DESIGN, DEVELOPMENT AND EXPERIMENTAL INVESTIGATION ON POST-COMBUSTION CO_2 CAPTURE PROTOTYPE PLANT

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By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled **"**DESIGN, DEVELOPMENT AND EXPERIMENTAL INVESTIGATION ON POST-COMBUSTION CO_2 CAPTURE PROTOTYPE PLANT**"** in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **Dr. Ravindra D. Jilte**, **Professor** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Signature of Examiner

Acknowledgement

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Place**: LPU, Phagwara** **Maulik M. Chikhaliya**

Date**:** **(11610246)**

INDEX

LIST OF FIGURES

ABSTRACT

The continuous and unabated emission of CO_2 from various industrial sources is a worrying sign for the future of this planet as it leads to global warming and alarmingly changing the geo-political and meteorological scenario of the world at a faster rate. In this project, CO_2 was removed from (CO_2+air) mixture using aqueous AMINE solution as the solvent in a packed bed absorption column. The column was operated counter currently using raschig ring as the packing material being randomly packed inside the column and study of different parameter like flow rate of solvents, temperature effects, effect of design parameter, effect of different packing materials on capture efficiency is measure.

CHAPTER-1

INTRODUCTION

In this world global warming is a bigger issue, Which is day by day increasing. It is a result of the emission of greenhouse gases like carbon dioxide, methane gases , nitrous oxides etc. are the major sources for global warming. In all these greenhouse gases, Carbon Dioxide contributes more than 60% to global warming on an average in this atmosphere because of its huge emission amount which come outside from industries and from combustion of fossil fuels in vehicles. The concentration of carbon dioxide in the atmosphere is now reach at 400 ppm which is significantly greater than the pre-industrial levels of 300 ppm and now it is produce a harmful effect on this atmosphere.

1.1 RESEARCH BACKGROUND

The constant and unabated outflow of CO_2 from different modern sources is a stressing sign for the fate of this planet as it prompts a dangerous atmospheric devation and alarmingly changing the geo-political and meteorological situation of the world and at a speedier rate. There has been a broad research going ahead crosswise over different labs around the world to alleviate this issue. Ingestion utilizing amine arrangements, ionic fluids; adsorption on permeable basic structures like zeolites, metal natural systems; common stockpiling (or, sequestration) under the good topographical developments (under earth's outside, sea depths);

synthetic change to helpful items are a couple of the many advances that have been taken to address the issue. Despite the fact that, a couple of them have defeated the innovative difficulties and fulfills the monetary practicality and as of now executed crosswise over different ventures yet a considerable lot of the procedures are yet to leave their early stages and still at the early stage (lab organize) of their improvement before being actualized.

1.1 .1 CARBON CAPTURE AND INTEGRATION OF WORK.

Ozone harming substance diminishment and alleviation innovation, especially in connection to CO2 is increasing expanding significance on account of environmental change fears. What's more, finished the last 25-30 years, there has been an ascent in concern due to expanding worldwide temperatures. Figure 1.1 delineates the plot between the expansion in the distinction between the worldwide mean surface temperature and the normal temperature from 1979-2017.

