HOT SEAT

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Vacuum pumps and nitrogen purge can equally achieve low ppm oxygen levels. However, pumps are slow to remove water vapor while an inert gas purge is time consuming.

VACUUM FURNACES rely on the lack of an atmosphere to protect heat-treated parts from surface oxidation or decarburization. The quality of the atmosphere required for a given process is defined by the quantity of residuals remaining after evacuation. Therefore, the ultimate pressure determines the composition of gasses (lower pressure produces fewer molecules of oxygen, nitrogen, and constituents such as CO2, argon, and several trace elements). The one variable is water vapor. Since most high-temperature vacuum furnaces are constructed with a water jacket called a cold wall, they have a separate thin inner insulated hot zone as opposed to insulation applied directly to the furnace case or a hot-wall style.

Typically, a vacuum furnace's hot zone or inner chamber will have only two or three inches (50 to 75 mm) of insulation wherein vacuum heat loss is reduced, thereby enabling a shorter pump down time due to less outgassing. Nitrogen and oxygen can be evacuated without concern. However, water vapor within the vessel exists in two forms—as a gas or vapor and as a condensed liquid adhering to the inner side of the water jacket. On a humid day, huge quantities of water can reside on the water jacket via adsorption as well as being absorbed into the microscopic porous surface layers of the mill scale on the steel wall. This phenomenon can be somewhat mitigated by painting the inner wall with specific materials designed for such a purpose. Although the absorbed water is reduced, the adsorbed surface layer will always be present when the cooling water temperature drops below the dew point of the ambient air. Vacuum pumps are notoriously deficient in removing water quickly. When initial evacuation begins, the sudden reduction in pressure causes the release of heat via evaporation and reduces the temperature of the surface water and surrounding environment, in some cases, to the point of creating a thin layer of ice. Once it is formed, this layer is difficult to remove until the steel wall heats up or until the pressure drops low enough to enable the heating system.

In many ways, the internal materials of construction used in vacuum furnaces dictate the pressure required for a given process. For example, a moly lined (radiation shields) insulation with moly heating elements will require lower pressures, sub-10 microns (.0133 millibar) to remove enough oxygen and water vapor to eliminate oxidation in steel (iron). If the same vacuum furnace has graphite insulation and graphite heating elements a pressure of 100 microns (.133 millibar) or higher would suffice because graphite will act as an oxygen "getter" reacting with oxygen at elevated temperature and is evacuated from the vessel. When very oxidation sensitive materials, such as titanium or aluminum, are heat treated, much lower pressures are required.

Generally, three stiles of vacuum pumps are required to achieve the selected pressure.

The basic first-stage vacuum pump can be a piston type or a rotary vane. These are used when the vessel is smaller and or when the pressure required is between 100 and 500 microns (0.133 and .66 millibar).

A second stage is a roots-type booster blower that usually has a pumping speed five to 10 times that of the first stage. These are employed when a much faster pump down is required or when pressures below 50 microns, but no less than five microns, are needed.

The third stage when pressures below one to five microns are required is called a diffusion pump. For decades, diffusion pumps employed distilled fossil fuel oils. Today, fossil oils have been replaced by nonflammable silicone based oils. Simply, the oil in the absence of air removed by the first and second stage pumps is boiled creating a vapor that is directed at high velocity through downforce jets trapping gas molecules that are subsequently evacuated from the system. Although these are called oil diffusion pumps, they don't actually pump the molecules. Since the first and second stage pumps reduce the number of molecules to trace quantities (the "mean free path"), the distance a molecule travels to collide with another molecule is so long that only by accident do gas molecules find their way into the inlet of the diffusion pump. Thus, the inlet of diffusion pumps must be very large and positioned as close to the internal volume of the vacuum vessel as possible.

To achieve an inert atmosphere equivalent to that produced by vacuum pumps, atmosphere heat-treat furnaces require a generated atmosphere of nitrogen or argon. Liquid nitrogen at its source will usually have oxygen levels of <10 ppm. A vacuum level of 100 microns (0.133 mbar) will reduce the oxygen level to 27 ppm. To achieve 27-ppm oxygen in an atmosphere system, approximately nine (9) volume changes of nitrogen are required. Unlike vacuum pumps water vapor is removed rather quickly due to the extremely dry -70°F (-56°C) dew point of liquid nitrogen. The majority of atmosphere furnaces have warm wall construction where the internal/external wall will typically run between 100°F to 150°F (38°C to 66°C) at elevated temperatures, eliminating the formation of water altogether.

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