Does Nitrogen Pressure Change with Temperature – Practical Application of Gas Laws

The gas laws. We all learned about them in school and promptly forgot all about them. I really think that we need to dig our books out, dust that information off and work to understand and apply it.

Many will say that nitrogen pressure doesn’t change with pressure like other gasses. This is false but read on.

Let’s start by looking at pressure a little differently. Pressure is a measure of the force exerted by a gas within a container. It exerts pressure because the individual molecules of the gas are colliding with the walls of the container. Those collisions are happening because each molecule has a specific amount of energy. So, in this way, we can view pressure as a measure of the amount of energy contained within our container of gas. That might sound complicated, so let’s kind of unpack it and see if we can understand it better.

We have a container that has a fixed volume, for example, 1 cubic foot. So at 0 psig, there is a certain number of gas molecules contained within that container and a certain number of collisions with the container walls occurring.

Now, let's take that container and we're going to double the number of molecules inside that container without changing its size at all.. We know that the pressure increased, but what did it take to do this? **Energy**.

Adding those additional gas molecules required that we add energy to force that extra gas into the container. The addition of energy to force additional molecules into the container resulting in an increase in pressure. The thing to remember now is the law of conservation of energy. Energy isn't created nor destroyed, it simply changes form.

Since heat energy is simply another form of energy so it stands to reason that adding or removing heat energy from our system will affect the energy level of the gas molecules and ultimately the pressure exerted by them. Let's return to our sample container of 1 cubic foot internal volume. We're going to expend enough energy to put enough molecules into this container to raise the pressure to 100 psig at a temperature of 70°F. If we add more energy not in the form of compressing more gas but in the form of heat energy, what will happen to the pressure in the container?

The heat energy is going to 'excite' the molecules in the gas, increasing the number and force of the collisions that are occurring that are the basis of pressure existing. Since we're adding energy, the pressure will rise and it will rise in a predictable and consistent way. The reverse is also true if we remove energy, the pressure will drop in the same consistent and predictable
way.

This is why we need to understand the gas laws as technicians. They allow us to predict and understand the pressure change caused by adding or removing heat energy from a sealed, pressurized system.

Practical application

Now that we understand how heat energy affects the pressure within a sealed system, we can apply this knowledge to pressure testing. A large number of factors are making proper leak testing at installation more important than ever and manufacturers are demanding more detailed leak testing procedures. Add to that the fact that our tools are more refined than old-school analog gauges and a leak of even 0.5 psi over a several hour period of time is easily something a technician can spot.

Let’s take a look at an imaginary but fairly realistic scenario to see how this works and what it means on the ground in the field.

New construction split system. Tonnage isn’t super important to this, but we just made the last brazed joint, it’s the end of a long day in the 90° heat and a nasty thunderstorm is brewing. Let’s get this thing pressurized and get home. Run the pressure up to 350 psig of nitrogen and get out of here. When we show up in the morning when it’s 65°F and find that the pressure has dropped almost 16 psig, that might make us a little nervous. We checked all of our joints with a mirror and with soap bubbles but we don’t see any leaks… where did the pressure go?

Before we get excited, let’s look at how the temperature change affected the pressure within this sealed system. We pressurized to 350 psig at 90°F and it’s now 65°F. With the gas law equations, we can know what the pressure in the system should be and eliminate time wasted looking for leaks that aren’t actually there. This is an expression of the gas laws known as Gay Lussac’s Law. In this, the system volume is a constant and can be disregarded. For our purposes, the copper piping we use to build systems is unchangeable, so we'll use this equation.

The first step is for change the equation around to isolate the answer we wish to get.
P2= T2 (P1/T1)

Now, we have a simple equation we can plug our numbers into and get the answer, right? Not quite yet. We have one more step before we get the calculators out. We need to convert the pressure and temperature valves that we have to absolute pressure and temperature readings, so add 14.7 to the pressure and 492 to the temperature to get to absolute scales

Now, our numbers look like this:
T1 = 582°R (Rankine)
P1 = 364.7 psia
T2 = 557°R
NOW, let's solve.
P2 = 557 (364.7/ 582)
P2 = 557 (0.6266)
P2 = 349.03.

But wait, our system dropped to 334 psig, so we have a leak…
We forgot one VITAL step. We need to convert our P2 reading back to gauge pressure.
349.03 – 14.7
334.33 psig

This says that the pressure loss within the system was due ONLY to the temperature change and was not due to a leak.
Time to get the vacuum pump out and finish this job up.

In summary, every gas responds to the gas laws in the same way. We use nitrogen because it is readily available (the air is mostly made of nitrogen), dry and it doesn't readily combine with other molecules under normal circumstances.

It does change pressure with temperature and all you need to do to find out how much it will change is by changing both the before and after temperatures to absolute scales (Rankine for Fahrenheit or Kelvin for Celcius) and convert your before and after pressure readings from gauge pressure (PSIG) to absolute pressure (PSIA). Once you have your solution you can convert back to Celcius or Fahrenheit

— Jeremy Smith CMS

P.S. — I made a little before and after calculator HERE