

# [Heat and mass transfer calculation for carbon capture pilot plant](https://assignbuster.com/heat-and-mass-transfer-calculation-for-carbon-capture-pilot-plant/)

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Heat transfer aspects Experiment Temperature reduction for the Hot Fluid ∆t Hot = T1 – T2 = 57. 5 – 53. 2 = 4. 3K   
Temperature increase for the Cold Fluid ∆t Cold= T4 – T3   
= 25. 4 – 13. 2   
= 12. 2K   
Table below shows the summary of the observations and calculations   
Obs. No.   
Vhot(g/s)   
Vcold(g/s)   
T1°C   
T2°C   
T3°C   
T4°C   
∆t Hot (T1-T2) K   
∆t Cold (T4-T3) K   
1   
50   
15   
57. 5   
53. 2   
13. 2   
25. 4   
4. 3   
12. 2   
2   
50   
20   
57. 2   
52. 7   
13. 3   
23. 3   
4. 5   
10   
3   
50   
27   
56. 9   
52. 4   
13. 1   
20. 8   
4. 5   
7. 7   
4   
50   
31   
56. 7   
51. 4   
13. 3   
21. 5   
5. 3   
8. 2   
Experiment 2   
Mean Temperature = (T1 + T2)/2   
= (57. 5 + 53. 2)/2   
= 55. 350C   
Cp of Water at Temperature T equals   
6x10-9 T4 – 1x10-6 T3 + 7. 0487x10-5T2 – 2. 4403x10-3 T +4. 2113   
Cp at 55. 350C= 4. 1789J/g   
The power emission rate from the hot water stream Qhot is   
= Vhot x Cphot(T1 – T2) J/s (Incropera and DeWitt 236)   
= 50 x 4. 1789 (57. 5 – 53. 2)   
= 898. 5J/s   
Cold water   
Mean Temperature = (T3 + T4)/2   
= (13. 2+ 25. 4)/2   
= 19. 30C   
At 19. 30C the specific heat of water calculated using the above equation is   
Cp at 19. 30C= 4. 1841J/g   
The power absorption rate from the cold water stream Qcold is   
= Vcold x Cpcold(T4 – T3) J/s   
= 15 x 4. 1841 (25. 4 – 13. 2)   
= 765. 7J/s   
Therefore the overall exchange efficiency ƞ   
= 85. 2%   
The calculations for all observations are presented in Table-2 (a) and (b)   
Ob. No.   
Vhot (g/s)   
Vcold (g/s)   
∆t Hot (T1-T2) K   
∆t Cold (T4-T3) K   
Average Temp Hot Stream   
Average Temp Cold Stream   
Cp of the hot stream   
Cp of the cold stream   
1   
50   
15   
4. 3   
12. 2   
55. 35   
19. 3   
4. 1789   
4. 1841   
2   
50   
20   
4. 5   
10   
54. 95   
18. 3   
4. 1788   
4. 1848   
3   
50   
27   
4. 5   
7. 7   
54. 65   
16. 95   
4. 1788   
4. 1858   
4   
50   
31   
5. 3   
8. 2   
54. 05   
17. 4   
4. 1786   
4. 1855   
Calculation of Cp for both streams using the prescribed formula   
Obs. No.   
Heat loss rate for hot stream   
Heat gain rate for cold stream   
Thermal Efficiency   
1   
898. 5   
765. 7   
85. 2%   
2   
940. 2   
837. 0   
89. 0%   
3   
940. 2   
870. 2   
92. 6%   
4   
1107. 3   
1063. 9   
96. 1%   
Calculation of Thermal Efficiencies   
We observe two important things from our findings. The first is that holding the mass flow rate and temperature of the hot stream steady and increasing the flow of the cold stream led to a steady improvement of the thermal efficiency of the apparatus. This supports the theory that increased flow creates more turbulence and improvement in the heat transfer coefficient. The second observation is that the improvement of efficiency might also have resulted in a gradual reduction of heat losses from the system as the experiments were performed one after the other and despite the fact that sufficient time was allowed for the system to become stable.   
