

PROCESS CONTROL OF DUCTILE CAST IRON BY MEANS OF THERMAL ANALYSIS

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HEN Foundry: Joao Cunha & Craig Taylor

TOTALLY DEDICATED TO THE CAST METALS INDUSTRY.



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AT CRANFIELD UNIVERSITY





INTRODUCTION TO THE LATEST THERMAL ANALYSIS SYSTEMS

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HEN have been, smelters, manufacturers, suppliers and innovators in molten metals industries dating back to the family pharmacy which was established in 1660.

Many of the measurement systems, devices and methods used now, are the results of collaborations and R&D within the global foundry industry. Decades old patents on many traditional products such as Thermal Analysis Cups (QuikCup) are now expired and so this has raised the bar, on the requirements for *Quality, Consistency, Cost Effectiveness and Value in Use*.

New Software and Product packages are once more raising the bar of the capabilities of Thermal Analysis in the Foundry. We will present some new products that can help achieve greater quality & consistency in melting and casting, reduce defects and help efficiencies in materials consumption and energy.





WHY THERMAL ANALYSIS?

Problems associated with (OES) spectrometer:

- Sampling – Chill mould conditions - White chilled
- Time consuming – three different steps
- Maintenance costs (Calibration)
- **Spectrometers** only measures chemical composition. High variation in the carbon determination.

The **thermal analysis** can measure the physical aspects of solidification, like for example:

- Nucleation of the graphite / Inoculation potential
- Graphite shape
- Carbide propensity
- Cooling Rate
- Solidification pattern

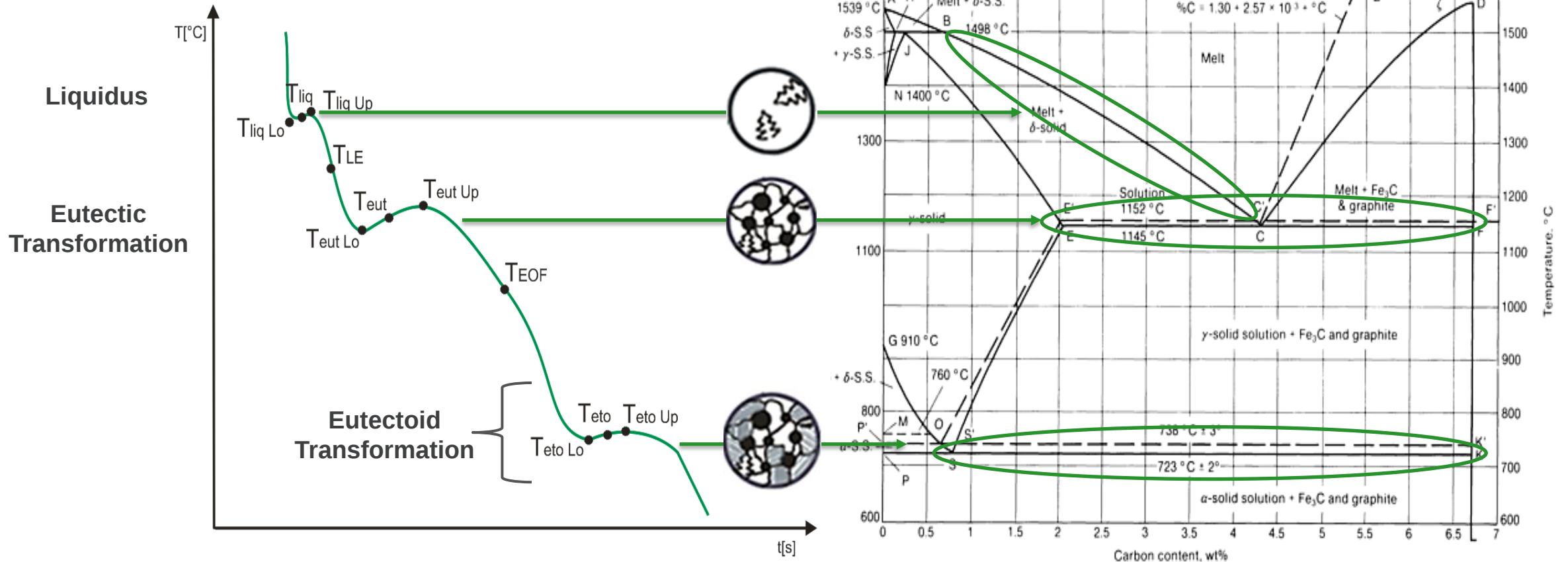
Thermal analysis is also a well-proven method commonly used in the iron foundry:

- Fast
- Accurate
- Reliable
- Low-cost control on the shop floor





THERMAL ANALYSIS OF CAST IRON



Relationship between Thermal analysis curve and Fe-C Equilibrium Diagram

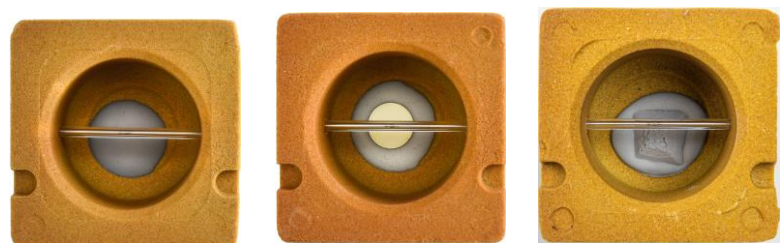




THERMAL ANALYSIS OF CAST IRON

CUP TYPES AND APPLICATIONS

With Tellurium → metastable solidification



QCTe

QCTeS

QCTeTe

- **Quantitative evaluation** of the melt.
- **Quantity** = number/amount: how much C and Si is dissolved in the melt.
- Calculation of the **carbon** and **silicon** content
- The melt is always forced into the same state (metastable) for constant conditions

without Tellurium → stable solidification



TSH

- **Qualitative evaluation** of the melt
- Accurate Volume = **Precision**
- **Quality** = property/condition: The properties and condition of the melt is evaluated
- **Prediction** of the **microstructure** or mechanical characteristics.
- The melt is sometimes deliberately influenced by added substances (Inoculants or Sulphur) in order to represent effects.

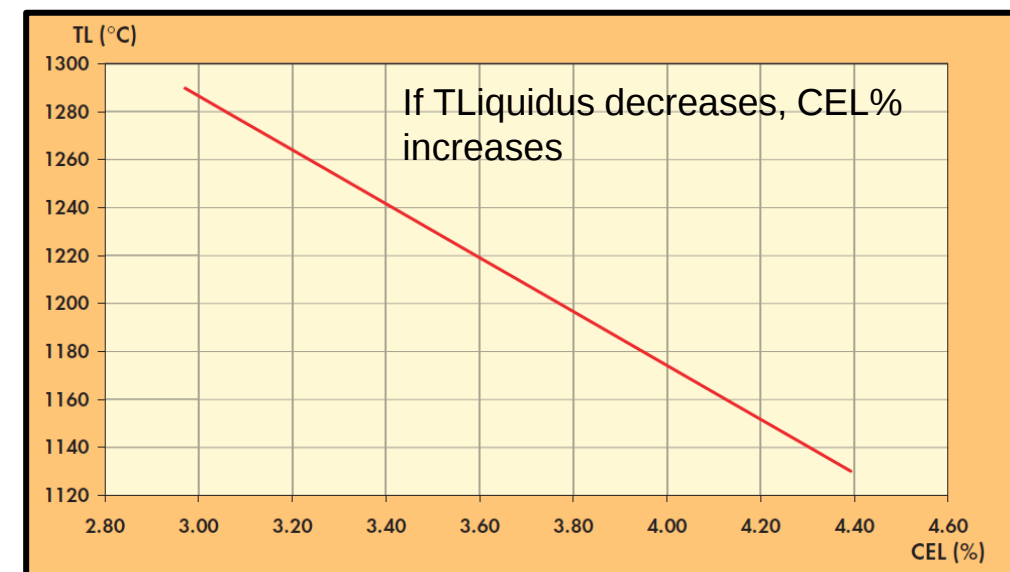
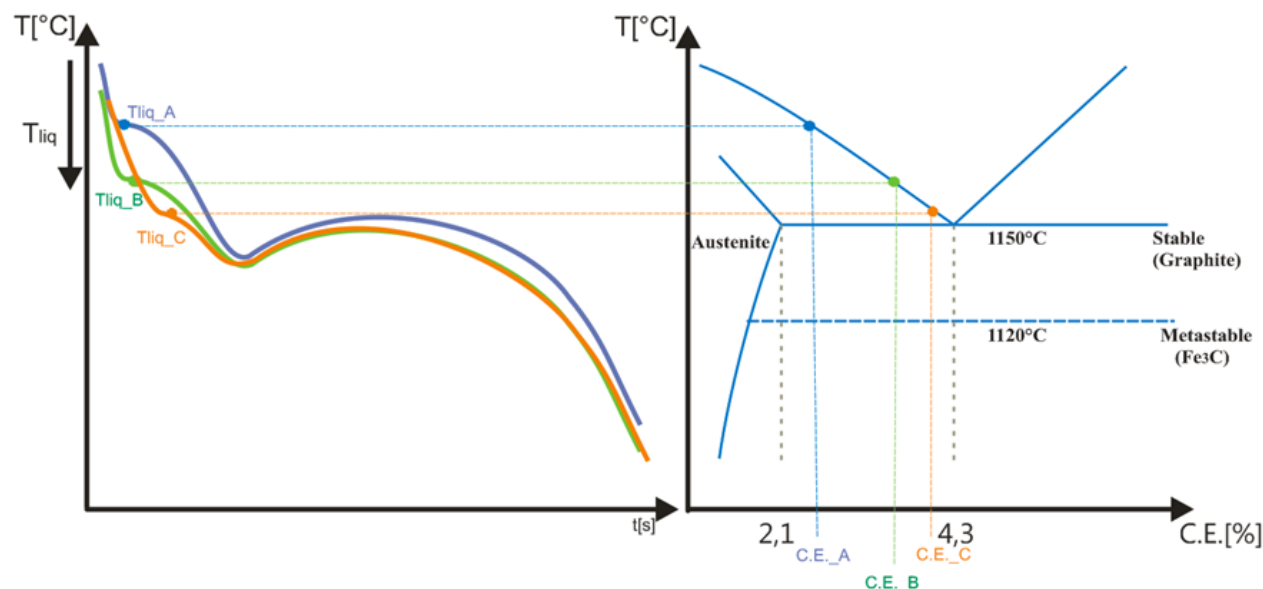




