# Improving humidity control in greenhouses and saving energy

*Elly Nederhoff & Bert Houter*
*CropHouse Ltd, New Zealand*
*Elly@CropHouse.co.nz*
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Humidity control in a greenhouse involves heating and venting, and often accounts for at least a quarter of the annual energy consumption. High energy prices force growers to be more cautious with heating. Humidity control is the first to be neglected, which allows fungal diseases to take their toll. Last month we dealt with energy-efficient temperature control, and this week we look at improving humidity control. How much venting and heating is needed, which of the two first, which humidity level to start, what settings? Energy-efficient humidity control as described in this article requires an advanced climate control computer, but some basic ideas of humidity control described below are hopefully useful for every grower.

**Effect of heating**

If the air humidity in the greenhouse gets too high, the intuitive response of growers is to increase the heating. This seems to help, but in fact it helps only for a short while. Heating increases the air temperature and reduces the relative humidity (RH). (This is because warm air can hold more moisture than cold air, see text box). But the higher temperature and lower RH stimulate the plant transpiration. In addition, warm pipes close to the root-zone stimulate root activity, boosting plant transpiration even further. Increased transpiration means increased moisture input into the greenhouse air. The greenhouse becomes a sauna, badly in need of some venting.

**Effect of venting**

Venting means air exchange: hot humid air leaves the greenhouse and cold dry air from outside enters the greenhouse. Outside air (nearly always) has a lower <u>absolute</u> humidity than inside air, even on a rainy day. This is because cold air can't hold a lot of water vapour. See explanation in text box. For example, outside air is 5 °C and 85% RH. Tables tell us that the moisture content is then 5.8 gram per m3 air (this is the absolute humidity). If the air inside the greenhouse is also 85% RH but the temperature is 20 °C, the moisture content here is 14.7 g/m3. Venting causes that greenhouse air with 14.7 g/m3 moisture is replaced by outside air with only 5.8 g/m3 moisture. So the greenhouse air becomes drier (the absolute humidity drops). Soon the freshly entered air warms up to 20 °C, but still contains only 5.8 g/m3. Tables tell us that air of 20 °C with 5.8 g/m3 moisture content has a relative humidity of 33%. Of course the air from outside mixes rapidly with the greenhouse air, and the end result is cooler and drier air in the greenhouse.

**First venting then heating**

Above we showed that heating alone is not the way to control humidity in a greenhouse, as it stimulates the transpiration. It must be accompanied by venting. Venting alone can control the humidity, particularly in summer. In winter, thought, venting causes the air temperature to drop, so venting must be accompanied by heating. The question is: which comes first? The proven technique is: **Step 1**: start venting to get rid of the moisture. **Step 2**: if venting can't do enough and the humidity rises further, additional heating has to come in to drive the moisture out. Heating also kicks in for maintaining the required air temperature.
This works well, but costs energy. We want to control the humidity in the most energy-efficient way. We don't want the vents wide open and the pipes burning hot. It is possible to get the same result with vents on a crack and pipes on a moderate temperature. First we focus on step 1, venting.

**Step 1: how to vent?**
How to vent for humidity control depends on the options in your computer. Most computers use 'normal' vent opening for temperature control, and use '*minimum vent opening*' for humidity control. Different computers use different lingo, like '*minimum vent position*' or '*vent position for humidity control*' and other variations. Here we use the last one.
The best way to control the humidity is if the computer uses the measured air humidity to vary the *vent position for humidity control*. This means the vents open wider when the humidity is higher. Figure 1 shows an example (note that not all computers can do this). When the RH level exceeds a certain level (here 82 %) the vents open a bit. If the RH rises further, the vents open further. At 87% RH or more, the vents are 20% open and won't open further. When the RH drops, the vents close proportionally. Below 82% RH they are fully closed. The '*settings*' that determine the control (here 82% RH, 87% RH, 20% opening) are chosen by the grower.

**Maximum vent opening for humidity control**
The settings for humidity control discussed above (82, 87, 20%, see Figure 1) have to suit the greenhouse, venting system, crop and season. Glass cladding is colder than double plastic, so attracts more condensation, which results in a less damp climate. Hence a glasshouse needs less venting for humidity control than a double-plastic house, meaning that the maximum vent position for humidity control can be lower. Crop size is important too. Young plants don't transpire a lot, so the humidity won't rise too quickly, and the maximum vent position for humidity control can be set lower.

**Seasonal adjustment**
The settings also need to be adjusted now and then to suit the weather conditions or in fact the season. In summer the vents must open quicker and wider than in winter in order to get enough effect. So in summer the line of *vent position for humidity control* must be steeper and end at a higher level. This is done by choosing a higher value for the maximum vent position, e.g. 40% instead of 20%. In contrast, in cold conditions, the vents should be opened very carefully, so the maximum *vent position for humidity control* must be set lower, even as low as 5% (see Figure 1, the green dotted line).
These weather-depending or seasonal adjustments can be made automatically in some high-tech computers. For instance the maximum *vent position for humidity control* (the 20% in Figure 1) is automatically lowered in cold windy weather, and automatically increased in mild calm weather. This requires another series of settings, which goes beyond the scope of this article.

