CENGraphite

CENTechnology
Applied to
Graphite

The world's first mass production of 99.9% pure graphite, freeing India's steel manufacturing from control by worldwide graphite cartels. US Patent – 4,780,112

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CENtechnology PROCESSES GRAPHITE ORE COMMERCIALLY

CENgraphite

The **CENtechnology** process will operate a **CENgraphite** plant capable of providing the graphite market for the first time ever, pure graphite commercially manufactured to a purity of 99.9% or better.

High grade graphite is a much sought after commodity internationally. The high tonnage cost of pure graphite makes **CENgraphite** an investment “winner”.

CENtechnology: The technology using raw graphite ore is extremely effective. **CENtechnology** produces in commercial volume - graphite with a purity value of **99.9% or better**, with approximately only 0.2% contaminants. Hitherto, such purity has not been achieved / available in commercially manufactured quantities.

Material: Graphite ore of the highest quality is available worldwide.

Particulates: All the particulates and metal oxides found in graphite ore are removed, these become **By-products** in marketable quantities. The leaching process of the ore provides a “no-waste” situation.

Electrodes: Electrodes and shapes can be manufactured in India.

Baking time: Synthetic graphite: Electrode baking time for synthetic graphite is around 23/24 days.

CENgraphite: CENGraphite requires only some 3 - 4 days.
The energy saved on the baking procedure alone is considerable.
Plus, the end product using pure graphite is far superior to the synthetic.

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Present Production Analysis:

- Merchant grades of natural graphite can contain up to 50% mineral contaminants.
- The highest graphite grades with mineral contents as low as 1.5% are difficult and expensive to achieve by physical beneficiation and therefore high volumes are not produced.
- China dominates the global market for natural graphites. Currently they are exporting in excess of 900,000 ton per annum of graphite in a range of grades representing some 41% of the total world market.
- Approximately 75.7% of the synthetic graphite consumed in the U.S. is used for electrode manufacture.
- Synthetic graphite technologies were developed many decades ago to cater for numerous applications in the metallurgical and chemical industries.
- Synthetic graphite is manufactured into "forms" and "shapes" by heating pre-formed masses of petroleum coke mixed with an organic binder typically petroleum pitch at very high temperatures over several **weeks**.
- Porosity is generally in the range of 5% - 30%. These products contain typically 25% - 40% of ungraphitised carbon which is prone to burning off in high temperature applications, this further increases the porosity.
- Being a poor conductor of electricity and heat, the ungraphitised carbon reduces electrical and thermal conductivities.
- Mineral contents typically less than 2%. Much of the global production of synthetic graphite is used as electrodes in the electric smelting of steel and aluminium, for which impurity levels in competitively priced natural graphites are unacceptable.
- Current prices for steel making electrodes exceed US$4,000/tonne.
- Graphite usage in aluminium smelting amounts to some 3-4 million ton plus.
- Graphite heat exchangers and retorts are used in many arduous process plant applications. The best materials available for these purposes have porosities of about 5% with inferior products up to 25%.
- Thermal conductivity falls off rapidly as the porosity increases.
- Since natural graphite has better thermal conductivity than the less dense synthetic materials, it would be preferable for most uses. Minerals contained in natural graphites have tended to contaminate process fluids.
- The heat exchanger and retort market could become one competitive market for **CENgraphite.**
- **CENgraphite** contains 0.3% or less residual mineral content and none of the heavy metals which contaminate smelter melts or other process fluids.
- Natural graphite material is thought to represent between 15% - 20% of the world graphite consumption.

- The top end of the market requires bulk graphite containing more than 99% crystalline carbon - a grade which by physical beneficiation is difficult and expensive to achieve.

- Despite the long heating cycles involved and the energy demand which is an inherent cost of synthetic graphite production, the graphitisation completion of the carbon rarely proceeds beyond 75% leaving the remainder as amorphous carbon.

CENgraphite Products

Companies presently using synthetic graphite could use **CENgraphite** in tomorrow's market :

- Furnace electrodes with higher electrical conductivity, hardness and strength.
- Heat exchangers, retorts and other process equipment with higher thermal conductivity, strength and resistance to chemical attack.
- Refractories with higher densities and resistance to chemical and metallurgical attack.
- Brake lining and special lubricants virtually free of abrasive minerals.
- Extended service lives in most applications.