STANDARD APPLICATION FOR THERMAL ANALYSIS

CARBON EQUIVALENT LIQUIDUS – QC APPLICATION

Carbon Equivalent (CE) is a value (%) relating the combined effects of different alloying elements on the eutectic composition. It indicates if a given melt is Hipo-eutectic ($CE < 4,3\%$), Eutectic ($CE = 4,3\%$) and hyper-eutectic ($CE > 4,3\%$)



$$CEL = 14.45 - 0.0089 \cdot TL$$

Standard error is +/- 0.047 CEL

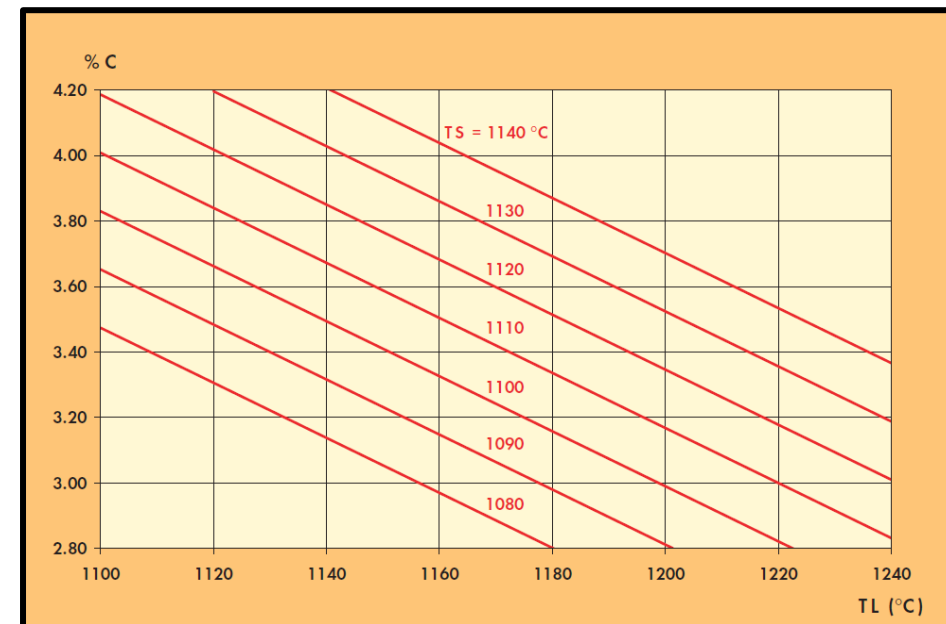
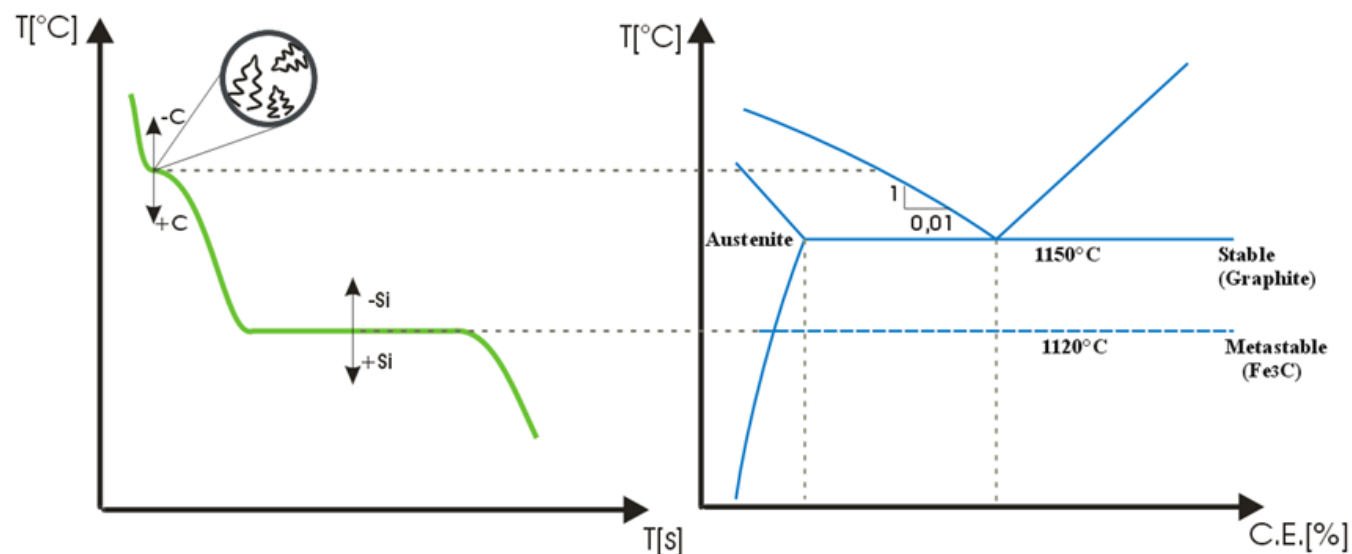
Can quickly be determined by means of thermal analysis (QC) using the **Carbon equivalent liquidus** correlation





STANDARD APPLICATION FOR THERMAL ANALYSIS

CARBON DETERMINATION THROUGH THE METASTABLE SOLIDIFICATION – QC TE/QC TES



$$\%C = - 6.51 - 0.0084 * TL + 0.0178 * TS$$

Standard error is +/- 0.039 C

The carbon can easily be determined by means of thermal analysis QC-Te / QC Te/S.

Two variables are needed: the liquidus temperature and eutectic/solidus temperature.

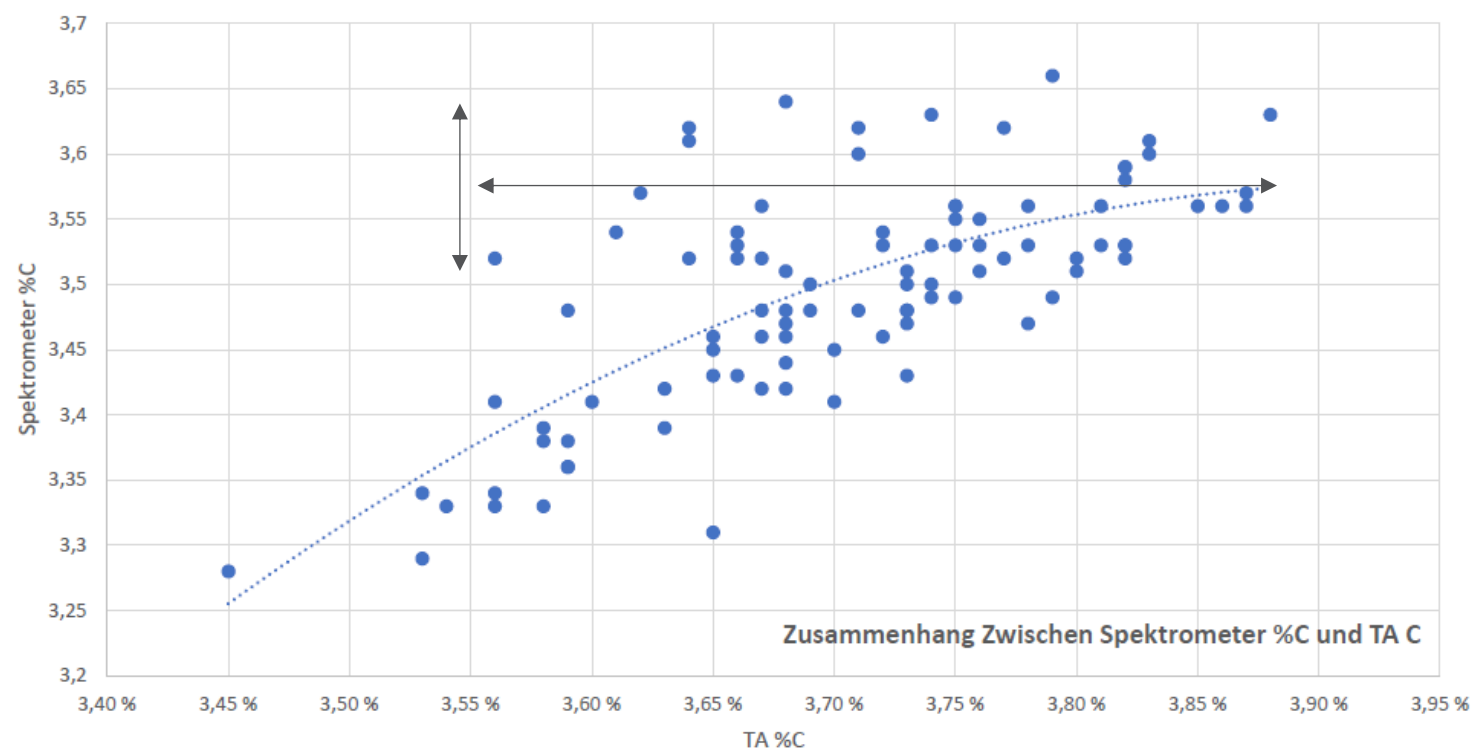
Fast and Reliable.





