The technology being primarily developed for this process involves the use of aqueous amines, e.g. aqueous monoethanolamine, as absorption solvent. Amine scrubbing has been used to separate carbon dioxide (CO_2) from natural gas and hydrogen since 1930. However, it is not yet used on a larger scale for CO_2 capture from coal-fired power plants. The process is energy consuming and the technology has not been implemented in large scale because of the capital costs of installing the facility and the operating costs. Scrubbers using aqueous monoethanolamine as absorption solvent for example use large amounts of heat for regeneration of the solvent used in the scrubber. Presently, there are no other industrial applicable technologies that will provide energy-efficient or timely solutions to CO_2 emission from conventional coal-fired power plants.

Further key areas in development work on the carbon capture process include process integration and optimization for applications in large-scale power plants.

There is an imperative need for improved scrubbing systems that preferably require less heat for CO2 capture.

Summary

Accordingly, there is, according to a first example, provided a method of scrubbing a gas comprising carbon dioxide (CO_2) to deplete the gas of carbon dioxide. The gas comprising carbon dioxide (CO_2) may typically be a result from combustion, such as flue gas or exhaust gas. However, also other gases comprising carbon dioxide (CO_2) may be scrubbed by the present method. An example would be to capture CO_2 from a power plant that generates heat and power from biomass. The method comprises the steps of scrubbing the gas in a scrubber with a first alkaline, aqueous scrubbing liquid to dissolve carbon dioxide (CO_2) as hydrogen carbonate (HCO_3^-) and/or as carbonate (CO_3^{2-}) in the first alkaline, aqueous scrubbing liquid, thereby providing a first spent aqueous scrubbing liquid comprising hydrogen carbonate (HCO_3^-) and/or carbonate (CO_3^{2-}). The first spent aqueous scrubbing liquid has a pH from about 7 to about 9, in order to optimize the subsequent regeneration.

The method further comprises the step of feeding the first spent aqueous scrubbing liquid to an anode chamber of an electrolytic cell with an anode and a cathode. The anode and the cathode of the electrolytic cell are separated by a membrane to provide the anode chamber and a cathode chamber. The membrane is permeable to alkali metals, such as lithium, sodium and potassium, but has no or low permeability to hydrogen carbonate (HCO_3^-) and/or to carbonate (CO_3^2). Typically, the

membrane is permeable only to cations. The membrane may be a cation-exchange membrane. In the electrolytic cell, the first spent aqueous scrubbing liquid is regenerated by electrolysis. In regenerating the spent aqueous scrubbing liquid, a number of electrolytic cells connected in parallel may be used. Before being fed to the anode chamber, the spent aqueous scrubbing liquid may be filtered to remove particulate matter.

In one aspect, the present disclosure refers to a method of scrubbing a gas, such as flue gas or exhaust gas, comprising carbon dioxide to deplete the gas of carbon dioxide (CO2), the method comprising the steps of scrubbing the gas in a scrubber with a first alkaline, aqueous scrubbing liquid to dissolve carbon dioxide (CO2) as hydrogen carbonate (HCO3-) and/or as carbonate (CO32-) in the first alkaline, aqueous scrubbing liquid, thereby providing a first spent aqueous scrubbing liquid comprising hydrogen carbonate (HCO3-) and/or carbonate (CO32-), the first spent aqueous scrubbing liquid having a pH from about 7 to about 9, feeding the first spent aqueous scrubbing liquid to an anode chamber of an electrolytic cell comprising the anode chamber and a cathode chamber separated by a membrane, regenerating the first spent aqueous scrubbing liquid in the electrolytic cell by electrolysis, the electrolysis increasing the pH of the first spent aqueous scrubbing liquid in the cathode chamber, the electrolysis further depleting the first spent aqueous scrubbing liquid of hydrogen carbonate (HCO3-) and of carbonate (CO32-) in the anode chamber by decreasing the pH, the regeneration further comprising generating gaseous hydrogen in the cathode chamber and a gaseous mixture of oxygen and carbon dioxide (CO2) in the anode chamber by electrolysis, and withdrawing regenerated alkaline, aqueous scrubbing liquid from the cathode chamber and re-circulating it to the scrubber wherein the gaseous hydrogen is withdrawn from the cathode chamber, and the gaseous mixture of oxygen and carbon dioxide is withdrawn from the anode chamber.

