

# Complete Carbon Fiber Solutions

Innovation. It's the fiber of our being.



*Spark the future.™*

## Your Complete Carbon Fiber Partner

Harper is the most trusted partner in thermal processing technologies for the carbon fiber industry. Our involvement in carbon fiber began at the market's inception in the 1970s, and since then we have been helping fiber manufacturers reach new and greater heights with our comprehensive offering.

Harper's value proposition is unequalled — decades of industry experience, a highly specialized, multi-talented group of employees, and a passion for partnership. We don't shoehorn a standard line of products to fit our customers' requirements. We specialize in first-of-a-kind solutions using our exceptional depth and breadth of knowledge and our extensive set of engineering building blocks. Harper's culture is one of genuine ingenuity and creativity, which ensures we are constantly challenging ourselves to craft the best-engineered technology solution for our customers' unique thermal processing needs.

With Harper, you will find a partner uniquely qualified to support the growing needs of the carbon fiber market. No one else offers an end-to-end approach with an all-encompassing range of technology and business solutions, delivered by a passionate and exceptionally skilled staff. That's why world-leading carbon fiber producers, cutting-edge start-ups, governments, universities and research institutes all depend on Harper to make their carbon fiber endeavors a success.

Harper's philosophy is not only to deliver comprehensive systems with the latest technologies, but also support our customers with portfolio of services and capabilities that help them stay ahead of the curve:

- Piloting Facility for Client Use
- Process Scale Up & Optimization Expertise
- Operating & Energy Efficiency Management
- Comprehensive Services & Maintenance

Oak Ridge National Laboratory's Carbon Fiber Technology Facility, a fully integrated line provided by Harper International



## Fully Integrated Process Lines

Our capabilities span from research scale with our Microline™ system, pilot scale lines such as with Oak Ridge National Laboratory (pictured left), and full production scale plants to 3M and 4M wide, giving our clients the most comprehensive technology offering no matter what stage of commercialization they may be in. Our experience includes a variety of precursors including PAN, pitch, lignin, polyethylene, and rayon in tow, nonwoven mat, or discontinuous, loose fiber form. From initial material handling to final product collection, working with Harper as your singular partner helps enable the most seamless and fluid plant operation possible. Harper's unique ability to link the many process steps in a production line helps ensure the most efficient performance for your organization.

Harper International's fully integrated process lines include:

- Material Handling, Treatment & Conditioning
- Gas Treatment & Handling
- Advanced Control Systems
- Oxidation Ovens
- LT, HT and UHT Furnaces

### Material Handling, Treatment and Conditioning

We take a comprehensive view of issues pertaining to material transport that extend beyond individual unit operations. Our expertise is designing end-to-end material handling throughout the system to ensure best functionality, preventing reduced throughput, loss of productivity, and the loss of quality that can result from a poorly devised material handling system.



Harper brings experience in pre- and post-treatment and material conditioning through a variety of techniques for the application of chemical solutions, whether chemical, electrochemical, plasma, or gaseous methods. We focus on thoughtful management of chemical preparation, as well as the minimization and treatment of the effluent solutions from the conditioning.

Harper engineers bring a wealth of experience in pre and post-treatment and material conditioning using a variety of solutions. Whether traditional or emerging methods – chemical, electrochemical, plasma, or gaseous treatments – we work with your process to ensure thoughtful management of chemical preparation and minimization and treatment of the effluent solutions from the conditioning.

### Gas Treatment and Handling

Harper approaches gas treatment and handling with several objectives. Not only do our designs focus on managing emissions and treatment of off-gas in an environmentally conscious manner, we also carefully consider opportunities for energy recovery within the process.

We help customers explore expansive opportunities for efficiencies and heat and energy integration – all aimed at reduced operating expenses and garnering a competitive advantage.

Harper's approach goes beyond the simple task of treating and abating from the plant and focuses on points of chemical process interface between the heat treatment and gas abatement equipment. Our expertise includes staged oxidizers, regenerative oxidizers, flares, wet scrubbers, dry scrubbers, filters, heat exchangers, condensers, and hydrogen recycling.



## Advanced Control Systems

From first point of engagement on a project, Harper designs with rigorous and thoughtful operations sequences to drive improvements in operations and quality. Our fully integrated control systems connect all equipment to one centralized system, to ensure the operation is that of a cooperative plant functioning on the same control platform rather than individual and isolated control platforms.

Harper's advanced operator-interface enables simple control of temperature, alarm management, sensor calibration, program recipe storage and retrieval, archiving of data and interface to central control systems of the thermal units, as well as advanced functions such as remote monitoring and proactive predictive maintenance.

