MeltLab Base Iron

by MeltLab Systems
844-MeltLab
www.meltlab.com

Fast • Accurate • Comprehensive

Base Iron Thermal Analysis

- Chemistry
  - Carbon Equalivant
  - Total Carbon
  - Estimated Silicon
- Oxidation
- Tramp Elements
- Sample Quality
- Additions
- Record Keeping
- Curve Keeping
- Data Export
  - Graph
  - Graph Data Points
- Office Version*
- Chill*
- Process Windows*
- Graphic Analysis*

* Additional Options not included with MeltLab License

The Stages of Iron Control

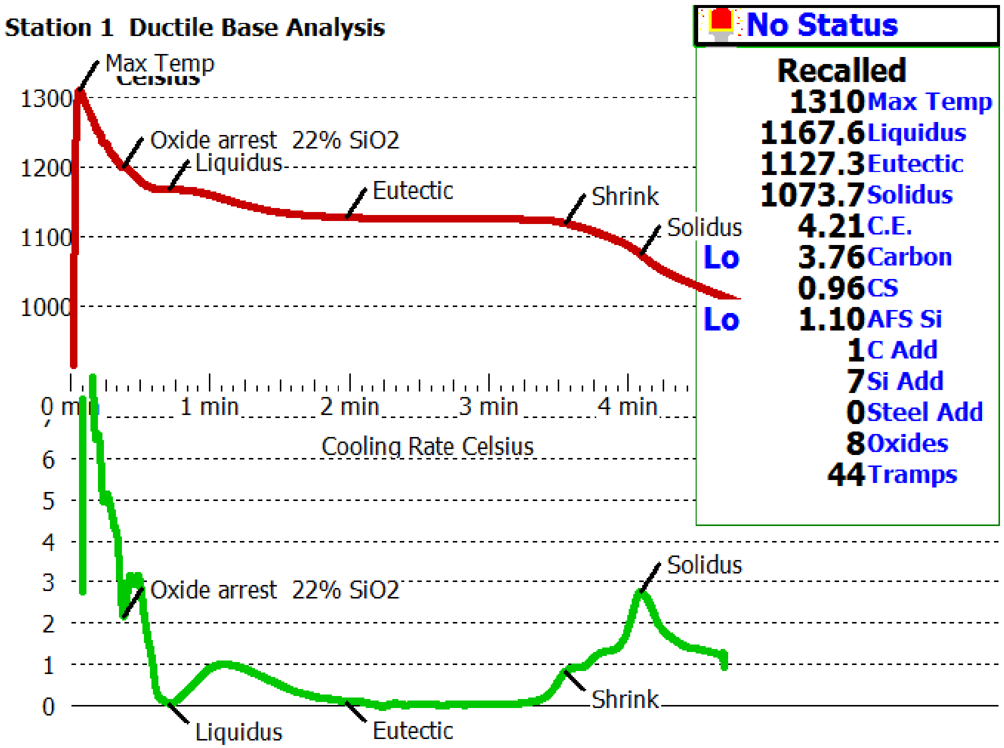
- Base Iron - chemistry
- Held Iron – chemistry and dead iron
- Final Iron – inoculation, treatment, defect removal

Each stage has different goals. Chemistry is the most important for the base and held irons. Microstructure is most important for the final iron. Carbides and shrinkage may happen in base and in held Irons, but must be eliminated by the final stage of the iron. Inoculation and treatment are not measured in base, but is key in the final stage of the iron.

Base Objectives

- Fix chemistry
- Add 1 unit Carbon
- Add 7 units Silicon
- Fix oxygen with SiC
- Shrink not important*
- Watch out for tramps

Tramps come from your melting stock and affect the freezing range of your iron.



Oxygen will reduce the effectiveness of your inoculation or magnesium treatment. It is best to remove it in the base iron, or melting process.

