Impervious Graphite
Engineered for Reliable Heat Transfer

Natural graphite is formed by subjecting carbon to 750°C @ 75,000 psi for millions of years. Throughout that process, the amorphous carbon is transformed to a softer, crystalline state known as graphite. Graphite is the most stable form of carbon.

In late 1800's Edward Acheson, founder of the Carborundum Company, accidentally manufactured synthetic graphite. His intention had been to create another crystalline carbon, diamond. Although disappointed at the time, his discovery resulted in a material that is used widely throughout many industries. Different grades of synthetic graphite, each with unique properties, have been formulated for a variety of purposes including, but not limited to, electrodes for steel production, plates in advanced batteries, and for heat transfer equipment.

Graphite and its Importance in Corrosive Environments

Graphite has long been a sought-after heat transfer material for harsh and corrosive process streams because it exhibits both metallic and non-metallic properties that contribute to equipment longevity and reliability. Graphite has high thermal conductivity and low coefficient of thermal conductivity (CTE), similar to or better than that found in metals. Additionally, graphite is inert, making it exceptionally resistant to corrosion. In total, these properties make graphite an ideal heat transfer media for many highly corrosive processes.

Characteristics of Resilient, Long-Lasting Graphite for Heat Transfer Applications

Graphite for use in heat exchangers can be designed specifically for that use. It should be fully graphitized, resulting in high thermal conductivity, low CTE, and the proper balance of ductility, strength, and resilience to withstand the system stresses posed by the higher temperatures and pressures common in these harsh process applications.

Toughness is the resultant of the ductility, strength, and resilience of a tube, and can be determined by an ASTM test standard. This test measures the fracture stress and the duration to failure. The longer the material can withstand the fracture stress, the more ductile material.

A more ductile graphite can absorb energy better than a more brittle graphite. Therefore, the more ductile graphite, will result in longer, more reliable heat exchanger operating life.

Several factors that influence the ductility of a graphite tube are:

1. The material composition
2. The graphitizing temperature
3. The percent of porosity

How Synthetic Graphite is Produced

The base material is either graphite flour or needle coke. It is mixed it with a pitch, that will act as a binder, and a lubricating fluid. The important aspects of this composition are particle distribution and the ratio between the base material and the binder. This will affect the porosity, which optimally will be between 8-12%.

The tube is extruded and put into a bake furnace. The continuous bake process will put the mixture under a vacuum, introduce it to a furan resin, pressurize it, and then bake it at 850°C.

This process will be done multiple times, controlling the pore size within the graphite. Baking the mixture at this temperature will transform the binder and furan resin into carbon. At this point, the tube material is carbon-graphite.

In order to complete the transformation of the carbon-graphite matrix to a graphite matrix, the tubes are subjected to a 2,600°C graphitizing oven. At this temperature, the remaining carbon will become graphite. We refer to this as fully graphitized, a critical characteristic of CG Thermal's Impervite® graphite tubes.

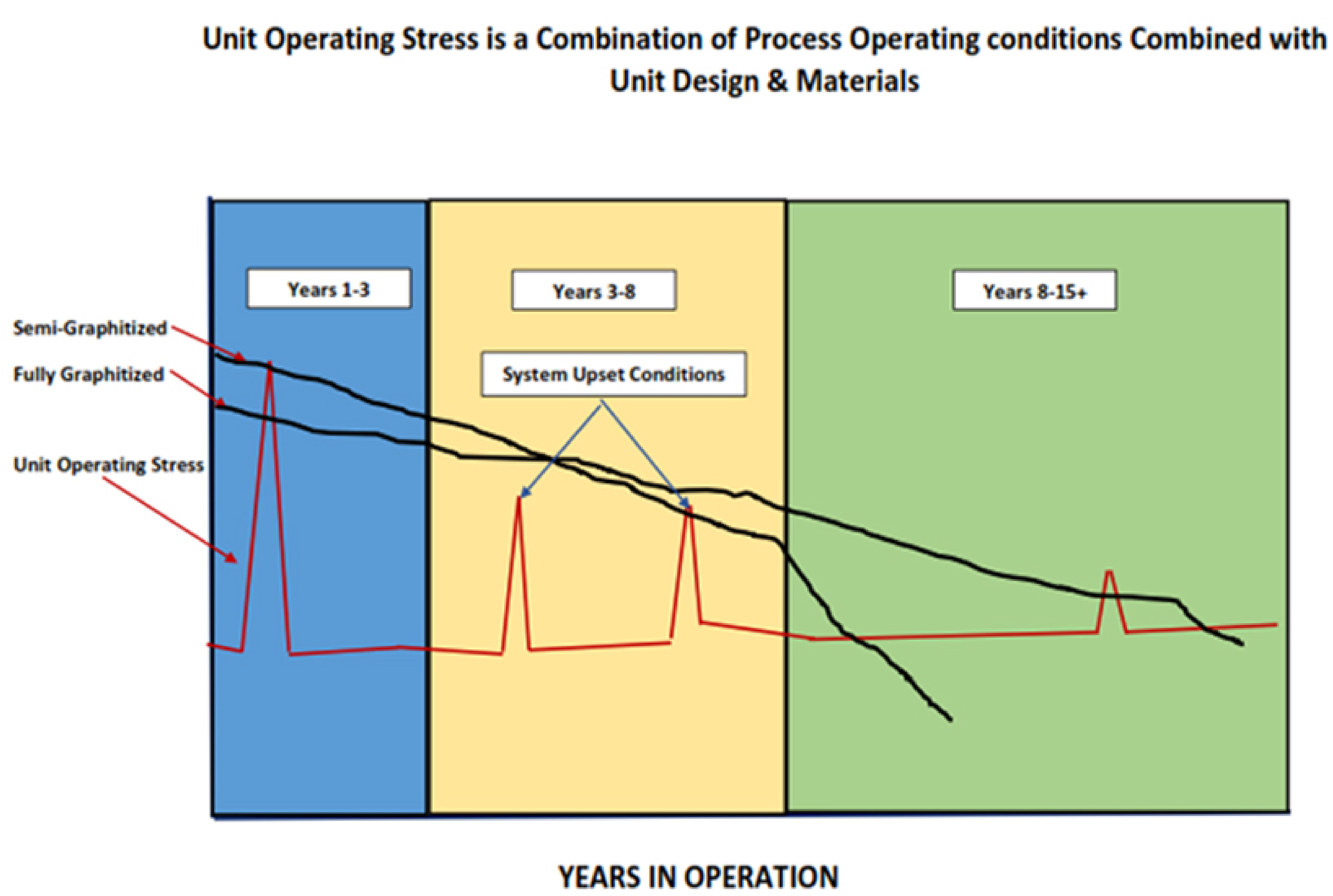
The absence of carbon is critical for several reasons:

