HOT SEAT

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Through comparison to common household devices, this column explores today's heat-treating process involving furnaces and pumps.

DEPENDING ON THEIR SPECIFIC heat-treatment application, atmospheric and vacuum furnaces use pumps. In this column, the pumps I reference refer to any device designed to move or remove fluids, such as water and oil, and gas. Fans also fall into this classification, including ones that circulate an atmosphere gas at ambient and elevated temperatures. Combustion air blowers and pressure boosters for cooling parts are also types of pumps.

A proper understanding of the applications and operations of these systems can be gained by comparing them with common household devices.

Everyone has heard about convection ovens, radiation from fireplaces or vacuum cleaners with superior suction and high efficiency home furnaces. Heat-treating furnaces use industrial strength versions of these same devices.

Have you ever wondered what's happening when you place your hand over the suction end of a vacuum cleaner or an object is sucked into the hose? When the vacuum motor speeds up and makes a high pitch sound, the motor is actually doing less work because less air is being moved by the vacuum cleaner's impeller,. Even though the motor is doing less work, it will overheat due to a lack of air circulation. Vacuum furnaces use vacuum pumps to evacuate the air from the chamber. When it is first turned on, the pump is working very hard because a lot of air is being removed. As the pressure is lowered, the remaining air density inside of the vessel is reduced.

Much like the vacuum cleaner, the pump motor sees much less resistance. Therefore, the horsepower required to turn the pump's rotors or piston is reduced. The motor speed, however, does not change. Vacuum pumps are cooled by water, so overheating is not a concern. They can run continuously this way.

Atmosphere furnaces employ fans to circulate an atmosphere over parts, which require carburizing, for example. In addition, the fans also assist in heating the parts when first charged into the hot zone. When room temperature parts are exposed to the hot furnace environment at 1700°F (926°C), the primary mode of heat transfer is by radiation. This is the same energy you feel when sitting directly in front of an open fireplace. Parts positioned on the outside surface of the load see radiant heat directly. Parts in the center are shielded from direct radiation so that the fan circulates hot gas through the load by convection. Here again, gas density plays a role in the effectiveness of the fan.

As with the vacuum cleaner and vacuum pump, gas density affects the fan's performance. As any gas is heated, its density is decreased by the ratio to absolute temperature, or the corrected influence of gas on the fan known as the standard temperature pressure, or STP. When endothermic gas used for carburizing is heated, the space between each atom in effect is increased. Thus, the number of molecules of CO + H_2 + N_2 that the fan can move per minute is reduced, resulting in decreased gas flow. At STP and ambient room temperature, a fan is designed to recirculate gas at a specified volumetric rate—6,000 CFM, for example. Each blade of a furnace's radial fan is similar in function to the multi-blade or squirrel cage fan in your home furnace and moves a fixed amount of gas or air creating a velocity and static pressure that slightly exceeds the system resistance throughout your homes heating and return ducts. In the winter, as the furnace heats the home's air, the density of the air is very slightly decreased. Conversely, in the summer, the air conditioner cools the air increasing its density slightly. In the summer, the fan motor works slightly harder. In winter, slightly less. In a carburizing furnace at 1700°F (926°C), a cubic foot of gas has expanded, but the fixed capacity of the fan has not. Therefore, each fan blade captures fewer molecules thus moving less gas consuming less horsepower.

Furnace designers face a conundrum when carburizing temperatures are increased to reduce carburizing time. The higher the temperature in an atmosphere furnace the fewer carbon bearing atoms occupy the furnace volume. Making up for fewer gas molecules requires the fan to rotate faster to circulate more gas through the load. Since the diffusion of carbon increases at a higher temperature while the number of CO molecules decrease the potential for starving the part's surface of carbon is a real possibility. However, rotating the fan faster dramatically increases the centrifugal stresses on the fan blades while the elevated temperature reduces the alloy's strength. This phenomenon is also the reason fans are not affective in a vacuum furnace. There are fewer gas molecules to move.

This column is the first in explaining some of the science involved and the issues designers face in an attempt to meet 21st century heat-treating demands.

ABOUT THE AUTHOR: Hot Seat columnist Jack Titus has an additional column in Thermal Processing for Gear Solutions, in which he discusses scheduled maintenance of furnaces, distortion control, and low-pressure carburizing. Jack Titus can be reached at (248) 668-4040 or jtitus@afc-holcroft.com. Go online to www.afc-holcroft.com or www.ald-holcroft.com.