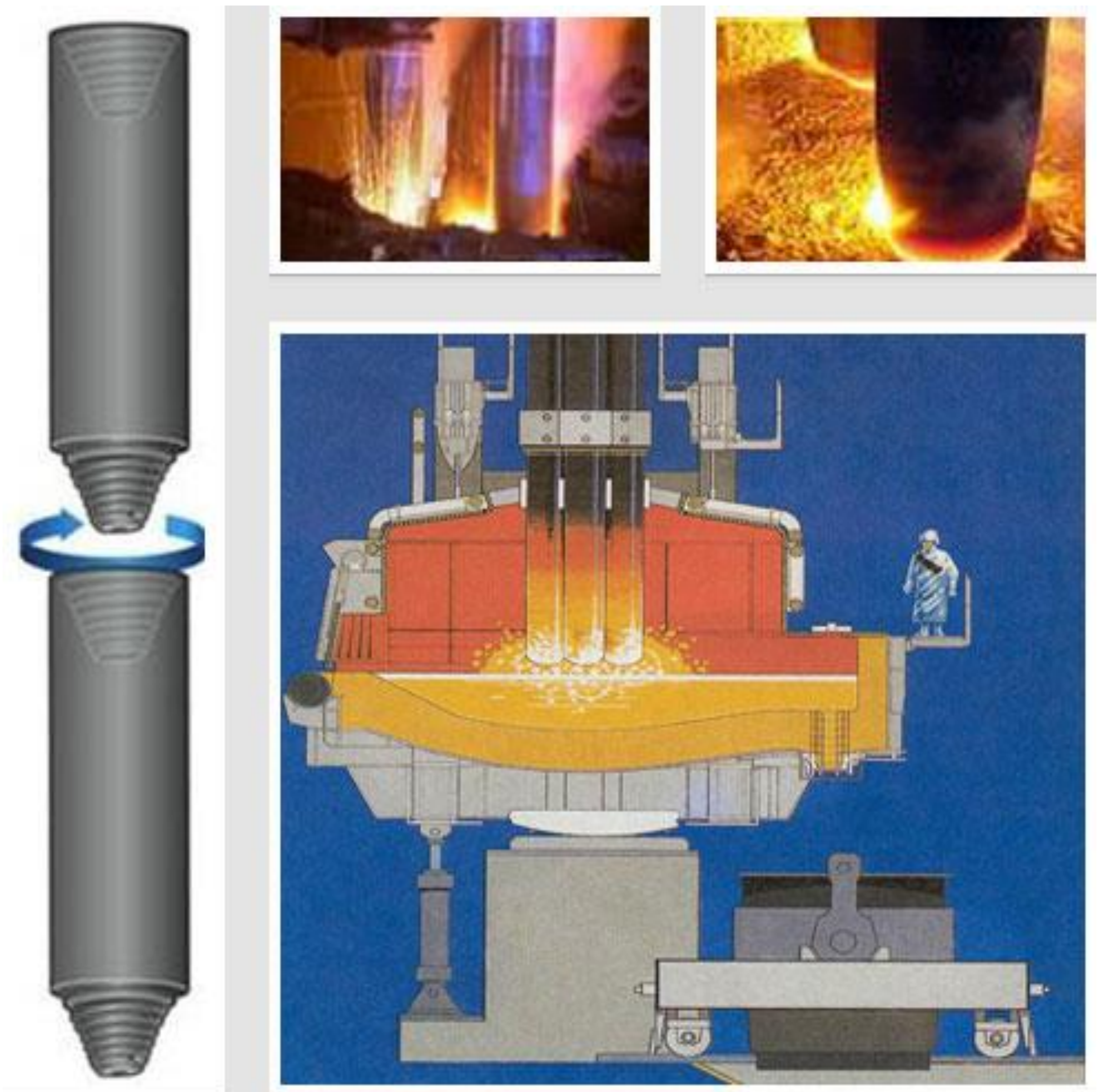
Electric Arc furnace Electrode consumption



