Effective Vacuum Systems

By Steve Hill, CO

There has recently been some discussion on how to create and control vacuum pressure during thermoforming.

Twenty-five years ago, there was no debate. Maybe half of the braces we made were plastic, and almost none of our sockets. It wasn't uncommon to see a lab using the same wet/dry vacuum to thermoform in the morning as it did to clean up in the afternoon.

But we're past that now. The amount of thermoforming we do has exploded, and a small investment in the right equipment, such as state-of-the-art ovens and high-volume, dedicated vacuum systems, can pay for itself very quickly by reducing time and waste. With proper techniques and equipment, your outcomes can dramatically improve.

The goal of thermoforming is simple: remove the volume of air trapped between the heated plastic and the mold after the plastic has sealed around the vacuum source.

But achieving this goal is fraught with complications. The plastic must be heated to the proper forming temperature, there must be an effective air wick to promote even vacuum across the mold and vacuum must be achieved fairly quickly since the plastic doesn't stay at forming temperature for long.

Heating the plastic is a function of your oven and the subject of a different article. An effective air wick is pretty easily accomplished for most applications with a layer or so of nylon stocking.

A proper vacuum system, however, is more complicated. This article outlines the basic things you need to consider when setting one up.

The pump

Creating vacuum can be accomplished in two ways: with rotary vane or with single-stage (venturi) pumps. Either way will work for most applications, and the decision may simply be personal preference.

A rotary vane pump is a positive displacement pump which uses an electric motor to spin a rotor that has vanes which slide back and forth. The rotor spins in an offset position inside of a larger cavity, drawing air in one end and pushing it out the other. This method can create both vacuum and compressed air, depending on its configuration.

The venturi pump uses magic (or physics, if you prefer) to create vacuum. Compressed air is blown into one end of a specially shaped chamber that narrows to create higher velocities. As the velocity increases, the pressure decreases until a low pressure, or vacuum, is created. The air then passes over and draws air from a second air inlet connected to the mold, resulting in vacuum you can use to thermoform.

One benefit to a venturi pump is that you can use the air compressor you already have to create vacuum, which saves buying a vacuum pump. The drawback is that if your compressor goes down, so does your vacuum.

The surge tank

The average rotary vane or venturi pump works fine, but can be improved if you add a surge tank. The rate at which your vacuum system removes air is measured in CFM, or cubic feet per minute. Most pumps should draw between 8 and 10 CFM. That's not bad, but there are ways to improve.

The average volume of air to be purged from an AFO mold is about $^{11}/_{44}$th to $^{11}/_{48}$th of a cubic foot. That means it will take 1 to 4 seconds to purge this air and then another 10 to 25 seconds to get the entire volume of space up to the desired molding pressure of 24 mercury inches.

While 10 to 25 seconds doesn't sound like a long time, in thermoforming time it is an eternity. When plastic comes out of the oven and off the tray, it starts losing heat very rapidly to the much cooler ambient atmosphere. Then, when it makes contact with the mold, its heat loss accelerates. (Of course, a foam liner can actually reverse this effect).

All of this heat loss can cause the plastic to fall below its ideal forming temperature range before the full force of the vacuum is applied to the material. The net effect is a poorly formed part. In order to avoid this, a vacuum system needs to apply lots of force as quickly as possible.

The way to get lots of vacuum pressure quickly is to use a surge tank. A surge tank allows for rapid evacuation of a large volume of air and solves the problem of quick forming, but using one also has a downside. If a proper seal isn't made and vacuum is lost early in the forming process, it can take a while for the tank to build that pressure back up again.

Meanwhile, your plastic is either cooling down or thinning out, and you're losing time. The larger the surge tank, the longer it will take to pull back up to forming pressure again. A strong vacuum pump can help offset this delay, but it's important to achieve a good vacuum seal upon forming.

Three key details

There are three key details to setting up a good vacuum system that most people forget. One is allowing for water evacuation. Vacuum systems and compressed air systems tend to attract water, whether they draw it from a wet mold or the system just builds up condensation. Since water seriously harms your pump, installing a drain valve at the pump's regulator will extend the life of your equipment.

Here is another detail to remember when setting up a vacuum system: vacuum doesn't like to go around corners. Whenever possible, use sweeps or just plain old kink-proof, non-collapsible hose instead of hard tubing with ninety degree bends.

Vacuum, like compressed air or water, tends to develop little eddies at the outside edge of those corners that reduce the usable volume of the plumbing. I know it sounds like a small thing, but as long you are going to plumb a system you may as well set yourself up for maximum effectiveness.

Finally, the most frequently overlooked component of a vacuum system is the plumbing. The race car business has a saying: "There's no replacement for displacement." The same is true for vacuum forming.

It doesn't matter how big a vacuum pump you run if the pressure and flow are restricted by tiny little 11⁄44″ lines. I always recommend using a vacuum line as large as your vacuum generator's input line, all the way to the surge tank. Also, the line from the manifold to the tank should be as large as the largest input on the tank. Generally a 1″ to 2″ line should get the job done. O&P

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