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TEMPERATURE EFFECTS

Temperature affects are a significant consideration when testing for leaks when using pressure or flow measurement techniques. These are two sources of temperature effects; adiabatic, the effect of changing the pressure of the test medium, and ambient, the effect on the test piece by the environment. The following looks at both:

Adiabatic Temperature Effects

The majority of gases and liquids expand with increasing temperature and the pressure of a gas contained within a confined space will increase accordingly (Boyles Law).

Temperature transients are caused when a gas is adiabatically expanded or compressed, therefore, always test at the lowest acceptable pressure.

In the most severe temperature sensitive applications it may be necessary to fill to the test pressure from a regulated charge source to minimize the pressure drop and hence the adiabatic effects on the test air.

Air that has been heated by the adiabatic process must cool to the surrounding temperature. This produces a pressure loss, which is not due to leakage.

We can calculate the effects of adiabatic compression/expansion of air in a vessel. With an ideal gas the state of air in a vessel can be expressed by the following isentropic relationship equations.

$P \times V^{\gamma} = \text{constant}$

where γ is the ratio of specific heats: (air = 1.402)

$T \times V^{\gamma - 1} = \text{constant}$

Now consider a component with an internal volume of 2.5 liters at atmospheric pressure and room temperature 20°C (V_0; P_0 and T_0).

Then inject the vessel with air at 2.4 bar (35 psig) and at a temperature of 20°C (P_1 and T_1). At the precise moment of compression calculations should be carried out in 2 parts; for the existing air and for the newly injected air.

Note: All values should be in absolute terms, and we will convert volume to cc's. For example

V_0 = 2.5 Liters = 2500 cc's

P_0 = Atm. Pressure = 1 bar abs.

T_0 = Room temp 20^0 C = 293^0 K

P_1 = 2.4 bar gauge = 3.4 bar abs.

$$P_0 \times V_0^{\gamma} = P_1 \times V_1^{\gamma}$$

$$\text{Therefore } V_1 = \left(\frac{P_0}{P_1}\right)^{1/\gamma} \times V_0 = \left(\frac{1}{3.4}\right)^{1/1.402} \times 2500 = \mathbf{1044cc}$$

$$T_0 \times V_0^{\gamma - 1} = T_1 \times V_1^{\gamma - 1}$$

$$\text{Thus } T_1 = \left(\frac{V_0}{V_1}\right)^{\gamma - 1} \times T_0 = \left(\frac{2500}{1044}\right)^{1.402 - 1} \times 293 = \mathbf{416.2^oK}$$

Therefore the temperature rise of the compressed air is: 416.2 - 293 = **123°K**

The raised temperature of the compressed air will be mixed with the incoming air and become uniform. The temperature at that time can be determined from Boyle's Law which states that P x V = constant:

Note: Volume of incoming air (2500 - 1044 = 1456 cc).

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$$\frac{P_1 \times V_2}{T_0} + \frac{P_1 \times V_1}{T_1} = \frac{P_1 \times V_0}{T_x}$$

$$\frac{3.4 \times 1456}{293} + \frac{3.4 \times 1044}{416.2} = \frac{3.4 \times 2500}{T_x}$$

$T_x = 334.33^{o}K$

Therefore, the temperature rise from the initial, ambient state is $334.33 - 293^{o}C = 41.33^{o}C$. Once the test pressure is achieved, the filling cycle is complete and the test component is sealed off from the supply. During the stabilization period the excess temperature will be radiated to room temperature. When the temperature Tx of the compressed air is lowered to room temperature To, the pressure Pa of the compressed air will be:

$$\frac{P_1 \times V_0}{T_x} = \frac{Pa \times V_0}{T_0}$$

$$\frac{3.4 \times 2500}{334.33} = \frac{Pa \times 2500}{293}$$

Pa = 2.98 bar absolute = **1.98 bar gauge**

Therefore the pressure in the component will have dropped by 2.4 - 1.98 bar, = 0.42 bar (6.04 psi). The rate of change will be dependant on the thermal mass and radiation efficiency of the test piece. Clearly if the temperature change occurs during the test phase then a non zero reading will be taken for a leak tight component. This is often referred to as a virtual leak.

Ambient Temperature Effects

Severe temperature variations may be experienced when testing adjacent to convector heaters, open windows etc.

It is worth noting a temperature change of $1^{o}C$ has the effect of changing the test pressure by approximately 0.35%. Hence, the higher the pressure the greater the temperature sensitivity, conversely increasing the vacuum decreases the temperature sensitivity experienced.

The effects of adiabatic and ambient temperature changes have been discussed. Extending the stabilizing time until the conditions have equilibrated can eliminate adiabatic changes.

Ambient temperature changes cannot be so easily controlled, although the ambient effects for the majority of applications is insignificant, heat exchangers are by design particularly sensitive to external temperature.

The pressure decay system offered by Differential test equipment features a short test period (1 sec), the temperature change during test being negligible and in most cases can be ignored. So provided the component is at ambient temperature and of reasonable thermal mass in relationship to surface area, no problems will be experienced.

If the temperature and hence the pressure in the component were to increase, flow devices will sense a flow from the component to the reference volume or regulated source, masking the possible effect of a leak. The same problem also exists for pressure decay measurement.

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