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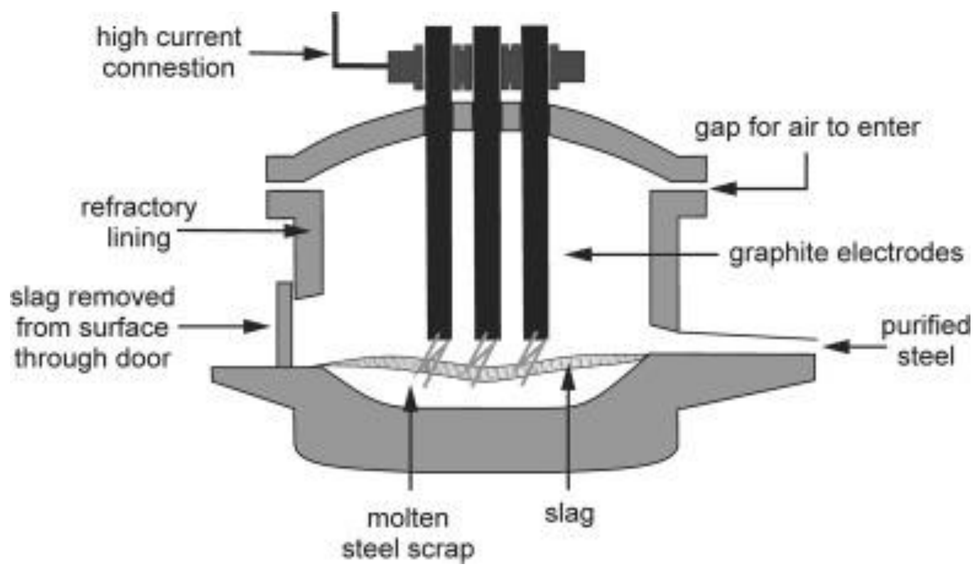
Since (2002)

Abstract:

Electrodes are from graphite it is used in several industries, one of important use in the metallurgy. The graphite has a good inertness towards gases, liquids and solids, the main feature of it is the high electrical conductivity. The graphite electrodes are used in the steelmaking furnaces to feed electrical energy to the Electrical Arc Furnace (EAF) working space. We try in this paper to analyzes the main reasons for the graphite electrodes consumption at two situations normal and emergency when it is used in the electric arc furnaces.

Introduction:

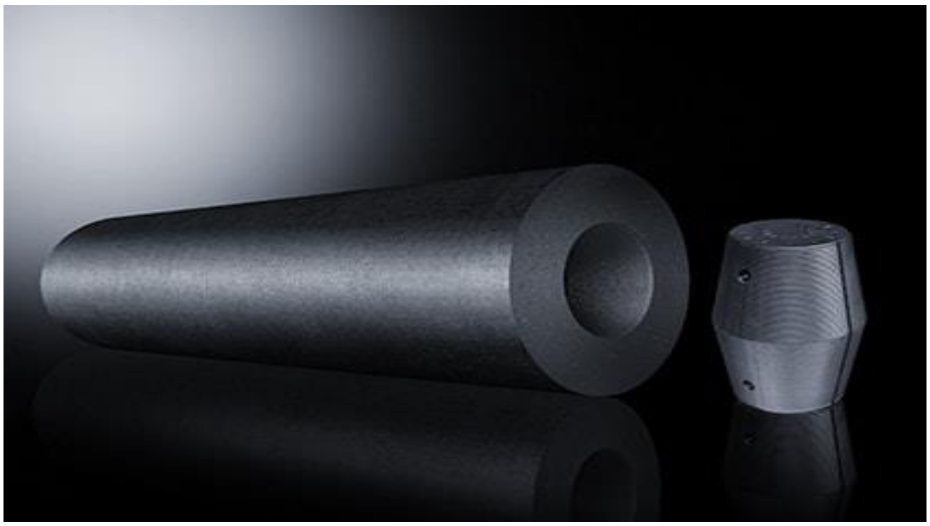
The electric arc furnace is the most flexible unit to melting, it can work with 100% of scrap or mix charge with Direct Reduction Iron (DRI), HBI and pig iron to combination a charge mix. The electric arc furnace one of the main steelmaking process in the later quarter of the 20th century, the EAF process produced about 30% of the total crude steel production in the world. About 50% of the energy in the EAF is supplied by electric arc and the other 50% being provided through chemical reactions. The graphite electrode is the part of supplied the electric from arms holders (clamps) to the charge mix into EAF to provide the melting process. During the melting process the graphite electrodes will consumed, it is important to study the graphite electrode consumption from all faces to control it and try to decrease the consumption as we can.



