# Table of contents

1 Introduction .......................................................................................................................... 2
2 Pouring ladle process .......................................................................................................... 4
3 Pouring furnace process ...................................................................................................... 5
4 System communication ........................................................................................................ 6
   4.1 System input 1 – Base Iron Information ...................................................................... 7
   4.2 System input 2 – Ladle Treatment ............................................................................... 7
   4.3 System input 3 – Pouring (Optional) ........................................................................... 7
   4.4 System Output 1 – Treatment additions .................................................................... 7
   4.5 System Output 2 – Display information ..................................................................... 7
5 Therm-O-Stack cup .............................................................................................................. 8
6 PhaseLab .............................................................................................................................. 9
   6.1 PhaseLab Basic .......................................................................................................... 9
   6.2 PhaseLab Navigator .................................................................................................... 10
7 CGI-Navigator ...................................................................................................................... 11
8 WireMaster .......................................................................................................................... 13
9 Display ................................................................................................................................ 15
Contact .................................................................................................................................. 18

Appendix A: Reference customers ........................................................................................ XIX
   Appendix A.I: Fritz Winter GmbH & Co. KG, Stadtallendorf, Germany .......................... XIX
   Appendix A.II: MAN Truck & Bus Deutschland GmbH, Nuremberg, Germany ............... XX
   Appendix A.III: Sinotruk, Jinan, China ............................................................................ XXI
   Appendix A.IV: Gienanth GmbH, Eisenberg, Germany .................................................. XXII
1 Introduction

The CGI/SG-Process is a complete process control system for the production of compacted graphite iron (CGI). The process is based on high precision thermal analysis technique, using the Therm-O-Stack CGI cup and the PhaseLab software, including a complete process control, documentation and data handling with the help of the CGI-Navigator software.

The process follows the procedure established in the diagram of the picture 1.1, presenting both production options, pouring furnace and pouring ladle.

The system’s features:

- Fully automated process control using cored wire machines
- Applicable for ladle & pouring furnace process
- High precision in casting properties
- Sound castings due to stable metallurgy
- Single step method for high production throughput
- Cost efficient in running expenses
- Metallurgical support in every aspect
- All process data is online visible throughout the foundry
- Modules for laboratory data handling and image analysis are available in one package
The CGI/SG-Process is composed by a group of products that communicate automatically between each other, being the following:

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PhaseLab-Basic</strong></td>
<td>Thermal analysis program to be used at the melting furnace or holding furnace.</td>
<td>Measures the liquidus temperature, C.E. [%], C [%], Si [%] from base iron.</td>
</tr>
<tr>
<td><strong>PhaseLab-Navigator</strong></td>
<td>Thermal analysis program to be used at the treatment station or pouring line.</td>
<td>Measures the liquidus temperature after treatment, as well as the complete cooling curve and all important parameters for the treatment efficiency evaluation.</td>
</tr>
<tr>
<td><strong>Therm-O-Stack Cup</strong></td>
<td>Thermal analysis cup to be used at the PhaseLab-Navigator station.</td>
<td>Defined volume cup, for iron sampling after treatment. Allows a high precision data acquisition from the solidification of the sample.</td>
</tr>
<tr>
<td><strong>CGI Navigator</strong></td>
<td>Process control and documentation software.</td>
<td>Software to evaluate the metallurgical quality of the melt after treatment, by means of magnesium and inoculant indexes, as well as the calculations of Mg and Inoculant wire needed for the treatment. The software also communicates directly with the PhaseLab, the Wire-Master and the display.</td>
</tr>
<tr>
<td><strong>Display</strong></td>
<td>Industrial Display for the foundry floor.</td>
<td>Display to provide information about the production steps to be followed in order to organize the operators.</td>
</tr>
<tr>
<td><strong>Wire-Master</strong></td>
<td>Cored-wire feeding machine for both Mg and Inoculation treatment.</td>
<td>Double-headed cored wire machine for the addition of the Mg and Inoculant wires for the ladle treatment. The machine has a direct exhaust system and has direct communication with the CGI-Navigator software.</td>
</tr>
</tbody>
</table>

Table 1.1: Short description of the products composing the CGI/SG-Process
2 Pouring ladle process

The base melt is prepared according to the required specifications. The melt is then tapped to a ladle, carbon, copper and tin additions can be performed at this step in order to adjust the melt to a specific grade. In the following step, the ladle is transported to the treatment station were the magnesium and inoculant wire additions will be performed.

