STUDY ON CO_2 CAPTURING PROTOTYPE

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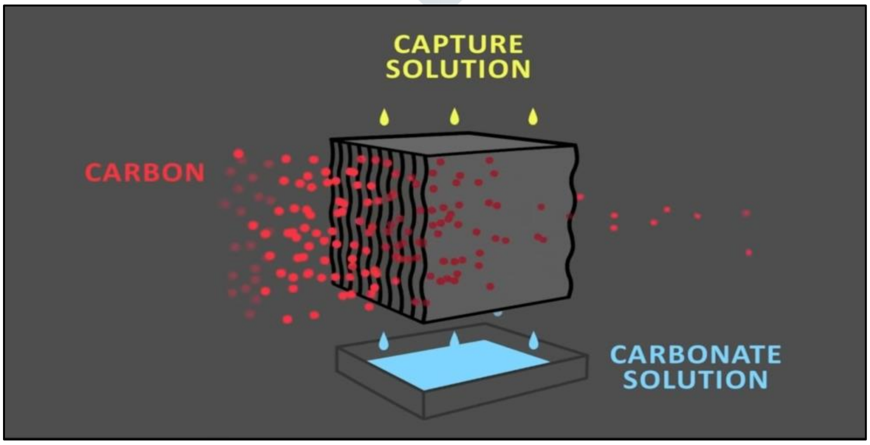
Abstract: Building a prototype air contactor and absorbing carbon dioxide from ambient air for 5-6 days outdoor operation to test our packing-based contactor design in an operational environment. Our operation with pulsed liquid flow allows us to fully wet the surface of our structured packing with a brief period of full flow, then to cut flow for duration of several minutes to let the liquid slowly react away as CO_2 is absorbed. The prototype contactor is manufactured from PVC or stainless steel depending on the cost per-surface-area, solvent used and pressure drop on per-surface-area basis. This prototype focuses on wet-scrubbing air contactor design that is rooted in the gas scrubbing and cooling tower industries and to regenerate our captured purified pipeline-quality CO_2. Extraction and usage of pure CO_2 from guanidine complex or Na_2CO_3 by slight heating or titration can be done.

1. Introduction

It is well known that CO_2 plays a dominant role in the green house gas family. Global climate changes leads to high interest in the technologies relevant to the CO_2 capturing that is one of the potential methods to reduce greenhouse gas emissions. Emissions of greenhouse gasses will increase the average global temperature by 1.1 to 6.4 °C by the end of the 21st century, as per investigated by Intergovernmental Panel on Climate Change (IPCC). A global warming of more than 2°C increase in global average temperature will lead to serious consequences, and IPCC have therefore stated that global green house gases emissions should be reduced by 50 to 80 percent by 2050 to avoid these consequences. About 80% of the world's energy supply is derived from fossil fuels. Around 6 billion metric tons of coal is used yearly, producing 18 billion tons of carbon dioxide (CO_2) which is around 40% of total carbon emissions. It has been scientifically proven that CO_2 emissions from these fuels have caused a change in the climate and leading to devastating effects on the lives of the future generation. The world depends a great deal on fossil fuels as a source of energy thus it is important that the capture and storage of CO_2 from power plants takes place. The capture and storage of carbon has the potential to reduce CO_2 emissions to the atmosphere and meet future targets, as it is applicable to the power and industrial sectors. Carbon capture and storage (CCS) is the process of capturing waste carbon dioxide (CO_2) usually from large point sources, transporting it to a storage site, and depositing it where it will not enter the atmosphere increasing greenhouse effect. The main aim is to prevent the release of large quantities of CO_2 into the atmosphere from heavy industry. It is a potential means of reducing the contribution to global warming and ocean acidification of carbon dioxide emissions from industry.

Experimental-Setup:

The setup consists of basically 3 chambers where the absorption and the collection will be carried out.



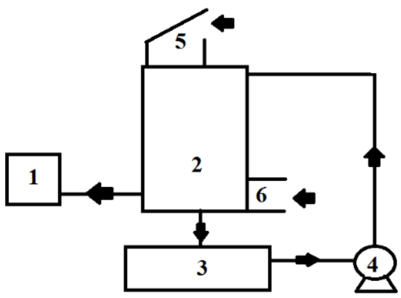
BASIC PROTOTYPE MECHANISM

1. The topmost chamber will be the dripping chamber where a strong hydroxide solution is fed for absorption. A particular flow rate and concentration for the dripping will be fixed.
2. The middle chamber will be our main reaction/absorption chamber where the CO_2 and hydroxide solution will come in contact through the packings provided.
3. The lowermost that is the third chamber will be final solution collection chamber which will contain the processed solution in the cross flow process of absorption.

2. External Design :

Main components design

A. Packing
B. Axial Fan
C. Centrifugal Pump
D. Body Support



1. Axial Fan/ Exhaust Fan.
2. Contactor with packing.
3. Liquid storage tank/ sump.
4. Centrifugal Pump.
5. Ambient Air Inlet (above packing) (80% approx.)
6. Ambient Air Inlet (below packing) (20% approx.)

