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Carbon Scrubbing from Exhaust of Diesel Generator Set

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Abstract— The effect of Global warming is growing at an alarming rate year by year and one of the major contributors to this is CO_2 emissions. In that, Diesel engine exhaust emission has a significant contribution. If we take a break down it is found that CO_2 around constitutes 12-15 % of total exhaust emissions. One of the easiest and clean methods for reducing the CO_2 emissions is using carbon scrubber to capture the C02. The project deals with capturing from the exhaust of Diesel generator Set. For this a carbon scrubber arrangement is used in which NaOH solution is taken as the scrubber. Along with carbon scrubbing one of the main advantages of this project is that the waste heat from flue gas is utilized to recover the NaOH which is lost. This is done with the help of a heat exchanger. This adds to the economy of the entire project in such a way that the NaOH lost during the scrubbing process is recovered in the regenerator by the heat exchanger and pumped back to the scrubber column.

Keywords— Carbon scrubbing, Waste heat, NaOH solution, Carbon di Oxide, Flue Gas, Heat Exchanger, DG Set

INTRODUCTION

One of the major environmental concerns that exist today is Global warming which is mainly caused by green house gas emissions. Carbon di oxide alone contributes around 72% of total GHG emission. The effect of global warming can be reduced to a greater extent by capturing the CO_2 at source level itself. The CO_2 can be mainly classified as stationary sources like power plant and non stationary sources i.e. mainly automobile emissions. Along with this various chemical processes like cement, refinery, iron and steel also contributed to CO_2 emission. In the present scenario capturing CO_2 has a great importance in respect to climate change. Many power plants and refineries are setting up their own carbon capturing technologies because of the CDM benefits and environmental concerns. Some of the commonly employed carbon scrubbing methods is amine scrubbing, solvent based absorption, regenerative carbon scrubbing, using activated carbon, algae based capture etc.

The method described in this project is post combustion capture of CO_2 from the exhaust of DG set. The system here captures CO_2 directly from the exhaust using a NaOH bath which is sprayed on the flue gas path. Using a heat exchanger the heat from flue gas is taken and NaOH can be regenerated.

SCHEMATIC LAYOUT AND WORKING

1. Layout

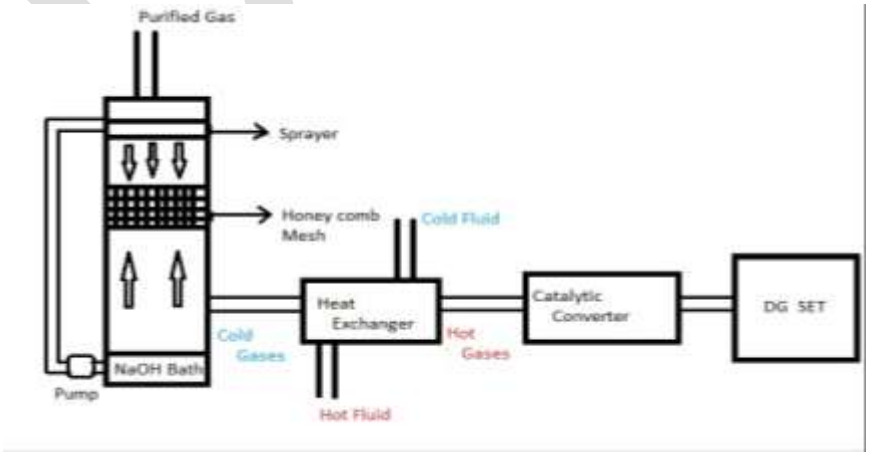

Figure 9. Schematic diagram showing the process

Working

The study was conducted on a 500 KVA DG set and the flue gas temperature is around 440 – 460 ^{o}C. The flue gas is the passed to a Diesel Oxidation Catalyst (DOC) catalytic converter so as to convert the un burnt hydrocarbons and carbon monoxide to carbon dioxide and remove the particulate matters. It is done because the presence of toxic gases in flue gas can degrade the quality of NaOH solution thus reducing the concentration required for the process. From DOC flue gas enters a shell and tube heat exchanger where heat is exchanged with incoming sodium bicarbonate solution so as to regenerate NaOH.

The Carbon scrubber arrangement is basically a tower like structure fitted with a sprayer and honey comb mesh so as to increase the time and surface area of contact between scrubber solution and flue gas thereby increase the capture rate. The scrubber solution used is NaOH at 85% concentration so that solution will not vaporize at high temperature. The flue gas is made to pass through a jet spray of scrubber solution where the carbon capture takes place. The following are the chemical reaction that takes place.

The NaOH solution after reacting with flue gas is regenerated by passing the sodium bicarbonate solution to a heat exchanger where the heat from flue gas is used to regenerate the NaOH back and CO_2 formed is distilled and is cooled and compressed for storage. The following are the chemical reaction taking place:

$2\ NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$ (1)

$Na_2CO_3 + Heat \rightarrow Na_2O + CO_2$ (2)

$Na_2O + H_2O \rightarrow NaOH$ (3)

2. Analysis

The assumptions made for the analysis are :

- The absorption process is counter current.
- The regeneration time is taken to be 15mn
- The heat loss from flue gas inside scrubber column is transferred to the NaOH at a constant process
- The concentration of NaOH almost remains the same after regeneration
- The temperature of cold fluid in the system is taken as 170deg C

The following table shows the test data for analysis

Table 1. Test data for analysis

Parameters	**Value**
Flue gas temperature (^{o}C)	450
Flue gas flow rate (kg/s)	1.86
Fuel consumption at 100% load (l/hr)	107
Density of NaOH (g/cm^3)	2.13
Boiling point of NaOH (^{o}C)	1388
Density of diesel (kg/l)	0.832
Density of CO_2 (kg/l)	1.977

Diesel Reaction Equation is given by:-

$2\ C_{15}H_{22} + 41\ O_2 \rightarrow 30\ CO_2 + 22\ H_2O$ (4)

Total Fuel Consumed = 0.832 * 107 = 89.02 kg/hr

Molar Concentration (Diesel) = 4.11 mol /l
Molar Concentration (CO_2) = 0.044 mol /l.
439.77 mole of diesel react to give 6596.55 moles of CO_2 per hr.

$$CO_2 + 2\,NaOH \rightarrow Na_2CO_3 + H_2O \qquad (5)$$

Weight of CO_2 = 290 kg CO_2
Weight of NaOH = 527 kg
Weight of Na_2CO_3 = 699 kg
Weight of H_2O = 118 kg

Conversion into liters
Volume of NaOH = 247.41 l
Morality = 0.16 M solution
Excess quantity to make up the loss in regeneration = 53 l
Total quantity of NaOH = 300 l
Actual quantity of NaOH that to be stored in the Scrubber Column is 75 l.

CONCLUSION

The project described here is a pilot scale one and with the integration of latest technologies and advancement the same thing can be implemented in bigger industries where the carbon emissions are more. The main advantage with this project is that all the raw materials and equipment used are readily available which adds to the overall economy and cost reduction. Also Sodium Hydroxide solution can be regenerated with the same heat recovered from the exhaust which is an add on advantage. One of the main limitations of this project is the use of higher concentration of Sodium Hydroxide solution due to boiling point problem as NaOH vaporizes. This is an area to work upon in which techniques which reduce the temperature of exhaust gases are to be found out. Also some assumptions are taken for doing out theoretical analysis, which when implemented physically may not stand for. In nut shell with the implementation of this arrangement a considerable amount of CO2 released into the atmosphere can be controlled there by reducing the global warming effects which is a major threat in the present scenario.

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