The magnesium and inoculant wire additions are calculated by the CGI-Navigator. This software is responsible for the control, documentation and optimization of the process.

After the treatment a thermal analysis sample is poured, with the help of a Therm-O-Stack Cup, and a curve is obtain in the PhaseLab software. The CGI-Navigator uses the data from this software and will determine if the melt state is in target conditions to be poured and, at the same time, calculates the additions for the following ladle.

If a new furnace melt is tapped, the system will perform a two-step treatment:

• A standard addition of magnesium and inoculant is performed that guarantees the melt to be undertreated for the CGI target conditions
• A thermal analysis is then made to help the system to calculate the magnesium and inoculant corrections

This will help the system to ensure that the new melt will be on the CGI target conditions, consequently minimizing the variation of the new melt in the process, thus achieving a single-step addition for the following ladles.

The highpoints of the CGI/SG system for a pouring ladle process are:

• Complete control and documentation of the process
• High flexibility, small volumes of different material grades can be produced
• One-step treatment achieved with optimization algorithm
• No pre-conditioning with Magnesium alloy needed
• Feedback loop from previous treatments to compensate changes in the base iron
• Control over the magnesium and inoculant fading until end of pouring possible
3 Pouring furnace process

The CGI production with pouring furnace is gaining more and more importance in the automotive series manufacturing. The treatment performed with cored magnesium and inoculant wires makes it easy to automate the process.

The process starts in the base melt that is prepared according to the required specifications and then tapped to a ladle. The ladle is transported to the treatment station where the additions of magnesium and inoculant wires will be performed. After the treatment the ladle is poured into the pouring furnace being added to the already existent melt. A thermal analysis is performed with the purpose of evaluate the melt state for CGI target conditions. The CGI-Navigator calculates the additions to be made, based on the metallurgical state of melt that is inside of the pouring furnace, sending this information to the treatment station. The next ladle will be treated according to the requirements of the melt in pouring furnace.

The highpoints of the CGI/SG system for a pouring furnace process are:

- Optimal adjustment of the metallurgical parameters
- High cast throughput
- Long filling cycle times on low pouring weights possible
- Correction to the furnace with every new ladle, even after breakdown
- Analysis of the iron in pouring condition from the pouring spout
- One furnace analysis after each filling, no ladle analysis needed
- Pouring furnaces can be used for CGI and SG production in turn
4 System communication

The CGI-process from Heraeus Electro-Nite is composed by the several elements mentioned in chapter 1, and the following image informs about the information flow inside the CGI/SG-Process.

The Figure 4.1 shows the information flow and communication between the several components of the system for CGI production. The several steps are described in the following sub-chapters.
4.1 System input 1 – Base Iron Information

The input 1 consists on the Thermal Analysis (Liq. Temperature, C.E [%], C [%] and Si [%]) and spectrometer information from base iron. This data is acquired by the cabinet positioned at the melting shop. The input 1.1 refers to the transfer of this information to the main control cabinet, where the CGI-Navigator software is operating.

4.2 System input 2 – Ladle Treatment

The Input 2 consists on information coming from the treatment step, related with the treatment temperature and the thermal analysis data from the last treated ladle. This information is used to evaluate the efficiency of the treatment and to calculate the needed addition to the following ladle. The data is automatically sent into the CGI-Navigator software.

4.3 System input 3 – Pouring (Optional)

The Input 3 consists on information (thermal analysis and temperature) coming from the ladle at the pouring line (before or after pouring). This information is used to evaluate the fading rate of the magnesium and also as a quality control parameter. The data is automatically transferred into the CGI-Navigator.

