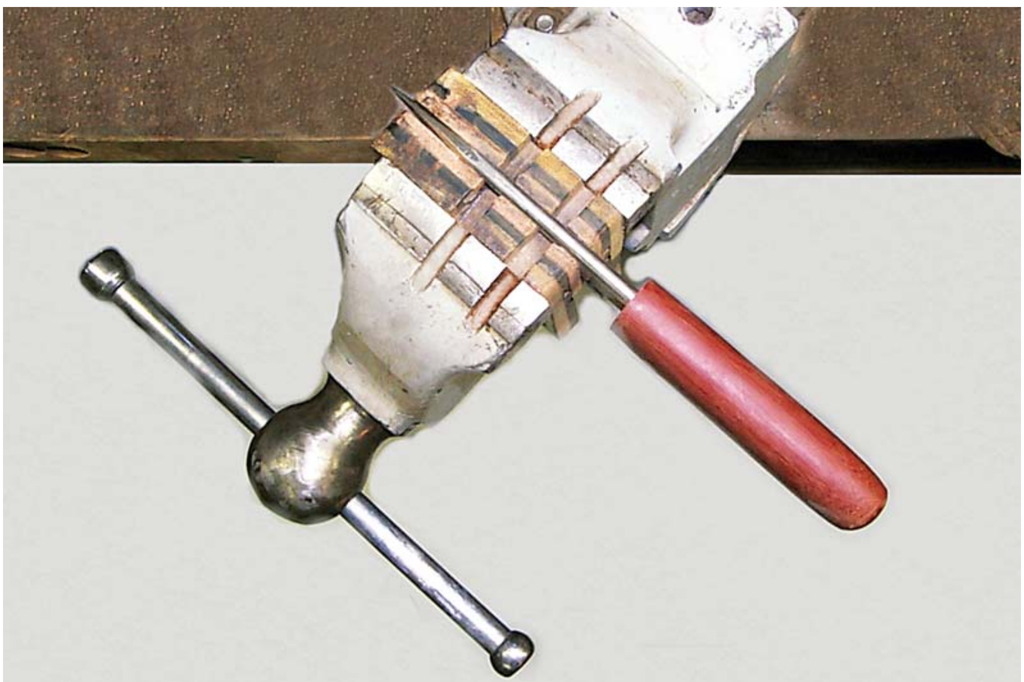
You'll want to have good light at your work area. More than one maker who has visited to get their knives critiqued learned that they had poor lighting in their shops. They could see lots of scratches in the blade and parts that didn't fit properly under the glare of my lights.

Smith and Victor are the best torches. I prefer Victor because I keep finding used parts for them. In this neck of the woods there must be 20 Victor outfits for every Smith. Look around for a good used outfit, then take it to a welding store to get it checked out or have someone familiar with them do it for you.

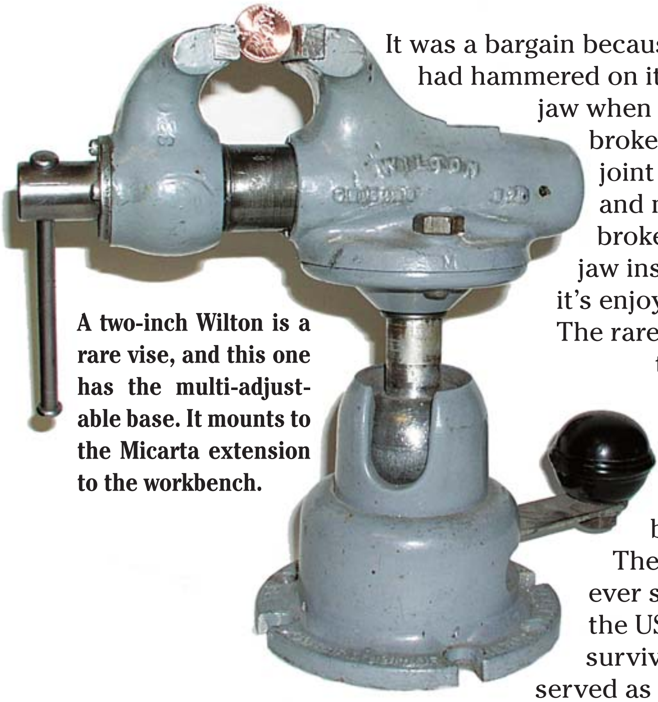
One new tool I bought is a high speed air operated turbo tool. I got it mostly for marking blades with a logo or owners name, cutting out backgrounds in engraving and carving in steel or other materials. I have dentist friends who pass on their used diamond and carbide bits. The diamond points I get are only dull on the end, I just grind them back past the dull and have 80 percent of the life left as long as the cut is on the OD. The fellow selling the turbo tool demonstrated a diamond point, just a cone, there were no flutes and it was writing on steel like it was a ball point pen. I've made a carbide cone tool and it doesn't work as good as the diamond but is more than adequate for the way I mark blades.

As for purchasing new tools, I'm all for it if you have the money and want to gamble that you'll stay with it long enough to get your money's worth out of them. Most of my good deals on tools come from those who don't stick with a hobby. I always look for used tools first, not necessarily to save money, but to get a better tool.

New vises of the best quality are expensive, but over the years I've been lucky enough to stumble onto some real bargains. The main vise in my smithy is 4-1/2-inch Wilton with pipe jaws. It lists at over $700. I bought it about 1983 in a second hand store for $35. I have a four-inch Craftsman ($10 yard sale special) mounted on a portable "retro-tech" work bench sitting out in the back yard where the $50 Knife Shop was set up. I paid $12 for the horizontally mounted three-inch Wilton.



This birds-eye view of the three-inch Rock Island vise shows how it is set out from the bench at a 45-degree angle. This allows me to work from the end or the side. The grooves in the jaws allow a folding knife put together with trial pins to be held in the soft jaw inserts. The vise is mounted to a piece of heavy steel plate which is bolted to the bench top.



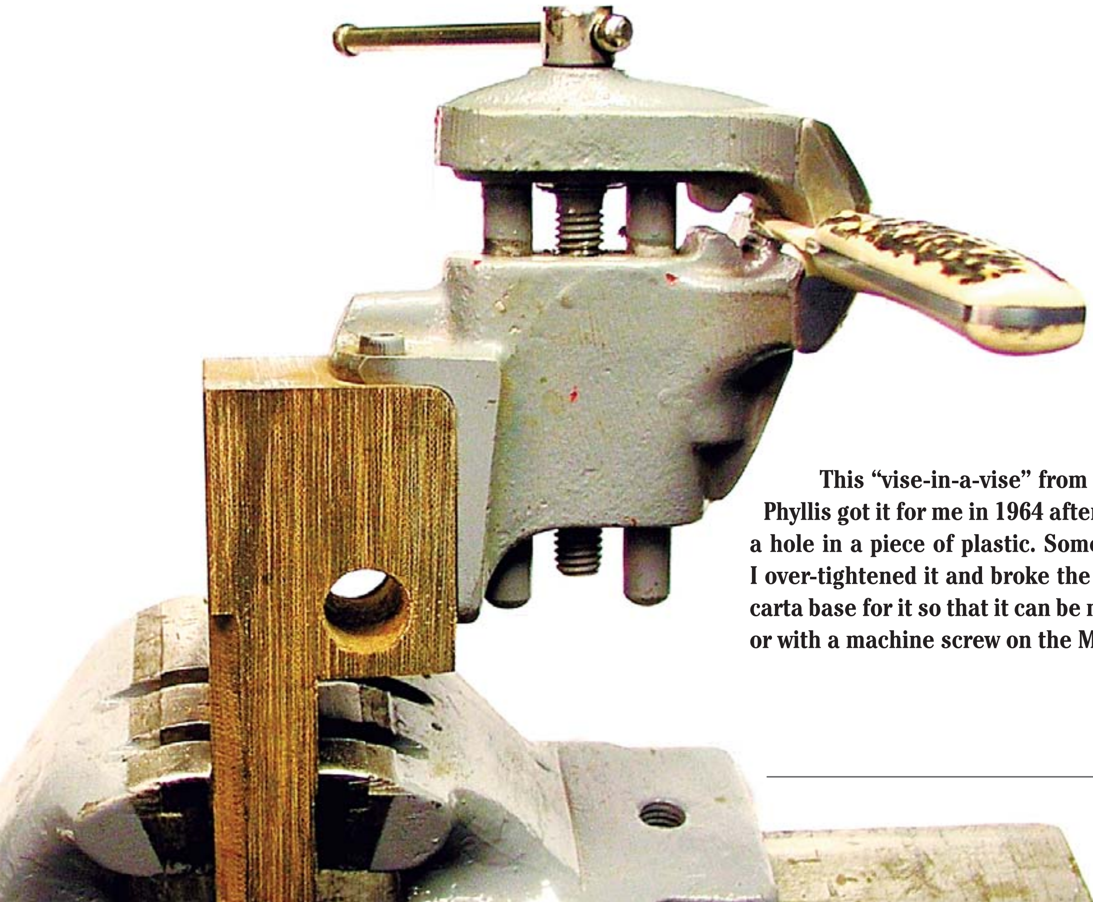
A two-inch Wilton is a rare vise, and this one has the multi-adjustable base. It mounts to the Micarta extension to the workbench.

It was a bargain because it was such a mess. Someone had hammered on it and broken a chunk out the front jaw when the screws holding the jaw inserts broke loose. It had been brazed but that joint had broken loose. The main screw and nut were good so I fished out the broken screws, made extended Micarta jaw inserts, then gave it a paint job and it's enjoying a new life on my workbench. The rarest vise I have is a two-inch Wilton that came with the swivel base. The two-inch is no longer made but the base is.

My #1 workbench vise is a three-inch Rock Island that came by way of a USMC Master Sergeant. The only other Rock Island vise I have ever seen was on the workbench inside the USS Bowfin. The Bowfin is one of 15 surviving WW2 submarines and is preserved as a museum. I was on it while visiting Pearl Harbor, and seeing the Rock Island vise confirmed the opinion I always had that my vise was a product of the Rock Island Arsenal during WW2.

For vise jigs used with #1, most important is a set of soft jaws. I use real old-fashioned sole leather that is glued to 1/4-inch Micarta. This allows the gripping of soft things without leaving a mark on them. I have a set of Micarta jaw inserts for #1 that are used to grip a blade that is having the guard hammered on for a press fit. #1 is also used for straightening and has half a dozen different ways to get a three-way bending action.

While it's not a true jig, the vise-in-a-vise is a very useful tool. It positions a folding knife spring right up close for doing filework. When fitting a guard the vise-in-a-vise holds the guard with the slot in the correct position for filing.



This "vise-in-a-vise" from Craftsman was the first vise I had. Phyllis got it for me in 1964 after I hurt my hand while trying to drill a hole in a piece of plastic. Sometime later after I had larger vises I over-tightened it and broke the tightening part off. I made the Micarta base for it so that it can be mounted vertically and horizontally, or with a machine screw on the Micarta bench-top extension.

Belt grinders for knife work

There are two main things you will be doing with your belt grinder, first comes profiling the blanks. You want the part of the belt grinder that you will use most at the height of your hands holding a blade with your forearms parallel to the ground. It works out for me at 47 inches. There are many brands to choose from but one thing that is important is belt size. The standard size is 2x72 inches. Use the internet to find prices and such, starting your search with Grizzly and Coote.

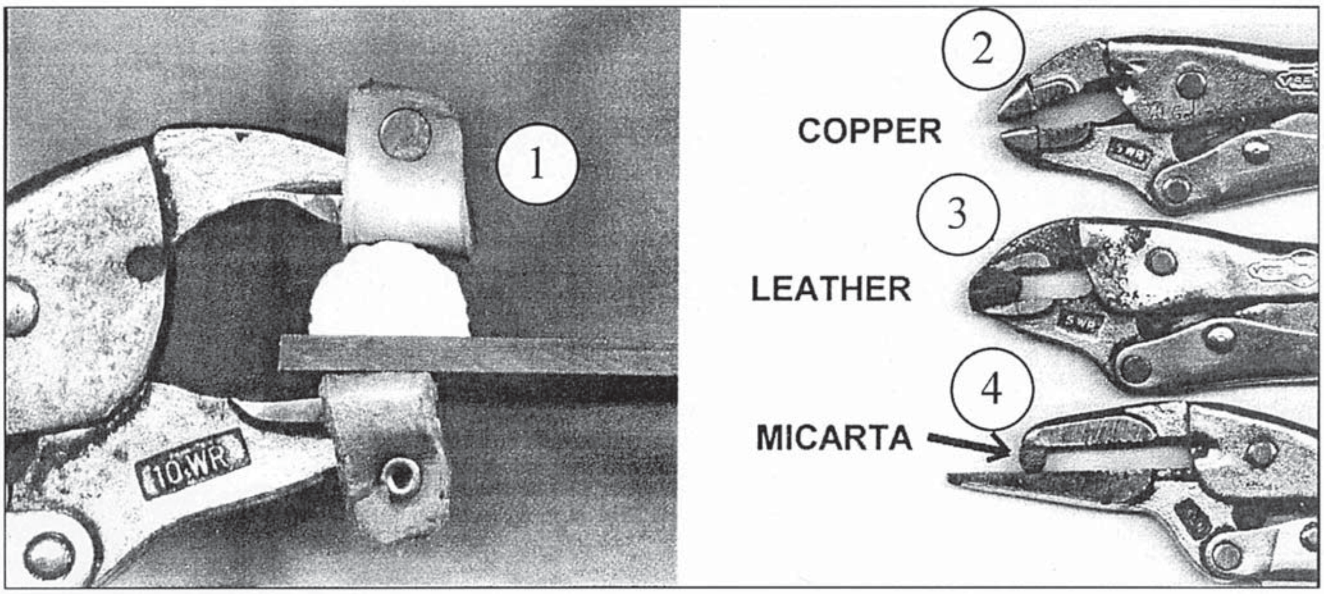
My #1 belt grinder is one I made and now getting close to 30 years old and it's got at least 250,000 miles on it. It runs a bit slower than the belt makers recommend but I like the control I have when belts run slower. I've got a good chapter on making belt grinders in my Krause Publications book, *The $50 Knife Shop Revised.*

I have a 6x48-inch Craftsman belt grinder that is my favorite when working on knives with blades 10 inches and longer. When forged it is difficult to get the sides flat with a narrow belt machine. Using a magnet to hold the blade, the 6x48 does a wonderful job of getting it flat. I grind a little on one side, then flip it over and hit the other side. That sometimes tells me I need to get a bulge out with the 2x72. Making the big ones is way more fun with the wide belt.

Modified Vise-Grips® for the knifemaker

Vise-Grips are the wrong tool for the right job. (A tool man told me that.) That's because there are times when nothing else will work even if it means marking up the object being gripped. I've worked past that and have become very fond of my modified "clamping pliers." I have 10 pairs of these modified Vise-Grip pliers. They have replaced most of the other clamps in my shop. Some are the large size, but most are the middle size.

To modify them I first grind out the pipe jaws and wire cutters in order to give clearance for the work being held. I then use super glue to attach thick sole leather



Grip pliers can be customized and made suitable for knife work.

1. This pair is fitted with slip-on leather grippers, as shown it clamps half-round handle material to the flat knife tang more securely than any other method.

2. Copper tube, fitted and shaped, holds metal parts without scratching it.

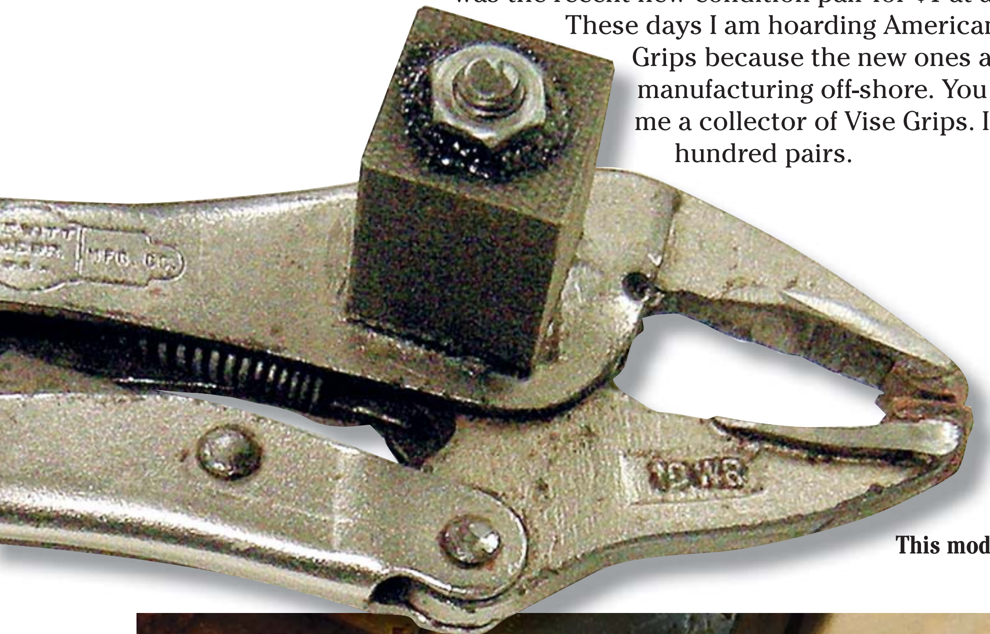
3. The contact points are hard sole-leather affixed with super glue and Micarta dust. It grips stag, ivory and pearl without cracking or marking it.

4. This version holds one side of a miniature folding knife for handwork or machine polishing. A larger pair like this holds guards for full-size knives for shaping and polishing. I got the idea for these when I found a pair with one broken jaw.

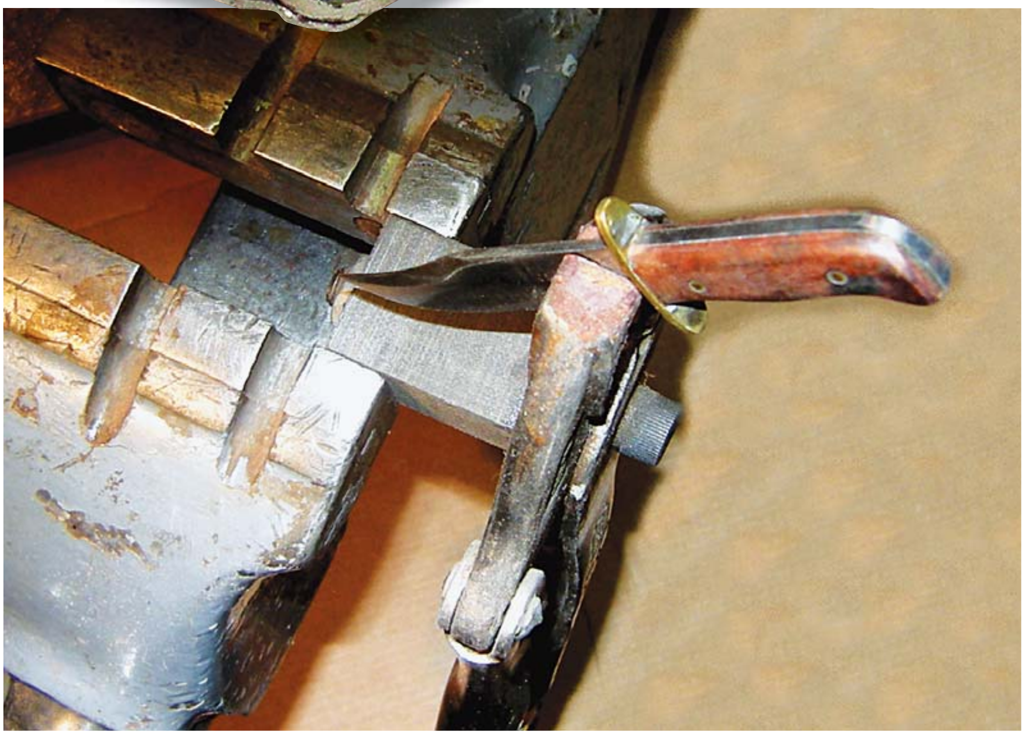
or Micarta pads. The pads have a radius, which is necessary to grip rounded surfaces. It also keeps the area of contact small and that, in turn, puts less strain on the pad. Super glue is applied around the jaw and Micarta dust is sprinkled on it to build up a fillet for strength. If the pad breaks loose, stick it back on with more super glue.

When held in a bench vise, the modified Vise-Grip clamp is the perfect work holder for small parts. Note the rivet heads that hold the pliers together. On versions 2, 3 and 4 in the image they have been ground flat so the Vise-Grip clamp can be held securely in the vise jaws. An improved model has a block of Micarta held with a machine screw that replaces the rivet. The block can then be clamped in the vise jaws as in the photo.

I get the locking pliers at yard sales, flea markets or junk shops only. I purchase the pliers, rusty or not, but in good mechanical shape, if they are less than $2. If they are nice and shiny the price is usually too high for me. An exception to this was the recent new condition pair for $1 at a flea market. These days I am hoarding American-made Vise Grips because the new ones are all being manufacturing off-shore. You might call me a collector of Vise Grips. I have over a hundred pairs.



This model has been improved for use in a vise.



The improved vise model held in a vise.

Knife Testing


Rudy Ruana in front of his shop in Mill Town, Montana, 1969.

I visited Rudy Ruana in 1969 and I don't remember seeing any belt grinders. There were several double-ended, pillow block arbors with large grinding wheels on them. The first thing I saw when I walked into the door was Rudy sitting on a stool in front of one of those grinding wheels. When he saw me he looked up and said he just wanted to finish this batch before he quit so I just watched him work. There was a tray with about 10 knives in it on each side of the grinder. Rudy would take a knife out of the tray on the left, make several smooth movements at the grinding wheel and place it in a tray on the right side. He was using the corner of a wheel to shape the inside curve on the cast aluminum pommel cap.

As he showed me around the shop I was amazed at how close to the finished shape his blades were when they came from the anvil. He said it took him only a couple of minutes on a grinding wheel to finish off a hunting size blade. His knives were not real flat and shiny like most of what is done today but they were 100 percent adequate for the hard working knives they were intended to be.

I owned two Ruana Bowie knives at the time of that visit and I had taken them with me in order to get a photo of Rudy holding them. When I showed them to Rudy he wanted us to go around to the back of the shop so he could show me how well he could "stick" (throw) them. Those Bowie knives had each cost me about two or three day's wages and I was not real excited about having them thrown. I told Rudy that even though I had heard that he was an expert knife thrower he didn't need to show me with my knives. Even though he assured me that it would not hurt them, he accepted the fact that I was protective of the knives. He had nothing in stock to throw and even seemed a bit disappointed that he could not demonstrate his knife throwing skills.

The confidence he had in the strength of his knives was something I had not seen before and it gave me a worthy goal to work toward. It forever changed the way I thought about what I was putting into my blades. I had only been making knives for about six years and it was a good time for me to be exposed to a combat quality blade.

There is very little value in stating what a particular blade will do if a fair comparison is not made with another blade of known value.

The testing program

I told the story of my friendship with Maynard Meadows in Chapter One. I give him credit for getting me into knife testing as well as being responsible for my Traditional Hunter model.

The questions we wanted to answer were these:

- Does one type of steel have a particular advantage over another in specific applications?
- How strong must a blade be for different types of use?
- What would a realistic strength test consist of?
- How sharp is sharp?
- Are there different types of sharpness and, if so, does one have an advantage over another?

It might seem that these questions would take an impossible amount of time and effort to answer. It is my hope that these three simple tests will take some of the mystery out of the questions:

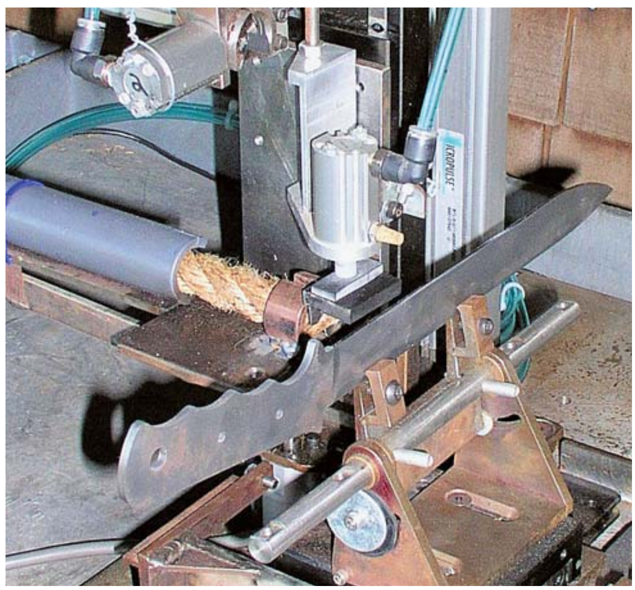
1. Endurance cutting ability, the ability to stay sharp.

2. Chopping ability, comparing and evaluating the efficiency of different blade cross-sections.

3. Strength testing is divided into two parts. The first is edge strength, the ability to resist chipping or cracking at the edge. The second is total blade strength, the ability to be flexed without damage.

Always compare the test blade with a blade of known value at the same time and on the same material. There is very little value in stating what a particular blade will do if a fair comparison is not made with another blade of known value. A blade made of a specific steel type must be tested at the highest hardness at which it will have adequate strength for its intended use. It is assumed that the test blade was given a proper heat-treatment. A slicing cut gets the test done quicker. A thin blade

The rope cutting endurance test.



Close up view of the rope cutter.

with a polished edge can be pushed straight down through the rope. Be prepared to do hundreds of cuts to prove anything.

Through my association with Charles Allen and Diamond Blade knives I got to see some of the test equipment that industry uses. They have one machine that cuts rope as an edge-holding test. The machine was designed to cut bundles of card stock with five percent abrasive particles in it. Tests were not consistently accurate so they converted it to rope and they like the results. (According to metallurgist Dr. Carl Sorensen they read about rope cutting in “The Wonder of Knifemaking.”)

There is another machine that measures the pressure necessary to penetrate a test material. The machine, made by CATRA (Cutlery & Allied Trades Research Association) is called a Sharpness Tester. The knife is clamped in the machine which pushes it into a specially made silicon rubber test material. The pressure measured to penetrate the silicon material is the measure of sharpness. The less pressure required, the sharper the edge. After comparing my results with the test machines, I have great faith in my test procedure for both endurance and sharpness testing.

Great care must be taken to see that the test blades have the same cross-section geometry. In order to get a fair comparison, the blade thickness and length must be the same. With the rules out of the way we will get down to some common sense observations about test procedures.

Before accurate test results can be arrived at, it will be necessary to discuss sharpening and to define exactly what a sharp edge is. A perfect edge is one in which the primary included angle comes to a crisp and exact point. The cross section of the blade must be quite thin in order to cut the rope in the endurance test. I prefer an edge with micro-teeth used as it comes off of the Fine India stone made by Norton. It is important that the wire-edge is removed in order to have a long lasting and testable edge. The ability of a knife to shave hair is not a valid test if the edge has a wire on it.

As the blade is abraded on the sharpening stone the edge gets thinner and thinner until the straight lines that form the included angle of the blade meet. At this point there is a thin wire or burr of blade material that simply bends back and forth under the pressure of the stone. The wire edge may be perfectly lined up from light pressure on the stone, or by careful use of the buffing wheel or strop. This edge will shave hair and slice paper but will fail quickly when the edge contacts wood, rope, hide or other hard objects. As the wire edge contacts hard materials it bends back and forth and finally breaks out, leaving a microscopic flat where the wire of steel pulled away from the edge.

The CATRA Sharpness Tester

Here, I'm standing next to the Diamond Blade test equipment at the Tejon Ranch Wild Pig Hunt.

