METHOD OF PRODUCING CARBON DIOXIDE FROM A GAS SCRUBBING PROCESS

Technical field

The present invention relates to a method of producing a substantially pure gaseous carbon dioxide (CO_2), by separating gaseous mixture of carbon dioxide (CO_2) and oxygen (O_2) after an electrolytic regeneration of a spent aqueous scrubbing liquid from a process of scrubbing a gas, such as flue gas comprising carbon dioxide. The substantially pure carbon dioxide is then compressed to a liquid CO_2 for transport. The CO_2 may be extracted from flue gas, ambient air or other sources.

Summary

Carbon dioxide (CO_2) is a gas that when emitted into the atmosphere is damaging to the climate as it contributes to the green-house effect and rise in global temperature. It is for example produced as a by-product when fossil fuel, e.g. coal, gasoline or diesel, is burned. Coal- and gas-fired power plants accounts for a large share of CO_2 emissions. It is a goal for many sectors to lower carbon dioxide emissions.

Emitted gases resulting from combustion and comprising CO_2 are typically denoted flue gases or exhaust gases. Depleting such emitted gases of CO_2 by lowering the CO_2 content in the emitted gases, can be done by so called scrubbing of the gases, i.e. removing the CO_2 from the gas stream by absorbing/dissolving CO_2 in a liquid.

As described in US11219860, the CO_2 withdrawn from the scrubbing process, or from an anode chamber of an electrolytic cell, after regeneration of a scrubbing liquid, is then conventionally compressed, or cooled and compressed to be transported of site for other downstream uses. However, the process of cooling and compressing gaseous CO_2 into a liquid carbon dioxide requires a substantial amount of power. There is an imperative need for improved scrubbing systems that preferably require less power for the CO_2 capture and compression. The method in accordance with the present disclosure, may be obtained using the method and system disclosed in US11219860.

It is in view of the above considerations and others that the examples described in this disclosure have been made. It is an object of the present disclosure, to provide

an improved method of preparing a substantially pure gaseous carbon dioxide, and a system and uses thereof.

The disclosure is defined by the appended independent claims. Examples are set forth in the appended dependent claims and in the following description.

Accordingly, in a first aspect, there is provided a method of preparing a substantially pure gaseous carbon dioxide from a gaseous mixture of carbon dioxide (CO_2) and oxygen (O_2), wherein said gaseous mixture is withdrawn from an anode chamber of an electrolytic cell, and wherein said electrolytic cell is fed a spent aqueous scrubbing liquid from a scrubber, wherein said scrubber scrubs a gas, having a first carbon dioxide concentration with a first alkaline, aqueous scrubbing liquid, wherein said spent aqueous scrubbing liquid is regenerated in the electrolytic cell by electrolysis, wherein the regeneration further comprises generating a gaseous mixture of oxygen and carbon dioxide (CO_2) in the anode chamber; and wherein said gaseous mixture comprises between 66 and 80 % v/v carbon dioxide and between 20% v/v and 34% v/v oxygen, the method comprising the steps of: treating said gaseous mixture of oxygen and carbon dioxide (CO_2) to remove at least 50% oxygen from said mixture.

The aqueous scrubbing liquid may be circulated between the electrolytic cell and the scrubber, where the scrubbing liquid may be a first alkaline, where a first spent aqueous scrubbing liquid is fed to an electrolytic cell, and a first regenerated aqueous scrubbing liquid is fed back to the scrubber from the electrolytic cell, after regeneration in the electrolytic cell. The treatment of the gaseous mixture of oxygen and carbon dioxide to remove oxygen from said mixture may be performed using a gas separator device, where the gas separator device may be a sorbent/solvent gas separator, a membrane separator and/or a cryogenic distillation separator, or any suitable method/device for treating the stream to separate O_2 from a CO_2 rich stream and create a CO_2 rich stream that has a reduced O_2 content.

The regeneration of the scrubbing liquid in the electrolytic cell results in a generation of a gaseous mixture of oxygen and carbon dioxide

This means that at least a substantial amount of oxygen is removed from the mixture. By removing oxygen, i.e. separating O_2 from the CO_2 of the gaseous mixture form

the anode chamber of the electrolytic cell, an increased efficiency is obtained in the CO_2 compression stage. The decrease in efficiency correlates with decrease in gas volume that is to be compressed. e.g. if there is 20% v/v O_2 in 80% v/v CO_2 the energy consumption can be reduced to 80% of the original value.

The carbon capture reaction in the scrubbing step takes place automatically. The operation of the scrubber is thereby an automatic process and requires no power apart from one needed to circulate the liquids. The regeneration process of the first scrubbing liquid that take place in the cathode and anode chambers of the electrolytic cell are electrochemical reactions, which inherently require electrical power. The electrochemical process regenerates the solvent, produces hydrogen at the cathode and a mixture of carbon dioxide (CO_2) and oxygen at the anode. The regeneration thus comprises generating gaseous hydrogen in the cathode chamber and a gaseous mixture of oxygen and carbon dioxide in the anode chamber by electrolysis.

In accordance with the present disclosure the percentages of concentrations of liquids or gas may be defined by % v/v i.e. a volume concentration of a solution, where a solution having 80% CO_2 and 20% O_2 may be seen as a solution of 100 units of a volume, has 80 units of CO_2 and 20 units O_2, where the units may be ml, litres,

According to the first aspect wherein at least 60% of the oxygen is removed from the gaseous mixture, or at least 70% of the oxygen is removed from the gaseous mixture, or at least 80 % of the oxygen is removed from the gaseous mixture, or at least 90% of the oxygen is removed from the gaseous mixture, or at least 95% of the oxygen is removed from the gaseous mixture, or at least 99% of the oxygen is removed from the gaseous mixture. This means that substantially all of the oxygen may be removed before compression, which even further increased the energy saved during the compression stage.