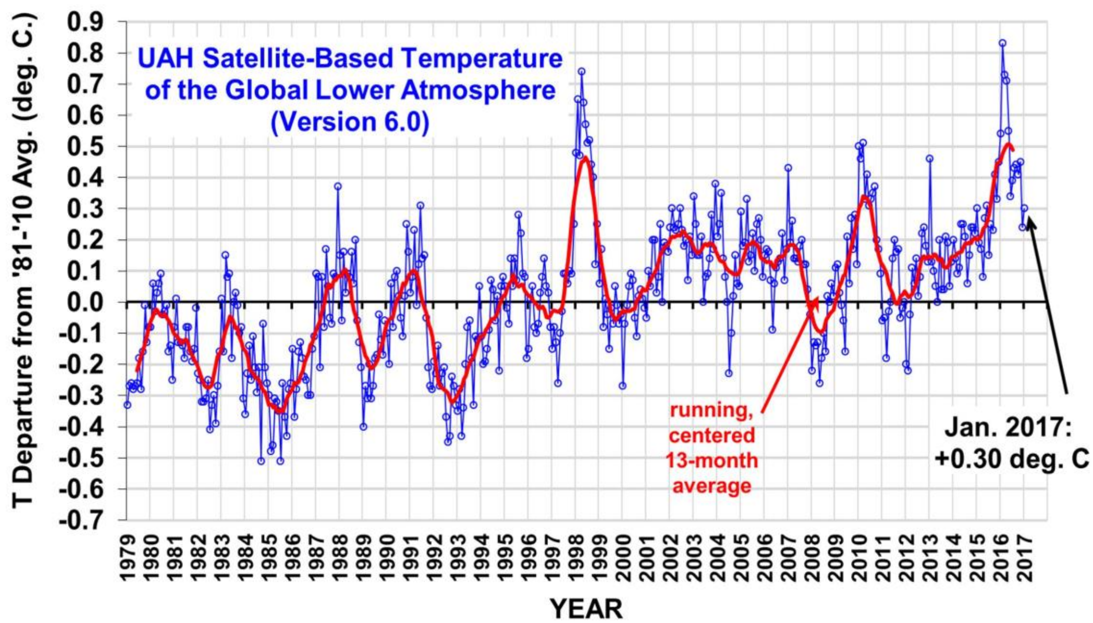

Figure 1.1: Global temperature vs. time (year) (temperature average from 1979-2017)

A large portion of the increments in the worldwide temperatures have been credited to the ascent in CO2 focuses in the environment because of human exercises. Figure 1.2 demonstrates the plot of environmental CO2 focus as measured at Mauna Loa Observatory, Hawaii