Schematic of an EAF.

What are graphite electrodes?

The electric arc furnace method recycles used iron scrap by melting it in an electric arc furnace. It is the graphite electrodes inside the furnace that actually melt the iron. Graphite has high thermal conductivity and is very resistant to heat and impact. It also has low electrical resistance, which means it can conduct the large electrical currents needed to melt iron. In recent years, graphite electrodes have been made even more efficient: they can now conduct even higher currents and more power. Using the expertise collected over a century of innovation.



Graphite Electrode Joint with Nipple

What are the main criteria of graphite electrodes?

a) High Electrical Conductivity (Low Resistance)

b) High Thermal Conductivity

c) Excellent stability and strength at high temperatures

d) Low Co-efficient of Thermal Expansion

e) High resistance to thermal shocks

f) Good chemical inertness

g) Oxidation only above 400oC

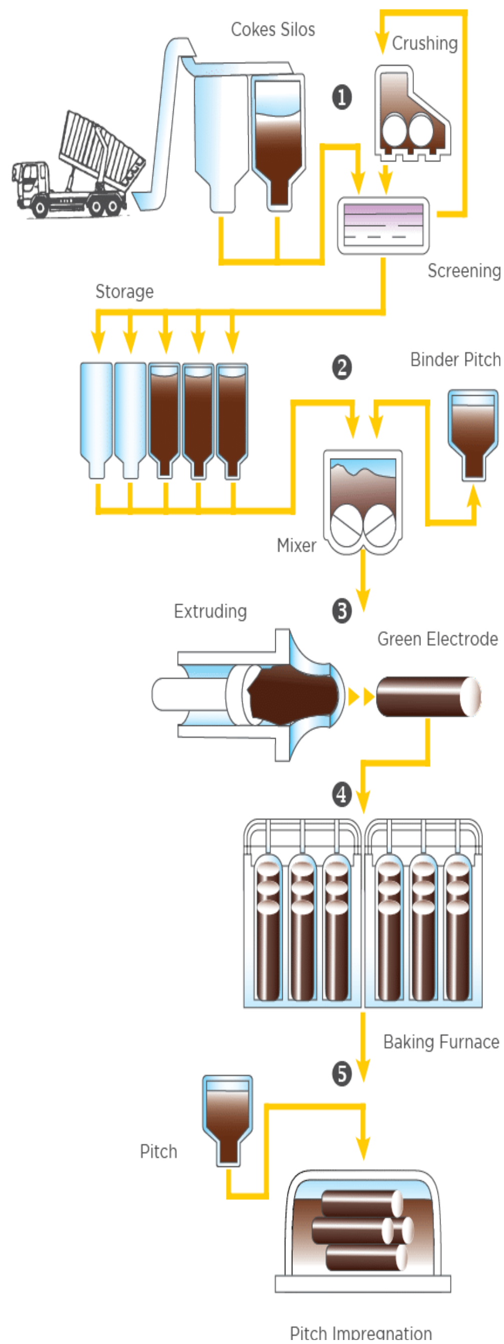
h) No melting point (Sublimation point > 3750 °C)

Manufacturing of Graphite Electrodes.

Basic Raw Materials

- Calcinated Petroleum Needle Coke.
- Binder Tar (Pitch).
- Impregnated Tar (Pitch).

Steps of Production Process.



1- Raw Material.

There are two types of needle coke which are made from petroleum and pitch. Needle cokes are sorted separately (based on grain size) after crushing and screening.

2- Mixing.

The crushed and screened needle coke is mixed with binder pitch in a controlled atmosphere at desired temperature.

3- Extrusion.

