# The Detrimental Impact of High-Speed Airflow in CEA:

## Reducing Mechanical Stress While Maintaining Temperature Uniformity

### Introduction

The key goal of controlled environment agriculture (CEA) is to produce high-quality fruits and vegetables at high yields. To attain this, a precedent has been set to increase light levels and $CO_2$ generation, but this has created new problems. Specifically, vertical farmers face issues with uneven gas distribution, tip burn and poor temperature uniformity. Farmers have attempted to solve these issues with increased airflow without considering the mechanical stress on plants caused by excessive air speeds.

Not only has this solution of increased airflow raised capital and operational costs, but it has also failed to deliver the promised quality and yield for those expenses. This may be connected to recent industry bankruptcies.

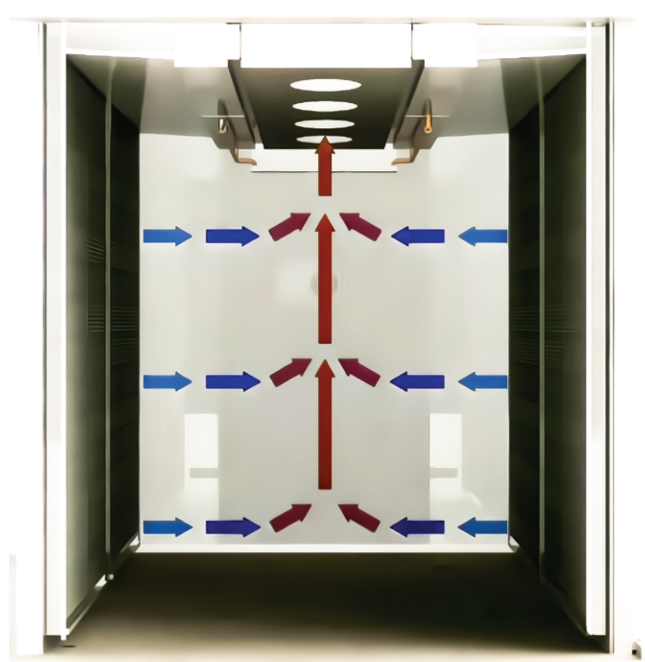
As Percival Scientific has reviewed various designs and served as a consultant for vertical farming manufacturers, growers and producers, we've typically seen designs with air speeds that are too fast. In response, this document provides basic information on best practices for air design in CEA.

### The Importance of Minimizing Air Speed

Under normal conditions, the effects of air movement are much less significant than those of other design variables, but they still occur. A minimum air speed is necessary for effective transpiration by the plants, and maintaining an air speed below the maximum helps prevent mechanical stress on the plant.

Typically, air movement influences growth by affecting heat transfer, transpiration, $CO_2$ uptake, and evaporation. These factors help determine a minimum necessary air speed. However, because the primary driver of these factors is the vapor pressure deficit of the air and soil, if temperature uniformity is achieved, the air movement should be sufficient.

An even more important consideration is the mechanical stress on the plant. Often, induced shaking or mechanical stress can significantly impact plant morphology, resulting in stem enlargement, reduced elongation or decreased leaf area. Generally, the air flow speed should not exceed 0.7 m/s, and ideally, many of Percival's designs aim to keep it below 0.3 m/s.