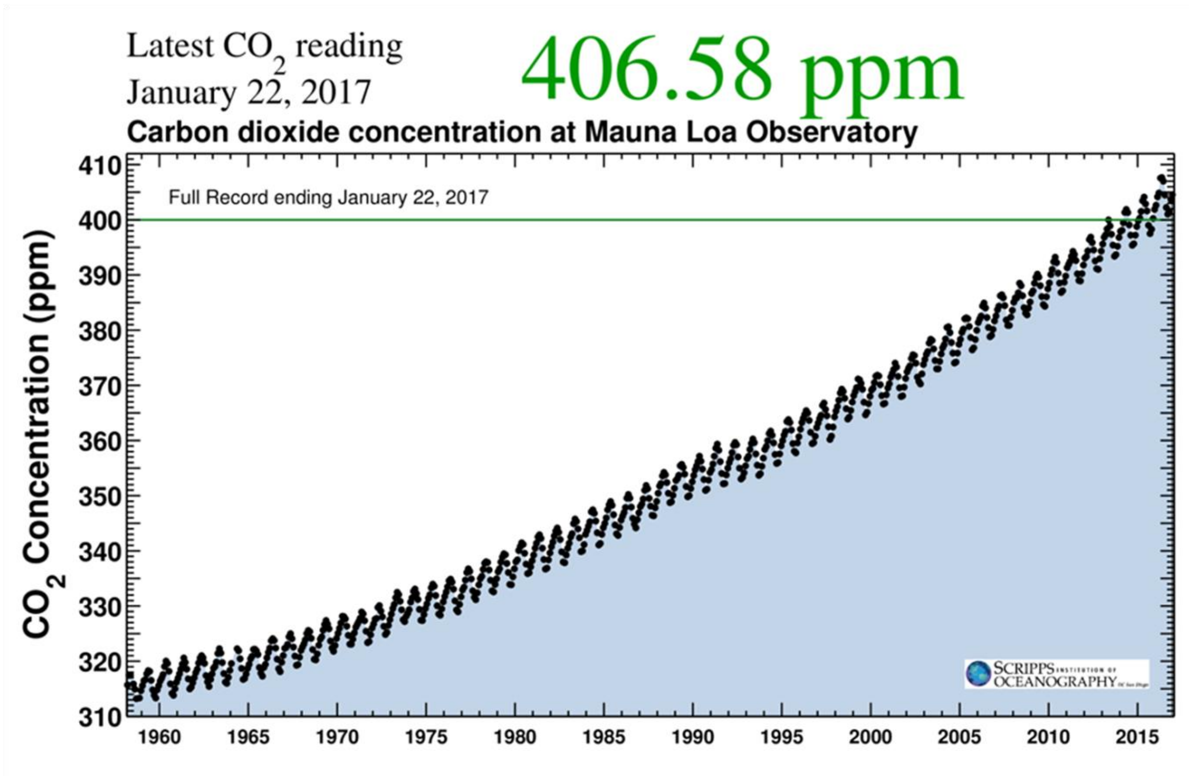

Figure 1.2: CO_2 concentration (in ppm) vs. time

The power creating regions – coal let go control plants and also flammable gas let go control plants - deliver thought and also huge wellsprings of CO2, and on these CO2 alleviation advancements can be tried and attempted. Consequently, there is an unavoidable need to put into utilization innovations that will accommodate the use of non-renewable energy sources in a cleaner way and give a course to a greener economy later on.

Figure 1.3 portrays the normal utilization of various sorts of energizes for world power age. From Figure 1.3, obviously coal will in any case flourish as the significant fuel that is utilized for power age in the coming years.

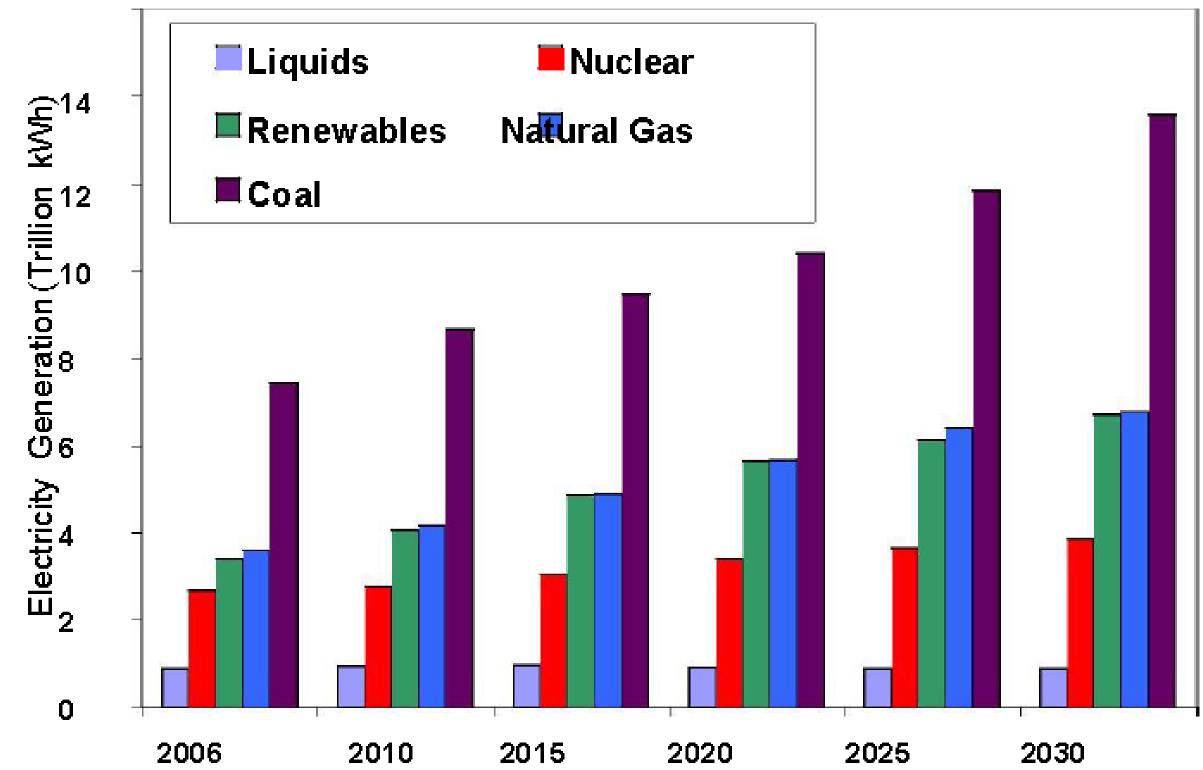

Figure 1.3: World Electricity Generation by Fuel combustion.