1. Packing:

Packing height (cm) = 45cm
Packing length (cm) and breadth (cm) = 37*37
Packing Materials: Ivory corrugated fibre and honeycomb packing
Packing material is used to spread the thin film of solution over large area as a major factor in uptake rate is the area available for the mass transfer.

2. Axial Fan:

Axial fan is used for maintaining pressure difference. It works on 15 Watts power.
The air delivering capacity of axial flow fans ranges from 10000 to 500000 cubic feet per minute (3 to 14000 cubic meters per minute).Depending upon the resistance factors.

3. Centrifugal Pump:

A non self priming centrifugal pump with flow rate of 150lph is been used.

Flow rate of liquid:-150lph
Type of pump:-Centrifugal
Energy Requirement:-10 Watts
Specification:-Non Self Priming

4. Body Support:

Material of construction of the body frame is aluminium.
Non corrosive.
Non reactive.
Total body dimensions
Length:-37cm
Breadth:-37cm
Total Height:-100cm
Side Covering:-Ivory transparent sheets.
Dimensions:-4x(37*100)

5. Final Design Parameters:-

Air velocity	10000 to 500000 cubic feet per minute
Packing specific surface	37*37*45
Packing air travel depth	45cm
Pump flow	150 lph
liquid flow	0.04 L/m^2s
Fan energy	15 Watt

3. Solvent Selection:

Development of more efficient solvents is crucial in reducing the cost of carbon dioxide absorption from combustion exhaust gases. Several solvents have been proposed for carbon dioxide absorption, but the question is how the best candidate could be selected through an efficient and economical short-cut evaluation method. Different factors affect the efficacy of a solvent for carbon dioxide absorption, these include solvent solubility, its vapour pressure, molecular weight and foaming tendency, degradation and corrosion properties; others are reaction kinetics, heat of reaction and regeneration energy requirement as well as the cyclic capacity. Environmental and cost factors are also to be considered; it is obvious that selection of the best solvent is not easy. However, the main concern arises when thinking of the overall process: solvent production, solvent use and regeneration, and environmental effects related to its use/emissions.
There are many solvents to capture $CO_2$from air includes

1. Monoethanolamine (MEA)
2. Sodium hydroxide (NaOH)
3. Guanidine

Sodium hydroxide is considered as best choice for CO_2 capture on comparing with MEA and other solvents.

4. Method Description :

1. The process packing was chosen to allow uniform liquid flow conditions to develop as the solution passed down through the packing. This was important, as proper flow conditions ensure that the surface wetting in the packed volume represents what would be achieved in a larger-scale system. At least 20 cm of height was required to achieve uniform liquid distribution, then the rest of the height served to mimic the realistic wetting conditions of a full scale contactor. Packing wetting phenomena is a key driver of overall contactor performance, and was hence one of the key aspects of study with the prototype.
2. It starts with dripping of solvent from top of the packing chamber which carries out the cross flow dripping process till the SS or PVC is perfectly wetted with solvent.
3. Directly above the structured packing volume is a perforated sheet used to distribute the hydroxide solution over the packing.
4. Once the solvent wets the packing, the process starts with passing of exhaust gas having high concentration of CO_2 from one side of the SS/PVC chamber. The counter current absorption takes place
5. After the counter current absorption process, absorbed CO_2 solution drips down to the solution storage chamber due to gravity
6. Our main aim is to test CO_2 concentration in solution obtained in the counter current process of absorption. This can be done by acid base titration with HCl as the product to be obtained will be $NaHCO_3$.

5. Experimental Analysis

Aim: To determine carbon dioxide contents of the experimental samples.
Apparatus: Burette, pipette, weighing machine.
Reagents: Phenolphthalein indicator, 0.05N NaOH.
Procedure:

1. Take 100ml of sample in titration flask and add 4ml phenolphthalein indicator.
2. If sample turns pink then it indicates absence of CO_2 in water.
3. If sample remains colourless then titrate it against 0.05N NaOH.
4. Appereance of pink colour is the end point.

6. Experimental Results:

Experiment No.	CO_2 absorbed after 1 hour (mg/lit.)	CO_2 absorbed after 2 hour (mg/lit.)	CO_2 absorbed after 3 hour (mg/lit.)
1	264	352	484
2	220	308	352
3	264	352	396
4	220	264	352
5	704	792	880
6	704	794	836
7	836	924	968

7. Result:

- After 1-2-3 hour of co-current contacting of air and NaOH satisfactory amount of CO_2 was absorbed in the sample.
- Increasing efficiency of the contactor by reducing the losses may give desirable amount of carbon dioxide capture.
- Amount of CO_2 Captured increases with increase in the time interval of the contacting.
- Thus CO_2 Capture prototype is successfully capturing sufficient amount of CO_2 from ambient air.

8. Conclusion

The efficient working of our self-designed prototype in absorbing CO_2 from exhaust air obtains pure CO_2 in liquefied form for efficient storage and use. We have presented the design characteristics, and several examples of operational methods, measurements, and results from our Outdoor contactor prototype.