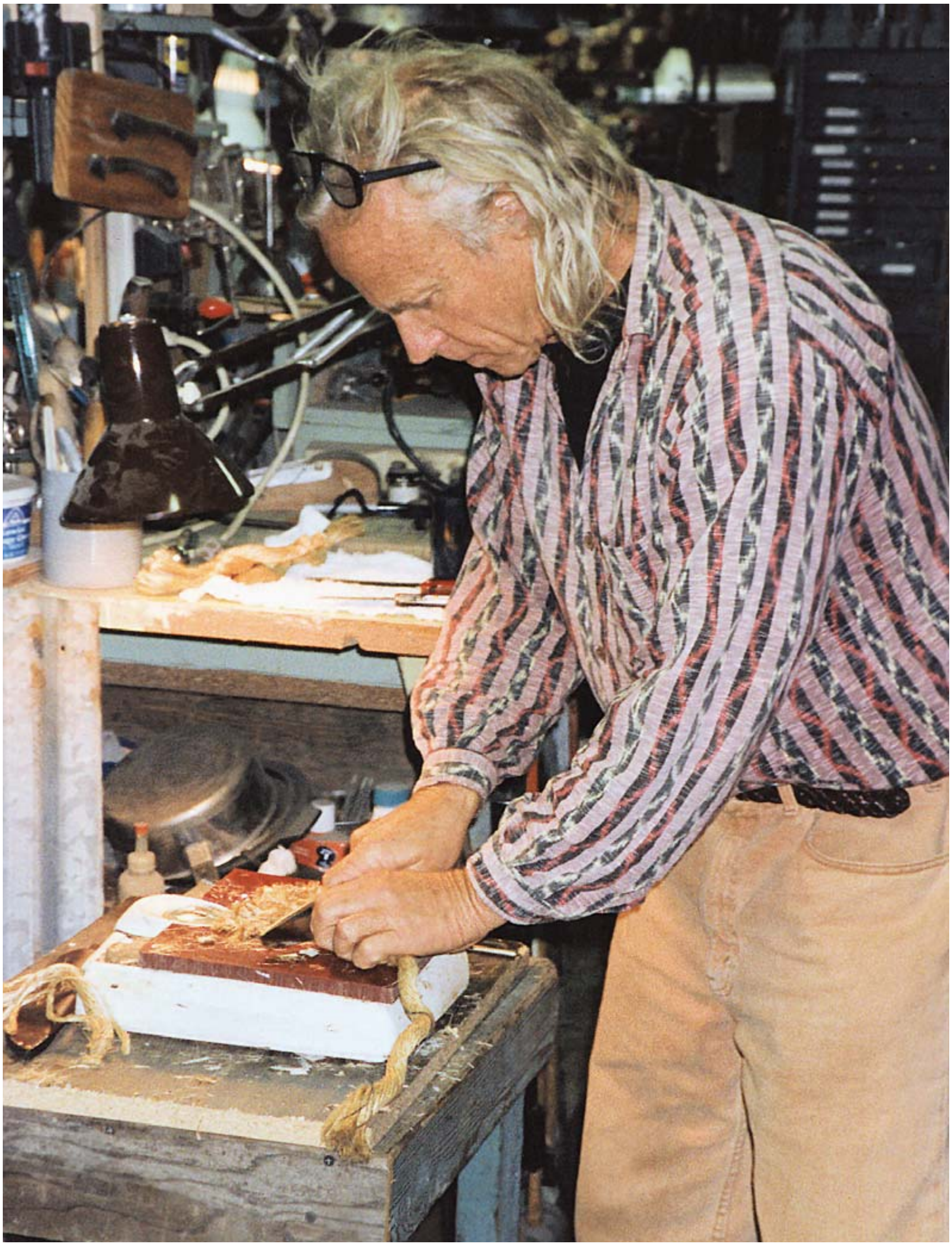
At other times the wire will bend over, causing the knife to appear dull. Actually the blade material that was doing the cutting is bent over. The best way to assure that the wire edge is off and that you have a true sharp edge is to back-stroke the edge across a smooth metal rod. Use an angle somewhat greater than the sharpening angle. You will be able to feel the wire by running a fingernail down the side of the blade opposite the side that was stroked on the rod. If the wire or burr it is still there, the fingernail will hook on it. The wire is removed by taking light passes on the fine stone at an angle of about 30 degrees. Take one pass down the first side, then one down the other side and keep checking it. Only enough pressure is applied to abrade the wire off. Once the wire edge is removed and the true sharp edge is properly set up, accurate testing can begin. (See the chapter on sharpening.)

The history of the testing program

I started out cutting cardboard as an edge-holding test. It was a boring and time-wasting process simply because a superior blade would cut until your arm was sore, and you were up to your knees in cut off pieces of cardboard. The first tests on rope were done in 1972. The purpose was to determine the difference between 440C and 154CM. My friend and customer, Maynard Meadows, had suggested using sisal rope, and very successful and time-efficient tests were achieved. We starting out cutting the full one-inch rope, but soon switched to the single strands as they dulled the test blades quick enough to make the testing time efficient.

Over the next eight years I made several dozen test knives to compare different steels, and also to compare the same steels with different heat treatments. Maynard, an avid big game hunter, would take the test knives on hunting trips in order to get a comparison in actual use. The field tests reinforced the results that we were getting with our rope cutting tests. I obtained abrasive resistance charts from two different steel companies, and by comparing their bar charts with my rope cutting tests, when the hardness of the steel was the same, I realized that I was within five percent of their ratings. I gained more confidence in my endurance testing as time went along.

One of the tests that I did early on, with the help of Paul Bos, was to determine the effect on edge holding as the hardness changed. Paul is a professional heat treater and was interested in helping in these tests. We ran test batches of D-5, 154CM, and 440C, giving half the blades their normal working hardness, the other half were drawn back two points on the Rockwell C scale. The blades drawn back two points would cut 15 to 20 percent less, which surprised both of us. Later when comparing a blade with a hardness of 54RC to a blade of 60RC, I found the percentage loss held up. The steel that did 40 cuts at 60RC would do 30 cuts at 58RC, 20 cuts at 56RC, 10 cuts at 54RC and at a hardness of 52RC, would hardly cut the rope one time.



Knifemaker David Boye cutting rope in the Goddard shop.

Endurance testing

Test blades are prepared with a width of one inch, thickness of 1/8 inch and length of 3-3/4 inches. Blades are flat ground to .020 inch at the edge. Sharpening is done on the Norton Fine India Stone, the wire edge being worked off with the stone. This gives a hair shaving, long-lasting edge that has what I refer to as micro teeth. Slicing cuts are made on a single strand from the one-inch rope. Care is taken to use an equal section of blade from one knife to the other. The edge will bite into the rope strand when freshly sharpened, but as slicing continues there comes a point when the edge no longer is biting into the fibers. This is the point at which slicing is stopped and the number of cuts is recorded. The edge loses its ability to shave hair at about the same time as it loses its bite into the rope. Each blade is tested at least three times and the results are averaged.

Update: The last 10 years or so I've been cutting on a scale. I quit cutting when the pressure reaches a certain point, usually 35 lbs. I had a normal variance of 10 percent and that has dropped to five percent by using the scale.

The slicing cut compared to a push cut

The blade with a buffed edge will push through the rope strand with much less pressure than if it has the micro-tooth type of edge. The limiting factor to the number of cuts with the polished edge is the amount of strength required. It is harder to determine when the edge actually quits working. Depending on how hard you wish to push, it uses four to 10 times more rope. The blade with micro-teeth will slice through the rope better than the polished edge. The slicing type test is faster and more accurate for the type of edge that I advocate. Over the years I have learned that the micro-tooth edge is superior for a working type knife.

The differences in rope

I had a Paul Bos heat treated 154CM knife that I kept for 15 years or more. It was "The Bureau of Edge Holding Standard." I called it a check blade. When I got a new supply of rope, I always did a cutting test with it; that way I would be aware of any change in the number of cuts expected. There are big differences in rope; some will dull a blade three times faster than others will. Using my 154CM check-blade and the original rope that testing was started with, I would get around 44 cuts on the average test. The last two batches of rope have been much more abrasive and the number of cuts has dropped to around 20. When testing on the rope from my Knife-Expo demonstrations, the number of cuts dropped even more, to around 15-17. The fibers in it are large, it is very stiff, and I had noticed that it was hard to cut during the free-hanging rope cutting demonstration I did at the show. A knife that would easily do three at a time on most of the ropes that I have cut would do only two at a time on that hard rope. For future testing I am advocating the use of 1/2-inch rope. It will be easier to find, and very comparable results were found when I compared it to using the single strands out of one-inch rope.

The free hanging rope cutting test

The free-hanging rope cut is primarily a test of the knife's sharpness. I do not use it as part of my testing because it has so many variables. The test has secondary value as a gauge of blade strength. I had a stock-removal blade break into several pieces while attempting to make one cut at a time on free-hanging one-inch rope. That blade was hard all the way through, no soft-back. A blade with too much soft-back may bend in the test. Cutting free-hanging rope is a very effective way to demonstrate, as a comparison, the cutting ability of different knives. It takes a blade with good geometry, made from good steel, correctly hardened and tempered and with a nearly perfect edge to easily complete the cut. It does not matter if the blade is forged or stock removal.

Testing the chopping ability of knives

At a knife show in Oklahoma I was asked to do a 2x4 chopping demonstration. I had just passed my ABS Journeyman Smith requirements. The only knife I had with me that was long enough was one of my test blades. The 10-inch blade, which was forged from a Nicholson Black Diamond file, weighed only 12 ounces. Regardless of the weight, it was a very efficient wood chopping and free-hanging rope knife. The narrow tang put the weight mostly in the blade, a real advantage in a chopping test. As I finished chopping through the 2x4 I heard someone say, "eighteen seconds!" Although I had never thought of timing myself on the 2x4 chop, it is a good comparison to make when testing a chopping type knife. When I returned home and timed myself on some Oregon 2x4s, I never could beat that time. That Oklahoma wood was very soft and because there was no double check of the timing, I cannot claim a record of some sort.

Another comparison to make is to count the number of swings it takes to chop through a wood 2x4. The number can vary a lot with a specific blade depending on the force of the arm swing, offset of the handle, wrist action, accuracy of the cut, and hardness of the 2x4. A knife with good steel, having at least a 10-inch blade and weighing 12 ounces or more, will chop an average-hardness 2x4 in half with around 25 swings.

In order to get as many comparisons as possible, I started measuring the depth of penetration into a piece of wood with a single blow, however, and this did not seem to be very consistent. I did a series of tests to determine the largest piece of wood that could be cut with a single blow. A pine or fir board 3/4x1-1/2 inches (actual measurement) is a good size to start with for this comparison test. The knives with a dropped handle would always out-chop the straight broom-handle designs. These were useful comparisons, but I wanted to eliminate the human arm and the advantage of good handle design. I wanted to be able to test only the efficiency of the grind (blade cross-section geometry). This is how the Chop-O-Mattic penetration test machine came to be built.

The Chop-O-Mattic edge test machine

Sets screws hold the blade horizontally with its back secured against a pivoting arm. The arm is raised a given distance, then allowed to fall free, and the knife-edge penetrates the edge of a piece of test material held by a clamp. The depth of penetration is measured with a vernier caliper and recorded. Accurate and uniform results are reached, and the human element is eliminated.

The specifications for the machine are as follows. The arm weighs 3-3/4 pounds. The distance from the pivot point to the striking point is 23 inches; the arm is dropped from a point that will give 14 inches of blade travel. Initial testing was done with no adjustment for the weight of the knife, which gave the heaviest knives an advantage. An improvement was done by adding a bolt upright on top of the arm. Washers and hex nuts are used to make the falling weight the same. One chop was done on each of three different materials with each knife. The total penetration on all three materials was totaled. The materials used were 3/4-inch Mahogany, 3/4-inch cedar, and 3-inch Delrin®. The knives were mounted to give a square hit on the test material. When there was a difference in the depth of the cut from one side to the other, the two measurements were averaged.

Testing edge strength

Those who don't do their own heat treating trust their heat treater to return blades with the hardness that was specified. If this degree of hardness has proven to give superior edge holding ability, and yet be strong enough to resist chipping out, then all is well. The maker doing their own heat treating will need to establish some type of testing process in order to insure the integrity of the blades they make. Bladesmiths do their own heat treating and often work with a larger selection of steels than a stock removal maker. The best possible heat treatment must be worked out for each steel type they work with. This starts by using the correct temperatures during the forging operation, continues with proper normalizing and annealing, and is finished by using the correct hardening temperature to gain maximum hardness with a fine grain structure.

Determining the tempering temperature for a new steel type is like walking a tightrope. On one side, the blade may be too hard and break; on the other side it may not hold an edge. The tempering temperature is very critical, 25 degrees F one way or the other will make a difference whether the edge will chip out or not. The fine line between too hard and too soft should be worked out carefully with actual tests and not left to chance.

The brass-rod edge-strength tester.

The brass rod test

The brass rod test was shown to me 47 years ago by a blacksmith who said he made knives in the 1920s-30s. It is the best test of edge strength I have found. Clamp a brass rod 1/4-inch in diameter horizontally in a vise with the top third above the jaws, or epoxy the rod to a wood base. Lay the edge on the rod at the same angle used for sharpening. Apply enough pressure so that you can see the edge deflect from the pressure on the rod. This pressure works out to 35-40 pounds. Use a good light source behind the vise so that you can see the deflection. If the edge chips out with moderate pressure on the rod, the edge will chip out in use. If the edge stays bent over in the deflected area, it will bend in use and be too soft to hold an edge. The superior blade will deflect and yet spring back.

JD Smith and Al Barton doing some unauthorized testing of a knife edge and a railroad spike.

I go one step further in testing camp knives and combat blades by chopping knots out of 2x4s. The grind I use for a big, rough-use blade is a compromise between a thin blade that is good for rope cutting and a thick, maxi-strength blade.

The knife breaker

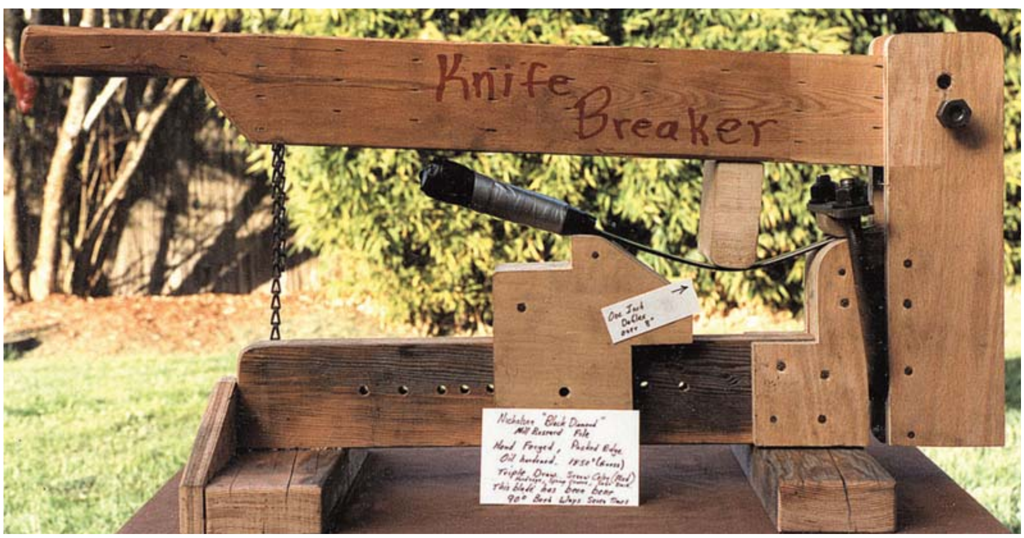
The knife breaker was built in order to have a standard test of the effectiveness of different thermal treatments on the strength of blades. I named the machine “Knife Breaker,” not because breaking blades was the purpose, but because it easily broke blades that could not be broken with maximum hand pressure. The purpose was to make it possible to deflect the blade a preset distance over a fixed distance. A heavy “U” bolt holds the point of the knife securely and the blade support is adjusted for the length of blade to be tested. A wood block to give the desired deflex is placed under the blade.

The photograph of The Knife Breaker shows it set up to test a blade. The wood block plus the 1/2-inch steel bar under the blade will test a deflection of 1/2 inch. By pushing down on the lever-arm up to 1,500 pounds of pressure can be put on the blade. To test the blade the arm is pushed down until the underside of the blade contacts the block. That puts an exact amount of pressure on the blade. A good test is a deflection of one inch over a length of seven inches.

The 90-degree flex test

When a knife dulls, it can be resharpened and a blade that takes a bend can be straightened and put back to work. When a blade stains, it will still work. A broken blade can spell disaster in a life or death situation where a blade of maximum strength is absolutely essential. The 90-degree flex test is a good way to determine the ultimate strength of a blade. The test was originated to prove the strength of a blade that is given the hard edge, soft back treatment. Though criticized by some as being too severe a test, it is useful and proves the worth of the soft back.

Close up shot of The Knife Breaker set up for a half-inch flex. The top of the wood block is one inch, add the half-inch steel bar, and there is half-inch of deflex.



The Knife Breaker flexing a blade one inch over a length of eight inches.

My testing procedures, including the flex test, give me a confidence that I otherwise would not have. If the blade has too much soft back, it may bend in normal use and won't have sufficient stiffness to be useful. If the hard edge extends too far up the blade, or if the body of the blade was not given the proper thermal treatments before hardening, the blade will break. It is reasonable to expect that a blade with the proper ratio of hard edge to soft back will be capable of being bent 45 degrees, and will "return to straight" with no cracking or breaking at the edge.

Often, when flexing a blade held in a vise it will be so strong that the vise jaw cutting into the steel will cause the blade to break at that point. When this happens, a true measurement of the strength of the blade is not possible. In order to get a true test of strength, I adopted the practice of placing a piece of hardwood with a rounded edge in the vise for the blade to be bent over.

That concludes the tests I have worked out to determine the overall efficiency of different steels, selective heat treatments, blade cross sections, sharpening methods, blade thickness, and etc.

Audra and Mike Draper with their blades that passed the ABS 90-degree flex test. Audra with a Damascus blade for Master Smith, Mike for Journeyman with a carbon alloy blade.

Conclusions

1. Sharpening procedures that will give maximum cutting ability are largely misunderstood.

2. There are three types of "sharp": false sharp (the wire edge), polished sharp, and micro-tooth sharp.

3. The polished edge has an advantage in the type of cutting where the knife is pushed through the material.

4. The edge with micro-teeth cuts better in the slicing type cut, and will last longer in the average cutting application.

5. There is no such thing as "hard-to-sharpen steel." Fat edges and thick blades cause this belief in some cases. Most of the time the sharpening stone being used is inferior and lacks the ability to work down the edge in a reasonable amount of time.

6. Hardness has more effect on edge holding ability than alloy content. The highest alloyed steel will not perform unless it is at its full working hardness.

7. In chopping tests, inferior steel with good cross-section geometry will out-cut superior steel with bad geometry.

8. The weight of a heavy knife is of little value if it has a fat edge.

9. Handle shape, size, and the angle to the blade are critical to the performance of the chopping-type knives.

10. The blade with a high polish will chop wood and cut free hanging rope better than one with a satin or sand blasted finish.

11. Superior knives will be developed if more accurate comparisons of performance are made and then the product can be modified in order to make it better.

12. If there must be a contest or challenge, it would be wise to remember that any knife can be beaten in either specific tests or overall testing by any or all of the following: better design, superior steel, more effective heat treating procedures, superlative sharpening technique, or by utilizing the ultimate in blade cross-section geometry.

13. A particular type of steel has a certain potential in cutting ability and strength. It matters not so much that it is forged or stock removal, but that it was given the proper thermal treatments to bring out the maximum in performance.

If you disagree with my tests or conclusions I hope that you will prove me wrong by designing better tests and by making more and better comparisons. Do not keep a secret of what you have learned.

A test with a sad ending

The cutting, chopping and flex tests for ABS Journeyman Smith have to be accomplished by the applicant with his/her own hand. One day, a journeyman applicant was in my shop bright and early, the one-inch rope for the rope-cutting test hung with care. The applicant easily passed the first test when he stepped up and neatly cut a piece from the free-hanging end.

Chopping a wood 2x4 in half two times is the second test. This test of edge-holding ability requires the blade to shave hair after making the cuts. As the applicant started chopping, his test knife broke at the junction of tang and blade. A visual inspection of the break showed a very coarse grain, and a cut made with a file indicated the steel was harder than it should've been in that area.

My experience led me to believe that something had gone wrong in the heat treatment. There are numerous small details to be worked out with one's own equipment and methods. The broken blade showed the applicant's lack of experience with his equipment and methods. It'll usually take quite a bit of practice to completely master the heat treating process. I relate this story to make the point that knowledge without practice and experience can be of little value. The applicant knew the fundamentals of selective hardening and yet the knife unexpectedly broke.

The total package

To start, let me digress to an earlier time. The year was 1977. A knife had been sent to me for a minor repair and also to test the blade's edge holding ability. It was a beautiful lock-blade folding knife with an ivory handle, filework and a damascus blade. There were not a lot of damascus knives at that time and damascus folders were the rarest of all. It was a nice piece of work – but it would not cut anything!

When I tried to sharpen it, I could not get the blade sharp enough to make a single cut in the test rope. I could have concluded that the steel wasn't any good, but I didn't. The blade was much too thick at the cutting edge to be of any use as a cutting tool, a problem I refer to as "defective cross-section geometry." It was not possible to determine the edge holding ability because of the thick edge. From outward appearances and as a collector's item that knife may have been considered adequate by some, but as a useful knife it certainly was not. This started me thinking about knives as a total package, one that must be complete if the customer is to get full value for his money.

I teach my students a simplistic version of the total package concept, and that is that they should make knives that work, feel and look good. If one of these areas is lacking, the effort in making the knife is mostly wasted. I understand that there is a market for fantasy and art knives, and as such it is not usually expected that they would ever do real work. Therefore, the exposition of my opinions that follows does not apply to such knives.

Deficiencies often found in beautiful knives — and possible cures

Good steel, bad heat treatment

I am convinced that there is too much emphasis on the type of steel that is being used in knives. I get many skillfully crafted knives in for testing that will barely cut anything. In most cases the maker picked a good steel type but gave it an inferior heat treatment.

Solution: Knifemakers interested in making real working knives should be doing some type of cutting comparisons with their knives. This is even more important for those who are doing their own heat treating. The number of heat treating furnaces in makers' shops is increasing. In my opinion, and especially concerning the high alloy steels Like D2, ATS-34, 440C and the CPM steels, a hardness tester is essential. The performance of these steels depends on the tempered hardness being exactly right. Formulas for tempering and freeze treating are only good when the blade achieves full hardness in the hardening cycle.

Good steel, good heat treatment, but bad cross-section geometry

At times the steel and heat treatment are good but the blade is too thick at the cutting edge to be of any real use as a cutting tool.

Solution: Once more, if the maker were doing any comparisons, it would be evident that something needed to be changed.

The knife is not properly sharpened

When I did my cutting challenge at Knife Expo, the knives that were brought to the demonstration area for testing were either not sharp or had a wire-edge. These knives were on tables for sale at that show! None were capable of making a slicing cut on rope. Can it be that the maker who delivers a knife with an improperly sharpened blade has not cut many things with his knives? These knives were mostly well designed and were made of good quality steel. The total package was deficient because the blade would not do what it is supposed to do, and that is cut.

Solution: Practice sharpening techniques and learn what type of edge gives the best results for each different kind of knife.

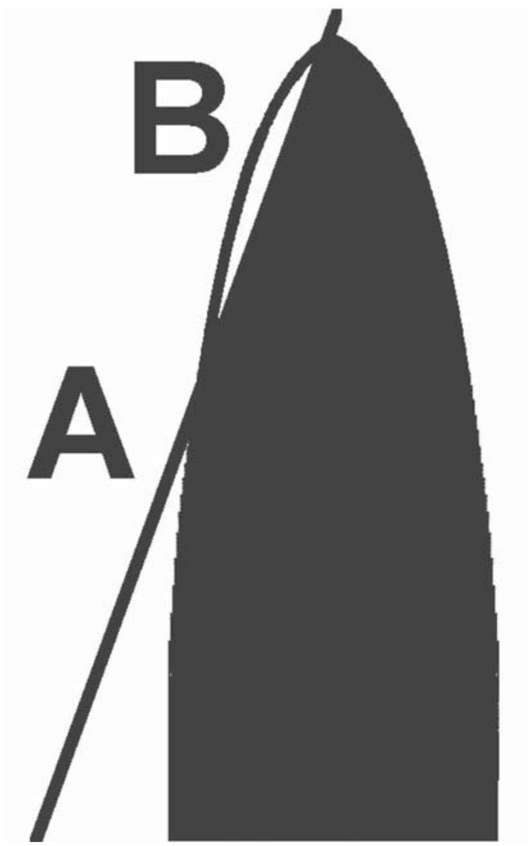
The Study Of Sharp

It was in the August '91 issue of *BLADE* Magazine® that I answered a question on sharpening. It was the fourth question to come in and an important one too. Sharpening is one part of knives and knifemaking that is confusing and misunderstood. Most knives are not sharp the majority of the time. Some of this is because they were never truly sharp in the first place, being too thick at the edge can cause this. Some knives are dull most of the time because the user simply does not take the time to keep the blade sharp. And, there is a lot of info on sharpening that puts the one trying to sharpen their knife at a disadvantage.

Before we discuss sharpening technique it will be necessary to understand a few very important factors in the sharpening process. First, and most importantly, the sharpening process should be thought of as three distinct and different operations: first roughing, then finishing and removing the wire edge. It takes either two different stones or one combination stone with the two correct types and size grit to do the total job.

The stone

For the roughing process a stone is required that quickly removes material from the hardest blade. This stone should have grit made of silicon carbide; there is nothing else that cuts quite so fast. The grit size will be around 150 to 240. I use the Norton Medium Crystalon (silicon carbide) for the roughing operation. The roughing stone leaves a coarse and ragged edge that will saw through fibrous materials but will not be suitable for any type of fine cutting. The finish stone smoothes up the edge and is used to take the wire edge off, leaving a true sharp edge. The finish stone is the Fine India (aluminum oxide). The grit size of 320 is fine enough to give a hair shaving edge yet leaves enough micro-teeth to give superior slicing ability.



The cross-section of a dull edge is rounded, the material at "B" needs to be removed. A sharp edge will appear when the two lines that make up the primary sharpening angle meet at infinity.

Sharpening fluid

For many years I used odorless kerosene for a sharpening fluid. Kerosene keeps the stone clean, creates the quickest cutting action and is economical. Honing oil will work but is slower cutting than kerosene.

About three years ago I started using the household cleaner Simple Green for a sharpening fluid. It is available in two forms, premixed and concentrated. The premixed household variety can be cut with 50 percent water for sharpening. When using the concentrate to mix your own there is no point of making it stronger than one ounce of Simple Green and four cups of water. I found the premixed Simple Green spray bottle in the household cleaner department at Wal-Mart, the concentrate was in the automotive department. Read the warning label on the concentrate about what to keep it away from. You'll get the sharpening done quicker because of the improved cutting action of Simple Green.

New stones are getting expensive. If they look like they are made of silicon carbide or aluminum oxide, I buy every dirty, worn stone I find at yard sales and flea markets. I clean them up and have them for sale at very reasonable prices. I used to soak them in solvent to clean them up but now I use Simple Green. If I want to see how a dirty stone works without cleaning it I will sharpen a knife on it. A plugged up stone won't cut very good without cleaning, but the Simple Green will clean the dirty stone as I sharpen on it. I can feel when the stone starts working as it should.

The Simple Green is fantastic to use for hand finishing blades with wet or dry paper. The abrasive wears right down to the paper backing without plugging up or slowing down.

About 18 months after I started using Simple Green the cutting action of my old favorite India stone was slowing down. I figured it was plugged up with the residue left when the Simple Green evaporates. I put the stone to soak in a full strength bath of Simple Green and after a week or so all kinds of gunk came out of the stone. I put it back to work and it was just fine. I'm sure that some of the gunk that came out was the residue of kerosene and some oil I put on the stone when it was new. And, there were times I used more of the concentrate in my mix than it called for.

Sharpening angle

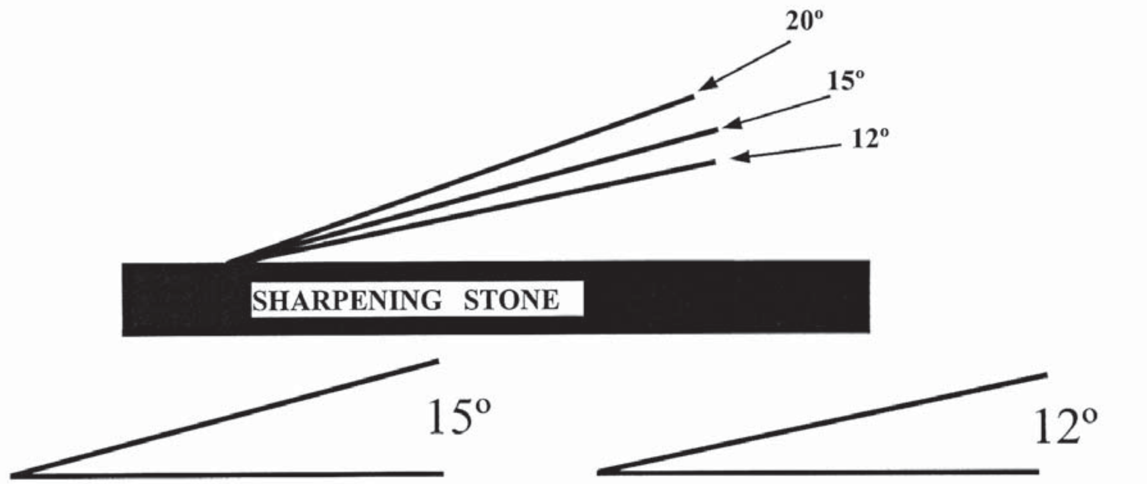
I use an angle of 12 to 15 degrees per side. The angle varying with the type of knife, less angle for light use, more angle for heavy use.

Leatherwork and wood carving knives are sharpened by laying them nearly flat on the stone. The thinner edge will cut the soft materials better, and the strength of the edge isn't a factor.

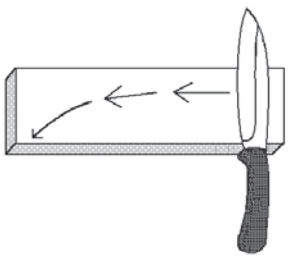
At the other extreme is the survival type knife blade where strength is required; in this case, the sharpening angle should be greater. The knife edge must have enough material in it to handle the particular type of work that it is intended for. The best angle for your own knives is best worked out by trial and error.

Sharpening systems

There are many types of sharpening systems. I rate them by the time it takes to remove the necessary steel and refine the edge. Many bench stones are made with inferior and irregular grit sizes. These are usually attractively priced, but slow cutting and wear out quickly. I prefer the Norton India/Crystalon stone because of the uniformity of grit size and the purity of the grit. This gives them a superior ability to remove even the hardest metal. Silicon carbide will cut the hardest knife blades, no questions asked. I have often said that there is no such thing as a hard-to-sharpen knife. There are knives that have blades that are too thick to be easily sharpened on any stone. What they need is re-grinding. Crystalon is the Norton trade name for silicon carbide, and India is their trade name for aluminum oxide.



The correct sharpening angle for any knife will depend on the blade cross section and the way it is used. Less angle makes a sharper blade but with a decrease in strength. As an example, a blade for wood carving or leather work might be sharpened by laying it flat on the stone. More angle makes for a stronger edge with less finesse in cutting. Examples of knives that need a stronger edge are camp knives and tactical knives. A good starting point with the average knife is anything between 12 and 15 degrees.

