

THE ELEMENT C

- Introduction graphite and carbon
- Lattice
- Classification of grain size
 - Fine-grained graphite
 - Coarse-grained graphite
- Properties of graphite and carbon
 - High temperature properties



Introduction

- Graphite and diamond are the two naturally occurring forms of the element carbon (C) and are mined. Graphite, as natural graphite, was already known in the old ages as a mineral with a typical crystalline structure. Graphite obtained technical importance only a hundred years ago, when E.G. Acheson successfully produced synthetic graphite in large dimensions and shapes. US-patent 542 982 from December 17, 1895 describes the graphitisation of carbon material in an electrically heated resistance furnace. This so-called electro graphite gained increasing use in the, at that time, still young electric industry as current-conducting electrodes due to its excellent electric conductivity.
- Graphite can be manufactured from almost any organic material that leaves a high carbon residue when heated in the absence of air. Graphite can come as [fine-grained](#) or [coarse-grained material](#). The theoretical density of mono crystalline graphite is 2,26 g/cm³. Graphite has a hexagonal layer [lattice](#) structure.
- Graphite is a material which has mechanical properties close to ceramics. Its [properties](#) are excellent thermal stability, chemical resistance and high electrical conductivity. It is thus widely used in the field of electro-metallurgy. The particle size of the solids used for production plays an important role as it strongly influences the final properties.



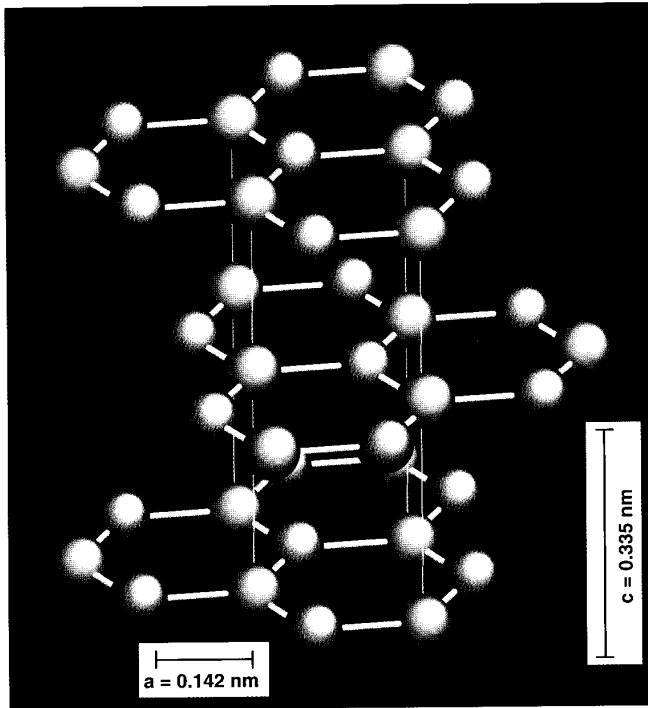
Introduction

- Graphite has been employed in chemical process equipment construction for more than 60 years. In this sector, its [applications](#) are determined in the first place by its chemical and physical properties and in the second place by its suitability as a material of construction for equipment.

[chemical properties of graphite materials](#)