1.2 DIFFERENT CO_2 CAPTURE SYSTEMS

There are, extensively, three sorts of frameworks for carbon dioxide catch which can be delegated

i) Post-Combustion CO_2 Capture ,

ii) Oxy-fuel Combustion CO_2 CAPTURE,

iii) Pre-Combustion CO_2 Capture

1.2.1 POST-COMBUSTION CO_2 CAPTURE

Post-combustion capture is only fundamentally a counter current flow procedure which is like vent gas desulfurization. It to a great extent includes the disposal of CO2 from the pipe gas which is delivered because of the ignition of the fuel. A schematic outline of post-burning catch is displayed in Figure 1.4.

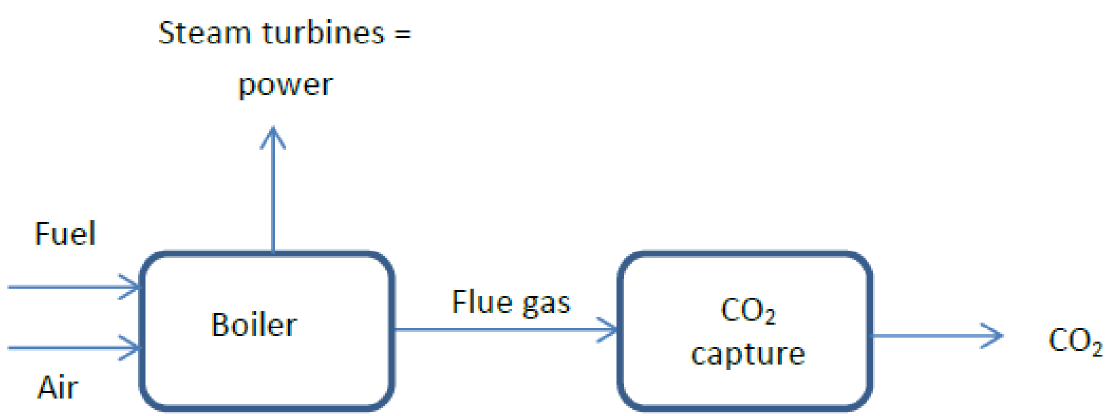

Figure 1.4: Line diagram of post-combustion capture

There are number of different techniques are available for the post-combustion CO_2 capture from the flue gases like physical absorption, chemical absorption, adsorption, cryogenic separation, membrane separation etc. but if comparison is done than, chemical absorption process is most efficient.

1.2.1.1 CHEMICAL ABSORPTION

CO_2 is separated from the flue gas which is came outside from the industries and bigger production plant. passing these flue gas stream through a continuous absorption column system and than in distillation column. The continuous system have an absorber column and also a distillation column. Absorption processes uses for the counterflow chemical reaction of CO_2 with a different aqueous alkaline solvent, like AMINE or NaOH solution. In the distillation column, the CO_2 that had been absorbed in absorption column by the solution and then a pure stream of CO_2 which is separated from rich mixture of solvent and gaseous is sent for compression process of carbon dioxide and at the same time regenerated solvent which is distinguish from rich mixture is sent back to the absorber column for re-process of capture..

1.2.2 Oxy-fuel Combustion CO_2 CAPTURE

The most imperative disadvantage of post-burning catch strategies is the weakening of the vent gasses because of the nearness of nitrogen. This downside can be stayed away from if the ignition is done/completed within the sight of oxygen as opposed to air. The ignition of non-renewable energy sources in an air of oxygen will prompt hugely high temperatures – as high as 3500°C. The temperature is controlled and directed to a level so the material of development can endure by reusing a little division of the fumes pipe gasses. Figure 1.5 delineates a schematic of oxy-fuel ignition.

