CARBON CAPTURE TECHNOLOGY OVERVIEW:

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Global climate change and the technologies to minimize the greenhouse gas emissions are at the centre of discussion in every global environmental forum. Carbon capture technology is one of such techniques which can be implemented to reduce atmospheric emissions of carbon dioxide from industrial installations. Coal based thermal power plants and cement plants are the major contributors of carbon dioxide emissions. Though the technology for carbon capture is proven and is in practice at many locations, the high operating cost and relatively higher energy consumption are major barriers to mass implementation. Also, the utilization or storage of the carbon dioxide captured pose major challenge. It is economically difficult to store and transport the carbon dioxide from the capture site to another location where this captured carbon dioxide can be used as either raw material for other processes or sequestered/injected to oil wells.

On a broader basis, the carbon capture can be possible through three routes namely post-combustion, pre-combustion and oxy-combustion capture. This paper briefly provides an overview of the generic technological approaches available towards carbon capture. The applicability and limitations of each of the three routes as above are discussed in the sections below.

Drivers for Carbon Capture:

The major drivers for implementing carbon capture technology are as below.

(1) Need for reduction of carbon dioxide emissions is getting recognised globally. Since thermal power plants are one of the major contributors to the carbon dioxide emissions, it is possible to target this industry to reduce the global emissions.

(2) With growing population and industrialization, it may not be possible to reduce the energy consumption from the present levels. It is equally difficult to replace fossil fuels (especially for a country such as India) though renewable and alternate energy sources are gaining popularity.

(3) There is no quick or shortcut method for eliminating or reducing the atmospheric carbon dioxide emissions from all applicable sources. Hence emphasis on reducing the emissions from major sources is required.

(4) Technological advancements, Development of new and better energy reducing solvents presents a promise to mitigate the climate change and carbon capture technology is one of the important tools to achieve global green house gas emission reductions.

Carbon Capture Technologies:

There are three basic routes for capturing carbon dioxide from process stream. The classification is based on the location of carbon dioxide recovery in reference to the combustion process. These are

(1) Post Combustion Process: As the name suggests, carbon dioxide recovery is carried out after the fuel is burnt in the combustion process. These processes are based on ‘Chemical Absorption’ principle. Currently, this is the most effective technology for carbon dioxide capture. Technology is already commercialised and in use in many large scale plants including power plants.

Other emerging technologies such as Adsorption or Membrane methods can also be employed using post combustion route. While the chemical absorption method is technically well proven and found as a commercially viable process, other methods such as adsorption, or membrane are still considered as developing processes. Though, these developing processes are being used in some specific niche applications, it is not yet commercialized for large scale installation to meet requirements of power or cement industry.

(2) Pre Combustion Process: Carbon dioxide recovery is carried out before the fuel is burnt in the combustion process. These processes are mainly based on ‘Physical Absorption’ principle. Cryogenics is an emerging technology used in pre combustion route. While the physical absorption method is technically well proven and found as a commercially viable process, cryogenic method is still considered as developing process.

(3) Oxy-Combustion Process: These can be considered as an alternative to post combustion process and instead of air; pure oxygen is directly used as combustion process. Though technically proven, this process is not used widely due to the additional costs associated with oxygen generation.

(1) Post Combustion Technology:

Post combustion technologies include Chemical absorption, Adsorption, and Membrane methods.

(A) Chemical Absorption Method:

Chemical absorption processes are employed in post combustion scenario. Recovery of carbon dioxide is carried out after the fossil fuel (or coal) is burned in the combustion process and the flue gas is formed. Flue gas carries the carbon dioxide formed from the combustion process. This flue gas is treated in chemical absorption process for recovering carbon dioxide before venting to atmosphere. Chemical absorption process uses solvents like Mono Ethanol Amine (MEA or other similar amine based solvents) as absorption media. Typical absorber and regenerator configuration is used. Flue gas is first sent to absorber wherein it is scrubbed with solvent. Clean and treated gas exits the absorber while the carbon dioxide containing rich solution from the absorber bottom is fed to the regenerator column for regenerating the solvent. Captured carbon dioxide leaves the regenerator top and the lean solvent at the bottom of regenerator column is recycled back to the absorber tower.

This is most effective and widely used commercially viable technique for carbon capture. Many proprietary solvents are being developed to reduce the energy consumption. Chemical absorption process using amine based solvents can typically recover 90% of carbon dioxide with a product purity in excess of 99%.

(B) Adsorption Method:

The gas stream containing carbon dioxide is passed over a surface of a solid adsorbent for carbon dioxide capture. Most commonly used and effective adsorbents include alumina, zeolite and activated carbon.

