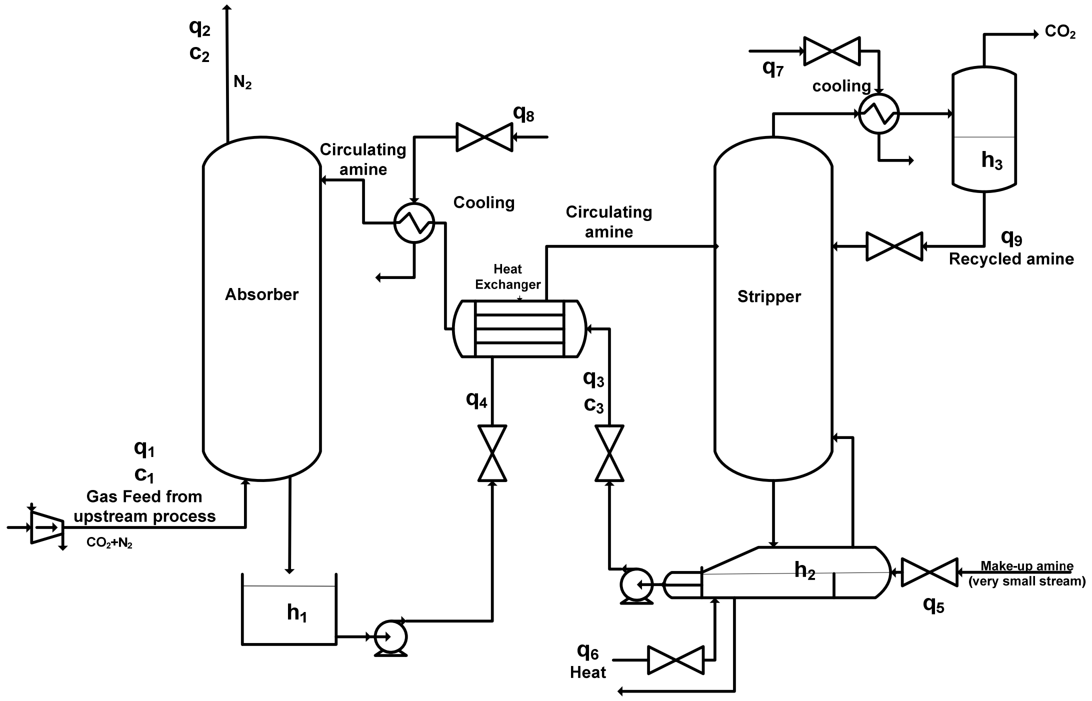


Figur 1. Anlegg for CO_2-fangst

Figur 1 viser flytskjema for en absorbsjons-stripper prosess for fjerning av CO_2 fra forbrenningsgass. I den "kalde" absorbsjonskolonna (venstre) absorberes CO_2 (som har fødekonsentrasjon c_1) i aminløsningen for så å frigjøres i den "varme" stripperkolonna (høyre). Kokeren i strippekolonna varmes opp med damp (q_6) og kolonna kjøles med kjølevann (q_7). Den sirkulerende aminløsningen q_3 kjøles til $40°C$ med kjølevann (q_8) før den fødes til toppen av absorberen. Trykket i toppen av stripperen skal være 1 bar. Konsentrasjonen (c_2) av CO_2 i gassen som går til atmosfæren skal være under 0.5%. For god drift av systemet skal konsentrasjonen (c_3) av CO_2 i aminløsningen (bunnstrømmen fra stripperen) være på en gitt verdi. Tap av amin erstattes med strømmen q_5.

(a) Bestem de 7 uavhengige variablene som kan manipuleres(pådrag, $MV'er$, u'er),

(b) Bestem de viktigste forstyrrelsene ($DV'er$,d'er)

(c) Bestem 7 uavhengige regulerte ("controlled") variable ($CV'er$, y'er) som vi kan regulere med de 7 $MV'ene$.

(d) Foreslå en reguleringsstruktur med 7 tilbakekoblingssløyfer og tegn dem på flytskjemaet. (Tips: Du skal ha med LC, TC, XC (der X står for sammensetning) og PC.)

(e) Forklar hva kaskaderegulering er og gi et eksempel på hvordan det kan anvendes på CO2-anlegget.

(f) Forklar hva foroverkobling er og gi et eksempel på hvordan det kan anvendes på CO2-anlegget.

ENGLISH TEXT

Figure 1. CO_2 Capture unit

The flowsheet of an absorber-stripper process for removing CO_2 from flue gas is shown in Figure 1. In the "cold" absorber (left), CO_2 (which has feed concentration c_1) is absorbed into the amine solution and it is released in the "hot" stripper column (right). The stripper column reboiler is heated with steam (q_6) and and the column is cooled with cooling water (q_7). The circulating amine q_3 is cooled to $40°C$ by cooling water (q_8) before entering the top of absorber. The pressure at the top of the stripper should be 1 bar. The concentration (c_2) of CO_2 that is released to the air should be less than 0.5%. For good operation the concentration (c_3) of CO_2 in the circulating amine (bottom stream from stripper column) should be at a given value. Loss of amine is compensated by the stream q_5.