- The thermal conductivity of carbon is low because the carbon structure is non-uniform, with stronger molecular bonds between the layers. The thermal conductivity of graphite is much higher because of the uniformity of the graphite layers. Therefore, a carbon-graphite tube will have lower thermal conductivity, resulting in less efficient heat transfer as well as low thermal shock resistance.

- Carbon is strong, but it lacks ductility, making it much more brittle. Carbon does not have the ability to absorb the type of fatigue loading seen in a heat exchanger during service. Tube life is based on its ability to absorb vibration and energy. Therefore, the less ductile carbon-graphite tube will have a short operating life than the fully-graphitized tube.

- Carbon reduces the thermal shock resistance of a graphite tube because it has a higher coefficient of thermal expansion and a lower thermal conductivity. Thermal shock resistance is described by this equation:

$$\frac{\textbf{Conductivity x Tensile Strength}}{\textbf{CTE x Young's Modulus}}$$



When comparing a fully graphitized tube with a carbon-graphite tube, the thermal shock resistance can be more than 2 times that of a carbon-graphite tube.
It should be noted that the initial strength of a fully graphitized tube is 20% less than a carbon-graphite tube. However, fully graphitized tubes will maintain their strength at elevated temperatures better than carbon-graphite tubes. With that, it is important to point out that the eventual failure in a graphite heat exchanger will not be determined by strength, but by the toughness of the material, which is directly related to its ability to absorb energy.