4.4 System Output 1 – Treatment additions

The Output 1 consists on the additions (in meters) of magnesium-wire and inoculant-wire to be added into the next ladle to be treated. These additions are automatically calculated by the CGI-Navigator software based on the various input data.

The Output 1 information is automatically sent into the control-cabinet of the wire-feeder-machine (Wire-Master), so that the needed wire lengths for the treatment are ready before the ladle arrives at the station.

4.5 System Output 2 – Display information

The Output 2 information consists of multiple messages to the operators at the foundry floor, organizing their actions and giving updates on the production status.
5 Therm-O-Stack cup

The thermal analysis system for the CGI production is based on the Therm-O-Stack CGI Cup and PhaseLab software.

The Therm-O-Stack CGI Cup is a dual chamber cup for thermal analysis. This cup has opened new possibilities in the foundries for the monitoring and control of metallurgical melting and casting processes.

It ensures a constant sample volume and a predictable heat transfer until the eutectoid transformation. Due to its structure, eliminates influences such as different filling heights and thus different sample masses and modules. The binder specially developed for this application prevents the disintegration of the cup and therefore a change of the heat flow, as usually occurs with conventional open cups after a certain period of time. The Figure 5.1 shows a Therm-O-Stack CGI cup in detail.

![Therm-O-Stack cup](image)

In the second chamber it can be introduced a nucleating agent in order to test the inoculation capability of iron. Through the use of inoculants it can be simulated, for example, the influence of late inoculation.

With a module of 0.5 cm, it allows the analysis of cast iron melts until the eutectic solidification within approximately 80 seconds.
6 PhaseLab

The PhaseLab software is the interface and data acquirement program for the thermal analysis system. The cooling curves are displayed and all the parameters concerning to the curve characteristics are determined. A screenshot from the program is presented in the Figure 6.1.

![Screenshot from the program PhaseLab, showing two CGI thermal analyses curves](image)

Figure 6.1: Screenshot from the program PhaseLab, showing two CGI thermal analyses curves

The PhaseLab measures the metallurgical parameters of a melt from which the CGI-Navigator determines the metallurgical quality of the melt. The software is provided in two different versions, PhaseLab-Basic and PhaseLab-Navigator, depending on the applications required.

6.1 PhaseLab Basic

The PhaseLab- Basic is a thermal analysis system for determining the base iron conditions. It features:

- The determination of CE-value, %C and Si% as well as the liquidus and eutectic temperature
- Flexible configuration, up to 6 stations in one PC
- Display of measuring values with additional LED indicators
- Expandable measuring channels for temperature measurement spears
- Indication of the measurement process via light signals and horns
6.2 PhaseLab Navigator

The PhaseLab-Navigator offers a modular design which enables thermal analysis and temperature measurement to be customized to your melting and casting operations. The user interface as well as the calculation formulas can be freely configured by the user.

It features:

- CGI and SG modules
- Up to 6 stations per PC
- Curve analysis based on function approximation
- Analysis of the temperature / time curve and the 1st, 2nd and 3rd derivation
- Determining the following sections of the cooling curve:
  - Pre-Liquidus Phase
  - Liquidus Phase
  - End-of-freezing Phase
  - Eutectic solidification Phase
  - Perlite/Ferrite Transformation
- Determination of the solidification type:
  - Hypoeutectic
  - Eutectic
  - Hypereutectic
7 CGI-Navigator

The CGI-Navigator serves as the control center in the CGI process. It collects all process-relevant data, e.g. from thermal and spectral analysis, and calculates the additions for the next treatment. Individual calculation models can be added into the system. Based on the current process status and the preceding steps, the CGI-Navigator gives directives that can be configured individually. It combines the entire process data from wire feeders, dosing facilities and melting/pouring process.

A well-arranged display of the relevant information allows the operator to have a quick overview of the process status and progress. Figure 7.1 shows a screenshot of the program calculator interface.

![Figure 7.1: Screenshot from the “Calculator” window from the program CGI-Navigator](image-url)
To analyse the production data, the report function can filter the data for single castings and arrange the process parameters in clear time lines and charts as in the example from the Figure 7.2.

