# CARBON DIOXIDE DOSING IN COMMERCIAL GREENHOUSES – GAS SENSORS FOR OPTIMAL CONTROL OF GROWTH CONDITIONS AND SAFETY

## Finding the sweet-spot for $CO_2$ makes tomatoes sweet too

Crops such as aubergines, cucumbers, tomatoes, capsicum peppers and lettuce are now regularly grown in modern greenhouses where light, water, temperature and nutrient supply are well controlled. It is also common to adjust the carbon dioxide ($CO_2$) levels in greenhouses to create an environment that is optimally conducive to growth. The micro-climate that is created must be monitored and controlled to ensure good growing conditions, avoid expensive over dosing and ensure the safety of the people looking after and harvesting the crops. It is all about finding the sweet-spot for growth, the optimal balance. For food producing and exporting countries, such as Australia and New Zealand, investment in high yield growing processes using a mix of environmental management technologies has been intense in recent decades.

Elevated levels of carbon dioxide during the 'daylight' growing hours enhance plant growth. In greenhouses, the growth rate and development of all plants can be improved by controlling $CO_2$ concentrations at levels of around 800 ppm. This is approximately twice as much as the natural concentration of $CO_2$ in natural ambient air. Higher $CO_2$ concentrations up to 2000 ppm have been used in greenhouses and hydroponics, but each incremental increase in $CO_2$ levels above 700 ppm has diminishing benefit to the plants. Despite these diminishing returns, some operators control the $CO_2$ levels at 1000 or 1200 ppm to fully exploit the potential of $CO_2$ addition.

Optimised $CO_2$ levels in greenhouses raise productivity and crop yields considerably, up to 40% during the darkest time of the year. In addition, they also improve the quality of the crop. When the $CO_2$ level in the greenhouse is optimised, the plants will produce uniform fruit, salads and vegetables of the best quality. So, $CO_2$ can maximise both the crop yield and the sales price for the harvest. This technique is applied to greenhouses using both hydroponic and conventional soil growing techniques.

*Greenhouses Harmelen NL*

### Creating and avoiding toxic environments

At high levels, $CO_2$ can be toxic to humans and bugs. For humans, the short-term exposure limit in many countries, including Australia and New Zealand, is 3% by volume (ie 30,000 ppm) and the long term 8-hour time-weighted average exposure limit is 0.5% by volume (ie 5000 ppm). For greenhouse pests such as white fly, exposure to a $CO_2$ concentration of 1% for one hour has been reported to be an effective fumigation technique.

So, it is theoretically possible to use elevated $CO_2$ levels for pest control in the greenhouse but achieving these high concentrations can be costly and needs to be done when people are not present in the greenhouse, for example overnight. Overnight dosing is possible, but the growth benefits of $CO_2$ are only realised when applied during 'daylight' growing hours. In some growing systems the 'daylight' conditions are simulated by artificial electrical light sources such as energy-efficient neon or LED lighting.

### Carbon dioxide dosing

In some countries such as New Zealand, it is important to heat the greenhouse to create optimal growing conditions. In Australia on the other hand, for much of the year thermal management means avoiding temperature run-away during peak daytime sunlight hours. This climatic difference has an influence on the $CO_2$ source. It is possible to burn natural gas or LPG to create both heat and $CO_2$, which in New Zealand might be an attractive combination. However, in Australia the heat generated by the combustion might be a negative rather than a positive input to the greenhouse

environment. In all cases, the generation of $CO_2$ from combustion also introduces humidity into the greenhouse, which again may be desirable to a certain extent or problematic in extreme cases. The use of direct $CO_2$ injection has the benefit that $CO_2$ can be added without the side effects of moisture build up or heat addition to the greenhouse. And, in some situations a mix of sources is used to optimise the range of climatic growing conditions.

