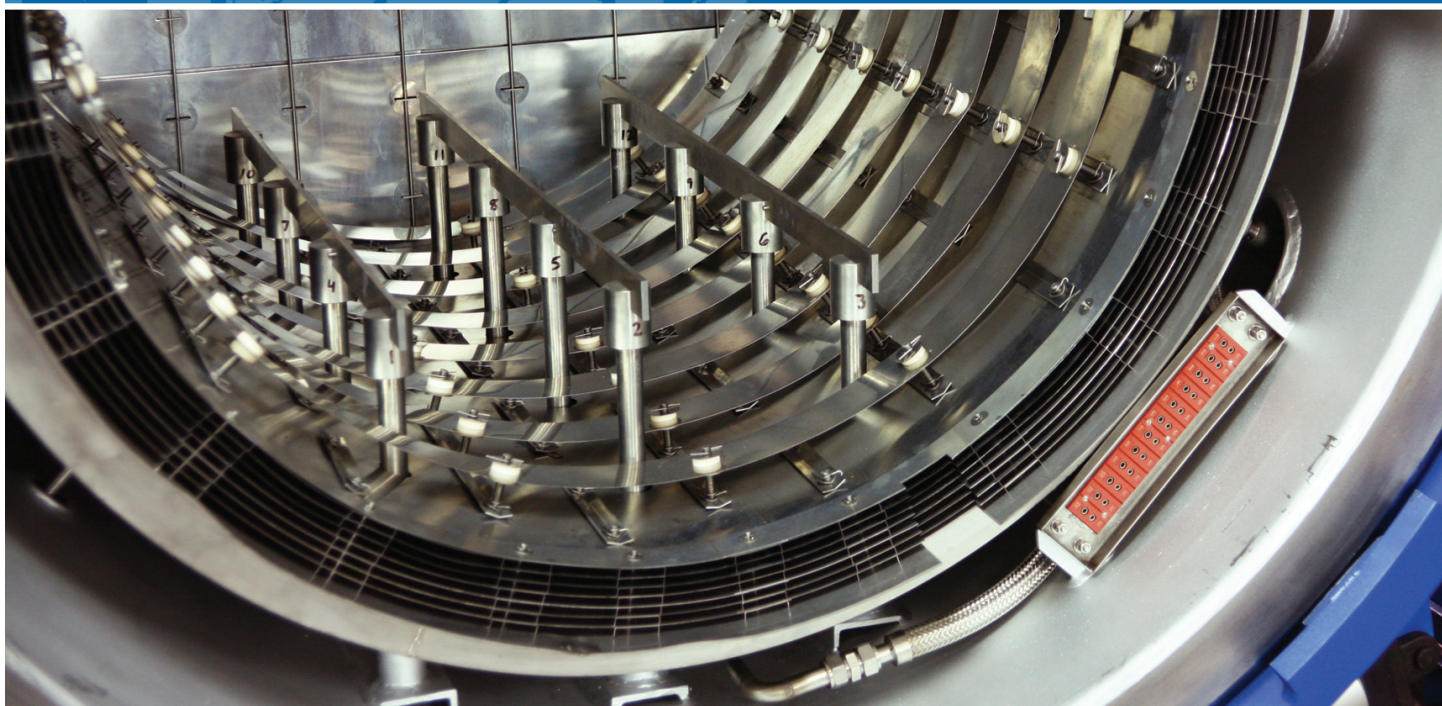


Operating a Vacuum Furnace Under Humid Conditions

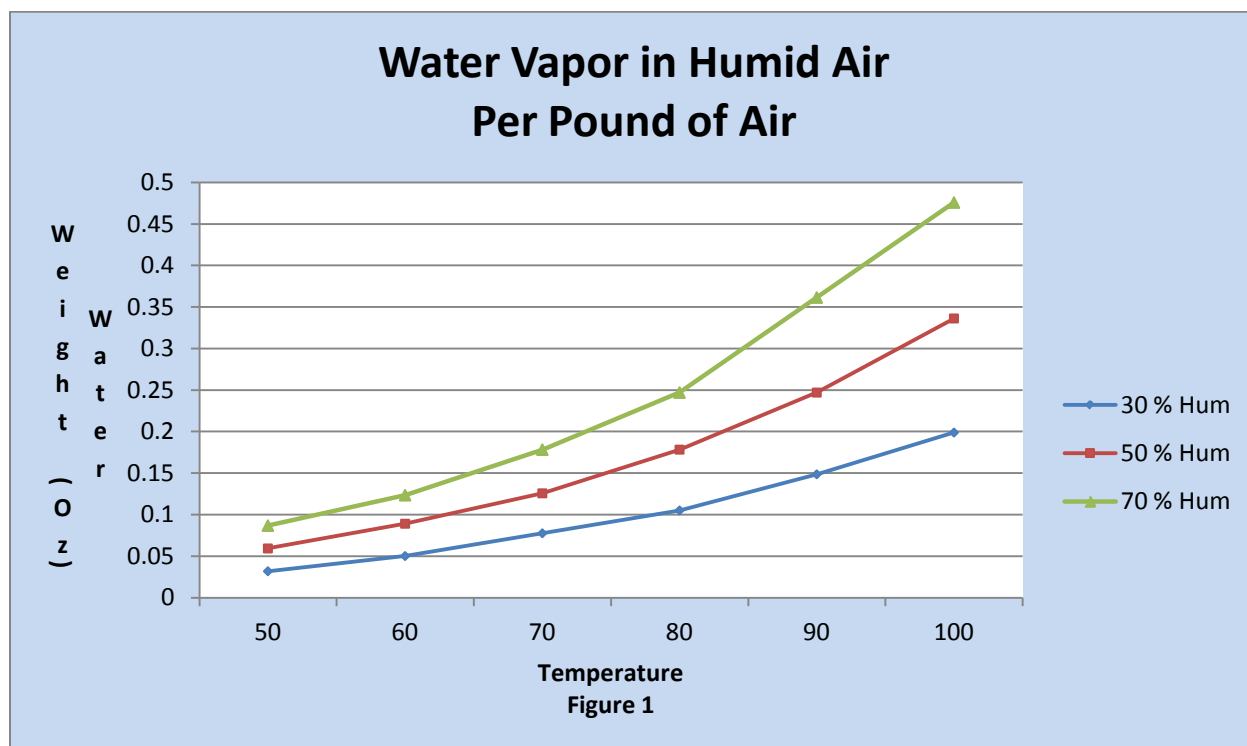


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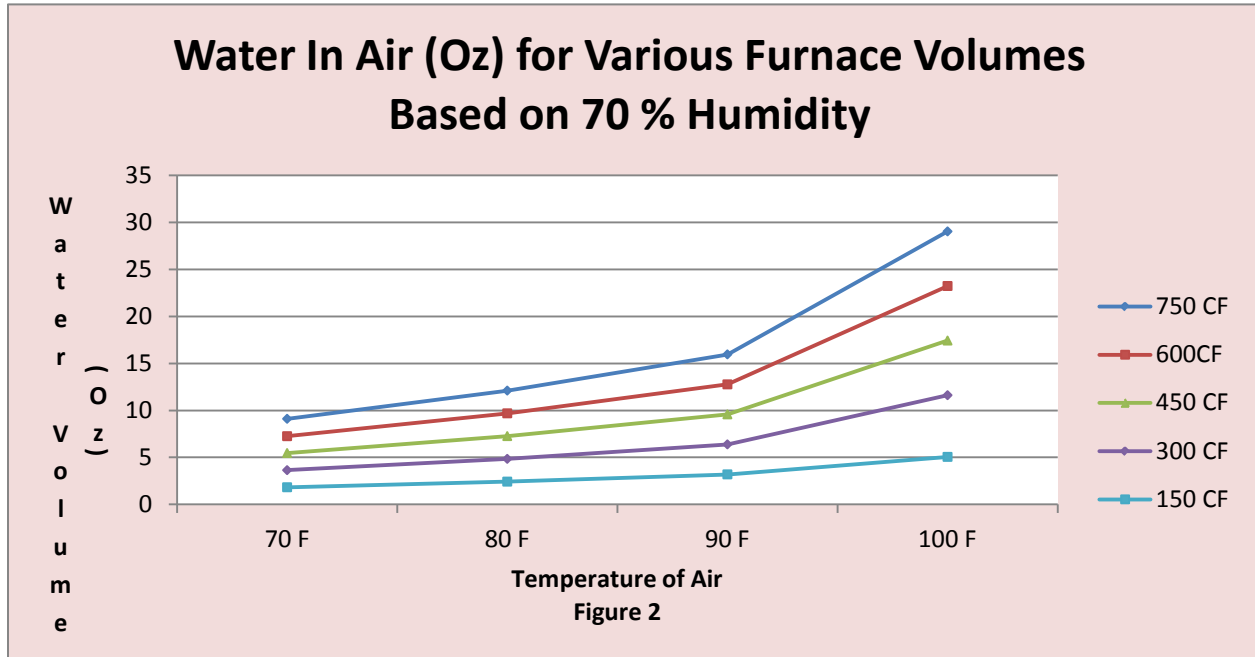
A specific concern to a vacuum furnace user is processing critical work during summer months with high temperatures and high humidity. This same concern could also be a problem on rainy winter months. Under these difficult conditions, it is most important to understand the impact that humid conditions can have on the final surface condition and appearance of the processed parts. Work discolored or oxidized by residual water vapor is unacceptable and must be controlled for many critical components like aerospace parts or medical implants and instruments. This paper will try to explain factors relating to humidity, air temperature, and methods to improve final product appearance and minimize possibility of contamination.