Our designs not only allow for function of the system under normal operation, but also focus on enhancements of plant safety and protective measures in transitional states. This can range from start up regimes and shut down regimes where the individual unit operations are coordinated in proper sequence to protect both the operator and equipment, to disruptive events such as exotherms and loss of utilities where multi-level security helps to manage the facility in a safe fashion.

## Furnace Technologies

Harper is the industry standard for continuous furnace technologies for the carbon fiber industry, offering LT, HT and UHT furnaces. We are proud to also be one of few who can offer UHT (ultra-high temperature) continuous furnace systems rated to 3000°C for use in the production of high modulus carbon fiber, primarily used in applications requiring high rigidity.

Harper's team of engineering experts makes use of innovative design techniques to navigate the difficulties of developing a system that must operate at such high temperatures for extended periods of time. Most materials used in the construction of a furnace, such as the heating elements and insulation, will be consumed as part of the reaction with exposure to such high temperatures. Harper employs its years of experience and multiple proprietary features to implement systems that perform reliably for extended periods at these elevated temperatures.

### Harper Slot Furnace Design Enhancements

- Unique end-seal design delivers excellent process gas flow uniformity
- Strategic heating element design achieves optimal temperature uniformity
- Advances in insulation packages to reduce energy consumption
- Carburization resistant muffle for extended muffle life
- Truly adjustable inboard and outboard louvers for precise control of fugitive air ingress and egress
- Well-proven atmosphere purge chambers improve product quality and extend the useful life of the insulation

### Harper Slot Furnace Capabilities

- Temperatures to 3000°C
- Electric or gas fired
- Carburization resistant muffle
- Easy internal access to facilitate maintenance
- Unique atmospheres (argon, nitrogen, CO<sub>2</sub>, steam)
- Vertical HT furnaces, high modulus and other custom designs
- Multiple independently controlled temperature zones
- Fully pre-assembled and carefully broken down to minimize field installation effort



## Oxidation Oven Technologies

Harper offers advanced Oxidation Oven technology to complement its industry-leading furnaces for carbon fiber processing. Our state-of-the-art oven designs available for tow-bands from 300mm to greater than 4000mm. Harper's designs incorporate a multitude of improvements beyond what's available on the market today, including energy efficient designs. These improvements come in the form of clearly stated performance guarantees. Some of these design innovations include:

- Superior atmospheric seals
- Continuous monitoring of supply, recirculation, and exhaust flow rates
- Improved, patent-pending nozzle design
- Process based instrumentation array
- Quadrant construction for improved installation

These technology advancements equal faster oxidation through elimination of the chimney effect, improved velocity uniformity and range, assurance of temperature uniformity at a variety of flow rates, and optimal control of the reaction ultimately enhancing fiber quality. These improvements come in the form of clearly stated performance guarantees.

The most distinctive feature of Harper's cutting-edge Oxidation Oven design, the innovative atmospheric end seal, reduces fugitive emissions, increases the active volume of the oven, and offers reduced energy consumption over alternatives. The seals have independent adjustment of the top and bottom inside and outside slots. Each pass has an independent vent with adjustable draw control and the exhaust plenum connects to a dedicated fan/VFD. As a result of these innovative design features, there is no vertical mixing in the seal, less air ingress, and virtually no process gas escape.

Harper's instrumentation improvements include a two-tier balancing methodology, responsive quench system and rapid cool down system, emissions monitoring, and inherently safer pressure relief system. Additionally, Harper's modular construction design is another advancement that sets us apart from the competition. Our ovens show a 90% reduction in labor versus similar field erection times into a full line pilot system (300mm).

Harper also provides as a part of our Microline™ system a proprietary multifold research oven offering parallel, cross, and down airflow directions in a single oven, which allows for true evaluation of different flow techniques. The oven's uniformity specifications meet or exceed best-in-class for each flow regime.



## Process Scale Up & Optimization

From spark to finish, get to market faster and more efficiently with Harper's Ignite™ process. Harper enables companies in the development of advanced materials, from the lab to full commercialization, helping make their innovations a reality. Utilizing our depth and breadth of experience in thermal processing, we partner with our customer to ensure success as they scale up their process operations.



Harper's support begins in early stages of research and development, whether at corporate R&D centers, universities, government institutions, or start-ups. Our mission is to assist these customers in turning the next generation of material innovations into profitable new markets.

## Engineering Studies

Customers count on our extraordinarily experienced engineering staff to conduct in-depth studies to determine equipment requirements and help define process parameters for optimal plant design to assist with technical and business strategy and financial planning. Our vast capabilities in thermal processing engineering studies include, but are not limited to:

- process cost model
- economics of increased production capacity with current and future state technologies
- analysis of best-suited thermal process technology system for new material innovations
- identification of opportunities for improved product quality and cost reduction
- engineering of material handling solutions for unique processing system

## Piloting Facility

Unlike any other provider, Harper offers its continuous carbon fiber pilot process line in Portugal as an open reference and capabilities demonstration to select Harper clients. This facility includes Harper's proprietary multi-flow oxidation ovens, advanced LT and HT slot furnaces rated for 800°C and 1800°C respectively, surface treatment and waste gas abatement systems, and winders.