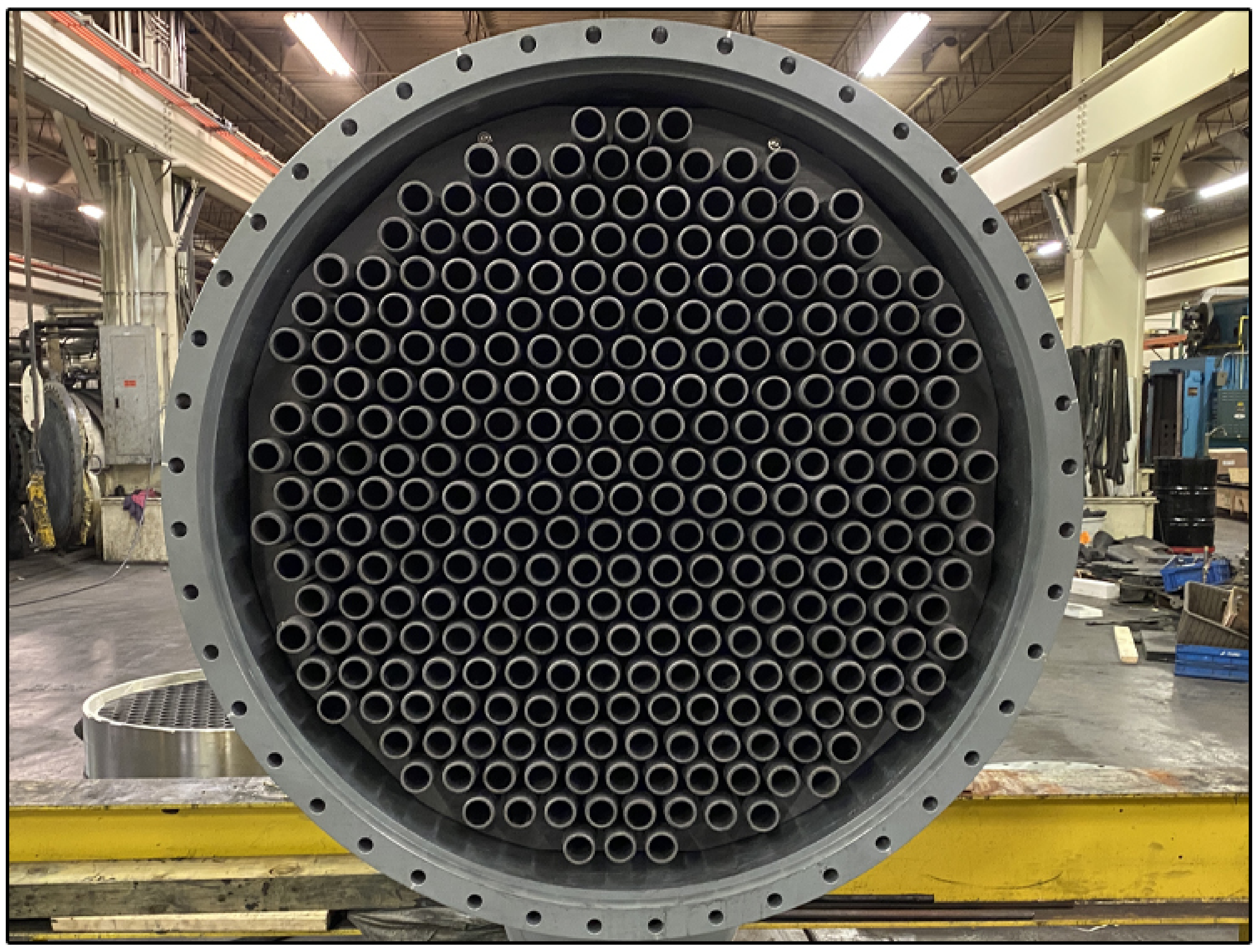
What is Graphite Impregnation?

As previously mentioned, the fully graphitized graphite will have anywhere from 8-12% porosity. That makes for a good filter, but not good heat transfer media.

During the impregnation process, a phenolic resin fills the pores and is baked to cure. This process is repeated several times to ensure that the material is fully impregnated, meaning all of the pores will be filled throughout the full thickness.

The graphite is rinsed between repetitive cycles to ensure no glazing occurs on the surface. This is a critical step, especially for block and other thicker shapes, to ensure full impregnation.

In addition to making the graphite impervious, the phenolic resin doubles the strength properties of the graphite and increases its ductility. This is why it is very important that the specified porosity be maintained during tube production.



The Result is Impervite®

Impervite® impervious graphite has a long history of reliability and exceptional operating life in the chemical processing industry.   That is due to close quality control at each step of production, ensuring the properties designed are consistently provided:

- Full graphitization of the base material with specified porosity, particle distribution and ratio of binder to coke/graphite flour.
- Full impregnation of the graphite with no glazing to ensure maximum resin pick-up for ductility and strength.

The Code Standard for Graphite Material

Part UIG of ASME code standard, can be followed when a G mark certification is required on a heat exchanger. Graphite material used in the construction of a G mark vessel must be tested and qualified. A material specification must be written which clearly dictates how the product will be made, then a Certified Material Qualification (CMQ) must be provided. The CMQ provides the results of a whole battery of tests for a graphite tube, including:

- Coefficient of Thermal Expansion
- Diffusion Rate
- Tensile Strength
- Compressive Strength
- Flexible Strength

These properties will have to be tested every 3 months to ensure they are still within certification. For graphite block materials, the same tests apply, but they don't have to be recertified every 3 months.

Common Applications for Graphite Heat Exchangers

Graphite is very stable in highly reducing environments. Therefore, it is widely considered as the economical and value-added choice for processes involving hydrochloric acid, phosphoric acid, and methyl chloride; especially at elevated temperatures and higher concentrations which exceed the capabilities of most metallic materials.

Graphite can also be an appropriate choice for mildly-oxidizing process applications. For instance, it can be used with sulfuric acid at concentrations as high as 70% when first cost is the driving factor. However, in a highly oxidizing environments, graphite will react to form carbon dioxide and result in material failure.

CG Thermal, Experts in Highly Corrosive Process System Design and Graphite Application

Equipped with more than 150 years of combined experience, we not only design and manufacture superior Impervite® graphite heat exchangers, but we also design the systems that may require those graphite heat exchangers.

To learn more about our graphite solutions or discuss your requirements with one of our experts, contact us today.

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