The price of raw graphite on the international market indicates that the quality dictates the final price. Prices vary with the quality offered and range from as low as around **US$200 to US$500** per tonne. Synthetic graphite at 97% purity sells in the range of $2000-3000 per ton. Ultra pure 99.9% graphite has never been manufactured in large quantities before. The CENGraphite process uses low priced graphite ore and purifies it into 99.9% Ultra Pure graphite at a manufacturing cost of around $40 per ton. It is anticipated that all the CENGraphite produced in the plant will be sold at these higher ranges.

- The worlds' graphite market is to some extent controlled by fluctuations in the steel and aluminium industry. These industries consume large volumes of graphite material which has been manufactured into" shapes". These shapes include electrodes and furnace refractory lining materials.
- **CENgraphite**, because of its very pure nature will make for considerable energy savings, also, provide for a more efficient production. This is easily demonstrated when the physical and electrical properties of **CENgraphite** are taken into consideration.
- Comparison table demonstrates the physical difference between **CENgraphite,** natural and synthetic graphite.

COMPARISON OF SOLID GRAPHITE PROPERTIES

	NATURAL GRAPHITE	SYNTHETIC GRAPHITE	CENgraphite
POROSITY %	10-20	8-25	2-5
GRAPHITIC CARBON %	< 96	50-70	>99
AMORPHOUS CARBON %	> 4	20-45	<1
BULK DENSITY, g/cm3	1.6 - 2.0	1.5 - 1.8	>2.15
ASH %	6 -10	0.5 - 2.5	0.1 - 03

- Natural material represents between 15% and 20% of the world graphite consumption. Four to six million tonnes of synthetic graphite in the form of shapes are produced each year for use in a number of industries including, the manufacture of steel and aluminium.

- Approximately 75.7% of the synthetic graphite consumed in the US during 1987 was used for electrode manufacture.

- Relatively pure natural graphite is used to manufacture brake linings, lubricants, electrodes, refractories and many other products, some of which require the use of high purity graphite.

- The top end of market requires bulk graphite containing more than 99% of crystalline carbon, a grade which by physical beneficiation is difficult and expensive to achieve.

- Electrodes and other shapes made from bonded petroleum coke are relatively porous, they contain significant amounts of ungraphitised carbon, their physical characteristics are inferior to high density shapes made from powdered and sintered pure natural graphite.

- About 560,000 ton of electrodes are consumed in electric arc furnaces for steel production. Because of the superior properties and competitive prices, this market is an ideal market for **CENgraphite.**

- There is a very large market for other shapes such as: heat exchangers, electrodes for the high alloy steel industry, brushes for electric motor and brake linings.

- Many new technologies for manufacturing light weight high strength materials are being actively researched. **CENgraphite** will accelerate much of this development by becoming a readily available, reliably pure feed stock product for many industries. Much of this development will be in carbon compounds and alloys of carbon and other minerals.

- **CENtechnology** offers a considerably cheaper route to superior quality graphite products than either the synthetic or natural graphites in today's markets.

- Long heating cycles (23/24 days) demand energy, an inherent high cost in synthetic graphite production. Graphitisation completion of the carbon rarely proceeds beyond 75% leaving the remainder as amorphous carbon.

- High purity natural graphite can be prohibitively costly. The removal of the ash contaminants prior to physical beneficiation allows the particle sizes to be reduced to that of a very fine powder product.

- Due to their lower porosity and higher graphite content, **CENgraphite** products are denser than synthetics or low purity natural shapes. Electrical and thermal conductivities, inertness, hardness, mechanical strength and resistance to attrition of a graphite product are directly attributable to its bulk density.

- **CENgraphite** contains 0.3% or less residual mineral content and none of the heavy metals which contaminate smelter melts or other process fluids.

- The **CENgraphite** process is applicable to all types of natural graphite ores.

- **CENgraphite** efficiency around 60%

- Synthetic graphite normally takes 23/24 days at 3000C to process.

- **CENgraphite** takes under **72 hours** at less than 2000C to process.

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Introduction to graphite

Carbon has two natural crystalline allotropic forms: graphite and diamond. Each has its own distinct crystal structure and properties. Graphite derives its name from the Greek word "graphein", to write. The material is generally greyish-black, opaque and has a lustrous black sheen. It is unique in that it has properties of both a metal and a non-metal. It is flexible but not elastic, has a high thermal and electrical conductivity, and is highly refractory and chemically inert. Graphite has a low adsorption of X-rays and neutrons making it a particularly useful material in nuclear applications.