STANDARD APPLICATIONS OF THERMAL ANALYSIS

CARBON DETERMINATION SPECTRO RANGE VS. THERMAL ANALYSIS





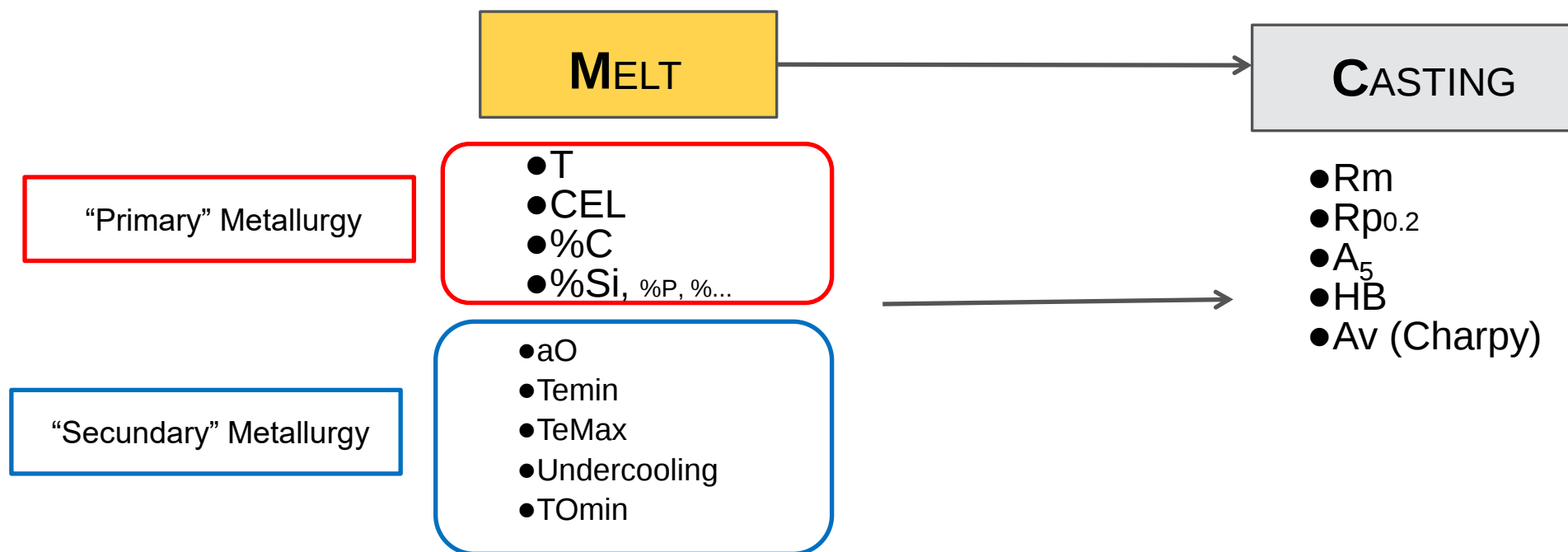
ADVANCED THERMAL ANALYSIS APPLICATION – PROCESS CONTROL

CONSIDERATIONS ON VALUE TO THE CUSTOMER

Customers question:

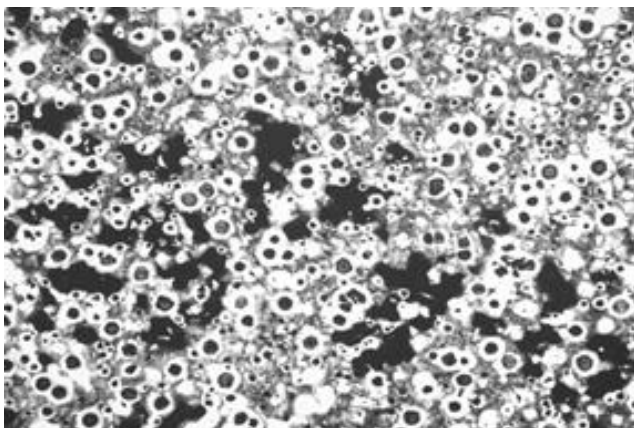
How can I control the Casting quality starting from the Melt ?

- Parameters Casting : mechanical properties
- Parameters Melt: measurements with our equipment

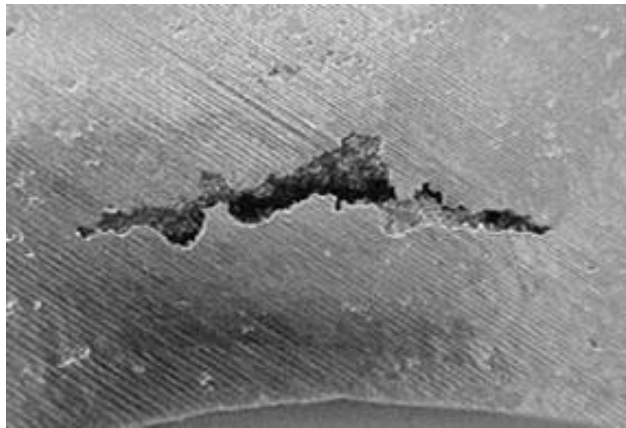


ADVANCED THERMAL ANALYSIS APPLICATION – PROCESS CONTROL

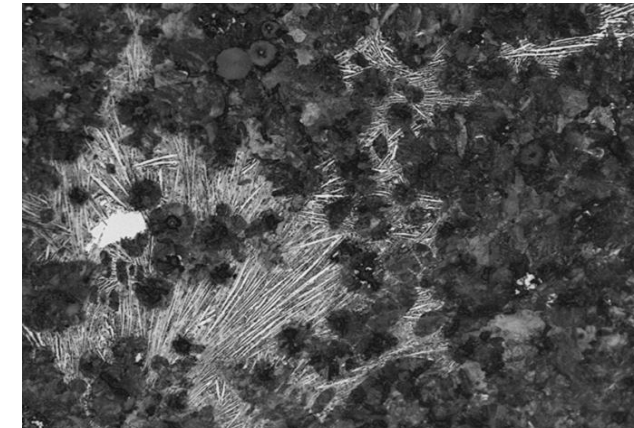
TYPICAL CUSTOMERS PAINS: CAN WE ESTIMATE BAD MELT QUALITY?



