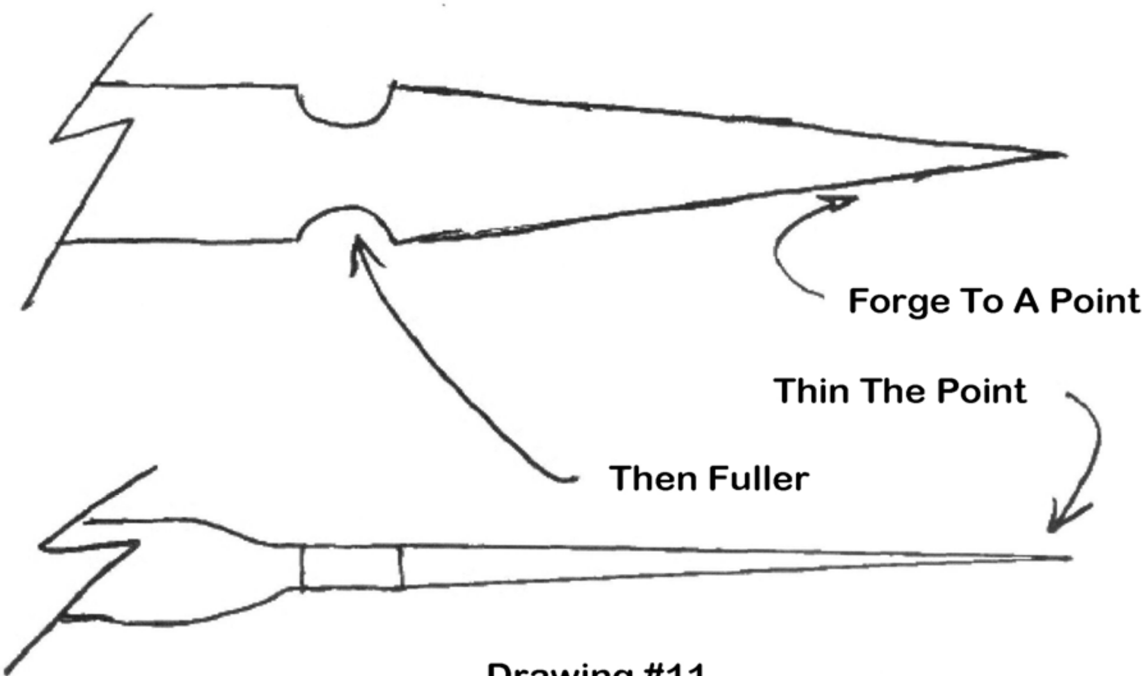
use a 1/4 inch diameter round rod and hammer it down into the edge of the bar (or file) at the base of the blade, flip the blade over and do the same on the other side. Make sure you leave about 3/4 inch width at the start of the tang for the Dirk, it is a long blade and tang and therefore requires a strong tang to be able to withstand the magnified forces resulting from that length.



Drawing #11

That is all you need to fuller for a dirk.

Cut off for the tang about 1-1/2" down from the fuller (or at least make the cut far enough down to allow a good strong, long tapered tang to be forged - again, it is easier to take material off later than to put it back). This is the material you will need to draw out the tang.

Now let us review. You should point and thin the blade BEFORE you fuller for the tang. This is so that you will not have a thinned (can you say weaker?) area on you blade while you are forging on it. Have you ever forged a leaf after necking it down to separate the material to make the wide leaf area, and then have it break off while you were forging on it? I have and it is infuriating. Well if you do the thinning first, you are inviting disaster. So, forge the blade first and then fuller for the tang, draw the tang and clean it all up - do it in that order and you will have a much greater success rate and a much stronger tang, too. Jim went over some of the finer aspects of the art (or science?) of metallurgy for the class. I will try to cover the basics here. We were using 1095 steel on our blades, the same material used to make modern files. 1095 steel is mostly iron with 0.95% (95 points) carbon content.