(a) Identify the 7 independent variables that can be manipulated for control (MVs, u's),

(b) Identify the most important disturbances (DVs, $d's$)

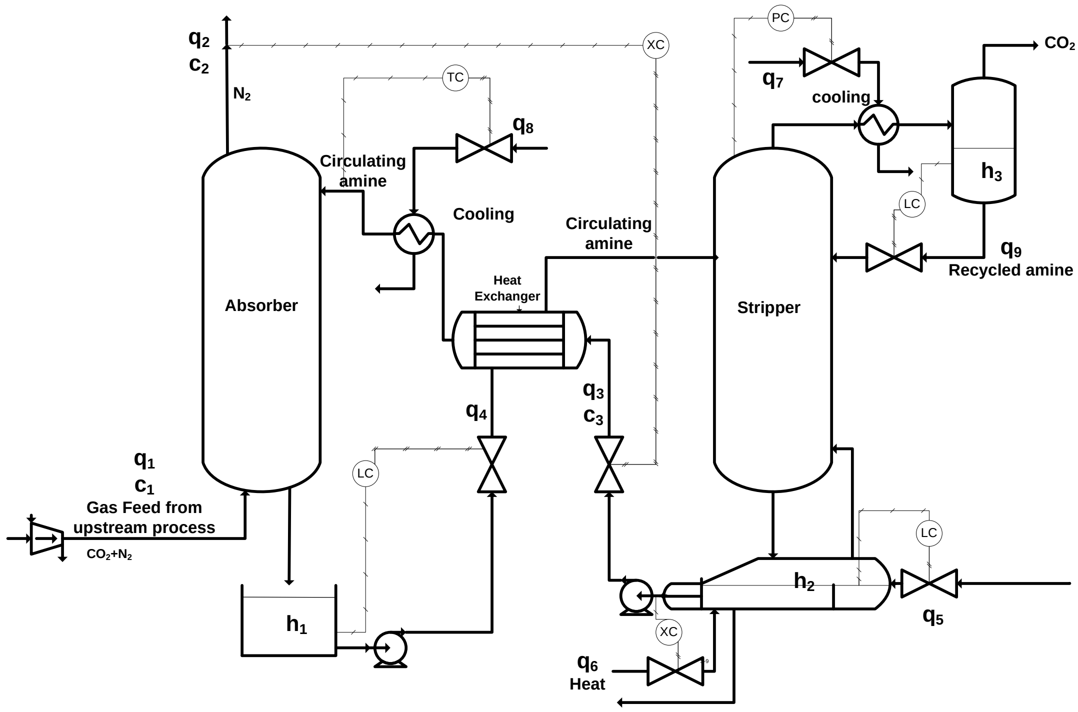
(c) Identify 7 controlled variables (CVs, y's) that we can control using the 7 MVs.

(d) Suggest a control structure involving 7 feedback loops and draw them on the flow sheet. (Hint: They should involve LC, TC, XC (where X denotes composition) and PC.)

(e) Explain what cascade control is and give an example of how it could be applied to the CO2 capture unit.

(f) Explain what feedforward control is and give an example of how it could be applied to the CO2 capture unit.

Solution:



(a) Independent variables (MVs):

$$q_3, q_4, q_5, q_6, q_7, q_8, q_9$$

(b) Main disturbances:

q_1 (Flow of gas feed), c_1 (concentration of CO_2 in feed)

Comment: q_2 is not an independent variable. It is given by what happens in the absorber (depends on the amount of q_1, i.e. q_1 □ q_2, approximately)

(c) 7 controlled variables

Temperature of absorber (□ $40°C$)
c_2 □ 0.5%
h_1, h_2, h_3 } Levels need to be controlled
Pressure of stripper (□ $1bar$)
c_3 (at given value)

(d) Control structure. “Obvious pairings”:

$$q_8 \Leftrightarrow T_{top}$$

$$q_4 \Leftrightarrow h_1$$
$$q_9 \Leftrightarrow h_3$$
$$q_5 \Leftrightarrow h_2$$
$$q_7 \Leftrightarrow P_{Stripper}$$

We then have left two compositions that need to be controlled (c_2, c_3) and two flows (q_3 and q_6). Since c_3 is determined by what happens in the column it is reasonable to use the heat input (q_6) to control c_3. The resulting pairing is then (see Figure)

$$q_3 \Leftrightarrow c_2$$
$$q_6 \Leftrightarrow c_3$$

(f) Cascade control is when the MV for one controller ("master/outer" controller) is the setpoint to another controller ("slave/inner" controller).

Example: Since c_3 can be difficult/slow to measure, we can control temperature somewhere in the stripper in an inner loop (TC) using q_6, and then adjust the temperature setpoint by the outer controller (XC) that controls c_3.

Others could be flow controllers on the valves etc.

(f) Feedforward control is when the measurement for the controller is an independent variable (disturbance d) rather than a dependent variable (output y).

Example: Measure the feed flow (q_1) and adjust the circulating amine (q_3) so the ratio q_3/q_1 is constant. The setpoint $(q_3/q_1)_s$ to the ratio controller should then be set by the controller (XC) that controls c_2. (This is actually a feedforward/ratio controller combined with a cascade)