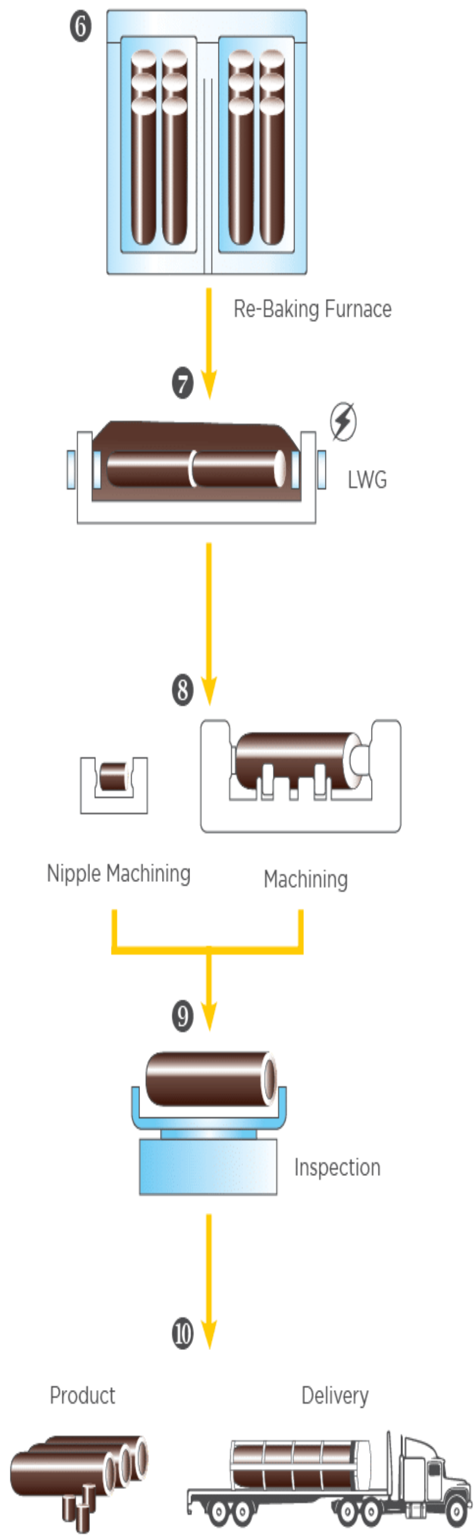
The paste of cooled to the required temperature and extruded into the required size as a (green electrodes).

4- Baking.

It is the process of carbonizing the binder pitch. (increasing the temperature up to 800 °C). It leaves a solid non- deformable body.

5- Impregnation.

The UHP/SHP electrodes are then impregnation with special pitch which improves the strength and resistivity of electrodes and they baked to coke the pitch used for impregnation



6- Re- baking.

The electrodes are re- baked at about 700 °C to coke the impregnation pitch.

7- Graphitization.

Baked electrodes are heated up to 2800 to 3000°C in lengthwise electric resistance furnaces to convert carbon into a crystalline structure- graphite.

8- Machining.

The electrodes are machined to the required tolerance on the length and diameter. The nipples and sockets are threaded to insure an optimal electrode – nipple joint

9- Inspection

Weight, length and other parameters are measured. Appearance and thread precision are inspected.

10- Shipment.

The qualified electrodes are packed and shipped

Graphite Electrodes Varieties

1- For DC Furnaces (direct current furnaces) Size: 22-32 inches

Electrodes for DC furnaces, which require 1 column of graphite electrodes. High maximum current density. The diameter of these electrodes is getting bigger: the current maximum diameter is 32 inches (800 mm).

2- For AC Furnaces (alternating current furnaces) Size: 16-28 inches.

Alternating current furnaces require 3 columns of graphite electrodes. They mostly use 20-28-inch electrodes, the standard size in electric furnaces.

3- For LF Furnaces (refining furnaces) Size: 10-18 inches

These electrodes are for refining materials like molten steel. LF Furnaces have a smaller capacity than DC

Graphite Electrodes Categories

According to different power and current, graphite electrode is produced by different raw materials and production processes. It can be divided into:

1- Regular Power Graphite Electrodes (RP)

The main raw material used in the production of the RP graphite electrode is petroleum coke and coal tar pitch. For ordinary power graphite electrode production, a small amount of pitch coke can be added. The sulfur content of petroleum coke and asphalt coke cannot exceed 0.5%. Regular power graphite electrodes are used in electric arc furnace (EAF) and ladle furnace (LF) for steel production.

