Bohler- Uddeholm Corporation (BUC) Blade Steels

This year I was fortunate to receive some steel samples from BUC. These grades are: Bohler M390 Microclean, Bohler K294 Microclean (A11), Uddeholm Elmax and Bohler N690.
All of these steels except N690 are made with the 3rd generation particle metallurgy process. My experience shows that this yields a very fine clean structure. I have heat treated and completed knives with all of them to date. For more information on designs and some photos see www.seamountknifeworks.com

General workability

M390, ELMAX and K294 are very well annealed and drilling, milling and rough grinding are pretty much the same as the other Particle steels we are familiar with. The steel is furnished in plate that is cut into strips (bars) for knife making blanks. Several thicknesses are available but the samples I worked with were .145 to .150 inch. Rolled thickness seems very uniform. Profiling and rough grinding was done with Norton SG (hogger) belts in 50 and 60 grit. Prior to heat treat, I grind to an edge thickness of about 0.030 and finish with 150 grit to minimize warpage during heat treat. I did detect some stress in M390 while removing the outer layer on the surface grinder. The solution is to take small cuts (.002 inch) and alternate sides and keep it wet with coolant and it will settle down in a couple passes per side. This is typical of other very high alloy steels since they are very difficult to roll into thin sheets. ELMAX, N690 and K294 did not exhibit this characteristic. All of these steels are very sensitive to tempering. Changes as little as 20 degrees F can make one point RC hardness difference.

M390 Microclean

Carbon 1.9, Chromium 20, Molybdenum 1, Vanadium 4, Tungsten 0.60

Heat-treating this grade took a couple of tries before I got what I wanted. My target hardness was 61 HRC but I missed this by quite a bit on the first attempt. With some help from BUC and some thermocouple calibration in my furnace, the final success came with the following recipe. Preheat at 1550 ^{o}F, Ramp to 2120 ^{o}F, hold 30 min and a rapid forced air quench down to room temperature. The as quenched hardness was 62-63 HRC. A four hour subzero in Liquid Nitrogen gave 63. Three tempers at 400 ^{o}F for one hour yielded a final hardness of 61. It is possible to push the final hardness up to 62 for enhanced wear resistance if torqueing, twisting and impact loads like chopping are avoided. Note: The data sheet shows a tempering hardness bump at about 1000 ^{o}F. but on the first attempt, I missed the peak and actually got about 58 as a finished hardness. In general the lower temperature range on these high alloy grades gives maximum corrosion resistance and slightly better toughness. For this reason I settled on the lower temperature range as the best overall procedure for this grade. According to the BUC metallurgist I consulted with the subzero moves the high temper hardness peak to the left of the curve. This is probably why I missed the peak on the first try.

I did some rope cutting and whittling on fir to get a feel for wear resistance and strength of the edge. I used 3/4 inch diameter rope and cut with my standard test procedure. Again, see the Seamount web site for more information on the rope cutting test procedure. In short, if a blade will make about 150 cuts on the 3/4 rope with less than 20 pounds on the scale and still have good bite, then I judge this blade to be good for a big game hunting knife. This knife is about 0.010 inch behind the cutting edge and was sharpened on a Norton Silicon Carbide (Crystalon) medium stone. Edge burr was removed with a loaded strop. I got the 150 cuts just fine and it was starting to slide a bit at about 180 cuts. I stropped the edge again and it was back to the original sharpness. This is very good cutting performance. I whittled on fir and twisted the blade out of the cut so it makes a kind of popping, scrunching sound. There was no edge chipping but some slight deformation. This is exactly how it should perform.
I carried this knife on a recent fishing trip to Baja. It was used for gill bleeding on fish and general boat use on two outings on the sea of Cortez. The sea has a high salt content and the weather was 80 ambient. There was no evident corrosion at all even though the knife was not rinsed in fresh water until the end of the day.
Overall, this steel is a very good choice for an all-around hunting, utility, salt-water carry knife. The steel is nice to work, very clean with very fine grain. Based on just three blades and limited field-testing I would judge this steel to be one of the best available for this type of knife. I think also it would make an excellent kitchen knife based on the wear, corrosion resistance and toughness.