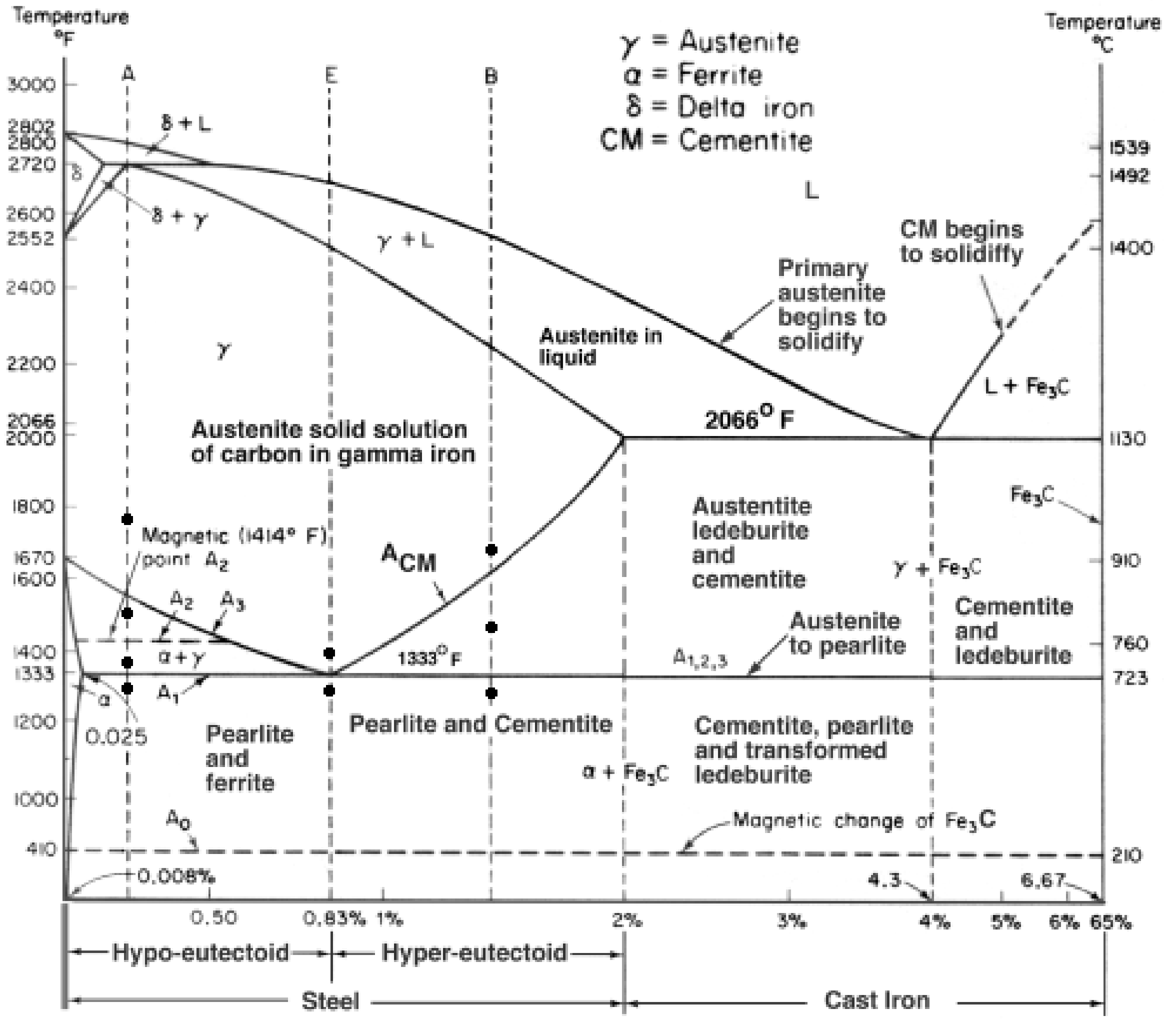
*Shrink and carbides often occur in base iron. But with proper inoculation at the next stage of iron control, they should disappear.

