Separation Processes 1: Continuous Assessment

Laboratory: Gas Absorber

2014

In this lab you will start-up, operate and shut-down a gas absorber in order to rate the process equipment (determine its effectiveness). The absorber you will operate is the CE 400 Gas Absorption column produced by Gunt-Hamburg. The manual for this equipment is also available on the MyAberdeen site for the course.

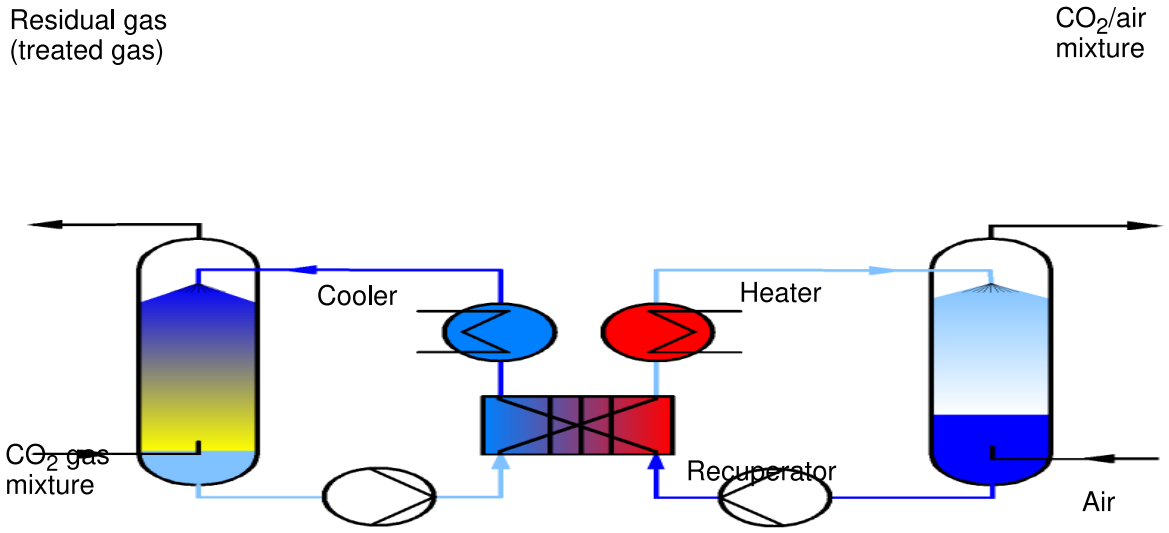

Figure 1: A simplified diagram of the gas absorber.

Your objectives for this lab session and report are to:

- To become familiar with columns (in particular absorption columns) and their associated ancillary equipment (storage, pumps, condensers, etc.).
- To gain a better understanding of the difficulties of controlling an absorber column.
- Perform a mass balance over the column to determine its operating capacity.
- To generate experimental data from the steady state operation of the column and to estimate the Height of packing Equivalent to a Theoretical Plate (HETP).
- To investigate the efficacy of the heater within the absorption column.

If there are any unusual circumstances or difficulties during your experiments these should be noted in your lab book and discussed in your report.

1 Requirements

To participate in this experiment, you will need

- To have read the student safety handbook in advance.
- A printed copy of this document, and to have read these instructions in advance.
- Your lab coat and safety glasses.
- Your lab book and a pen.

2 Regulations

If you have missed any of the above requirements, you will not be allowed to enter the laboratory so please ensure you are prepared. While in the lab, please act in a calm and safe manner and respond promptly to the instructions of the lab coordinators and demonstrators. If you miss your allocated laboratory session without good cause, you will receive a CAS 0 for the assignment and will be issued a C6 for the course. These laboratory sessions can take the full 3 hours to complete so you must arrive on time for the start of the laboratory session.

