

CO₂ enrichment and heat storage

Elly Nederhoff

CropHouse Ltd, New Zealand

Elly@CropHouse.co.nz

Published in the Grower 59(2), 2004, p. 31-32

The previous article in this series was about CO₂ enrichment, in particular about amounts of CO₂ needed under various conditions. Some general recommendations were discussed and some ball-park figures of required CO₂ amounts were presented. This article is about the amount of fuel that needs to be burned to produce CO₂, and about the storage capacity of a heat buffer. Again the aim is to provide some ball-park figures to assist decision making. The data are for natural gas, because that is normally the fuel for greenhouses where heat storage is used.

Energy and CO₂ content of natural gas

The energy content of a fuel is expressed by the gross calorific value (GCV) and the net calorific value (NCV). The difference between the GCV and the NCV is about 10%. It is the amount of energy that becomes available when a condenser obtains the energy out of the water vapour in the flue gases.

Natural gas in New Zealand has a GCV of around 39.5, and a NCV of around 35.5 MegaJoule per m³ volume (MJ/m³). Another characteristic is the amount of CO₂ produced by combustion of a fuel. For NZ natural gas this figure is 52.8 kg/GJ. This means that 1 GigaJoule (GJ) of natural gas is equivalent to 52.8 kg CO₂. Converted to volumetric units, 1 m³ of natural gas is equivalent to about 2 kg CO₂.

Natural gas needed for CO₂ enrichment

In the previous article in this series we approximated how much CO₂ is needed under certain conditions. The main data are repeated here in Table 1. The CO₂ requirement was given for situations without venting or with very little venting. It is impossible to be exact about the venting, because then we also need to be precise about type of greenhouse, type of vents, wind speed and other factors that affect the ventilation rate. Things can only be calculated more precisely if details are known. Obviously more CO₂ is needed when the vents are opened further. When the ventilation rate is substantial it is impossible (or at least uneconomical) to maintain a really high CO₂ level. It is then feasible to aim for only slightly elevated CO₂ levels, just above ambient level.

The required amounts of CO₂ (Table 1) can be used to calculate how much natural gas needs to be burned. For instance the required CO₂ supply rate of 2 g/m²/hour is first converted to handier units: 20 kg/ha/hour. Then we use the fact that 1 GJ of natural gas is equivalent to 52.8 kg CO₂ (see above). This means 20 kg CO₂/ha/hour requires combustion of nearly 0.4 GJ of natural gas per ha per hour. To obtain the very high CO₂ dosing rate of 190 kg/ha/h, we need to burn 3.6 GJ/ha/h. These and other data are shown in Table 1.

Heat storage tank (buffer)

Modern glasshouse enterprises in NZ, especially the larger companies, increasingly use a heat storage tank (or buffer). Originally the only purpose of a buffer was to store heat that was produced during the day for CO₂ enrichment, and to release that heat during the night for heating the greenhouse. Nowadays in the Netherlands heat buffers are also used for energy management in a wider sense. The traditional buffer was a so-called 'closed buffer' whereas the new system is called 'open buffer'. These two variations will be discussed in a following article.

The heat storage capacity of a heat buffer can easily be calculated. The key factor is the heat capacity of water, which is 4.2 MJ/m³/°C. This means that input of 4.2 MegaJoule of energy increases the temperature of 1 m³ water by 1 °C. If a heat storage tank is for instance 125 m³ and the temperature increases by 40 degrees (say from 55 to 95 °C) the amount of heat stored is 125 x 40 x 4.2 = 21,000 MegaJoule (MJ) or 21 GigaJoule (GJ). We have to consider that the boiler and the buffer are not 100% efficient: they lose about 10% energy. Hence the amount of energy to be burned by the boiler is about 10% higher (23.3 GJ), and the amount that can be retrieved later from the buffer is 10% less (19 GJ).

Natural gas combustion and CO2 levels

What matters for CO₂ enrichment is the 23.3 GJ of natural gas that is burned when the buffer is heated up from 55 to 95 °C. As described above, 1 GJ of natural gas is equivalent to 52.8 kg CO₂. So 23.3 GJ is equivalent to 1230 kg CO₂ (52.8 x 23.3 = 1230). If the greenhouse is for instance 2 ha, and we assume there are 8 hours in a day for CO₂ enrichment, it follows that the average CO₂ production rate is 77 kg CO₂ per ha per hour (1230 : 2 : 8 = 77). The table shows that 77 kg/ha/h CO₂ is sufficient to maintain a CO₂ level of 900 ppm under fairly good light conditions if the greenhouse is closed (note that this only happens at very low outside temperature!). With fairly good light conditions and a little bit of venting, this amount of CO₂ will be enough to maintain about 500 ppm. Obviously if the windows are opened further more CO₂ is lost and the CO₂ level will drop.

Summary

More and more growers are installing a heat storage tank or buffer. This was primarily intended for CO₂ enrichment, but overseas it is increasingly used for energy management. Next article will discuss the modern set-up of the so-called 'open buffer'. The size of the buffer depends on the amount of CO₂ required (see previous article, partly repeated in the table in this article), as well as on the amount of energy that can be used.

The relevant characteristics of NZ natural gas are: gross calorific value or GCV of 39.5 MJ/m³, net calorific value or NCV of 35.5 MJ/m³, and CO₂ production of 52.8 kg per GJ. The other important characteristic is the heat capacity of water: 4.2 MJ/m³/°C. These data and some examples enable the grower to do their own calculations on buffer size, amount of natural gas burned and amount of CO₂ produced.

Table 1: required amounts of CO₂ (to compensate photosynthesis and loss), and the required natural gas combustion rates for maintaining certain CO₂ levels, either without ventilation (only air leakage) or with very little ventilation. These are only ball-park figures.

CO ₂ level:	350 ppm		500 ppm		900 ppm	
light level:	low	high	low	high	low	high
with vents closed:						
CO ₂ supply rate (g/m ² /h)	2	3-5	4-5	5-7	5-6	7-10
CO ₂ supply rate (kg/ha/h)	20	30-50	40-50	50-70	50-60	70-100
natural gas rate (m ³ /ha/h)	10	15-25	20-25	25-35	25-30	35-50
natural gas rate (GJ/ha/h)	0.4	0.6-0.95	0.8-0.95	0.95-1.3	0.95-1.1	1.3-1.9
with very little venting:						
CO ₂ supply rate (g/m ² /h)	2	4-5	6-7	7-9	15	17-19
CO ₂ supply rate (kg/ha/h)	20	40-50	60-70	70-90	150	170-190
natural gas rate (m ³ /ha/h)	10	20-25	30-35	35-45	75	85-95
natural gas rate (GJ/ha/h)	0.4	0.8-0.95	1.1-1.3	1.3-1.7	2.8	3.2-3.6



Figure 1. This property has a huge heat buffer (green), as well as a tank (white) for storage and supply of liquid ('pure') CO₂. The smaller green tanks in the background are for water.