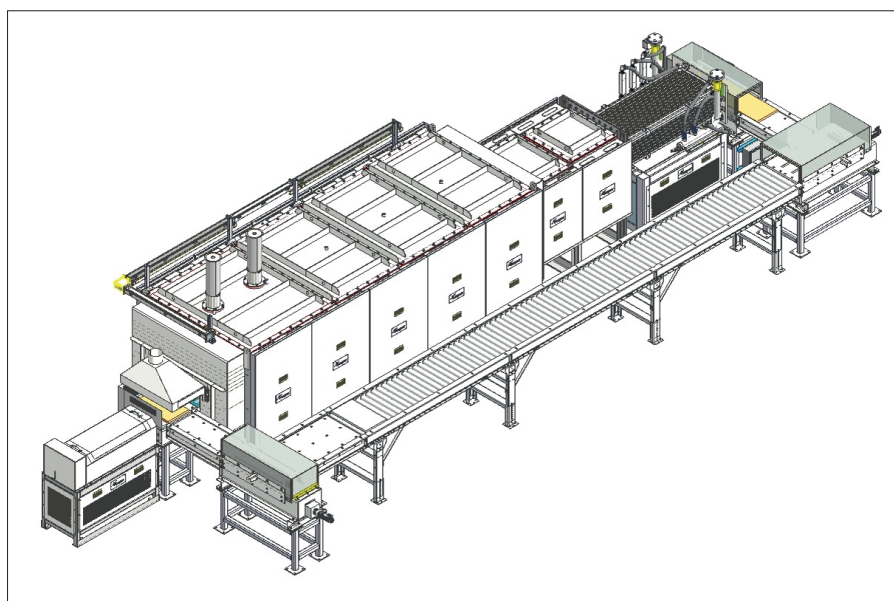


## Versatility of Pusher Furnace Technology – an Ideal Solution for the Continuous Processing of Batch Materials

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Often times in thermal processing, the equipment used to facilitate the process is driven by the specific application. The conventional thermo-chemical treatment of select materials goes back decades, further ingraining the mindset of a given practice to be utilized in the given industry. However, advancements made in pusher furnace technology allow for the adaptability of system designs to provide innovative solutions for a variety of materials and processes.



**Fig. 1** Pusher furnace system for advanced ceramics

Pusher furnaces are frequently used for heat treating powders, bulk materials, and net shapes for applications often involving metal oxides, technical ceramics, rare earths, energy device materials, and nuclear materials. Conventional applications include calcination, sintering, oxide reduction, purification, metallizing, and de-binding. This type of technology is advantageous in providing a high production volume with a particularly uniform homogeneity of reaction. Systems can be designed for processing to a maximum of 2800 °C in specialty atmospheres, and can be gas or electrically heated depending on the temperature range.

A mechanical pusher mechanism is used to transport the product carrier sequentially into the furnace. This moves a train of boats through a tunnel along where the material undergoes the heating and cooling cycle. Pusher furnaces are ideal for processes requiring exacting control of temperature and

atmosphere, often for those with longer residence times requiring multiple specific temperature hold points and moderate gas-solid reaction (Fig. 1).

### Design considerations

Pusher furnace design considers the more intricate details of the system to appropriately meet the processing constraints. The major aspects of the system are detailed below:

- Zone sizing and insulation: independently controlled temperature zones expose the material to a temperature profile along the length of the tunnel. Individual zone construction considers the load geometry to meet the production rate, all while providing the optimum temperature uniformity, energy efficiency, and materials of construction.
- Heating elements: design and element layout is dependent on the atmosphere(s), temperature range, and even process by-

products for the specific application. The type and location of the heating elements influences the maintenance access, efficiency, and temperature uniformity of the heating chamber(s).

- Cooling implementation: relevant for both the furnace involved equipment and the material processing. Temperature rating of the system, furnace integrity, surface temperature, ambient environment and

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**Fig. 2 Harper nuclear fuel sintering pusher furnace**

safety are all factors for the involved equipment. For the material, thermal shock concerns, space requirements and operating expenses can impact the overall design.

