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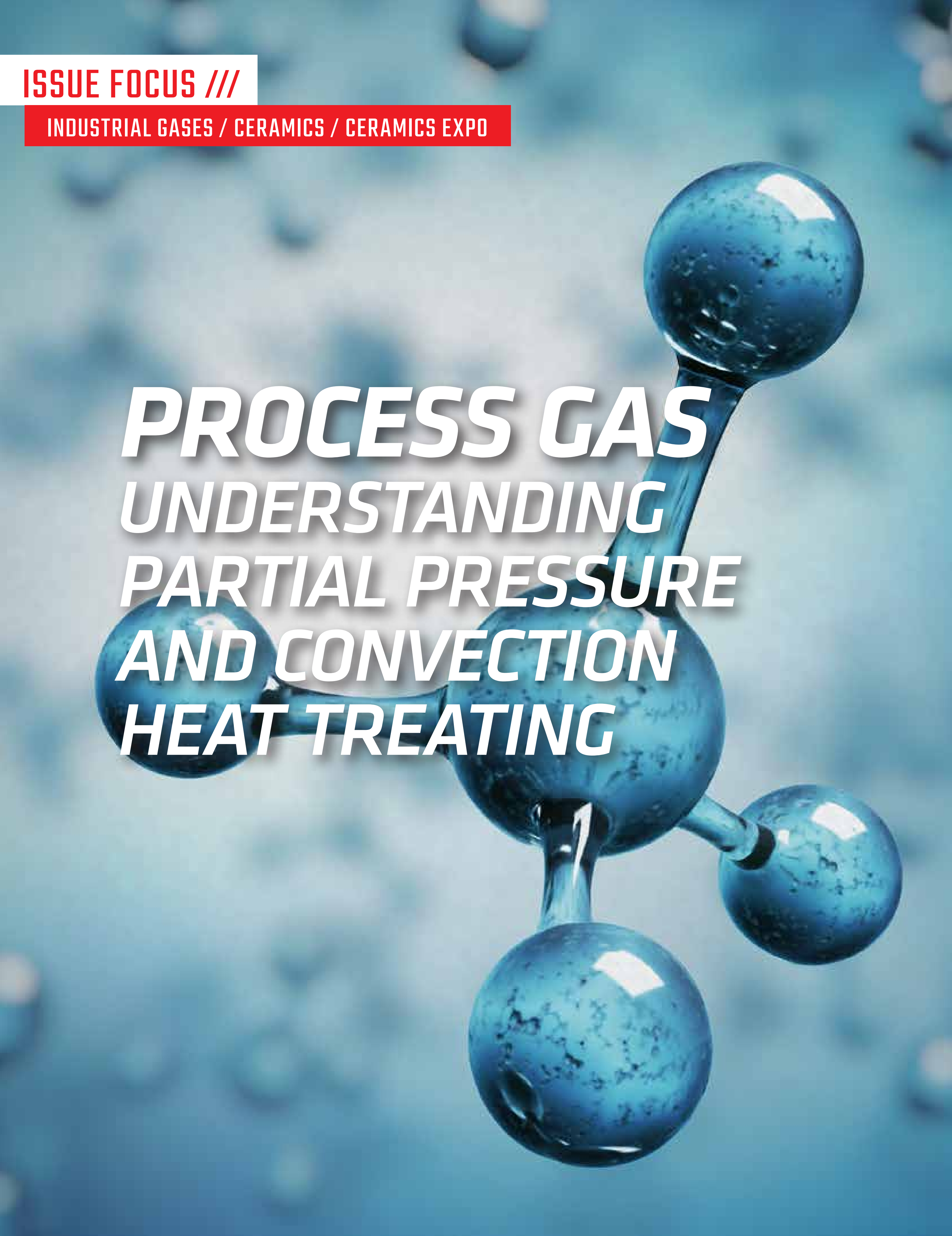


PROCESS GAS

UNDERSTANDING PARTIAL PRESSURE AND CONVECTION HEAT TREATING

While vacuum furnace operators tend to focus on the delivery of quenching gas, the ability to deliver a process gas during the ramp and soak steps gives operators an opportunity to increase the functionality of their furnace.