2- High Power Graphite Electrodes (HP)

The raw material of HP graphite electrode is made of high-quality petroleum coke plus needle coke, through multiple processes of calcination, impregnation and graphitization. HP (high power) graphite electrodes are used in high power electric arc furnaces (400kv.A/t).

3- **Ultra-High-Power Graphite Electrodes (UHP)**

mainly used in ultra-high-power steelmaking arc furnace.
Graphite electrode is mainly made of petroleum coke and needle coke as raw materials, coal asphalt as binder, and is made by calcining, batching, mixing, pressing, roasting, graphitization and machining. It is the conductor that releases electric energy in the form of arc to heat and melt the charge in arc furnace. Graphite electrode means ultra-high-power graphite electrode allowed to use graphite electrode with current density greater than 25A/cm 2

Resources of Graphite Electrodes Consumptions.

1- Normal Graphite Electrodes Consumptions.
2- Suddenly Graphite Electrodes Consumptions.

1- **Types of Normal Graphite Electrodes Consumptions.**

1-1- Tip consumption.
1-2- Side consumption.

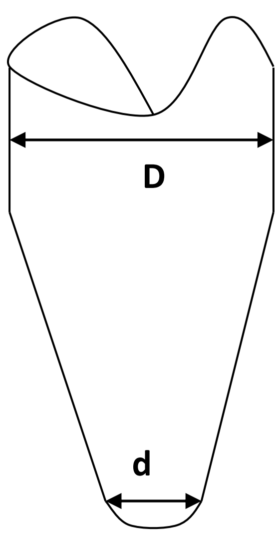
Side Dimensions

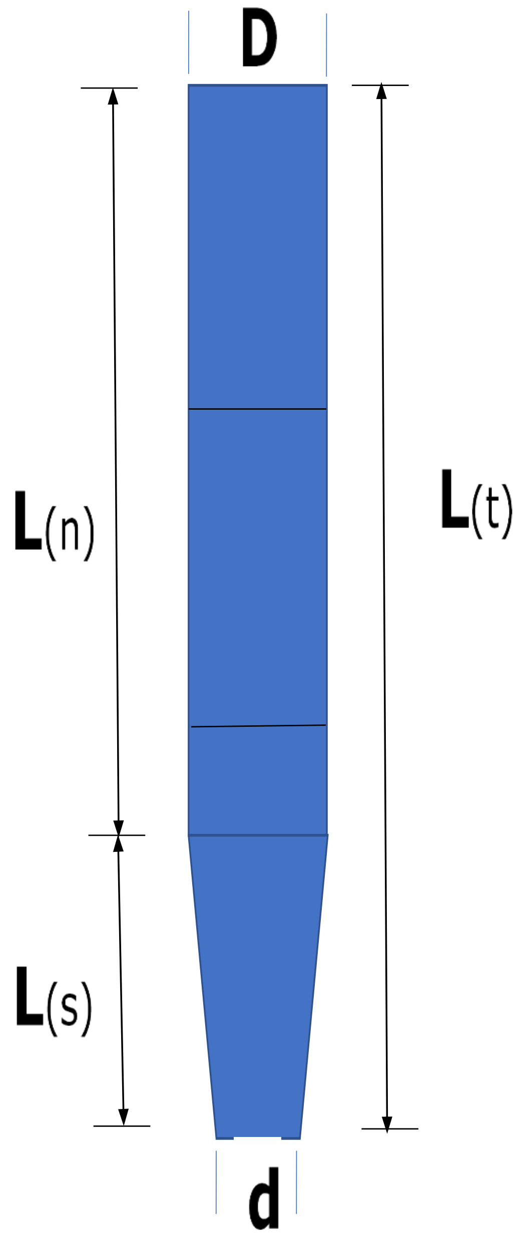
$$L_n = (0.65: 0.7)\ L_t$$

$$L_s = (0.3: 0.35)\ L_t$$

Tip Dimensions

$$d \approx 0.7D$$





1-1 Reasons of Tip consumption.