The unusual combination of properties is due its crystal structure. The carbon atoms are arranged hexagonally in a planar condensed ring system. The layers are stacked parallel to each other. The atoms within the rings are bonded covalently, whilst the layers are loosely bonded together by van der Waals forces. The high degree of anisotropy in graphite results from the two types of bonding acting in different crystallographic directions. For example, graphite's ability to form a solid film lubricant comes from these two contrasting chemical bonds. The fact that weak Van der Waals forces govern the bonding between individual layers permits the layers to slide over one another making it an ideal lubricant.

World production of natural graphite was estimated to be about 992,000 tons in 2005, with China being the biggest producer (700,000 ton) followed by India (120,000 ton run of mine), Brazil, Mexico and then the Czech Republic. Indian marketable production is 10% to 20% of run-of-mine production.

(http://www.indexmundi.com/en/commodities/minerals/graphite/graphite_t8.html)

Graphite usage, stable for some years, appears to be about to undergo a renaissance. Advantage is being taken of the electrical conductivity of graphite—highest among the non metals—and of its light weight. There is renewed interest in making plastics conductive. Graphite has the advantages over the carbon blacks of producing lower viscosity compounds and being cleaner to use. End uses that are beginning include fuel cell components, energy cell components, graphite reactor fuel elements and intercalation compounds. Farther off on the horizon are uses in magnetic levitation and lower cost synthesis of diamonds.

Large scale fuel cell applications are being developed that could consume as much graphite as ALL other uses combined. Mineral Commodities Summary 2006 - US Geological Survey - Page 77 (http://minerals.usgs.gov/minerals/pubs/mcs/2006/mcs2006.pdf)

Growing need for high-purity graphite - Forecasted growth of the transportation fuel-cell market, as well as stationary and portable power fuel cells and increases in lithium-ion battery production, from the present 1.2 billion units a year to more than 2.5 Billion units a year by 2012 alone provides an enormous opportunity for CENGraphite manufacture. Both alkaline and lithium-ion batteries require the purest graphite. Graphite purified to 99.9% is the popular choice for this kind of electrical application.

Graphite Pricing

There are several levels of quality of graphite used in determining its market value. Examples of recent pricing relative to the specifications are as follows: - Basis of CIF U.K. Port US$ / ton (2004)

Type	Carbon Quality	Price
Crystalline, large flake	94%	$570 - $780
Crystalline, large flake	90%	$480 - $550
Crystalline, medium flake	90%	$370 - $410
Crystalline small flake	80 - 95%	$270 - $500
Amorphous powder	80 - 85%	$220 - $235
Synthetic (Switzerland)	99.5%	$2,710

As a general rule the larger flake sizes sell at the highest prices amongst the natural graphite products.
Each has its own pricing structure and even within each category, price is strongly affected by purity, types of contamination and crystal size. There is also a very large specialized market for synthetic graphite.

Graphite Classifications

There are two main classifications of graphite, natural and synthetic.

Natural Graphite

Natural Graphite is a mineral consisting of graphitic carbon. It varies considerably in crystallinity. Most commercial (natural) graphites are mined and often contain other minerals. Subsequent to mining the graphite often requires a considerable amount of mineral processing such as froth flotation to concentrate the graphite. Natural graphite is an excellent conductor of heat and electricity. It is stable over a wide range of temperatures. Graphite is a highly refractory material with a high melting point (3650°C.)

Natural graphite is subdivided into three types of material:

- **Amorphous**
- **High Crystalline**
- **Flake**
- **Synthetic**

Amorphous Graphite

Amorphous graphite is the least graphitic of the natural graphites. However, the term "amorphous" is a misnomer since the material is still crystalline. Amorphous graphite is found as minute particles in beds of mesomorphic rocks such as coal, slate or shale deposits. The graphite content ranges from 25% to 85% dependent on the geological conditions.

Amorphous graphite is extracted using conventional mining techniques and occurs primarily in China, Mexico, North Korea, South Korea and Austria.

Uses: Carbon parts, Coatings, Pencils, Lubricants

Crystalline Graphite

Crystalline vein graphite is believed to originate from crude oil deposits that through time, temperature and pressure have converted to graphite. Vein graphite fissures are typically between 1cm and 1 m thick, and are typically > 90% pure. Although this form of graphite is found all over the world, it is only commercially mined in Sri Lanka by conventional shaft or surface mining techniques.

