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The Gas Laws and how they affect Strength & Tightness Testing
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There are several gas laws and they can be a bit dull. One of them however is very useful if you want to work out the effect on nitrogen pressure when ambient temperature changes while you are pressure testing. The rule that we need to use is Gay-Lussac's Law. Joseph Louis Gay-Lussac was a French scientist working in the 1800s (see the last section for information about the other gas laws, they are also very useful!).

Gay-Lussac's Gas Law

Gay-Lussac worked out that if you change the temperature of a gas in a container with a fixed volume (such as a refrigeration system), the pressure inside the fixed volume will change in direct proportion to the temperature change:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Where:

- P is the gas's pressure in bar absolute (bar absolute = bar gauge + 1);
- T is the gas's temperature in Kelvin (Kelvin = ^{O}C + 273);
- P_1 and T_1 are the starting pressure and temperature, and P_2 and T_2 are the finishing pressure and temperature.

Applying the Gas Law to Strength & Tightness Testing with Nitrogen

This gas law tells us that when we are testing with nitrogen, if the temperature of the nitrogen changes then so will its pressure. If there is no leak in the system the gas law tells us what the pressure change will be. We need to manipulate the equation to do this:

$$P_2 = \frac{P_1 \times T_2}{T_1}$$

So if you noted the pressure and ambient temperature at the start of the test (P_1 and T_1) and you measure the temperature at the end of the test (T_2), the equation tells you what to expect the pressure to be (P_2). Remember that you need to use bar absolute and Kelvin for pressure and temperature.

Example

If you are testing the high side of an R404A your tightness test pressure will be 24.8 bar g, which is 25.8 bar absolute. If the temperature at the start of the test was 7^{O}C (280K), and 18^{O}C (291K) at the end of the test the pressure at the end of the test should be:

$$P2 = \frac{25.8 \times 291}{280} = 26.8\ bar\ abs = 25.8\ bar\ g$$

If the pressure is lower than 25.8 bar g, the system is leaking. If you don't take the temperature change into account, a rise in temperature such as that in the example, can mask a leak.

If the temperature varies around the system, measure the highest and lowest and calculate the average temperature. For example, for a system with outdoor and indoor pipe work, if the outdoor temperature is 10°C and the indoor temperature is 21°C the average temperature is (10 + 21) / 2 = 15.5°C.

Calculator

We can supply a simple calculator on an Excel spread sheet which does the calculation for you. Contact info@coolconcerns.co.uk to get a copy. You input the starting pressure in bar gauge and the start and finish temperatures in °C and the calculator does the rest for you!

An example of the output is shown for the high side of a transcritical R744 system with the same temperature variation as the R404A example.

Nitrogen Pressure Change	Inputs
Starting Pressure P1 (bar g)	120.00
Starting Temperature T1 (°C)	7.00
Finishing Temperature T2 (°C)	18.00
Finishing Pressure P2 (bar g)	124.75
Pressure Change (bar)	4.75

Recording the Pressure & Tightness Test

The start and finish temperature and the expected finish pressure should be recorded on the pressure test certificate to justify when a pressure change is not caused by leakage.

The Gas Laws

In 1662 **Boyle** found that the volume (V) of a gas is inversely proportional to its temperature:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Over a century later in 1787 **Charles** found that the pressure of a gas multiplied by its volume is a constant:

$$P_1 \times V_1 = P_2 \times V_2$$

The **Combined Gas Law** puts these two laws with Gay-Lussac's:

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

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