1-1-1- Scrap Charge Mix.

a- Avoid a big piece in the top of charge Bucket.
b- Proper layering in charge bucket (according to scrap density).
c- Consistent carbon and metallization in DRI and avoid charging it in the top of bucket.
d- Charging a good scrap. No (nonconductive, dust, rust, Ext..).

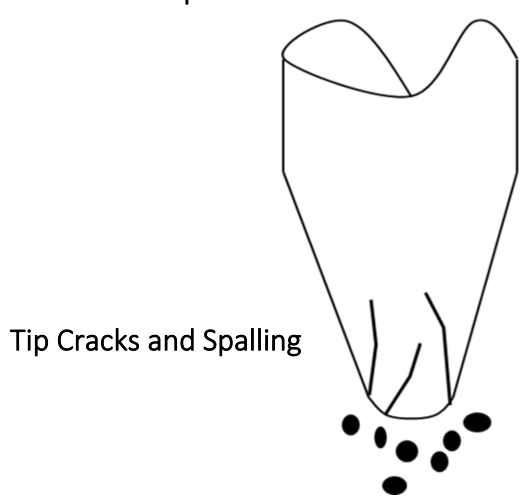
1-1-2- Furnace operations.

a- Higher electrode penciling due to

* Incorrect Modules Angle.
* Increase in current density due to reduction in Tip diameter.

b- Increased Power on Times (Increased KWh/T)

* Cause a Tip Cracks and Spalling Losses.
* With Higher DRI %, Lower Arc Lengths are required to be maintained and the opposite with scrap.



c- Slag Foam reduces Tip oxidation and subsequently reduces Current Density at Tips.

d- Increase in Tap Temp increases consumption of Electrode Tip & side Oxidation.

e- Increases Arc Intensity Lead to Tip filling down and spalling (Due to low Electrode PCD).

1-1-3- Mechanical and Electrical.

a- The electrodes are not completely perpendicular to the horizontal plane of the furnace.
b- Electrodes shaking during regulation.
c- Bad off gas efficiency.
d- EAF Is not completely closed (between panels and slag door.
e- Stable phase balance.
f- Electrode Regulation sensitivity.
g- Use suitable melting profile.

1-2- Reasons of Side consumption.

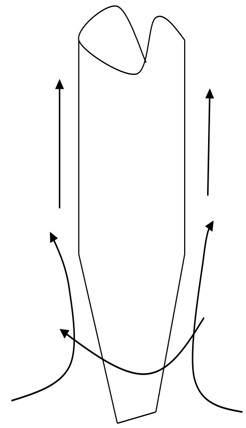
1-2-1- Furnace operations.

a) Massive flames from electrodes port Delta holes.
b) Incorrect position and setting for EAF Modules.
c) Unstable arc and abnormal ON/OFF.
d) Flammable material content in charge mix.
e) Opening slag door several times more than need (Electrode one wear it's more than other electrodes by about (10%) When slag door opens for long time this percentage was increasing).
f) Increase of FeO in the slag.
g) Un suitable working profile (Electrical, Chemical and timing).
h) Charge high amount of DRI in bucket and charge it by wrong way.

1-2-2- Mechanical and Electrical.

a) Spray water Ring Design and installation and water flow rate (The cooling for Electrodes by spray water Decreasing Electrode consumption by 7 % to 8 %).
b) Abnormal gas movement into EAF Due to many vacancies between panels.

c) **Off gas evacuation system efficiency (low efficiency of fume suction lead to Electrode burned and pitting in the surface).**



d) **The PCD is more than normal.**
e) **The electrical load between electrodes imbalanced (incorrect phase balance).**
f) **Lower productivity due to delays between power ON/OFF.**

2- <u>Suddenly Graphite Electrodes Consumptions.</u>

2-1- Electrodes /Nipple breakages.
2-2- Stub loss.
2-3- Electrodes unwinding/slipping.

