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RESEARCH ARTICLE

EVALUATION OF ABSORPTION AND CAUSTICIZATION OF CARBON DIOXIDE SCRUBBED CHEMICALLY FOR SEQUENSTRATION.

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Abstract

Climate change and its effect on Indian monsoon in recent years is now having adverse effect on agriculture and less production of grains, vegetables and other life commodities. Various anthropogenic sources are responsible for climatic variations and atmospheric environment pollution. It was recognized in the early 20th century that the known major greenhouse gases in the atmosphere caused the earth's temperature to be higher than it would have been without the greenhouse gases. Foundry industry being more in number at Maharashtra especially Kolhapur City is playing very important role in emitting Carbon Dioxide (CO_2) and other pollutant due to use of Coke as a fuel for combustion in foundry industry. Cupola technology in casting industry releases more Carbon Dioxide through the stacks which leads to Global Warming. Hence it is necessary to capture and store the emissions of Carbon Dioxide before its release into atmosphere and reuse whenever necessary. This paper envisages application of Carbon Capture and Sequestration (CCS) by chemical absorption technology which further elaborates how efficiency of carbon capture in foundry can be increased and thereby optimizing the chemical reactions in the process.

Introduction:-

Greenhouse gases are components of the atmosphere that contribute to the greenhouse effect. Without the greenhouse effect the Earth would be uninhabitable; in its absence, the mean temperature of the earth would be about −19 °C (−2 °F, 254 K) rather than the present mean temperature of about 15 °C (59 °F, 288 K)[1]. Greenhouse gases include in the order of relative abundance water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Greenhouse gases come from natural sources and human activity. The major greenhouse gases are water vapor, which causes about 36–70% of the greenhouse effect on Earth (not including clouds); carbon dioxide, which causes 9–26%; methane, which causes 4–9%, and ozone, which causes 3–7% [2]. It is not possible to state that a certain gas causes a certain percentage of the greenhouse effect, because the influences of the various gases are not additives. Other greenhouse gases include, but are not limited to, nitrous oxide, sulfur hexafluoride, Hydroflourocarbons, Perflourocarbons and Chlorofluorocarbons [3]. There are more than 5,000 foundry units in India, having an installed capacity of approximately 7.5 million tons per annum [4]. The majority (nearly 95%) of the foundry units in India falls under the category of small-scale industry.

Carbon Capture and Sequestration (CCS) is a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere [5]. CCS has the potential to reduce overall mitigation costs and increase flexibility in achieving greenhouse gas emission reductions. The widespread application of CCS would depend on technical maturity, costs, overall potential, diffusion and transfer of the technology to developing countries and their capacity to apply the technology, regulatory aspects, environmental issues and public perception [6]. CCS is an approach to mitigate global warming by capturing Carbon Dioxide (CO_2) from large point sources such as fossil fuel power plants and storing it instead of releasing it into the atmosphere [7]. Technology for large scale capture of CO_2 is already commercially available and fairly well developed. Frank Zeman has proposed a very simple model for CCS from ambient air [13]. As per Frank Zeman, CO_2 is absorbed by an alkaline NaOH solution to produced dissolved sodium carbonate. The absorption reaction is a gas liquid reaction, strongly exothermic. Then the carbonate ion is removed from the solution by reaction with calcium hydroxide ($Ca(OH)_2$), which results in the precipitation of calcite ($CaCO_3$). The Causticization reaction is a mildly exothermic, aqueous reaction that occurs in an emission of calcium hydroxide. Causticization is performed ubiquitously in the pulp and paper industry and readily transfers 94% of the carbonate ions from the sodium to the calcium cation. Subsequently, the calcium carbonate precipitate is filtered from solution and thermally decomposed to produce gaseous CO_2. The calcinations reaction is the only endothermic reaction in the process. The thermally decomposition of calcite is performed in a lime kiln with oxygen in order to avoid an additional gas separation step. Hydration of the lime (CaO) completes the cycle. Lime hydration is an exothermic reaction that can be performed with water or steam [13].

Materials and methods:-

The present study was carried out at one of foundry industries at Kolhapur. This is ferrous foundry with production capacity of 7 tons per day with divided blast cupola technology. The samples of gaseous containing CO_2 were collected from sampling port with the help of vacuum pump using Tedlar bags of 5 liter capacity each and connected to Gas Chromatograph for gas analysis and determination of efficiency of capture of CO_2[8]. CO_2 capture from stack using NaOH solution was also done. The vacuum pump of 5 liters per minute flow rate is connected to an impinger having 60 ml (or more) pure solution of 1M NaOH [9]. The solution of NaOH must be stored in a closed container unexposed to air and must essentially be free from sodium carbonate. The pump is placed near charging port and switched on so that the gas is allowed to pass through the impinger for 15-30 minutes [10]. Also, Analysis of samples was done in Gas Chromatograph (GC) using Thermal Conductivity Detector (TCD) to detect concentration of CO_2 in ppmv [11]. The instrument was calibrated using standard CO_2 gas of 99.99% purity [12]. Calibration was done for each day of analysis so as to minimize errors due to varying environmental conditions such as temperature. The samples were injected thereafter and results were tabulated.

Results and discussions:-

Determination of Efficiency i.e. Average efficiency of Absorption of CO_2 was found to be 91.00% while average efficiency of Causticization was expressed and found to be 89.92%. Our results indicate that CO_2 can effectively be captured in bulk caustic solution with more than 90% efficiency. If low concentration of CO_2 emissions is encountered, then the size and capacity of the capture unit will be reduced, thus making the unit more economical. If high concentration of CO_2 emissions is encountered, then the precipitate formed will be more, and thus, the foundry can save on the cost of purchase of limestone. Efficiency of absorption of CO_2 into caustic solution was found to be more than that of conversion of sodium carbonate to calcium carbonate.

Conclusions:-

The proposed design is cheaper and more efficient in scrubbing CO_2 as compared to absorption units such as packed towers. The caustic solution is fully recovered in the process. Since the absorption reaction is highly exothermic, provision of heat exchanger could be made to transfer the energy suitably. In foundries, the calcium carbonate precipitated out could be recycled to help in the removal of slag from the furnace. The precise concentration of CO_2 inside stack could not be determined due to very high temperatures encountered in the furnace. The additional costs of installing and operating control equipment will have to be borne with in developed countries. However, developing countries like India can obtain carbon credits for capturing CO_2 emissions and can sell them for additional income. If Particulate Matter from Cupola is not collected before it enters into CCS system, CO_2 capture efficiency may hamper and gets reduced. Hence cyclone separator is recommended for collection of Particulate Matter with 95% efficiency.

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