In electrolysis, water is converted into oxygen and hydronium ions (H_3O^+) at the anode, whereas water is converted into hydrogen and hydroxide ions (OH^-) at the cathode. The electrolysis thus increases the pH of the first spent aqueous scrubbing liquid in the cathode chamber and depletes the first spent aqueous scrubbing liquid of hydrogen carbonate (HCO_3^-) and of carbonate (CO_3^{2-}) in the anode chamber, by decreasing the pH to shift the equilibrium towards carbonic acid in turn shifted into carbon dioxide. The regeneration further comprises generating gaseous hydrogen in the cathode chamber and a gaseous mixture of oxygen and carbon dioxide in the

anode chamber by electrolysis. The chemical reactions and description of the operation of the processes are further described in the Detailed Description herein further below.

The method further comprises the step of withdrawing regenerated alkaline, aqueous scrubbing liquid from the cathode chamber and re-circulating it to the scrubber.

One key difference from the set-up of commercially available amine scrubbers is that the scrubbing liquid in the present method is regenerated by electrochemistry, while scrubbers in the art typically use large amounts of heat for regeneration of the scrubbing liquid used in the scrubber.

According to the present method, in regenerating the scrubbing liquid its pH is increased. Further, the regeneration, as already explained, also generates carbon dioxide and hydrogen, which may be used downstream for synthesis of organic compounds, such as methanol, thus adding further value to the process. The process is ideal for processes such as downstream Power-to-X processes.

The gaseous hydrogen is withdrawn from the cathode chamber and the gaseous mixture of oxygen and carbon dioxide is withdrawn from the anode chamber.

Withdrawing hydrogen, oxygen and carbon dioxide from the regeneration process is advantageous as hydrogen and oxygen can be used to generate electricity, e.g. by a fuel cell, to operate the process partly. Further, hydrogen and carbon dioxide (CO_2) can be used for synthesis of organic compounds, e.g. methanol, thereby compensating for the cost of running the process.

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 that takes 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 actual power consumption will depend on the technical implementation of the process. Overall, the process requires a large amount of electrical energy rather than heat. This is positive, as electrification of the regeneration in carbon capture processes is highly desired. Further, some of the energy may be recovered as heat for district heating. Regeneration of amine-based scrubbing liquids reduces the overall efficiency of a power plant as some of the heat generated rather than being distributed, has to be used to re-generate the scrubbing liquid. Regeneration of alkaline scrubbing liquids comprising dissolved metal hydroxides may be regenerated electrical energy thus not affecting the overall efficiency of a power plant.

In order to dissolve carbon dioxide and shift the equilibrium towards hydrogen carbonate (HCO_3^-) and of carbonate (CO_3^{2-}), the first aqueous scrubbing liquid needs to be alkaline, i.e. have a pH exceeding 7, such as 8 or higher.

Thus, the first alkaline, aqueous scrubbing liquid may comprise a metal hydroxide. According to an example of the method, the first alkaline, aqueous scrubbing liquid comprises one or more of dissolved potassium hydroxide (KOH), dissolved sodium hydroxide (NaOH) and dissolved lithium hydroxide (LiOH). The first alkaline, aqueous scrubbing liquid may comprise potassium hydroxide (KOH). Given its high solubility in water, potassium hydroxide (KOH) is a preferred metal hydroxide.

In the anode chamber, a gaseous mixture of oxygen and carbon dioxide is formed. The ratio between carbon dioxide and oxygen may be approximately 4:1, which allows for an efficient separation of CO_2 and O_2.The method may thus further comprise a step of separating this gaseous mixture of oxygen and carbon dioxide into a first stream, rich in oxygen and/or depleted of carbon dioxide, and a second stream, rich in carbon dioxide and/or depleted of oxygen. The gaseous mixture of oxygen and carbon dioxide may be compressed and/or cooled to provide for separation of liquid

carbon dioxide (CO_2) from gaseous (O_2). According to one example of the method,

carbon dioxide (CO_2) and/or oxygen (O_2) withdrawn from the anode chamber is compressed into liquid carbon dioxide and/or compressed oxygen (O_2).