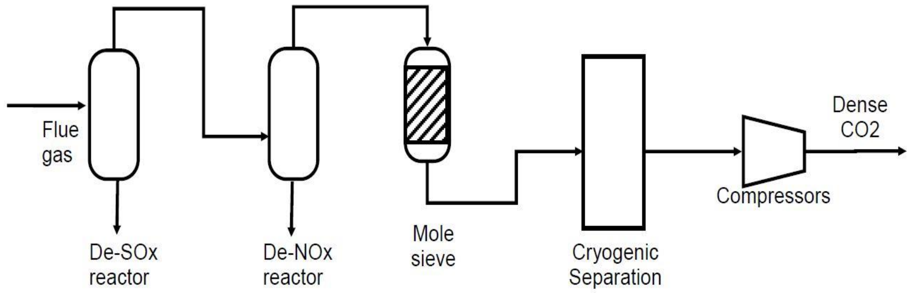

Figure 1.5: Line diagram of oxy-fuel combustion capture process

1.2.3 Pre-Combustion CO_2 Capture

On account of pre-combustion, the carbon substance of the fuel is to some degree diminished preceding burning, with the goal that when it is combusted, a flood of unadulterated CO2 is created. Pre-burning strategy for de -carbonization can be utilized to deliver hydrogen, to create/produce power or both. Figure 1.6 presents line diagram of pre-combustion co_2 capture process.

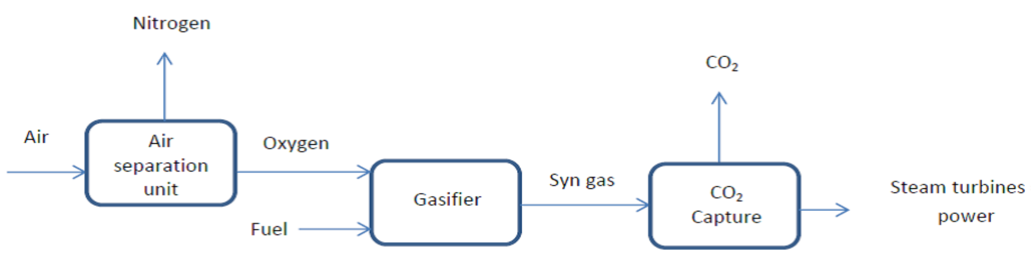

Figure 1.6: Line diagram of pre-combustion capture process

CHAPTER-2

Scope Of The Study

The study find its usefulness in decreasing the CO_2 emission which comes outside from the industries with a very big scale which they through-out directly in the atmosphere. Recently in the industries they used different technologies like oxy fuel, membrane based and Pre combustion capture of CO_2 but By the Post combustion CO_2 capture using chemical process is most efficient and less cost process and it efficiency is around 90% .This process has more capacity to absorb CO_2 at less time. The changes in design parameters and with different column structure design increase the capture ratio with different solvents.

CHAPTER-3

Objectives Of The Study

The objectives of this project work are explain below:

(a) To remove CO_2 gas from a mixture of carbon dioxide and air by using aqueous AMINE solution in an absorption column using counter current flow of air and gas mixture and liquid.

(b) To see the effect of different types of random packing materials and structured packing capture efficiency on the same set-up and compare the efficiency of both.

(c) To observe the effects of different solvent flow pattern as well as rate of flow and temperature of solvent on reduction of CO_2 in mixture.

(d) Simulation can be done using ASPEN PLUS software for design and improvement of the system of post-combustion CO2 capture and compare with practical work.

(e) Simulation study can be done for increase the wetted surface area of structured packing.

(f) Simulation study can be done for improvement of wetted surface area of structured packing

CHAPTER-4

REVIEW OF LITRATURE

Wayuta Srisang et. Al [2016] In this investigation assess the two strong corrosive impetus and two tertiary amines with monoethenolamine on the CO2 catch process execution as far as warmth obligation, cyclic limit and safeguard productivity utilizing a seat scale amine-based post-burning CO2 catch pilot plant with various measures of every strong corrosive impetus in the desorber.

Xiao Luo et al. [2016] In this examination they chipped away at the retention and desorption limit of dissolvable for that they utilized AMINE at various molar proportion in water and check the rate of assimilation and desorption in AMINE .For this procedure they utilize MULTYPLE FAST SCREENING METHOD for examination and they found that the ingestion procedure, as the molar proportion of DEEA was expanded, the underlying lean stacking of mixed MEA/DEEA arrangements diminished.