K 294 (A11)
Carbon 2.0, Chromium 5.2, Molybdenum 1.3, Vanadium 9.7

The best way to describe this grade is to say that this is the BUC version of CPM 10V.
Since I am very familiar with heat treating the CPM version the first heat treat trial on this one was successful. Aim hardness was 63-64 HRC. Preheat at 1540 ^{o}F, ramp to 2140 ^{o}F and hold for 30 minutes. With a forced air cool down to room temperature the as quenched hardness was 65 HRC. Direct immersion in liquid Nitrogen and a hold for 2 hours did not increase the 65 hardness. Three tempers at 1000 ^{o}F for 2 hours yielded a final hardness of 63 HRC.
The finish grind on this steel after heat treat is to say the least a challenge. The 10% Vanadium is there for wear resistance and it shows up during the finish process. There is some Sulfur added to this grade for ease of machining and I would say it helps. Drilling and milling are fine but grinding and finish is still at the very high end of effort for a knife blade steel.
Sharpened the same way and with the cutting procedure above on M390 yielded over 240 cuts before any smoothing of the edge could be detected. This grade also responds well to a loaded strop and a few strokes put it back to shaving sharp. The same whittling test on Fir showed some very fine yielding at the thin edge. If pushed very hard (abused in my mind) and at **this high hardness** it is possible to get some fine chipping as well. CPM 10V and now this grade are my standards that I compare all other to for wear resistance and edge holding. I like this version; it has very fine grain and is clean and reasonable to work with. I have not done any corrosion resistance tests yet, just one blade completed, but a hunter utility blade is going to require care in cleaning and drying before storing to insure it stays corrosion free. It comes down to the right steel for the application. I would take the M390 fishing and use the K294 for

the tough big game skinning and dressing tasks. Wild pigs are the greatest challenge for a hunting knife and I cannot wait to try K294 on my next pig hunt.

Elmax
1.7 carbon, 18 chromium, 3.0 vanadium, 1.0 Molybdenum

If you are used to working with CPM S30V this one will be familiar. Pretty much the same heat treat process as for M390 will work but in general I got the same final hardness using lower austentizing temperatures. On the first knife with this steel I did a finish grind with a 220 belt and went direct to a 'Scotch Brite' fine belt. This finish is pleasing and is fine enough to make a good working knife. Initial cutting tests show ELMAX to be in the same category as CPM S30V at the same hardness. It is capable of an extremely sharp edge due to the fine structure. I have seen some Charpy toughness tests done by Bohler–Uddeholm that show ELMAX dynamic toughness to exceed several other steel grades used for custom knives. This good toughness can be used to advantage by increasing the hardness up a couple of points (to 62 HRC) and still be left with an edge that will resist chipping and have good strength to resist rolling. I think the best application for this grade is all around using knives, kitchen knives and fillet knives. Cost per pound is lower than M390 and if both are heat treated at the same hardness ELMAX only gives up about 20% in edge holding. If sharpening is convenient then this difference would be hard to detect in actual use.

N690
1.1 Carbon, 17.3 Chromium, 1.1 Molybdenum, 1.5 Cobalt

This one was a pleasant surprise. It kind of looks like 440C based on the chemistry but acts very different in use. The addition of Cobalt and Molybdenum change the character it seems. Custom makers do not have access to VG10 which has a closer chemistry. VG10 is a very popular all around steel, so it is fortunate to now have a similar grade to work with. It responds nicely to the initial austentizing cycle by providing up to 63 HRC with a forced air quench. After the cryo cycle it is then possible to temper down to 60/61 on a temperature range of 375-400 F. At this hardness it has very good edge strength and will limit rolling on a thin edge with hard use. The grain structure is visible in the initial grinding and it looks like D2 or 154 CM with the visible carbide strings. This is not a particle based steel and the larger grain size contributes to very aggressive cutting personality. When sharpened on a medium Silicon carbide or diamond stone it will cut abrasive materials like cardboard and rope very nicely. The corrosion resistance is excellent due to the large chromium content so I think this grade will make a very versatile all around use knife. I have done a couple fillet knives with N690 and have tested it on rope and cutting fir. At 60 HRC and a very thin edge I did not detect any chipping but some incipient rolling. This shows good ductility and means the heat treat is close to optimum. Next test will be a check out filleting some large salmon or halibut. I just have to take some time off making knives and get to the ocean. This steel has been used by many European production and custom makers for years and it is obvious why it is one of the standby steels over there. Another nice factor is that N690 is very reasonable priced compared to other commonly used blade steels.

The heat treat results outlined above were done in my shop with my furnace, hardness tester and tempering furnace. Calibrations in other set ups may vary and results can be different depending on user techniques. In general I found the information on the BUC data sheets for these grades to be very good for knife blade type applications.

I cut manila rope to get an idea of edge retention and toughness and to predict performance in the field. My results can vary from test to test, depending on the rope thickness, humidity and batch of rope. Other's testing will get different results (number of cuts etc.) using a different batch of rope, scale and slicing techniques. The CATRA test eliminates more variables but I find in general that my method will parallel the CATRA results pretty close with large differences (+/- 20%) clearly showing up.

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It is neither wealth nor splendor, but tranquility and occupation that give happiness. Thomas Jefferson