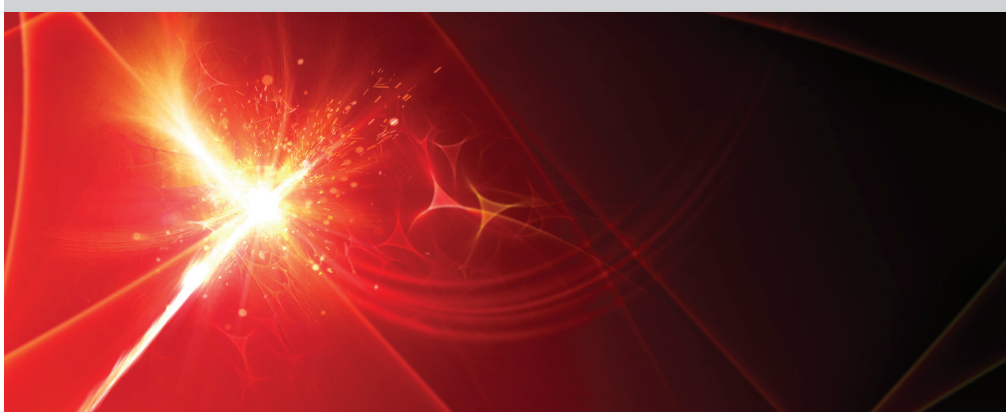


Research & Pilot Facilities

Lab & Pilot Scale Thermal Processing Technology for Advanced Materials Research



Spark the future.™

Harper's Technology Research Center

Harper Headquarters, NY, USA

Let Harper help bring your next material innovation from spark to reality. Hundreds of companies have used our Technology Research Center for process development and process optimization as they work toward commercial scale-up or with systems requiring unique process specifications. Customers can utilize numerous thermal systems to gather data and fine tune their processes. With a focus on varying production rates, temperature regimes, processing times, atmosphere compositions, and flow rates, using Harper's Technology Research Center results in savings on the investment ultimately required for new thermal processing systems.

Harper has a wide variety of thermal systems that can handle your process conditions. Additionally, we have the ability to make modifications to tailor the existing pilot equipment to specific customer process requirements. Our range of equipment includes:

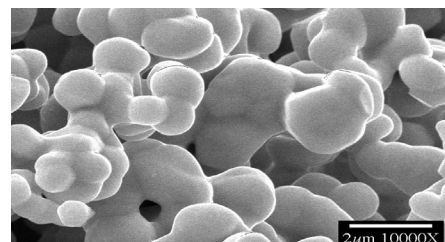
- Batch or continuous furnaces
- Sizes from small kilns to large furnaces, with 3 temperature zones
- Furnace conditions from atmospheric to nitrogen or specialty gases, with temperatures up to 2500°C

Along with our thermal systems, Harper provides state-of-the-art laboratory environments to help transfer your technology from the lab to the global marketplace. Our comprehensive range of lab testing capabilities include:

- SEM/EDX
- electron microprobe
- qualitative and quantitative powder XRD
- high temperature XRD
- particle size analysis
- surface area measurement
- DTA and TGA
- thermal diffusivity
- dilatometry
- thermal and elemental analysis

As a result of their experience in the testing and feasibility stage, many customers work with Harper 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 models
- identification of opportunities for improved product quality and cost reduction
- investigation of solutions for transition from batch to continuous processing
- engineering of material handling solutions for unique processing systems
- analysis of best-suited thermal process technology system for new material innovations



Harper's Technology Research Center

Partner Research Facility

Oak Ridge National Laboratory, USA

Oak Ridge National Laboratory is home to the Department of Energy's Carbon Fiber Technology Facility. As a part of the Energy Efficiency and Renewable Energy (EERE) program office, this 42,000 sq. ft. innovative technology facility serves as a national testbed for government and commercial partners to scale-up emerging Carbon Fiber technology. The 390-ft long processing line at this DOE facility was manufactured by Harper International and is the ideal outlet for Carbon Fiber research and development. It is capable of custom unit operation configuration and has a capacity of up to 25 tons per year, or 4.3kg per hour, allowing industry to validate conversion of their Carbon Fiber precursors at semi-production scale. The facility aims to be a collaborative research center and is designed as one of the most sophisticated and capable lines in the industry. Clients can take advantage of their testing and piloting needs with the Carbon Fiber line's extensive capabilities including:

- Rated capacity 25 tons/year based on 24k PAN tows
- Configured for PAN, polyolefins, lignin, and pitch precursors; Upgradable for rayon and high modulus carbon fibers
- Designed for 3k to 80k tows and web up to 300mm wide x 12.7mm loft
- Oxidation temperature to 400°C with airflow configurable for parallel, cross or down flow
- High-temperature carbonization to 2000°C