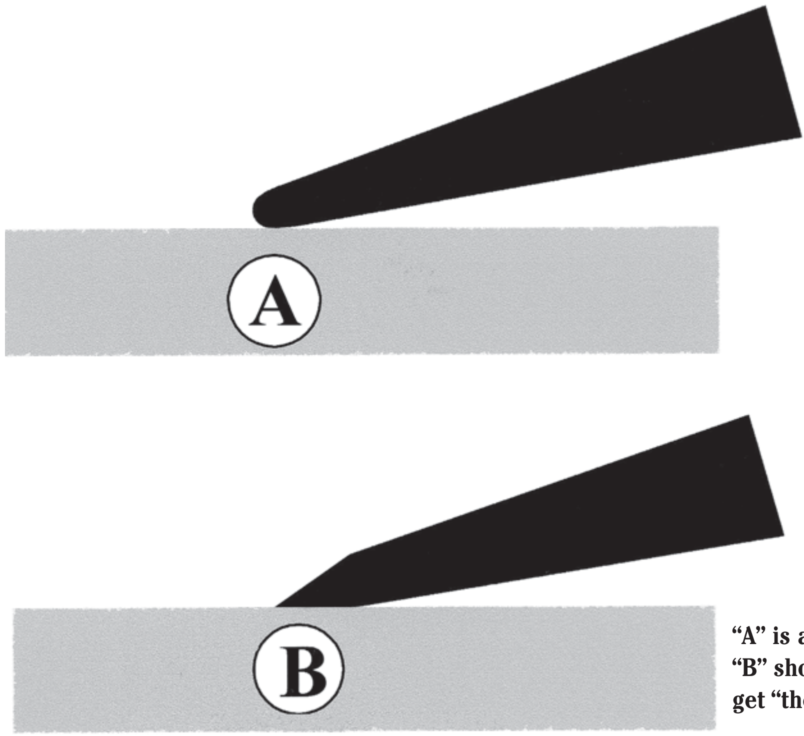


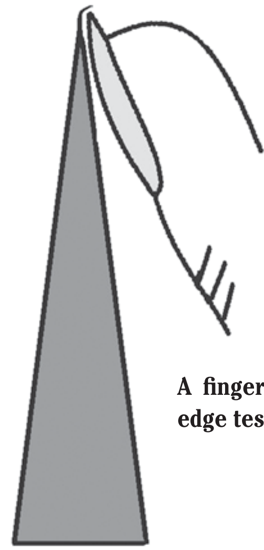
The proper motion in sharpening. Make five passes on the back side of the edge, then five on the front and check for progress. (The front side of a knife is what you see when you hold it with the tip to the right and the edge down.)

In my collection of stones, that's a Norton India/Crystolon second from the bottom, third stack from the right.

Arkansas stones have a very slow cutting action. I have better things to do with my time. They will give a very good edge if you don't mind spending the extra time involved.

The sharpening process is started by taking cuts across the stone in the direction of the arrows (see illustration). Do five strokes, and then reverse the direction for the other side of the blade. To maintain the correct angle for the full length of the blade it is necessary to lift the handle of the knife as you get towards the tip, it's a compound angle. Count the strokes and be sure to do the same amount on each side. I start with five passes on each side and then look for the wire edge. Take a red marking pen and run a line of ink down both sides of edge before starting. This gives a visible indication of where you are contacting the edge on the stone.





A fingernail is a good wire edge tester.

"A" is a highly enlarged cross section of a dull blade. "B" shows that enough material has been removed to get "the two lines that meet at infinity."

To help yourself learn the correct angle, make a wedge out of wood or cardboard. You could use the 15-degree angle in the illustration. Place the wedge on the stone with the knife on it to give yourself a visible reminder of the sharpening angle. An edge will not be truly sharp unless the bevels are true and flat and it takes good control to achieve this. Practice is the key.

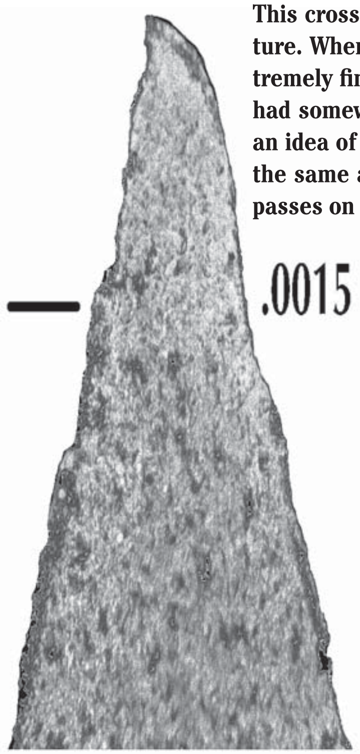
The wire edge

It is important to understand the wire edge and how to get it off of the freshly sharpened blade. The wire is formed as the two sharpening bevels meet at the edge. What I call a wire is a thin piece of blade material that bends back and forth from the action on the stone and is not removed (see drawing). When the wire edge is not lined up, the knife will not appear to be sharp, yet sufficient material may have already been removed. Since the edge does not feel sharp it is often worked some more on the stone and many knives are worn out prematurely from this overworking.

When the wire edge is lined up the blade will seem to be sharp. I refer to this phenomenon as "false sharp." The blade may shave hair and slice paper, but when the edge contacts any type of hard substance the wire edge bends over and the knife does not cut.

Removing the wire edge

My favorite way to remove the wire edge is to stroke the edge very lightly on the finish stone at an angle of around 30 degrees. The strokes are alternated from one side to the other and are very light. You will feel the hook of the wire with a fingernail and it will be on the opposite side from the last stroke. As the blade is stroked with the light cuts the wire is abraded off, leaving the true sharp edge. It might seem that the steep angle used to get the wire edge off would slow down the cutting ability of the knife, but it doesn't because not that much material is removed when it is correctly done. With the wire edge removed you will have a superior and long lasting edge.



This cross section photomicrograph was made to look at the grain structure. When I saw the picture the first time I paid no attention to the extremely fine grain. It was the buffed, razor edge that got my attention. It had somewhat of a wire on the side opposite the last side buffed. To get an idea of the magnification, the thickness at the horizontal line is about the same as the average piece of paper. A few extremely light-pressures passes on a fine stone would have made the razor edge even sharper.

It is very easy to lose the sharp cutting angle at the edge when trying to get the wire edge off by buffing or stropping. If you like to finish an edge this way, do it after removing the wire on a stone. The angle on the strop or buff is critical; if too steep, the edge gets rounded off and the edge loses its true sharpness. I recommend getting the wire edge off on the stone, then buffing or stropping to polish the edge when that is wanted or needed.

The strop stick

A very excellent strop stick can be made as follows. You will need a strip of wood one inch wide and about a foot long, also a strip of leather as wide as the wood and about eight inches long. Glue the leather to the wood, leaving a handle at one end. I use the same green polishing compound on the strop that I use for buffing blades. The leather is lightly coated with the green compound and your strop is ready to use. A little stropping goes a long way, don't overdo it. Several passes down each side will refine the edge without losing its bite. Experiment with your knives to see how much "polish" you want on your edge.

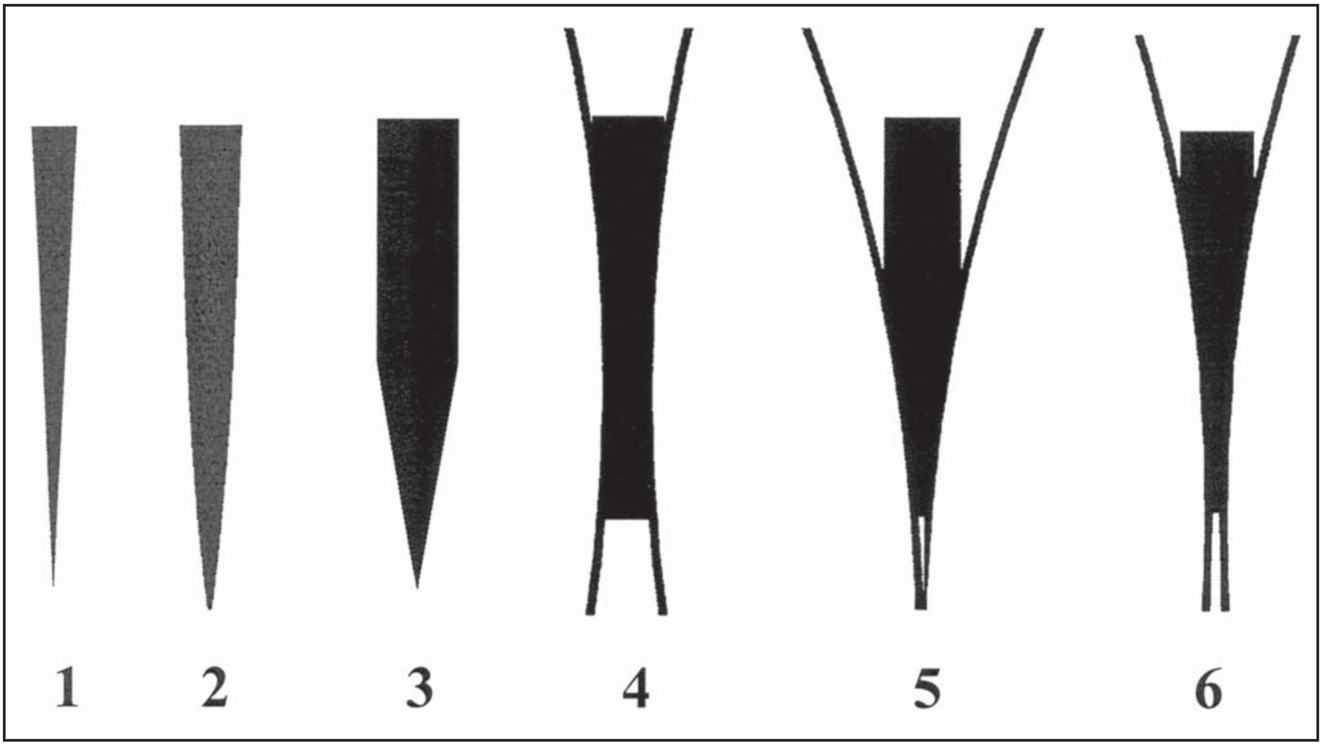
If you appreciate fine knives, it is worth the time to practice sharpening until it is mastered.

The convex edge

A convex edge can be thick or thin or somewhere in between. Flat-ground, hollow-ground or convex ground blades may have either a convex edge or conventional edge.

The advantage of the convex edge when it is properly done is the extremely thin cutting edge. When properly established on a convex ground blade it gives the maximum in cutting ability, and yet it has more strength than the flat or hollow ground blade.

A convex blade profile is developed by using the slack belt section on the belt grinder to form the sides of the blade into a convex shape. The true form of a convex ground blade has the sides of the blade carried right out to a sharp cutting edge. A high degree of sharpness is achieved by buffing or stropping the edge. The polished-convex is a slashing type edge, perfect for cutting free hanging rope. The true potential of the convex blade is not realized unless the whole blade is polished to a high degree. The slick surface of the blade reduces friction against the material being cut and increases the depth of penetration in the chopping tests. The true convex edge has no advantage in an endurance cutting test when compared to a flat ground blade that is correctly ground and not left with a thick edge. I do not recommend a polished edge on a working type knife. The hard use knife needs to be capable of sawing through tough materials; this is not possible with a polished edge.



This illustration shows some of the different cross sections found on knife blades.
#1 is the common wedge ground blade.
#2 Convex
#3 Scandi (Scandinavian)
#4 Fat hollow grind
#5 A thin hollow grind that is low on the blade.
#6 This hollow grind is higher on the blade with a larger diameter wheel.

Many of the (so called) convex edges being put on production knives are rather fat and slow cutting in comparison to the edges put on knives made by knowledgeable custom makers. By actual micrometer measurement, the fat blades have as much as two - three times more material at the cutting edge. Please refer to the cross-section drawing to see the actual physical differences in three blades. The drawing makes it very clear why some blades do so much better in the cutting and chopping tests.

Hollow ground or convex, which is best?

The advantage of the convex type blade, when properly done, is the thin cutting edge. However, it will gain little if the blade is too thick in the cross section. Some of the best cutting blades I have tested were flat ground with only the last eighth-inch or so being convex in shape. The thickness of the blade and the quality of the edge have more to do with the ability of a blade to penetrate rope and wood than the particular type of cross section.

Here is a story about two knives. The new hollow-ground blade would not saw through a single strand from a one-inch rope. The knife with a convex grind cut the rope easily. The owner was confused because hollow-ground knives are supposed to cut well because they are thinner. I had the gentleman send me the hollow-ground knife in question so I could analyze it for him.

When the knife came I could see why it did not have much chance of slicing through a rope. It was not that sharp to start with and even though the hollow grind was thin at the edge, the sharpening angle was quite steep. The knife was a heavy survival-type knife and yet it had a short, thin hollow grind. After looking the knife over and thinking about it for awhile I decided that I did not understand what the maker had in mind. The grind in relation to the type of knife made no sense to me.

When the rope slicing is over, the sharpest and thinnest blade will win every time. This blade would not be good for a tactical knife or camp knife. There may be as many different types of grinds as there are states in the USA. Each knifemaker will have to work out what is best for the knives he/she makes. One thing I am sure of is that there are too many makers making beautiful knives that do not have good cutting ability.

It has been nearly 20 years since I had a conversation about testing with another maker. He told me that I should just make the knives and sell them and not spend so much time testing. All I have to say about that is this; he's been out of the business for at least 15 years and I'm still in it.

Sharpening the convex edge

Sharpening a "convex" edge can be two different things depending on how the knife was made. The most common convex blade type is convex all the way to the edge. The other type is a convex blade cross section with a primary sharpening angle. Blades that are convex all the way present a challenge to sharpen without scratching up the blade. In the process of being made many of this type never see a sharpening stone. The slack belt grinder does the work with a fine belt and then the edge is buffed. The average knife user will not be able to duplicate the degree of sharpness the blade had when the edge was new.

The convex edge is sharpened by back stroking it on the stone. It will help you learn the technique by inking about a quarter inch of the blade at the edge. Use a red pen because it shows up real well on the steel. The idea is that you can monitor where the steel is being removed by the stone. Start with a fine stone if it's not too dull, medium if the edge is in bad shape. Be careful to match the profile that was on it at the start. If you prefer a polished edge, finish it with a leather strop stick with fine polishing compound rubbed into it.

Sharpening serrated blades

In normal use, the only parts of a serrated blade that get dull are the high parts, or points, of the serrations. The exception is a knife that's been abused by using it on wire, nails, staples or other metallic objects. In such cases there can be chips in the bottoms of the serrations. The chips that are down in the serrations won't have much effect on the cutting ability of the blade because it's the high parts of the serrations that do most of the work.

Back then we didn't know what a tactical knife was, so we called them folding fighting knives.

I've been carrying different partially serrated Spyderco Clipits for 20 years. My wife, Phyllis, and I have used the Spyderco fully serrated kitchen knives for 20 years. The kitchen knives need light touch-ups once or twice a year and are sharpened exactly like a plain-edge blade. It takes five or more years of sharpening before there's much wear on the serrations. The points of the serrations gradually wear down from the light sharpening required, but this doesn't seem to result in less cutting ability until the serrations are nearly gone.

Serrations can be re-cut with a narrow grinding wheel dressed to the correct shape. Depending on the hardness of the blade, it might be possible to use a file of the correct size to freshen up the serrations. It's a slow process but can be done by wrapping wet or dry sandpaper around a push stick of the correct shape.

As a historical note, I started making folding knives with partially serrated blades in 1974.

A customer named Ernest Brooker suggested such a blade for a folding fighting knife I was making for him. I liked the idea and continued to use it. Back then we didn't know what a tactical knife was, so we called them folding fighting knives.

The Smithy And The Forged Blade

THE VILLAGE BLACKSMITH

Under a spreading chestnut-tree
The village smithy stands;
The smith, a mighty man is he,
With large and sinewy hands;
And the muscles of his brawny arms
Are strong as iron bands.
His hair is crisp, and black, and long,
His face is like the tan;
His brow is wet with honest sweat,
He earns whate'er he can,
And looks the whole world in the face,
For he owes not any man.
Week in, week out, from morn till night,
You can hear his bellows blow;
You can hear him swing his heavy sledge,
With measured beat and slow,
Like a sexton ringing the village bell,
When the evening sun is low.
And children coming home from school
Look in at the open door;
They love to see the flaming forge,
And hear the bellows roar,
And catch the burning sparks that fly
Like chaff from a threshing-floor.
He goes on Sunday to the church,
And sits among his boys;
He hears his daughter's voice,
And it makes his heart rejoice.
It sounds to him like her mother's voice,
Singing in Paradise!
He needs must think of her once more,
How in the grave she lies;
And with his hard, rough hand he wipes
A tear out of his eyes.
Toiling, – rejoicing, – sorrowing,
Onward through life he goes;
Each morning sees some task begin,
Each evening sees it close;
Something attempted, something done,
Has earned a night's repose.
Thanks, thanks to thee, my worthy friend,
For the lesson thou hast taught!
Thus at the flaming forge of life
Our fortunes must be wrought;
Thus on its sounding anvil shaped
Each burning deed and thought.

By Henry Wadsworth Longfellow

The Goddard smithy

I didn't have a spreading chestnut tree so I built a lean-to on the back side of my shop. That was in 1983. The floor space is about nine feet by 15 feet and adequate for my needs. The climate in the Willamette Valley of Oregon is mild, our average temperature is 55 degrees F, so I get by real well. I'm so used to the fresh air that I don't have nearly as much fun when I have to forge inside a building. The hydraulic press makes very little noise so I can do some heavy forging without shaking the neighborhood. I'm outside the city limits in a residential neighborhood. My neighbors are understanding and were surprised when they found out all that I was doing in my back yard. It's not like I'm hammering all day, every day. A three-hour forging party will keep me busy with finish work and heat treating for up to two weeks.

The Goddard Smithy and Tool Sale

Inside the "Lean-to Smithy"

Early wire damascus work, from my "all steel" phase. The one with the fossil ivory handle sneaked in.

An introduction to the forged blade

The new bar of steel was smooth and clean, straight as an arrow and had a nice fine grain. It is a terrible thing that I'm going to do to that bar of steel, but I'm a bladesmith and it has to be done. I will subject it to sufficient heat to get it a bright orange color, at that temperature the steel becomes "plastic." It's not really that soft but it is soft enough so that it can be shaped with a hammer. It may appear that I am taking my frustrations out on the steel, but the hammer blows are carefully planned and struck. When finished, the bar of steel will have been transformed into the rough shape of a knife blade. The once smooth surface of the steel bar is now mutilated by hammer dents, dings, and an ugly layer of scale on the surface. It will most definitely require a measure of stock removal before it will make a presentable blade.

There was a time when all blades were forged but the machine age came in and changed that. Hand forging was eliminated by the invention of machines that would stamp out blade shapes from a sheet of steel. Manmade, high-speed grinding wheels and later on abrasive belts made it feasible to shape the total blade with what became known as the stock removal method.

The handmade knife world was running headlong towards being mostly stock removal until Bill Moran came along and showed us the modern version of Damascus steel. I saw some of Moran's Damascus at the Knifemakers Guild Show in 1974 and it changed my life. I wanted to learn to make it but it was nine years before I got started. I wish that I had known sooner that I could forge blades of damascus steel it in my back yard without a smoky coal forge and a power hammer. And yes, a large anvil on a stump set in the ground, tongs, hammers and a building to contain it all.

There was a lot for me to learn and I did it the hard way by trial and error. My first real forge was a homemade coal fire pot that I welded up from scrap steel. It worked pretty well but I soon found an old Champion cast iron fire pot and switched to it. I learned about foundry coke from my artist blacksmith friend David Thompson. I developed a brick box furnace to burn it, and it worked all right but the source of good quality, clean burning coke dried up and by then I was learning about gas furnaces from my friend Gene Chapman.

Those first brick-box gas forges we made were not very efficient but they made coal forging slow and old fashioned. I learned the basic dragon breath, tube-type, ceramic-fiber-lined forge design from Gene. I'm still using a refined version for all of

That's me (front), knifemaker Bill Harsey (white cap) and stunt pilot and airplane builder Steve Wolf with the template. I took my welding furnace to the hanger where Steve builds airplanes and we heated two pieces of 3/4-inch thick by six-inch wide 5160 to bend them to make landing gear for a stunt plane. Steve held the altitude record in a prop-driven airplane at that time.

my welding and a smaller and low temperature version for forging and heat treating.

Bladesmithing today is more gas forges, hydraulic forging presses and homemade air hammers than anything else. Some bladesmiths still burn coal but more gas forges are being used all the time. The mechanical power hammer will always be with us but the technology that they use is outdated and can't compete with current developments in air and hydraulic forging machines. If you're going to manufacture damascus steel it's another story. You'll need the largest power hammer you can afford.

Forging is not only the most basic metalworking process but a lot of us find it's great fun to heat a piece of steel, take hammer-in-hand and then coax the orange-hot steel bar into a new and exciting object. Shaping a blade with hammer and anvil hasn't changed much for thousands of years. Making a blade can be accomplished with very simple tools when it is forged to shape.

Forging the blade close to the final dimension eliminates the need for grinders and belt sanders to get the blade to the finished shape, and files and hand stones are all that is necessary to finish it. There is no need for torches or electric furnaces, because the heat source for forging is used to harden and temper the blade. I have been helping a young man get started forging by e-mail and phone. His anvil is a large sledge hammer; this shows an attitude of getting it done with whatever you have.

Does forging make a better blade?

Just because a blade is forged does not mean that it will have superior strength and cutting ability. The steel it is made from must have a high carbon content, proper forging temperatures must not be exceeded and proper normalizing and annealing temperatures must be followed. This must be followed up with the best possible hardening and tempering. Then and only then, assuming that it has good cross section geometry, it just might make a superior blade.

The beginning bladesmith will have to do a lot of practicing to learn the accurate color judgments necessary for superior blade making. It's important to finish the blades at just the right degree of thickness, or what I call having good cross-section geometry.

This shows Dave Rider's stump-anvil, one-brick forge, hammer and tongs, with all of it fitting into the ammo can. Note the coil spring material on the stump and one rough forged blade.

It is wise to stick to one type of steel in the learning phase, and I recommend 1084 or 1086 carbon steel. It is reasonably priced, available in a variety of sizes, and makes very good knives. The most versatile size is 1/4x1 inch. Once smaller knives are mastered it is time to make some camp knives and then later the king of all knives, the Bowie. I can recommend nothing other than 5160 for larger type knives.

I'm real fond of the front coil springs from the small import cars, most seem to be made of 5160. When cut into one coil pieces, straightened and forged out, it is a good size for small knives. What you have is 5160 chromium steel in a size that isn't available in normal supply channels.

The anvil, the bladesmith's most important tool

The first anvil used by a metalsmith was probably a large rock with a flat spot on top. And, it makes sense that he used a rock for a hammer. Think about it, how else could he have forge-welded his rough smelted iron together and shaped the first metal hammer. I have a video that shows contemporary African ironsmiths making iron and forging tools. For rough forging, a large rock is used for an anvil and a smaller rock is used as a two-handed sledge hammer.

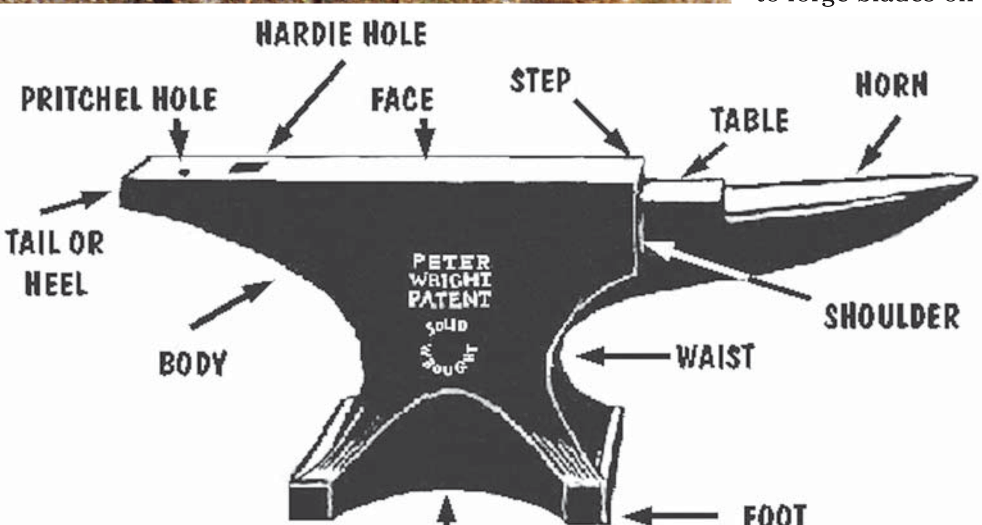
The anvil evolved from rock to cast iron and then steel. By the 1850s, the anvil reached perfection with a welded-up construction using two or three pieces of metal in what is called a London pattern anvil.

The shape of an anvil is perhaps not as important as that it be hard and tough to withstand the blow of the hammer without denting or breaking. The anvil also needs to be heavy enough to absorb the heaviest blow of the hammer. (A heavy hammer requires a heavier anvil.) The horn that is typical of the blacksmith anvil is not necessary for forging knives. The Japanese sword maker uses an anvil that

That's the first anvil I made being used at a hammer-in at Wendell Fox's smithy. Larry Milligan is holding and Shawn Vallotton is being the striker. The base that it is on is too light for doing serious forging but is nice when it comes time to haul it around the country.

Dave is using the stump anvil up in the woods.

has no horn; it is a simple rectangle of steel. The Japanese have no need for a horn, and it is easier to forge blades on a short, rectangular anvil anyway.



The many features of the London Pattern anvil.

As far as I am concerned, the anvil is the king of tools. A blacksmith who has mastered his craft can make virtually any object. All that is required is imagination, inspiration, a hammer, an anvil, a source of heat, and a good supply of iron and steel. A skillful smith can do good work on any heavy chunk of steel. A specific anvil shape only makes specialty work easier. A soft anvil will get dented up quickly and that makes it difficult to do good work. You have to work harder on a soft anvil because the hammer does not get the bounce it does off a hard anvil. If you plan to do much forging, it will be well worth the effort to find a first-class anvil.

The true value of an anvil with a hard face is not easy to understand until you have worked on both hard and soft ones. I would rather work on a small anvil with a good hard face than a big, but soft one. When I was getting started forging, I had a 150-pound Acme cast anvil in my indoor forge area. As anvils go it was quite soft but I used it for several years and got by just fine as long as I didn't know any better. I sold it and replaced it with an 85-pound Hay-Budden. That little anvil was as hard as any anvil I have ever seen. Only then did I realize how much easier it was to forge on a hard anvil. Because of its extremely hard face, the little Hay-Budden acted like a heavier anvil.

Finding and selecting an anvil

In my experience, the best of the classic anvils are Hay-Budden, Trenton and Peter Wright. These brands were made using the welding process described above. Carry a one-inch ball bearing with you when you go anvil shopping. Drop the ball onto the face from about 18 inches. The best anvils will bounce the ball back into your hand. Any bounce less than 60 percent should be considered fair. Less than 40 percent is poor.

When one of the name-brand anvils has poor bounce it may have been through a fire. A quality anvil can be heat treated to bring it back to life. I hardened a 125-pound Peter Wright that was dead soft. The ball-bearing test only dented the face with little bounce. I will save the story of heat treating it for another time. Suffice it to say it took a lot of heat to get it hot and a lot of water to cool it fast enough to get it hard. The results were very good. One of my students is the new owner and it has worked out well.

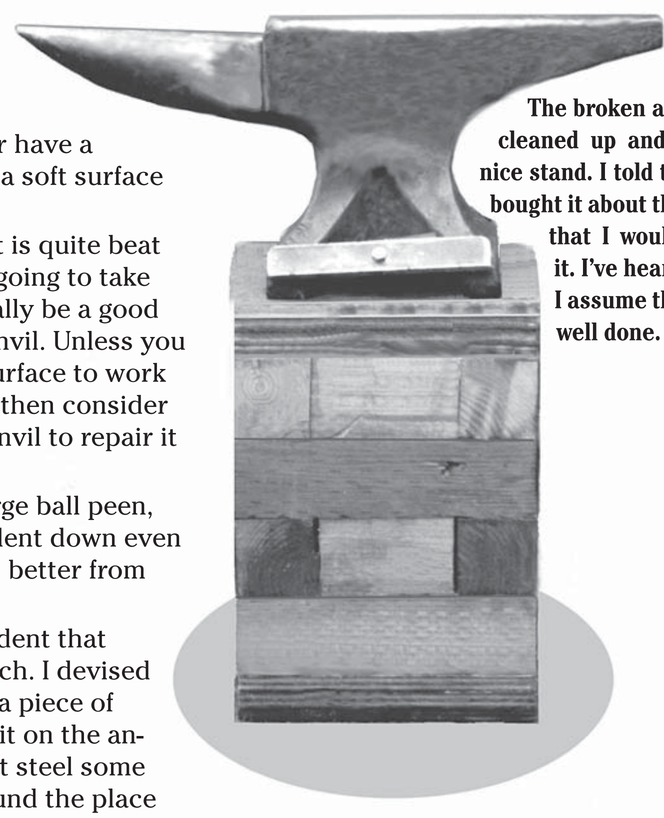
Judging from what I have seen, the average Hay-Budden has a harder face than most Peter Wrights do. I believe that is why I have seen more good-condition (those with less chipped corners) Peter Wright anvils. When a forged anvil has a hard face welded on it, the hard face is most often visible. The hard plate is usually about 1/2-inch thick on anvils in the 150-pound size range.

