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# KNIFE METALLURGY 101

BY BRIAN SAVIDANT

Ever wonder where the steel in your knife came from. If so, read on. The study of steel making and heat treating is a full university course but I have attempted to simplify the processes involved to make for more enjoyable reading. In this article we will trace the origins of steel and how it is produced and then look at the all important heat treatment of steel that can make or break a knife. Then, we will finish with some fun heat treating that you can do in your own work shop.

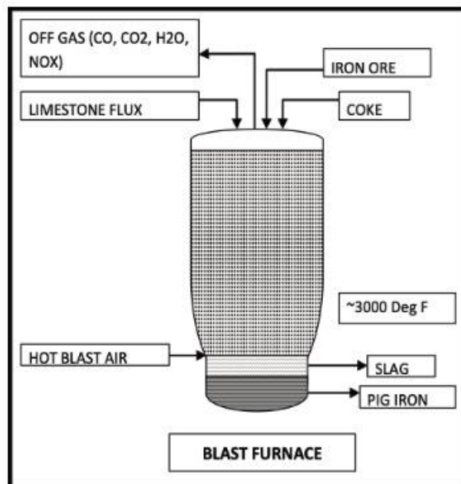
But first let's define steel. It is iron with a carbon content of less than 2%.

## Ores That are Mined for Steel

Like all metals, steel starts off its life as an ore that is mined from the ground. In the case of steel, the major ore minerals are magnetite ( $\text{Fe}_3\text{O}_4$ ) and hematite ( $\text{Fe}_2\text{O}_3$ ). If you guessed that magnetite is magnetic you are correct. Don't worry about their scientific names. Suffice it to say that the iron is tied up with oxygen.

## The Blast Furnace and Why is it Called Pig Iron?

The next part of the process is to strip the oxygen away from the iron. This is where the blast furnace comes in. In the blast furnace the iron/oxygen mineral is introduced and melted at high temperatures along with coke (carbon). The carbon strips away the oxygen from the iron resulting in what is known as pig iron. It was called pig iron because historically when the furnace was tapped the iron ran down



a trough and into smaller side molds. It reminded early steel workers of a sow pig nursing her young piglets and thus the term "pig iron". The pig iron that is produced contains 3 to 5% carbon which is too high for steel. It is also far too brittle for knife making. This brings us to the next part of the process.

## How Steel is Made (Basic Oxygen Process)

Just one of the ways in which steel is produced is in the Basic Oxygen Process. Molten pig iron is poured into a brick lined vessel that looks like a triple size cement mixer. A water cooled lance is introduced and blows a finely controlled amount of almost pure oxygen at supersonic speeds into the molten bath. The oxygen combines with the carbon producing heat and carbon monoxide and carbon dioxide which is

a greenhouse gas. This allows the operators to produce steel (iron with less than 2% carbon). The steel thus produced is rolled into the many common forms that we are used to seeing. Knife makers are most interested in thin steel sheet and flat bar. The steel thus produced is known as plain carbon steel.

## PLAIN CARBON STEELS

There is a range of plain carbon steels, each having a certain amount of carbon in them. High carbon or tool steel generally has over 0.6% carbon and responds very well to heat treating. This is what allows the metallurgists to do their magic with regards to hardening and tempering and why it is a common knife material. 1095 is a common grade of knife steel. In any event a high carbon plain steel knife if well taken care of (dried or oiled) will give a lifetime of service. Low carbon or mild steel lacks the ability to be hardened and should not be considered for knife steel.

## Stainless Steels

Chemists and Metallurgist have long ago determined that the corrosion resistant properties of steel can be improved by alloying or mixing it with chromium and nickel. The two most common types of stainless steel are Aus-



*99.99% Electrolytic Nickel an Alloy  
Used in Austenitic Stainless Steel*

tenitic and Martensitic.

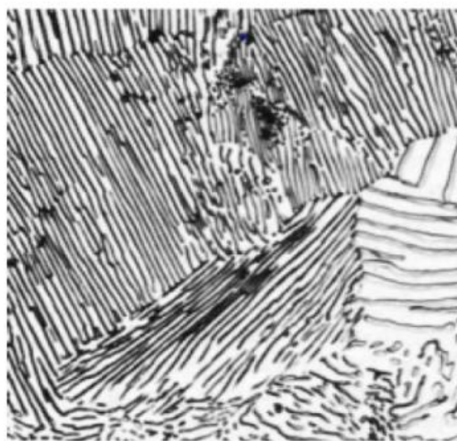
**Austenitic Stainless Steel (non magnetic):** Steel that is alloyed with chromium and nickel is known as austenitic steel and will maintain its silver like shine. It is commonly known as 300 series steel. Common grades are 304, 310 and 316. Because it maintains its shiny surface, this is the stainless steel that is used to make kitchen equipment and dairy utensils amongst other things. The down fall of this austenitic steel is that the nickel prevents it from being hardened by heat treatment. This makes it largely unattractive to knife makers.