Y. Haroun et al [2014] The liquid hold-up and the level of wetting of pressing are examined as capacity of fluid stream rate and divider surface trademark and finished up with interfacial viable range and the level of wetting of pressing increment as the fluid stream rate increasesand as the contact point diminishes so wetted territory is assume a greater part in a co2 cature.

Yoshiyuki Iso et al. [2013] The present investigation concentrates on point by point depictions of interfacial flowsin the organized pressing of segment , and also how such marvels are influenced by divider surface treatment for that they builds up a numerical reproduction method utilizing Computational Fluid Dynamics (CFD) and in addition a lab-scale trial testing procedure

In this work they look at two changed surface wavy and smooth plate at 60 degree slant

What's more, they found that by including some surface structure more wetted zone cover.

J.J. Cooke et al. [2012] In this work they used ANSYS CFD FLUENT product for simulate the flow on smooth and with ridge plate which is at different angle 30 and 60 and find out the wetted surface area on the plate which is at different angle in both the case and this study is helped for design a structured packing which used in the absorption column.

Chao Wang et al. [2012] this study focused on measurement of three characteristics of packing material contact area of liquid-gas,mass transfer, and five different structured and random packing have been tested

Yuanchang Peng et al. [2011] This paper summaries the effect of the reactors structure, absorbent type and operating conditions on absorption efficiency and also shows present developmental directions in CO_2 capture work. Study has beed done on the effect of different temp. of solvent on the CO_2 capture efficiency and effect of flow rate of flue gases on the capture efficiency is also done.It also shows the concentration of carbon dioxide in flue gases effect on capture efficiency.Effect of flow rate of solvent on carbon dioxide capture are also studied.

CHEN Jiangbo et al. [2009] This study investiget a detailed investigation of flow in a structured packing in a ANSYS CFD FLUENT product. In this study they used VOF(Volume Of Fluid) method for simulate the mixture gas and liquid flow . thisstudy find mass-transfer behavior in a typical representative unit of the structured packing. This study gives the mass transfer between gas and fluid in a structured packing which is the main parameter for structured packing.

Jorge M Plaza et al. [2009] In this study simulation work is takes in the aspen plus with amine solvent in this simulation both absorber and strriper model used a RateSep for simulation and one pilot plat is also made for compare the results with simulation work in tis model they introduced one intercooler and got capture efficiency upto 90% and he conclude that add an intercooler is decreased height 13%.

Jorge M Plaza et al. [2009] In this study they simulate post combustion CO_2 capture with AMINE in a ASPEN PLUS product. In this simulation Both the absorber and the stripper used RateSep to rigorously calculate mass transfer rates. After simulation they compare that result with the lab model and they find 3.8% difference in stripper and three-stage flash configuration which efficiently utilizes solar energy was developed it reduce by 6%.

Hongqun Yang et al. [2008] In this review paper progress made with absorption,adsorption and membrane separation is discussed. In this paper different method which are used in recent scenario is explained and compare these different methods with each other and also compare the capture efficiency of different methods from this we got an idea of implement of new work

Akanksha et al. [2006] In this examination Numerical approach for breaking down ingestion rate and comprehension of the miniaturized scale level cooperations of different procedures going inside the reactor was proposed by building up a numerical model for A constant film contactor has been outlined and assimilation result did. The numerical plan reproducing the outcomes in view of energy, mass and warmth adjust gives a robotic translation of the exploratory outcomes.

B. P. Mandal et al. [2001] This work shows an examination of CO2 retention into fluid mixes of MDEA and MEA, and AMP and MEA. They made one model and utilize these all dissolvable at various molar part and fine the catch proficiency and presume that the expansion ofa little sum ofMEA to a watery arrangement of MDEA or AMP essentially improves the upgrade factor and rate of retention for the two solvents.

Sanjay Bishnoi et al.[2000] This work is about the ingestion of CO2 into fluid arrangements of piperazine in a wetted divider contactor.In this investigation perusing is taken out at an alternate temp. go from 298-333 K result demonstrates Measurements of the rate steady in this work are considerably higher than beforehand revealed esteems.