Square corners on the face are not necessary for knife work. I do not let chipped edges bother me as long as I have a hard and somewhat flat face. I usually take an angle grinder and round off the chipped edges. I have a hardy tool with square edges for the rare times I want a sharp corner on which to forge. Chipped anvils can be built up by welding but that softens the rest of the hard face. I would rather have a hard anvil face with rounded corners than a soft surface with square corners.

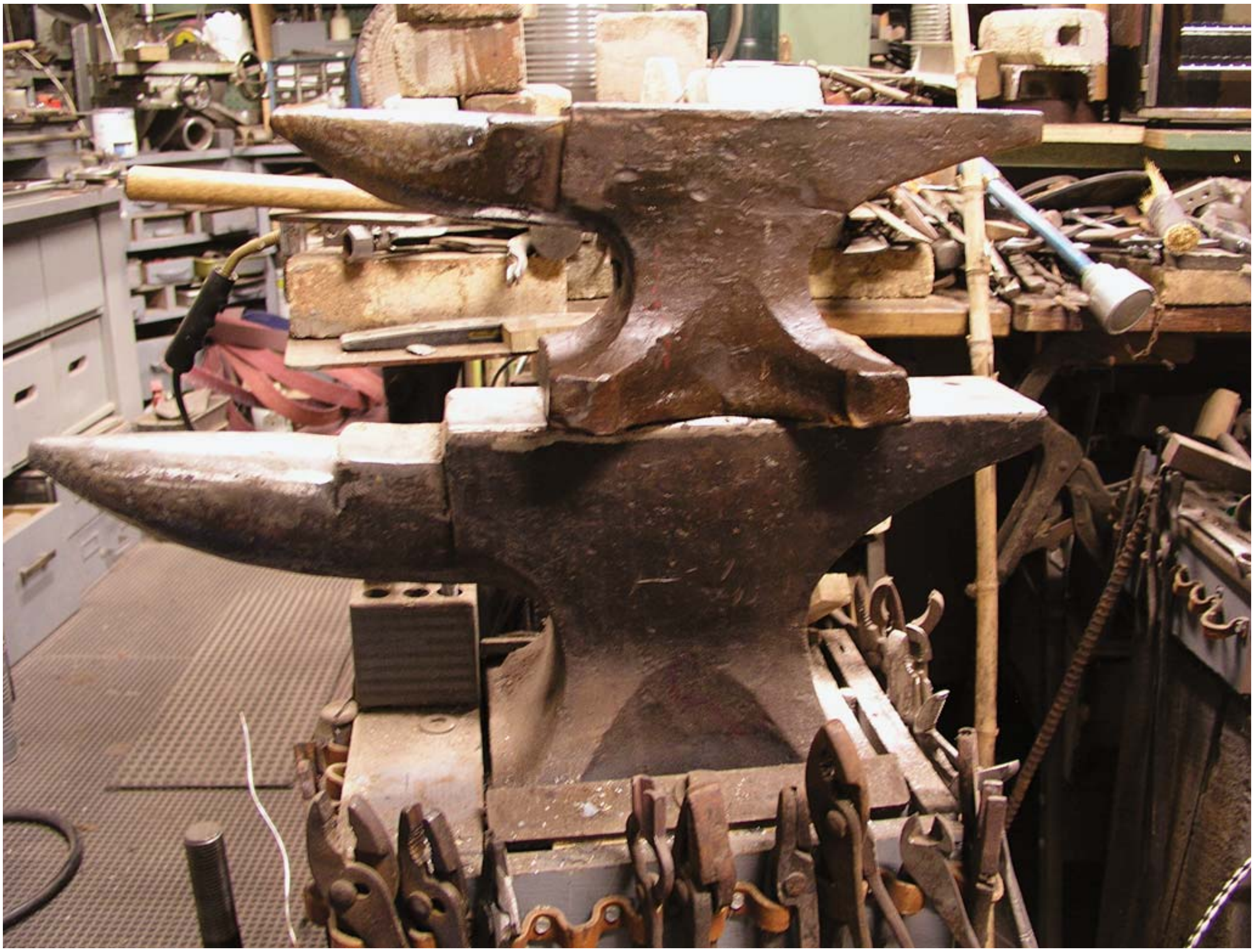
Good work can be done on an anvil that is quite beat up. During the learning phase, the anvil is going to take some abuse from the hammer. It may actually be a good idea for a beginner not to forge on a new anvil. Unless you are a silversmith you don't need a virgin surface to work on. It is best to use an anvil for awhile and then consider what needs fixing on it. If you weld on an anvil to repair it you will usually soften it. (Not good!)

To fix a dent on a soft anvil I'll take a large ball peen, (peen end) and work the area around the dent down even with it. Over a period of time the anvil gets better from the work hardening.

A question was asked about a hammer dent that was .035 deep, which is about 1/32 of an inch. I devised the "Divot Test" which goes like this. Heat a piece of steel to the forging temperature and place it on the anvil face directly over the divot. Give the hot steel some good hammer blows directly over and around the place



The broken anvil all fixed, cleaned up and bolted to a nice stand. I told the folks who bought it about the repair and that I would guarantee it. I've heard nothing so I assume the repair was well done.



A little 55# Hay-Budden taking a rest break on a 150# Peter Wright.

where the divot is. Let the steel cool and inspect both sides of the forged piece. If your hammer dings are just as noticeable as any hump left by the divot, then no work should be done on the anvil. I do 99 percent of my forging in an area that is about three inches by four inches. If you have that much smooth area on a good hard anvil that's all you really need.

If you are buying from a knowledgeable tool dealer, you can expect to pay an average of $2 to $3 per pound for the aforementioned brands of anvils in good condition. You will pay around $4 per pound for a new anvil. It is good to know how to tell a cast anvil from the ones with a forged body with welded-on faces (wrought anvils). Forged anvils have square holes at the waist and sometimes in the bottom, which is how they are held secure while being forged, ground and heat treated. Old cast anvils do not have the square recesses and are squat and chunky compared to forged anvils that are more slender and graceful.

The English system of marking the weight on an anvil

Most English anvils are stamped with the weight using three numbers. The numbers are usually in the waist area, with the first one at the far left, the second one in the center and the third one on the right. The first number equals 112 pounds (CWT or hundredweight); the middle number is quarters of 112 added to the first number; and the last number is the actual weight. Thus, a Peter Wright anvil, which is marked "1-1- 6," is 112 pounds plus one quarter of 112 (28 pounds), plus 16 pounds, which equals 156 pounds.

Good luck in your search for an anvil. It is a fascinating tool and can turn up in the strangest places. Ask around. You may be surprised at how close to home

James Covert with his 400# homemade anvil.

you will find one. I went to look at a small coal forge that a plumber had used to melt lead. His widow had seen my sign, "WANTED TO BUY, BLACKSMITH TOOLS." I usually put the sign on my table when I have my knives for sale at a local show. I bought the small rivet-type forge and a lead pot. I asked about other tools and the lady told me that there was an anvil around somewhere on her place but she had not seen it for a long time. I looked around inside a falling-down shop building. Behind a door that had come off its hinges and half buried in the ground was the 150-pound Acme cast anvil that I wrote about earlier in this story. The lady put a fair price on it, so I lugged it off with the forge and lead pot.

The makeshift anvil

The lack of an anvil is the one thing that delays many people who would like to get into forging. A good quality anvil is a specially shaped, heavy chunk of steel with a hard surface. The hard surface makes the work easier but is not essential. Any heavy piece of steel will work, 100 pounds is a minimum size to start with. The weight is necessary to absorb the blow of the hammer. More weight is needed whenever the anvil and base are bouncing around under the hammer. The horn on a traditional shaped blacksmith anvil is rarely used by a bladesmith and ends up being an unnecessary attachment. Some bladesmiths use the horn for drawing out but it is not efficient for that. A rounded back corner on the face of the anvil works much better.

A very simple, yet useful rail anvil. Total weight, base and all, was 85#. The angle iron attachment deadened the ring, a lucky discovery. I used it for the whole two days at a workshop I taught and got by just fine. Not that I didn't have anything heavier, I wanted to make the point with the students that they should get started, not wait for a "real" anvil.

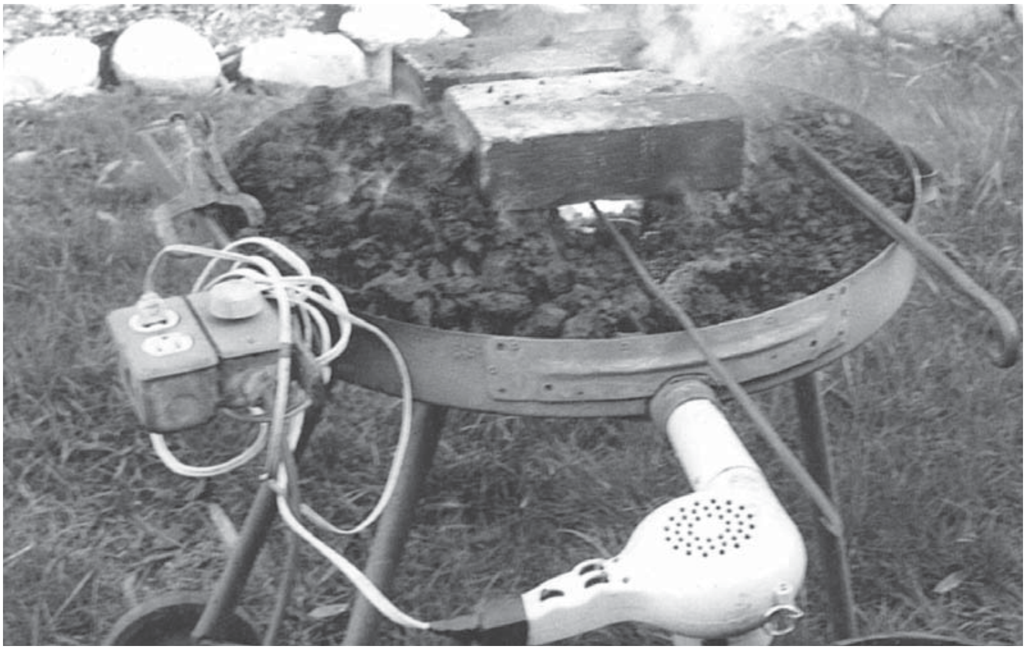
The anvil by itself weighs 110#, it sits on a 100# rectangle of lead which sits on enough iron hidden in the base to give a total weight of 485#. It is nice to work on because the heaviest blow won't disturb the scale on the base. That means that all the inertia of the hardest, five-pound hammer blow goes into the work being forged. When I made it I said that it would be the last anvil that I would ever make. I was wrong. But, that's another story for another day.

The rail anvil

I started with a 35-pound piece of rail that had been resting and rusting on my junk pile for several years. Rail sizes are designated by the weight of the rail by the yard. Hundred-pound rail is 100 pounds to the yard. My rail must have been close to 120 pounds. It was 6-1/2 inches high and 2-5/8 inches wide. While not the largest size, it would work for my experiment in anvil making. I read somewhere that 144-pound rail is the largest and it would be used where the traffic was heavy and fast.

I started by rough cutting the shape of a horn and tail with the oxygen/acetylene torch. An anvil for a right-handed person will have the horn at the left side. Be sure to make the horn so that the most rounded edge of the top rail is away from you. This will give a nice rounded surface for drawing out. The horn was finished with a cup wheel on a disk grinder and then smoothed up with a disc sanding attachment. A 1/2-inch hole was drilled in the table that would accommodate a cut-off hardy made out of an old cold chisel.

I welded in plates made of 1/2-inch thick steel on each side, running it from the bottom of the top rail to the base. This was to add weight and hopefully quiet the bell noise created when forging on rail. This was followed by boxing in one end, filling the cavity formed with scrap steel and melted lead, then welding up the open end. The whole assembly was then welded to a 3/4-inch plate that was slightly larger than the base of the rail. The welds were then smoothed up with a disc grinder. The rounded edges of the rail were built up with Stoody #1105 buildup rod and then



The $5 coal forge. Using the fire bricks as a roof contains the heat and that makes it more efficient, especially so when there is a good supply of coked coal on hand.

smoothed up with the disc grinder. The finished weight is around 125 pounds and is a good size to haul around to demonstrations. If I were to consider my time as money it must have cost me around $400 to make the rail anvil.

After several years of using the rail anvil at demonstrations I decided it needed a one-inch hardy hole. I wanted to be able to use the spring fullers and other anvil tools that fit my Peter Wright. I obtained another piece of rail the same width and with the torch cut a one-inch square out of one end. After cleaning up the square cut-out that would become the hardy hole, I butt welded it to the tail end of the anvil and then welded in heavy plates as braces on the sides and bottom.

The face is not as hard as it could be but it is hard enough to allow good forging. When the face gets a dent in it I simply peen the surface around it down to match. The peening process work-hardens the face and with time it will only get better. The little rail anvil has seen a lot of hard use at hammer-ins and demonstrations and I would still have it if a student hadn't talked me out of it.

Any anvil needs to be fastened securely to a heavy base. If the anvil bounces around from the hammer blows it is not heavy enough. A heavier base will help the problem, or a thick chunk of steel can be placed between the anvil and base to boost the weight of the anvil. My favorite anvil bases are made of layers of particle-board, which are glued and nailed together. This type base is heavier than most wood and is always flat on the bottom and level on the top.

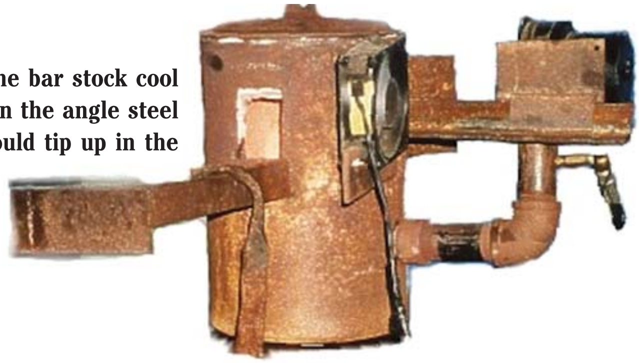
The forge

Blades can be forged using charcoal, coal, commercial coke or gas. Charcoal is not practical, unless you want to make your own. I used commercial coke for several years until I learned about homemade gas forges. The local supply of foundry coke had gone dry by then, so switching to gas was a good thing.

A simple coal forge can be made for far less money than a gas forge. See the photo of the $20 forge shop. It was a project done to show that a forged blade can be made with simple, homemade tools. I made the forge from a rusted out barbecue. The disadvantage is that coal is messy and slow compared to gas. My smithy is in a residential neighborhood and I would have a difficult time trying to work with coal. I don't recommend setting up with coal as a general rule. I prefer gas because it is clean and efficient.

My propane forge/furnaces are all homemade. At present, each is a horizontal

Don Fogg's upright gas forge. Note the cooling fan that keeps the bar stock cool where you will be handling it. Also note the crook tool hanging on the angle steel that supports the bar stock being forged. A long sword blade would tip up in the forge, but the crook tool holds it down where it is supposed to be.



steel tube lined with ceramic fiber that is coated with refractory cement. The burner tube is made of iron pipe fittings. Plans for half a dozen different gas forges are available on the Internet.

I first saw the upright version of a gas forge at The Alabama Forge Council Bladesmith Symposium. Don Fogg was using it and I think he built it. (See photo.) The main advantage is that the work is farther away from the flame. Combustion takes place in the bottom of the forge away from the work piece. Unburned oxygen is much less apt to reach the top where the work is. This makes it possible to achieve a more suitable atmosphere for forging and welding.

The volcano forge

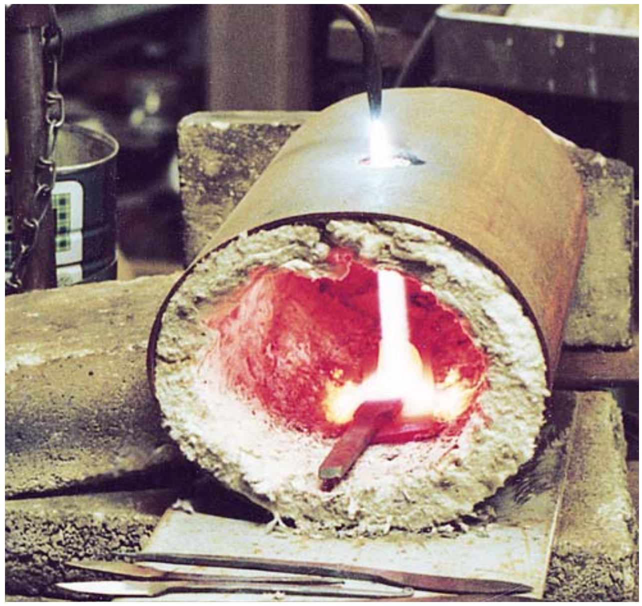
James Covert knows how to work clay and has made a very efficient forge. He was inspired to make it after watching a documentary about knifemaking in Malaysia.

The advantage of using the volcano style forge is that less fuel is used. The covered heat chamber makes it very efficient by holding the heat in. As the volcano gets up to working temperature the work is being heated from all sides by radiant heat. The roof of the volcano reflects heat and the hole causes a draft for efficient burning. Fuel can be fed from top, right and left. He uses wood to conserve on charcoal.

James tells us how he made it. "Materials used: worn out rectangular grill with the lid attached so that when closed it gives protection from the weather; wire

Covert's Volcano Forge, it just may be the forge of the future. It doesn't need oil, coal, gas or electricity… just scrap wood.

I call it the "Dirt Cheap" forge.



This was used in the days before I got into gas forges. It is pretty much obsolete now.

mesh for support of the shape; refractory clay; 50 percent clay, 50 percent sand and couple handfuls of wood ash and water; metal pipe running down center for air supply. I mix paper from shredded documents with the fire-clay/adobe, it gives structural support and makes the clay body lighter when it burns out. This is called paper clay when you use paper pulp with clay. I fired this up right after I built it, the same day, wet and everything held together, no worries. The best part of this forge is…it was FREE!!!!"

Makeshift forges

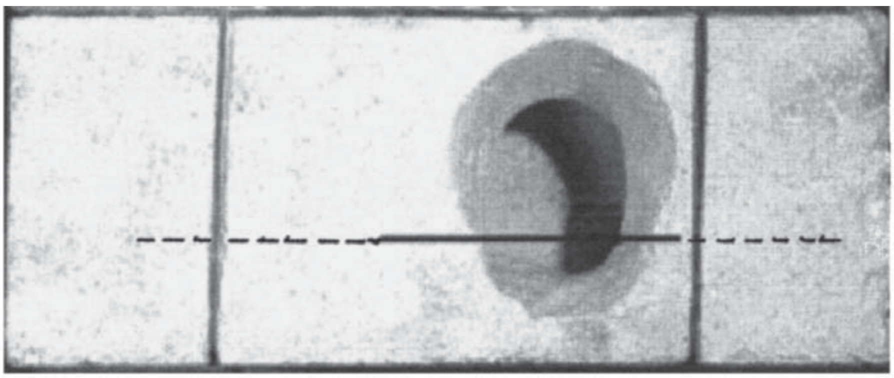
I call this one The Dirt Cheap Forge. Make a depression in the ground and pipe an air supply into one side. Use charcoal or hardwood for fuel. To get more heat out of it, place a cover of firebricks over it to create a heat chamber. Once the bricks get hot the metal will heat much faster and the bonus is a larger work piece can be heated than on the open fire.

An oxygen/acetylene torch can furnish the heat for a heat chamber made from a steel tube lined with ceramic fiber. The one shown in the photo served me for a number of years inside my shop as a heat source for forging and heat treating. The One Brick Forge is used these days and that saves some dollars. Once I started making and using the homemade dragon-breath furnaces, the torch furnace got retired. A stack of firebricks will also work as a small forge. Make the box with a brick on top with a hole in it and direct the torch flame into the hole just like the photo shows with the tube type. In use the blade would have to be kept in motion, never left with the flame on it. The oxygen/acetylene flame is over 5,000 degrees F and that will do real damage and do it quick.

The world's smallest forge

The one-brick forge is all grown up now in a better version. All good things evolve and this one certainly has. If we need to get technical, the one brick forge is now the two and a half brick forge. See the photo at the right. When a single soft brick gets hot enough inside to get blades up to the forging temperature it also has to cool down at the end of the forge session and this is when the cracks form. Much cracking is avoided by backing the soft, high temperature brick up with a common hard brick, or another high temperature brick, then put a split hard brick on top.

The one-brick forge, extendo model.



The fire hole, the one that the flame enters, is cut in just enough below the bottom of the heat hole so that the flame can circulate around the work being heated.

This causes slower cooling and less cracking. Use a full sized brick on top if you don't have access to a split brick. It's best to make a lightweight frame of angle iron to support the bricks. And while you are at it build a rest on the front. I've used stainless steel wire to hold this one together but any wire will work.

The heat chamber doesn't need to go all the way through if you can get your largest work in it. I use the extendo principle, see the photo. The one-brick is drilled all the way through. A half brick sits at the back end, it is drilled part way through …for long work the open end is put against the front brick, for short work it is reversed and blocks off the back end of the heat chamber. See the photo at the bottom for the location of the heat hole… the flame wants to be able to wrap around the bottom of the work so as to heat it more uniformly… the line on the brick shows the bottom of the heat chamber.

The one-brick forge is the perfect source for heating small-to-medium-sized parts. The little forge might sound like a novelty item but I guarantee that it will do real work. I've forged and hardened blades up to seven inches long with it. The one in the photo gets used almost every day for the finish forging on small blades and the heat treating of small blades and springs. It's my heat source of choice for forging the rat tails on my friction-folder blades, and also the thong holder on the end

The propane bottle safety can should be securely attached to the workbench. Punch some holes in the can around the base. If a bottle of propane was leaking, the gas being heavier than air could build up in the can, ignite and shoot the bottle out like a mortar.

of a folding knife spring. The tempering gizmo makes the mini-forge even more versatile by eliminating the need for an electric oven for tempering. Best of all, the one-brick forge makes it possible for anyone who has no more space than what a small table occupies to get into forging.

Firebrick sources

If you don't have any firebricks lying around, you'll find them in the Yellow Pages under refractory products. If you don't find them there, call a brick mason and ask him where he gets his firebricks. You'll need one soft, high-temperature firebrick for the forge chamber. The other bricks or split bricks can be the hard type. One brand of soft high-temperature insulating brick is the New Castle 2600 degrees F insulating brick.

Carve the one-inch-diameter heat-chamber hole lengthwise completely through the soft brick with a junk knife blade, or drill it out with an old drill bit. Then use the knife to make the hole oval so that it is about two-inches from top to bottom. The one-inch hole in the side is the fire hole; it goes in only far enough to reach the heat hole. Note that the fire hole is slightly below the bottom of the heat hole. That's so the flame can wrap around the object being heated. Also, note that the fire hole is ahead of the center of the brick, you'll get a more even heat that way. Gas forges, including this little one heat the blade by radiation. The flame heats the liner, the liner reflects the heat to the blade.

Don't put the torch tip directly in the fire hole; keep it an inch or so from the opening and aimed so that the flame curls around the heat chamber. Experiment with your torch to see where the flame is aimed to get the most heat.

It's a good idea to coat the inside of the one-brick forge with fire clay of some type. I use Parker-brand Furnace and Retort Cement. Check for this in the wood stove department of Home Depot or Lowes. The furnace cement is a 3,000 degrees F product that also works well in my large propane forge/furnace. The hard coating of cement will keep the soft brick from wearing away and also will allow it to hold more heat. (Once more, the radiant heat from the liner heats the blade.)

A disadvantage of the one-brick forge is that many torches run too hot for heat treating small blades. The JTH7 solves that problem with the regulator type valve. Another drawback of the one-brick forge is its small chamber. For example, a section of coil spring to be straightened won't fit into it. As with the hardening sequence above, the part to be heated is held in the recess with the torch positioned so that the flame can wrap around it.

The 16-ounce propane bottles can be dangerous if they fall off of a work bench.

The Fraction Forge

Miniature knife forged from a wire from a cable on the Brooklyn Bridge. Obtained when the bridge was repaired after a barge hit it in the '90s. There was no electricity used in making this little knife. The blade was finished with files and sandpaper.

Even when turned off, if dropped the valve can open or break off. The roof burned off of a house in our neighborhood when a bicycle fell against a work bench and knocked off a Bernz-O-Matic torch. The top broke off and the pilot light on a gas water heater ignited the escaping propane. Flames went up the wall and into the attic through the open crawl hole. Find a large juice can or whatever that is large enough to hold the bottle and affix it to the work bench with wood screws, or clamp it to the work table when used with a portable outfit. The 16-ounce propane bottle is a large juice can that is hooked to the wood holder with screws.

After using the mini-brick forge for awhile the brick started to crack and come apart. I repaired it by wrapping it with iron wire that is set down in a groove carved in the brick. The photo shows the mini forge sitting on the hard bricks. When I use it inside my shop it is surrounded on the back and top with hard bricks to support it.

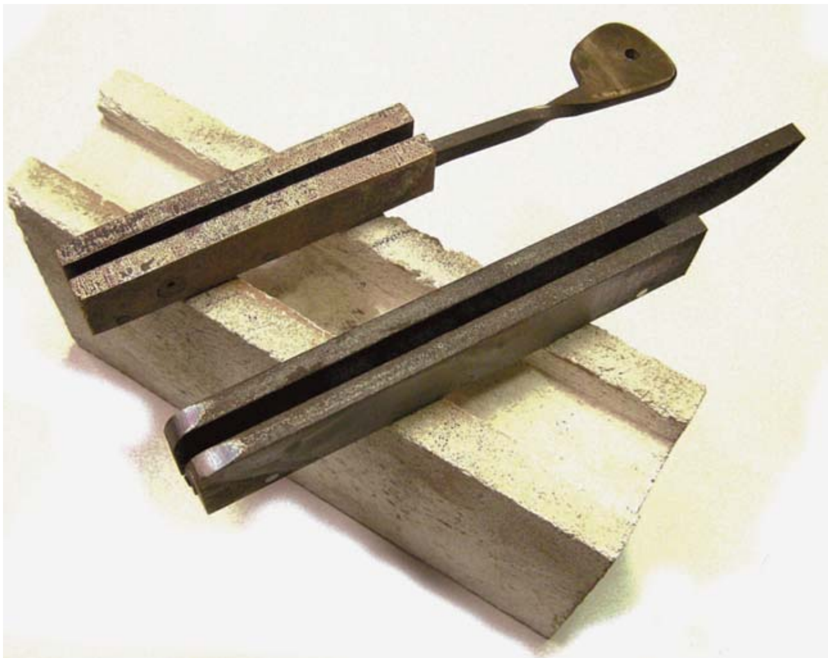
Carve a notch in the side of a soft fire brick to make a cavity large enough for heating parts that are larger than the hole in the mini forge. This works for straightening out coil springs or other curved pieces. The part to be heated is held in the recess where the flame can wrap around it so that it is being heated from all sides.

I've made half a dozen different sizes of the mini forge in tin cans that were

I haul this one around in a tin can. It works either way, horizontal or vertical as in the picture. The background and bottles are not on fire.

lined with Kaowool® brand ceramic fiber insulating material. The flame is directed into the can through a hole in the side. The goal is to direct the flame so that it rolls around the inside of the liner. As the liner heats up the heat radiating from the liner heats the work. The tin can forge is nothing but a miniature of the tube-type homemade gas forges that are so popular with bladesmiths.

A Mapp or oxygen/acetylene gas torch can be used in the same way. Either will give more heat than propane, which will make it possible to heat larger pieces. Be very careful when using oxygen/acetylene, because the 5,000-degree F flame will destroy anything that gets too close.



Tempering blocks and their heating brick.

The fraction forge

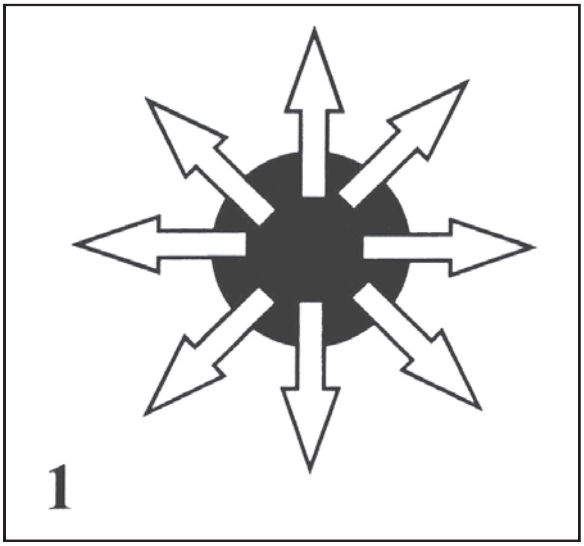
I like to make miniature knives, some are made of damascus steel and that means a little fire is necessary. I made what I call the Fraction Forge to handle the smaller jobs. I got some bargain soft bricks that had been cut wrong and they make the perfect Fraction Forge.