**Martensitic Stainless Steel (magnetic):** This steel is alloyed with just chromium. It has good corrosion resistance but does not stay quite as shiny as austenitic steel. On the other hand martensitic stainless steel can be heat treated in all the common ways such as hardening, annealing and tempering. It is typically known as 400 series steel. This martensitic stainless steel is very popular with knife makers. Common knife grades are 420 and 440C.

### Heat Treating

Looks can be deceiving. If you could polish and look at steel under a special microscope you

would see that it is not homogeneous but rather is made from many tiny grains. It would look somewhat as shown below. Just a few of the many heat treating processes are, annealing, hardening, tempering, normalizing, carburizing, nitriding, cyaniding, cold treatment (cryogenic),



*Slow Cooled Annealed 0.8%  
Carbon Steel HRc 10 (pearlite)*



*Quench Hardened but Brittle Steel  
HRc 65 (martensite)*

spheroidizing, and on and on. The trick in heat treating is to produce the right grain structure. This is determined by what temperature the steel is heated to and then how quickly it is cooled followed by tempering. This dictates what the granular structure will be.

### Tempering

To make the knife useable it needs to be tempered. This is done by reheating the steel to an elevated temperature somewhere between 400 and 1000 deg F and soaking it at that temperature for

a period of time before slow cooling it. This results in a tough steel with the ability to absorb impact with only a slight reduction in hardness. This makes for a good knife.

### Hardness

It amazes me that knife advertisers do not mention the hardness of their blades. The hardness is critical and often indicates the quality of the knife. The cutting ability or the ability to hold an edge is closely related to the hardness. The hardness will make a knife harder to sharpen but will result in it holding its edge for longer.



*440C Knife Made by Author HRc 57*

An online search found a number of manufacturers that list their hardness. Buck being my favorite was at the top of the list. I have toured their plant in Post Falls, Idaho. Not surprisingly, they did not take us through their proprietary heat treating area.

### Fun With Heat Treatment

All you need to have some fun is an old hacksaw blade and a torch. Just take a pair of pliers and you will be able to easily break off the end of the blade! Now, heat a couple of inches of the end of the same blade to cherry red and allow it to slowly cool in air, dry sand or wood ashes. Then, take the pliers to the end and you will see that it will bend with-

out breaking. Congratulations you have annealed the end of the blade. Now, heat that same end to a cherry red and plunge it and agitate it in a can of water. Try the pliers again and you will see that you have now hardened the blade and made it brittle again.

### Surface Coatings

Personally, I cannot see the advantage of knife coatings other than for esthetics. My belief is that any coating is removed from the knife edge upon sharpening. Whatever you do to prevent corrosion of the edge will also protect the rest of the knife. Having said that, I do have some knives with very nice coatings but they see little use.

### Damascus Steel

This steel is made by repeatedly folding the steel over on itself and forge welding it together. This has great esthetic appeal but I don't see what it adds to the qual-

ity of the knife. Buy one if you like the looks.

### What about Pig/Cast Iron?

Let's not forget about our old friend pig iron. Not that the pig or cast iron is not useful. On the contrary it has excellent high temperature oxidation resistance (think fireplace grates). It also easily resists corrosion by water (think underground water lines). At temperature it is very fluid, allowing it to be cast into intricate shapes. It is however quite brittle and extremely difficult if not impossible to weld. It can however be brazed.

### Knife Truths & Tips

1) When purchasing a knife, the grade of steel can be misleading especially if it is not properly heat treated. The best bet is to go with well known long time knife makers. If in doubt ask them about the hardness of the blade or look on line.

2) My EDC "Every Day Carry" is a Victorinox Spartan (Most Canadians don't carry knives for self defense).

3) Victorinox makes an absolutely superb paring knife (0.073" thickness).

4) Some knives look good and are just fun to buy.

5) You can never have too many knives or fishing rods.

### References

If you would like to learn more I highly recommend the 1966 publication "Monograph 88 Heat Treatment and Properties of Iron and Steel" by the US Department of Commerce at <https://nvlpubs.nist.gov/nistpubs/Legacy/MONO/nbsmonograph88.pdf>

*Brian Savidant holds a degree in Metallurgical Engineering from McGill University. He is retired after a 35 year career at both a nickel/copper smelter and at an oil refinery.*



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