

Preforms: what you need to know about storage time/conditions

We share proprietary research on how both time and storage conditions can impact the performance of your preforms. If you are blow molding bottles from stored preforms, this white paper will help you improve your process.



Introduction

Have you experienced issues blow molding bottles from inventoried preforms? Have you spent hours trying to tweak your blow molding equipment settings, without really getting to the root of your problem? The problem could very well be with the length of time your preforms have been stored and not the preform geometry or problems with the resin from which they were molded.



How long can I store my preforms?

A question frequently asked of our plant support personnel is: Can I use stored preforms to blow bottles? If yes, then how long can they be stored and what problems can present themselves during longer storage periods?

The short answer is that preforms stored three, six or 12 months, respectively, will each process differently. The older the preform, the more difficult it will be to processing so that the container meets performance criteria. The time of year the preforms were injection molded, along with the environmental conditions in which they are kept, will also impact performance.

To really understand the impact of storage duration and environment, we studied 2 liter and 20-ounce preforms from our inventory that were more than a year old. These preforms were dried under vacuum at 40° C to get them back to a condition similar to when they were first molded.

But first, let's set the stage, with definitions and other background.

Dry vs. wet preforms

The term "dry preforms" refers to freshly injection molded preforms that haven't had the chance to absorb much moisture from the atmosphere. Because PET is a hygroscopic material, it absorbs moisture continually throughout its life at different rates depending on humidity of the environment. A "wet preform" is created when it is exposed to atmospheric moisture. This makes the preform behave differently during reheating and blow molding, which also means the bottle's performance attributes will not be the same had it been blown from a dry preform.

How does a blow molder end up in this situation?

Oftentimes, it may seem like good economic sense to mass produce preforms and store them for future blow molding runs. However, the downside to this strategy is that older preforms do not process the same. This means that the blown containers don't meet performance specs unless the processing conditions are tweaked sufficiently or have a reasonable factor of safety. For example, the preform would have to be over-designed for the intended bottle. It could have excess weight or orientation than what's needed for the application.

Importance of understanding performance differences

Increasingly, containers are blow molded from light- and optimalweight preforms. This implies that when material is distributed over the bottle surface optimally (and with right orientation) it leads to the best properties and good performance.

But it's important to point out that there is not much excess material in a preform. A slightly thinner or less oriented sidewall may lead to additional growth and deformation that would not meet the specifications. If the material distribution shifts due to different material stretching and blowing characteristics, then the blown container may have poor performance. Examples include a lower top load or higher creep expansion during pressurization. For carbonated beverage packages, this leads to a more distended look and a high-fill point drop along with other problems associated with shorter shelf life. For household chemical packaged oval containers, this could be thin corners more prone to denting and poor material distribution.



Conducting research

Wet preforms used in the study were 2 liter 44.6g and 20-ounce 21.5g that were dried under vacuum at 40° C. Higher temperatures were not used because the softer, amorphous material could shrink and distort. Further, air drying preforms in a resin hopper will not work because the airflow necessary to dry a preform is much different than that needed for pellets.

Here are the conclusions that the study found. Let's review each one and what value/impact this knowledge offers the blow molder.

Diminishing moisture permeation rate with time

First, the study shows that it is not practical to convert wet preforms to good, dry preforms because it would take too long (several weeks). There is no suitable equipment to accommodate thousands of preforms in a vacuum environment to rapidly deplete the absorbed moisture. In addition, higher temperature environments may increase the rate of moisture loss (improve drying speed) but may cause deformation in the preform which can cause even bigger problems during the blow molding process.

Wet preforms absorb more heat under the same process conditions

It is conceivable that if moisture is embedded in the wet preform, additional heat would be required for the preform to get to the same temperature as the dry preform. The moisture may also retard the transmission of infrared energy through the PET preform sidewall, lengthening the time taken to get the preforms inside surface to achieve the same temperature.

preforms more significantly Larger (bigger diameter) containers require large preforms. Since blow molding pressures are similar for both larger and small

Moisture impacts processing of larger diameter

blow molding pressures are similar for both larger and small bottles, the same the force on the sidewall of the larger diameter preform creates greater stress, leading to more deformation on material of the same strength. Think in terms of gas cylinders. They are typically long and skinny. If they were wider, it would take more metal and strength to construct them for the same pressure. Hence, during blow molding adjustments have to be made not only for the heated preform temperature but also the blow pressure and timing to make the wet preform stretch similarly as the dry preform.