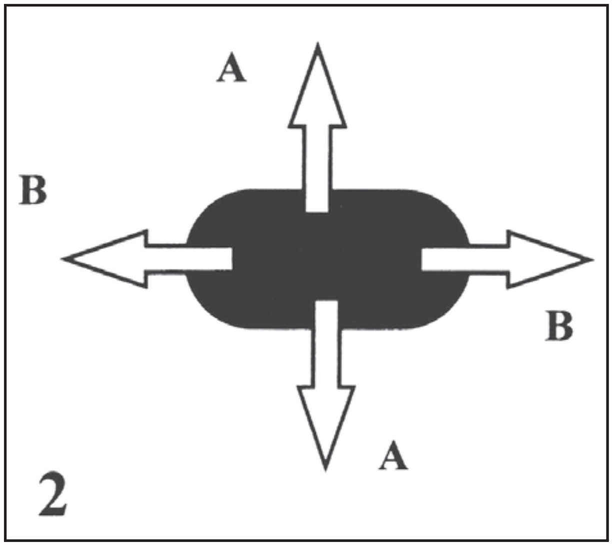
The bladesmith's hammer

I forged a blade once using a carpenter's claw hammer just to prove it could be done. It was a painful experience. There was a lot of shock transmitted back into my hand and the weight of the hammer was inadequate to move the metal. A hammer with a good handle of the proper weight and shape will make forging a lot easier.

The most common mistake made by the beginner is to use a hammer that is too heavy. The heavy hammer can move too much material in the wrong direction. It becomes a battle of first pushing the hot metal one way, then back the other way. This causes an excessive amount of hammering and that leads to fatigue and wild

My favorite hammer.





When the face of a hammer leaves a round impression on the work, the material is spread equally in all directions (see figure 1.) When forging blades, this will cause the edge profile to take a lot more curve than it really needs. A blow with a fullering style hammer leaves an impression on the work that is twice as long as it is wide (see figure 2.) This blow moves the material twice as much in the "A" direction as it does in "B." The "A" direction would be the direction that the bevel in a blade is being forged. The result is much less curvature being developed in the blade. The blade gets its bevel and wider much faster with less hammering.

hammer blows. Control is far more important than brute strength when forging knife blades. If you can get good control of the heavy hammer, you should use it, otherwise stick to a lighter hammer until your muscles and control develop. Every blade you forge will have one hammer mark that is deeper than all the rest. You'll have the blade ground out to the final shape and there will be one last hammer ding that looks like a gravel-pit on the nice clean surface. It can take a tremendous amount of grinding to clean these up so it's best to not make them in the first place.

I reshape the heads of my hammers so that the striking face is either roughly square or rectangular in cross section. The straight side of the hammer allows the knife edge to be forged right down thin without hitting the anvil face. When the hammer head is round in cross section there is always part of the face overhanging the edge portion of the blade. As the edge gets refined, the hammer is hitting the face of the anvil. The face is slightly rounded with a small flat in the center. The corners are slightly rounded too. If the edges of a hammer are sharp and square it is easy to make a cold shut in a blade. A cold shut is formed when a hammer blow forces metal over onto the surface of a previous blow. If a cold shut is not ground out as soon as it is created it can be forged deep into the surface.

The shape of the hammer face will have a large effect on the direction that the metal is moved. When forging the bevel into a blade it will curve upwards, this curve will usually be more than is wanted. A hammer with a round striking surface

I call this type blade a "Buffalo Skinner", and it could be called a beginner pattern. This shape just happens when there is no preform, just start with a rectangular bar, forge out the tip and wedge and you'll end up with the upturned tip, skinner type blade. This is the first blade forged by the author, the year was1965.

will create even more curve than the rectangular type. (See the drawing that illustrates the flow of the metal when struck with different shaped hammer faces.)

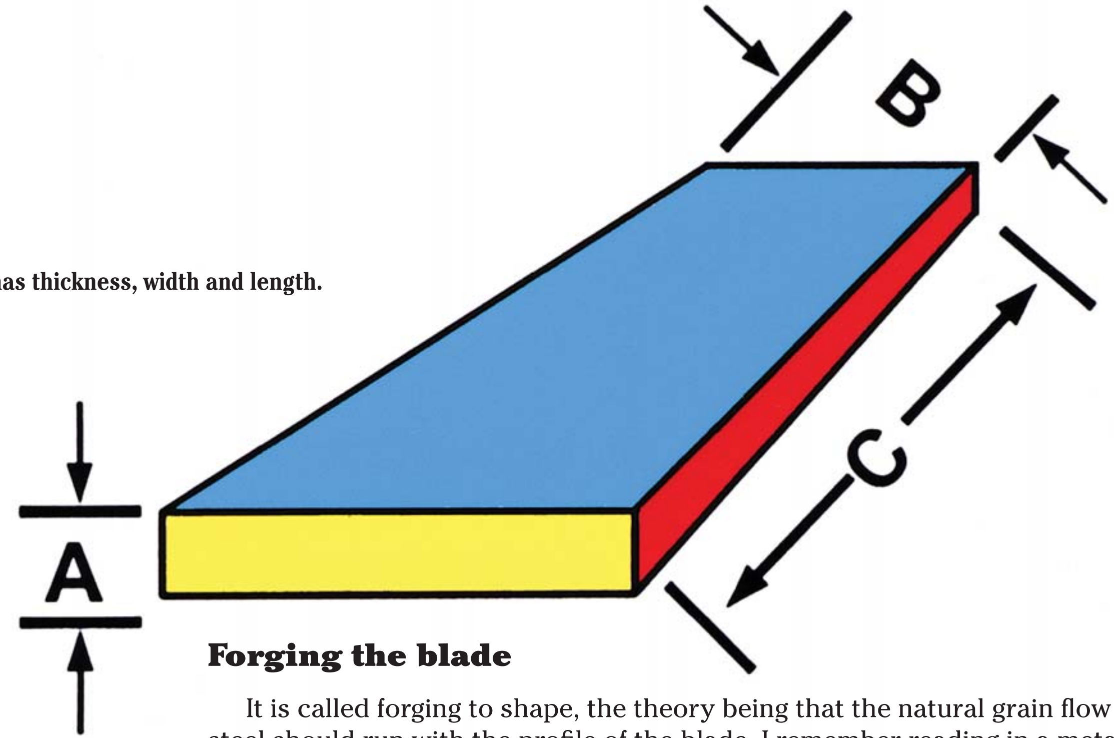
I made my favorite hammer with a shock-absorbing handle as per Bo Hickory's instructions that appeared in several blacksmith association newsletters. I'm bothered by nerve damage, carpal tunnel syndrome and arthritis. I wouldn't have believed the difference it made until I worked back and forth between the shock-absorbing handle and a solid one. Discovering this type of handle made longer hours of forging possible. The difference is amazing and I'll never use anything else for heavy work. It is just the thing to help my worn out wrist and elbow. I can't prove it but the modified hammer with the springy handle seems to move more metal with a given blow. Several old-timers have told me that a handle with spring in it would give a harder blow and I believe it now. The shock-absorbing handle is sensitive enough that when working on an anvil that is not secured to the anvil base, the rebound of the work/anvil can be felt with the hammer! Almost everyone who has used one of the hammers that I have modified has taken the time to modify their heavy hammers (two pounds plus) the same way.

I've made the handle two different ways, depending on whether it was a hammer with a good handle in it, or on a new handle to be installed in a head. On a new handle, I cut in from the wedge end (approximately 4-1/2 inches) up to a drilled hole. The sides of the cut-out are sanded and smoothed up with a radius on the inside edge of the cut-out. A wood spacer is super glued into the space that the head will take up, and then the wedge slot is re-cut. Handle is installed as per usual.

On an existing handle, I drill a 3/16-inch hole up next to the head. Then I cut a slot with the band saw the whole length of the handle, right up to the drilled hole. After smoothing up the slot I then glue (epoxy) in a spacer of a dark wood to get the handle back to the beginning dimension. The dark wood gives the hammer a custom look. If you have a milling machine, the slot could be milled out with a 3/16-inch end mill or router bit.

Tips for "never loose" handles.

Pick out new handles very carefully, make sure that they are straight and have no flaws in them. The best handles have a straight grain with the growth rings running in the same direction as the hammer blow. Make sure the handle is dry by putting it in a warm and dry place for several weeks before installing. Make sure there are no sharp edges on the hole in the hammer head. Take a file or small grinding wheel and put a nice smooth radius on the side of the head that the handle goes into. If left sharp, it will keep cutting the wood rather than wedging in and the handle will keep working loose. Use a rasp to work the handle down to a tight fit on the head. The head should seat up tight on the handle before the wedge is hammered into place. With the head affixed tight onto the handle, the head and four or five inches of the handle should be placed in a container of linseed oil. Let soak for three weeks, remove, wipe dry and go to work. The head will never come loose.



A rectangle has thickness, width and length.

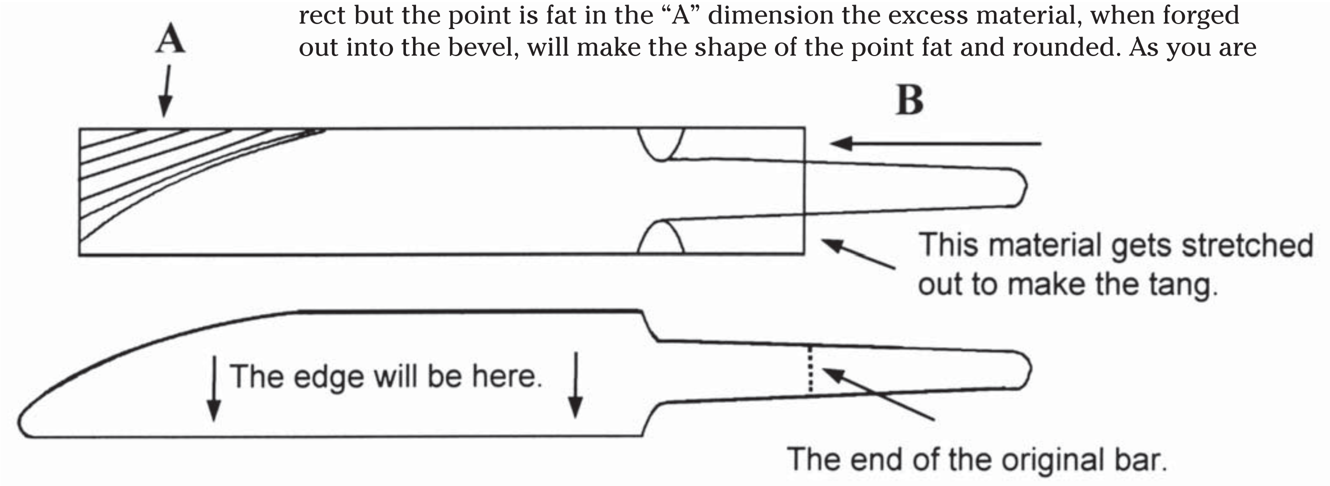
Forging the blade

It is called forging to shape, the theory being that the natural grain flow in the steel should run with the profile of the blade. I remember reading in a metallurgy book that there can be as much as 20 percent less strength in steel parts that are made with their long axis at 90 degrees across the natural grain. I've never seen any research on knife blades in regards to their orientation on the bar they were made of. Thirty-five years ago most of my blades were torch cut out of bandsaw steel. I always cut them with the grain running with the length of the blade. I had no real theory for a basis, it just seemed to be the best thing to do.

In order to forge a specific blade shape, a preform of the blade must first be forged. Each different blade shape has its own unique preform. If a rectangular bar of steel is forged to a point and beveled with no preform it makes a wild, crescent-shaped blade that I call a "Buffalo Skinner." This is the shape that almost everyone ends up with when they forge their first blade. Learning to make the correct preform for different blade shapes takes some of the mystery out of forging to shape.

To make the lesson easier to explain I've assigned "C" to the length, "B" to the width and "A" to the thickness of the bar stock. (Note the dimensions A, B, and C on the bar of steel in the drawing.)

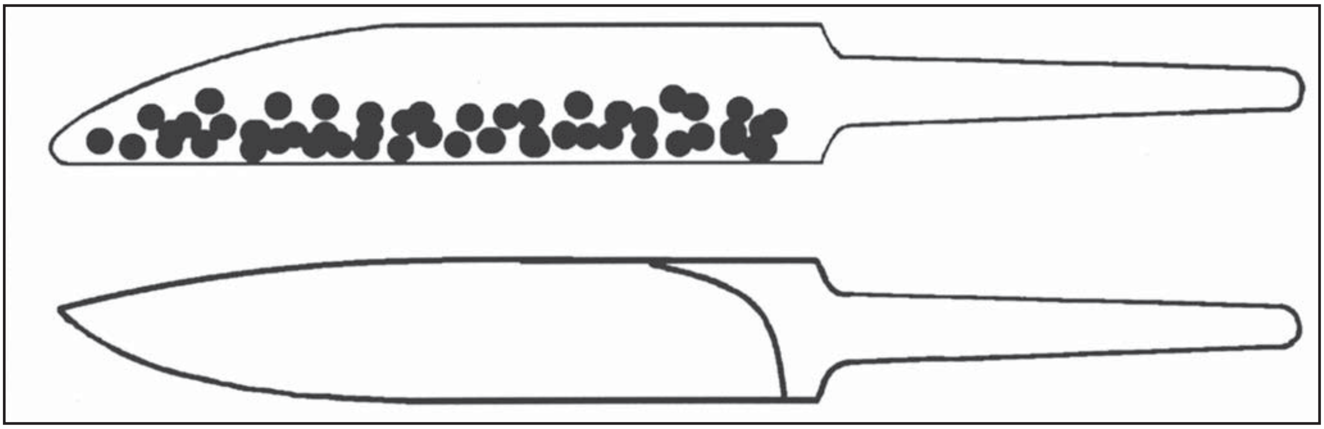
The preform is formed in the "B" dimension with no attempt at forging in the bevels. As the preform takes shape the thickness at "A" will increase. This should be continually worked down with the hammer as it forms. If the preform is correct but the point is fat in the "A" dimension the excess material, when forged out into the bevel, will make the shape of the point fat and rounded. As you are



Forging the preform.

keeping the "A" dimension from getting too thick you can actually forge in a slight taper towards the point. This is known as distal taper. The material at "A" will get hammered down to make the preform shape of the point. Note that the blade gets longer as the point is drawn out.

The material at "B" gets drawn out to form the tang. Make a punch or chisel mark on the edge of a bar of steel at a distance of 3" from the end, then forge a blade on the end of the bar and see if the tip of the blade isn't very close to 4" from the mark. The finished preform looks like an upside-down blade. The hammer blows that form the bevel will cause the tip of the preform to move up towards the back line of the blade. (The hammer blows are indicated by the black spots on the preform in the drawing.)



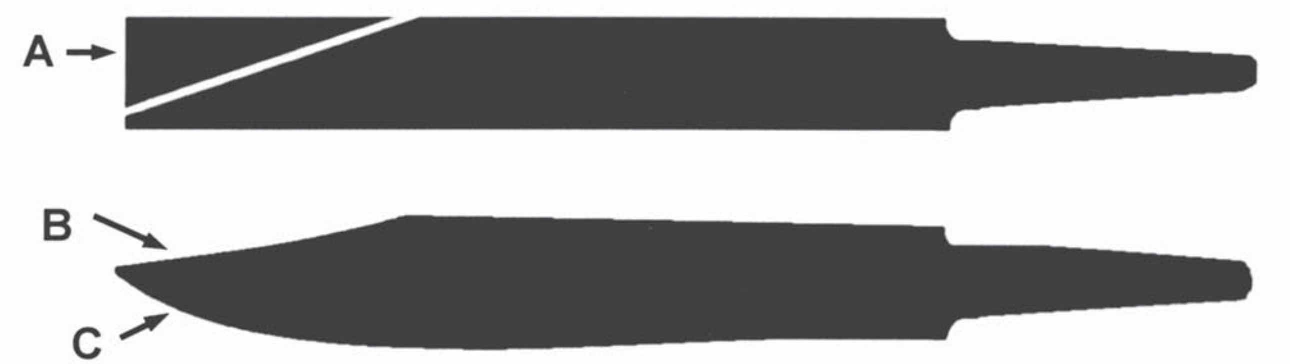
The blade curves up as the bevel is forged in.

The belly of the blade is formed (almost) automatically with very little hammer work on the profile of the blade. If the blade develops too much curvature in the belly it can be fixed at an orange heat by pushing the point back down with light hammer blows. This is called a bending blow because of the position of the anvil under the blade. With practice, the point and blade shape can be forged exactly to shape. When starting out it is all right to do some stock removal on the profile.

The bevel is usually forged down to within approximately 20 percent of the finished thickness at the edge. If not left at least this thick the blade is prone to warp or crack and might even get too thin during the finish grinding process.

The hot-cut preform

Using a hot cutter to shape the preform of the point is a quicker way and also very traditional with blacksmith knifemakers. (See drawings) To make a "Clip" blade, the blade blank is cut off at an angle similar to "A." It can be removed with an abrasive saw, band saw, or hot cutter. The clip "B" and belly shape "C" forms almost automatically as the bevel is forged.



The cut-to-shape preform.

A four minute demo blade that started as a hot cut preform.

Hot or cold cut preform for a butcher type knife.

The American Bladesmith Society does not consider a blade made from a hot cut preform as being "forged to shape." Test blades must be forged to shape from the bar stock. However, hot cutting the point is the way many old time smiths did it and probably for good reason. Much of the steel available at the time could not be pointed up in thin sections without coming apart. I found the following in the 1876 book, "American Blacksmithing, Toolsmiths and Steelworkers Manual" by John Gustaf Holstrom and Henry I. Holford. "Never try to forge the point of the knife, but cut it to shape with a chisel." The book does not give the reason but I always assumed it was because the crucible cast steel that was common in that day was difficult to forge to shape without splitting. I can find no difference in the quality of the finished blade between one that is pointed up with a hammer (forged to shape) and one that is forged from a hot-cut preform. That is why I teach both methods.

I have an "exercise" that I like to do when I teach or demonstrate. I start with a piece of 1/4x1-1/4-inch (1084) that I've hot cut to the preform shown as "A" in the drawing. I forge the bevel into the blank, and in one heat, and end up with the finished shape very close to that shown in the drawing. Sometimes the point of the blade is even higher; it depends on how soon I run out of heat. You could call it a "clip point" blade shape, and I've always wondered if the name came because the smith "clipped" the bar of steel before forging the bevel. Not having to forge the preform into the bar is very fast and efficient.

To make a semi-skinner, or butcher knife shape, two angle cuts are made as per "AA." The point shape "BB" forms itself as the bevel and some distal taper is forged in. Distal taper is that seen when looking down the spine of a blade. It gives the knife better balance and allows the blade to flex more before breaking. It's the same principle as the bow limb.

Forging the bevels

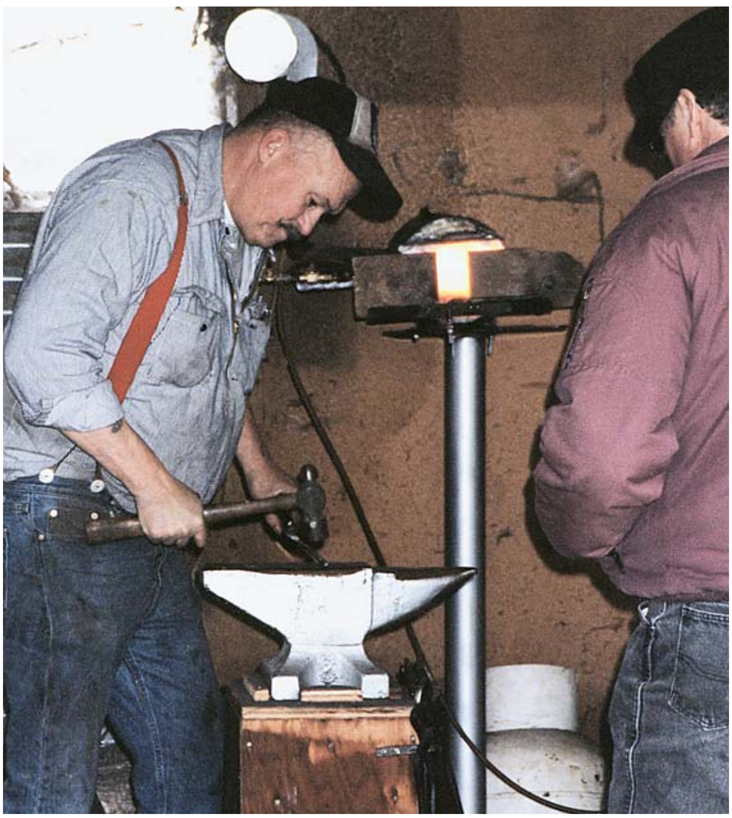
Always forge the blade uniformly on both sides, as this keeps the stresses equal and the material flows into the desired shape in a more orderly manner. Count out five to ten blows, then turn the blade and give it the same amount. Do the counting thing until you get into the habit of working the steel equally on both sides.

A common mistake made by beginners is trying to forge after the steel has cooled to the point that it is not moving under the hammer. My students get tired of hearing me yell at them, "Keep it hot!" or "GET IT HOT!" It's not only a waste of time to hammer on steel that does not move under the hammer but the steel can be damaged by hitting it too hard at a temperature under the forging range. Steel types 1084, 1095 and 5160 should be forged in the range of 1850-2050F. Keep the material hot and everything will go better. Good forging theory says that you start the forging at the high end of the forging temperature and each heat would be at a slightly lower temperature until the blade is finished. You won't be able to do this at first but you will eventually be able to do it if you keep at it.

It took me 16 years of forging to get to the point where I can use a four-pound hammer on a regular basis. This makes it possible to shape a four-inch blade in one heat. That's starting with the method used by the old time smiths of hot cutting the end of the bar at an angle. The hot cut section forms the "clip" on the back of the blade.

It is important to combat the scale that forms with each heat. To help keep scale at a minimum it is important to keep the fire slightly rich. A fire with excess oxygen will create a lot of unnecessary scale. A "butcher block" brush has very stiff, flat wires and works very well to scrape the scale off each time the blade is taken out of the fire. Obnoxious scale can be scraped off with the flat end of a planer blade or old file.

Wet forging is a Japanese method, and it's messy but worth the effort. I started using the method after seeing some Japanese swordsmiths do it on a video. They use a mop made of straw to apply water to the surface of the anvil. The hammer is set in a container of water. When the blade is set on the anvil face and hit with the wet hammer there is a small explosion of steam and that's what loosens the scale. Each additional blow continues the process. Once the blade has been returned to the fire to be heated for the next forging heat the anvil face is wiped clean of scale and then moistened once more.



Wendell Fox demonstrating a finishing heat.

I learned another good "trick" watching this same video. The blade is picked up off of the surface of the anvil after each blow, and then rested back on the anvil just as the hammer gets there. It's sort of like you go tap, tap, tap on the anvil with the flat side of the blade and with every tap the hammer meets the blade just as it hits the anvil. This causes the blade to retain heat longer and that means more steel gets moved with each heat. It is the type of thing that takes practice but it sure is fun when you get it working.

The finishing heat

When you are satisfied with the blade shape it is time for the finishing heat. The term "finishing heat" is used in modern metallurgy books and it is a very logical way to end the forging process. I can find no references to packing as a forge process in any modern metal working or metallurgical books. That's why I teach the use of a "finishing heat," some call it packing. I use the words finishing heat because it more accurately describes what is being done. I don't like the word "packing." The only way I pack steel is in a suitcase, and it's in the form of knives that I'm taking to a knife show.

The way I do a finishing heat is as follows. The blade is brought up to a temperature that is under the point where scale forms. I work the blade over with light and even hammer blows down into the temperature range where there is little or no color visible. It leaves the blade smooth and relatively clean and free of scale. The light blows do not move the steel or change the shape very much but serve to even out the surface.

Forging a narrow tang

Some bladesmiths forge the tang first and then shape the blade. Others will start with the blade end and then make the tang. If the blade is finished real close to shape and you hold the blade to do the tang, the blade will usually get messed up and need to be redone. I usually rough the blade in, then do the tang. The rough forged blank is then held by the tang to do the finish forging on the blade.

Most forged blades have narrow tangs and there are several ways to do it. It is not always a neat and clean method but the edge of the anvil can be used as a bottom tool to start the step-down where the blade meets the tang. To do this, hold the spot where you want the tang to start over the edge of the anvil. The hammer blow should be directly over edge of the anvil. By turning the blade 180 degrees the step down on the other side can be forged in with careful hammer blows. It takes skill and power with the hammer to accomplish it this way. One of the following methods is better.

The spring fuller

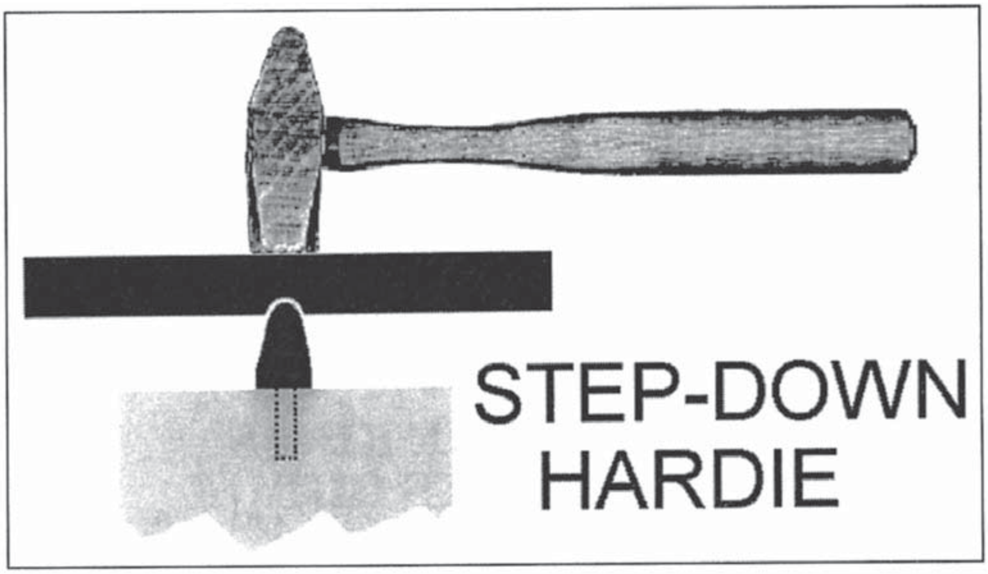
An easier way to make the tang step-down is to use a spring fuller. They are easily constructed from any half-inch diameter round bar stock. Mild steel will work but will eventually wear out, and coil spring material or a handle for a bumper jack will hold up longer. The center section is forged down to about 1/4-inch thick. It is

I used a bumper-jack handle to make this spring fuller. Those who have used mild steel found out that it will not hold up to the work required. It was normalized after forging to shape and it came out real springy.

then forged and bent into the shape shown. See the photo of one made from the handle for a bumper jack. While there is still some heat in the bottom member, arc weld a square shank onto it to fit the hardie hole in your anvil. (Arc welding high carbon steel without it being preheated to at least 200 to 300 degrees F will cause the weld to crack and break.) The spring fuller does not need to be hardened and tempered. Once it is shaped it should be brought up to the normalizing temperature and then allowed to air cool. This will leave it in a tough condition with plenty of strength and spring.

The step-down hardie

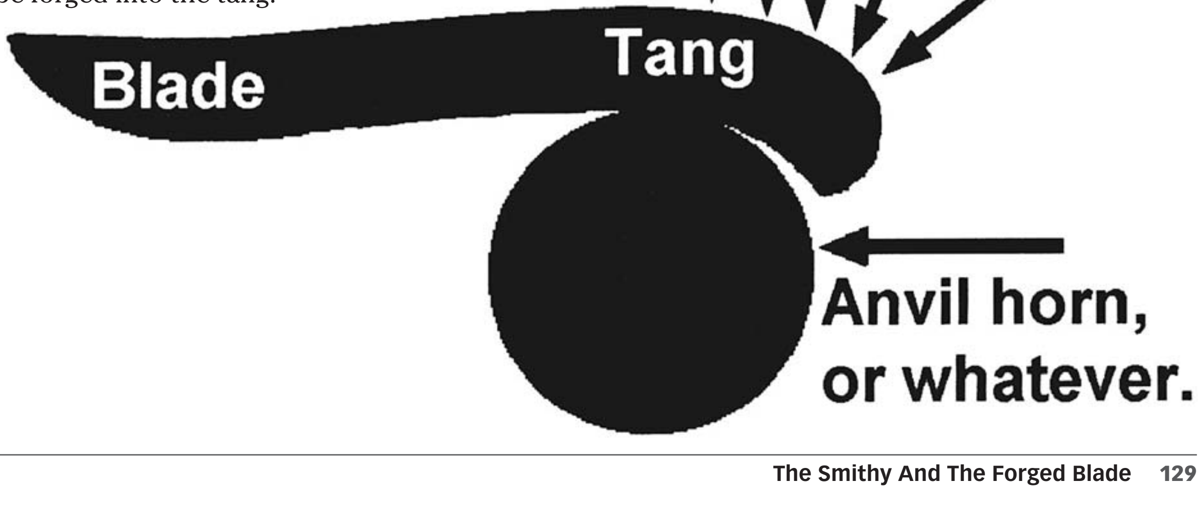
The step-down hardie will make it easier to get a narrow tang started. It can be fabricated out of almost any type steel. Axles or torsion bars from motor vehicles and jack-hammer bits are my favorite materials for hardie tools.



The step-down hardy can be used on only one side of the handle to make a full tang shape, or on both sides to form a narrow tang.

Forging a full tang blade

Most knife handles are wider at the butt end and curve down from the centerline of the blade. The curve in the handle should be forged in first by either using the wedge tool or by working it over the horn. With the handle profile forged to shape the taper can then be forged into the tang.



That mysterious process known as packing

"Packing" is a process that some bladesmiths use in their forging process. The practice came to us out of the 19th century and has been passed down to us by generations of smiths. It is accepted by some, but questioned by others. The procedure as most describe it has little or no basis in modern metallurgical theory. My 1948 Metals Handbook has a definition of "Mechanical working" which is a process described as follows. "Subjection metal to pressure exerted by rolls, dies, presses, or hammers, to change its form or to affect the structure and consequently the mechanical and physical properties."