CHAPTER-5

RESEARCH METHODOLOGY

The set-up basically consists of a iron Absorption column that is packed with Random packing column material raschig rings of 8-10 mm. Solvent Liquid is supplied from the top of the Absorption column through a pump.CO_2 gas from cylinder and atmospheric air mixture is passed from bottom of the absorption column and this both are passed through different rotameters which is measured the flow of air and CO_2 from cylinder , the mixture of these both are passed in upward direction of absorption column which is passed through random packing which is ceramic reschig rings.

In absorption column, a gas and air mixture is contacted with a liquid in between portion of reschig rings for absorption process which is accrued between liquid and air and gas mixture .Mass transfer is accrued between liquid and gas . After the absorption of CO_2 gas in AMINE, this rich mixture is passed through the heat exchanger where the rich mixture is heated up at 110 degree centigrade and then it is passed through the scrubber which is made up of iron column and packed with a reschig rings. Rich mixture is supplied from the top of the scrubber(distillation tower) where CO_2 gas is distinguished from riched mixture and reading of CO_2 gas is taken out from top portion of distillation column through gas analyzer.

AMINE liquid is collected form distillation column bottom side and it is stored in one tank and it is again feed to the absorber column through pump which is passed through condenser where temperature is decreased of AMINE liquid to 40 degree centigrade.

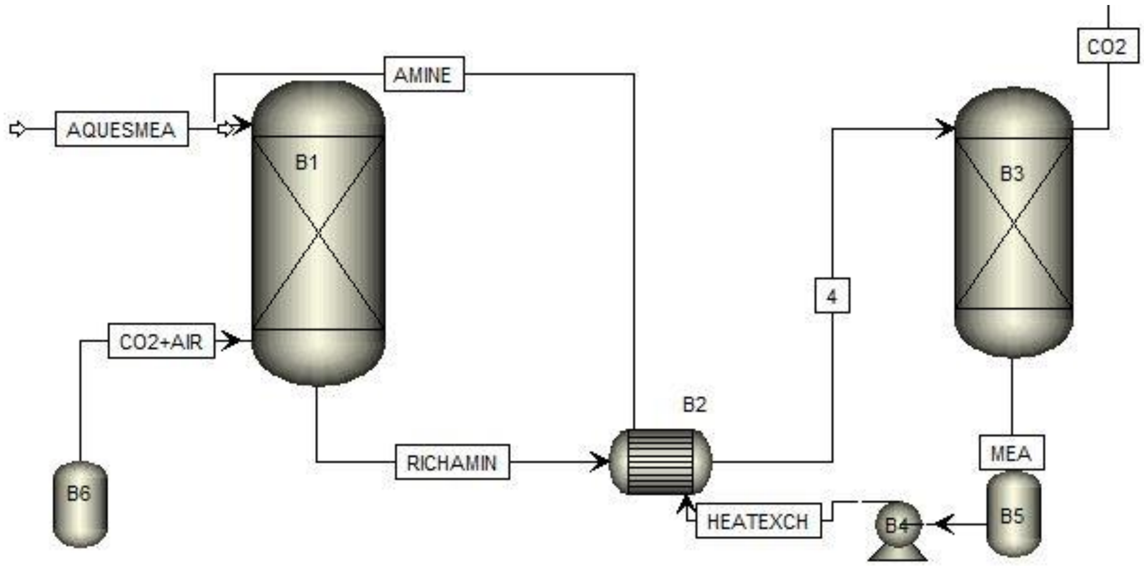

Figure : 1.7 Set-up for CO_2 capture.

B1 = Absorption column

B2 = Heat Exchanger

B3 = Distillation column

B4 = Pump

B5 = Storage tank

B6 = CO_2 cylinder

- **Geometric dimensions of set-up:**

Column : Iron, diameter 51 mm, length 790 mm

Random packing material : Ceramic Raschig rings of size 8-10 mm

Circulation of water : By Pump

Circulation of air and CO_2 : By blower and compressor

Flow measuring Device : Rotameters (one each for feed, air and CO2)

CHAPTER-6

Model Description and Materials

- **Absorption column and Scrubber:**

Absorption column of 51 mm diameter and 790 mm length are used for continuous counter flow contact of liquid and gas, which is filled with ceramic reschig rings packing materials.The liquid is distributed through the ceramic reschig rings over downward flow of liquid and it also creat a large surface area to contact the gas and liquid.