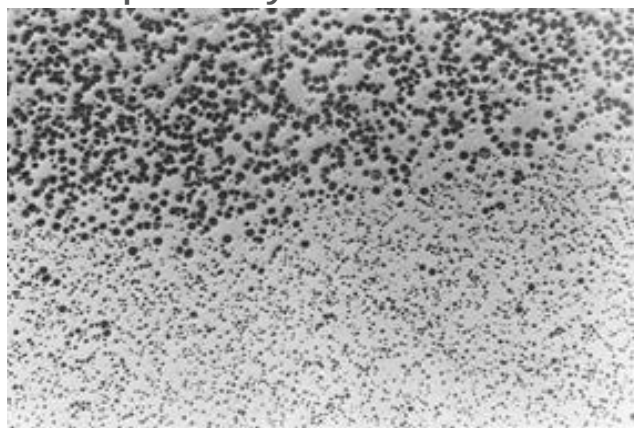
Microporosity



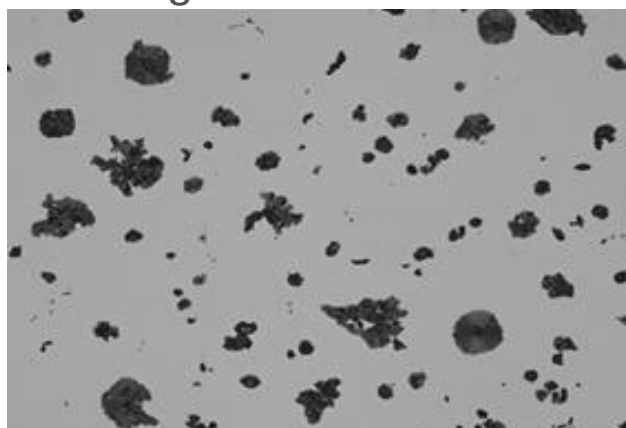
Shrinkage



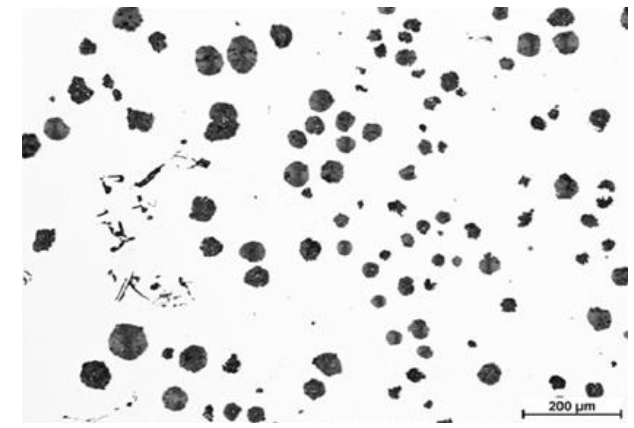
Carbides



Graphite flotation



Graphite degeneration



Magnesium oxide inclusions



ADVANCED THERMAL ANALYSIS APPLICATION

THERMAL ANALYSIS CUPS FOR QUALITATIVE EVALUATION



Can determine:

- CE %
- Liquidus temperature
- Undercooling
- Carbide Propensity
- Magnesium Index
- Perlite/Ferrite Ratio

TSH sensor characteristics:

- **Two sampling chambers** that can be filled with different alloys (ex: sulphur, inoculant)
- Stable solidification (grey solidification)
- Two thermocouples for cooling curve measurement
- Mostly used for Compacted graphite Iron and Ductile Iron applications
- **Constant sampling volume** and cooling conditions for reproducible results
- Needs an specific cup-holder for 2 Channels Cup.

Can be used for:

- Grey Iron
- Ductile Iron
- Vermicular Iron
- Aluminum

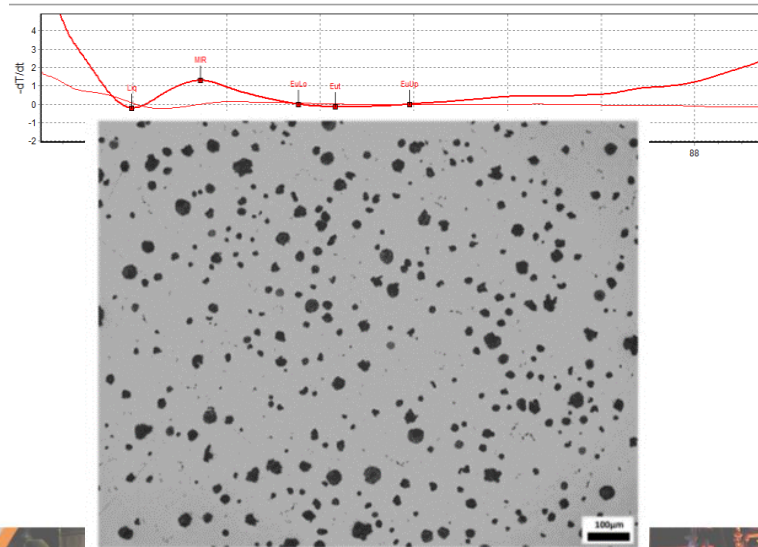
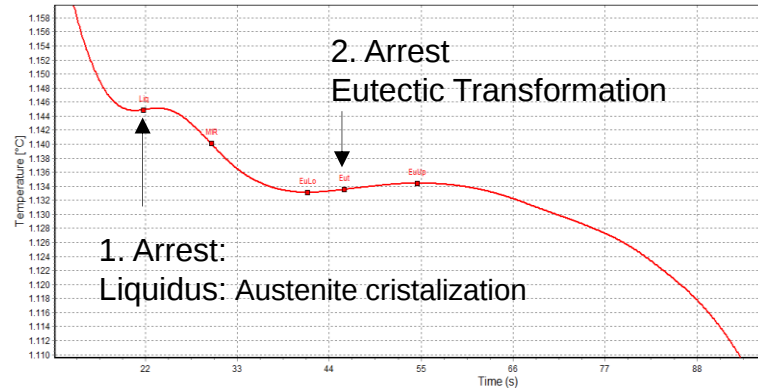




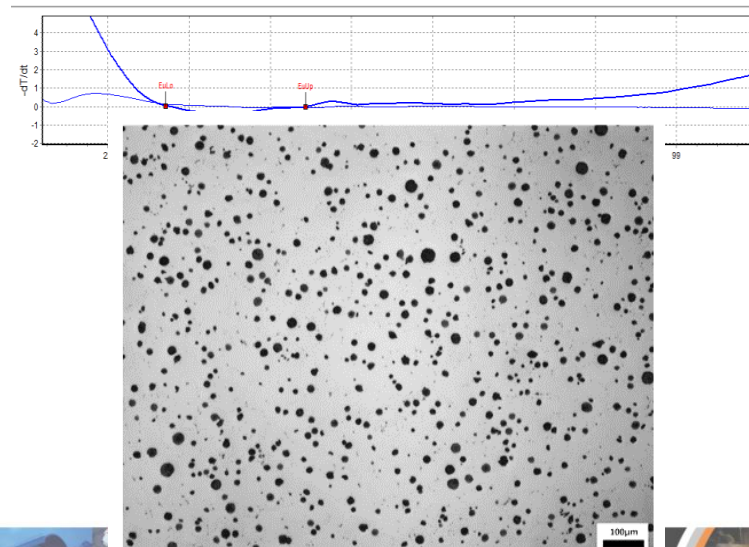
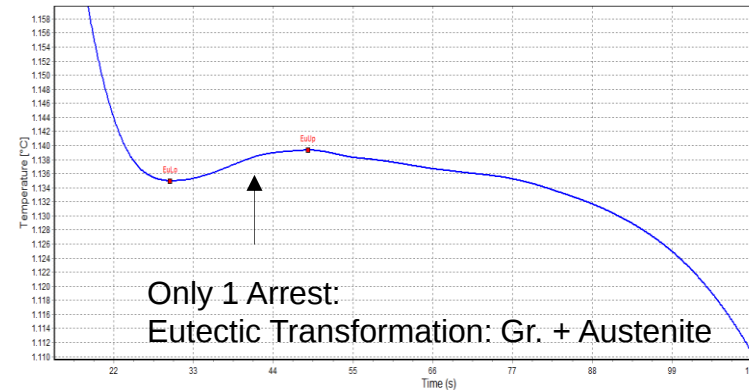
ADVANCED THERMAL ANALYSIS

THE DIFFERENT CURVE PATTERNS? IT'S IMPORTANT!

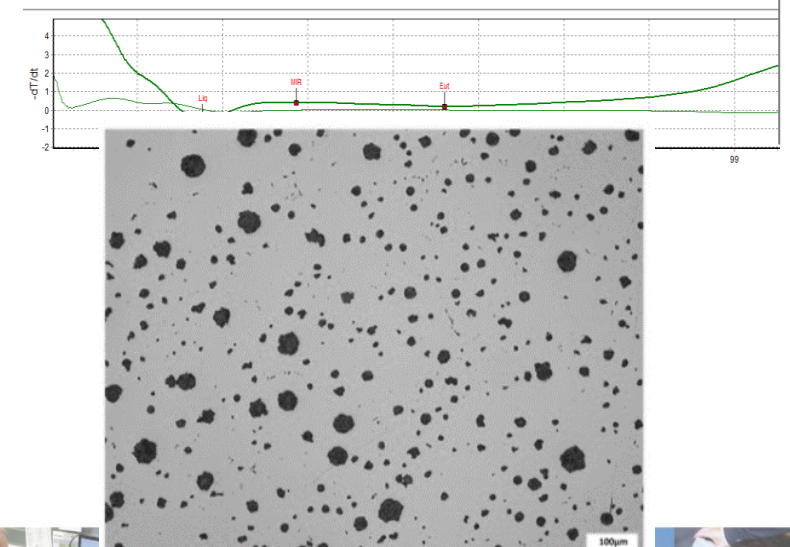
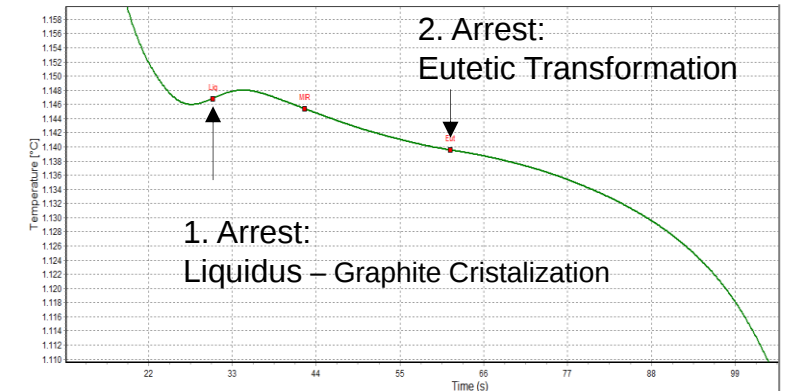
Hypoeutectic