The complete information of the process is saved in a database and directly provided in the program window. The Figure 7.3 shows a screenshot of the process documentation window.
8 WireMaster

The WireMaster DualTrack is a double headed cored wire addition machine for the ladle treatment that adds the magnesium wire and inoculant wire (Figure 8.1 (a)). The machine is controlled by a control cabinet (Figure 8.1 (b)), placed next to the machine, that receives the treatment parameters directly from the CGI-Navigator software.

Hanging at the side of the wire machine, there is a small control panel to be used by the operator to start the treatment. The operator does not type in any additions, once these are automatically transferred by the CGI-Navigator into the control cabinet.

The following diagram (Figure 8.2) explains step-by-step how the use of the wire-machine is done during production.

The wire-machine construction is projected to fit the customers ladle and available area. The wires used for the treatment have a 13mm diameter.
Figure 8.2: Diagram for the action performed at the treatment step
9 Display

In order to organize the operator’s work during the production, and provide easy-to-see information about the ongoing process, an industrial display is installed (Figure 9.1), normally close to the treatment machine, to provide the following information:

- Tapping weight for the next process cycle;
- Request to measure the treatment temperature;
- Measured treatment temperature;
- Calculated magnesium and inoculant wire additions;
- Request to take the Thermal analysis sample after the treatment;
- Result from the thermal analysis evaluation;
- “OK” or “not OK” information to go to pouring.

The information showed at the displays, is sent by the CGI-Navigator software.
List of figures

Figure 1.1: CGI/SG-Process practice for pouring furnace, following the blue arrows, and for pouring ladle which follows the green arrows ................................................................. 2
Figure 4.1: Diagram with the communication flow at the CGI/SG-Process ......................... 6
Figure 5.1: Therm-O-Stack cup ......................................................................................... 8
Figure 6.1: Screenshot from the program PhaseLab, showing two CGI thermal analyses curves ......................................................................................................................... 9
Figure 7.1: Screenshot from the “Calculator” window from the program CGI-Navigator ....... 11
Figure 7.2: Screenshot from the process chart window from the program CGI Navigator ..... 12
Figure 7.3: Screenshot of the process documentation window ........................................... 12
Figure 8.1: a) Wire treatment machine; b) Control cabinet .................................................. 13
Figure 8.2: Diagram for the action performed at the treatment step ....................................... 14
Figure 9.1: Industrial display at the wire machine, controlled by the CGI-Navigator .......... 15
Figure 9.2: Industrial display at the pouring line, controlled by the CGI-Navigator .......... 15
List of tables

Table 1.1: Short description of the products composing the CGI/SG-Process ....................... 3
Contact

Heraeus Electro-Nite GmbH & Co. KG
Eickener Str.111
41063 Mönchengladbach

Telefon: +49-2161-948869-0
Fax: +49-2161-948869-1
Web: www.electro-nite.de

Persönlich haftender Gesellschafter: Heraeus Electro-Nite Verwaltungsgesellschaft mbH, Hanau
Geschäftsführer: Ralf Kopacki
Registergericht: Hanau HRB 6289
Sitz der Gesellschaft: Hanau
Registergericht Hanau HRA 5325
Ust-Id-Nr.: DE 812588745
Appendix A: Reference customers

Appendix A.I: Fritz Winter GmbH & Co. KG, Stadtallendorf, Germany

Casting: Cylinder Head
Model: DAF MX Cylinder head
Cylinder Capacity: 12.9l
Weight: 250Kg
Foundry: FW, Stadtallendorf
Casting: Cylinder Head
Model: D 20
Weight: 27.5Kg
Foundry: MAN Nürnberg
Appendix A.III: Sinotruk, Jinan, China

Casting: Engine block
Model: D20, D26
Cylinder capacity: 10l, 12l
Weight: 310 Kg
Castings per year: 80 000
Foundry: Jinan, China
Casting: Clutch disc
Weight: 2,5Kg
Foundry: Eisenberg
Appendix B: Metallurgical parameters CGI Production

Appendix B.I: Base iron composition (induction furnace or holding furnace)