By ANDREW WRIGHT

Designed to pump out atmospheric gases at the beginning of a heat-treating process, while also being capable of introducing process gases to reach specific sub-atmospheric pressures, vacuum furnaces are excellent at controlling the amount, source, and quality of gas within the furnace vessel at any time during a process.

Introducing inert gases during the quenching process is a widely recognized technique for controlling the rate and results of the quench. Additionally, adding specific process gases as chamber temperatures ramp up can offer further benefits, enhancing outcomes across various heat-treating applications.

The first action in a vacuum furnace process is to remove atmospheric air from the pressure chamber. Heating metal parts makes them exceptionally receptive to reactions with elements commonly found in atmospheric gases (such as water vapor or oxygen), so removing atmospheric gases significantly limits unwanted reactions. But, purposefully introducing process gases can create reactions or conditions that are desirable as a part of the process.

The ability to backfill with a process gas during ramp-up can create important advantages. Some operations may want to introduce a very low volume of gas (0.01 Torr to 10 Torr) to help remove oxides by using hydrogen, to add an element like carbon for the purposes of case hardening, or to add an inert gas in order to limit chromium sublimation during a high temperature process involving steel. Other recipes may want to introduce enough of a process gas (1 Atm or more) to enable convection heating by operating an internal fan in order to evenly heat parts that have complex geometries or large cross-sections.

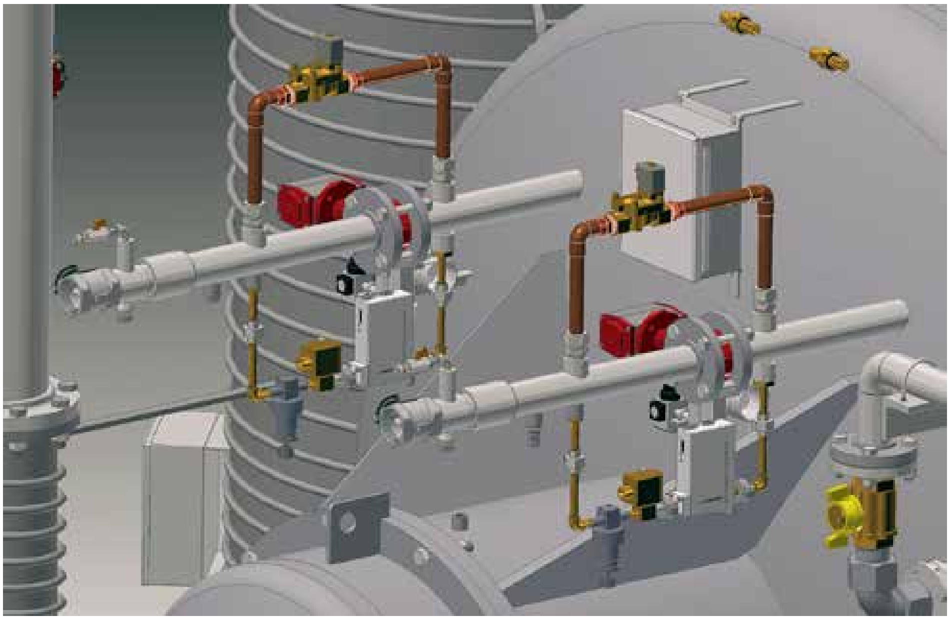
PARTIAL PRESSURE: MAINTAINING REACTION CONTROL AT NEAR-VACUUM PRESSURE

Partial pressure processes are recipes that introduce a very low flow of process gas into the furnace after it has been pumped down that can create or control reactions as the temperatures rise. Process gases can range from inert gases such as argon or nitrogen, to reactive gases such as hydrogen or acetylene.