Eutectic



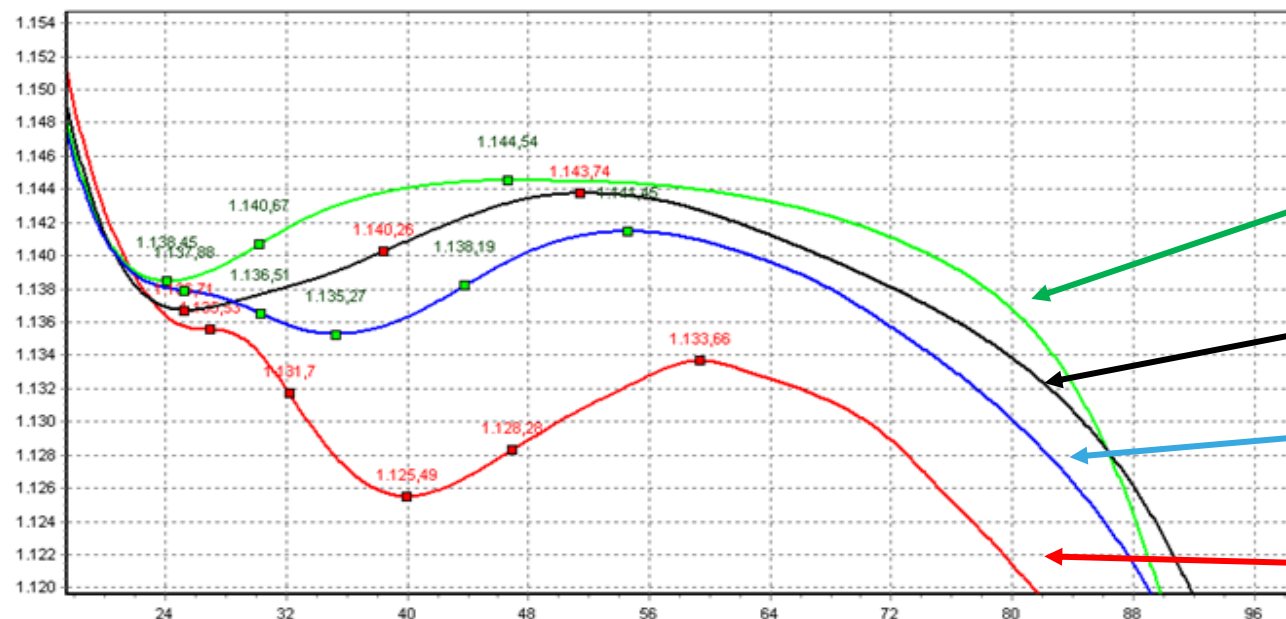
Hypereutectic





ADVANCED THERMAL ANALYSIS

HOW MUCH INOCULANT IS THE MELT NEEDING?

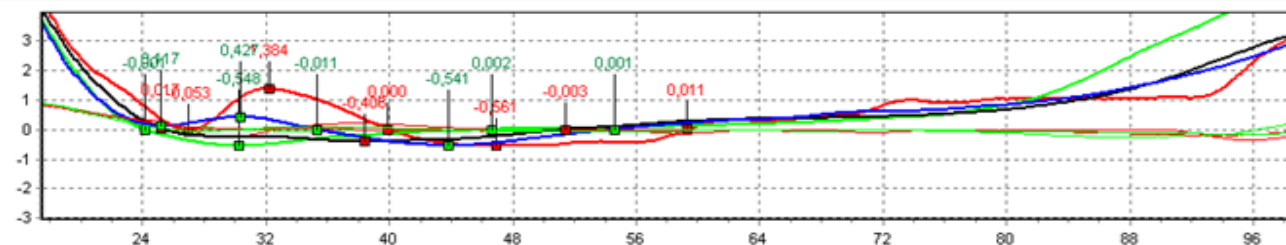


0,15% inoculant added
eutectic

0,10% inoculant added
eutectic

0,05% Inoculant added
Hipoeutectic

No inoculant added
Hipoeutectic with high undercooling



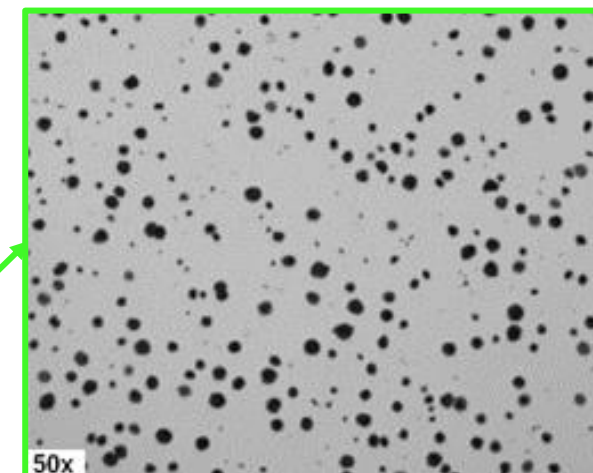
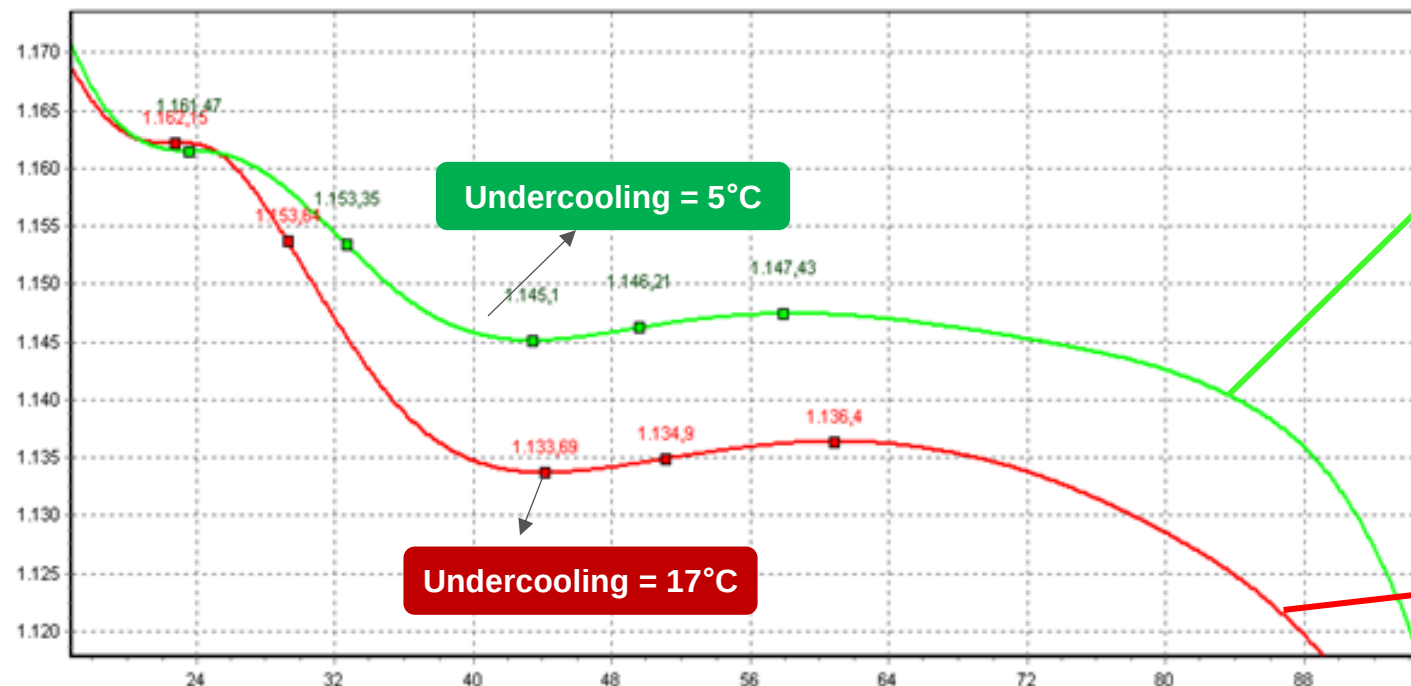
Keep the **eutectic undercooling** as low as possible without changing the curve pattern!
Improving this way the inoculant addition and avoid costs with over inoculation and scrap