Meanings of Terms

- Maximum Temperature – going above 2540 F risks melting the thermal couple in ElectroNite 200 and 400 series cups.
- Liquidus Temperature – caused by austenite dendrites forming and determines the Carbon Equalivant value.
- Eutectic Temperature – caused by iron + carbon (eutectic material) forming. Combined with liquidus calculates the Carbon value.
- Solidus – temperature at which grain boundaries freeze. Effects Austempering.

Chemistry Control

- Phase Diagram gives C.E. or Carbon Equalivant
- Carbon is calculated from Liquidus and Eutectic
- Silicon is derived from C.E. and Carbon



The Three Iron Chemistries

- Carbon Equalivant – from the phase diagram. Silicon and other alloys make the iron appear equalivant to this carbon.
- Carbon – this was developed by GIRI (now ICRI) and confirmed by BCIRI. Compares favorably with combustion analysis. Better than Spectrometer analysis.
- Silicon – rough calculation to be corrected by the spectrometer, but can be used when Spectrometer is down.

Is the Carbon Equalivant correct?

- C.E. is calculated directly from the liquidus. Spectrometers can only guess what the liquidus might be based on imperfect equations.
- Some other TA units misread the liquidus by several degrees by not using derivatives.
- Other TA units take the Liquidus undercooling temperature instead of the growth temperature.
- If in doubt check the temperature calibration, and the cups – those are the only things that could cause error.

Carbon Issue
Spectrometers are not really good at carbon.

- In the range of 3% +, spectrometers have two issues: formation of graphite in their samples, and graphite in their standards.
- NIST has a standard of no more than 0.1% graphite in their 3%+ standards (caused by a mild temper). This is more than enough to through off even a good spectrometer.

Combustion Carbon

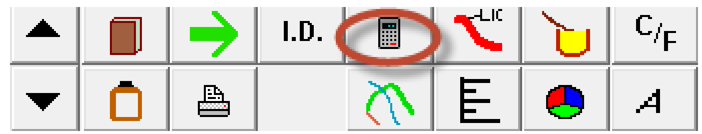
- LECO warrants their instruments to be within 1% of concentration. For an Iron of 3.50% Carbon that is +/- 0.035 Carbon. That is on par with the MeltLab's results when the LECO is properly calibrated.
- Combustion carbon standards should be shaken before used, or the fines will settle and throw off the calibration.
- MeltLab Carbon analysis is faster and cheaper than combustion analysis.

Estimated Silicon

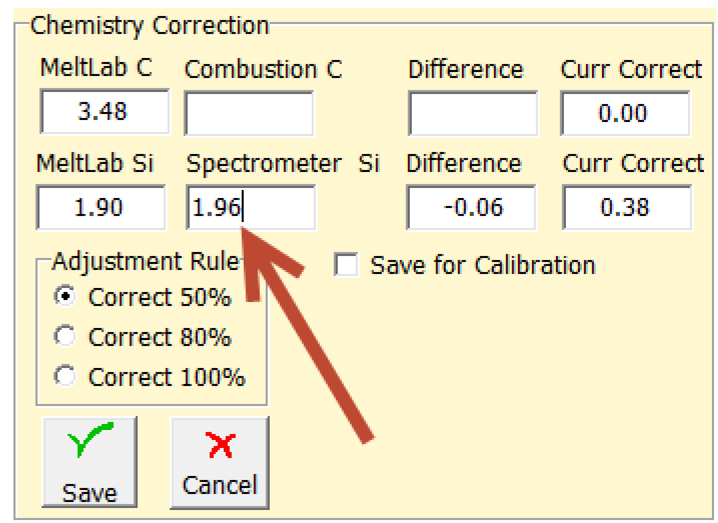
- $CE = C + (k_1 * Si) + k_2$
- Solving for SI = $(CE – C – k_2)/k_1$
- But actually $CE = C + k_1Si + k_2Mn + k_3P – k_4Cr$ – ASM Cast Metals (Doro Stephenescu)
- So 0.10 Manganese will cause a 0.06 change in the calculated silicon.
- Resolution: use different silicon equations for different irons where manganese or chrome change a lot.