Adsorption processes has potential to reduce overall energy requirements when compared with the absorption processes. This is due to the fact that when ‘Absorption’ method (either physical or chemical) is used, the solvents are regenerated to release captured carbon dioxide. During the ‘solvent absorption-regeneration’ cycles, water is continuously recycled, heated and condensed resulting in large need of energy. Relatively, lesser energy is required when ‘Adsorption’ method is used.

However, there are still challenges in the adsorption process with respect to getting heat efficiently in and out of the sorbent material. Even though this method is promising, it is still energy intensive process as substantial costs are incurred in desorption process. On a large scale, this technology is not yet proven and may not be economically feasible.

(C) Membrane Method:

Membranes allow the selective passage of a gas through specially made materials. Driving force for the separation is differential pressure across the membrane. While selecting a suitable material for membrane, two important physical parameters that affects the performance must be evaluated. First one is related to selectivity and second one addresses permeability. Selectivity reflects the extent to which a membrane permits specific molecules to be carried across the membrane material, and not others. This reflects purity part. The second parameter, permeability, addresses the quantity of a given molecule that can be transported for a given pressure difference Permeability dictates the surface area required for separation.

This method is dependent on the nature of membrane materials and it is again energy intensive process as pressure is the driving force for the separation. This technology is considered as developing process as it is not yet applied commercially for any large scale applications.

(2) Pre-Combustion Technology:

As stated earlier, the pre combustion processes include physical absorption and cryogenic methods.

(A) Physical Absorption:

Physical absorption processes are employed in pre combustion scenario. Recovery of carbon dioxide is carried out before the fuel is burned in the combustion process. For the cases wherein the power plants are

based on coal gasification technology, the coal is first treated with steam and hydrogen to form syn gas. This syngas can be then burnt in combined cycle power plant to generate electricity. Carbon dioxide is captured after the gasification and before the combustion of syn gas in a process using physical solvents.

The solvents used in the process do not react with the gas stream (as is the case with chemical absorption process) but it involves physical absorption into the solvent. Carbon dioxide is recovered as a flash gas when the rich solvent stream pressure is dropped. There are various commercially proven processes based on this technology; each one employing different proprietary solvents. 'Selexol' and 'Rectisol' are the most commonly used (patented) technologies.. While the Selexol technology uses dimethylethers of polyethylene glycol as solvent, Rectisol technology is based on cold methanol. Purisol technology use N-methyl-2-pyrolidone as a solvent.

Physical absorption process works at a high pressure. Gasification and combined power cycle plants are complex processes. But, as far as the recovery of carbon dioxide is concerned, it is relatively easier and cheaper in this process due to the high operating pressure and high concentration of carbon dioxide in syngas stream. For conventional power plants or cement plants, the flue gas post combustion is available at atmospheric pressure and hence this process can not be employed.

(B) Cryogenic Process:

In cryogenic process the gas stream containing carbon dioxide is compressed and cooled in multiple stages to induce phase changes in carbon dioxide and other gases allowing them to be separated. As this technology is based on phase change, the process is effective for a wide boiling gas mixture. Further, the carbon dioxide behaviour itself is too complicated as it can lead to the formation of solids and in-turn can damage equipment; reduce heat transfer rates making the process ineffective. Cryogenic processes are not yet used at a commercial scale for capturing carbon dioxide.

(C) Oxy - Combustion Technology:

Conventionally, air is used as source of oxygen in the combustion process. In the oxy-combustion process, pure oxygen is used in the combustion process. A dedicated air separation unit is required to source the oxygen for combustion. The flue gas shall have carbon dioxide and water vapours. On condensing, the flue gas, water can be separated. Resultant flue gas after knocking off the water will be concentrated with carbon dioxide. As the combustion process is carried with pure oxygen, the reaction temperatures are higher than the air case. To maintain boiler operating temperatures, a large portion (~70%) of the flue gas is required to be recycled back to boiler.

Typically, carbon dioxide of 80% to 98% concentration can be obtained depending on configuration of oxy-combustion process. Use of this technology eliminates the need for post combustion chemical absorption methods.

Concluding Remarks:

Due to the global warming, Carbon capture technologies are gaining attention. Conventional power plants are a large source of carbon dioxide emissions and efforts are being made to employ suitable technology specifically in power industry to minimize the emissions. There are various technologies commercially available such as absorption, adsorption, membranes or cryogenics. However, the physical and chemical absorption techniques are commercially viable and are employed on large scale industrial installations. High capital costs and high energy requirements clubbed with utilization of the captured carbon dioxide are the main barriers in implementing the carbon capture technology. Various technologies are being experimented and are at various stages of implementation.

A significant push at government level with incentive programs has witnessed acceleration in deployment of this technology. Tata Consulting Engineers (TCE) has adequate knowledge and expertise to provide services in technology selection and in providing customized solutions in the field of carbon capture.