A) Understanding Humidity/Temperature Concerns

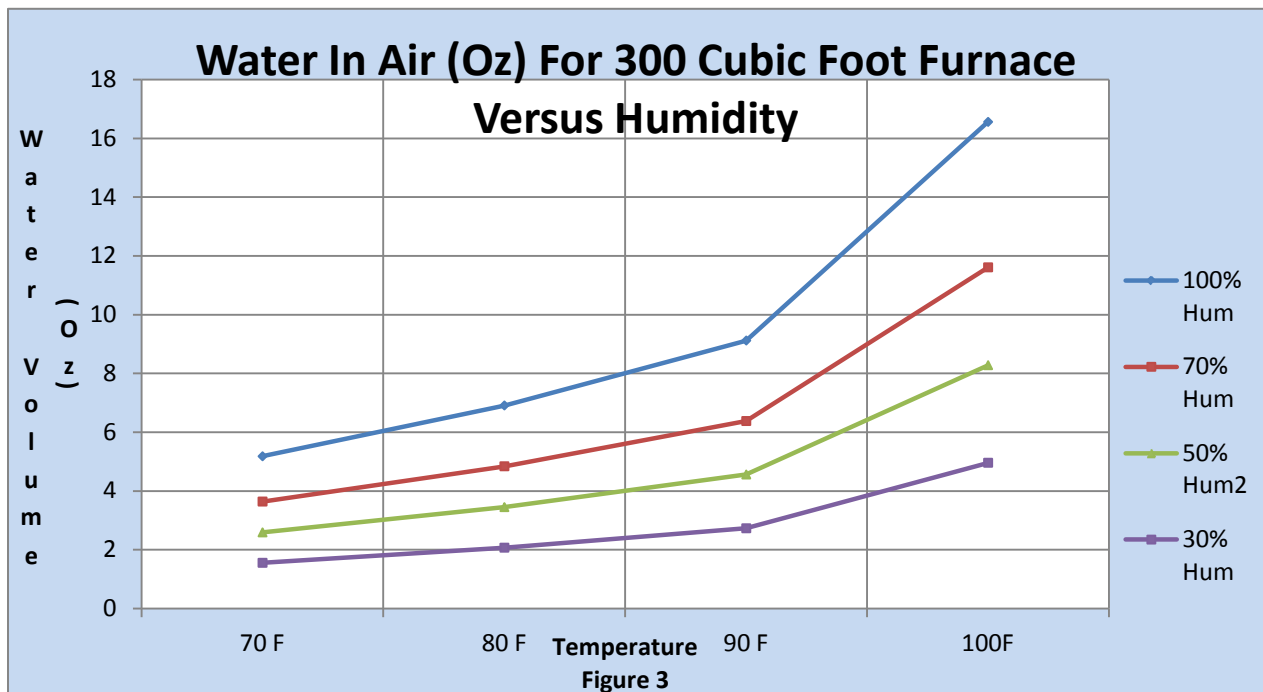
The amount of water vapor contained in a specific volume of air is a function of relative humidity and air temperature. Relative humidity is defined as the ratio of the actual vapor density to the saturated vapor density, dew point, times 100 %. The saturated vapor density varies based on the actual air temperature. From these parameters, we are able to calculate the actual amount of water that exists (by weight) at different temperatures and different humidity values. Results of our calculations are plotted in Figure 1. This illustrates the amount of water that can accumulate within a vacuum chamber under certain humid and temperature conditions.



The amount of water existing within a vacuum chamber prior to initiating pump-down, is a function of furnace volume, relative humidity and air temperature. Figure 2 illustrates the amount of water by volume that can be expected for a given volume of furnace. As shown in Figure 2, larger furnaces must pump out considerable amounts of water.



The 300 Cubic Foot curve would be typical of the volume associated with one of our most popular furnaces, the HFL-5748 furnace. We have taken this volume and plotted water volume



expected for various humidity levels and operating temperature conditions. This plot is shown in figure 3. Typically, as is shown, when operating at a relative humidity of 70 % and an outside temperature of 90 °F, we would have to pump out approximately 6.25 ounces of water.

