Mathematical calculations used within Dixon ring characterisation

Croft Engineering Services, based in Warrington, innovatively utilise the properties of woven wire mesh to manufacture pioneering filters, to serve a niche market in a vast range of applications.

Figure 1- A photograph of 1/8" Dixon rings as tested within this work.

Croft Engineering Services, back in 2003, developed a manufacturing method to produce Dixon rings, a very small revolutionary random column packing, used within the chemical industry. Dixon rings were originally developed by Dr O G Dixon while working for ICI in 1946.

When Dixon rings were first manufactured 65 years ago, Dr Dixon used a split pin to wind the mesh around forming the Dixon ring shape. However this was extremely slow and laborious and the real potential for Dixon rings was not initially found.

The reason Dixon rings have made a return, over 50 years later, is due to their superior efficiency compared to other random packings including Pall rings and Intalox saddles.

The difficulty facing Croft Engineering Services was that they could manufacture Dixon rings to superior quality easily, however the difficulty came in that they were unable to quantify and compare the performance to other random packings and this put potential customers off as they were unwilling to try Dixon rings without some proof of performance.

This is where my work started, I was brought in to quantify the performance of Dixon rings and compare them to competitor column packings.

One of the main quantities that performance of column packings is compared on is Mass transfer efficiency. This piece of work shows how once the results are obtained from testing in a counter current water/carbon dioxide setup (figure 2), using maths the optimum conditions and the performance at optimum conditions of carbon dioxide absorption by water can be found

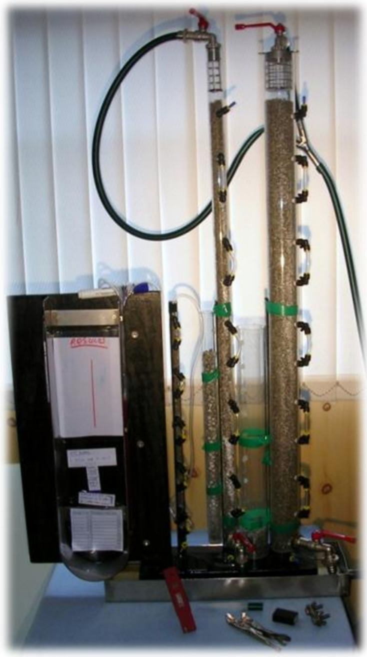

Figure 2- A photograph of the test rig used within this work

The table below shows a sample of results obtained from testing using the rig shown in figure 2.

Description of condition	pH start	pH after 60 seconds	pH change per minute	CO_2 absorbed per minute ppm
Water 0.5 l/min CO_2 2 l/min	6.72	4.76	1.96	364.80
Water 0.5 l/min CO_2 4 l/min	6.76	4.65	2.11	515.30
Water 0.5 l/min CO_2 8 l/min	6.79	4.67	2.12	527.30
Water 0.5 l/min CO_2 10 l/min	6.70	4.69	2.01	409.32
Water 0.5 l/min CO_2 14 l/min	6.80	4.94	1.86	289.77

This data was plotted in Microsoft Excel to produce a surface plot shown, as shown in Figure 3, to easily view the optimum conditions.

The purpose of this work, as well as finding the optimum conditions for absorption of carbon dioxide was to actually work out the efficiency of absorption.

As pure carbon dioxide gas was used the concentration of initial inputted gas was easily calculated as follows

Carbon dioxide (CO_2) is formed from the constituent elements one carbon atom and two oxygen atoms

The molar mass which can easily be read off the periodic table for Carbon is 12.01 and Oxygen is 16.00.

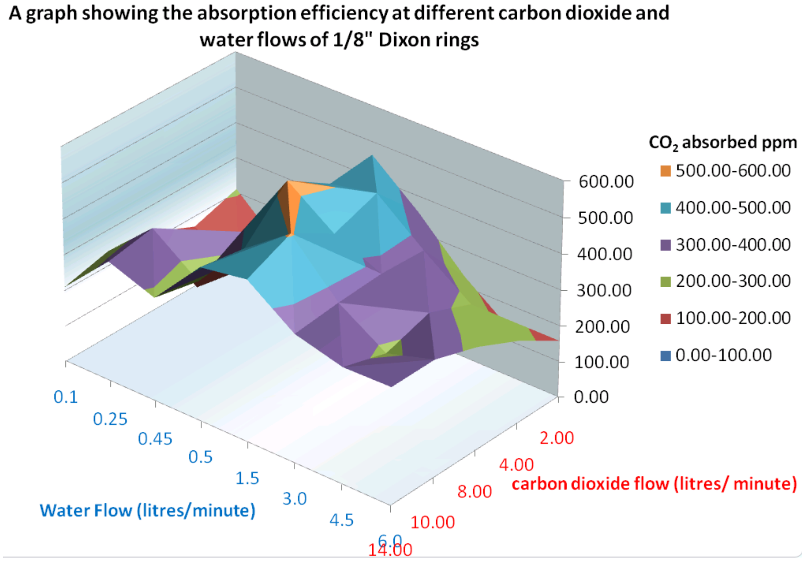

Figure 3- Surface plot of 1/8" Dixon ring performance

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Therefore the total molecular weight of a carbon dioxide molecule is 40.01 grams/mol.

The density of carbon dioxide gas at standard temperature and pressure (1 atmosphere 273.15K (0^0C)) is 1.97 grams/litre

Rearranging the formula Density= Mass / Volume

to give Mass = Density x Volume

Then the mass of one litre of carbon dioxide can be calculated.

Mass = 1.97 x 1 = 1.97g

From this the number of moles can be calculated using the formula

Moles = Mass / Molecular weight
= 1.97 / 44.01
= 0.044642857 per litre

This calculation can be checked because at standard temperature and pressure a mole of any gas occupies 22.4 litres:

1 litre = 1 / 22.4 moles = 0.044642857 moles

This indicates that the calculation is correct.

We now know the total moles of carbon dioxide flowing though the column, we now need to calculate the amount of carbon dioxide absorbed.

Using the calculations above we currently have an absorption measured in parts per million.

If we assume we are using pure water at standard temperature and pressure the density of water is 1 kg/litre.
As the name suggests one part per million can be written a 1g per 1000000g, or in this case 1mg per 1000000mg
1000000mg = 1kg and as we have stated 1 kg = 1 litre. Therefore,

1ppm = 1mg/litre

Now we need to calculate the number of moles absorbed using the formula Moles = Mass/ Molecular weight.

Firstly we need to convert mg/litre to g/litre to keep in standard units:

1 milligram = 0.001grams

Therefore we need to divide milligrams/litre by 1000 to get grams/litre and then divide by the Molecular Weight (44.01 g /mol) as column 3 of the sample data below shows.

The last calculation is to calculate the % absorbed. Tthis is done by dividing the number of moles absorbed (column three of table) by the number of moles of inlet gas (0.0447626) and then multiplying by 100 (column 4 of table) . There is no need to include the actual flow i.e. 2/4/8 litres/minute as they cancel within the calculation.

CO_2 absorbed per minute ppm (mg/litre)	CO_2 absorbed per minute (g/litre)	Moles/litre	% absorbed
364.80	0.36480	0.008289025	18.52
515.30	0.51530	0.011708702	26.16
527.30	0.52730	0.011981367	26.77
409.32	0.40932	0.009300613	20.78
289.77	0.28977	0.006584185	14.71

This is the end of the calculation and the efficiency at optimum conditions can easily be seen and reported to potential customers along with the other technical information.