Further, hydrogen formed in the cathode chamber is withdrawn. Hydrogen withdrawn from the cathode chamber may be used as a fuel to provide electricity, either internally or externally. Hydrogen and oxygen may be used to fuel a fuel cell. The electricity formed may optionally be used to operate the electrolytic cell regenerating the spent aqueous scrubbing liquid. This is advantageous as it at least partly compensates for the electricity consumption of running the process. Further, it may also be of interest to sell hydrogen on the open market.

The anode chamber is typically not operated such that all hydrogen carbonate (HCO_3^-) is converted to carbon dioxide. The method may thus further comprise withdrawing an aqueous stream still comprising some hydrogen carbonate (HCO_3^-) from the anode chamber. This stream may be concentrated, such as by reversed osmosis. The resulting concentrated stream comprising hydrogen carbonate (HCO_3^-) may be re-circulated to the electrolytic cell, thus facilitating further removal of hydrogen carbonate (HCO_3^-).

Typically, the gas comprising carbon dioxide and the scrubbing liquid are fed in contraflow manner to the scrubber to provide for efficient removal of carbon dioxide.

According to one example of the method, the scrubbing of the gas comprising carbon dioxide is performed in at least a first stage and in a second stage. This provides for efficient removal of carbon dioxide, while still providing for optimizing the pH of the spent scrubbing liquid to be regenerated. The scrubbing may be performed in more than two stages.

In scrubbing the gas comprising carbon dioxide in a first stage and in a second stage, the regenerated alkaline, aqueous scrubbing liquid, withdrawn from the cathode chamber, is fed as a second alkaline, aqueous scrubbing liquid to the second stage of scrubbing downstream of the first stage of scrubbing. A second spent scrubbing liquid, resulting from the second stage of scrubbing, is at least partly, fed as the first alkaline, aqueous scrubbing liquid to the first stage of scrubbing upstream of the second stage of scrubbing.

In scrubbing the gas comprising carbon dioxide in several stages, spent scrubbing liquid, resulting from a downstream stage of scrubbing, may be, at least partly, fed as the alkaline, aqueous scrubbing liquid to an upstream stage of scrubbing. Further, the regenerated alkaline, aqueous scrubbing liquid, withdrawn from the cathode chamber, may be fed as an aqueous scrubbing liquid to the last stage of

scrubbing downstream. Furthermore, spent scrubbing liquid from the first stage of scrubbing may be fed to the electrolytic cell to be regenerated.

In scrubbing the gas comprising carbon dioxide in a first stage and in a second stage, the pH of the second alkaline, aqueous scrubbing liquid is preferably higher than the pH of the first alkaline, aqueous scrubbing liquid in order to remove carbon dioxide efficiently. The pH of the second alkaline, aqueous scrubbing liquid may be in the range 12 to 14, such as about 13.5. Further, the pH of the first alkaline, aqueous scrubbing liquid may be in the range 8 to 10, such as about 9.

In scrubbing the gas comprising carbon dioxide in several stages, the pH of the aqueous scrubbing liquid will be lower in up-stream stages than in down-stream stages.

In one exemplary example, the first spent aqueous scrubbing liquid may be fed into the electrolytic cell, where the first spent aqueous scrubbing liquid may have a pH from about 7 to about 9 when the first spent aqueous scrubbing liquid enters the electrolytic cell. This means that the method may provide a recirculation arrangement and/or regeneration arrangment, where the arrangement is configured to reduce the pH value of the first spent aqueous scrubbing liquid to a pH of about 7 to about 9, in order to optimize CO_2 regeneration. The reduction of the pH value may be achieved by utilizing liquids or compositions that are regenerated during the electrolytic process, in order to ensure that the reduction of pH of the first spent aqueous scrubbing liquid occurs in a closed circulation system, where the electrolytic process regenerates the necessary components for the reduction in pH. Alternatively, the reduction of of the pH value of the first spent aquous scrubbing liquid may be obtained by mixing the scrubbing liquid during the scrubbing process to reduce the pH to about 7 to 9.

In one exemplary example, the alkaline solution introduced into the cathode chamber may be have a pH of between about 12 to about 14. Thus the difference in pH between the anode chamber and the cathode chamber may be between about 5 and about 7. Thus the alkaline solution introduced into the cathode chamber may have a pH that is about 5 to about 7 higher than the pH of the first spent aquous scrubbing liquid introduced into the anode chamber.