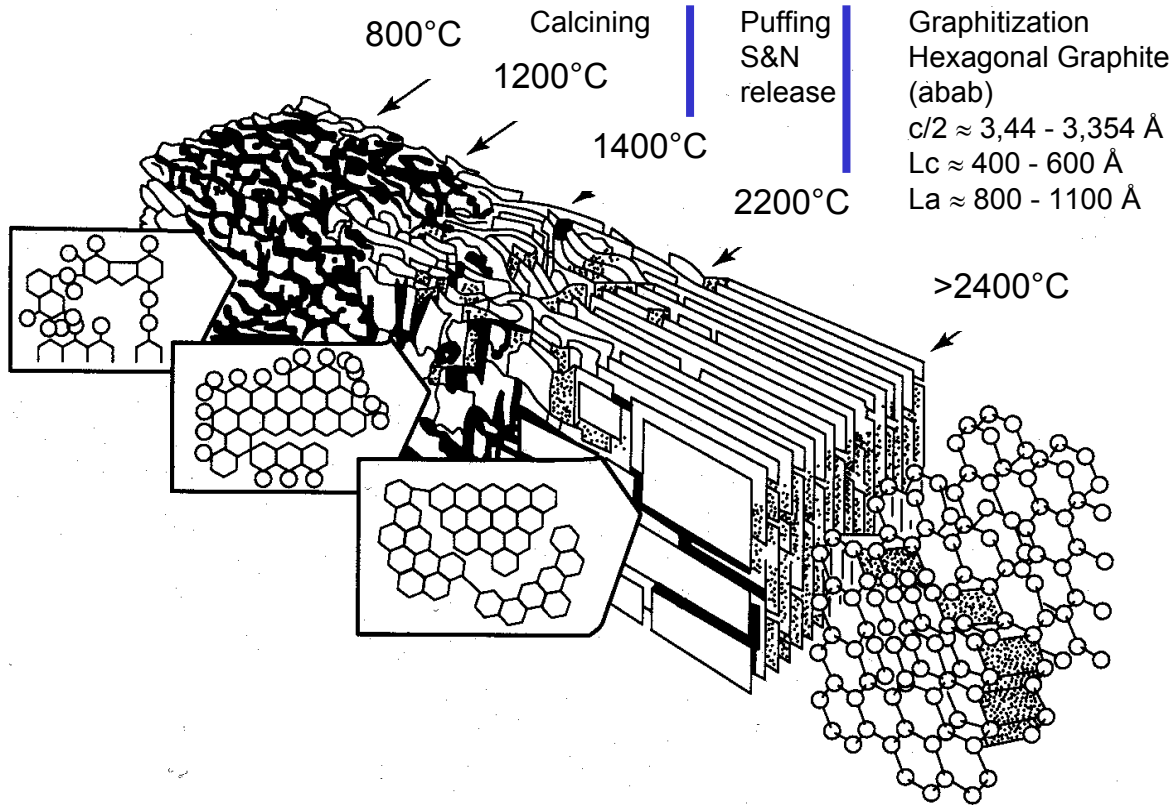
Lattice



- Both natural and electro-graphite have a [hexagonal layer lattice](#). Its more or less perfect formation in the electro graphite depends largely on the degree of crystalline order of the solid particles and the primary products obtained upon carbonising the carbonaceous binder materials used for its manufacture. The particle size of the solids used plays an important role as it strongly influences the final properties.



Graphite Lattice Formation



H. Marsh, 1991



Classification of grain size

➤ **Fine-grained Graphite**

Fine-grained particles are produced by milling from coarse-grained raw material. Within the wide field of carbon ceramics, the technology of fine-grained carbon and graphite was developed. This proved to be in many respects an independent manufacturing technique. The materials thus obtained are called fine-grained graphite. Their grain size distribution ranges from 1 mm to 0.001 mm. Quite a number of combined properties, especially in small-sized shapes, can only be obtained by using fine-grained solids, being the lower end of coarse-grain material down to dust particles in the sub-micron range.

➤ **Coarse-grained Graphite**

Coarse-grained graphite has a maximum grain size less than 25 mm. Nearly all of these grades are manufactured by extrusion. The processing of a lump or coarse-grain solid, as it is received as shipment, is economically more advantageous.



Classification of grain size

Classification of fine grain size

(based on size measuring techniques of the initial raw materials. The measuring techniques involved are not applicable to the finished product).

Graphite material can be classified by grain size as follows:	
Ultrafine (or micrograin graphite)	Less than 10 microns maximum grain size
Superfine	Between 10 and 50 microns maximum grain size
Fine	Greater than 50 but less than or equal to 100 micron maximum grain size
Medium	Greater than 100 microns maximum grain size

“Semiconductor Graphite” CB-4-1989, National Electrical Manufacturers Association, Washington, Decision , 1989



Properties of industrial graphite

- Good electrical conductivity: the temperature coefficient of electrical resistance of graphite is negative in a certain range of temperature, unlike that of metals. Near absolute zero, graphite has only a few free electrons and acts as an insulator. As temperature rises, electrical conductivity increases
- Good thermal conductivity: outstanding heat transfer properties
- Unique mechanical strength: the tensile, compressive and flexural strength of graphite increases as temperature increases to 2700 K. At 2700 K graphite has about double the strength it has when at room temperature. Above this temperature its strength falls (see [graph](#)).
- Low coefficient of thermal expansion
- High thermal shock resistance: rapid heating or cooling is not a problem
- Graphite is not wetted by molten glass or by most molten metals
- Low coefficient for friction
- High chemical resistance
- Corrosion resistance: oxidation resistance in air up to 500°C
- Low capture cross-section for neutrons.