Correcting Silicon

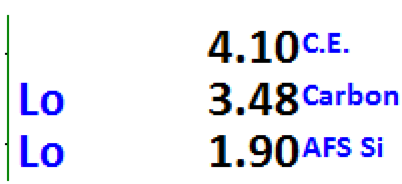
Select Chemistry Correction from Toolbar

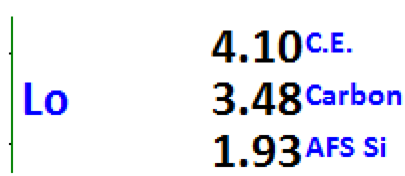


When you then click on “Save” the analysis will change from 1.90% silicon to 1.93% silicon, but the carbon and C.E. will remain the same. The chemistry correction box will then disappear and all chemistries of that metal grade will then have the same correction.



Before and After





Problems with Oxygenated iron

- Oxygen in the form of Manganese oxide or silicon oxide is common in molten iron. It comes from rusty scrap and preheaters in induction melted irons, and from the same sources as well as the oxygen blast in cupola melting.

- As the iron cools down, the oxygen transfers to the iron and the silicon to form mullite. When inoculants are added to the iron, the oxygen reacts with the inoculants to reduce their effectiveness. Most inoculants include calcium to remove the oxygen. Calcium oxide is a runny slag that then needs to be filtered out of the iron with another expensive process. You pay for the calcium, you pay for the filter.

- When magnesium is added to form ductile iron, it removes the oxygen as magnesium oxide – the most expensive way known to remove oxygen. You can easily loose 5 points of magnesium to the oxygen in the iron. I have seen as much as a 10 point loss, though that is not common.

Solving the Oxygen problem

- With cupola melting, there is a process and a company that makes silicon carbide injectors that will clean up the iron.

- With induction melters there are two methods: the addition of silicon carbide to the iron, and running a low silicon, high carbon chemistry and letting the oxygen burn out in the form of carbon monoxide. This may require more expensive silicon (75% grade) to be used on tapping to bring the chemistry into range. The best way is to include up to 2% SiC in the charge. Higher levels of SiC run the risk of eating away at the furnace walls. Late additions of SiC run the risk of not fully dissolving before pouring. No one wants to buy a casting with undissolved SiC in it – very hard to machine…

- Of course, MeltLab for base iron control is the final check on your oxygen levels, to see if you got it right or need a small correction.

Tramp iron – the unknown problem

- When the iron solidifies, the low melting elements/compounds move to the grain boundaries. This is called micro-segregation.
- The temperature that the grain boundary freezes at is then a measure of how free your iron is from impurities. The tramp index is the difference between the eutectic temperature and the temperature that the grain boundary freezes at in Celsius.
- Little is understood about the effects of micro-segregation, but Applied Processes, the pioneer of Austempered Ductile Iron, insists that ADI castings must be made with low levels of micro-segregation in order to be properly heat treated. Micro-segregation has also been blamed for low temperature embrittlement of ductile iron.

Cups and their issues

- Two types of cups for iron: those with and those without tellurium.
- With tellurium are for chemistry.
- Without tellurium are for microstructure.
- Cup wire is +/- 2 degrees F (Special Limits). Standard wire is +/-5 degrees F.
- Wire can melt.
- Glass tube can crack.
- Tellurium can boil too much and cause under filled cup.

Pouring a full cup

- Without a full cup
  - Start of Liquidus can be missed
  - Ferrite/Pearlite looses accuracy
- Plain cups are easier to fill than tellurium and are more important to fill. Cover the top of the cup with ceramic fiber or better a core that will strike off excess iron.
- Sample Quality measures the time to cool between to temperatures. Shorter time means less full cup or pearlitic iron – a mystery yet to be solved.