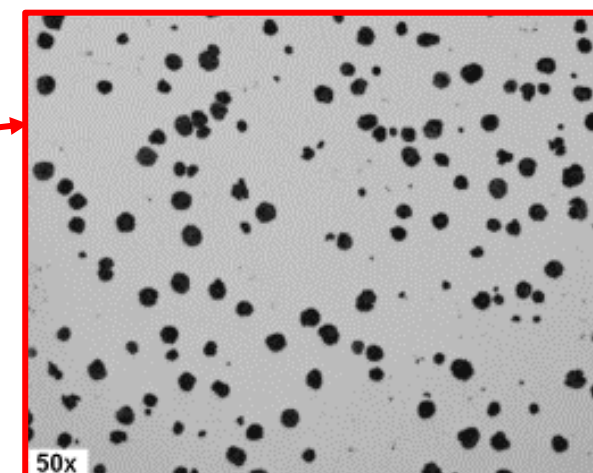


ADVANCED THERMAL ANALYSIS APPLICATION

DUCTILE IRON INOCULATION STATE



Microstructure inoculated chamber
→ Nodule count = 415/mm²



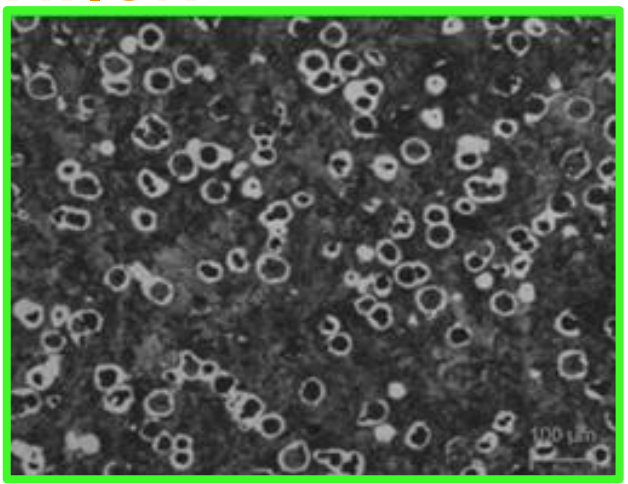
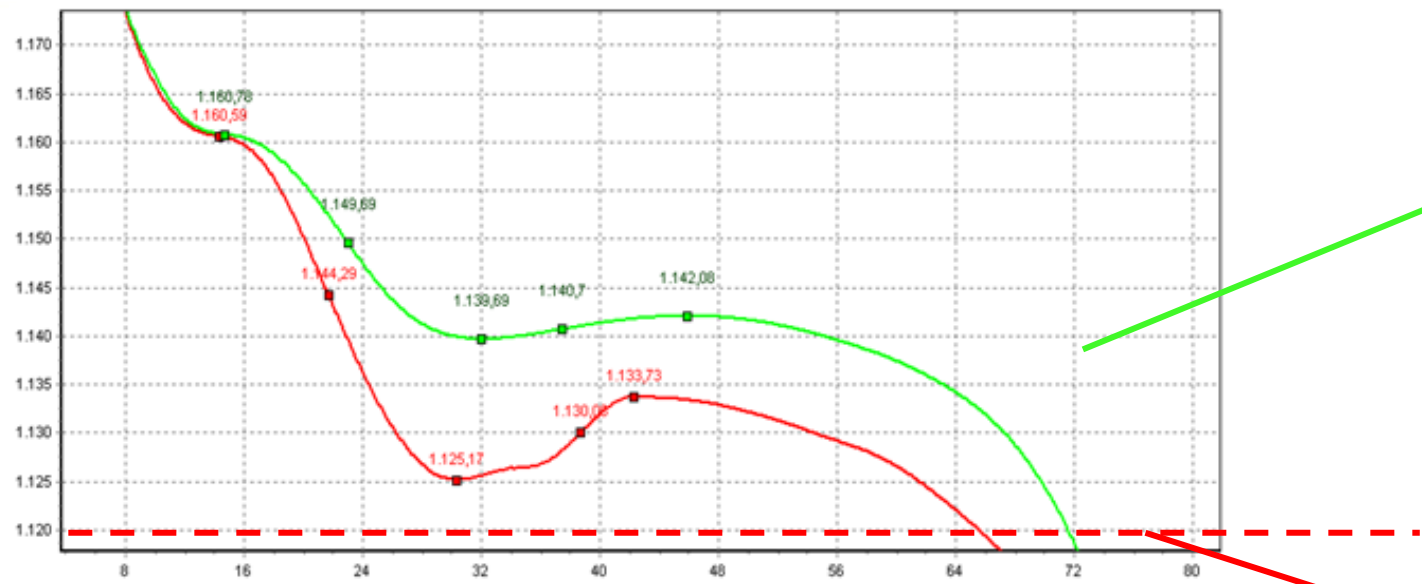
Microstructure inoculated chamber
→ Nodule count = 211/mm²

- Magnesium is OK
- Undercooling is out of range!
 - Increase Inoculant addition in 0,05% to improve Nodule count

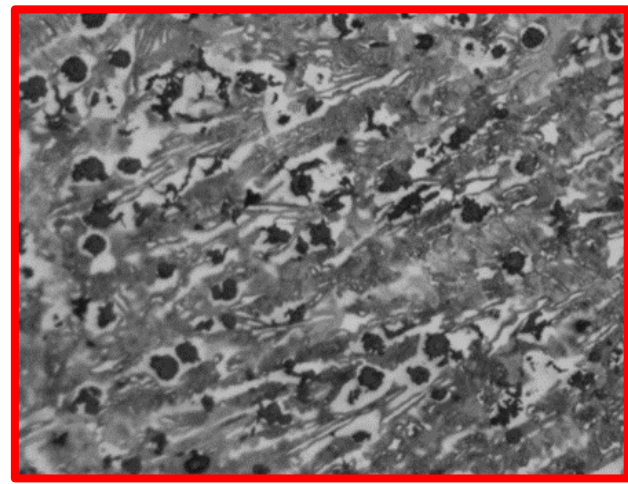


ADVANCED THERMAL ANALYSIS APPLICATION

DUCTILE IRON INOCULATION STATE



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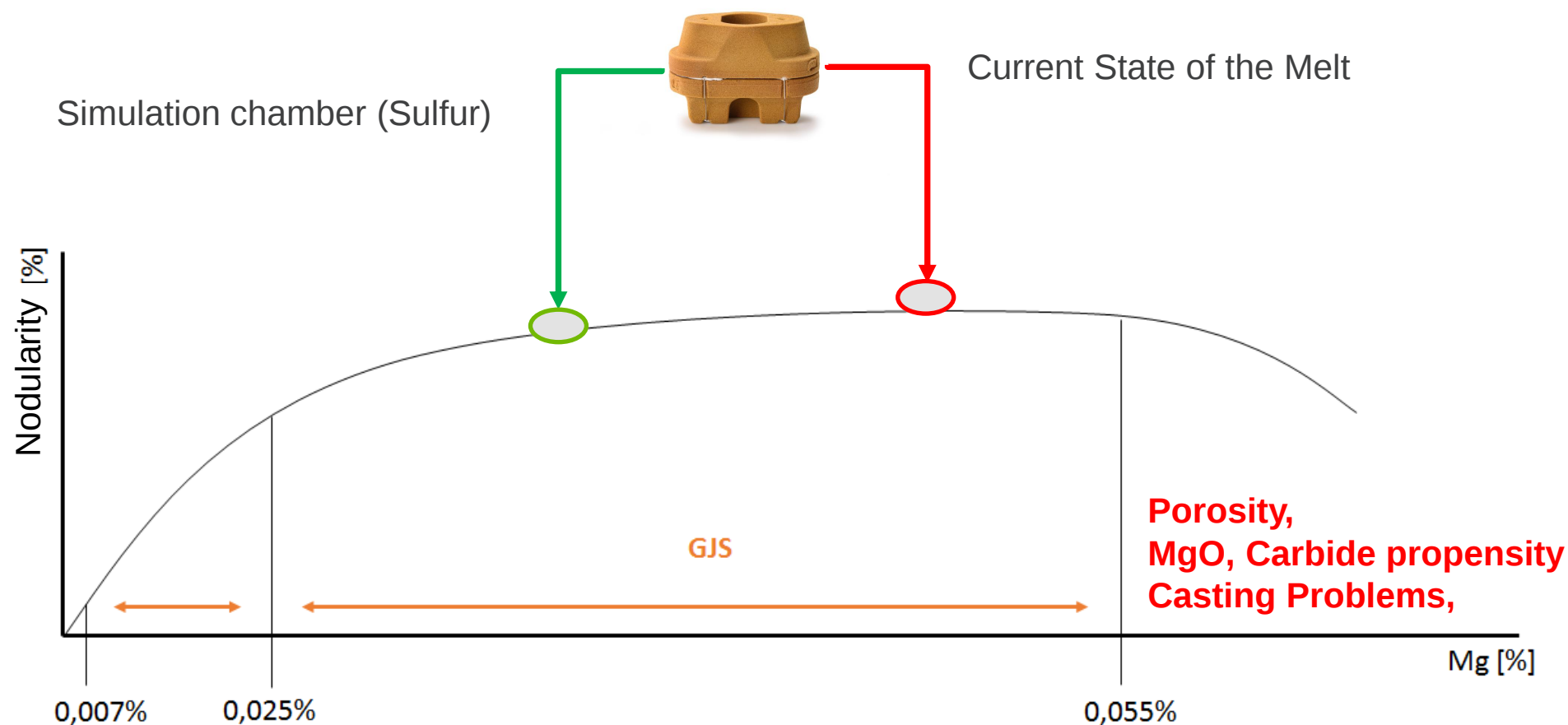
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ADVANCED THERMAL ANALYSIS