In examples according to which the scrubbing of the gas comprising carbon dioxide is performed in a first stage and in a second stage, regenerated alkaline, aqueous scrubbing liquid withdrawn from the cathode chamber may be mixed with a part of the second spent scrubbing liquid to provide the second

alkaline, aqueous scrubbing liquid. By mixing these liquids, the pH of the second alkaline,

aqueous scrubbing liquid is lower than the pH of the regenerated alkaline, aqueous scrubbing liquid withdrawn from the cathode chamber. The pH of the second alkaline, aqueous scrubbing liquid may thus be adjusted by changing the ratio of regenerated alkaline, aqueous scrubbing liquid withdrawn from the cathode chamber to the second spent scrubbing liquid. Further, part of the second spent scrubbing liquid may be mixed with a part of a first spent scrubbing liquid, resulting from the first stage of scrubbing, to provide the first alkaline, aqueous scrubbing liquid. By mixing these liquids, the pH of the first alkaline, aqueous scrubbing liquid will be higher than the pH the first spent scrubbing liquid, and the first spent scrubbing liquid may be partly re-cycled.

In order to further optimize the pH within the electrolytic cell, part of the regenerated alkaline, aqueous scrubbing liquid may be re-circulated to the cathode chamber. The regenerated alkaline, aqueous scrubbing liquid may be diluted by an aqueous stream before re-circulating it to the cathode chamber. This aqueous stream may be provided by withdrawing an aqueous stream still comprising some hydrogen carbonate (HCO_{3-}) from the anode chamber and concentrating it, such as by reversed osmosis, to provide an aqueous stream depleted of hydrogen carbonate (HCO_{3-}) and a concentrated stream comprising hydrogen carbonate (HCO_{3-}).

According to a second example, there is in corresponding manner 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 comprises a scrubber arrangement for scrubbing a gas with an alkaline, aqueous scrubbing liquid to dissolve carbon dioxide as hydrogen carbonate (HCO_3^-) and/or as carbonate (CO_3^{2-}) in the alkaline, aqueous scrubbing liquid. The system further comprises a regeneration arrangement for regenerating spent aqueous scrubbing liquid by electrolysis.

The scrubber arrangement comprises a scrubber. The scrubber has an inlet for the gas to be scrubbed and an outlet for a gas depleted of carbon dioxide. The scrubber further has an inlet for receiving the alkaline, aqueous scrubbing liquid and an outlet for withdrawing spent aqueous scrubbing liquid. Preferably, the inlets and outlets are arranged to provide for scrubbing in a counterflow manner.

The regeneration arrangement comprises an electrolytic cell, or a number of electrolytic cells connected in parallel. The electrolytic cell comprises an anode chamber and a cathode camber separated by a membrane. The membrane is permeable to alkali metals, such as lithium, sodium and potassium, but has no or low permeability to hydrogen carbonate (HCO_3^-) and/or carbonate (CO_3^{2-}). Typically, the membrane is permeable only to cations. The membrane may be a cation-exchange

membrane. The anode chamber comprises an anode inlet for receiving the spent aqueous scrubbing liquid from the scrubber arrangement and an anode outlet for withdrawing oxygen and carbon dioxide. The regeneration arrangement may further comprise a filter for filtering spent aqueous scrubbing liquid to be fed to the anode inlet of the anode chamber. Further, the cathode chamber comprises an outlet for withdrawing regenerated aqueous scrubbing liquid and hydrogen. The outlet for spent aqueous scrubbing liquid of the scrubber is in flow communication with the inlet for the spent aqueous scrubbing liquid of the anode chamber. Similarly, the outlet for regenerated aqueous scrubbing liquid of the cathode chamber is flow communication with the inlet for the alkaline, aqueous scrubbing liquid of the scrubber.

