NeoGraf™ Solutions

WHITE PAPER

Polystyrene Insulation R-value Enhancements Using Graf+® Graphite Powder & Graf-X Graphene Nano-Platelets

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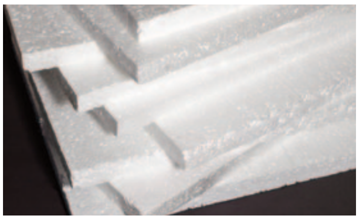
Overview

The building and construction market utilizes many different types of insulation to meet or exceed building standards throughout the world. One of the hallmarks to a well-designed building is the energy efficiency of the building as a system. A key component of the energy efficiency system is the insulation selected. This white paper explores how Graf+® graphite powder and Graf-X™ graphene nanoplatelets revolutionize polystyrene insulation, one of the most cost-effective energy efficiency systems.

Polystyrene foam is commonly produced from two processes; extruded polystyrene slab-stock (XPS) and expanded polystyrene boards (EPS) made from beads. Polystyrene foams are underutilized in the industry because of their relatively low thermal performance, but when Graf+ micronized graphite is incorporated, the R-value of the materials can be increased by up to 20% depending upon the thickness and the density of the foam. By acting as nucleating agents during foam formation, they improve crystallization within the foam's structure and increase the thermal reflectivity properties. This allows designers to use similar thickness products with better thermal efficiency or to utilize thinner products to make equivalent thermal performance, optimizing polystyrene insulation for energy efficiency and sustainable building practices, all while enabling more design freedom for the architects, engineers, and designers.



Polystyrene Foam

The types of polystyrene NeoGraf typically enhances are expanded polystyrene (EPS) and extruded polystyrene (XPS). XPS products (i.e., Styrofoam) are typically used as closed-cell insulation boards for walls, roofs, and foundations. XPS foams are generated through a large-scale extrusion process generating slab-stock. The slab-stock can be cut into various thicknesses for the final application.

EPS products are closed-cell and typically used for packaging and insulation applications. Expanded polystyrene foams generally first start as a bead and then are treated in a way to make the beads adhere to one another as they expand and form a desired shape in a mold.

Observed Thermal Enhancements with Graphite and Graphene Products to Increase Insulative Performance (R-value increase as well as heat reflectivity)

With respect to insulation, the industry measures results in R-values, which are derived from Lambda (λ) values. Lambda value's (aka K-values) "measures a product's thermal conductivity in units of W/mK" or BTU (hr·ft·°F). R-value measures the thermal resistance of a material, "the quantity determined by the temperature difference, at steady state, between two defined surfaces of a material or construction that induces a unit heat flow through a unit area". Essentially this means how well a given material resists heat transfer (thermal conductivity) at a given thickness. Typically, R-values increase with increasing insulation thickness. Knowing this, the value derived from utilizing Graf+ and GNP powders increases the R-value of a foam without increasing foam thickness.

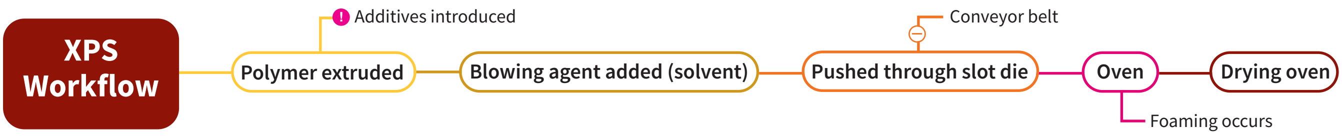
Successfully achieving R-value increases within the same foam thickness or less foam thickness has been typically demonstrated in XPS as mentioned earlier. The success is attributed to:

- Graf+/GNPs increasing the insulative properties (reducing thermal conductivity) by attenuating infrared radiation (R-value increase). Thickness matters, as the reduction in thermal conductivity and the resulting improved R-value will be more pronounced in a thinner board (~1 inch) compared to the results seen in a thicker board (~1.5+ inch).
- Graphite/GNPs acting as a nucleating agent to enhance crystallization of the polymer especially in the x-y plane of the structure.

The enhanced crystallinity of the polymer matrix when introducing the powders aids in phonon transport. Expanded natural graphite (ENG) (intercalated and thermally treated, lower density) lends itself more to creating a superior conductive pathway vs (unexpanded) flake natural graphite (NG), in relation to the percolation threshold due a more dendritic structure. The manufacturing process of extrusion assists in aligning the plate-like structures parallel to the surface increasing the x-y crystallinity of the polymer and reducing the z directional conductivity. Since ENG is less dense than NG, it is important to be mindful of viscosity during processing. There is a balancing act with loading levels of Graf+ and GNP powders and thickness/density of the foam, and the resulting effects on the XPS foam in question. For example, at relatively lower loading levels (2-8%), you will see an improvement in heat reflectivity. If a foam product is already designed to be fairly dense and/or thick, it inherently will have good R-value and the value of adding powders to it will not be as meaningful compared to adding the powders to a thinner and/or less dense board.