*Coregas bulk $CO_2$ tank*

TJ Croeser, Sales Manager at the industrial gases supplier Coregas in New Zealand comments: "dosing of carbon dioxide to the greenhouse can be from a $CO_2$ burner generator, from a carbon dioxide supply cylinder or tank. Greenhouse $CO_2$ generators are often simple LPG (or propane) burners, which produce $CO_2$ and heat from combustion of the LPG. However, enhanced flexibility and improved dosing control can be achieved by using carbon dioxide gas, which can be supplied by Coregas in New Zealand in bulk liquid tanks, gas cylinder packs or single cylinders".

## Gas detection - measurement and control

To control the $CO_2$ level in the greenhouse, an NDIR sensor is typically used. The target set point will generally be 800 ppm of $CO_2$. When the sensor detects a reduced $CO_2$ level in the greenhouse it will activate the $CO_2$ dosing system. When the required $CO_2$ level has been achieved, the measured value will increase, and the control system will shut off the $CO_2$ supply.

For safety reasons, it may also be desirable to install propane gas detectors if LPG is being burned to generate $CO_2$ or methane detectors if natural gas is used. If the flame does not ignite, or is quenched, then the fuel gas can flow freely into the greenhouse and quickly generate a flammable atmosphere.

*Gastech D Guard 2 gas monitor*

Jim Filov, Marketing Manager at gas detection manufacturer Gastech comments further on equipment selection and installation: "we recommend NDIR sensors for $CO_2$ as they offer exceptional accuracy, reliability and overall performance. When detecting combustible gases, NDIR technology can also be used for, methane or propane, which is available in our D-Guard2 product range. A critical point to consider when locating these fixed gas detectors in the greenhouse is where the gas build-up is most likely to take place.

"For example, methane from the natural gas grid is generally at ambient temperature and is a light molecule, so it will tend to accumulate in higher levels in the greenhouse. Location of the methane detector under the roof space would be regarded as best practice. On the other hand, propane is a heavy molecule and when it expands out of a gas cylinder it is cold. So, a build-up of un-combusted propane is more likely to take place at a lower level in the greenhouse and mounting a propane gas detection safety device close to the ground would be ideal.

"For the $CO_2$ its self, it may be warm, if generated by combustion, or close to / just below ambient temperature if supplied from a direct injection system. It is also a relatively heavy molecule. So, there is no blanket recommendation to go high or low. For the optimal location of the $CO_2$ sensors, our engineers would survey the greenhouse and estimate the gas flows and mixing regimes to propose a suitable location via precise gas and flame mapping and area modelling".

In professional greenhouses, the gas detection sensors will be fixed, so it is not possible for the end user to take the $CO_2$ gas detector out of the greenhouse into clean pure air and run


*Geothermal greenhouses Hveragerdi Southern Iceland*

an auto calibration based on the normal $CO_2$ concentration in ambient air. So, a specialty gases calibration gas mixture cylinder containing, for example, 800 ppm $CO_2$ in a balance of nitrogen can be used to calibrate the sensor close to its measured value. Similar certified specialty gas cylinders containing known concentrations of methane or propane can be used to calibrate the other detectors. A cylinder of high purity nitrogen can be used to set the zero reading on these gas detectors. Alternatively, the gas detectors may be removed from the greenhouse and calibrated by the manufacturer or professional, accredited gas detection service company and calibrated in their off-site laboratory.

And with the last word to Croeser of Coregas NZ on the topic of safety: "let's put the undisputed economic benefits of $CO_2$ dosing to one side for a moment and get down to brass tacks… there is nothing more important in that greenhouse than the gas detectors and alarm system. Every employee relies on it for their safety. Carbon dioxide is invisible and does not have a noticeable smell, so a dangerous concentration can't be detected by humans until it's too late. The same can be said for propane from gas cylinders. That's why we offer only the best quality NATA-certified calibration gas mixtures for gas detector sensor calibration applications."


*Port of Rotterdam with Shell Pernis Refinery in the background*

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