One partial pressure heat-treating process can be used as a purge to ensure most of the remaining atoms and molecules found in atmospheric gases are flushed out of the furnace by adding an inert gas. Inert gases such as argon, when added to the vessel during ramp-up, can push aside smaller atoms or molecules of gases such as hydrogen, oxygen, and nitrogen, compelling them to quickly find the exits as the system evacuates the furnace a second time.

Inert gas can also aid in slowing down the sublimation process of elements such as chromium, which tends to evaporate at high temperatures and extremely low pressures. Even the smallest amount of pressure from an inert gas can help prevent chromium-based steel products from deteriorating.

Some steels are particularly susceptible to oxidation and may even have built up oxides on their surface prior to thermal processing. Introducing hydrogen into the heat-treating process at specific temperatures can encourage certain metal oxides to react with the hydrogen within the chamber, thus reducing in occurrence. (While it's common sense to be very careful when introducing hydrogen to any system from a safety standpoint, it's also not typically advisable to use hydrogen in processes involving parts containing titanium or certain copper alloys.)



A furnace design that includes two ports for partial pressure gas, regulated by mass flow sensors.

In transformative processes, such as AvaC low-pressure carburizing, for example, adding a process gas such as acetylene at a low pressure can help deliver a case-hardening solution that meets specific requirements. This can be particularly effective in parts that have very complex microgeometries: powder metal fabrication, for example.

Beyond these processes, partial pressure gas systems can also be

The addition of an inert gas to a system at 1 atmosphere of pressure or higher can aid in convective heat delivery that can better control a complex part's thermal consistency.

Here we see a regulator gauge connecting to a mass flow sensor, further regulated by a blocking valve and a partial pressure manual throttle valve to maximize control over the gas flowing into the system.

employed to prevent diffusion bonding between parts and fixtures, as well as providing an interim cooling step that can make vacuum cooling more efficient.

CONVECTION THERMAL PROCESSING

Convection processes introduce inert gas into the pumped down system until the pressure within the vessel is at or above 1 atmosphere. One atmosphere of pressure is comparable to the amount of air pressure in a room at room temperature.

It might seem counterproductive to pump down a furnace to a near vacuum, only to fill it with another gas to the same pressure as it was before the pump, but by carefully controlling the elements present within the gas backfill, thermal processors will ensure their parts will not react with unwanted elements that may be present in ambient air — such as water or oxygen.

Vacuum furnaces primarily deliver their thermal payload via radiant heat. Within a vacuum, the lack of atmosphere removes the chance that heat will be transferred by way of convection. This gives the operator significant control over the process temperatures and chamber consistency throughout the critical steps of thermal transformation. But, since radiant heat delivers energy in a linear direction, curves and crevasses may significantly affect the consistency of the heat-treating process.

The addition of an inert gas to a system at 1 atmosphere of pressure or higher can aid in convective heat delivery that can better control a complex part's thermal consistency. Convection heating is much more efficient than radiant heating at lower temperatures.

Currents created by an internal fan ensure heat is delivered throughout the geometry of a sophisticated piece. The moving gas can offer a more consistent thermal delivery into the hollows and nooks to ensure the parts are brought to temperature at a much quicker rate before being pumped out for the final soak. The resulting process ensures more consistent temperatures across all surfaces from the start of the ramp through the thermal peak in a much shorter time, leading to faster cycle times for complicated parts.

CONCLUSION

While vacuum furnace operators tend to focus on the delivery of quenching gas, the ability to deliver a process gas during the ramp and soak steps gives operators an opportunity to increase the functionality of their furnace. Vacuum furnaces are an ideal tool in delivering consistent, clean parts using processes such as partial pressure or convection heat treating because of their exceptional control over gases present in the chamber during a thermal processing cycle.

ABOUT THE AUTHOR

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