Properties of industrial graphite

- Problem-free machining with standard machine tools: graphite can be machined easily. Complicated parts with close tolerances can be machined with precision.
- Reasonable cheap material in comparison to other material with similar corrosion resistance
- Graphite does not melt but sublimates at about 3900 K. In air, graphite is resistant to oxidation up to temperatures of about 750 K.
- Graphite displays extremely low creep at room temperature, its flow characteristics being comparable to those of concrete. Creep in graphite is strongly dependent on the grain orientation (creep is defined as plastic flow under constant stress).



Baked carbon

➤ **Baked carbon**

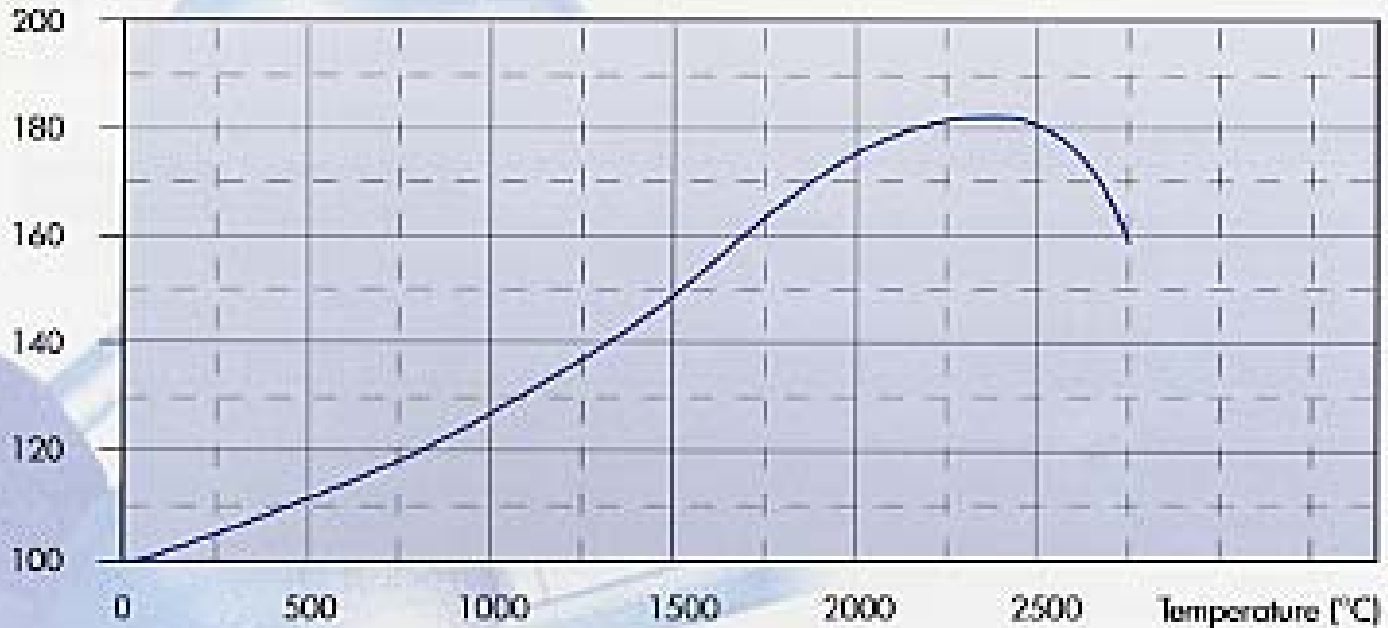
Baked carbon is a product manufactured from pitch, carbon black or other raw materials and binders and has a similar hexagonal layer [lattice structure](#) to graphite, but this is a less perfect one.

[chemical properties of carbon materials](#)



Properties

Relative mechanical strength in %, (RT = 100 %)



High temperature properties

- Electrical resistivity
- CTE
 - CTE delta
 - CTE
- Thermal conductivity
- Specific heat
- Strength
- Young's modulus