Figure : 1.8 Absorption column and Distillation column(Stripper)

- **Ceramic Reschig rings:**

Raschig rings are pieces of tube, approximately equal in length and diameter, used in large numbers as a pecked bed within columns for distillation and absorption column.

Figure : 1.9 Ceramic rings 8-10mm

- **Rotameter:**

A **rotameter** is a device that measures the volumetric flow rate of fluid in a closed tube. In this set up three rotameters with the range of 10-100 litre/hour are used for measure flow of air, measure flow of CO_2,measure the flow of AMINE liquid.

- **CO_2 Cylinder**:

In this set-up CO_2 cylinder is used for to mix CO_2 with an atmospheric air and pass it to the absorption column for absorption process which is taken place in the packed column.

CHAPTER-7

PROPOSED WORK PLAN AND TIMELINES

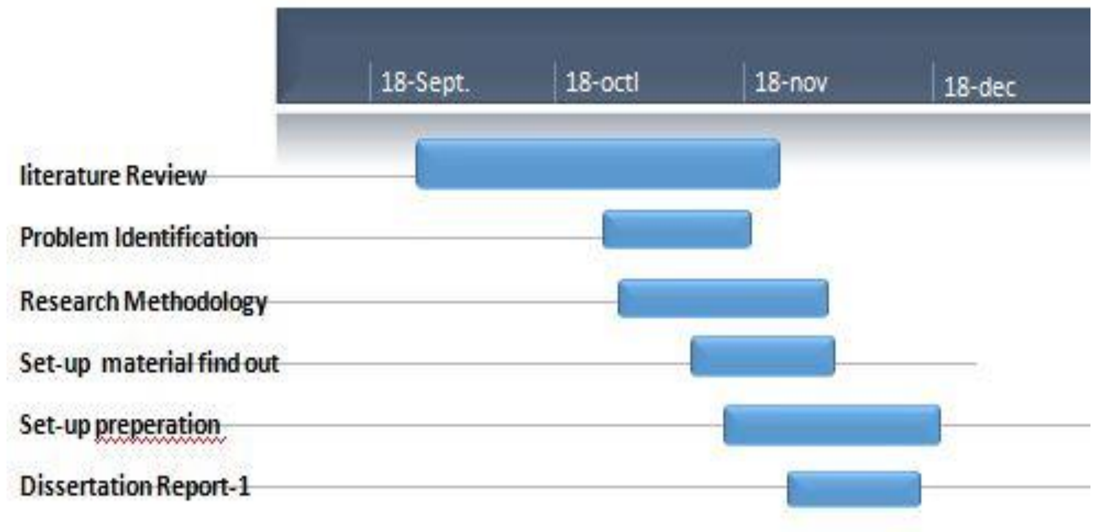

Figure : 1.10 Work plan with timelines.

CHAPTER-8

EXPECTED OUTCOMES

Since the investigation used different sorbent like NAOH,KOH,AMONIA,AMINE etc. with different types of packed bed column and structured column model which in literature, is studied by few researchers. Moreover, The main outcomes that can be expected out of present study are:

- The variation of different solvent liquid on co_2 capture can be determined
- The different design of absorber column on efficiency of captured CO_2 can be found.
- Effect of different parameters i.e. temperature, packing materials, mass flow rate etc. On capture of CO_2 can be determined
- The investigation can found the effect of different flows and different type of sprinkle of solvent liquid on capture of CO_2 .

CHAPTER-9

SUMMARY AND CONCLUSION

In the present study from the literature rivue CO_2 capture is possible to done in lab model which is developed where one absorption column with 51mm dia. And 790 mm length and one stripper with the same dimension which is filled by random packing material reschig rings which is used of 8-10 mm up to 400mm and different combination in water of AMINE liquid is used for check efficiency of CO_2 and simulation work is also done by ASPEN PLUS for check capture efficiency.

Implementation in Design of structured packing by different corrugation and with different surface textured is also going on by ANSYS CFD FLUENT product.

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