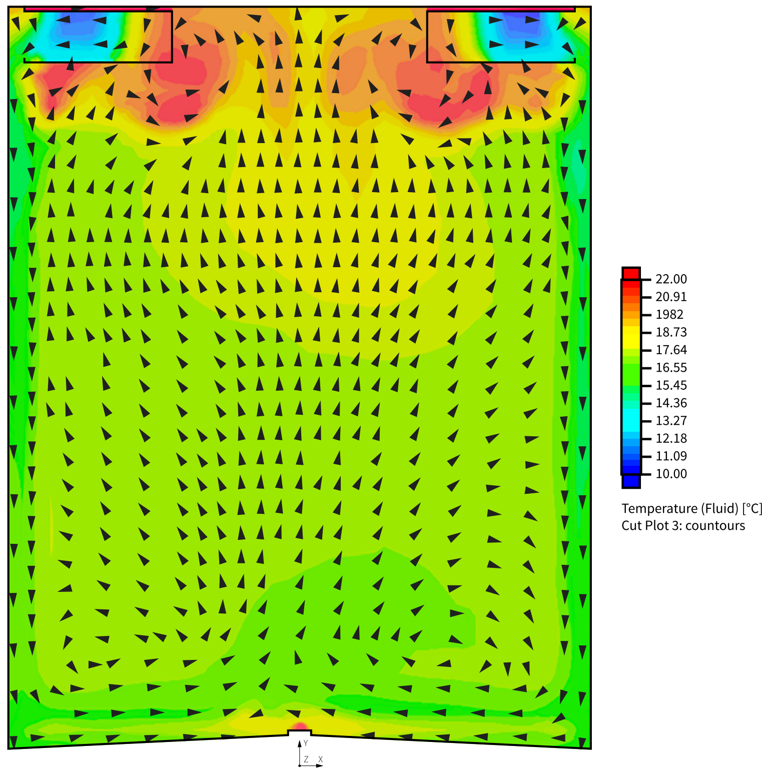
Standard airflow for Percival walk-in chambers with horizontal movement over a large area to reduce overall air speed.

It should be noted that air speed is a tricky variable when it comes to monitoring its impact on crops. Unlike other variables, which often show gradual effects, the effect of air speed can show up abruptly with irreversible damage. The negative impacts of high air speed only show themselves beyond a certain level, which is often not well-defined (some plant species may tolerate up to 5 m/s gusts before presenting issues). That is why we recommend exercising caution and avoiding CEA designs with large fans that produce powerful airflow. Simply put, plants don't thrive in high winds.

## Balancing Against Temperature Uniformity and $CO_2$

The increase in airflow velocities in CEA designs is because more airflow results in more air exchange. Greater air exchange per unit time allows more air conditioning in terms of thermal balancing, and it also introduces or removes other gases like water vapor and $CO_2$ into or from the environment. These factors are often the most crucial for the quality and yield of the plant. For example, strawberries often require extremely high temperature uniformity to produce high-quality crops.

A secondary factor is that because high light intensity is crucial to growth, it is often set too high, resulting in tip burn. To alleviate this, some growers react by simply pumping up the air speed. However, many times this proves to be the wrong solution since tip burn results from a complex collection of factors. Moreover, the addition of higher-capacity fans only increases the space's capital and operational costs with minimal benefit.




CFD (computational fluid dynamics) simulation showing expected temperatures and airflow patterns within a Percival grow space to help optimize temperature uniformity and airflow rate.

What should be done instead is to first ensure that the air speed in the space does not exceed a certain level specified by the grower, and then design around that. This may require sacrifices in the design, such as the maximum level of light intensity, but these should be minimal relative to the benefit to production. One should carefully balance the emphasis between volumetric and linear airflow. For example, airflow can be decreased while still maintaining the number of air exchanges by increasing the area across which the air is dispersed. $CO_2$ and humidity should be introduced in multiple locations. Higher light intensities can be achieved by making the lights more uniform, which also helps with temperature uniformity. Uniformity can also be achieved by paying more attention to the computational fluid dynamics (CFD) design, as well as the algorithms and control devices managing the space's HVAC system.

## Conclusion

With all the variables to consider in CEA, it's easy to overlook the significant impact that air speed has on crops. Failing to do so can lead to higher operational costs, lower yields and reduced crop quality. Other methods can be used to achieve the desired design goals without increasing air speed to unsustainable levels. Generally, a grower should ensure that the air speed does not exceed 0.7 m/s, and in many research applications, a gentle airflow of around 0.3 m/s is preferred.