Heat Treating of Molding Plane Irons

By Bill Anderson and Peter Ross

Steels have the unique property of being able to be hardened and softened at will, back and forth, without consequence. This property sets steel off from iron and is due to the presence of a small percentage of carbon dissolved into the iron. Other minor components (chromium, manganese, vanadium, etc.) affect the mechanical properties of the steel.

Tool steel of the time before the steel industry developed in the modern manner was generally simply iron and up to about 1% carbon with other impurities. Much of the early steel had less than one percent, perhaps as low as one half percent. Modern steels such as 1095 steel and W1 steel have about 1 percent carbon, and so are an approximation of the older steels in this sense. The W refers to the fact that during the hardening process, this steel is optimally quenched in water. Other common steels are O1 (oil quenching) and A2 (air quenching). Most antique tools steels are probably equivalent to W1. Before steel manufacturing was developed in the modern industrial scale, production of steel was labor and energy intensive and could only be made in limited quantities at a time. It was essentially a cottage industry in Sheffield, England, for example. The steel was known as “cast steel”. Bars were sold to tool makers who forged and shaped this scarce material. Because of the high cost of the material, plane irons were made principally of iron (no carbon) with a small ’lozenge” of cast steel was forge welded to the cutting face of the iron. There were other types of steel (blister and sheer steels, for example) that were is use as well.

Steel in its softest state is said to be “mild”. In this state, the metal is easily worked but will not hold a cutting edge. When steel is heated to a critical temperature (more about this later), then quenched appropriately, it is said to be “hardened”. If the steel is allowed to cool slowly (in air or in an insulated medium), it is said to be “normalized”—not quite as soft as mild, but very workable. In the hardened state the metal is very brittle, the cutting edge will fracture, and the metal will be too hard to shape. If the hardened metal is subjected to appropriate lower temperatures, some of this brittleness can be removed and the metal will be able to be shaped and will hold a cutting edge. This is called “tempering”.

Hardening

Often I do the hardening and tempering process at under the guidance and care of Peter Ross, blacksmith. However, when left to my own devices, I sort of wing it.

I do all of these steps in natural light, but not necessarily outside in the bright light, because I want to be able to see color changes easily.

I use MAPP gas fitted with a Bernzomatic TS8000 nozzle. These can be purchased at any big box store. The nozzle allows me to start and stop the flame at will, or to have it operate continuously. The MAPP gas gives a hotter flam than the generic propane gas canisters. I use a face shield for eye protection, leather gloves for my hands, and I hold the iron in a pair of vise-grips. The iron is held just beyond the cone of blue flame at the nozzle.

Thin parts of an iron will heat up more rapidly than thicker parts and will cool off more rapidly as well. This will dramatically affect the hardness or softness achieved during hardening or tempering. In addition, over reheating an edge can actually burn the edge off or drive the carbon out of the steel. For this reason, I generally leave the shaped iron blunt. That is, I leave a square edge on the cutting edge that is about ¼ to 1/3 the thickness of the iron at that point.

Rather than heating the iron directly at the cutting edge, I will heat down low on the flag, near the junction with the tang and allow the heat to migrate up to the cutting edge. Depending on the size of the iron and the conditions, I may have a second MAPP gas torch going and hold the iron between the two to get an even heat.

The critical temperature is the temperature at which steel transforms from one crystalline state to another. This is generally said to be at a "cherry-red" color for the heated iron and that temperature is around 1450 degrees Fahrenheit (look at the chart to compare colors and temperatures). However, the steel loses its magnetic properties at very near this point as well and so this is the indicator that I use. As the color develops, "swipe" the iron against a magnet sitting on a steel plate on the bench. As soon as there is no magnetism, quench the iron. Don't look at the iron and contemplate the color or debate the loss of magnetism. You should swipe across the magnet and go directly into the quench when the time arises, with no hesitation.

I generally quench in peanut oil (I like the smell! Any oil will work), even though some of the irons I am working with are water quench steels. Most of the irons I work with are oil quench steels, and so for convenience sake I use the same quench for all irons. Oil quench is a bit slower than water quench and so the iron does not wind up quite as hard as if it was water quenched. On the other hand, plane irons are so thin that they may cool fast enough in oil, even though they may be water quench steels. However, since I am evaluating the end process (tempering) by the actual performance of the iron (ability to be filed during shaping, holding a cutting edge) it is all relative. When I quench, I dip the iron in halfway up the flag and swirl the iron around in the oil, while dunking the iron up and down. This seems to lessen the temperature shock.

Normalizing

Occasionally an iron that has been hardened or tempered needs to be brought back to a soft state, generally because extensive reshaping is in order. When Peter Ross normalizes, he leaves the hot iron on the forge near the fire so that it cools very slowly. I do not have a forge in my shop, so I will cool in an insulator to slow down the cooling process. I use a 5 gallon bucket of vermiculite. I have a couple of steel bars that I heat red hot, and plunge them into the vermiculite in the center of the bucket, fully covered. When the plane iron is fully heated, I will push this down between the iron bars into the vermiculite, making sure the iron is completely covered and leave it for several hours.

Tempering

I use two methods for tempering: oven and MAPP gas methods.