In another aspect, the present disclosure refers to 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 (200) for scrubbing a gas with an alkaline, aqueous scrubbing liquid to dissolve carbon dioxide as hydrogen carbonate (HCO_3^-) and/or as carbonate (CO_3^{2-}) in the alkaline, aqueous scrubbing liquid, and a regeneration arrangement for regenerating spent aqueous scrubbing liquid by electrolysis, wherein the scrubber arrangement comprises a scrubber, the scrubber having an inlet for the gas to be scrubbed and an outlet for gas depleted of carbon dioxide, the scrubber further having an inlet for receiving the alkaline, aqueous scrubbing liquid and an outlet for withdrawing spent aqueous scrubbing liquid, and the regeneration arrangement comprises an electrolytic cell, comprising an anode chamber and a cathode camber separated by a membrane, the 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 comprising an outlet for withdrawing regenerated aqueous scrubbing liquid and hydrogen, wherein the outlet for spent aqueous scrubbing liquid of the scrubber is in flow communication with the inlet for the spent aqueous scrubbing liquid of the anode chamber, and the outlet for regenerated aqueous scrubbing liquid of the cathode chamber is flow communication with the inlet for the alkaline, aqueous scrubbing liquid of the scrubber.

An advantage of this system is that it comprises both a scrubber arrangement and a regeneration arrangement where output from the scrubber arrangement can be regenerated by electrolysis and reused in the scrubber arrangement, enabling and optimizing a complete, energy and cost efficient system of depleting gas of carbon dioxide, driven by electrical power.

According to one example, the scrubber arrangement comprises a first and a second buffer tank for alkaline, aqueous scrubbing liquid. Further, the scrubber comprises at least a first and a second absorber. It may comprise more than two absorbers. Further, a number of scrubbers may be used. A number of scrubbers may be either connected in series or in parallel.

The first absorber comprises an inlet for receiving alkaline, aqueous scrubbing liquid from the first buffer tank. Further, the first absorber comprises an outlet for withdrawing spent aqueous scrubbing liquid from first absorber to feed to an inlet of the first buffer tank. Thus, alkaline, aqueous scrubbing liquid may be circulated between the first absorber and the first buffer tank. While the presence of the first buffer tank is preferred, it may according to some examples be dispensed with and the alkaline, aqueous scrubbing liquid may be re-circulated over the first absorber by a first pipe system connecting the inlet and the outlet of the first absorber. Further, the first buffer tank is in flow communication with the inlet for the spent aqueous scrubbing liquid of the anode chamber.

The second absorber comprises an inlet for receiving alkaline, aqueous scrubbing liquid from the second buffer tank. Further, the second absorber comprises an outlet for withdrawing spent aqueous scrubbing liquid from second absorber to feed to an inlet of the second buffer tank. Thus, alkaline, aqueous scrubbing liquid may be circulated between the second absorber and the second buffer tank. While the

presence of the second buffer tank is preferred, it may according to some examples be dispensed with and the alkaline, aqueous scrubbing liquid may be re-circulated over the second absorber by a first pipe system connecting the inlet and the outlet of the second absorber. Further, the outlet for regenerated aqueous scrubbing liquid of the cathode chamber is in flow communication with the inlet of the second absorber. Furthermore, the outlet of the second absorber is in flow communication with the inlet of the first absorber.

If the scrubber arrangement comprises more than two absorbers, they may be arranged such that the outlet of a downstream absorber is in flow communication with the inlet of an upstream absorber. Further, an inlet of the last absorber (i.e. the most downstream absorber close to an outlet for scrubbed gas) is in flow communication with the outlet for regenerated aqueous scrubbing liquid of the cathode chamber. Furthermore, an outlet of the first absorber (i.e. the most upstream close to an inlet for the gas to be scrubbed) is in flow communication with an inlet for the spent aqueous scrubbing liquid of the anode chamber. Typically, the alkaline, aqueous scrubbing liquid may be re-circulated over each absorber by means of a pipe system connecting the inlet and the outlet of the respective absorber. Similar to the first and second absorber, any further absorbers may be in flow communication with a corresponding buffer tank.

To further provide for adjusting flows independently, the scrubber arrangement may further comprise a third buffer tank for regenerated aqueous scrubbing liquid. The third buffer tank is in flow communication with the outlet for regenerated aqueous scrubbing liquid of the cathode chamber and with the inlet of the second absorber. Further, the scrubber arrangement may comprise a fourth buffer tank for spent aqueous scrubbing liquid. The fourth buffer tank is in flow communication with the first buffer tank and with an inlet for the spent aqueous scrubbing liquid of the anode chamber.

This design enables regenerated aqueous scrubbing liquid of the cathode chamber to be reused in the scrubbing process and enables optimization of the pH of the liquids before being recycled into the scrubber.