2-1- <u>Electrodes /Nipple breakages.</u>

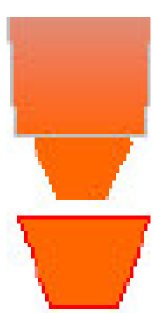
2-1-1- Electrode Joints Handling.
2-1-2- During Electrode Joint tightening.
a) Excessive Electrode Joint tightening.
b) Loss Electrode Joint tightening.

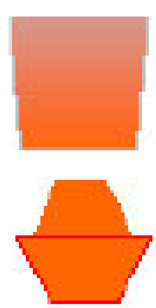
2-1-3- Due to nonconductive material charged with charge mix.
2-1-4- Early Lime charging by conveyor or charged relatively in the top of bucket
2-1-5- Big hump fills down from side wall.
2-1-6- Heavy parts of Scrap or skull slipping.

2-1-7- Electrodes regulation.
2-1-8- Low Hydraulic response during Electrode regulation.
2-1-9- High Electrode shaking.
2-1-10- The electrode speed (Up/Down).
2-1-11- The co-axiality between Electrodes and Delta Roof holes.
2-1-12- Roof movement 'Relative movement' when EAF shell not clean with new Delta and small gap.
2-1-13- Explosion into EAF.
2-1-14- Roof Shift (Alignment between Roof and EAF shell).
2-1-15- EAF tilting angle problem or high speed in tilting movement (hydraulic problem).
2-1-16- Clamping in the electrode (force, position, distance, ….).
2-1-17- Low clamping force (Electrode slipping)

2-2- <u>Stub loss.</u>

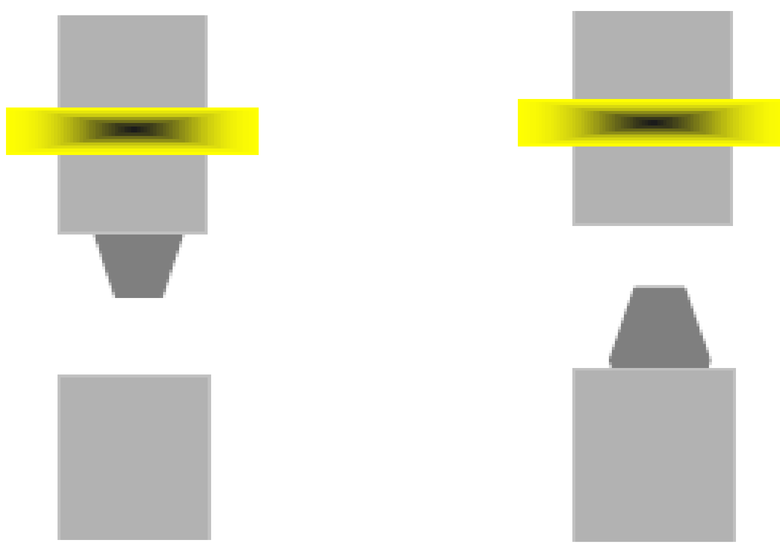
2-2-1- Many cracks in Tip.
2-2-2- High Penciling(d<0.7D).
2-2-3- Work with High current Curve (Short Arc).
2-2-4- Socket cracks due to high amount of flam (around port hole).
2-2-5- Charge big parts of scrap in the top of bucket.
2-2-6- Nonconductive material in scrap mix.
2-2-7- High speed lowering during regulation.
2-2-8- High shaking and vibration in column movement.
2-2-9- Bad Electrode (Raw material/manufacturing)





2-3- Electrode slipping (Nipple/Socket).

- 2-3-1- Bad thread M/C.
- 2-3-2- Joint two brands with different tolerance (out of standard).
- 2-3-3- Dirty Joint/Socket.
- 2-3-4- High/Low torque while tightening.
- 2-3-5- Nipple / Socket thread damaged during Joining process.
- 2-3-6- Socket cracks due to Problem in Lifting plug.
- 2-3-7- Clockwise Phase rotation.
- 2-3-8- Bad fume cause High flame lead to increase of thermal expansion.
- 2-3-9- Wrong clamping position.