from room temperature up to > 2000 °C

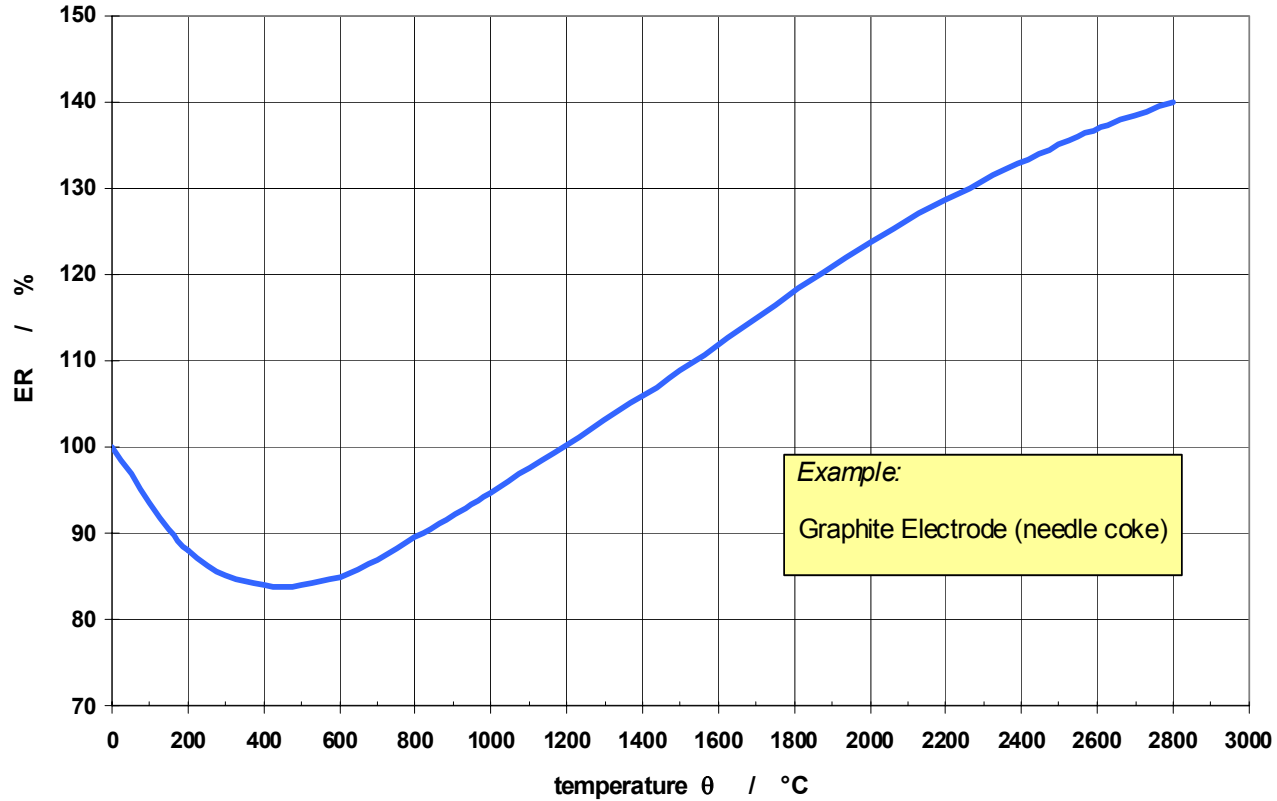
All graphs are showing typical property trends.

Absolute values will vary according to raw materials and processing.