Partner Research Facility

University of Dayton Research Institute, USA

Harper has partnered with the University of Dayton Research Institute to offer our clients access to additional innovative R&D systems. The UDRI Multiscale Composites and Polymers division operates an industrial scale, continuous process high temperature Pusher style furnace manufactured by Harper. With this furnace, materials are placed on a tray or loaded into graphite boats which are placed on the track system and "pushed" through the hot zone of the furnace under inert atmosphere. The advantage of Pusher furnaces compared to a conventional batch oven is that the time consuming process of heating up and cooling down the furnace is removed, resulting in dramatic cost reductions and process uniformity. Harper's clients can take advantage of testing their advanced materials with the facility's equipment capabilities including:

- Maximum temperature: 2500°C
- Purged nitrogen atmosphere
- Maximum part size of 19 in. x 19 in. x 3 in.
- Adjustable residence time at temperature, from 30 minutes to 6 hours



Harper's Technology Research Center



Partner Research Facility - Oak Ridge National Laboratory

Partner Research Facility

Carbon Fiber Pilot Line , Portugal

Harper offers its complete carbon fiber pilot process line at a partner's facility in Lavradio, 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.

Here, Harper clients can utilize the facility for validation of their carbon fiber process, confirmation of material quantities to enable downstream research, assessment of feasibility of continuous operations, and validation of design parameters for further scale up.



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, we partner with our customers to ensure success as they scale up their process.

Harper's support to emerging industries 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. Just like our experience in the Carbon Fiber market, we help customers develop unique thermal processes and efficiently and effectively progress them into complete production lines.

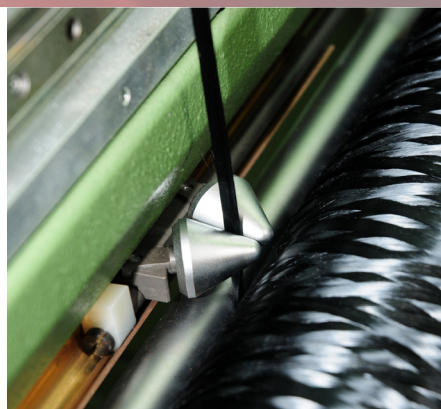
As customers ramp up their operations, Harper offers the widest range of solutions in lab scale, pilot scale and full-production scale sizes. Through multiple research and piloting facilities, customers have the ability expedite development while saving time and money by utilizing Harper's equipment and technical support. We have the building blocks to design for the most challenging thermal processes, using our vast experience to devise a first-of-a-kind system every time. From material handling to final product collection, and everything in between, Harper provides complete solutions for your advanced material process plant. We're focused on helping customers link the process steps to achieve greater efficiencies in reduced operation costs, increased quality and productivity, and strategic risk mitigation.



Partner Research Facility - Portugal

Proven Partnerships. Unlimited Possibilities.

Using our depth and breadth of experience in thermal process programs, we partner with our customers from day one to ensure success as they scale up their operations through process development, optimization, piloting and production. Harper offers clients access to a number of extensively outfitted research and piloting facilities to help de-risk their process and develop the most efficient and effective thermal processing regime to meet their goals. We understand the importance of R&D necessary for the scale up of advanced materials.



Higher degrees of innovation.

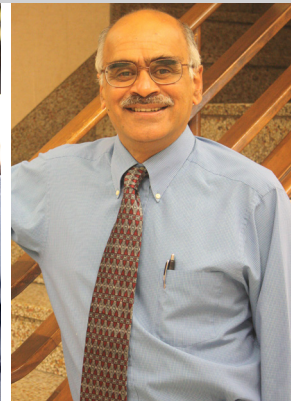
Harper International is a global leader in complete thermal processing solutions and technical services essential for the production of advanced materials. From concept to commercialization, from research scale to full production line operations, Harper is perpetually on the cutting edge of the most innovative furnace and oven designs in the world. For decades, we have pioneered some of the most unique, customized systems available, with a focus on processing materials at high temperatures up to 3000°C and in non-ambient atmospheres.

Harper serves advanced, cutting-edge material markets including Fibers & Filaments, Powders, Metal Oxides, Technical Ceramics, Rare Earths, Graphene, Energy Device Materials and Nuclear Materials. Our support to these emerging industries begins in early stages of research and development, whether at corporate R&D centers, universities, government institutions, or start-ups. Harper is a partner through the entire development process assisting in the scale up and commercialization of advanced materials that will change our everyday lives.

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. 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.

"Taking core technology designs and catering them to our customer's special and unique thermal processes. That's where we really shine"

— Peter Witting Ph.D.
Senior Process Technology Engineer



"I've developed several processes from lab scale through commercialization throughout my career as a material scientist prior to joining Harper. The most critical stage is going from small to large scale and to a continuous process. The differences in each process or material development are interesting and challenging, and this is where Harper's expertise shines through when we partner with our customer."

— Prasad Apte Ph.D.
Director of Technology

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