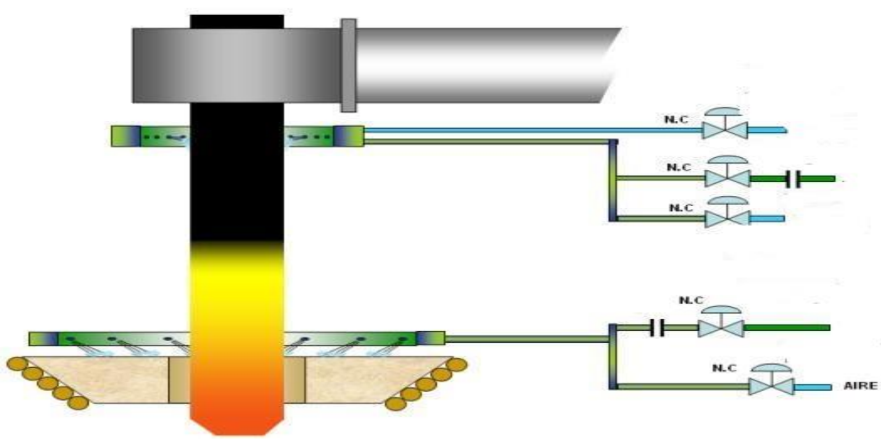


Non-conventional methods to decreasing Electrode consumption.

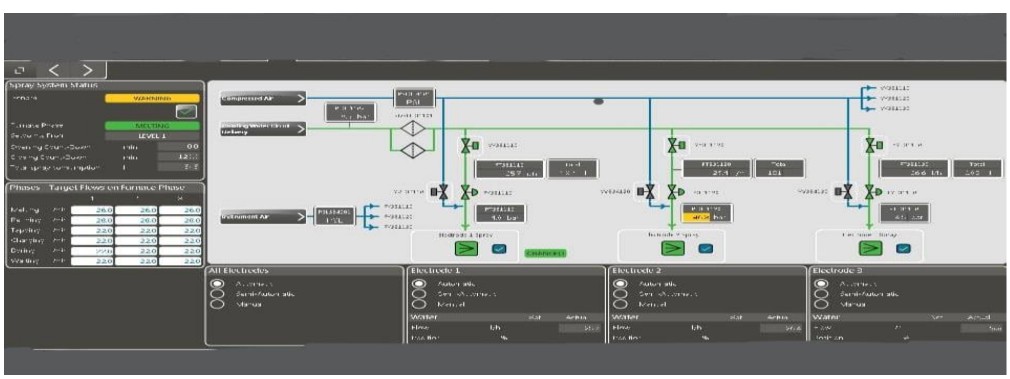
Recently some ways developed to decreasing the Graphite electrodes consumption by using extra material or tools for example.

1- Add chemical composition for spray water to decreasing the side oxidation.
2- Use chemical composition to paint all electrode surface (coating) to decreasing the side oxidation.
3- Installed extra spray water ring over port hole to cooling the red part of electrode (the tip).
4- Developed an electrical control unit to make a dynamic control of spray water flow/air for spraying system with the electrical power parameter's related to the actual working conditions

Extra spray water ring



Dynamic Spray (water / air) flow control



Conclusion

The electrodes Mainly from graphite made and it is consumed with use to Melting Iron EAFs and Metal heating in L.F, this consumption divided to two categories Normal consumption (due to usage) and suddenly consumption due abnormal situation (Accidents, Mistakes, …). The normal consumption mainly happened at electrode tip (Tapered shape) and Electrode side (Straight shape) due to Process (heating, profile, Slag conditions,), Electrical (Volte, current, …) and Mechanical (Loss in arms or columns, PCD, ….). The sudden Consumption happened due to many reasons Like Electrodes /Nipple breakages (Nonconductive material, Explosion into EAF, Electrode Joints Handling, …), Stub loss (High Penciling(d<0.7D), Many cracks in Tip, Bad Electrode, …) Electrode slipping (Nipple/Socket). We need to control all Consumption resources to decrease it. There are other ways do decrease the electrode consumption by using outsource (Non-conventional methods) for example (Use chemical coating, Add chemical composition to spray, ….).