Experiment 3   
A sample of the calculations is as follows:   
Temperature reduction for the Hot Fluid ∆t Hot= T1 – T2   
= 56. 4 – 48. 3   
= 8. 1K   
Temperature increase for the Cold Fluid ∆t Cold= T4 – T3   
= 42. 9 – 21. 3   
= 21. 6K   
the summary of the observations and calculations   
Obs. No.   
Vhot(g/s)   
Vcold(g/s)   
T1°C   
T2°C   
T3°C   
T4°C   
∆t Hot (T1-T2) (K)   
∆t Cold (T4-T3) (K)   
1   
40   
14   
56. 4   
48. 3   
21. 3   
42. 9   
8. 1   
21. 6   
2   
34   
20   
55. 5   
43. 4   
21. 3   
40. 7   
12. 1   
19. 4   
3   
28   
26   
56. 4   
40. 4   
21. 1   
37. 4   
16. 0   
16. 3   
4   
22   
32   
56. 8   
35. 8   
21. 2   
34. 9   
21. 0   
13. 7   
The calculations show that with increase in the flow rate of both streams the temperature drop of the hot stream increased steadily. On the other hand, the temperature rise of the cold stream decreased substantially. The clear jacket allowed the observation that the jacket was continuously full at all times and because neither stream had any color, it was not possible to notice whether the turbulence of the two streams changed at all. In future experiments it might be a good idea to introduce a small stream of dye into both streams to observe turbulence. However, this would lead to a change in the mass flow rate and more importantly in the specific heat capacity, which would have to be accounted for in subsequent calculations.   
Experiment 4   
Mean Temperature = (T1 + T2)/2   
= (56. 4 + 48. 3)/2   
= 52. 350C   
Cp of Water at Temperature T equals   
6x10-9 T4 – 1x10-6 T3 + 7. 0487x10-5T2 – 2. 4403x10-3 T +4. 2113   
Cp at 52. 350C= 4. 1783J/g   
The power emission rate from the hot water stream Qhot is   
= Vhot x Cphot(T1 – T2) J/s   
= 40 x 4. 1783 (56. 4 – 48. 3)   
= 1353. 8J/s   
Cold Stream   
Mean Temperature = (T3 + T4)/2   
= (21. 3+ 42. 9)/2   
= 21. 60C   
At 21. 60C the specific heat of water calculated using the above equation is   
Cp at 21. 60C= 4. 1783J/g   
The power absorption rate from the cold water stream Qcold is   
= Vcold x Cpcold(T4 – T3) J/s   
= 14 x 4. 1783 (42. 9 – 21. 3)   
= 1263. 7J/s   
Therefore the overall thermal efficiency ƞ   
= 93. 3%   
The calculations for all observations are presented in Table-4 (a) and (b)   
Obs. No.   
Vhot (g/s)   
Vcold (g/s)   
∆t Hot (T1-T2) (K)   
∆t Cold (T4-T3) (K)   
Average Temp Hot Stream   
Average Temp Cold Stream   
Cp of the hot stream   
Cp of the cold stream   
1   
40   
14   
8. 1   
21. 6   
52. 35   
32. 1   
4. 1783   
4. 1789   
2   
34   
20   
12. 1   
19. 4   
49. 45   
31   
4. 1779   
4. 1791   
3   
28   
26   
16. 0   
16. 3   
48. 4   
29. 25   
4. 1779   
4. 1796   
4   
22   
32   
21. 0   
13. 7   
46. 3   
28. 05   
4. 1777   
4. 1800   
Calculation of Cp for both streams using the prescribed formula   
Obs. No.   
Heat loss rate for hot stream   
Heat gain rate for cold stream   
Thermal Efficiency   
1   
1353. 8   
1263. 7   
93. 3%   
2   
1718. 8   
1621. 5   
94. 3%   
3   
1871. 7   
1771. 3   
94. 6%   
4   
1930. 1   
1832. 5   
94. 9%   
Important findings of this experiment are that the thermal efficiency of the plate and frame heat exchanger is better than that of the concentric tube heat exchanger and secondly, with the increase in flow rate the efficiency improved only marginally. This is perhaps because with the multiple pass arrangement where the two streams changed direction frequently an element of turbulence was already present that did not change much with the change in flow rates. However, the observations taken are too few to arrive at this conclusion with confidence.   