3 Experimental Procedure

1. Before entering the lab, you must have read the student safety handbook and be wearing your lab coat and safety glasses.
2. Power up the control console and turn on the cooler. The temperature should reach around reach around 10–11°C before column start-up is continued.
3. Open the main valve on the CO_2 gas cylinder and set the regulated pressure to 0.8 bar.
4. Switch on the water supply to the column and check for any leaks.
5. Check the level of water in the absorber column (K1). If the water level is above the capped gas outlet the gas system must be purged of water before sampling of the inlet gas can be carried out. Use the valve in front of W2/W3 to purge the system.
6. Enable pump P2, which removes loaded absorbent from the bottom of K1. Automatic level control will prevent the pump running dry.
7. Enable pump P1, and set the flow of absorbent to 200 ltr/hr. Confirm that the level control is keeping the level of water at base of the column to around 5–10 cm.
8. Fully open the valve V10.
9. Turn on the compressor and set the air flow rate to 20 ltr/min (1.2 m^3/hr).
10. We need to establish a partial vacuum in the regeneration column (K2) to enhance the desorption process. To do this, close the valve V19, open the control valve V20 fully. Once the pressure in K2 drops to 0.5 bar, slightly open the control valve V21 and let “stripping” air into the regeneration column from below. The regeneration column should operate at 0.5 bar.
11. Set the CO_2 gas volumetric flow rate to 5 ltr/min with the control valve V1.

12. Partially close the valve V10 to slightly pressurise the absorption column K1. The inlet gas pressure should read somewhere around 0.05 bar relative. This will facilitate sampling of the gas.
13. Recheck all gas flows/pressures and adjust valves where needed. These will have been altered by the pressurisation of K1 and the partial vacuum of K2.
14. Allow the column to come into equilibrium before periodically sampling the gas at the bottom, middle and top of the column.
15. Periodically check the concentration of CO_2 in the atmosphere of the laboratory using the gas meter supplied. This should never be allowed to exceed 0.5%.
16. Investigate the effect of using the built-in heater on the efficiency of the system.

4 Sampling Procedure

1. Select the location of the column to sample by opening S1/S2/S3.
2. Allow the sample lines to purge with fresh gas from the column (10–15 s).
3. Ensure no water is present in the sample gas, as this will damage the gas analysis unit. Empty the water trap if needed.
4. Attach the gas analysis unit to the column and take a reading.
5. Remove the unit and close the sample valves (S1/S2/S3).
6. Ensure you record the inlet temperatures of the gas and absorbent streams in your log book.

5 Shutdown Procedure

1. Stop the flow of CO_2 to the column.
2. Turn off the cooler circuit.
3. Stop the flow of absorbing water to K1, and turn off P1.
4. Open V19 to re-pressurise K2, then close V20.
5. Ensure the absorbing column K1 is drained of liquid.
6. Stop the flow of air to K1 and switch off the compressor.
7. Turn off pump P2.

6 Report Requirements

Your report should include the following topics:

- Describe the purpose of the W2/W3 heat exchanger unit using the temperature dependence of the coefficient in Henry's law.

- Perform a mass balance over the absorption column (K1) and determine the composition of all streams. How much CO_2 is this unit absorbing per hour? What information is missing?
- Calculate a worst-case estimate for the number of theoretical stages in the column (the lowest number of stages your calculations will allow). Discuss how you might generate a more accurate estimate.
- Determine the worst-case estimate for the HETP of the column. What difficulties are there with this estimate?

7 Equipment Notes

- The level set control for the liquid level at the bottom of K1 is set **inside** the control panel. It shouldn't need adjusting but it is available for changing.
- It is crucial that the absorption column operates at a slightly higher than atmospheric pressure, so that gas samples can be taken. You should avoid operating at high pressure (> 0.05 barg) as the opening of the sample ports will greatly affect the operating pressure of the column, thus affecting the readings you collect.
- A group of students filled a sink with water, placed the vacuum pump outlet tube in, and used an inverted beaker to measure the removed air flowrate as 27×10^{-6} m^3 s^{-1}. This is the removed CO_2 AND the stripping air under normal conditions.