Flake Graphite

Flake graphite is found in metamorphic rocks uniformly distributed through the body of the ore or in concentrated lens shaped pockets. Carbon concentrations vary between 5% and 40%. Graphite flake occurs as a scaly or lamella form in certain metamorphic rocks such as limestone, gneisses and schists.

Flake graphite is removed by froth flotation. "As floated" graphite contains between 80% and 90% graphite. Flake graphite is produced with >98% through chemical beneficiation processes. Flake graphite occurs in most parts of the world, the largest producer being China.

Quality is determined by the carbon content and the particle size. The flake form occurs in only a few locations around the world. Global demand for coarsely crystalline flake has increased 40% over the last five years and is expected to continue to increase annually for the foreseeable future. The high-tech sector is the main consumer of high-quality flake graphite.

Flake graphite is used for industrial applications requiring high carbon content to ensure high-performance levels. Although this requires additional processing costs to assure the quality product demanded for these applications, the profit margins are correspondingly greater.

The trend in this market sector is for higher carbon and higher purity levels. The advent of advanced purification methods for graphite facilitates new applications for graphite across all industry sectors.

Markets for this grade include:

- **Brake Linings/Pads**
- **Batteries**
- **Friction Materials**
- **Fuel Cells**
- **Gaskets**
- **Seals**
- **Bearings**
- **Foils • Shrouds**
- **Electrical Brushes**
- **Brick**
- **Composites**
- **Crucibles**
- **Carbon Pans**
- **Coatings**
- **Medical Applications • Graphite Sheets**
- **Computer Circuit Boards**
- **Sports Equipment**
- **Lubricants**
- **Powder Metal**
- **Refractories**
- **Electrodes for steel manufacture**

Synthetic Graphite

Synthetic graphite can be produced from coke and pitch. It tends to be of higher purity though not as crystalline as natural graphite. There are essentially two types of synthetic graphite. The first is electrographite, which is pure carbon produced from calcined petroleum coke and coal tar pitch in an electric furnace. The second type of synthetic graphite is produced by heating calcined petroleum pitch to 2800°C. On the whole synthetic graphite tends to be of a higher price, lower density, higher porosity and higher electrical resistance than natural graphite. Its increased porosity makes it unsuitable for refractory applications. Synthetic Graphite consists mainly of graphitic carbon that has been obtained by graphitization, heat treatment of non-graphitic carbon, or by chemical vapour deposition from hydrocarbons at temperatures above 2100K.

CENGraphite

Manufactured with the Turner-Lloyd CENfuel process, CENGraphite will revolutionize all industries utilizing high purity graphite. Higher purity (99.9%) means a higher quality product and significantly lower manufacturing costs of graphite electrodes.

Markets for this Ultra Pure grade include:

- **Fuel Cells**
- **Lithium-Ion Batteries**
- **Nuclear Reactors**
- **Fuel Cells**
- **Refractories**
- **Electrodes for steel manufacture**
- **Synthetic Diamonds**
- **Composites**
- **Nano-Technology**

Graphite Electrodes

Graphite electrodes are large columns of graphite used in electric arc furnaces in steel-making "mini-mills." This method of making steel is the fastest growing in the United States, and now accounts for 50 percent of the steel manufactured in this country. The electrodes generate the intense heat necessary to melt scrap and further refine steel. Nine electrodes, joined in columns of three, are used in the typical electric arc furnace. Because of the intensity of the melting process, electrodes are continuously consumed.

Graphite electrodes are used mainly in electric arc furnace steel production. They are presently the only products available that have the high levels of electrical conductivity and the capability of sustaining the extremely high levels of heat generated in this demanding environment. Graphite electrodes are also used to refine steel in ladle furnaces and in other smelting processes.

An electric arc furnace is essentially a big recycling machine. Simply put, it's a large pot into which scrap steel, like old cars, bicycles, and refrigerators, are dumped. The furnace operator loads (called charging the furnace) carefully screened and selected scrap steel into this big pot. Then, the operator swings the furnace lid back over the pot and lowers it into place.

The electrodes are part of the furnace roof structure. Electrodes can be small, 75 millimeters (3 inches) in diameter, or quite large, up to 750 millimeters (30 inches) in diameter and as much as 2800 millimeters long. The largest weigh more than two metric tons (4,400 lbs.). The manufacturer of the furnace determines the size the electrode should be.