Other modern books on forging practice refer to a "finishing heat." It is mentioned in many, but not all of the blacksmithing books written in the late 1800's. When it is mentioned it is usually in reference to forging chisels, and is not mentioned very much when knives are discussed. One reference I can find to packing of blades is in Alex Bealer's "The Art Of Blacksmithing."

When I got into forging I asked several established bladesmiths to explain their method of packing. There were some differences in the methods used but the basic formula was something like this. "Hammering the edge portion of the blade with a light hammer as it cools down to the point that the color is barely visible in a dark place." At the same time I asked two different metallurgists what they thought of "packing" theory. Both explained that the steel recrystallizes during the hardening operation. Their opinion was that the temperature of the hardening operation would undo any grain refinement done in the packing process. So now we have two opinions on the subject, but let's get even more.

Following is how packing is described by a variety of sources:

1. "The edge is packed by hammering it lightly to `jiggle´ the carbides into alignment. Forging reduces the size of the carbides along the edge surface, while packing tightens the crystal structure so the molecules remain on the knife's edge longer."

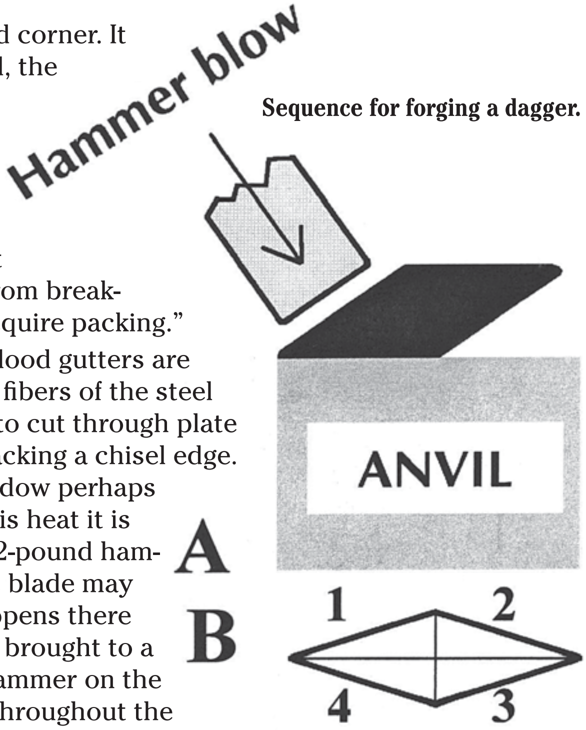
2. The subject was packing the cutting end on chisels used for cutting steel. "Just as it is cooling from a bright-red heat to a dull-red heat, strike it two or three sharp blows in a triangular pattern. This will compact the steel molecules yielding them impervious to high speed drill bits or even a new file which is hard for most cutting jobs. Compaction is a bit tricky for the beginner since one blow too many will reach the compaction threshold where the molecules cannot be forced any closer together resulting in splitting."

3. "The final refinement of the grain size is referred to as `packing´ and is done at the same time that the final shape of the bar is finished. Packing the steel is very important and involves hammering the steel at a dull red color for a long period of time. Grain refinement in parallel rows is essential for strong, high quality cutting edges. The smaller the grain size, the stronger the material."

4. "The hammer blows may appear to be random, but each one is serving a purpose. The grains are being elongated in the direction of maximum stress, somewhat like wood grain. The hammering breaks up large grains and produces a fine-grained, tough, strong structure. As the steel cools out of the red condition, light blows pack the surface and edge. One must be careful at this point, though, because hammering when the steel gets too cool may form cracks."

5. From an old blacksmith book in a section on making chisels: "Packing is exactly what its name implies. It is a technique whereby the fibers of the carbon steel are packed tightly with hammer blows to provide an extra degree of density to the chisel or punch point. Packing is done with a light hammer at a sunrise-red heat. So important is the heat, neither too bright nor too dark, that it is wise to provide a dark chamber of some sort, a small keg or box, on the forge so that the red can be judged more accurately. Often in daylight or in the glow of the forge fire it is impossible to ascertain a sunrise red, yet if the metal is much hotter packing will not occur…" Actual packing is done with a light hammer, usually a ball peen, about 1-1/2 pounds in weight. When the chisel edge attains sunrise red in the forge it is taken out and is

laid across the horn or on the anvil face next to its rounded corner. It is struck rapidly with the hammer at one point on the anvil, the smith turning it from one side to the other while he draws it toward him under the blows. This is continued until all red disappears and hammering is stopped. On chisels, the last three hammer blows are important. One should be placed on either side of the edge and the last placed in the middle of the edge at a slightly higher point. These last blows arrange the fibers so as to prevent the chisel edge from breaking in a crescent shape in later use. Wood chisels do not require packing."



Sequence for forging a dagger.

From Alex Bealer's "The Art Of Blacksmithing": "After blood gutters are formed a fine sword will have its edge packed, to mass the fibers of the steel and enable the weapon to hold its edge longer when used to cut through plate armor. Packing a sword follows exactly the technique of packing a chisel edge. The blade is heated until it turns red when viewed in a shadow perhaps furnished by a barrel set on its side next to the forge. At this heat it is placed on the anvil face and quickly hammered with a 1-1/2-pound hammer. Packing must be done with even blows; otherwise the blade may warp when quenched in brine during hardening. If this happens there is only one way to eliminate the crookedness. The blade is brought to a bright orange-red and tapped smartly with a four-pound hammer on the end of the tang. Such a blow will rearrange the molecules throughout the blade and allow it to be hardened without warping on the second trial. Of course, rearranging the molecules also destroys the packing and this must be repeated before hardening and tempering."

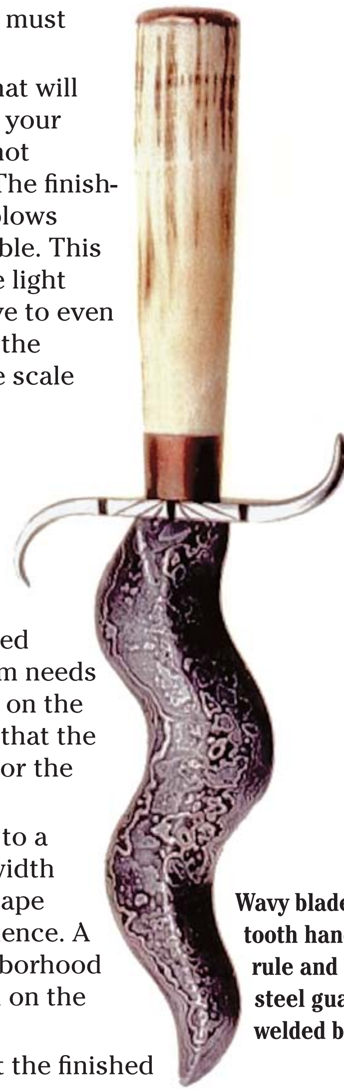
Now that you have the all of that great information on packing, what will you do with it? I recommend using a finishing heat. I will assume that your blade is pretty well shaped and that proper measures were taken to not overheat it or leave it with a lot of scale hammered into the surface. The finishing heat means working the blade over with light and even hammer blows down into the temperature range where there is little or no color visible. This will leave the blade smooth and relatively clean and free of scale. The light blows do not move the steel or change the shape very much but serve to even out the surface. If there are still rough and uneven places or scale on the surface, heat it up to a temperature that is just under the point where scale forms and do the light hammering once more.

You may call it packing if you like but always remember that the steel recrystallizes both in the normalizing and quench heats. Call it anything you want, but I'd rather you don't say that you've jiggled, compressed or lined up the molecules.

Forging a dagger

Forging a double-edged blade has some unique problems associated with it. The first is to try to figure out how much narrower the preform needs to be from the finished profile. The second is to hold the rough blade on the anvil at the correct angle to get the bevels even. The final problem is that the forging has to be kept even on all four surfaces of the blade in order for the finished blade to be symmetrical.

All blades start with what I call a preform. The bar stock is forged to a certain shape (a preform) so that it will have the correct shape and width once the hammer blows spread the edge or edges out. The proper shape and size of a preform is something that is learned primarily by experience. A general rule is that the finished blade will be somewhere in the neighborhood of 30-50 percent wider than the preform. The exact width will depend on the thickness of the bar stock and how thin it is forged at the edge.


Wavy blade dagger, hippo tooth handle, copper ferrule and pommel cap, steel guard, pattern welded blade.

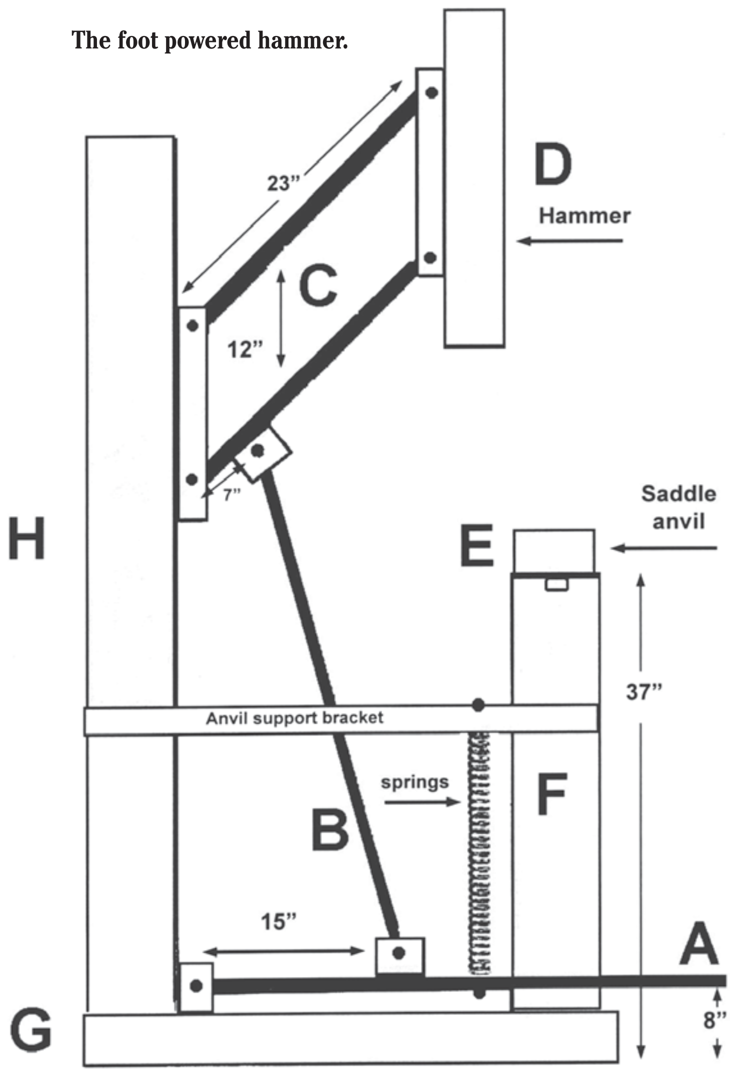
Let's start by forging a preform that is 70 percent of the width that the finished dagger shape should be. While forging this preform some distal taper should be forged into it, otherwise after forging in the bevels the point will be wider than was wanted. The preform has to be symmetrical or else the finished piece won't be. If necessary file or grind it to a symmetrical shape before forging the bevels.

If you look at a dagger blade from the end you will see four facets. For the purpose of this forging lesson you should number them 1, 2, 3, and 4 in a clockwise direction (see drawing "B"). Start the forging by working a bevel on the surface that will become facet #1 of the blade. It is of the utmost importance to not make any hammer blows past the centerline. You will be forging approximately one third of the bevel into the blade, and remember that you will be bringing the other side down to meet at a centerline. As you do this note that the forged portion will belly out from the opposite edge but don't worry, it will straighten itself out with the next forging. Forge the same amount of bevel into facet #3. If you forged both edges equally the shape will be symmetrical. Now go to facet #2, and finally #4. Keep working around the blade in this manner, all the time being aware of where the anvil is under the blade (see drawing "A"). If you don't keep the anvil under the flat side of the blade you will be putting kinks and bends in the blade and that will make the forging harder.

It is easy to tell if you are forging everything equally, as you look at the profile it will be symmetrical, and when you look at it from the point end you will see a diamond shape (see drawing "B"). Forge and look, forge and look. Take it slow and easy, this is not an easy thing to do. Forge the bevels down to where there is a flat edge approximately 1/16-inch thick where the edges meet. You will need this much material in order to clean up the blade prior to heat treating. If you forge the bevels too thin at the edge the dagger will get narrow real fast.

One of the requirements for The American Bladesmith Society master smith rating, is to make a classic European style dagger. I believe that style was chosen because it is the most difficult knife to make perfectly symmetrical.

The foot powered hammer.



Power for forging

Foot-powered hammers

We live in a residential neighborhood and the smithy is in the back yard. The foot-power hammer and hydraulic press are the solution for noise. For 10 years I used a foot powered hammer that I built. It works on the principle that when you depress the foot pedal six inches with 35 pounds of pressure, the 55-pound hammer comes down 12 inches with a mighty blow. The two-to-one ratio of hammer travel to the foot lever gives a tremendous increase in power. A single blow from it has nearly the same power as a 50-pound Little Giant mechanical hammer. It has sped up my production of welded and straight forged blades considerably. The time spent shaping blades is reduced to 20 percent of doing it all with hand hammering. Most of the heavy hand hammering is eliminated. Blades come out straight and flat from under the flat dies.

The old-time blacksmith always had a helper who would swing a heavy two-handed sledgehammer when needed for drawing out heavy stock. The striker, as he was called, would also strike set tools that the smith would hold on the work for fullering, swaging, flatting, hot and cold cutting, punching, etc. The foot-powered hammer takes the place of a strong and willing helper, and doesn't cost anything to feed. It's not as efficient for drawing-out as a mechanical power hammer but is still a tool worth having. Once you get used to it, it is a hard tool to do without.

There are some foot-power hammers being built that have a straight drop on the hammer. That's a much better action than the swing-arms of the type I built. With a pulley or cam setup I believe a four-to-one ratio is possible with a straight drop hammer. With a spring-action / shock absorber built into the foot lever I believe I could operate one and not damage my metal and plastic knee joints.

Mechanical power hammers

Little Giant is the most common. The disadvantages of a mechanical hammer are numerous. They are often expensive to purchase, and there are lots of parts to wear out. They are heavy to move and noisy, too. If you have one, use it, but before purchasing one check out the options that follow. I had a Little Giant power hammer set up at a friend's shop and got good use out of it in my early years as a smith. As I got used to the foot-powered hammer and forging press I no longer used it and so I sold it to my friend whose shop it was in. (I retained visiting rights.)

In 1984, with my newly acquired 50# Little Giant, which was set up in the shop of artist blacksmith David Thompson. David owns it now, but I have visiting rights.

Air hammers

Commercial air hammers like Nazel and Chambersburg are the ultimate forging machines. They are even more expensive to find, move and set up than the smaller mechanical hammers. Unless you are going into a production operation I wouldn't recommend considering one. On the good news side, there are some smaller, imported air hammers that are very suitable for the bladesmith.

My artist blacksmith friend David Thompson bought a Nazel 4B from a man who rescued it from a scrap yard. David moved it to Eugene and now has it set up and operational. This machine will forge hot steel that is six inches thick.

A whole new generation of homemade air hammers has developed. Plans are everywhere on the internet. My friend Jeff Crowner has one that has an interesting design feature, the large 90-degree pipe being the whole frame.

David with his Nazel 4B.

Jeff Crowner named his one-of-a-kind air hammer, “Big Blue Thumper.”

Putting the big squeeze on a one-inch diameter bar of 52100.

Hydraulic forging machines

I use a hydraulic forging press for the work that I used to do with the foot power hammer. It's slower but not to the point that I feel handicapped. The really big advantage is that they are quiet compared to foot-powered hammers or a power hammer.

The art of schwocking

Two bladesmiths are working when one of them says, hand me your club. Club? That's cave man talk. A better word has to be found, something with a "ring" to it. Besides that, having the appropriate word at just the right time is a necessary part of communication in our complicated and busy world. When fumbling around for the right word that won't come out, why not make up a new one? The noise when using the club on a piece of hot steel sounds kind of like "schwock." Therefore, the club was dubbed schwocker and the art of schwocking may have gained some class.

The first time I saw schwocking demonstrated was by Al Bart, an old time blacksmith. He used a wood club to bend the hot part he was working on. The club wouldn't mark the work like a hammer blow would. I'll say that it is an essential tool for the bladesmith.

The well equipped blacksmith or bladesmith shop should have an anvil-height stump with some grooves and a large recess. There are two types of hammer blows: the forging blow and the bending blow. Placed on the appropriate spot on the stump and hit with the schowocker the hot part can be bent into the proper shape. The bladesmith will use the schwocker and schwocking to put more or less curve into a blade, or perhaps use it to straighten the blade.

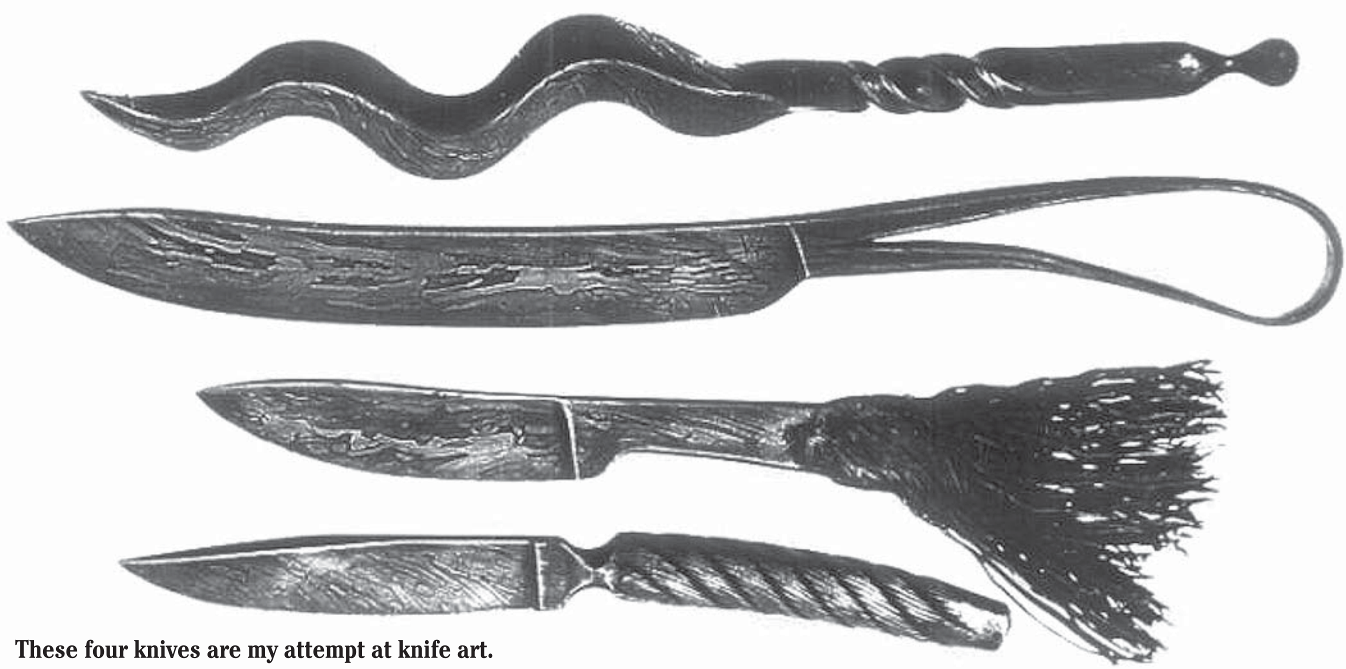
They may look like clubs but they are not! In the hands of a qualified bladesmith or blacksmith they are schwockers.

Damascus Steel

It is unlikely that damascus steel was ever made in Damascus, Syria. It is more likely that the city of Damascus was the trade center where either the steel or blades were obtained and that is how the figured steel came to be named. If you look up damascus steel in the dictionary, it is defined as “steel with a pattern on the surface.” The dictionary also defines “damask” as “a reversible figured fabric.” Damask is also used to describe “peculiar” markings on the surface of steel. This brings up an intriguing question: Could it be that damask cloth was made before the steel was so named? If so, the patterned steel may have gotten its name from the cloth, not the city.

Damascus steel was easy to define back in 1973 when Bill Moran first displayed his pattern-welded blades at the Knifemakers Guild Show. It’s not so easy to define today. My list of types keeps growing and growing. Electrical discharge machining, powder-filled patterns, layers made of powder metallurgy steel, there is no limit to the possibilities.

Damascus steel would be two or three different things depending on where you were in the world at any particular time. A Viking warrior might have had a composite blade that would fit the modern definition of pattern welded. A Persian assassin could have had a dagger of what we would call Wootz.



These four knives are my attempt at knife art.

The knife is no longer just a cutting tool or weapon. Damascus steel has made knives a "canvas" that is used to show off the steel. There is a new art form where patterned steel is used like paint is used on canvas. Maybe the time will come when damascus steel is simply hung on the wall or made into sculpture. Why not? As it is now, lots of people spend big money for decorated paper and canvas to put on their walls.

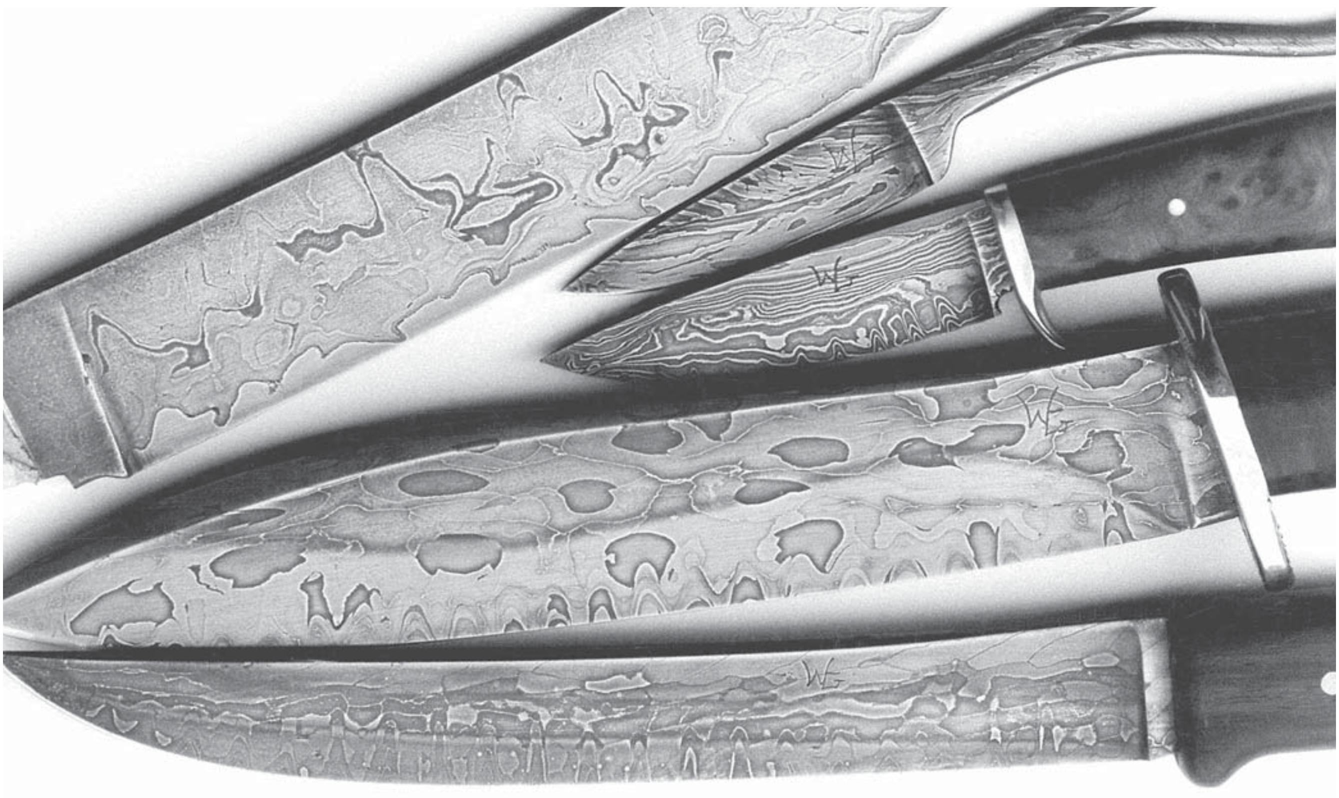
A customer once asked me to make up sample pieces of all the different types of damascus. It would be a collection to admire and study. I never found time to do it, but the idea may be sound. Perhaps bladesmiths should start making up standard-size example pieces to sell to collectors. One inch by two inches would be a nice size.

Classification of damascus materials

There is a need to call the different damascus types by a proper and appropriate name and not simply lump them all together as damascus steel. I am willing to accept as "Damascus" steel in any form that has either a crystalline or mechanical structure that is visible when brought out by etching. This definition fits damascus steel into common usage and keeps it in a historical context.

The patterned blades brought back to Europe by the returning Crusaders, the Viking and Merovingian blades, the Indonesian Kris, the Japanese sword, the German blades of the first half of this century and the current production are, from the mechanical and visual characteristics, very different things. I believe it is time to stop arguing about what is or is not damascus steel, or what genuine damascus steel is. The term "damascus steel" should be used for the whole general class of steel with patterned blades. The specific types should then be identified and referred to by names that accurately describe the origin of their basic metals and their method of manufacture.

The accompanying outline lists all the types of damascus steel with which I am familiar. The name assigned to a specific class is either one accepted in common usage or something that I felt was appropriate. It is presented for reference and your



Five different types of damascus steel made in my shop. Top left, bicycle chain. Right side top to bottom: wire damascus, pattern-welded, chain saw chain and motorcycle chain.

consideration as a more accurate way to communicate about this material. Modern metallurgists have made the distinction between crystalline and mechanical damascus. "On Damascus Steel" by Leo S. Figiel M.D., distinguishes between the two. The crystalline type originates from a homogeneous, cast source in either a billet or bar. The mechanical type originates from a heterogeneous source and is laid up by forge welding. Every known type has to fit into one or the other of these two classes.

DAMASCUS STEEL TYPES

I. Crystalline (homogeneous source)

- A. OLD WOOTZ
    - 1. Indian (crystalline)
    - 2. Persian (laminar)
- B. MODERN WOOTZ
    - 1. Crystals arranged in long sheets, laminar grain.
    - 2. Crystals arranged in a more random pattern.
- C. ETCHED TO BRING OUT DENDRITES AND CRYSTAL PATTERN.
    - 1. From bar stock
    - 2. From cast blade shapes
    - 3. Hammer Steel by JD Smith, Wootz appearance from grain flow manipulation.

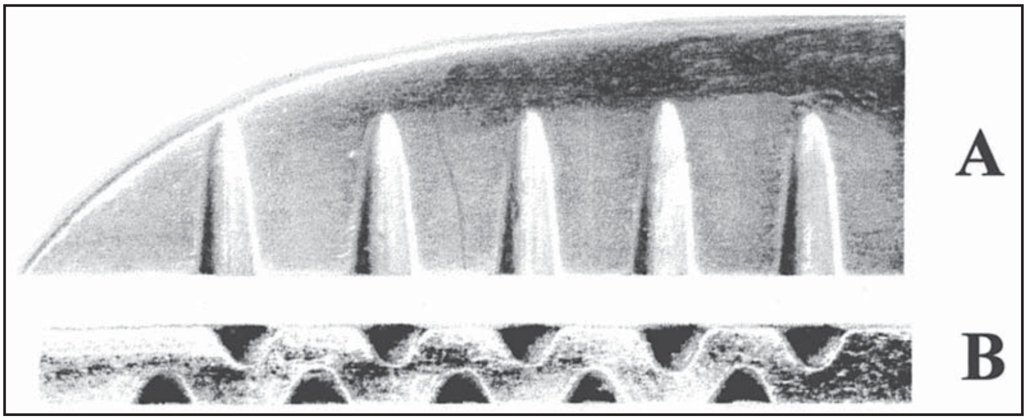
II. Mechanical (forge or furnace welded, heterogeneous source)

- A. PATTERN WELDED (LAYERED STEEL)
    - 1. Layered where the individual layers are homogeneous
    - 2. Layered where the individual layers are heterogeneous
    - 3. "Turkish," twisted rods
    - 4. High density
- B. MOSAIC
    - 1. Patterns formed by pipe, wire etc.
    - 2. Patterns cut by EDM
    - 3.Combination of powder and pre-forms
- C. WIRE
    - 1. Wire rope source
        - a. All steel wires made up of dissimilar alloys
        - b. Steel of varying carbon/alloy contents and iron wires
        - c. All high carbon steel
        - d. Made up combinations, (wires or strands from mixtures of the above)
    - 2. Other wire sources
        - a. Street sweeper
        - b. Piano wire
        - c. Other wire combinations
- D. CHAINS
    - 1. Motorcycle
    - 2. Bicycle
    - 3. Timing
    - 4. Chain saw
    - 5. Drive chain

III. Particle metallurgy or powder Damasteel (particle metallurgy) steel and iron powder (pioneered by Devin Thomas)

A specific damascus blade should be classified and called by a specific name. If a blade is made by forge welding a motorcycle chain together, call it "motorcycle-chain damascus." If you weld up a bicycle chain by itself and then stack it with a bar that was welded up from cable, then fold it a few times, it becomes composite-bar pattern welded. If your blade was not welded but etched to bring out the crystalline damask, it is either etched bar-stock damascus or etched cast damascus.

Hammer Steel by JD Smith.