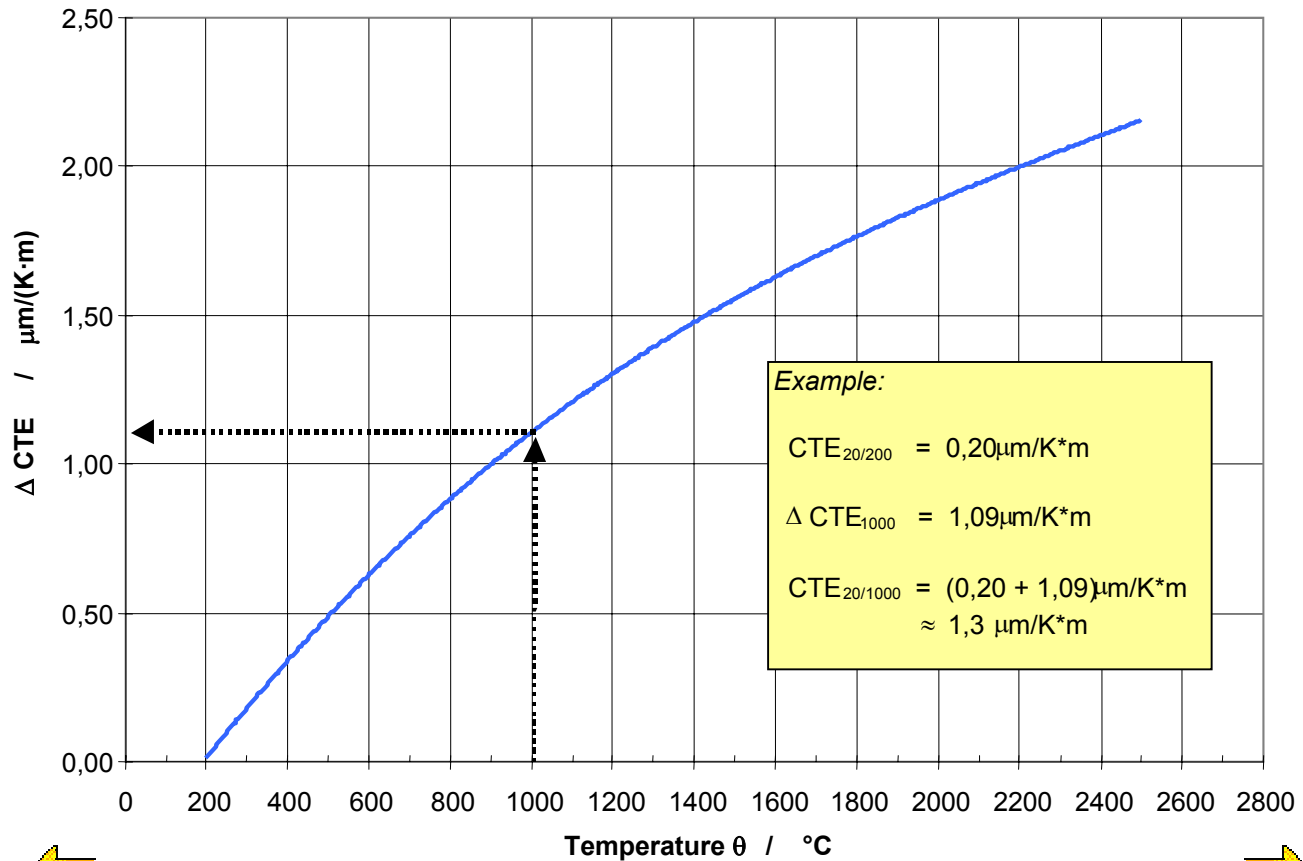
ER

Electrical Resistivity ER of Graphite : Relative Change vs. Temperature θ



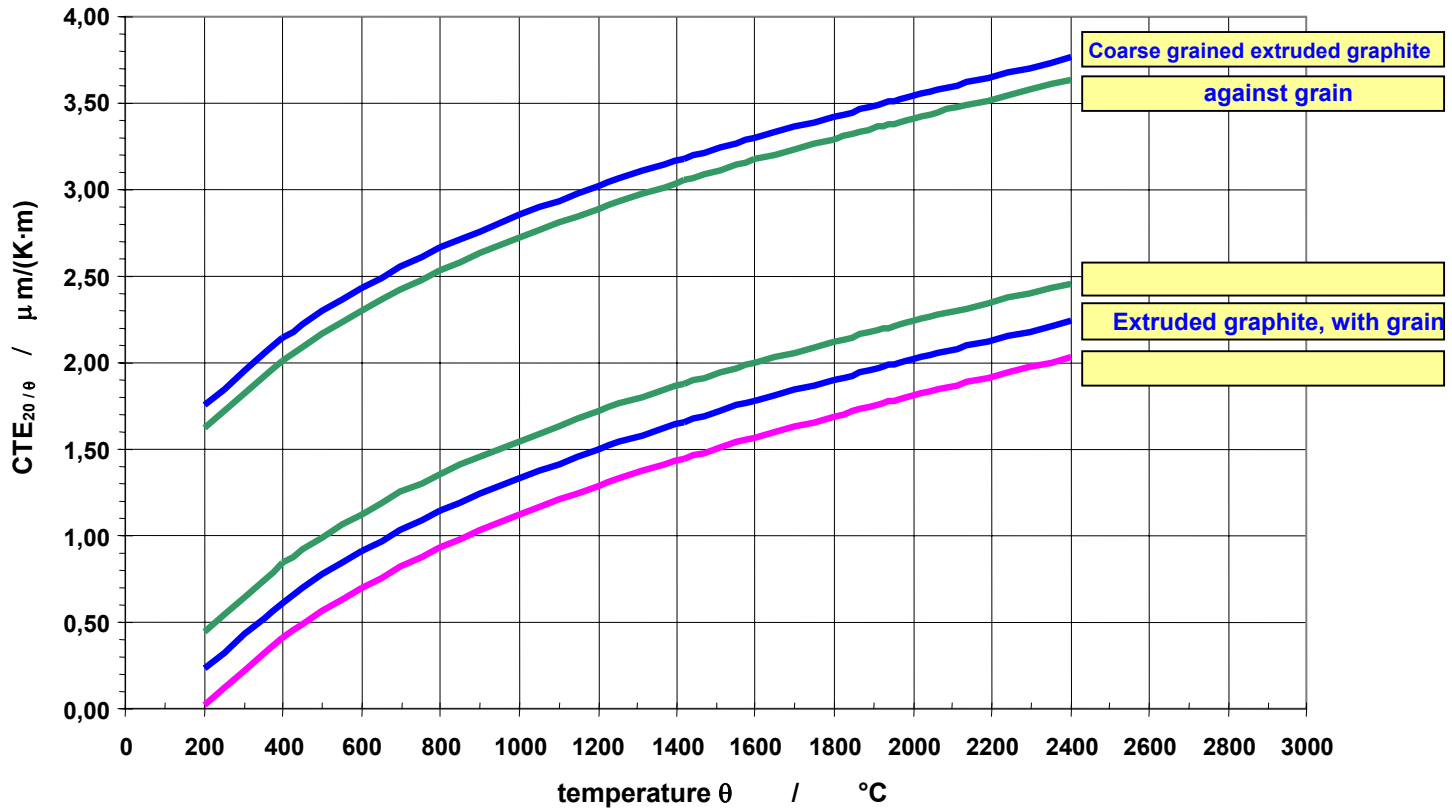
Δ CTE