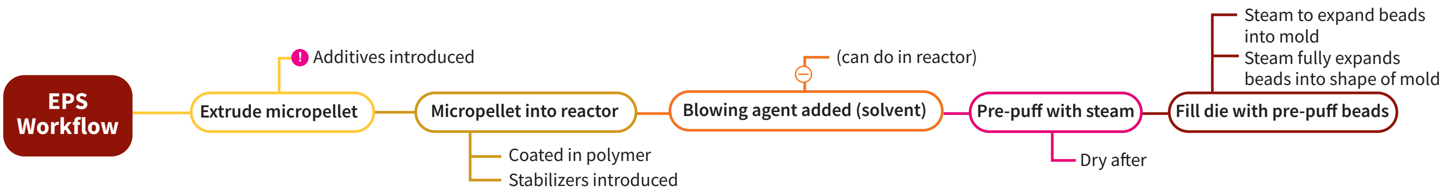
In many customer projects, NeoGraf Solutions has been able to successfully utilize our additive products to increase R-value within the same board thickness or enable a thinner board for a given R-value. This allows a foam manufacturer to use thinner boards in the same project, which also reduces the total amount of material used to insulate the same space. Space savings enabled be the thinner insulation is valuable in automotive, packaging, and building/ construction applications.

The XPS process utilizes a continuous extrusion process to create slabs of foam. An example of a XPS process is shown below, showing the addition of a powder (via masterbatch) being performed at the initial step of extrusion.



— Figure 1 —

There are several ways of making EPS foams. One example of the workflow can be seen below, showing the addition of a powder (also via masterbatch) being performed at the initial step of extruding a micro-pellet (<1mm diameter).



— Figure 2 —

A common method of introducing graphite into these systems is by introducing masterbatch products into the production environment. This prevents the foam manufacturer from dealing with the extremely low-density powders, eliminating the need for any special handling or dust concerns. NeoGraf currently offers several masterbatch products for the XPS and EPS foam insulation markets as seen in Figure 3, with additional grades in development:

Typical Properties				
Grade	Carrier	Graphite Loading %**	Melt Flow Index g/10 min*	Moisture Content %***
Graf-M™ EPS(01)	GPPS		5.0(200°C, 5.0kg)	
Graf-M™ XPS(01)	EMA	40	1.0(230°C, 2.16kg)	0.2%
Graf-M™ XPS(02)	GPPS		0.18(200°C, 5.0kg)	

— Figure 3 —

Ultraviolet (UV) Light Stability

Graphite and other carbon allotropes have natural UV absorption properties. There are numerous papers online that document the abilities of graphite and graphene's ability to absorb UV radiation (typically measured via UV-Vis spectroscopy) with the range of absorption being correlated to the number of atomic layers within a given particle.

The UV wavelength range of sunlight is:
- UVA (315-400 nm)
- UVB (280-315 nm)
- UVC (100-280 nm)

Graphite is nonreactive to UV light and can lend those properties to a material it is loaded into, depending on the concentration, which can increase longevity for outdoor foam applications.

Conclusion

The integration of Graf+® graphite powder and Graf-X™ graphene nano-platelets revolutionizes polystyrene insulation by enhancing R-values. These additives offer improved thermal performance, heat reflectivity, and crystallization enhancement. Foam manufacturers can achieve higher R-values with the same thickness or thinner boards, resulting in significant space and material savings. Industries such as automotive, packaging, and building & construction can benefit from these advancements, promoting energy efficiency and sustainability. The observed thermal enhancements highlight the potential of Graf+® graphite powder and Graf-X graphene nano-platelets. Embracing these innovative solutions paves the way for a greener and more efficient future in insulation technology. The design freedom provided by using thinner insulation should not be overlooked as architects and designers no longer have to sacrifice a certain look to achieve efficiency standards. This is truly a win-win for the environmental efficiency standard regulators and the architects, engineers, and designers.

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About NeoGraf Solutions

NeoGraf Solutions, a world leader in graphite materials science, has been manufacturing carbon and graphite products for over 140 years. Today, the company's high-performance products are used in a variety of demanding applications in a diverse array of industries. NeoGraf specializes in developing and manufacturing high-quality natural and synthetic graphite sheets and powders used in the latest consumer electronic devices, building and construction materials, transportation, and sealing and gasketing. With internal research, development, and manufacturing capabilities, NeoGraf provides high-quality products, environmentally sustainable solutions, and new opportunities for our customers. For more information, visit www.neograf.com.

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