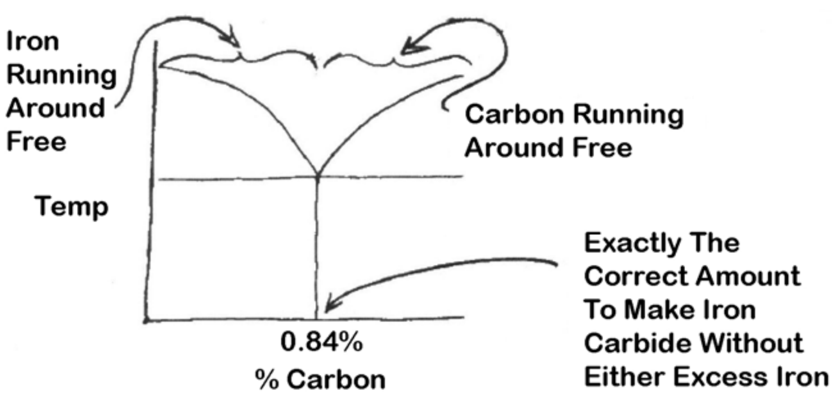
Jim reported that dirks of old had been made of steels in the ranges for 1070 to 1040. In other words, they had a carbon content of 0.7% (70 points) down to 0.4% (40 points).

Then Jim got to the good stuff. These steels are known as water hardening steels. Other water hardening steels available to modern blacksmiths are WI and W2, 1084 and 1084 with Manganese. He used the words "cherish them" when talking about the modern steels.

Being a little more specific - W 1 is 1% (100 points) carbon, otherwise it is the same as 1095 steel. W2 is basically the same as W 1 except it has some Vanadium content which is a grain refiner. A small grain structure is very desirable in blades as it makes them have greater toughness and less brittleness tendencies.

Jim seemed to have a great appreciation for 1084 steel. He said "it is the best of the 10 series steels, they just quit making it." There is still some of it out there but the supplies are drying up. He justified his assertion that this is the best steel by informing us that 0.84% (84 points) carbon in iron is the exact amount to fill the crystalline structure carbon occupies in steel without have a surplus or a shortage of carbon in the matrix. This results in the best metallurgical mix for hardening and tempering.

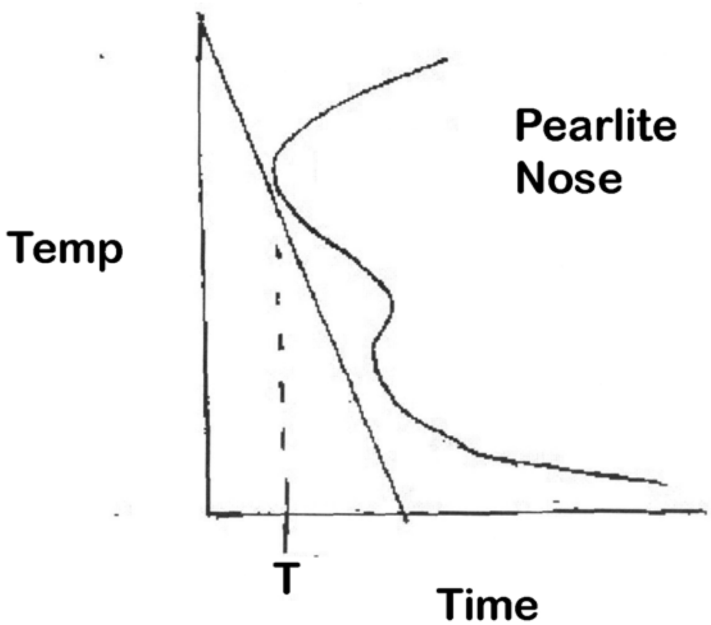
Lastly Jim stated that 1084 with Manganese was "the best steel there is, and here is why." He then started drawing a equilibrium phase diagram for iron and carbon (see the diagram below). For those of you who know what an equilibrium phase diagram is, this will be easy, for those that do not, I will TRY to explain as best I can. **REFER TO THE DIAGRAM BELOW - drawing #12.** In the case of this diagram, the term "phase" signifies where the solution is a solid or a liquid. Basically the diagram represents a graph of temperature versus carbon concentration in iron. View the carbon concentration in iron as if you had a solution of carbon in iron. There is a point where the graph has three regions that meet at one point. The region above the curves signifies the temperatures above which the solution is a liquid (molten) at varying concentrations of carbon in the liquid phase. The inclined curves represent the temperature at which the solution will melt at a given carbon concentration. If you view the solid steel cubic matrix as having a certain number of "holes" available for carbon to fill, the two regions on either side of the bottom of the curves represent the solid form of the solution with varying amounts of carbon in the solution. The region to the left of the vertical boundary between the two lower regions represents the solid solution with less than enough carbon to fill all the "holes" in the solid matrix, and the region to the right represents the solid solution with more carbon than is necessary to fill all the "holes" in the solid-matrix. The vertical line between the two lower (solid) regions is the concentration of carbon in the solid solution that has exactly enough carbon to fill the "holes" in the solid solution matrix. The condition where you have exactly the concentration of carbon to fill all the holes" without having an excess of carbon in the matrix is called the equilibrium concentration, in this case. Guess what that concentration is? It is 0.84% (84 points) carbon. Thus the reason 1084 steel is the perfect steel for making blades. Manganese makes the 1084 even better, since as mentioned above, it makes the grain structure in the finished piece finer and therefore better for use in blades.



