TECHNICAL BULLETIN

The Impact of Cold Temperatures on Desiccant Breather Performance

At higher temperatures, the rationale for desiccant breathers is obvious. Warm air holds more water in the vapor phase, so using a desiccant breather helps to protect a machine when warm, moist air enters the reservoir or oil sump. But, what happens as the air cools and we approach the freezing point of water? How does lower ambient temperature affect both breather performance and air flow?

To understand what happens, we first need to know how air and water coexist and the impact that temperature plays on three important properties: absolute humidity, relative humidity, and dew point.

Absolute Humidity

Absolute humidity is the measurement of the amount of water in grams per volume of air, independent of ambient temperature. Typically, absolute humidity is expressed in grams of water per cubic meter of air (g/m3). Since the amount of water vapor that the air can hold is temperature dependent, the maximum absolute humidity, the highest amount of water air can hold, will vary based on temperature. For air at 30°C (86°F) the maximum absolute humidity is approximately 30g/m3 while at 0°C (32°F) the maximum absolute humidity is around 5g/m3.

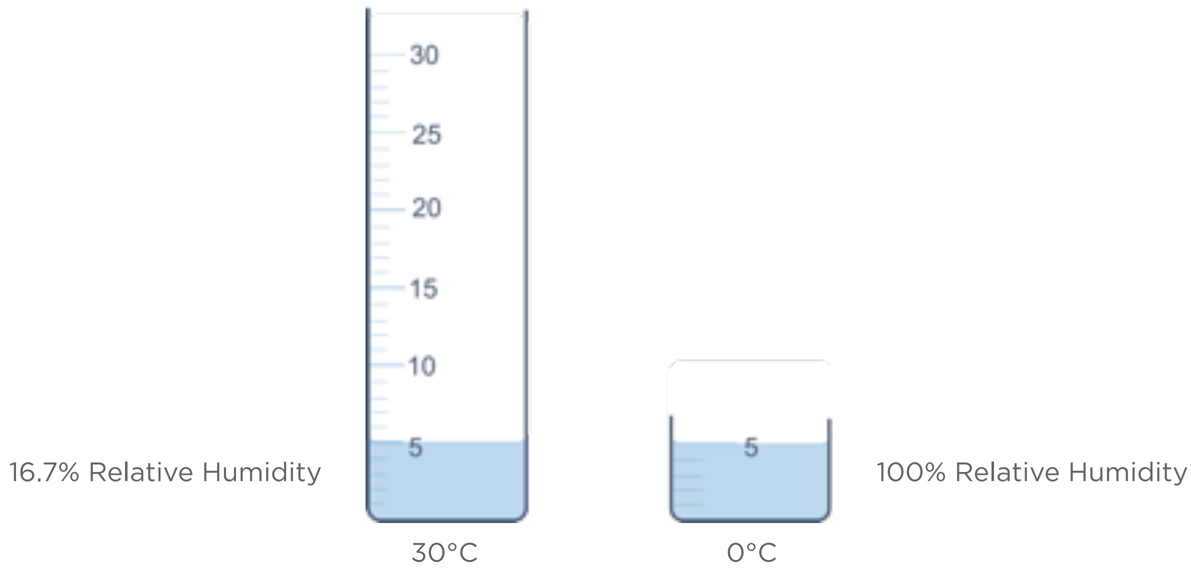
Relative Humidity

Relative humidity is the measurement of how much water is in the air, relative to the maximum absolute humidity at a given temperature. Relative humidity is typically expressed as a percentage (%). As an example, at 30°C (86°F), air that contains 15g/m3 has a relative humidity of 50% since it has exactly one half of the maximum absolute humidity at that temperature. Relative humidity cannot exceed 100% since at this point, the air is said to be saturated; it, simply, cannot hold any more water unless temperature increases.

To better understand relative humidity, think about absolute humidity in terms of a beaker of a known size. At 30°C (86°F) the maximum absolute humidity is 30g/m3, so the beaker which represents the maximum amount of water it can hold is a 30g beaker. By contrast, the size of a beaker that represents the maximum absolute humidity at 0°C (32°F) would be 5g.

Let's compare the two beakers (below). If we pour 5g of water into the 0°C (32°F) beaker, it will become completely full. So, we would say the air that holds 5g/m3 of water at 0°C (32°F) has 100% relative humidity.

Now, let's pour the same 5g of water into the 30°C (86°F) beaker. Since the 30°C (86°F) beaker has a capacity of 30g, pouring 5g of water will cause the beaker to become approximately 1/6 full; the relative humidity is approximately 16.7% (6÷30).



Comparison of the maximum absolute humidity and relative humidity at 30°C and 0°C

Dew Point

The dew point is the temperature at which the air must be cooled to reach 100% relative humidity. Using the example above, air that contains 5g of water at 30°C (86°F) has a relative humidity of 16.7%. But as the air cools, the maximum absolute humidity decreases with temperature, so the relative humidity of the air will start to increase such that at 0°C (32°F) the relative humidity is 100% and the air will be considered saturated.