- Power and controls: the involved equipment can vary in the complexity of the control system, level of automation, return systems, and implementation of fully integrated feed loading and product unloading. In some cases, skid mounting, gas treatment and handling, and turnkey installation are also incorporated into each individual design. Installations are managed all over the world, with each location having distinct electric supply requirements.
- Maintenance and installation: operator access locations are a design criterion that can be highly process dependent. High maintenance and replacement part areas are identified to minimize the required downtime in performing scheduled maintenance. Modular construction tactics during fabrication can allow for the equipment to be adjusted to facility layout limitations, while maximizing the field installation efficiency.
- Atmosphere flow and seal type: atmosphere flow and direction is essential to facilitate any reaction, and also to allow the appropriate exhaust of volatile(s) evolved during treatment. A muffle is frequently used to provide the necessary separation of the process and furnace interiors.

End seals of the furnace prevent oxygen ingress corresponding to the process requirements. These can vary based on the type of atmosphere(s) involved, process materials, purity requirements, or furnace interior.

- Process muffle design: for applications with specialty atmospheres or that contain volatile by-products, a muffle is used to contain the load and involved gases. Muffle cross-section and material design is dependent on the characteristics that best fit the process and the selection of each is often reflective of the particular benefit provided.

A few systems examples are highlighted below to convey the flexibility of pusher furnace technology in providing the appropriate technological solution.

## Pusher furnace technology for nuclear fuel

Pusher furnace systems are often suitable for nuclear fuel sintering processes due to the ability to provide the high-temperature capability, along with hydrogen atmosphere and dew-point control. Typically, nuclear fuel sintering furnaces utilize molybdenum heating elements located on the sides of the load space with high alumina oxide based refractory, and are electrically heated with temperatures to 1800 °C.

Harper International has supplied numerous pusher tunnel kilns for sintering processes in the nuclear fuel industry including PWR,

PHWR, and CANDU reactors. An example of a Harper provided nuclear fuel sintering pusher furnace is shown in Fig. 2.

Harper has sustained a relationship with a nuclear fuel processor over multiple decades, contributing to the current design of Harper's nuclear pusher tunnel kiln systems. This has led to enhancements including higher temperature furnace operation, longer uniform operation life cycles, and a reduction in ambient heat release and energy usage.

## Pusher furnace technology for advanced ceramics

Harper International recently provided a highly specialized system for the production of an advanced ceramic material used in the automobile industry. This system was developed as a part of the customer's transition from a batch to a continuous process, thereby increasing efficiency. A model of the pusher furnace technology designed to accommodate these specific needs was shown already in Fig. 1.

Pusher furnace technology was deemed appropriate for the process due to the ability to provide highly uniform heat treatment for each individual material load. This system includes alloy heating elements in the de-binding region, and silicon carbide heating elements in the high-heat region capable of providing temperatures up to 1300 °C. The elements were located over and under the material load, with a separate top and bottom zone in the high-heat region for enhanced process control.

Material handling was a major design point for this system as stable transfer through the furnace and involved equipment was critical due to the high sensitivity of the load to movement and vibrations. All pushing mechanisms were outfitted with smooth ramp-up/ramp-down capabilities and position sensing to be monitored by the Harper provided control system.

Low friction surfaces were also implemented at high risk areas and the system incorporated an adjustable hearth line over time adapting to tile wear.

A turnkey solution was supplied for the client including all interconnecting materials provided by Harper. This allowed for the system installation to be completed promptly for expedited thermal testing of the system.

## Ultra-high temperature pusher furnace technology

Harper International has more than 60 continuous graphite furnace systems installed and in operation in the last 15 years. These furnace systems are used to process materials such as carbon fiber, carbides, non-oxide ceramics, and carbon powders. Pusher furnaces represent some of the most interesting of these graphite systems, with an example shown in Fig. 3.

Graphite pusher furnace systems often are supplied with more design constraints than those operating at lower temperatures due to the materials of construction. In order to maintain the furnace integrity, the heating chamber needs to operate under an inert atmosphere to protect the graphite and have water cooled protection of the seals. One benefit of graphite systems is the ability to rapidly heat and cool the systems. The material is less prone to thermal shock, and therefore can be cycled more effectively than ceramic based refractory systems.

Harper's clients are able to take advantage of testing advanced materials with an in-



**Fig. 3** Ultra-high temperature graphite pusher furnace

novative R&D pusher furnace system. Over 10 years ago, Harper partnered with the University of Dayton Research Institute/US in providing an industrial scale, ultra-high temperature developmental furnace. Through this relationship, Harper is able to

take advantage of testing advanced materials with the UDRI electrically heated system. The system is capable of reaching temperatures to 2500 °C in an inert atmosphere with defined residence times up to 6 h.