The electrodes are assembled into columns, usually 3 to a column. Graphite connecting pins-tapered and threaded on each end screw two electrodes together. Some furnace operators assemble the columns on the shop floor and lift them into place whole. Others add electrodes one at a time to the top of the column while it is still on the furnace. Each electrode column has a large steel arm which moves it up and down.

Furnaces using 3-phase AC (alternating current) electricity have 3 electrode columns; DC (direct current) furnaces only need one column of electrodes, but they are generally larger in diameter.

Once the furnace lid is in place, the electrodes are lowered until the tip of the electrode column almost touches the top of the scrap steel. Huge amounts of electricity--large furnaces use enough electricity for a town of 40,000 people--flow through large water-cooled cables into the electrodes. At the bottom of the electrode column, the electricity jumps (or arcs) from the electrode tip to the nearest piece of scrap steel. The intense heat of this electric arc melts the scrap steel, hence the name of the electric arc furnace.

The tip of the electrode will reach 3,000 degrees Celsius or 5,000 degrees Fahrenheit, half the temperature of the surface of the sun. Electrodes are made of graphite because only graphite can withstand this incredible temperature. Eventually all the steel is melted. The furnace operator turns off the power and raises the electrode columns. The furnace is then tipped on its side to pour the molten steel into giant buckets called ladles. The ladles quickly carry the molten steel to the steel mill's caster which is the next step in making new and useful products from recycled scrap steel.

Graphite Electrodes Cartel Lawsuit

A graphite electrode is an input in the manufacturing of steel; its function being to conduct high levels of electricity in an electric arc furnace in order to melt scrap steel. According to the Antitrust Division of the U.S. Department of Justice, **"there was a price-fixing conspiracy among the major producers of graphite electrodes as early as July 1992 and continuing until at least June 1997."**

During 1998-99, UCAR International, SGL Carbon, Showa Denko Carbon, and Tokai Carbon pled guilty while Carbide Graphite cooperated under the Antitrust Division's Corporate Leniency Pro-gram. At the time that collusion was initiated, these companies comprised 94% of market sales which totaled US$300 million annually in the U.S. Government fines exceeding US$600 million were assessed by the United States, European Union, and Canada and there were many private damage suits as well. Examination of the price of graphite electrodes suggests that the cartel was successful in its efforts to raise prices. Mitsubishi Corporation was later convicted of acting as "ringleader" and fined $134 million.

The conspirators and their fines are listed below -

Showa Denko – Japan - $32 million in USA – 10.5 million Euros in Europe

Tokai Carbon Co Ltd – Japan – $6 million in USA – 12 million Euros in Europe

Mitsubishi Corp – Japan – $134 million in USA

Nippon Carbon – Japan – $2.5 million in USA – 6 million Euros in Europe

SEC Corporation – Japan - $4.8 million in USA – 6 million Euros in Europe

SGL Carbon AG – Germany – $135 million in USA – 69 million Euros in Europe

UCAR International Inc – USA – $110 million in USA – 42 million Euros in Europe

The Carbide/Graphite Group – USA - $00 – Amnesty in USA – 6 million Euros in Europe

Research shows that in addition to price fixing, these eight corporations conspired to:

1. Limit the availability of graphite electrodes to customers worldwide.

2. Prevent the spread of graphite electrode manufacturing technology to any corporation that was not a part of the cartel.

Graphite Electrodes Cartel effect on India

The effect of the Graphite Electrode Cartel Group upon India and other developing nations was severe. By limiting availability of graphite electrodes to India, the total amount of steel manufactured throughout the country was controlled, thus affecting the industrial growth and national security of India. In addition, by preventing any India based company from implementing a graphite electrode manufacturing program, India's future steel making capability was limited to whatever amount was "allowed" by the cartel. The result is that the entire industrial capacity and military manufacturing capability of India was held hostage by these eight corporations.

These lawsuits were filed by the various countries cover the time period of 1992 – 1997. It is not beyond the realm of speculation to suggest that these kinds of conspiracy groups or "cartels" could have existed prior to 1992 and could even continue unto this present day. It is clear that the national security of India and the wellbeing of her citizens cannot be entrusted to the decisions of such multinational conglomerates.

A two part plan is envisioned that would free India from the dependence on foreign graphite electrode manufacturers for her steel manufacturing capability.

Phase one includes the construction of a CENGraphite plant to provide a supply of ultra pure graphite for manufacturing and export.

Phase two would include the construction of one or more plants for graphite electrode manufacture to provide India with her own capability in this area. This would prevent future threats to India from foreign graphite manufacturers.