According to the first aspect, the method may further comprise the step of compressing said oxygen depleted gaseous mixture into a substantially pure liquid carbon dioxide. This means that the liquid carbon may easily be transported for other downstream uses. The gas having a first carbon dioxide concentration is any one of a flue gas, an exhaustive gas, air.

According to one alternative of the first aspect wherein the step of treating said gaseous mixture to remove at least 50% oxygen from said mixture comprises: flowing said gaseous mixture through a heating device, thereby consuming said oxygen and creating an output flow of carbon dioxide and dihydrogen oxide (H_2O). The heating device may be a separate burner, or for instance a generator producing district heating and power, and the full flow of the gaseous mixture of carbon dioxide and oxygen could be used instead of air. The carbon dioxide and water may thus be further separated by condensation, and the pure CO_2 can be further cleaned, cooled and compressed for transport.

The heating device may be fed with a fuel, and wherein said fuel is any one of hydrogen, natural gas or biogas and said hydrogen may be a gaseous hydrogen withdrawn from a cathode chamber of said electrolytic cell.

According to another alternative of the first aspect, the step of treating said gaseous mixture to remove at least 50% oxygen from said mixture may comprise utilising said gaseous mixture as an oxidizer in a processes step of scrubbing a flue gas for CO_2.

Through this treatment, if all the oxidant is oxygen mixed with carbon dioxide, the flue gas will intermittently consist of pure CO_2, which can thus be cooled and compressed directly for transport with limited pre-treatment.

According to yet another alternative of the first aspect the step of treating said gaseous mixture to remove at least 50% oxygen from said mixture comprises utilising said gaseous mixture as an oxidizing agent in an aerobic biological treatment process.

By an aerobic biological treatment process is meant for instance a wastewater purification process, and through this treatment the oxygen is depleted during the wastewater purification process and the purified CO_2 can be collected, cooled and compressed for transport.

According to a second aspect there is provided a system for scrubbing a gas, such as flue gas or exhaustive gas, comprising carbon dioxide to deplete the flue gas of carbon dioxide, the system comprising:

- a scrubber arrangement for scrubbing a gas with an alkaline, aqueous scrubbing liquid, comprising a scrubber; and
- a regeneration arrangement for regenerating spent aqueous scrubbing liquid by electrolysis, wherein:
- the regeneration arrangement comprises an electrolytic cell, comprising an anode chamber comprising an anode inlet for receiving the spent aqueous scrubbing liquid and an anode outlet for withdrawing oxygen and carbon dioxide,
- wherein the scrubber is in flow communication with the electrolytic cell;
- a gas separator device for separating oxygen and carbon dioxide withdrawn from the anode chamber from each other, and
- a compressor unit for compressing said substantially pure carbon dioxide withdrawn from said separator device.

According to a third aspect, a regeneration arrangement is provided for regenerating a spent aqueous scrubbing liquid to provide alkaline, aqueous scrubbing liquid, the regeneration arrangement comprising an electrolytic cell, comprising an anode chamber comprising an anode inlet for receiving the spent aqueous scrubbing liquid and an anode outlet for withdrawing oxygen and carbon dioxide, and the cathode chamber comprises an outlet for withdrawing regenerated aqueous scrubbing liquid;

- a gas separator device for separating oxygen and carbon dioxide from the anode chamber from each other,
- a compressor unit for compressing carbon dioxide withdrawn from the first gas separator.

According to one alternative of the systems according to the second or third aspect, the gas separator device may be a heating device. By heating device is meant a device such as a burner, an engine or a generator.

According to another alternative, the gas separator device may be an aerobic biological process facility such as a wastewater treatment plant.

According to the second and third aspects, at least 50% of the oxygen is removed from the gaseous mixture of carbon dioxide and oxygen withdrawn from the anode chamber by or in the gas separator device. Alternatively, at least 60% of the oxygen is removed from the gaseous mixture, or at least 70% of the oxygen is removed from the gaseous mixture, or at least 80 % of the oxygen is removed from the gaseous mixture, or at least 90 % of the oxygen is removed from the gaseous mixture, or at least 95 % of the oxygen is removed from the gaseous mixture, or at least 99 % of the oxygen is removed from the gaseous mixture.

Although the present disclosure has been described above with reference to specific examples, it is not intended to be limited to the specific form set forth herein. Rather, the disclosure is limited only by the accompanying claims and other examples than the specific examples described above are equally possible within the scope of these appended claims.

In the claims, the term "comprises/comprising" does not exclude the presence of other elements or steps. Additionally, although individual features may be included in different claims, these may possibly advantageously be combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous.

In addition, singular references do not exclude a plurality. The terms "a", "an", "first", "second" etc. do not preclude a plurality.

Brief description of the drawings

These and other aspects, features and advantages of which the invention is capable of will be apparent and elucidated from the following description of embodiments of the present invention, reference being made to the accompanying drawings.

Fig. 1 shows a flow path between a scrubber and an electrolytic cell,
Fig. 2 shows a regeneration arrangement of the process scheme,
Fig. 3 shows a Voltage/Current graph for an electrolytic cell, and
Fig. 4 shows a graph showing the CO_2 concentration in volume percentage of a CO_2 mixture stream exiting the electrolytic cell.