9. Future Scope:

- The project indicate that CCS systems will be competitive with other large-scale production and assembly options such as nuclear power and renewable energy technologies.
- These studies show that CCS prototype could reduce the cost of stabilizing CO_2 concentrations by 30% or more if the large scale use of this technology is done.
- The project is very much feasible as compared to the todays scenario of the energy saving technologies .
- Even with the help of other expensive and rare solvent the storage and capturing capacity of the solvent world increase in the large extent.
- The solvent capacity to hold the carbon dioxide is the major aspect of the entire project with consideration of its cost.
- The prototype arrangement in the large scale in the places where the concentration of carbon dioxide will be more can prove out to be very beneficial for carbon capture and storage as the pollution levels in the environment reduces and the stored carbon dioxide can be further used for various processes.
- In 2008, global primary energy supply reached 12 267 million tonnes of oil equivalent (Mtoe) and the related emissions of CO_2 amounted to 29 Gt. Nearly one-third of global energy demand (4 254 Mtoe) and one-quarter of worldwide CO_2emissions (7 $GtCO_2$) are attributable to total industry and fuel transformation. Within the industry and fuel transformation sectors, 31% of emissions are attributed to the production of iron and steel, 27% to cement production, 10% to petroleum refining and 7% to high-purity CO_2 sources.
- Some types have practically 100% carbon-neutrality; others must account for CO_2 arising from cultivation practices or transformation processes. 18% of total global energy-related CO_2 emissions in 2050. Reducing CO_2 emissions from these sectors is therefore an essential part of global action to prevent dangerous climate change.
- To achieve the ambitious goal outlined in the ETP BLUE Map Scenario of cutting CO_2 emissions to 50% of 2005 levels by 2050 , substantial deployment of CCS in industrial applications is necessary.
- Other options for reducing emissions – including improving energy efficiency through the application of best available technologies, fuel substitution, materials recycling and energy recovery – are not sufficient to reach this goal.

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REFERENCES :

1. YADOLLAHTAVAN , SEYYED HOSSEIN HOSSEINI , 2016 , 'A NOVEL RATE OF THE REACTION BETWEEN NAOH WITH CO_2 AT LOW TEMPERATURE IN SPRAY DRYER'.
2. SANG-JUN HAN, JUNG-HO WEE, 2012 , 'CARBON DIOXIDE CAPTURE CAPACITY OF SODIUM HYDROXIDE AQUEOUS SOLUTION'.
3. JOSHUAH K. STOLAROFF, DAVID W. KEITH AND GREGORY V. LOWRY, 2008 (FEB 06), CARBON DIOXIDE CAPTURE FROM ATMOSPHERIC AIR USING SODIUM HYDROXIDE SPRAY.
4. Geoffrey Holmes, Kevin Nolda, Tylor Walsha, Kenton Heidela, Matthew A.Hendersona, Jane Ritchie, Paul Klavins, Arvinder Singha, and David W. Keitha,b, 2013 , 'Outdoor prototype results for direct atmospheric capture of carbon dioxide'.
5. Harshdeep Singh, Prashant Gupta, AkshaySoni, Rohit Joshi, Ram Jatan Yadav, Ashutosh Singh, 'International Research Journal of Engineering and Technology (IRJET)'.
6. Science Direct, Petroleum, www.keaipublishing.com/en/journals/petlm.

7. DTI. Review of the feasibility of carbon dioxide capture and storage in the UK, DTI Report URN 03/1261, September 2003, Department of Trade and Industry, London; 2003.

8. Holloway, S and Baily, HE. The CO2 storage capacity of the United Kingdom. In: Holloway, S. editor. The Underground Disposal of Carbon Dioxide, Final Report of joule 2 Project No. CT92- 0031. British Geological Survey, Nottingham; 1996.

9. Harshdeep Singh, Prashant Gupta, Akshay Soni, Rohit Joshi, Ram Jatan Yadav, Ashutosh Singh, 'International Research Journal of Engineering and Technology (IRJET)'.

10. Geoffrey Holmes, Kevin Nolda, Tylor Walsha, Kenton Heidela, Matthew A. Hendersona, Jane Ritchie, Paul Klavins, Arvinder Singha, and David W. Keitha, 2013, Outdoor prototype results for direct atmospheric capture of carbon dioxide.

11. Charles A. Seipp, Neil J. Williams, Michelle K. Kidder, and Radu Custelcean, 2016, CO2 Capture from Ambient Air via Crystallization with a Guanidine Sorbent.

12. Anusha Kothandaraman , 2010, 'Carbon Dioxide Capture by Chemical Absorption: A Solvent Comparison Study'.

13. Ugochukwu E. Aronua, Hallvard F. Svendsena, Karl Anders Hoffb, Olav Juliussenb , 2009 , 'Solvent selection for carbon dioxide absorption'.

14. Gough C, Shackley S, editors. An Integrated Assessment of Carbon Dioxide Capture and Storage in the UK. Technical Report, Tyndall Project T2/2i, October 2005.

15. Shackley S, Gough C, editors. Carbon capture and its storage - an integrated assessment. Aldershot: Ashgate; 2006 (forthcoming).