A1	Cooling unit
A2	Heater before desorber inlet
K1	Absorption column (Absorber)
K2	Regeneration column (Desorber)
P1	Circulation pump for delivery to the absorption column
P2	Circulation pump for delivery to the regeneration column
P3	Circulation pump in cooling circuit
P4	Vacuum water jet pump
V	Compressor for air
W2/ W3	Heat exchanger
W4	Heat exchanger (recuperator)
V1	CO_2 control valve
V2	Air control valve
V3	Non-return valve
V4	Ball valve for gas sampling at base of column
V5	Ball valve for gas sampling at centre of column
V6	Ball valve for gas sampling at head of column
V7	Ball valve
V8	Ball valve for releasing the pressure measuring point in the centre of the column
V9	Ball valve for releasing the pressure measuring point at the head of the column
V10	Control valve for adjusting the column pressure
V11	Safety valve on absorption column
V12	Control valve for adjusting the water flow rate
V13	Ball valve for liquid sampling from absorption column
V14	Ball valve for draining the water cooling circuit
V15	Ball valve for sampling regenerated absorbent
V16	Solenoid control valve for regulating the level in the absorption column K1
V17	Control valve for absorbent before regeneration column K2
V18	Non-return valve
V19	Ball valve for equalising the vacuum in column K2 after the experiment
V20	Control valve for adjusting the water quantity for the vacuum water jet pump
V21	Control valve for adjusting the quantity of stripping air
V22	Solenoid valve for filling the columns (K1 & K2) with water
V23	Ball valve for manually blocking the water supply connection
V24	Ball valve for draining the regeneration column
V25	Ball valve for releasing the pressure measuring point at the base of the column

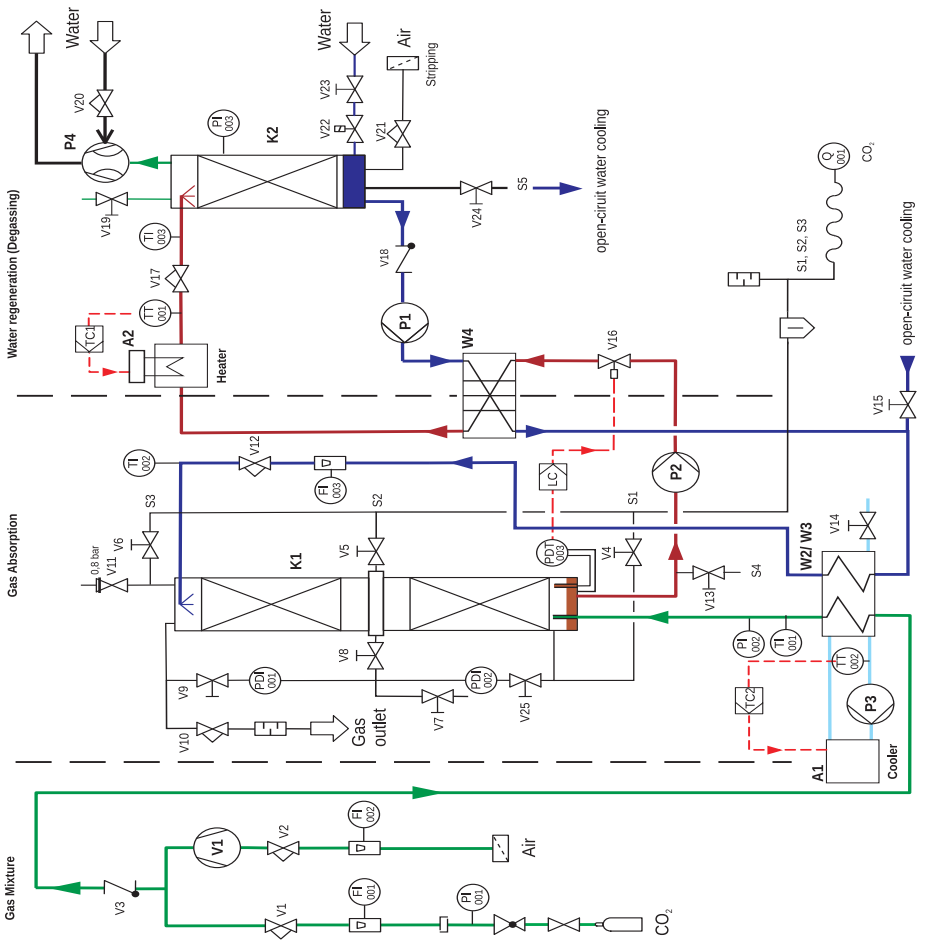

Figure 2: The process flowsheet for the CE400 unit.