<table>
<thead>
<tr>
<th>Element</th>
<th>Min amount [%]</th>
<th>Max amount [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>3,40</td>
<td>3,55</td>
</tr>
<tr>
<td>Si</td>
<td>2,00</td>
<td>2,10</td>
</tr>
<tr>
<td>S</td>
<td>0,010</td>
<td>0,015</td>
</tr>
<tr>
<td>P</td>
<td>0,0</td>
<td>0,025</td>
</tr>
<tr>
<td>Cu</td>
<td>0,0</td>
<td>According to CGI grade</td>
</tr>
<tr>
<td>Mn</td>
<td>0,0</td>
<td>0,35</td>
</tr>
<tr>
<td>Cr</td>
<td>0,0</td>
<td>0,08</td>
</tr>
<tr>
<td>Mo</td>
<td>0,0</td>
<td>0,02</td>
</tr>
<tr>
<td>Pb</td>
<td>0,0</td>
<td>0,002</td>
</tr>
<tr>
<td>Ti</td>
<td>0,0</td>
<td>0,02</td>
</tr>
<tr>
<td>Al</td>
<td>0,0</td>
<td>0,004</td>
</tr>
</tbody>
</table>

Appendix B.II: Creation of the base iron

The base iron for the CGI production can be created directly as a synthetic composition. There is no need for using pig iron or SiC additions to obtain a special metallurgical state of the iron. There may be a limitation in the usage of returns, due to the agglomeration of Cerium and Lanthanum. These limitations will be individually discussed between the Heraeus metallurgist and the customer.

If the low sulphur levels can’t be obtained, Heraeus will suggest a pre desulphurization step. This can be done by the wire machine, too. Just a special low Cerium desulphurization wire is needed for this process step.
Appendix B.III: Ladle or furnace process

If a grey iron pouring furnace is available and cost effective, Heraeus recommends this unit for the usage in the production trials and future production. The furnace can be initiated by rinsing it with a high Magnesium and Cerium containing melt prior to the CGI process. Solely the rate of flow through the induction system must be monitored, due to slag formation with the Magnesium containing charge. This slag is normally diminished in later grey iron production phases.

Appendix B.IV: Wires

Depending on the country, Heraeus will recommend two wire suppliers for you to choose an optimal solution.
Appendix C: Metallurgical parameters SG Production

Appendix C.I: Appendix B.I: Base iron composition
(induction furnace or holding furnace)

<table>
<thead>
<tr>
<th>Element</th>
<th>Min amount [%]</th>
<th>Max amount [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>3,40</td>
<td>3,55</td>
</tr>
<tr>
<td>Si</td>
<td>2,00</td>
<td>2,10</td>
</tr>
<tr>
<td>S</td>
<td>0,010</td>
<td>0,110</td>
</tr>
<tr>
<td>P</td>
<td>0,0</td>
<td>0,025</td>
</tr>
<tr>
<td>Cu</td>
<td>0,0</td>
<td>According to grade</td>
</tr>
<tr>
<td>Mn</td>
<td>0,0</td>
<td>0,35</td>
</tr>
<tr>
<td>Cr</td>
<td>0,0</td>
<td>0,08</td>
</tr>
<tr>
<td>Mo</td>
<td>0,0</td>
<td>0,02</td>
</tr>
<tr>
<td>Pb</td>
<td>0,0</td>
<td>0,002</td>
</tr>
<tr>
<td>Ti</td>
<td>0,0</td>
<td>0,02</td>
</tr>
<tr>
<td>Al</td>
<td>0,0</td>
<td>0,004</td>
</tr>
</tbody>
</table>

Appendix C.II: Creation of the base iron

The base iron for the CGI production can be created directly as a synthetic composition. There is no need for using pig iron or SiC additions to obtain a special metallurgical state of the iron. There may be a limitation in the usage of returns, due to the agglomeration of unwanted elements. These limitations will be individually discussed between the Heraeus metallurgist and the customer.

Appendix C.III: Wires

Depending on the country, Heraeus will recommend two wire suppliers for you to choose an optimal solution.