Drawing #12

For reference, critical temperature is reached in steel when the molecules are heated to a point that they are vibrating (on a molecular level) so violently that they no longer line up with each other and therefore have no polarity. This means that a magnet will not stick to the iron after it is brought above the critical temperature. In steel, this temperature is about 1650 degrees F - approximately a cherry red. That is why so many old recipes for hardening and tempering tell you to bring the piece up to a cherry red before quenching.

Next, Jim drew another drawing on the chalkboard. The curve was a time-temperature transformation curve, and looked like Jimmy Durante's nose and upper lip in profile (looking left). See the diagram below - Drawing # 13. The vertical axis on the graph represents temperature and the bottom axis represents time, and thus the name. The transformation part of the curve's name comes from the curve representing the time and temperature relationships for various forms of steel to form. If the steel is cooled slowly it allows the formation of pearlite, which is soft, if it is cooled quickly pearlite is not allowed to form and the steel gets very hard and brittle. The nose part of the curve is called the "pearlite nose" and tells you how fast you must cool the steel to make it harden well. Here is where it gets interesting. The temperature for the pearlite nose for most steels (if my memory serves me) is about 900 degrees F. For 01 steel (oil hardening) the time to the pearlite nose temperature is 9.8 seconds. For 1095 steel the time is one second. So what does this mean? Well, if you want to totally harden 1095 steel you must cool from the critical temperature to below the pearlite nose temperature (about 900 degrees F) in less than one second. To totally harden 01 steel you must cool from the critical temperature to below the pearlite nose temperature in less than 9.8 seconds. Now if you look closely at the figure below you may notice that if you start the sudden cooling with the steel temperature higher than is really needed to be at the critical temperature - say another 100 degrees higher - you will actually have a harder time getting below the pearlite nose temperature in the allotted time. This is why it is important to not start the quench at a temperature that is significantly above the critical temperature.



Time T = 9.8 Seconds For O1 Steel
Time T = 1 Second For 1095 Steel

O1 Is Softened By Annealing
1095 Is Softened By Normalizing

Drawing #13

Conversely, to soften steels (say you want to file a blade - do you normalize, or do you NEED to anneal?) the pearlite nose can guide you in that timing as well. For instance if you want to soften 1095 steel, you can accomplish it by taking much longer than one second to pass below the pearlite nose temperature - this can be accomplished by normalizing, but with 01 steel you must anneal it - so that you pass below the pearlite nose temperature over a period of time much longer than 9.8 seconds. Remember this metallurgy as you will need to recall it when I discuss the hardening and tempering of the blade a little later in this article.

For future reference, 5160 steel has a five second pearlite nose. Think about this - Jim told us that because of this intermediate time, you can get edge hardening from air cooling or even in vermiculite. In other words if you are using 5160 for a blade you would need to be careful when annealing or normalizing so as to NOT have a hard edge. You normally anneal or normalize before you file and work on finishing the blade - and you want it soft.

The basic three step method of hardening and tempering a blade is:

First, normalize - bring the blade up to the critical temperature and then air cool (or anneal it if it is steel with a long time to the pearlite nose temperature).

-Note that Jim and Chuck told us to bring the blade up to a blue heat (about 600 degrees F) before heating up to red. This is because of stresses that may have built up inside the metal - by warming up slowly, steel loses one half its strength at 600 degrees and. this means there will be much less of a chance of cracking or breaking if you heat it slowly.

Second, harden - quench the steel in oil. Some steels can be quenched in water, but why take a chance on cracking or breaking a blade you have a lot of work in by quenching too fast? A light oil works just as well without the risk.

Third, draw the temper - after cooling bring the blade back up in temperature slowly to relieve some of the brittleness and impart toughness to the blade. Jim sated that Rockwell C 59 (or 58) is best for BLADES, since if they are any harder you will have to use a diamond sharpener.

I will go through the exact process we used for hardening and annealing these blades in a few paragraphs, but for now we will have a few suggestions on making dirk sheaths.