CTE of Graphite vs. Temperature: Difference of CTE_{20/200} to CTE_{20/θ}



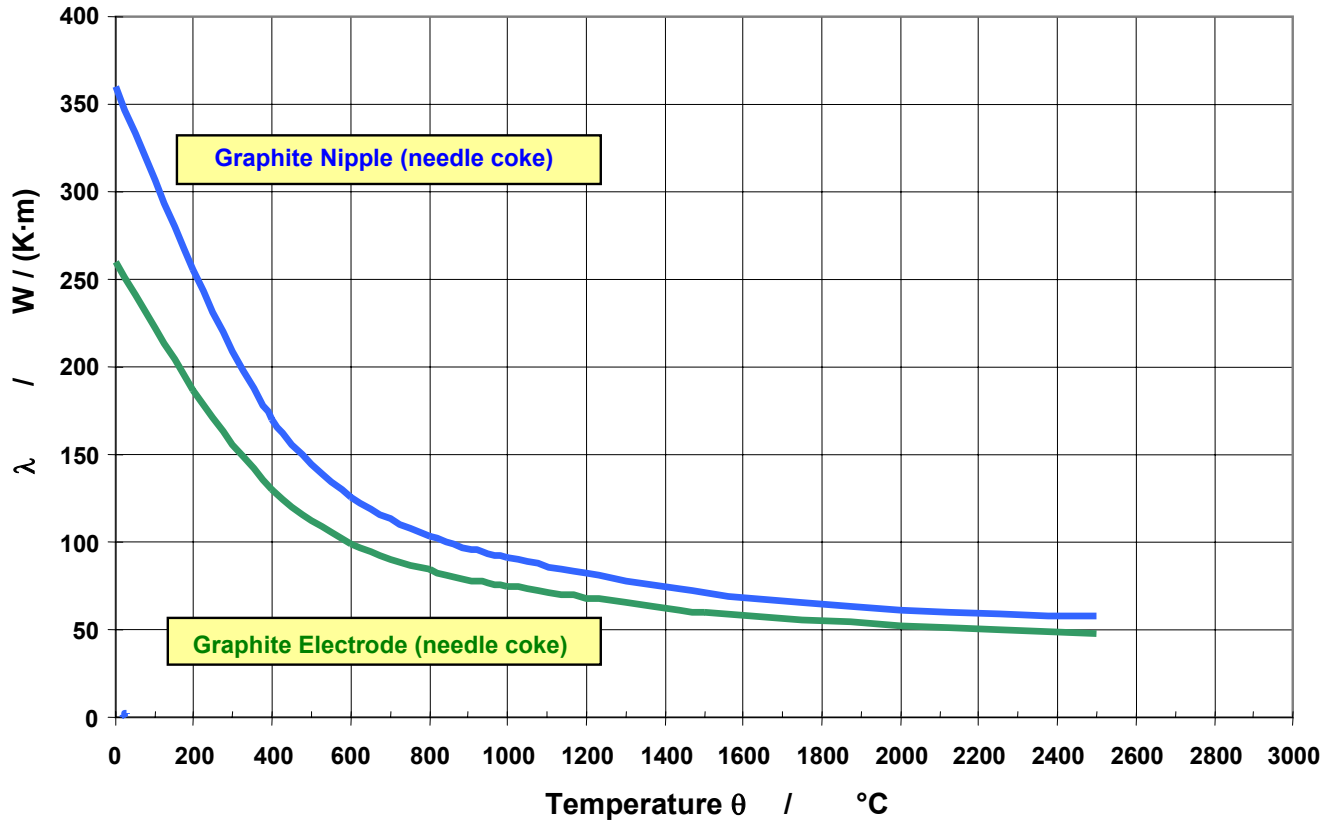
CTE

CTE_{20θ} of Graphite vs. Temperature θ