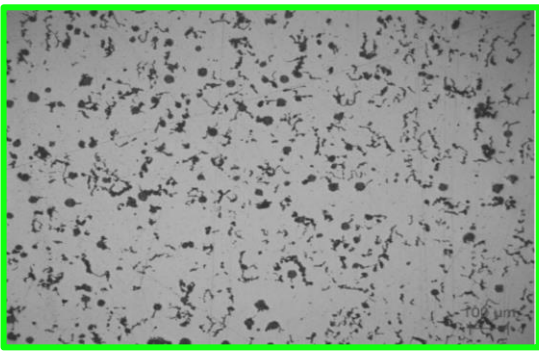
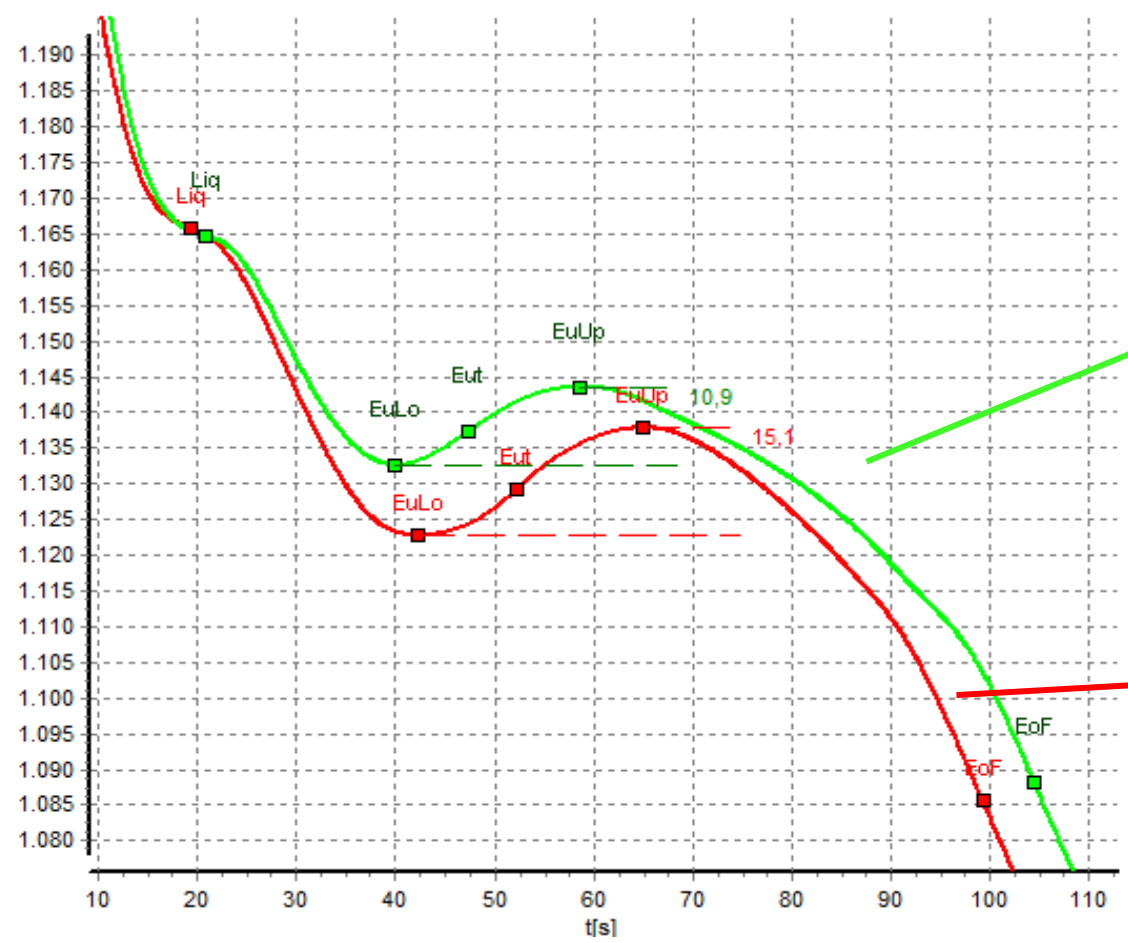
APPLICATION DUCTILE IRON CHECKING MAGNESIUM CONTENT AND NODULARITY