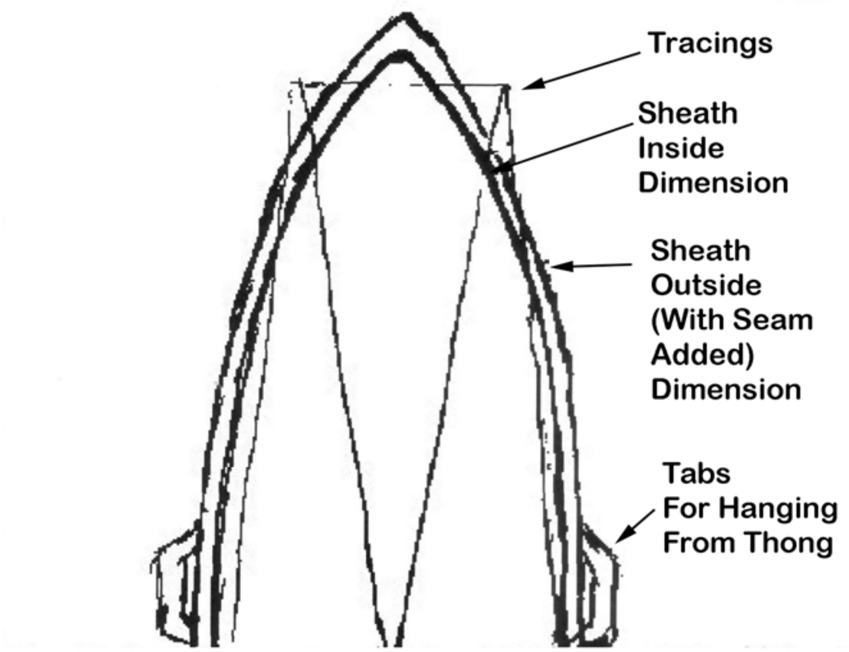
Sheaths:

Make the sheath BEFORE you put the final finish on the blade - the blade will rust since you will be wetting the leather.

First, trace the blade - both sides - mirror images onto a large piece of kraft paper (think brown paper bag) to make a pattern. You will use the pattern to cut the leather to the proper size and shape. Add 3/8th inch all the way around the pattern to allow material enough to sew the seam. Also add a tab on each side of the top of the sheath to allow a loop to be made at the top of the sheath for hanging from a thong, or maybe a belt. Make sure to leave enough extra (but not too much) to allow for the leather to shrink after wetting. See the drawing below for the details on laying out the sheath pattern.

Buy OAK tanned leather for your sheath. It forms well when wetted and tends to hold its' shape well after it dries. Cut out the pattern You may try to test fit the paper pattern to the blade if you like, but realize that the pattern has to account for the thickness of the leather, so the pattern may seem to fit larger than a piece of leather cut the same size.   When forming the sheath, the seam goes in the back. Notice that the tab for the thong loop will also be in the back, in line with the seam.

Hardware can be added for a fancy sheath, and Jim discussed several possibilities along with methods of fabricating and attaching them. It seems more like jewelry work, but the effect to the overall package can be profound. We did not make sheaths, but did learn quite a bit about their manufacture.



Drawing #14

Now, back to the important topic of hardening and tempering.

The method we used to harden and temper these blades is called differential hardening, and here is how we accomplished it. Keep in mind that by the time you are ready to heat treat the blade should be at least 95% completed and FINISHED. The only finishing needed after the hardening and tempering process will be the final polish and then the hafting.

Basically, the differential hardening process involves hardening the tip and edge of the blade by quenching only those parts in oil, and then tempering (relieving the hardness) the entire blade using a torch. At his point I must mention that I assume that the blade was normalized or annealed to enable finishing work to be completed. It is important to normalize or anneal before performing the quench step.

To perform the quench in oil - prepare a pan of oil long enough to allow the entire blade and tang to be put into it. Make sure you have a long enough pan, and then put a "crutch" on the bottom of the pan of oil so that only about 1/2" of the blade edge will sit in the oil. The "crutch" is something that will sit in the bottom of the pan and the blade will rest on it as it is being quenched, and will hold the blade at the correct depth in the oil. Remember you are only quenching the edge (and the tip, of course), not the entire width of the blade. When your oil quench tank is set up the blade will need to be heated to the critical temperature before being quenched. It is IMPORTANT to heat evenly on both sides of the blade to prevent it from warping. It is also important to not bang it against anything, including the coke in the fire or the forge itself, for the same reason - these are long, thin blades and will bend very easily while hot. Use extra care to handle gently and you will not have to repeat this process because of a bent blade.