The regeneration arrangement may further comprise a first compressor unit for compressing hydrogen withdrawn from the cathode chamber and/or a second compressor unit for compressing oxygen and carbon dioxide withdrawn from the anode chamber. Further, regeneration arrangement may comprise a first gas separator for separating oxygen and carbon dioxide withdrawn from the anode chamber from each

other. Typically, the first gas separator is arranged downstream the second compressor unit to separate liquid carbon dioxide from gaseous oxygen.

This way the system can provide compressed hydrogen, compressed oxygen and carbon dioxide, as well as separated oxygen and carbon dioxide, for commercial exploration.

According to one example, the regeneration arrangement further comprises a concentrator, such as a filter, for concentrating an aqueous stream comprising some hydrogen carbonate (HCO_3^-) withdrawn from the anode chamber to provide a concentrated stream comprising hydrogen carbonate (HCO_3^-) and an aqueous stream depleted of hydrogen carbonate (HCO_3^-). The concentrator is arranged in flow communication, typically by pipes, with the electrolytic cell such that:

- the aqueous stream comprising some hydrogen carbonate (HCO_3^-) may be withdrawn from the anode chamber and fed to the concentrator;

- the concentrated stream comprising hydrogen carbonate (HCO_3^-) may be withdrawn from the concentrator and fed to the anode chamber; and/or

- the aqueous stream depleted of hydrogen carbonate (HCO_3^-) may be withdrawn from the concentrator and fed to the cathode chamber.

The regeneration arrangement may further comprise a first balance tank for regenerated alkaline, aqueous scrubbing liquid. The first balance may be arranged in flow communication, typically by pipes, with the electrolytic cell and it may have:

- a first inlet for receiving regenerated alkaline, aqueous scrubbing liquid from the cathode chamber;

- a second inlet for receiving the aqueous stream depleted of hydrogen carbonate (HCO_3^-) withdrawn from the concentrator; and/or

- an outlet for feeding diluted regenerated alkaline, aqueous scrubbing liquid to the cathode chamber of electrolytic cell.

Further, the regeneration arrangement may comprise a second balance tank for spent aqueous scrubbing liquid. The second balance may be arranged in flow communication, typically by pipes, with the electrolytic cell and it may have:

- a first inlet for receiving spent aqueous scrubbing liquid from the scrubber arrangement;

- a second inlet for receiving the concentrated stream comprising hydrogen carbonate (HCO_3^-) from the concentrator; and/or

- an outlet for feeding spent aqueous scrubbing liquid to the anode chamber of the electrolytic cell.

In scrubbing flue gas in a power plant, the scrubbing and the regeneration are typically run continuously at the plant. It is however possible to run the scrubbing separately from the regeneration. As an example, the scrubbing may be operated in a vehicle, whereas the regeneration takes place at a central unit, which may serve several vehicles. The vehicle may be provided with a scrubber arrangement comprising a third buffer tank for regenerated aqueous scrubbing liquid and a fourth buffer tank for spent aqueous scrubbing liquid. By providing the vehicle with such a scrubber arrangement, it may be run independently of the rearrangement until the third buffer tank runs empty and/or the fourth buffer tank becomes full.

According to a third example, there is thus provided scrubber arrangement for scrubbing a gas, such as flue gas, comprising carbon dioxide to deplete the flue gas of carbon dioxide. As already described above, the scrubber arrangement comprises a scrubber having an inlet for the gas to be scrubbed and an outlet for gas depleted of carbon dioxide. The scrubber further has an inlet for receiving the alkaline, aqueous scrubbing liquid and an outlet for withdrawing spent aqueous scrubbing liquid. The scrubber arrangement comprises a first and a second buffer tank for alkaline, aqueous scrubbing liquid, and the scrubber at least comprises a first and a second absorber. The first absorber comprises an inlet for receiving alkaline, aqueous scrubbing liquid from the first buffer tank and an outlet for withdrawing spent aqueous scrubbing liquid and feed it to an inlet of the first buffer tank. Thus, alkaline, aqueous scrubbing liquid may be circulated between the first absorber and the first buffer tank. While the presence of the first buffer tank is preferred, it may according to some examples be dispensed with and the alkaline, aqueous scrubbing liquid may be re-circulated over the first absorber by a first pipe system connecting the inlet and the outlet of the first absorber. The second absorber comprises an inlet for receiving alkaline, aqueous scrubbing liquid from the second buffer tank and an outlet for withdrawing spent aqueous scrubbing liquid from the second absorber to feed to an inlet of the second buffer tank. Thus, alkaline, aqueous scrubbing liquid may be circulated between the second absorber and the second buffer tank. While the presence of the second buffer tank is preferred, it may according to some examples be dispensed with and the alkaline, aqueous scrubbing liquid may be re-circulated over the second absorber by a second pipe system connecting the inlet and the outlet of the first absorber. The outlet of the second absorber is in flow communication with the inlet of the first absorber.