Drier preforms stretch less

From a resin manufacturing and economics perspective, lower stretching, higher IV or higher molecular weight resin costs more because it takes longer to solid state and manufacture. Because dry preforms stretch less, they strain harden sooner and the material distribution is more uniform. Additionally, the blown bottle has better sidewall orientation and mechanical properties, which is the ultimate objective.

Moisture acts as a plasticizer, allowing for more stretch

Technically speaking, moisture acts as a plasticizer or a lubricant that allows polymer chains to slide past each other more freely. That means that a preform will stretch further and move away from the specification of material distribution and mechanical orientation needed to pass specifications.

Study methodology

Our goal was to show that there are processing and performance differences for wet vs. dry preforms. Free-blowing is a common scientific way of ascertaining differences in stretching characteristics of different materials such as a colored preform, preform molded with additives, or with different resin IV. A heated preform is blown to its natural stretching range and then stops. This characteristic is known as strain hardening and is unique to a certain category of polyester materials such as PET. In this study, we used the free-blowing attributes to show the heating and stretching differences between the dry and wet preforms. For more detailed information, please review the following graphs.



Vacuum oven drying of preforms

Newly-made preforms have a moisture level close to 0 parts per million (ppm). However, preforms that have been stored for a long time and/or have been subjected to extremely humid environments can reach upwards of 10,000 ppm.

For purposes of this study, we wanted to show how much time it takes to bring the moisture level from 3000 to 200ppm using a relatively low temperature to minimize preform dimensional deformation. (We typically see 3000 ppm preforms after three to six months of moderately humid storage.)

The study results show two things. The first is only when there is a moisture level difference in those ranges, you will also see a difference in performance. Secondly, the plot shows that it is not viable to dry these wet preforms and reuse them as it will take more than 50 days to do so.



Figure 1.

- The oven temperature was raised to 40°C from 22°C after 15 days to speed up the drying process.
- Over the course of 50 days, the initial moisture level of ~2,800 ppm was reduced to ~250 ppm of H₂0.
- Note the diminishing rate of moisture removal from days 29-45.

PreTemp analysis

PreTemp is an instrument designed and manufactured by PTI that is used to measure the inside and outside preform temperature accurately. It was used in this study to show the difference in wet and dry preform temperatures when they were blasted with the same infrared energy for the same duration.



Figure 2. Internal temperature - 20oz

Figure 3. Internal temperature - 2L



Heating Time: 58 seconds // external temperature: 122°C

Heating Time: 61 seconds // external temperature: 119°C

IR spectrum of 20oz preforms

These plots with high resolution equipment shows how energy is absorbed differently in the infrared region (where the lamps in a blow molder operate) for wet and dry preforms. It shows that wet preforms absorb more energy.



Figure 4.

Drier preforms absorb less IR energy.

IR spectra of preforms normalized for thickness

This shows that the dried preforms absorb less energy and allow more transmittance that helps heating through the thickness efficiently. Materials that retard transmittance automatically result in greater temperature differential between outer and inner surfaces.







Free-blow balloon data summary

The free-blow data is a great way to quantify the differences between the wet and dry preforms for the two sizes. We measured the dimensional and volumetric differences to bring this out along with the average temperature of the preform for the wet and dry states.

Figure 7.

Wet preforms heated under similar conditions as dry preforms resulted in larger free-blow balloons.



2L Wet

2L Dry

Figure 8.

DSC Thermogram showing the lower measured glass transition temperature of a wet preform compared to a dry preform.



Tables 1 and 2.

Differences between free-blow balloons generated from wet and dry preforms heated under similar conditions.

	20oz (21.5g)	2 և (44.6g)
Diameter	1.20%	4.60%
Height	2.40%	5.00%
Overflow	7.90%	14.90%

	20oz (21.5g)		2L (44.6g)	
	Wet	Dried	Wet	Dried
IV (dL/g)	0.776	0.775	0.823	0.831
Moisture (ppm H₂0)	2388.7	221.3	2629.0	263.3

Summary

As the study shows, in high humidity environments you should avoid storing preforms beyond three to six months. Going beyond that threshold will cause both processing and performance issues. Additionally, here are some key points to remember:

- Diminishing moisture egress rate with time from a drying perspective
- Wet preforms absorb more heat under same process conditions
- Moisture has more of an impact on the properties of larger diameter preforms
- Drier preforms stretch less
- Moisture acts as a plasticizer allowing for more stretching and lesser strain hardening