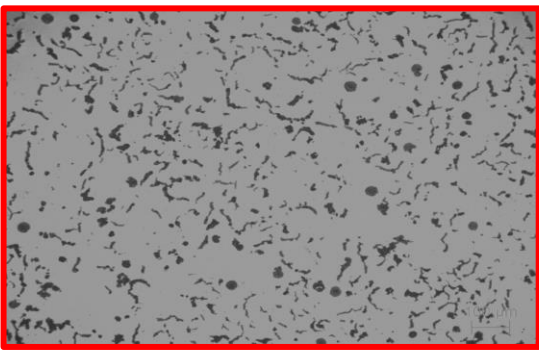


ADVANCED THERMAL ANALYSIS

CHECKING COMPACTED GRAPHITE IRON NODULARITY



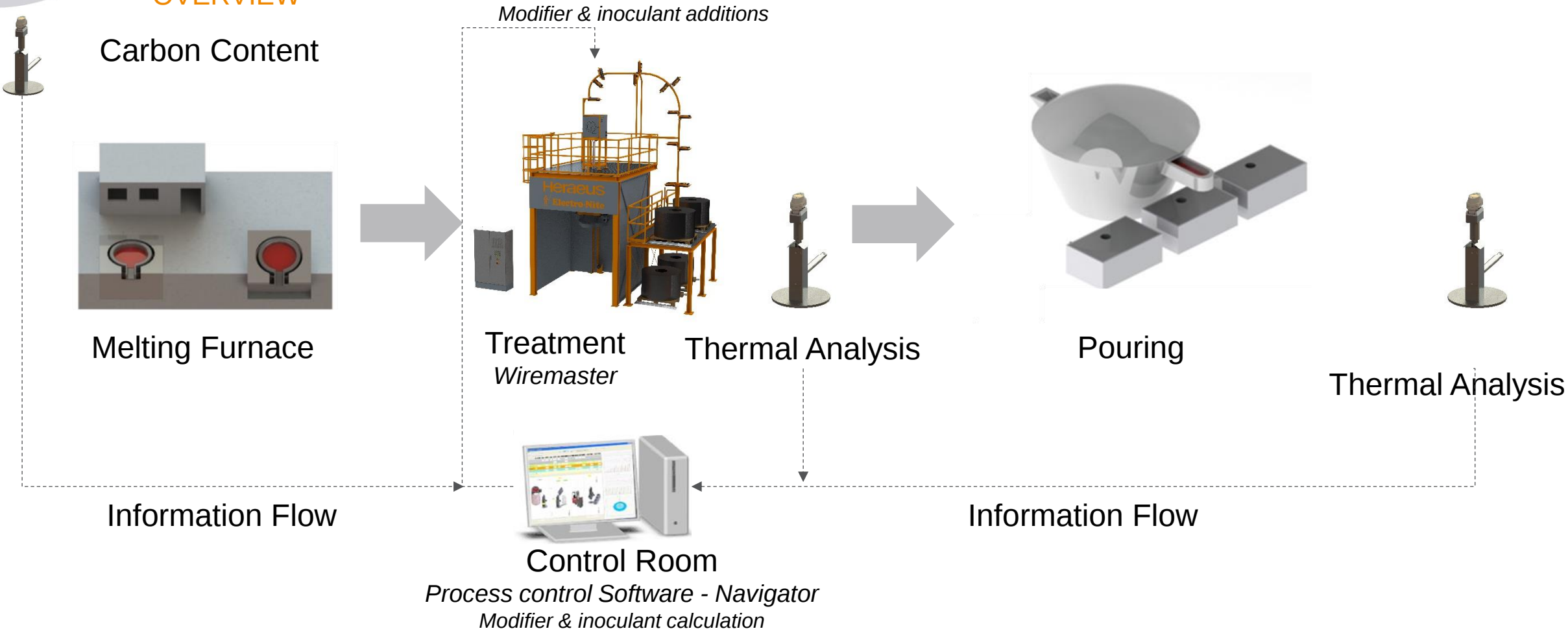
Nodularity [%]: 22



Nodularity [%]: 10

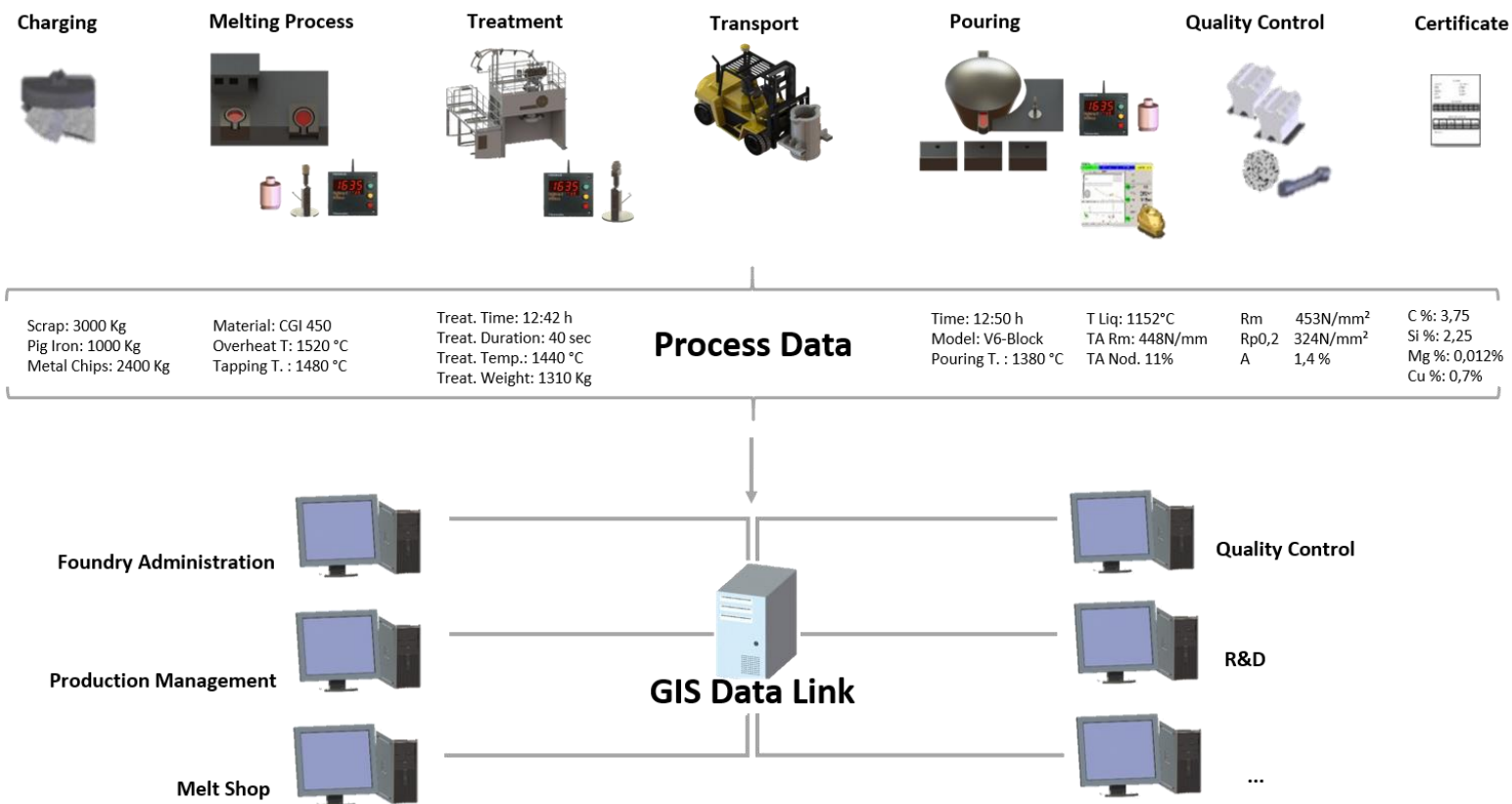


ADVANCED THERMAL ANALYSIS & PROCESS CONTROL OVERVIEW





LOGGING SOFTWARE GIS – FOUNDRY INFORMATION SYSTEM



- Collection, visualization & documentation of all production data
- Connection to HEN instrumentation: DL, DTE, QLE, Celox, WireMaster;
- Optimized information flow
- Control of the production process
- Follow up of the casting process from the base metal preparation until the poured casting
- Modular structure

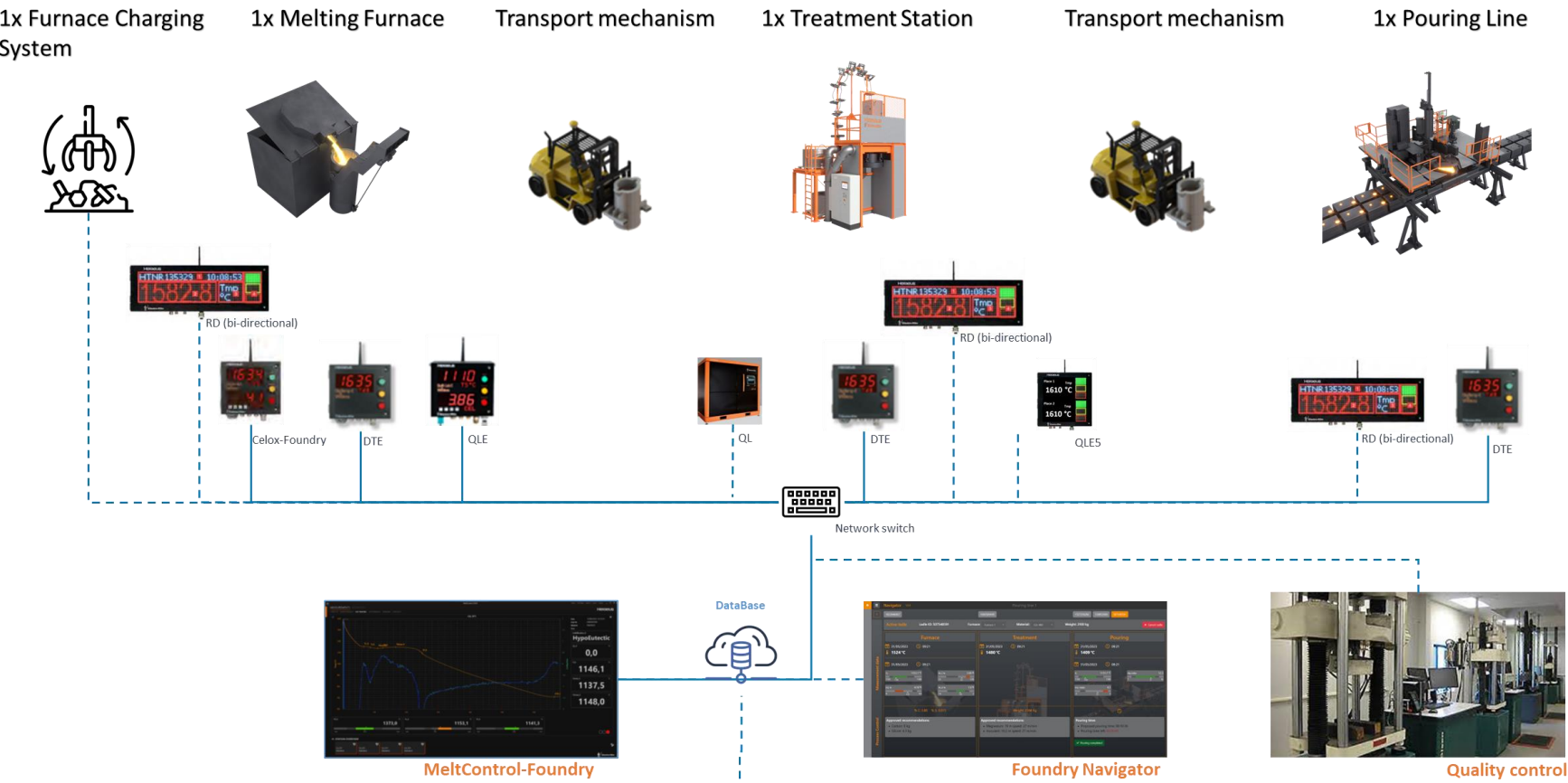
All data is available in the foundry network.





PROCESS CONTROL – A PRACTICAL EXAMPLE AT *UCB UK & SPAIN*

THERMAL ANALYSIS AND MEASUREMENTS IN THE IRON FOUNDRY





WHAT IS MELTCONTROL® FOUNDRY

- MeltControl® Foundry is a digital analysis and data visualization tool for melt quality control in foundries that can be integrated into an existing factory network through a client-server setup
- It displays real-time measurement curves from Heraeus Electro-Nite instruments.
- It provides access to Thermal Analysis and Temperature measurement data.





FEATURES OF MELTCONTROL® FOUNDRY

Some of the MeltControl® features include:

- **Inoculation Index** to evaluate the inoculation/graphitization
- **Nodularity/Mg Index** to evaluate the Mg treatment
- **Correction instructions** for Carbon and Silicon
- **Material master data** with colour coding for values within and outside spec.
- **Customizable dashboard** to display those parameters that are critical for your process





FOUNDRY INSTRUMENTATION FOR TEMPERATURE AND THERMAL ANALYSIS





2 CHANNEL THERMO-STACK CUP AND WIRELESS TRANSMISSION