If the scrubber arrangement comprises more than two absorbers, they may be arranged such that the outlet of a downstream absorber is in flow communication with

the inlet of an upstream absorber. Further, an inlet of the last absorber (i.e. the most downstream absorber close to an outlet for scrubbed gas) is in flow communication with the outlet for regenerated aqueous scrubbing liquid of the cathode chamber. Furthermore, an outlet of the first absorber (i.e. the most upstream close to an inlet for the gas to be scrubbed) is in flow communication with an inlet for the spent aqueous scrubbing liquid of the anode chamber. Typically, the alkaline, aqueous scrubbing liquid may be re-circulated over each absorber by means of a pipe system connecting the inlet and the outlet of the respective absorber. Similar to the first and second absorber, any further absorbers may be in flow communication with a corresponding buffer tank.

According to one example, the scrubber arrangement further comprises a third buffer tank for regenerated aqueous scrubbing liquid. The third buffer tank has an inlet for receiving regenerated aqueous scrubbing liquid, such that the third buffer tank may be filled up with regenerated aqueous scrubbing liquid. Further, the third buffer tank is in flow communication with the inlet of the second absorber. Furthermore, the scrubber arrangement may comprise a fourth buffer tank for spent aqueous scrubbing liquid. The fourth buffer tank is in flow communication with the first buffer tank, such that the fourth buffer tank may be filled up with regenerated aqueous scrubbing liquid in operating the scrubber arrangement. The fourth buffer tank further has an outlet for withdrawing spent aqueous scrubbing liquid, such that the fourth buffer tank may be emptied.

By providing such a scrubber arrangement, it can be utilized without being directly connected to any regeneration arrangement. It may for example be installed in a vehicle for scrubbing an exhaust gas obtained in the operation of the vehicle. The third buffer tank can be filled with alkaline, aqueous scrubbing liquid to be used in the scrubbing process. Spent aqueous scrubbing liquid can be withdrawn from the fourth buffer tank to empty it at a convenient time point, such as when re-fueling the vehicle, for it to be emptied after being filled up during the process.

Correspondingly, there is, according to a fourth example, provided a regeneration arrangement for regenerating a spent aqueous scrubbing liquid comprising hydrogen carbonate (HCO_3^-) and/or carbonate (CO_3^{2-}) used in electrolysis to provide alkaline, aqueous scrubbing liquid. The regeneration arrangement has already been described herein above. It comprises an electrolytic cell. The electrolytic cell comprises an anode chamber and a cathode camber separated by a membrane. The anode is present within the anode chamber and the cathode is present within the cathode chamber. The anode chamber comprises an anode inlet for receiving the

liquid to be regenerated, may be withdrawn from the fourth buffer tank. Furthermore, the fourth buffer tank has inlet for receiving spent aqueous scrubbing liquid. Thus, the fourth buffer tank may be filled up in emptying a corresponding buffer tank of the scrubbing system.

The regeneration arrangement may further comprise a first compressor unit for compressing hydrogen withdrawn from the cathode chamber. Further, the regeneration arrangement may comprise a second compressor unit for compressing oxygen and carbon dioxide withdrawn from the anode chamber, and/or a first gas separator for separating oxygen and carbon dioxide withdrawn from the anode chamber from each other. Typically, the first gas separator is arranged downstream the second compressor unit to separate liquid carbon dioxide from gaseous oxygen.

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, in which:

Fig. 1 shows a flow path between a scrubber and an electrolytic cell;

Fig. 2 shows a process scheme of a system for scrubbing flue gas;

Fig. 3 shows a scrubber arrangement of the process scheme of Fig. 2;

Fig. 4 shows a regeneration arrangement of the process scheme of Fig. 2;