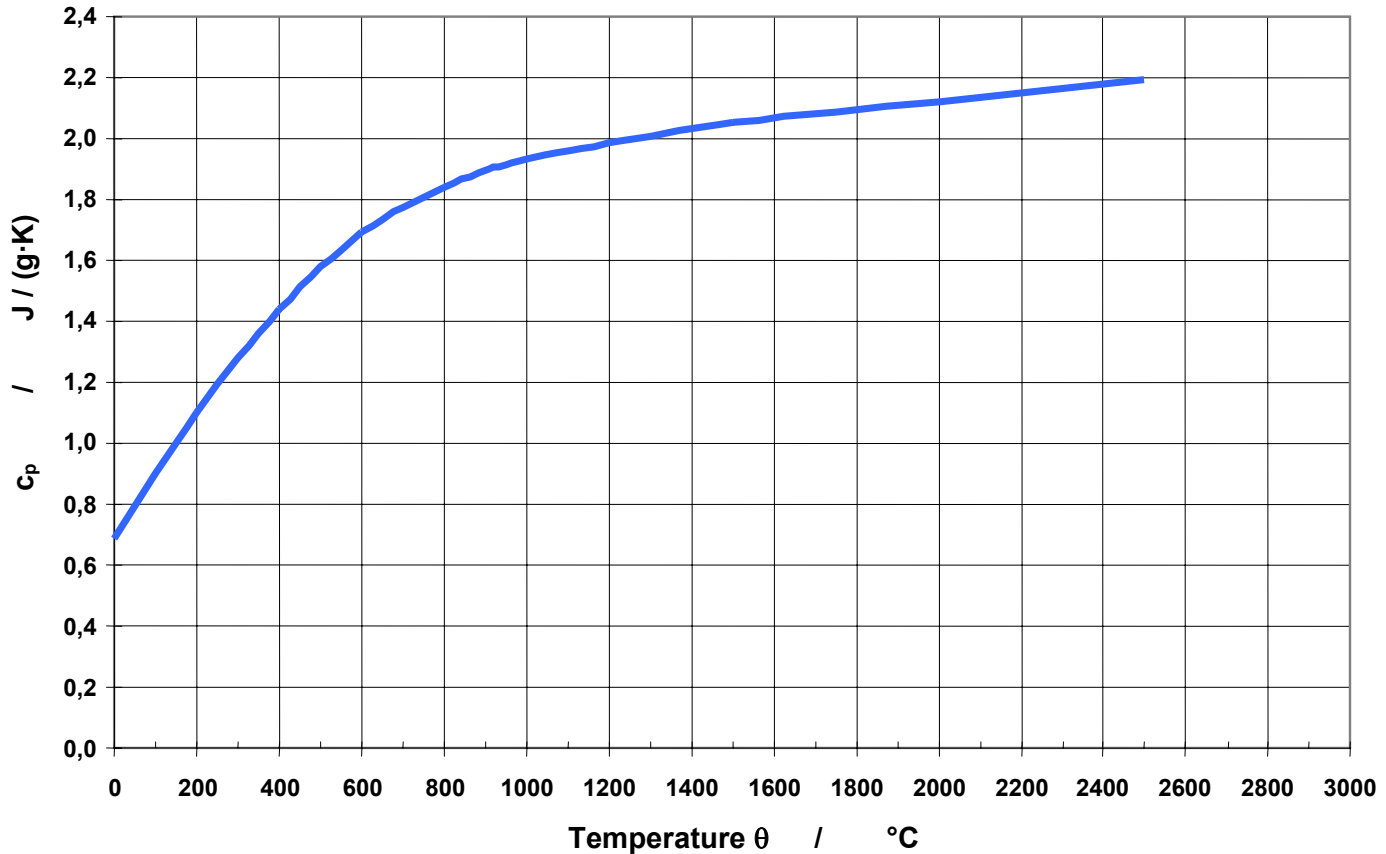
TC

Thermal Conductivity λ of Graphite vs. Temperature θ



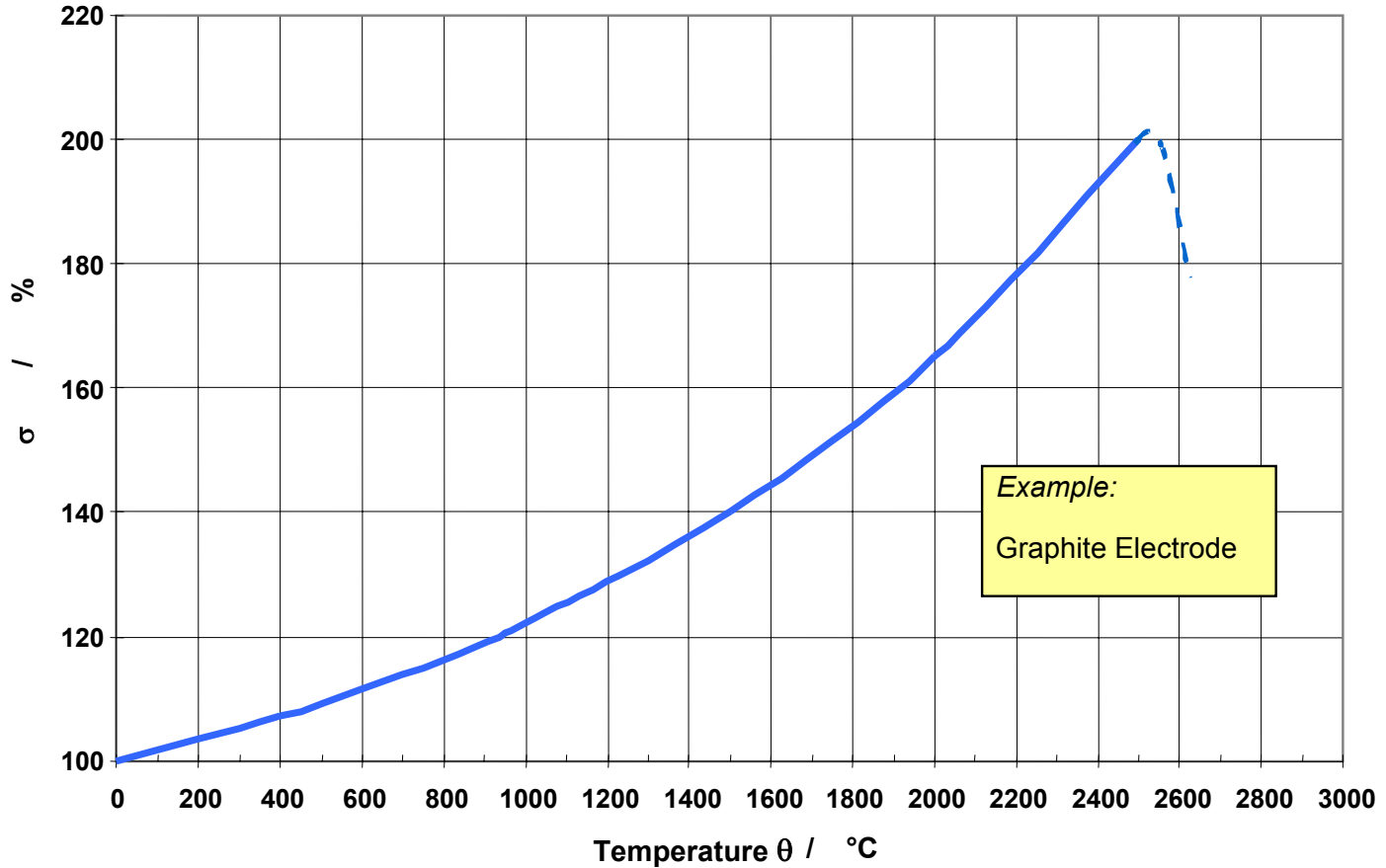
C_p

Specific Heat c_p of Graphite vs. Temperature θ



σ

Mechanical Strength σ of Graphite : Relative Change vs. Temperature θ



YM

Young's Modulus YM of Graphite : Relative Change vs. Temperature θ