The use of a pilot scale line is a core step in the development of a precursor-based carbon fiber to enable a client to produce carbon fiber samples of sufficient quality, under nearly identical continuous operating conditions as those seen in a production facility. Harper's facility can help support client goals of validation of the material quality under ideal conditions as well as the production of material quantities sufficient to drive marketing and down stream research needs. Harper clients can also obtain carbon fiber samples to be analyzed for physical properties such as strength and modulus.

## Operating & Energy Efficiency Management

Give efficiency the green light. Harper's Beacon™ program is designed to drive greater energy efficiencies and lower operating costs through careful analysis of the carbon fiber conversion process. It is the only offering of its kind that is focused on enabling carbon fiber manufacturers to position themselves for the exceptional growth that the market is poised to experience in expanded applications such as automotive.



With our extensive experience in furnace technology since the market's inception, Harper has developed a model that analyzes various plant configurations and capacities, precursors, integration scenarios and energy recovery options and ranks the environmental impact of the process line. The Beacon model is a complex analysis of more than 100 design parameters. This endeavor establishes a baseline and a facility-specific metric that can be used to develop improvement plans to drive greater energy recovery and lower operating costs.

Harper offers the Beacon program as a tool for carbon fiber manufacturers interested in achieving greatest output cost effectively with environmental responsibility. Within the area where we are experts, the carbon fiber conversion process, it is our commitment to help drive the industry to meet its full potential.

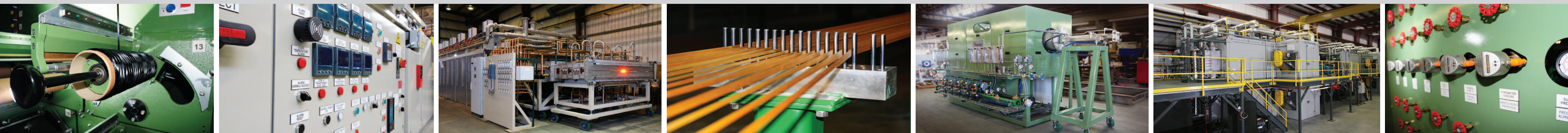
## Comprehensive Service & Maintenance

Harper's comprehensive Pulse™ team service offers one-call technical support, domestic and overseas field service, proactive preventative maintenance programs, fast-turnaround genuine replacement parts, and engineered solutions for a broad spectrum of your service and maintenance requirements. The Pulse team brings a passionate, collaborative and innovative focus nurtured by years of process technology know-how to bring timely and practical solutions to the most difficult challenges.



With the demands of today's competitive business environment and ever-escalating downtime cost, timely replacement with quality parts is a must. Our experienced engineers and technical specialists will collaborate with you to identify the optimal replacement parts or design solution to meet your needs. Our team is also available for consultation on any aspect of our process technology equipment from installation through operations, troubleshooting and general maintenance support.

Visionary customers appreciate collaboration with the Pulse team of experienced engineering professionals to develop innovative solutions to a number of diverse technical and engineering challenges ranging from upgrading equipment for process or production optimization, energy management or to increase reliability and performance. Harper also provides enhanced control systems, instrumentation and technologies tailored to meet the stringent control requirements and specialized needs of emerging technologies and complex applications.



## *Thermo. Dynamic.™*

Harper International is a global leader in complete thermal processing solutions and technical services essential for the production of advanced materials. From concept to commercialization, from research scale to full production line operations, Harper is perpetually on the cutting edge. For decades, we have pioneered some of the world's most innovative, customized systems, with a focus on processing materials at high temperatures and in non-ambient atmospheres.

Harper's philosophy is not only to deliver comprehensive systems with the latest technologies, resulting in distinctive solutions, but also to design features that ensure the most efficient and effective operations to support our customer's growth. Whether it's optimized waste gas treatment, control systems with predictive maintenance, or energy efficiency techniques, Harper always has the complete solution in mind.

Of course, saying we're the partner for you doesn't get the job done — we're eager to prove it.

*"There's nothing standard here at Harper, almost everything we do is one-of-a-kind."*

*– William Stry Ph.D.  
Senior Process Technology Engineer*



*"In the field we work one-on-one with everyone, from the site supervisor to the contractors, to the engineers and the project manager."*

*– Renee Bagwell Ph.D.  
Senior Process Technology Engineer*

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