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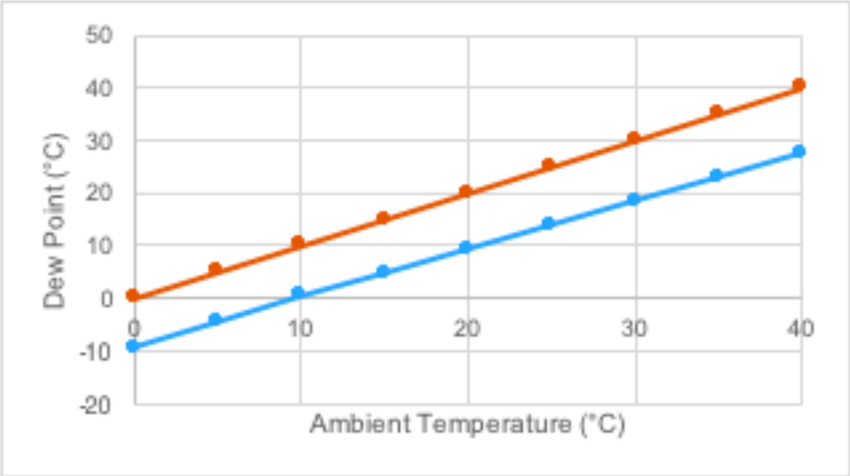


Variation of Dew Point with Temperature for 50% and 100% Relative Humidity

How Desiccant Breathers Work

Desiccant breathers contain small beads of amorphous silica gel. These beads have tiny nano-capillaries that serve to nucleate water vapor. As air passes through and around the beads, water vapor from the air collects in the capillaries, removing it from the air flow, effectively reducing the relative humidity of the air at a given temperature. The result is, the air that passes through the breather and enters the reservoir or oil sump has a very low relative humidity. In fact, in most situations a desiccant breather will maintain the relative humidity in the headspace, and by inference, – the oil – below 30–40%.

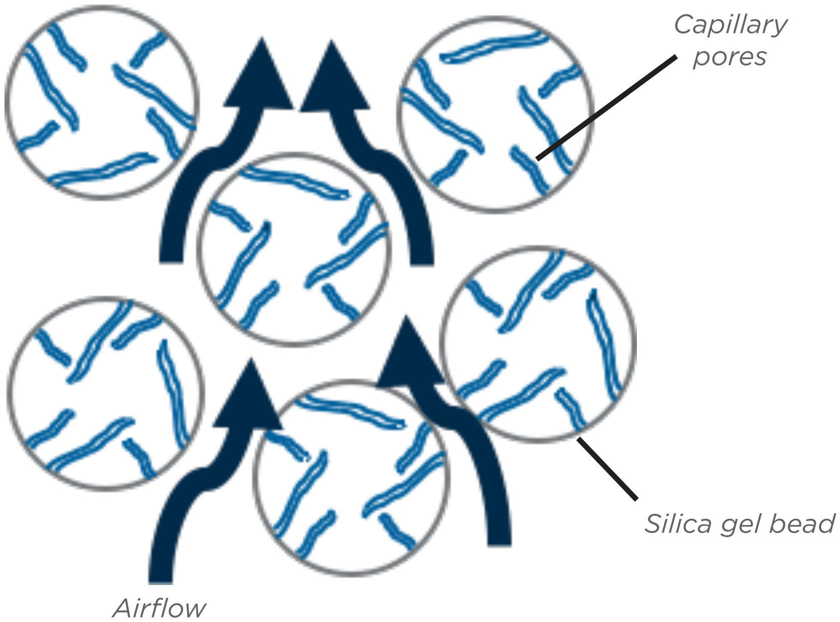
How Do Cold Temperatures Affect the Breather Performance?

The key to understanding how the performance of a desiccant breather changes with temperature is to understand how absolute and relative humidity change with temperature. Since cold air cannot hold as much water as warm air, when the ambient temperature drops the relative humidity of the ambient air outside the breather will be higher for a specific absolute humidity. As an example, consider a cold winter day (close to 0°C (32°F) in a location where the air is at 80% relative humidity. Based on the previous examples, if the air is at 0°C then the maximum absolute humidity will be close to 5g/m3. So, if the air has 80% relative humidity, the actual absolute humidity will be around 4g/m3 (5g/m3 x 80%).

As the air passes into the breather, the temperature will start to increase as the temperature of the oil warms the air inside the reservoir or oil sump (assuming the machine is running). Since the absolute humidity is unrelated to temperature, it will remain at 4g/m3 as the air heats up, but will slowly drop as the water vapor collects in the capillaries inside the silica gel. But since the maximum amount of water the air could hold (as defined by the maximum absolute humidity) increases with temperature, if the temperature inside the breather is 30°C (86°F), even an absolute humidity of 4g/m3 (i.e. assuming the silica adsorbs no water) now only represents a relative humidity of 13.3% (4÷30). So even if the breather had no silica gel and adsorbed no moisture, as the air passes through the headspace it would maintain a very low relative humidity and be well below the dew point. In fact, if the ambient temperature is always close to freezing, there's little benefit to using a desiccating breather and it would be better to use a non-desiccant particle breather.

The Impact of Freezing on Breather Performance

Based on the previous discussion, installing a desiccant breather on an application where nighttime temperatures drop close to 0°C (32°F) has no deleterious effect on the ability to control humidity inside the machine, but is beneficial when daytime temperatures increase and the air can hold more moisture.



Variation of Dew Point with Temperature for 50% and 100% Relative Humidity

But what happens when we go below the freezing mark? Because of the way water is adsorbed into the tiny capillaries inside the silica gel beads, the air pathway, which is largely around the beads, as opposed to through the beads, is unaffected even if the breather were completely saturated with water. And in the event that the water was to freeze, it would freeze inside the capillary structure, and not impede air flow.

Conclusions

Desiccant breathers are an effective means of preventing the ingress of moisture and particles into any reservoir, storage tank, or oil sump. They are most effective at higher ambient temperatures and relative humidity, but they can also be used at very low temperatures without compromising any headspace humidity or air flow rates, even under freezing conditions.

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