**At what humidity level to start venting?**
One of the settings for humidity control is the humidity level where the control starts (82% RH in Figure 1). It can also be 75% or 85%. Why choose 82%? The aim of humidity control is avoiding condensation to avoid diseases. Condensation on the plant happens when plant organs are colder than their surroundings. Cold plants can be avoided by proper temperature control, i.e. letting the temperature rise slowly instead of rapidly (see explanation in last month's article).
Another factor to consider is the temperature distribution in the greenhouse. Condensation on the plants occurs on cold spots, so in greenhouses with an uneven temperature distribution. It also happens if the humidity measurement is very inaccurate. In these cases, humidity control must kick in at a low RH level, even as low as 75% RH, just to be safe. If the temperature is quite even and the humidity measurement accurate, it is safe to let the humidity control start at a higher humidity level, e.g. 82 or even 85% RH. Starting at a low humidity level (e.g. 75%) costs enormous amounts of energy. Starting at a high level (e.g. 82%) saves a lot of energy. This explains why an even temperature distribution improves the energy-efficiency.

**Step 2: additional heating**
When step 1 (venting) is not powerful enough to reduce the high humidity, step 2 (additional heating) can become necessary. It is especially needed in winter. It is done by additional minimum pipe temperature in dependence of RH. (Not all computers can do this though). If possible, choose the settings so that the pipe temperature starts increasing in the middle of the RH range for venting, which is 85% in the example above (Figure 1). So the extra minimum pipe must kick in at 85% RH. In this example it starts 'cold' (20 °C) when humidity is 85%, and reaches the top temperature (here 40 °C) when humidity is 95%. These settings (start point, end point and end temperature) are chosen by the grower. Factors to consider are the stage of the crop and the heating system (location, number and diameter of the heating pipes).

**Less advanced computers**
The refined methods discussed above are not available on simple computers or control units. Most don't have the vent control as discussed in Figure 1. They can open the vents on a crack (minimum vent opening) when the RH exceeds a certain threshold. The threshold level and (usually) the size of the crack can be set. But the crack does not automatically get bigger with higher humidity. In other words this is a so-called 'on/off' control of a fixed crack.
Similarly, most simple controllers can't steer minimum pipe in dependence of RH. They can have a fixed minimum pipe temperature with an on/off control. However, some simple systems can reduce the minimum pipe temperature when the radiation increases due to sun shine. This is an excellent feature to avoid unnecessary energy use.
One very common type of computer works with 'purging': regular bouts of venting or heating or both (not discussed further here).

**Part of a greater picture**
The above is all about humidity control. Temperature control can cut right through humidity control. So vents open for two reasons: ridding excessive moisture as well as excessive heat due to sun shine. Also heating happens for two reasons: driving out excessive moisture and maintaining temperature. Last month's article and this article explain both aspects separately. It is wise to look at the bigger picture and study the graphs in your control computer. Look at temperature, humidity, pipe temperature and vent opening. Be on alert if you see vents open and pipes hot. Wonder why this is. Is the humidity really too high? Or could the same climate be achieved by lower pipe temperature and vents less wide open? In that case carefully alter the settings and keep checking those graphs every day! Or ask an expert.

**Relative and absolute humidity**

Warm air can contain more moisture than cold air. The columns show water content (as gram water per m$^3$ air) at various temperatures. 100% is air saturated with water.

| **Humidity:** | **80%** | **85%** | **90%** | **95%** | **100%** |
|---|---|---|---|---|---|
| **Temp ↓** | | | | | |
| **5 °C** | 5.4 | 5.8 | 6.1 | 6.5 | 6.8 |
| **10 °C** | 7.5 | 8.0 | 8.5 | 8.9 | 9.4 |
| **15 °C** | 10.3 | 10.9 | 11.6 | 12.2 | 12.9 |
| **20 °C** | 13.9 | 14.7 | 15.6 | 16.5 | 17.3 |

E.g.: outside air of 5 °C saturated with water contains 6.8 g/m$^3$, and outside air of 15 °C, saturated with water contains 12.9 g/m$^3$. So colder air is drier. Greenhouse air of 20 °C of 80-100% contains 13.9 – 17.3 g/m$^3$. So venting removes moisture from greenhouse.

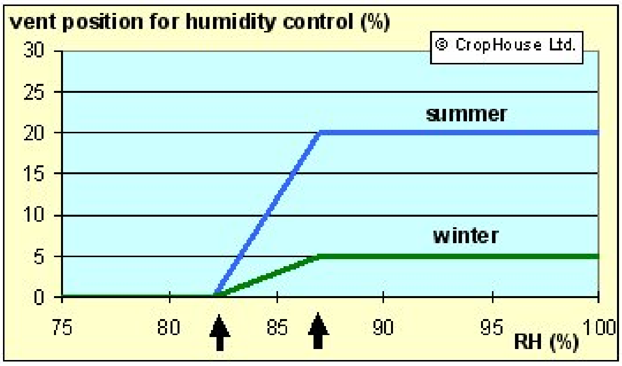


***Figure 1, Step 1:***
*Vent position for humidity control ('minimum vent opening') depends on the Relative Humidity (RH). In summer its maximum must be higher than in winter.*

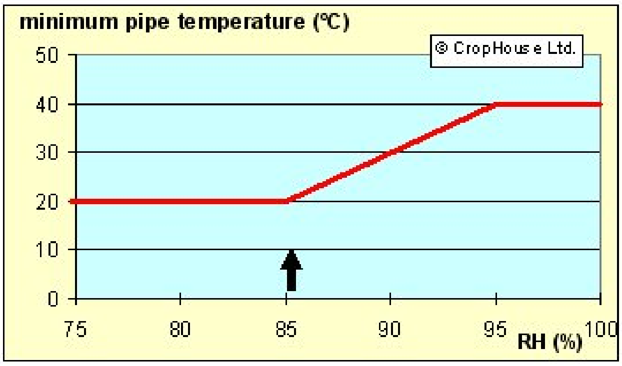


***Figure 2, Step 2:***
*If step 1 does not do enough, step 2 kicks in: the minimum pipe temperature rises with increasing humidity. Start point (85%) is halfway RH-range of step 1 (Fig 1).*