Steel production

- Furnace linings made from carbon and graphite are applied for the production of primary iron.

- Graphite electrodes and nipples (connecting pins) are applied for the production of steel. Their production is similar to the graphite production. After the baking process (for carbon material) and/or the graphitization process (for graphite) the material is machined within well-defined tolerances on length and diameter. The nipples and sockets are threaded to assure optimal electrode nipple joining.

Intro

Make your own steel – online!
Production process of Electrodes
Steel Production: intro

- Steel is one of the most important and widely used products in the world. Currently, the steel industry is undergoing a process of change. As a result of ongoing technical and economic developments, the production and use of electric arc furnace steel is, beneath the steel production in a blast furnace, becoming increasingly important, continuously gaining share of world-wide steel production over the past 30 years.

- For the manufacture of graphite electrodes for the use in the EAF selected coal-tar or petrol cokes are crushed, milled and sieved to sort it by the specific different particle size fractions. Depending on the end use different fractions are mixed together with a liquid coal tar pitch as a binder. This mix is extruded into a green product with the near final shape and dimension of the resulting electrode. This rods are baked to approx. 800°C - 1000°C and according to the needs for the final quality of the electrode impregnated with an petroleum pitch and rebaked. Than the graphitisation step follows where the material is graphitized by heating it up to 3000°C.
Crude Steel Production in the World

Crude Steel Production in the World

Source: IISI-Statistics
Steelmaking Process Chain

Raw Material

Scrap metal
Direct reduced iron (DRI)
Hot metal

Melting in an EAF

Secondary Metallurgy (LF)

Continuous Casting

Rolling

Finished Products
EAF Process

CHARGING
- Scrap
- Direct reduced iron

MELTING
Addition of oxygen and/or fuels

OXIDATION PHASE
Oxidic slag for picking up undesired tramp elements (addition lime, coke)

REDUCTION PHASE
- Reducing slag for oxygen and sulphur removal
- Addition of alloying elements

TAP

STEEL
Electric Arc Furnace (EAF)

Scheme of an Electric Arc Furnace

Electric Arc Furnace in use
Due to different wear mechanisms, the length of the electrode is reduced during the process. In order to keep the arc (1) stable, the height of the electrode has to be readjusted continuously.

Electrode Regulation

Impedance $Z = \frac{U_{sec}}{J}$
Due to the different wear mechanisms the electrode used in the EAF has to meet the following criteria:

1. Good electrical conductivity in order to withstand the high current density required by the metallurgical process
2. High thermal conductivity to minimise the temperature differences inside the electrodes when in use and, consequently, to reduce internal stresses
3. Low thermal expansion resulting in high thermal stress resistance
4. Strength at high temperatures to withstand the stresses when in use
5. Chemical inertness and non-wetting to glass and most metals

<table>
<thead>
<tr>
<th>Material Parameter</th>
<th>Graphite Electrode (top performance 800mm)</th>
<th>Carbon Electrode (typical values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent density</td>
<td>1.69 – 1.75 g/cm³</td>
<td>1.6 – 1.7 g/cm³</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>10 – 14 N/mm²</td>
<td>4 – 7 N/mm²</td>
</tr>
<tr>
<td>Spez. electr. resistance</td>
<td>4.0 – 4.8 Ωµm</td>
<td>22 – 36 Ωµm</td>
</tr>
<tr>
<td>Coefficient of thermal expansion</td>
<td>0.3 – 0.6 x 10⁻⁶ K⁻¹</td>
<td>1.2 – 2.5 x 10⁻⁶ K⁻¹</td>
</tr>
</tbody>
</table>
Wear Mechanisms for an Electrode in Use

Continuous Wear
- Surface oxidation
- Tip Sublimation
- approx. 10,000 °C
- 30 A/cm²

Discontinuous Wear
- Stub end Loss
- Electrode Break:
  - Nipple
  - Socket
  - Body
  - loosening

On
Off
Production Process of Electrodes

The electrode Production:

- Mixing and Extrusion
- Baking
- Impregnation and Rebaking
- Graphitization
- Machining
Mixing and Extrusion

The milled coke (for graphite electrode primary needle coke is used) is mixed with coal tar pitch and some additives to form a uniform paste. This is brought into the extrusion cylinder. In a first step the air has to be removed by prepressing. Than the actual extrusion step follows where the mixture is extruded to form an electrode of the desired diameter and length.

To enable the mixing and especially the extrusion process (see picture on the right) the mixture has to be viscous. This is achieved by keeping it at elevated temperature of approx. 120°C (depending on the pitch) during the whole green production process.

Scheme of the extrusion process
Two types of baking furnaces are in use:

**Carbottom furnace:**
Here the extruded rods are placed in cylindrical stainless steel canisters (saggers). To avoid the deformation of the electrodes during the heating process the saggers are also filled with a protecting covering of sand. The saggers are loaded on railcar platforms (carbottoms) and rolled into natural gas-fired kilns.

**Ring furnace:**
Here the electrodes are placed in a stone covert cavity in the bottom of the production hall. This cavity is part of a ring system of more than 10 chambers. The chambers are connected together with a hot air circulation system to save energy. The voids between the electrodes are also filled with sand to avoid deformation.

During the baking process, where the pitch is carbonised, the temperature has to be controlled carefully because at the temperatures up to 800°C a rapid gas build up can cause cracking of the electrode.
Impregnation and Rebaking

Due to the outgasing during the baking process the electrode is porous with a low density.

Therefore an impregnation step is added where the electrode is loaded with up to 13% of pitch, which is carbonised in another rebaking process step.
Blast Furnace

Furnace linings made from carbon and graphite are applied for the production of primary iron. In a blast furnace iron is produced by the reduction of iron-ore by coke at high temperatures up to 1900°C:

$$\text{Fe}_2\text{O}_3 + 3 \text{ CO} \leftrightarrow 2 \text{ Fe} + 3 \text{ CO}_2$$

The typical height of a blast furnace is 20 – 30 m with a diameter of 15 m. The wall-thickness ranges from 0.5 m to 1.2 m. The load capacity is 300 – 1000 m$^3$. Modern blast furnaces can produce up to 11,000 metric tons of iron per day.

Due to the high temperatures and the reducing atmosphere carbon products are used for the coating of the inner walls of the blast furnaces. The life time of the inner walls is about 10 years. After this period the furnace has to be coated again completely.

Different parts of the furnace need furnace linings of different quality and grade of graphitization.
Furnace Linings

Machining:
The production of these furnace linings is in principle similar to the production of electrodes and anodes. The small tolerances for the dimensions and the individual shape of each furnace lining make high demands on the experience of the producer.

Final Checking:
Before being shipped to the customer the furnace linings are mounted on a special joggling plate in order to check whether the joint between the furnace linings fulfils the tolerance for a maximum of the gap of 0.2 mm.
Example for the Mounting of Furnace Linings
UNDER CONSTRUCTION