Fortunately, the range for tempering (300 to 600 degrees Fahrenheit) is also the general range that ovens (even bench top ovens) operate in. I have calibrated both my kitchen oven and benchtop ovens using an accurate thermometer and I keep this information available. (Note: if you use your benchtop oven outside in the winter, etc., this will affect the calibration). I generally start the tempering process at 300 or 325 degrees, and let the iron sit in the pre-heated oven for at least 15 minutes. I pull the iron out, and then let it air cool. I test the iron using a file. If the file catches a grip, but it does not appear to file too easily, then I consider this done. If the file skates across the iron, I will adjust the stove up by 25 degrees and repeat the process until I believe I am successful.

The MAPP gas method is based on more traditional principles. As the iron or steel is heated up, surface oxidation occurs. The metal passes through a series of oxidation states. Each of these states has a different color. It just so happens that the oxidation state colors that we can see with our eyes also correspond to the range where tempering occurs. In a manner of speaking, this range of colors acts like a thermometer. The color tells us what temperature the iron has been raised to but does not tell us the hardness. The hardness at each state depends on how hard the iron was when it was initially hardened, and on the composition of the steel. However, monitoring the changes in color will allow us to follow the tempering process step by step.

To prepare the iron, polish the face of the iron with an emery cloth to brighten the steel. Do not touch this surface from this point on, as this will skew the results. Begin heating the iron near the flag/tang junction and allow the heat to flow up to the cutting edge. This should be done in moderate natural light. As you see the color transitions occur, you may want to hold the iron closer or farther from the flame, or even to turn the flame off and on. The goal is to even out the color transitions at the cutting edge so that the iron is evenly tempered at this point.

At each color change, it is advisable to stop and evaluate the hardness of the tool with a file. The file should just bite into the steel, and not skate across it. If the tool is still too hard, re-polish the face and heat again to the next color transition. This is a trial an error process. Heating to a particular color every time will not work, since it is unlikely that the irons every time you do this process were hardened to the exact same degree

Working with Antique Irons

When I am reshaping antique plane irons, I generally use a grinding wheel stone of some sort, which will allow me to shape the relatively hard (hardened and tempered) plane iron. The grinding process can generate a lot of heat and temperatures can raise enough to take away part of the tempered state of the steel and make the tool too soft to use, so frequent cooling in water is necessary. If the iron does not need to be shaped too dramatically, then filing may be possible, although the likelihood of wearing down the file is high.

If I need to reshape the iron dramatically (changing the profile completely, for example), then it is sometimes useful to soften (normalize) the iron. Essentially I make the iron soft and easy to shape. The iron is heated to its critical temperature (the point where it loses its magnetic property), then either allowed to air cool slowly near the heated forge or is quenched in a bucket of vermiculite (a good insulator). When I am using the vermiculite method, I will heat a couple of lengths of iron and embed then in the bucket. When I quench the plane iron, it is embedded near these irons so that the cooling process will be lengthened and the iron more nearly normalized.

After normalizing, the iron can be shaped with files to a new profile. The reshaped iron will need to be re-hardened, then re-tempered. One caution here—since these irons are forge weldings of iron and steel, it is entirely possible that the iron can fracture at the weld, and also the cutting edge can be burned off. For this reason, I generally use oil to quench the steel (a slightly slower quench) rather than water, and I make sure to leave to cutting edge of the iron somewhat blunt. I finish out the shaping after the tempering process is done.

Only a small part of an antique plane iron is actually steel, the rest of the tool is iron. This is important because iron cannot be hardened and tempered, only steel. Those parts of the tool (the back end of the flag, and the tang) which were heated up and quenched will remain soft and malleable. Modern irons are all steel. They will be brittle and break if the tang for example was heated up and quenched but not tempered afterwards.

Working with Contemporary Irons

I have two sources for irons (other than orphan antique irons). Lie-Nielsen makes tapered plane irons in a variety of widths in both O1 and A2 steel. Their irons are cut by a process (lasers?) that results in a very hard edge all around the iron. This needs to be ground off to get to the normalized metal. The irons are tapered in length and are an excellent choice, notwithstanding the flame hardening.

My principal source for irons (both molding plane and bench plane irons) is Peter Ross (rosspm@msn.com), formerly head blacksmith at Colonial Williamsburg for 30 years or so. Peter's irons are superlative. They are made to order from W1 or O1 steel, flat, tapered in length, look very traditional, and are very price competitive. Generally, I will file and surface the irons a bit, drawfile the tangs, and tap out any irregularities on a small anvil. These irons are supplied in a normalized state, thus easily shaped from the get go.

Below is a color chart for hardening and for tempering compiled from several sources. Every source seems to have a different set of color names and temperature transitions. Consider this a general guide. An excellent source is ***The Perfect Edge***, Ron Hock (2009), Popular Woodworking Books (ISBN 978-1-55870-858-7).

Hardening Process	Temperature (Fahrenheit)	Color
	White	2190
	Light Yellow	2010
	Yellow	1920
	Light orange	1800
	Orange	1710
	Light red	1600
	Light cherry	1490
	Cherry	1400
	Dark cherry	1290
	Blood red	1200
	Brown red	1110

Tempering Process	Temperature (Fahrenheit)	Color
	650	Steel Grey
	640	Light blue
	570	Dark blue
	560	Full blue
	550	Dark purple
	540	Full purple
	530	Light purple
	520	Brown-purple
	510	Spotted red-brown
	500	Brown yellow
	490	Yellow brown
	480	Dark yellow
	470	Deep straw yellow
	460	Straw yellow
	450	Pale straw yellow
	440	Light yellow
	420	Pale yellow