As stated earlier, another precaution that Jim and Chuck practice is that they heat the blade to a blue heat before bringing it up to a red heat. The reasoning is stated a few paragraphs above. While heating do not heat the tip until you are ready to go to the quench tank, this will help avoid burning the tip of the blade accidentally.

When the entire blade has been brought up to the critical temperature including the tip, pull the blade from the fire, and if it is above the critical temperature you will see "shadows" dancing in the color of the blade. This is actually the metal molecular structure changing from one type of cubic structure to another. Wait until the shadows disappear (do not let the blade cool off much). To me the "shadows" look like the Northern Lights dancing in the metal. When the "shadows" disappear it means that the metall at the same cubic structure, and if the blade was a little above the critical temperature when you brought it out of the fire, you wait until all parts are right AT the critical temperature and then you QUENCH.

To perform this particular quench, the tip should be quenched first for a count of three, then place the edge of the blade on the crutch and hold there on the crutch until the back of the blade goes black in color. At this point you have hardened the edge and tip of the blade. Immediately after the back of the blade turns dark put the entire blade into the oil and watch the bubbles rise from the hot blade to the surface of the oil. This shows that there was still a lot of heat in the back of the blade, and as a result it will be much softer than the edge.

After the quenching in oil is complete - stick the entire blade into Vermiculite to cool slowly. An interesting note is that Chuck had us stick the blade into the vermiculite vertically. I think that this not only allowed a lot of blades to be put into the vermiculite at one time, but also minimized the stresses and forces imposed on the blade while inserting them.- The "stabbing" motion of inserting the blades did not require any bending or twisting forces in the blade. This is important as there evidently is enough stresses built up during the quenching of steel that there is the possibility of the blade cracking or breaking. If I recall correctly, I think we tested the hardness of our edges before inserting into the vermiculite by running a new, sharp file across the edge to assure that it would bite and not skate on the one hand, but not dig into soft metal on the other - just as a double check. After the blade has cooled to a warm temperature (one you can touch), it is time to temper the blade. This is accomplished by first polishing the blade to a bright finish, and then using a propane torch to heat the BACK of the blade so that a blue oxidizing color moves from the back towards the edge of the blade. Stop tempering in an area then the blue color runs to the edge of the blade.

The blue color signifies a temperature of about 500 degrees, which is exactly the right temperature for tempering 1095 steel. Start at the tang and heat the back of the blade until the blue color moves to the edge of the blade and then progress further down the blade and so forth until the entire blade is tempered. BE CAREFUL near the tip, since it will heat very quickly and get TOO soft if you accidentally heat it to much. I repeat, be careful at the tip so as to not overheat it!

Pay attention to where you point the flame of the torch. If you hole the flame so that you heat the back of the blade but the flame travels forward to the edge, you will heat the edge faster than the back and get the edge too hot before you realize what you have done. This means you will have a soft spot on the edge which is undesirable. Point the flame away from the blade's edge at all times.

After tempering, once you can repeat the process of tempering a second time if you want to assure that the temper is absolutely right. Just polish the blade once again and re-temper as described above.

To get to the final finish, polish one last time or if you prefer, just leave the blade blue.

Chuck Patrick was asked about how the handles were held on in the old days. Chuck explained that a substance called Cutlers Pitch was used to hold handles on, or pewter was poured into the handle with the tang in place to secure the handle.

Chuck then gave a demonstration of pouring pewter to secure a handle. First, buy a NO LEAD, gravity pour pewter. He gets his from Nye in New York City. Pewter melts at about 350 degrees F and this allows a Kraft paper dam to be used to hold the pewter in place. So, place the tang into the handle where it is to be permanently located, and tape a heavy kraft paper dam around the front of the handle ate the same time plug any hole in the back of the handle sot paper dam will not leak out and you are ready to pour. Make sure all the holes are closed as the liquid pewter will surely run out if they are not plugged.

To melt the pewter, first heat the ladle and then put the pewter into ladle and keep heating the ladle until the pewter melts. Slowly pour the pewter into the dam, and when it is full pour any remaining pewter onto a cool metal surface to save for the next pour.

I highly recommend this class for those who are interested in the traditional methods of forging and finishing a Scottish Dirk. I love the history and the methods that our brothers practiced in days of old.

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