Additions

- By setting upper and lower ranges for element, recovery rates, and weight to be corrected, you enable the computer to calculate additions.
- Calculates carbon, silicon and steel additions.
- Can Calculate
  - to range
  - to center of range
  - next charge
- Handy calculation tool also on front screen

Record Keeping – writing to file

- System can write out test results to a remote file.
- Set the time span of each file: Daily, Weekly, Monthly or Yearly.
- Set the format of the file: comma or tab delimited.
- Set the folder location of the file for each metal grade.
- Choose headers or no headers.
- Choose extension: .Txt or .XLS (.CSV soon to be added)
- Choose the tests to be included.
- Do so for each metal grade.

Curve Keeping

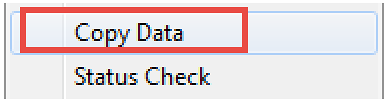
- The last 100 curves are saved for each MeltLab station. Access these curves through the brown book icon on the tool bar.
- Up to 2,000 curves can be saved to a permanent archive file for each year. Access these through the File|Archive function.

Data Export – Graph

- Copy the graph of any station by one of many commands (Ctrl C, tool bar, pull down menu, right click).
- Go to Word or Excel and paste the graphic.
- Note some versions of Excel clear the copy buffer on program startup so you may need to start Excel first, then copy the graph from MeltLab, then switch to Excel and paste.

Data Export – Graph data points

- Have the sample you are interested in on screen.
- Right click the graph you want.
- Select Copy Data.



- Go to Excel and paste (note previous problem with Excel erasing copy buffer).
- Records up to 3,000 data points and derivatives.

1	Thermal Analysis Data Points										
2	MeltLab™ Station 1 Ductile										
3	Secs	Millivolts	CJ Temp	Raw Temp	Smoothed	1st Derv	Rate of Co	2nd Derv	3rd Derv	4th Derv	5th Derv
4	0.148	52.1173	0	2318.5	2318.5	-82.376	82.376	21.2754	-7.13475	4.796959	-1.74183
5	0.289	52.5029	0	2358.31	2358.31	-74.354	74.354	12.4221	-5.62896	4.503755	-1.75904
6	0.431	52.7965	0	2389.23	2389.23	-67.188	67.188	6.9236	-4.43247	4.24524	-1.76899

Office Version of MeltLab

- Through a special setup, a second MeltLab can function from an office and have access to the data and configuration over a LAN.
- This allows a supervisor or Metallurgist to track what is currently happening on the shop floor and to make adjustments and reports from the comfort of an office.
- This requires a stable LAN or Local Area Network that both the functioning MeltLab and the office MeltLab have access to.

Chill Measurement*

- Nucleation sites are lost during holding. These seed crystals on which graphite can grow, stick to the sides of the furnace or the slag on top of the iron. These seed crystals come from cupola melting, melting pig iron, and melting returns.
- Using a plain cup (no tellurium) the undercooling of the eutectic will increase as the seed crystals are lost. When no seed crystals are present, the iron will freeze white with little or no undercooling. The eutectic temperature drops from a grey eutectic to the lower white eutectic.
- The Dual Cup analysis is a good way to see where the iron is as it shows both the undercooling and the separation between the grey and white eutectics and can predict chill and therefore measure the inoculation level of the iron.

* Additional Options not included with MeltLab License

Dual Cup – a measure of inoculation

- The separation between the gray and the white eutectic is a measure of the chill of the iron.
- This is important for achieving consistent chill in gray and white irons.
- Two separate cups are poured from the same spoon of iron – one with tellurium and one without.
- The results were published in AFS Transactions 96-127 by D.A. Sparkman and C.A.Bhaskaran.