Experiment 5   
Mean Temperature = (T1 + T2)/2   
= (57. 9 + 53. 6)/2   
= 55. 750C   
Cp of Water at Temperature T equals   
6x10-9 T4 – 1x10-6 T3 + 7. 0487x10-5T2 – 2. 4403x10-3 T +4. 2113   
Cp at 55. 750C= 4. 1790J/g   
The power emission rate from the hot water stream Qhot is   
= Vhot x Cphot(T1 – T2) J/s   
= 50 x 4. 1790 (57. 9 – 53. 6)   
= 898. 5J/s   
Cold Stream   
Mean Temperature = (T3 + T4)/2   
= (14. 2+ 25. 5)/2   
= 19. 850C   
At 19. 850C the specific heat of water calculated using the above equation is   
Cp at 19. 850C= 4. 1837J/g   
The power absorption rate from the cold water stream Qcold is   
= Vcold x Cpcold(T4 – T3) J/s   
= 16 x 4. 1837 (25. 5 – 14. 2)   
= 756. 4J/s   
Therefore the overall thermal efficiency ƞ   
(Dincer and Konoglu 136)   
= 84. 2%   
The calculations for all observations are presented in Tables below   
Calculation of Cp   
Obs. No.   
Vhot (g/s)   
Vcold (g/s)   
∆t Hot (T1-T2) (K)   
∆t Cold (T4-T3) (K)   
Average Temp Hot Stream   
Average Temp Cold Stream   
Cp of the hot stream   
Cp of the cold stream   
1   
50   
16   
4. 3   
11. 3   
55. 75   
19. 85   
4. 1790   
4. 1837   
2   
50   
20   
4. 6   
10. 1   
55. 5   
19. 15   
4. 1790   
4. 1842   
3   
50   
26   
4. 9   
8. 3   
55. 35   
18. 05   
4. 1789   
4. 1850   
4   
50   
34   
5. 2   
6. 8   
55   
16. 90   
4. 1788   
4. 1859   
Calculation of exchange Efficiencies   
Obs. No.   
Heat loss rate for hot stream   
Heat gain rate for cold stream   
Thermal Efficiency   
1   
898. 5   
756. 4   
84. 2%   
2   
961. 2   
845. 2   
87. 9%   
3   
1023. 8   
903. 1   
88. 2%   
4   
1086. 5   
967. 8   
89. 1%   
Calculation of exchange Efficiencies   
Important findings of this experiment are that the thermal efficiency of the plate and frame heat exchanger is comparable to that of the concentric tube heat exchanger but lower than that of the plate and frame heat exchanger. Secondly, with the increase in flow rate of the cold stream the efficiency improved marginally. In this case again, the conclusion can be that the design allows for introducing greater turbulence in the shell-side stream through the baffles provided.   
Mass transfer aspects   
Mass transfer is calculated as shown below;   
Mass transfer = Overall mass transfer coefficient x Actual driving force mol/m3   
Overall mass transfer coefficient= (Kreith, Manglik and Bohn 175)   
KG Mass transfer coefficient in the gas phase m/s   
KL Mass transfer coefficient in the liquid phase m/s   
Kov Overall mass transfer coefficient m/s   
m Solubility of carbon dioxide at equilibrium   
E = = 1. 011   
Ha = = 0. 382   
Ha -Hatta modules   
D CO2 , am - CO2 diffusivity in the MEA solution m2/s   
k2 Forward second order reaction rate constant m3/mol. s   
CMEA - MEA concentration mol/m3   
E Enhancement factor   
E = = 57. 25   
  
Overall mass transfer coefficient= = 0. 716   
Mass transfer = 0. 716 x 0. 278 = 0. 1991   
Works Cited   
Incropera, Frank and David, DeWitt. Fundamentals of Heat and Mass Transfer. New York: John Wiley & Sons, 2002. Print   
Dincer, Ibrahim & Mehmet Konoglu. Refrigeration system and application. Chichester : John Wiley & sons ltd, 2011. Print   
Kreith, Frank, Raj, Manglik & Mark, Bohn. Principles of heat transfer. Stanford: Cengage Learning, Stanford UK, 2011. Print