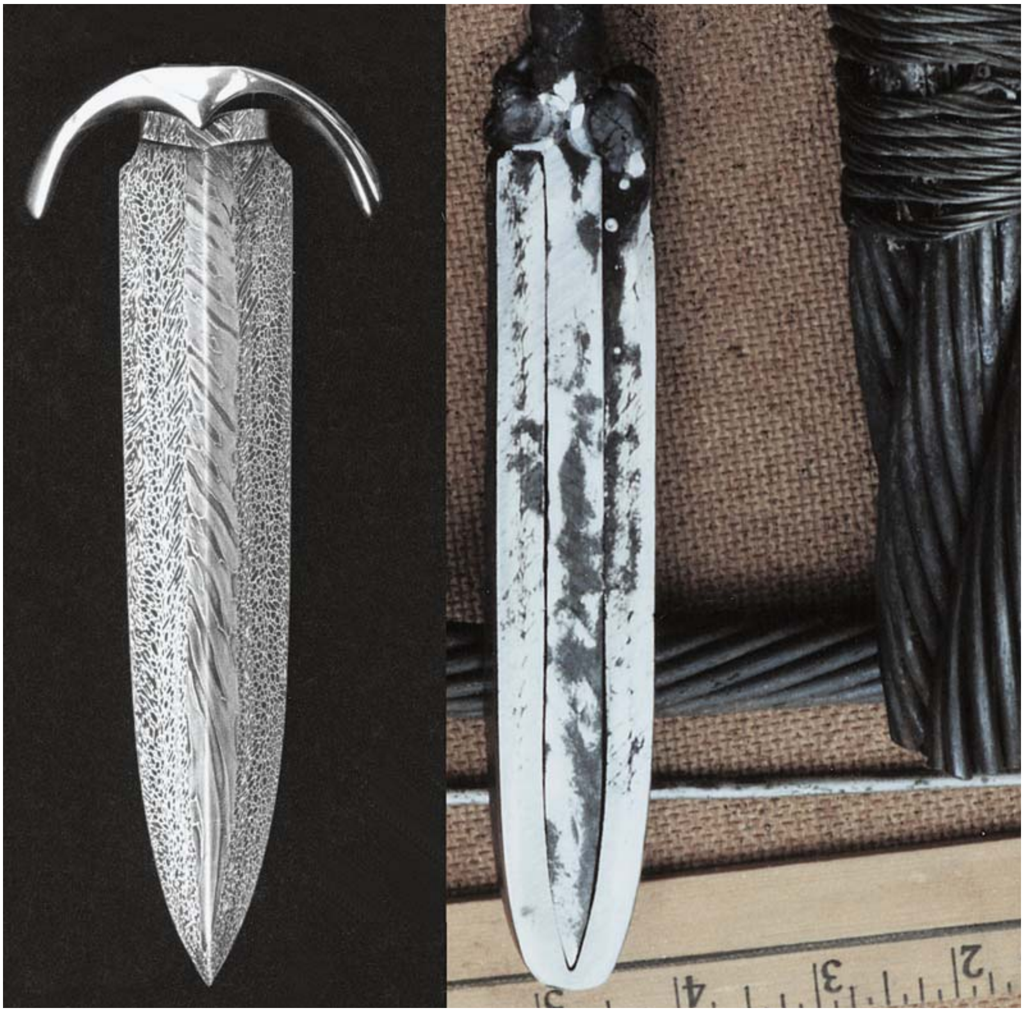
A ladder pattern is created by grinding grooves, alternating from front to back. The edge is straight, overall thickness 50 percent or more because it gets thinner from forging the grooves, and it will curve a lot. I let the grooves run out about half way or a little more up on the blade. I like the wood grain pattern in the back portion of the blade. The blade is then forged out exposing the pattern.

Does damascus steel have advantages?

There is a great deal of difference in the strength and edge-holding ability of blades made by forge welding the elements together. Some variables that affect the performance of the finished product are the starting materials, welding temperature, number of folds, pattern development and heat treatment. These factors are individually important and yet, to a large degree, depend on and affect each other.

If the layered damascus blade is to have superior strength and cutting ability, it should actually have hard and soft layers in the finished blade. This should give it superior strength and the DCE (Damascus Cutting Effect) would work. DCE theory says that as the soft layers wear away, the hard cutting surfaces are exposed. I have seen DCE work only on blades that had a very fine ladder pattern at the cutting edge. A lot of carbon is lost in the welding process, so it is important to start with steel of at least .95 or more carbon. Up until about 1985 most pattern-welded steel started out with good quality wrought iron or mild steel to make the starting billet. Since that time more and more pattern-welded steel is made of all high carbon steel, the difference in alloy content giving the blade its pattern.

Welded damascus is possible because combinations of steel and iron will weld together when heated to a certain temperature in a reducing atmosphere. Temperature and atmosphere is the important thing; hammering only pushes all the parts up against all the other parts. The normal temperature for welding steel and

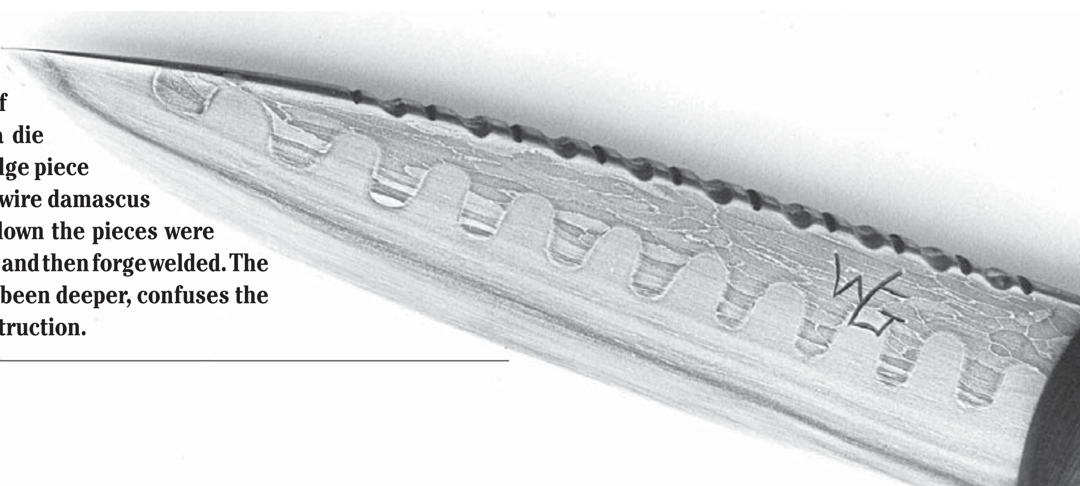


The composite dagger blade was made from two kinds of cable. The core was a single strand taken out of the large cable. I took out every other wire and replaced it with old iron telegraph cable, then welded up and forged into the flat bullet shape. The outer piece was welded up fine wire cable, it was wrapped around the core and forge welded. The finished blade is at the left.

iron together is around 2,100 to 2,400 degrees F. At these temperatures the carbon migrates from areas of high to low concentration. This is known as “diffusion” or “carbon migration.” The speed at which diffusion takes place is relative to time and temperature; the more time and the higher the temperature, the faster the rate of diffusion. This is why it is important to weld at the lowest temperature possible, get it done quickly and fold the blade material no more than is necessary.

I learn the most about the structure and internal soundness of my welded blades by doing a destructive test of the tip portion of a heat-treated blade. The fracture pattern that a damascus blade shows when broken is an excellent indication of whether or not the welding was worth the effort. The superior blade is resistant to breakage and shows an irregular pattern when it does give up. As a crack forms across a hard layer, it is stopped by the adjoining soft layer.

The soft layer must be pulled apart before the crack can continue into the next hard layer.



Another of my experiments with composite blades. The edge piece of heavy saw plate was formed with a die made for the hydraulic press. The edge piece was then pressed down into the hot wire damascus material. When everything cooled down the pieces were cleaned of scale; tack welded in place and then forge welded. The edge quench line, which could have been deeper, confuses the visual effect of this method of construction.

If the blade breaks cleanly and has a crystalline appearance, it is a sign of complete carbon migration. It is possible to have a 500-layer piece of pattern-welded material that shows a nice pattern, yet the carbon is evenly distributed throughout the material with all the layers being close to the same hardness. Another good indication is the hardness of the blade out of the quench. When too much folding or welding at too high a temperature is done, the blade will not respond well to the hardening process, an indication of excessive carbon loss.

I was disappointed with the strength and cutting ability of my first layered damascus blades. They did not measure up to most of the things I had read about the material. For the first two years of my damascus making, I tested each new heat-treated blade. I would clamp 1-inch of the point in a vise and flex the blade 90 degrees. Whenever the blades were hard enough to hold an edge well, they would break. If they had very much strength, they would not have edge-holding ability. All of these blades were of the iron/steel, 500-plus layer type.

As I progressed in my bladesmithing skills, I started to look more closely at many of the claims made for damascus steel and realized that these claims were based on opinion and not on any comparisons made with other knives. My discussions with other bladesmiths verified my opinion that not many comparisons were being made. This brings me back to my first rule of knife testing: Test results have little or no value unless a "same test, same day" comparison is made with another knife of known value. I was chasing a phantom set of attributes and decided then and there to write my own rules for my damascus steel. The layered steel would be compared to all other types of mechanical damascus steels for a fair perspective to be determined.

What about the ancient blades that were said to have cut a silk scarf floating in air and then cut through swords, armor, rocks and anvils? When I put it in perspective it seems that the fame of damascus steel was gained at a time when most blades were iron, or steel that would be inferior to present-day low-quality materials. It is my opinion that the strength and cutting ability of the ancient blades will not equal the best selectively hardened and tempered modern non-damascus blades. My opinion will be hard to prove because of the lack of ancient blades available for testing.

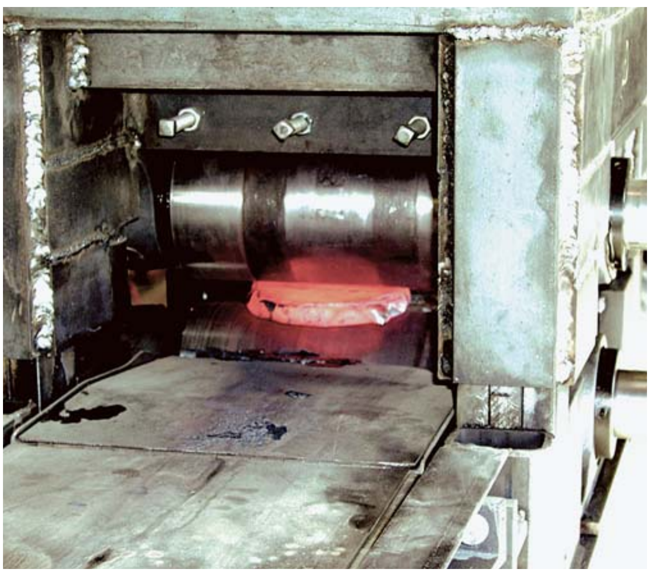
The strength of a welded damascus blade depends on a number of variables. The most important is that there are alternating hard and soft layers running throughout the blade. The study of the fractured surface of a layered blade that had superior strength shows that there is an uneven breaking in the fracture. Think of a crack trying to work its way through a layered blade; the hard layers are easy to fracture but when the crack comes to a soft layer it has to tear the soft layer apart before the fracturing can continue. In most layered steels there are occasional flaws that also provide an easy path into which the crack can spread. When a welded

My starting billet for making a billet of wire damascus is four pieces of 3/4-inch or larger with a piece of 1/2-inch or 5/8-inch down the middle. This bundle is forge-welded into a rough square, reheated to the welding heat and forged corner to corner into a square. It is forged down to the rough blade shape using a welding heat each time. There is no folding, the reduction in size at the welding heat gives the least amount of flaws.

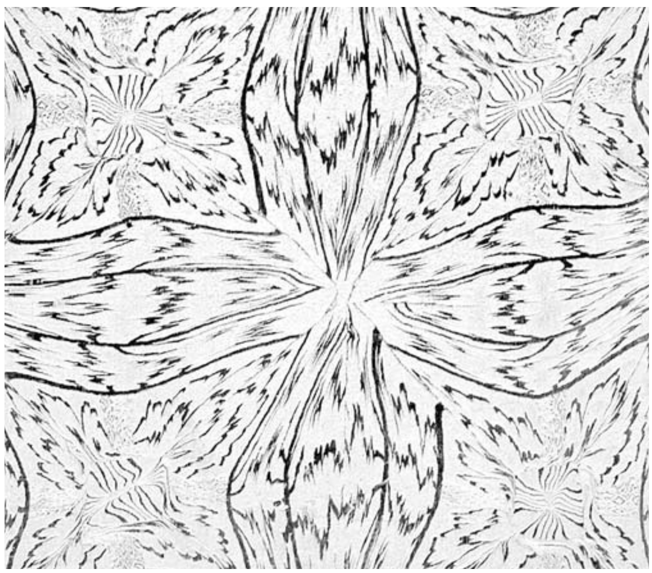
The elements that will make the mosaic are packed in the can and it is filled with the proper powder.

The can has been welded shut and a handle attached.

The monster rolling mill is ready to go to work



The billet begins its runs through the rolling mill. It is stretched and stretched and shaped into square bars. Cut and stacked, welded and drawn out.



Here is finished mosaic tile, and don't ask me exactly how the pattern was done.

The process of etch and rub, etch and rub gives a depth and appearance that I have not been able to get any other way.

damascus blade breaks clean with a crystalline appearance, it indicates that something went wrong. The usual cause is too much folding. Such a blade will often show a beautiful pattern but will have no more strength or cutting ability than an average homogeneous blade.

Wire damascus

Some of the problems encountered when making layered steel are eliminated when wire rope is used to make damascus. Wire rope should be used that is all high carbon material (whether it is high carbon can be determined by a quench test of the rope before welding). The diameter of the individual wires will, to a large degree, determine the strength and cutting ability of the welded-up blade. The high carbon wire decarburizes to a depth of approximately .005 inches during the welding process. The decarburized outer portion of the wire becomes nearly pure iron. This effect is what causes the pattern and other damascus properties in blades welded up from wire.

If the starting billet is made of 3/8-inch cable which usually has wires that are .015 inches in diameter, the finished blade will have just one third or less of the total carbon with which it started. (.85 carbon to start, less than .30 when finished). This blade would be strong and beautiful but would have little cutting ability when compared to a blade made of wires .040 to .060 in diameter. The proportion of remaining high carbon material is much greater as the wires get larger. This is useful in controlling the physical properties and appearance of the billet by using different-size wires in the core, edge, back or outer skin.

The layers in a finished wire damascus blade do not run in straight lines; they twist through the blade, alternating their twist from one side to the other. The best blades that I have tested are made by starting with a large enough bundle to make the finished blade with no folding. When correctly done, the material known as wire damascus will always be stronger than the layered material.

Non layer damascus

Damascus by the can

I had the privilege to attend a damascus party at Ed Schempp's shop. The emphasis was on powder damascus and his shop is wonderfully outfitted for production. Most powder damascus material goes into making mosaic damascus. Pictures of finished mosaic damascus knives are everywhere so I won't show a lot of that.

Damascus made from chain

I compared bicycle chain, motorcycle chain, various assortments of timing chains and chain-saw chain. I got the best cutting ability from chain-saw damascus. It takes a lot more work to prepare a billet for welding but it is worth the effort. Most modern chain-saw chains have chrome-plated cutting teeth. I have not been successful at welding chrome-plated parts, so I grind off the portion of the cutting tooth that is plated. It would seem from quench tests on the chain before welding and the appearance of the etched blade that there are three different alloys of high-carbon material in the chain with which I have worked. This fact, along with the shape of the pieces of chain, gives chain-saw damascus blades their exceptional beauty and cutting ability.

A new generation of damascus materials

In the last 20 years there have been three advances in techniques and equipment that have eliminated many variables that have a negative impact on the quality of making the layer-welded material. The first advance was the development of gas furnaces specifically designed for welding all types of damascus steel. These furnaces are rapidly replacing coal forges as the heat source used by the bladesmith for welding. Welding is usually accomplished at a lower temperature in a gas furnace and that is beneficial for the quality of the blade. It is very easy to overheat or even burn up a billet in a coal forge. When welding in a properly regulated gas furnace, it is nearly impossible to overheat the billet.

The second development that has improved the quality of layered damascus is the elimination of the folding process. It's easy, start with enough layers of material to make the finished blade. I call it one-weld damascus. The first time I saw this done was in 1983 by artist/blacksmith David Thompson and his uncle, Ron Thompson. They made some billets of layered damascus by stacking layers of metal-cutting band-saw blade material mixed with steel-strapping material. The billet was welded, drawn out and forged into blades with no folding.

"Twisted nickel" made by Jim Ferguson is another one-weld layered damascus. His original steel combined nickel with spring steel which he welded it under a large press. He then twists it and forges it flat, creating a billet with a large, distinctive twist pattern. His current web page shows a nice variety of patterns.

Devin Thomas uses a different method to "dry" weld layers of stainless and other steel. He also produces mokume with his method. "Dry" welding means that no flux is used. I have examined numerous blades made by this process and it is the cleanest layered material that I have seen. Devin is currently developing damascus made with a combination of pattern pieces and metal powders.

When a mixture of high alloy and low-alloy steels are welded together, the resulting billet is not always compatible to a lot of drawing out. In eliminating the multiple stretching, folding and re-welding, the one-weld damascus process makes the welding of stainless steel and other difficult-to-weld steels much more feasible.

The combination of modern technology with better and more suitable starting materials will guarantee that damascus materials will continue to improve. With each passing year the odds of making a finished blade of better quality improves.

Etching damascus steel

I use Archer etchant (a ferric chloride solution) and it gives me good results, but it took me awhile to figure it out. Here is how I do it.

Mix the fresh etchant with three or four parts of water. Maintain the temperature of the etch bath around 60-70 degrees F. I get the best results by starting with a hand-rubbed 400-grit finish. I put the bare blade (that means no fingerprints) into the etchant by hanging it on a wire. Allow the etch to work for five to eight minutes, then take it out and put it into a strong solution of TSP (trisodium phosphate) and water. TSP is sold in the paint department of most stores. It is a chemical neutralizer for ferric chloride.

Allow the etched blade to neutralize for several minutes, then wash the carbon deposit off of the surface with soapy water and some fine steel wool. I then give the blade a quick hand rub with 1,000-grit wet or dry paper to check the progress of the etch. Most blades of cable and motorcycle chain need anywhere from two to four cycles of the five- to eight-minute etch/rub followed by the TSP. Some pattern-welded blades respond well to one eight- to 12-minute etch. The process of etch and rub, etch and rub gives a depth and appearance that I have not been able to get any other way.

As it comes out of the bottle, the etchant is too strong and it eats all the layers at the same rate. This usually results in a poor appearance because there is little delineation between the layers. Other times the appearance will be granular and pitted looking. A slower etch always brings out more pattern.

Some commercial damascus does not have much pattern to it. I've had lots of questions about this, but little experience etching the commercially available damascus. Try the method I recommend, and if you still are having trouble it may be the material.

Folding Knives

My advice for those wanting to make folding knives is to buy some cheap knives, old and new, broken or not. Take them apart and study the relationship of the parts, clean them all up and reassemble the sides with new handle slabs. Do it with LinerLocks®, lock backs or automatics, whatever type you are most interested in. Or, get busy and complete the friction folder project that follows. I had intended to do a whole series for *BLADE* Magazine®, jackknives, lock blades, LinerLocks® and crown folders. I didn't get any further along on it after the Friction Folder project. Search on Amazon.com and Google for folding knife repair, making folding knives and etc. See what comes up and, don't forget to check the book departtment at Krause Publications.

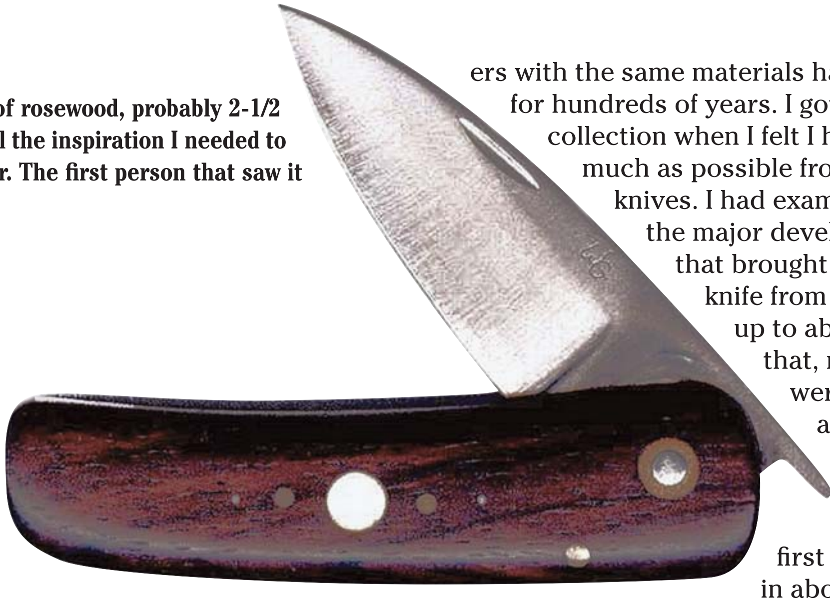
I made my first folder about 1965; it was a big ugly thing that had an awful action. The only thing about it that was remarkable was a miniature bowie knife inlayed in the walnut handle. It was stolen out of my shop along with some other fold-

My thanks to Gene Chapman for this photo. He wrote, "The top knife I made years ago, hand forged blade from a bastard file, turned Osage Orange handle, tin coated steel bolster and a bronze blade pin. Bottom knife a recent internet auction buy, appears old and typical of other penny knives images seen on the internet. I added two old large cents, 1817 and 1827 dates."

I had decided to specialize in folders in 1973. This group shot was my inventory for The Knifemaker's Guild Show in 1977. Look close so you can see the miniature folder with stag handles. It is resting on the folder with the duplex bolsters. Also, note the first crown folder I made, as you will read about it in the text.

ers from my collection. In 1966 I sawed a deer antler crown in half and was trying to figure out how to make it into a folder. I was stumped and the parts sat around until 1977. I had made over 200 folders by then and was able to finish up what may have been the first crown folder in modern times. I'm currently working on #661.

It was around 1969 when I started a collection named "The Evolution of the Folding Knife." I didn't know much when I started except that primitive and old folding knives were very interesting to me. My chronology of evolution was arbitrarily decided upon by the complexity of the action and construction. Primitive folders are difficult to date because some places in the world the same style fold-



There was this little piece of rosewood, probably 2-1/2 inches long, and that was all the inspiration I needed to make my first friction folder. The first person that saw it added it to his collection.

ers with the same materials have been made for hundreds of years. I got tired of the collection when I felt I had learned as much as possible from studying the knives. I had examples of most of the major development steps that brought the folding knife from the most basic up to about 1840. After that, most folders were factory made and I didn't have much to learn from them.

I made my first friction folder in about 1981. I suppose I got the idea from the primitive friction folders in my evolution collection. Folding knives without springs have been around for a long time. There is an often-told story about one of the artifacts discovered under a stone wall that was torn down in England. The remains of a folding knife were found in what was supposedly a Roman campsite. The crude drawing I've seen of it makes it look like it did not have a spring.

The old friction folders I've studied are of three general types. Most of these have a handle made of one piece of wood, antler or horn that has been slotted for the blade. I've classified them as follows.

Type 1. Two-pin, pin-Stop. There is one pin for the blade pivot, the other pin serves as a blade stop in the open (and sometimes closed position). This is the simplest of all folding knives, one handle piece, one blade and two pins. The ancient craftsman who invented the folding knife probably only used one pin for the pivot with nothing to stop the blade but the handle material. A change was needed when the handle material split from the pressure exerted by the tang when the knife was in use. The first evolutionary step would have been to build the next model with a second pin to stop the blade.

Type 2. Tang Extension Stop: One-, two- or three-pin construction.

Type 3. Ferrule-Stop: The blade pivot area is round in cross section with a sheet metal band around it. In the open position the blade stops on the edge of the ferrule. Some have the metal that makes the ferrule bent in making a bearing surface for the blade. Gene Chapman's booklet "Penny Knife" shows how to make this style of knife complete with details for fabricating the ferrule that makes a bearing surface for the tang.

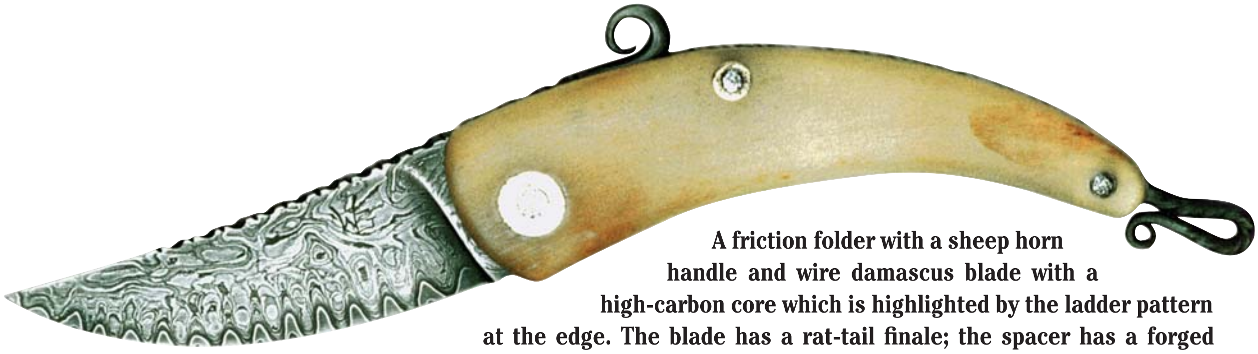
I find it difficult and time-consuming to slot antler and horn so I usually split it and make a spacer of steel. This gives me more area to do file work or engrave and it also gives me the option to forge a thong holder on the end of the spacer.

How to make a friction folder

You may not want to make a friction folder but the lessons learned will help you along. Consider it Grade School in the Folding Knife Curriculum.

Materials needed

1. Handle material: An antler tip or chunk of wood four inches long will contain a 3-1/2-inch blade. An antler tip handle piece should be symmetrical in cross-section and straight in the plane that the blade will set. It's really difficult to order stag through the mail and get ones that will work. All my particularly beautiful and well-matched tip handles were hand-picked from suppliers at knife shows or saved from



A friction folder with a sheep horn handle and wire damascus blade with a high-carbon core which is highlighted by the ladder pattern at the edge. The blade has a rat-tail finale; the spacer has a forged thong holder. The forged details are the "frosting on the cake."

elk antlers that I cut up for handles. Because of curves in both directions, not all elk antlers will have usable tips for anything other than very small folders.

2. Blade and spacer material: Saw steel or O-1 precision-ground flat stock, 1/8 of an inch thick, 3/4 of an inch or more wide for the blade and another that is 1/4 of an inch wide for the spacer type. The critical thing is that the material is flat and parallel. Folding knives of any type will have a smoother action when the blade material is absolutely parallel in the pivot area. Precision-ground flat stock (O-1) may appear expensive but by the time you finish the project you will have saved more than enough time to count it money well spent.

3. Pin stock, 3/32 of an inch and 1/8 of an inch. Welding wire, brazing rod, nails, an old-style metal clothes hanger or whatever you have or can find, just make sure you have a drill bit the size for your pin stock.

The design

You will have to figure out the pivot point for a specific handle width only one time. Keep a pattern of it and the next time you will have the action figured out beforehand. I have something more than 120 patterns for folders I have made since 1972. What that means is I have a pattern for the action for just about any size of design that comes along.

The best way to design a folding knife of any type is to first decide on the blade size and shape, and then work out the handle to contain the blade. The exception is when a crown stag or antler tip is used, then the handle shape and size becomes the starting point. Most friction folders are slotted for the blade. I like the style with a spacer because it gives me freedom for forged details at the end, and also space to do file work or engraving on both the inner and outer surfaces of the spacer. I also find it less time-consuming. I can make several spacers in the time it takes to slot a handle by hand.

What follows is the step-by-step sequence for designing and making a spacer-style friction folder from an antler tip. If an antler tip is not available, use wood or Micarta; shape it as you want and jump ahead to Step 4.

Step 1: Cut the antler tip to length and split it down the middle.

Step 2: Grind the inside surfaces flat and make both sides the same thickness.

Step 3: The two sides are usually not symmetrical in cross section to each other. Some material may need to be removed from the outline of one of the handle pieces in order to keep both pieces the same profile.

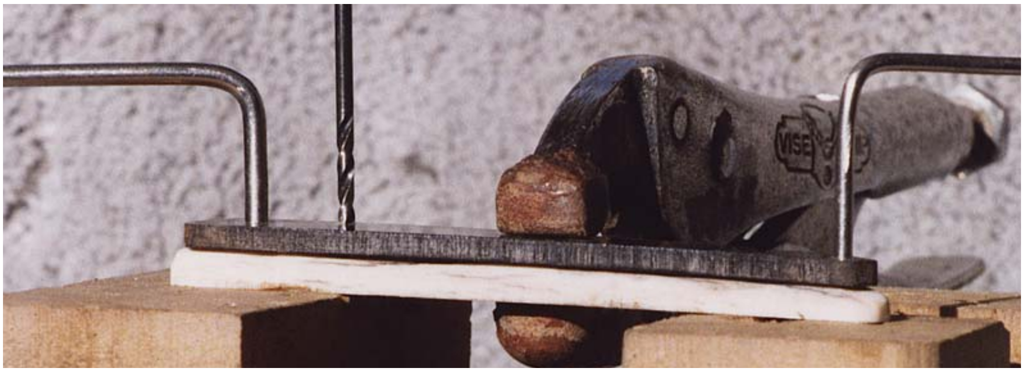
Step 4: Designing the action, I call it the "action" because it is the mechanical part of a folding knife. It always starts with the pivot point and the top and bottom edges of the blade. Trace the profile of the handle piece onto cardboard.