B) Applying These Conditions To Actual Operation

If we take a fairly humid day of 70% relative humidity, the weight of water in the air at 100 °F is roughly 2.7 times that of water in the air at 70 °F. At 70% relative humidity, water is in solution in the air and will be absorbed into the vacuum furnace hot zone insulation and also will be absorbed into the work being processed. Contamination or dirt that was removed from previously processed work could remain within the furnace and also collect moisture if the furnace hot zone is not properly cleaned. In addition, when heated, machining oils in the work break down into carbon compounds that will further absorb moisture inside the hot zone and the vacuum chamber. All of these factors contribute to much more difficult pumping conditions during humid days.

Roughing pumps do not pump water vapor very well causing the vacuum pump blank off to rise and further reduce the ability of the vacuum furnace to pump moisture. Several simple and practical steps can be taken to try to minimize the actual water vapor absorbed within the furnace internals. These include:

- 1) Never leave the furnace open when not in use. Always close the door immediately upon emptying and quickly pump it down to -10" Hg so that the insulation and internal components cannot soak up the humidity.
- 2) The cooling water for the furnace jacket should always be circulating at a temperature that is at least 10 °F warmer than factory ambient temperature. This will minimize moisture condensation on the chamber walls and hot zone materials.
- 3) A commercial vacuum furnace that is continually running cycle after cycle 24/7 will possibly start to produce dirty work after a certain period of time (possibly two years) due to oils and dirt contaminating the hot zone and cold walls of the chamber. This furnace condition is much more pronounced during humid operating days. When this starts to occur, completely remove and clean the hot zone, possibly replacing some of the graphite felt insulation if severely contaminated, and sand blast any deposits off the chamber wall. The gas to water heat exchanger should also be removed and soaked in a solvent, such as Rydlyme, a mild cleaning solution. After a reasonable soaking period, remove the heat exchanger and flush with water to remove the solvent. Then, be sure that it is blown off with a strong air hose to remove free water from the cooling fins. Finally, bake the water out of the heat exchanger in an air oven at 350 °F for four hours.

After the hot zone and heat exchanger have been thoroughly cleaned and re-assembled in the furnace, run less critical work for the first few cycles to condition the furnace.

C) Other Possible Operating Factors

- 1) Often a workload that must be processed arrives at the furnace in a very wet condition. This could be due to actual rain exposure or to very humid storage condition. This is particularly critical on dense loads such as various sheet or coil stacks. Upon loading the work in the vacuum furnace and initiating pump-down, often the vacuum level does not reduce to below 1 Torr. Also, any work thermocouples will eventually show a decrease in temperature from ambient to 10-20 degrees below ambient or even to a temperature of 32 °F if a significant amount of water was initially present. This is due to the water that existed that turned to ice as the vacuum pumping occurred. To overcome this condition, introduce a partial pressure (5 Torr) of nitrogen or argon and heat the furnace to 500-600 °F and hold until the thermocouples recover to above ambient temperature. Once this occurs, the cycle may be continued per the process requirements once the proper vacuum level is established.
- 2) Some components used in processing such as ceramic blocks or Refrasil insulated type thermocouples, can often contain excessive amounts of water. Regarding the Refrasil thermocouples, prior to processing critical work, they should either be baked out in an oven or used in a non-critical lower temperature cycle (tempering, etc.) and when not in use, stored in a closed box. Any ceramic blocks or spacers should also be baked out prior to using in a critical cycle similar to the Refrasil thermocouples.
- 3) Selection of the vacuum roughing pump used on the furnace is most important. Vacuum pumps from different manufacturers have varying sizes of oil reservoir capacity. Some have small reservoirs which could quickly be affected under humid conditions, regarding pumping speed and ability to handle moisture. We have found that the best solution for the industry is the standard Stokes Designs, such as the Models 212 and 412, where both incorporate a much larger oil reservoir and provide greater capacity to handle the moisture and minimize oil contamination.

D) Recommended Procedure During Humid Conditions

There are various methods that can be used to better operate the vacuum furnace under humid conditions, including repeated pump downs and backfills with inert gas. However, based on our experience, we would recommend the following:

- 1) Pump the furnace down until the vacuum level reaches 2×10^{-4} Torr or it has pumped for at least one hour before turning on any heat.
- 2) Heat the furnace to a temperature of 800 °F and hold for one hour.
- 3) Allow the furnace to recover acceptable vacuum, usually in the low 10^{-4} Torr range.
- 4) Continue the cycle per the normal processing requirements, but maintain heating rates to maintain vacuum within the high 10^{-4} Torr range (on the ion gauge).

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References: The Engineering Tool Box – Water vapor – Weight in air

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