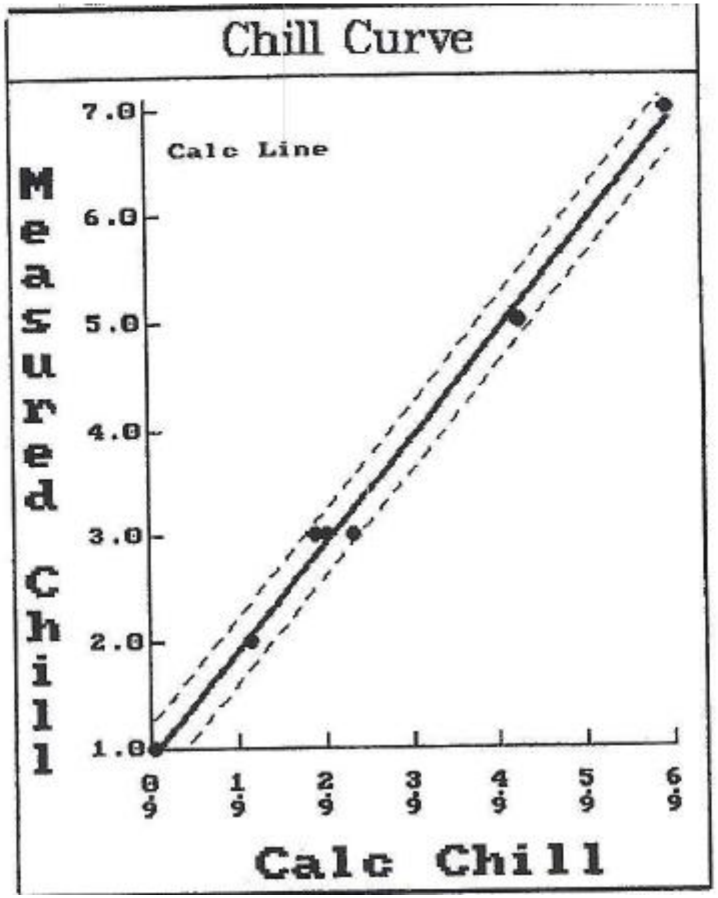


Table 1.
Chill Results of Experiments Conducted at AFS/CMI

Liquidus	Delta °C	Chill mm	Calc Chill	Error
2267	95.4	1	0.945	–0.055
2269	72.3	3	2.806	–0.194
2267	81.5	2	2.055	0.055
2286	23.0	7	6.874	–0.126
2275	67.4	3	3.243	0.243
2131	57.8	3	2.927	–0.073
2282	5.1	11*	8.274	*
2207	37.1	5	5.151	0.151

Note: The following is an explanation for the abbreviations used in Tables 1–4.

Liquidus = Liquidus Temperature

Delta °C = TEU-TCE (TEU = Temperature of Eutectic Undercooling from non-tellurium cooling curve. TCE = Temperature of Carbidic Eutectic from the tellurium cooling curve).

Chill = Chill tested at the foundry.

*Calc. Chill = k_1 * Liquidus + k_2 *(TEU - TCE) + k_3: Thermal analysis chill.*

Error = Calc. Chill-Chill

Process Windows for MeltLab

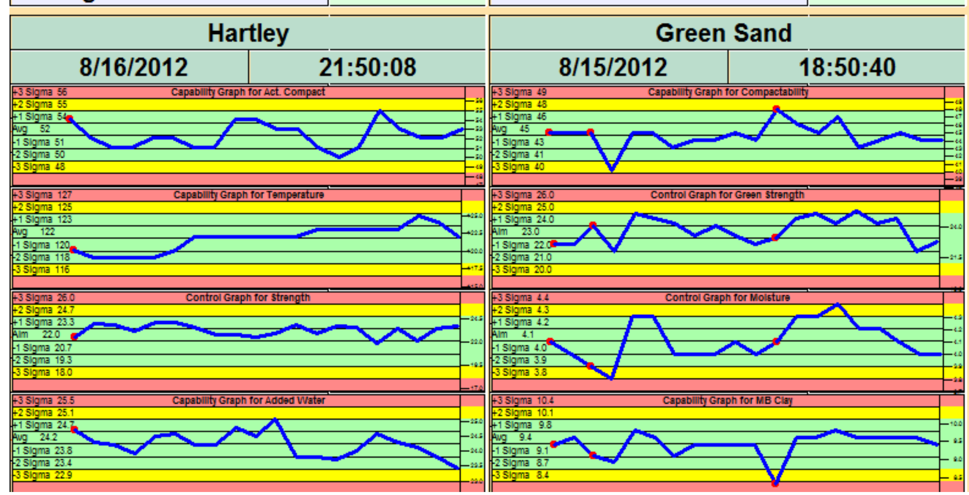
- Process Windows for MeltLab is a GSPC© product that can display selected MeltLab tests in multiple data and statistical graphic format over a LAN.
- Requires a stable LAN
- Requires a full GSPC license or a partial GSPC license for MeltLab only.
- Tests are selected from available MeltLab results.