Step 5: Cut another piece of cardboard that is large enough to make the blade pattern.

Step 6: Locate the centerline of the handle pattern, and mark where it is an equal distance from the end and both the top and bottom.

Step 7: Align the cardboard blade piece with the handle and push a map tack

At the left is the drill press jig for drilling upside-down. On the right is the jig used for every day drilling.



The modified locking pliers are the best way to clamp the partially round antler handle slabs to the plastic pattern.

through the handle pattern into it. This creates the pivot pin location.

Step 8: Swing the blade pattern piece (B) through an arc that will show the open and closed positions, and mark it as to length and width to fit in the handle pattern (A). Finish the blade pattern by refining the outline of the blade. Some adjustment of the pivot-hole location of blade and handle may be needed to position the blade properly in both the open and closed positions. I do not have a formula to give you. I find it by trial and error on the first pattern in a certain width handle. (See the drawing showing the pattern pieces. Note that it took me two tries to get the proper pivot location.)

Step 9: This project is a spacer-type friction folder, so the location for the stop pin is worked out at this time. This point is not negotiable but is determined by the three points designated 2a, 2b, and 2c on the pattern design illustration. The location may not make sense until the blade pattern is rotated on the handle pattern.

Step 10: The spacer-style handle will require three holes in each side. The holes for the spacer are 3/32 of an inch; the blade pivot pin is 1/8 of an inch. For pin material on this type of folder I use mild-steel welding wire. I can then use cold blue solution to color the heads of the pins for an antique look.

Step 11: With the cardboard pattern pieces for both handle and blade working properly, it is time to drill the holes in either pattern piece of the actual knife parts. Masonite®, plastic, aluminum or steel will all work to keep a master pattern. The handle holes that go through the spacer can be a little oversize and it will not matter much, but the hole in the blade must fit the pin precisely. Even a properly sharpened drill bit may drill an oversize hole. Here is how I do it. Drill a hole that is smaller than the finished size, and then open it up with a drill bit of the size you want. The finished hole will be very close to the correct size. As an example, first drill with a 3/32-inch bit to finish and with a 1/8-inch bit for the pivot holes.

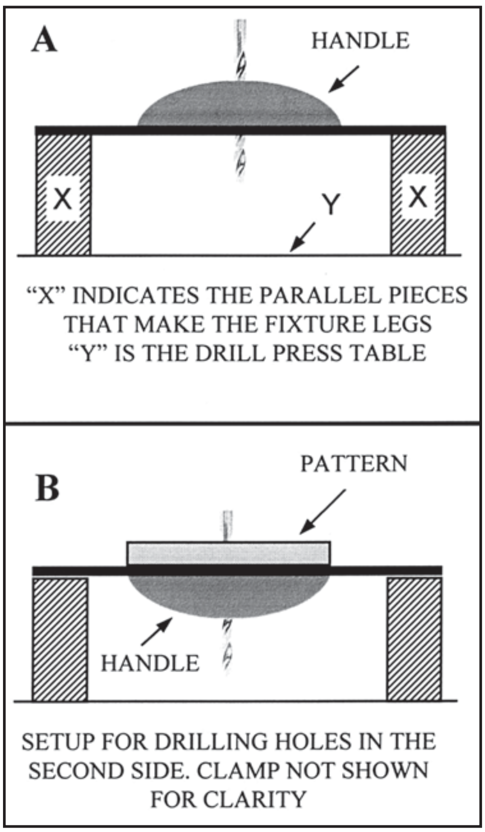
Pattern parts & location points

See the drawing mentioned above. “A” is the cardboard pattern traced from the pre-shaped handle. “B” is the oversize cardboard piece used to design the blade. Note the pencil marks that show the outer limits of the blade shape. “C” and “D” are the finished pattern pieces. Note that there are two sets of holes at position “1.” This is from the trial-and-error method of determining the correct location of the blade in the handle. The position marked by the “2” on the end of the tang is where it stops at point “2” up against the spacer in the handle when the blade is in the open position. Point “2” on the bottom of the tang stops against the spacer and keeps the edge portion of the blade from bottoming out when the blade is closed. The spacer-type handle is held together by two through pins indicated by “3”; “4” indicates the position and shape of the spacer. Now is the time to transfer that pattern to the materials used to make the knife.

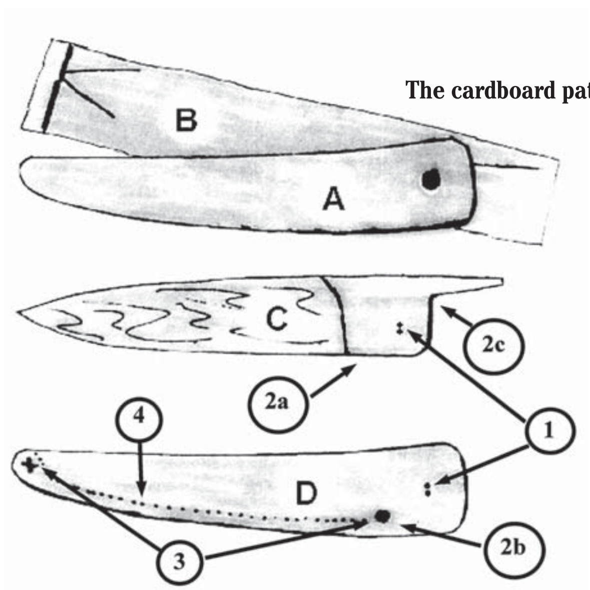
Drilling the handle material

1. Trace the pattern onto the handle material with a sharp pencil. Do not use anything other than a lead pencil when working with any natural handle material, especially stag or ivory. Stag and ivory are porous and the ink can go deep into the surface. One dot from a felt-tip marker may ruin a good handle slab. Saw, grind or file to the rough shape. At this stage I usually take the shape to the outside of the line. The excess material will be removed when the parts are stacked together.

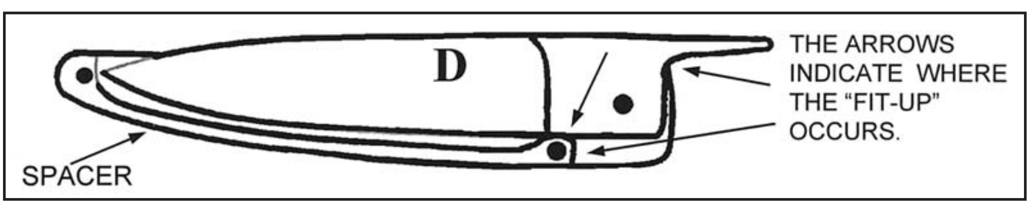
2. The steel for the spacer and blade can be coated with layout dye (available from knifemaker and industrial supply companies), or use a red or black marking pen. Be sure to keep the layout dye or marking-pen ink away from your handle material. Clamp the pattern piece securely onto the material and carefully trace around it with a sharp scribe. Sharpening the end of a worn-out triangular or round file will make a quick



The first side is the drill guide to drill the second side.

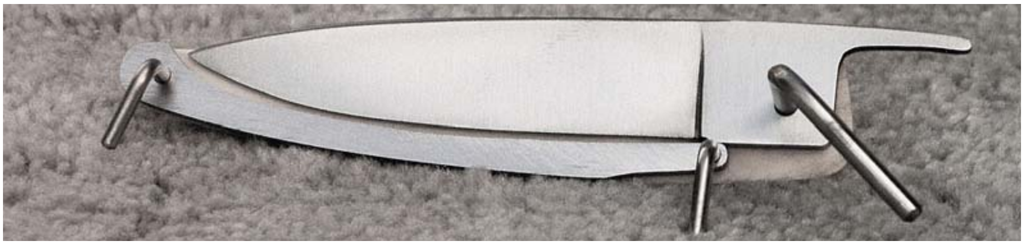


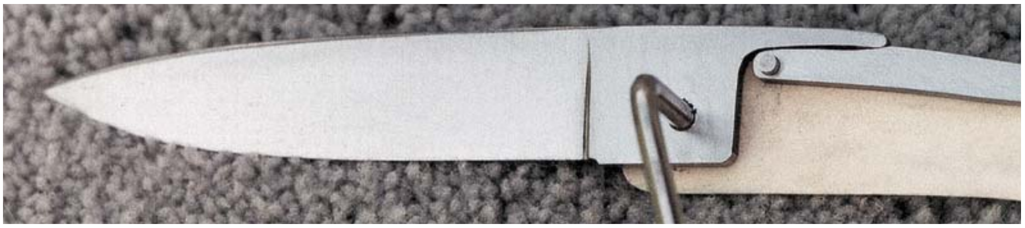
The cardboard pattern pieces.



This drawing shows the shape of the spacer.

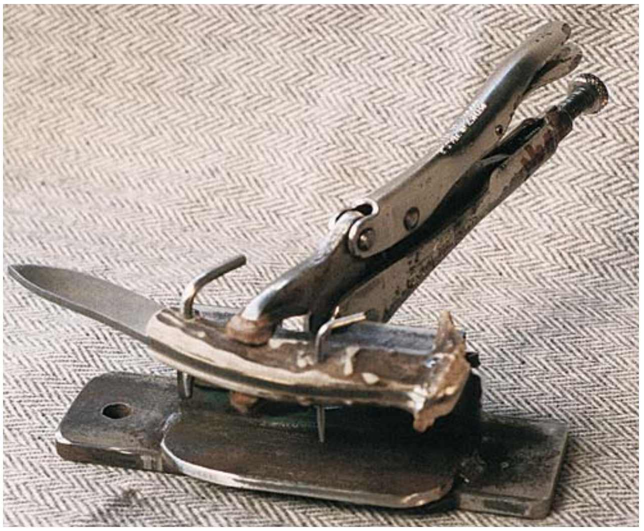
Top: The final fit when closed.
Bottom: The open position.





This is the hand-turned countersinking tool.

The pin holding jig in use.



A crown folder in the jig ready for grinding.

The finished project.

scribe. Needles for the old-fashioned wind-up record players are still available. The steel they are made of is very hard and, when super-glued into the end of a piece of wood or antler, they make a nice scribe for marking steel.

3. With the outline of the handle material shaped, it is time to drill the three holes in each handle side. (See drawings and photo of the drill jig that makes it easier to drill the rounded stag slabs.)

The jig allows the slab to be drilled upside down with the flat side kept parallel with the steel plate. If the handle slabs were parallel, they could be placed on the table of the drill press and that would make the jig unnecessary. The cross section of stag slabs of the type used for friction folders are often more half round than rectangular. The first side is easy to drill because the flat side is down.

To use the pattern for a guide to drill the second side, the pattern is placed on the top of the plate with the slab to be drilled on the under side. The alignment of the first hole is by eye and the two are then clamped in position on the jig. The plate will have some oversize holes drilled in it for clearance on the drill bit. This is the best way I have found to get the holes in both halves at 90 degrees to the inside of the knife.

An alternate method is to use a flat piece of steel placed on two parallel pieces of material. A drill-press vise will work if the jaws are parallel with the base and are also deep enough to get the clamp in while clamped to the handle slab. Note the modified clamping-type pliers in the photo. It provides a perfect clamp for holding half-round materials. Also note the trial pin in place so that one half of the folder can be used as a jig to drill the other half. This is how I do it with one-of-a-kind folders where a pattern is not being saved for future use; these are usually the type made with an antler crown for the handle.

4. Clamp the handle pattern onto the blade blank and drill the 1/8-inch pivot hole as indicated by the No. 1 in drawing “C.”

5. Clamp the handle pattern on the spacer material and drill the 3/32-inch holes indicated by “2” and “3.”

6. Grind the blade and spacer to the rough shape. When the blade profile is ground, take care to not grind beyond the drilled hole and stay outside the scribed line in the area of fit-up. (See arrows on drawing “D” on page 151.)

7. Assemble the back-side handle slab with the spacer and blade in position with trial pins as shown in drawing “D.” Rotate the blade between the open and closed positions and work down the material for the final “fit-up.”

8. Work slow and easy to get the blade to sit correctly in the open and closed positions.

9. Once you are satisfied with the fit-up, it is time to grind the bevels on the blade.

10. Heat-treat and finish the blade and make the final fit and finish. The spacer for this type folder can be left in the soft condition.

11. The two handle pieces are assembled with trial pins and shaped on the “round”. (That means rounding off the rectangular edges.) The inside surfaces are also finished and relief is given to the area where the tang will rub.

The relief is necessary so that the tang does not show rub marks when in the open position. I mark the arc with a divider, then remove the material with files, scrapers and sandpaper. The handle sides are 90 percent finished before assembly.

Final assembly starts with setting the pins that hold the handle together. This is the last chance to check the fit-up on the action. (See photos.)

12. Riveting the friction folder together should be done only after some “pin-setting practice” on scrap materials. The rivet is simply a pin that has been “headed” on both sides. I form the recess for the head by hand turning a countersink made from a conical-shaped mounted point. Any kind of power or speed on the countersink and the results will often be more than is needed. I do not have a formula for how large the countersink should be made. Start with a recess that is approximately 20 percent larger than the pin size.

See the photo for a simple angle-iron jig that will grip the pins tightly without smashing them. The jig is made by placing the angle iron pieces in a vise with a thin piece of cardboard between them. Holes are drilled down the center, one for each size of the pin stock to be held. With the cardboard removed, jig in the vise jaws; a tight grip is applied to the pin stock.

The first practice exercise is to form a head on a piece of the pin material you will be using. Make a series of light hammer blows around the edge of the pin. The hammer should have a slightly rounded face. Note the shape of the hammer face in the photo of the pin stock in the jig. As you pein the head, observe the action of the hammer on the pin. Note the high spot formed in the center of the pin and work it off with a file. Make another round of light hammer blows on the end of the pin. With careful and even blows, a perfect head can be made. Next, practice on making a head on the pin stock while it is in a piece of wood or scrap stag. The trick is to make the head big enough so that it will not pull out but not so big that it splits the handle material. It's your choice to make a flush-headed pin or one with a dome sticking up above the surface.

I use a jig to grind the back of the folder square with the spacer or spring. See the photo of the jig with a small crown folder in grinding position on page 152.

Final assembly starts by riveting the two handle halves and spacer together. A little peening is done on one side of the pin then a little on the other end and then back to the front. It's better to start with a little more pin stock than needed because it can always be filed off. Once that is done, a final cleanup is done around the edges of the handle. Wipe out the inside of the handle to get rid of dust and grit and then it is time to rivet the blade in position. Take care to not get the pivot pin too tight. A piece of .002 shim stock with a notch in it can be inserted between the blade and handle piece. As the peining progresses, the shim is checked from time to time to see when the handles start to grip it. Don't set the pivot pin so tight that you can't get the shim out. I only did that one time.

Don't set the pivot pin so tight that you can't get the shim out. I only did that one time.


The Really Big One, eight feet four inches long, steel fittings, oak handle.

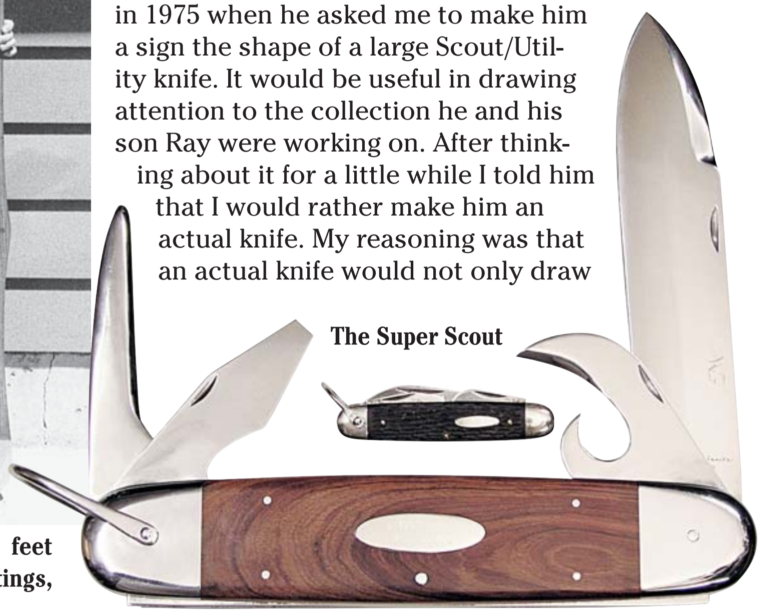
I use all hand work to finish the outside surfaces of a folder. Sandpaper backed up with a firm surface will work the heads of the pins down. Finish with fine-grit paper and 0000 steel wool.

Sharpen the knife and you are almost ready to put it in your pocket. Because there is no spring to hold the blade shut, I recommend that friction folders intended for use as pocketknives should be carried in a leather pouch.

To make the antler handled folder stronger it is good to use birds-eye washers for the pivot pin holes.

Making the big ones

I'm going to blame it on Dennis Ellingsen. It was in 1975 when he asked me to make him a sign the shape of a large Scout/Utility knife. It would be useful in drawing attention to the collection he and his son Ray were working on. After thinking about it for a little while I told him that I would rather make him an actual knife. My reasoning was that an actual knife would not only draw


The Super Scout

Doctor's Knife, 12 inch handle, brass fittings, maple handle slabs. This style folder goes back at least to Civil War days. The flat end of the handle was used to crush tablets, and some doctor's knives have spatulas as a second blade. It was used for mixing ointments.

attention to it but would be a good investment. The knife I made was three times the scale of a normal sized knife and came out at around four and a half pounds. Its name is Super Scout and he wears the name proudly on the shield.

The next big one was made with the intention of getting it in the Guinness Record book. It was a single blade folder that was eight feet four inches long when opened. I got the idea for it while wondering if any of my knives would survive a thousand years or more. I cooked up a mental picture of a giant folding knife leaning in a corner of the basement of a museum somewhere. When it was finished the weight was 128 pounds. I made it for a local collector, and after a few years he sold it to a cutlery shop in Hollywood California where it was displayed in the window. A collector friend would go to see it every so often and he kept me informed. Then, one day it was gone; he was told that it was sold and taken to England. I wonder if it is in the basement of a museum.

When asked how I did it I would say, "Like the body-fender repair guy, he holds the grinder up to the car, not the other way.

The liners were thick bandsaw steel, bolsters 3/4-inch thick mild steel that was arc welded to the liners. Parts were ground to shape on a 12-inch, hard wheel grinder I had built previously. Our 16-year-old son Steve had great fun holding up the back end while I controlled the front.

I put together a quickie work table with the heavy duty brackets to hold it with the edges up. The bench was necessary to have a work space large enough for the parts. I used a nine-inch industrial strength disc grinder for all the work on it. I made fine finish and polishing pads for disc grinder.

Our county fair had a good art/hobby department and I had won several ribbons for knives. Steve and I carried it in on our shoulders. Yes, we got strange looks. The nice lady in charge was stumped as to what class to put it in. She settled on Metal Sculpture because nothing else was entered at that time. I won the blue ribbon.

I made two other big ones. In 1978 I made another scout knife that was four times the scale, it weighed about nine pounds. I also made a physicians knife that was intended to draw folks to the collection, it was four times the size of the one I made the pattern from.

A challenging friction folder

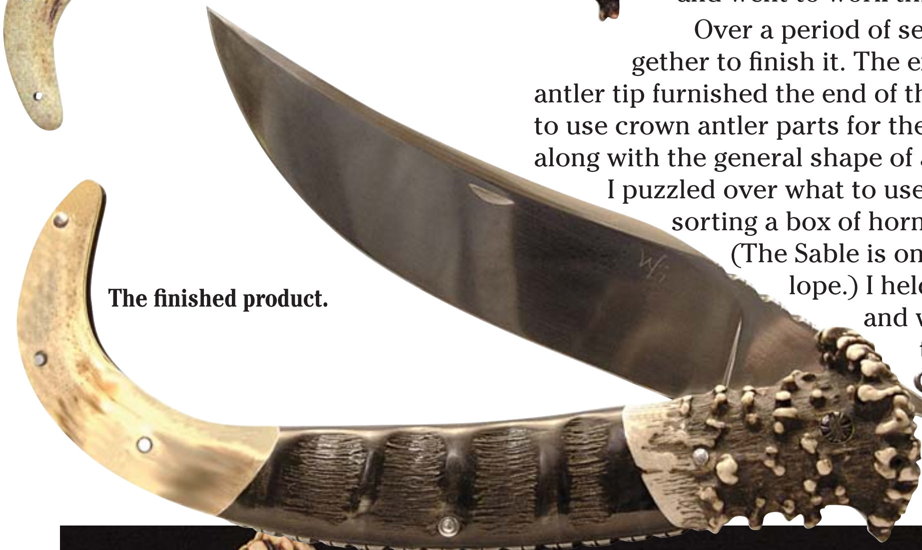
It all started one day when I was trying to get the slight warp out of a 15-inch bowie knife blade. I was using the three point set-up in a vise, the blade was at the tempering temperature and yet it broke instead of getting straightened. I was shocked

The two sides for the big friction folder. The crowns are from different animals in order to get some that matched.

beyond belief, this doesn't happen with 5160…and there is that moment that the answer comes. This wasn't a 5160 blade it was 52100. That blade should have been tempered at a higher temperature. It was one week before the Oregon Knife Show and I wanted this bowie to enter in the knifemaker's competition. I went to work and made another blade of 5160. I was able to get the bowie finished and won best forged and best of show with it.

I'm not one to let good steel go to waste so I correctly tempered the end piece of the broken bowie blade. I could see it as a friction folder blade so I forged a rat tail on it and went to work thinking about a handle.

Over a period of several years I got the materials together to finish it. The extreme curve in a non-typical elk antler tip furnished the end of the handle. I thought it would be unique to use crown antler parts for the blade end so I got them worked out along with the general shape of a handle. For the longest part of a year I puzzled over what to use for the center panels. One day I was sorting a box of horn and I found two pieces of Sable horn. (The Sable is one of the largest of the African antelope.) I held them up against the rough pattern and was visualizing them nestled between the elk antler and deer crowns. It worked out very satisfactorily, I've tried to imagine some other material to go with those antler parts but it just won't work.



The finished product.

My first crown folder.

It isn't for fishing, it looks like a fish.

"Uncle Grizzly" with the kids. The distinctly different wood bolsters is the unique feature of a Goddard crown folder.

Crown folders

I was fascinated enough with deer antler crowns that early on in my career I sawed one in half with the idea of making a folding knife out of it. The year was 1965 and I truly was underestimating my skill to attempt folding knives. I had no belt sander, I drilled holes in my fixed blades with an electric drill. My grinder was made out of a washing machine motor. I had a folding knife record book started and #4 was the unfinished crown parts, but the story has a happy ending. By 1977 I had made over 300 folders and knew enough to finish it up. It's in the show group shot at the head of this chapter, and was the first knife I sold at the show.

Somewhere along the way #4 got an engraving job and my knifemaker friend Barry Gallagher ended up with it. His expert photography skills did a fantastic job of showing all the details. And, I got to visit it during the time Barry owned it.

The "Fish" crown folder needed an antler that was straight enough to have a blade inserted. The antler came from England, and I'm not sure what kind of deer shed it. It was a challenge to get the slot for the blade, that's part of what I'm about.

A mule deer antler came along with the largest straight section I had seen. It was the end of a lifetime search and I worked it into a folder that got the name of "Uncle Grizzly."

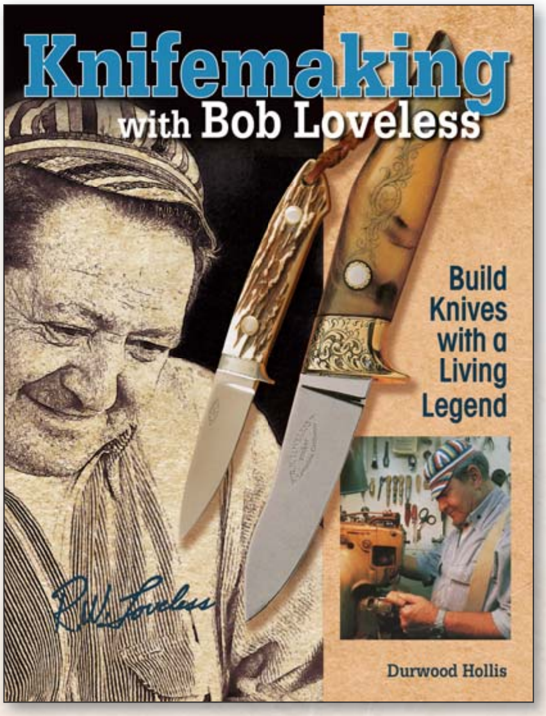
The miniature crown folder, one-inch handle size.

A collector of miniature knives wanted a crown folder with a one-inch handle. I carved the crown out of a piece of elk antler. The display base was made out of a deer crown.

The folding knife as art

I have tried to define an art knife in the past and it isn't easy. I recently settled on the art knife as being any knife purchased for its beauty, uniqueness, collector value or whatever other reason that has nothing to do with using a knife. Much of the handmade knife world is becoming a thing where the craftspeople are artists first and knifemakers second.

This beautiful folder from Barry Gallagher is sure beautiful. It has everything, mosaic damascus, carved ivory handle, filework everywhere. Pure art, I'm sure of it. *Photo courtesy of Barry Gallagher*



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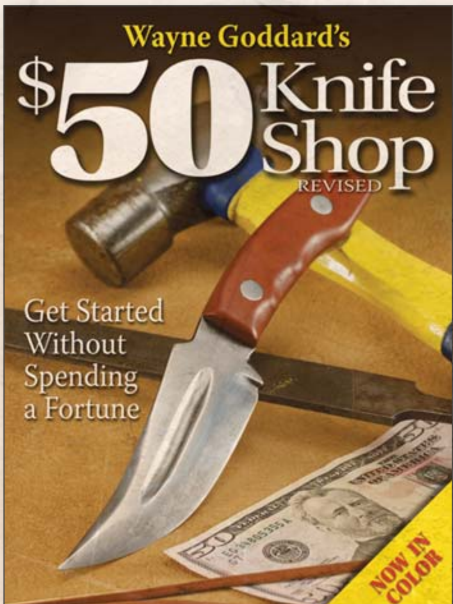

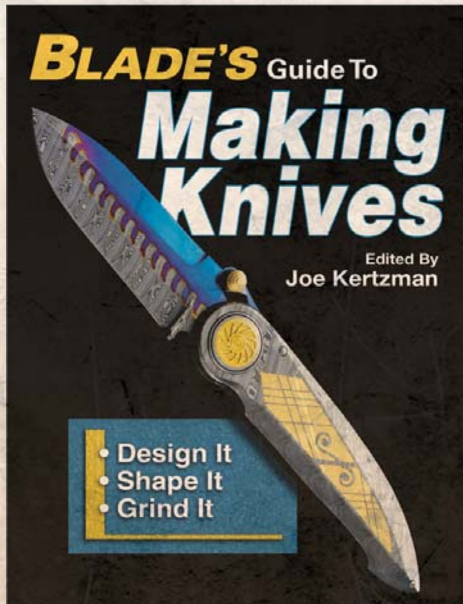

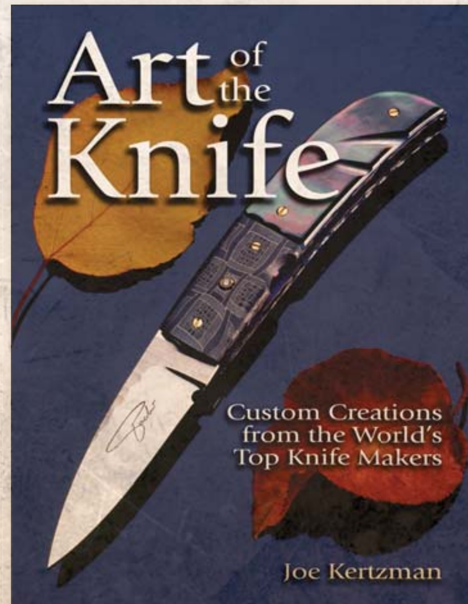

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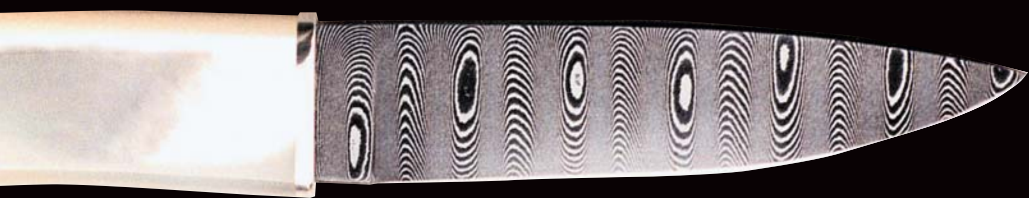

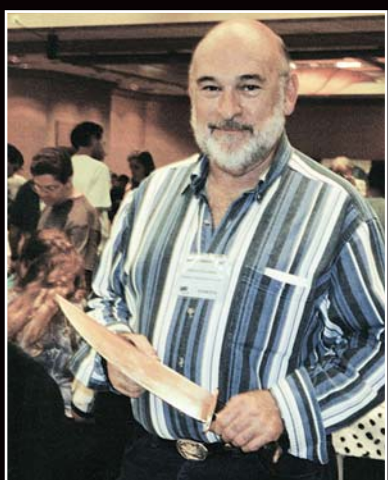

About the Author

Master smith Wayne Goddard is an icon in the field of knifemaking. As a full-time maker, teacher and writer, Goddard works as hard to teach knifemaking skills as he does to acquire them. His affiliation with *BLADE Magazine* has brought new and interesting information, tips and tricks to thousands of would-be knifemakers.

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