Types of windows

- Text based data can display up to 12 variables per window
- Graphics based data can display up to 4 graphics per window

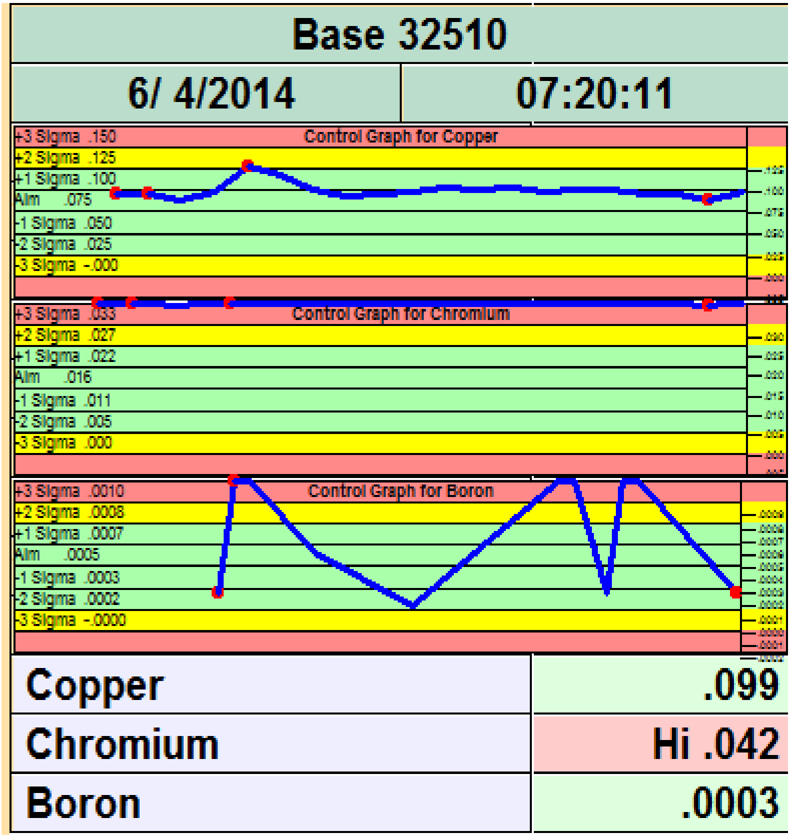
Hartley	
8/16/2012	21:50:08
Batch	123
Temperature	122
Conductive	.35
Compact Aim	52
Act. Compact	53
Needed Water	23.5
Added Water	23.4
Bias	14.7
Weight	4524
Amps	189
Moisture	Hi 5.20
Strength	23.7

Green Sand	
8/15/2012	18:50:40
MB Clay	9.4
Moisture	4.0
Compactability	44
Hartley Comp	52
Green Strength	22.8
Hardness	92
Volatile	
Permeability	92
Specimen Wt	149
Working bond	4.07
Mulling Eff	53.1
Avail Bond	7.7



Mixed Graphic Windows

- Here is a 4 graph window with the 4th graph left blank.
- Data underneath shows through.



Graphic Statistical Process Control

- The full GSPC system provides full results data capture into a process data base with many different Graphics and Reports for years of data.
- Not limited to MeltLab, but also includes chemistry, sand, physical properties and much more.
- See the GSPC Training Folder for more information.