REMOVAL OF CO₂ FROM FLUE GAS

Abstract: This invention concerns a method and plant for energy efficient removal of CO₂ from flue gases by scrubbing the flue gas. The invention is especially suited for use in connection with thermal power plants fuelled with carbon-containing fuels, and it may easily be implemented into existing power plants. The invention is based on the realisation that the steam required in the stripping column(s) may be obtained by a second CO₂ generating process with a steam system tuned to supplying the stripping column(s). Thus a process plant according to the invention will comprise two sections: a primary CO₂ generating process that serves as the main product supplier; a CO₂ capturing (often denoted scrubber) plant for capturing and separating CO₂ from the flue gases in the primary and secondary CO₂ generating processes; and a second CO₂ generating process which serves as a second product supplier and which has a steam system tuned to deliver the required steam for running the desorption column(s) of the CO₂ capturing plant.
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This invention concerns a method and plant for energy efficient removal of CO₂ from flue gases by scrubbing the flue gas. The invention is especially suited for use in connection with thermal power plants fuelled with carbon-containing fuels, and it may easily be implemented into existing power plants.

Background

Fossil fuels have been the most important energy carrier in the world for almost a century. Presently they cover about 4/5 of the global energy consumption, and practically all sectors of the present industrial societies are highly dependent upon using fossil fuels as energy carrier including the energy sector. A large portion of the world demand for heat and electric power is based on use of thermal power plants fuelled with fossil fuels.

The combustion products of fossil fuels are mainly gaseous CO₂ and H₂O (in case of using hydrocarbon based fossil fuels). The present consumption of fossil fuels produces about 25 billion metric tonnes CO₂ per year which is discharged into the atmosphere. Fossil fuels are remains of ancient biomass that have been transformed to carbon or hydrocarbon compounds in certain geological formations. When fossil carbon is retrieved from the geological formations and combusted, it will enter the present carbon cycle of the earth and thus change the equilibrium state of this cycle. This results in an accumulation of CO₂ in the atmosphere and oceans, as well as increasing the biomass of the world. Approximately half of the discharged CO₂ is accumulated in the atmosphere, and has so far resulted in an increase of the atmospheric concentration of CO₂ by about 30 % since 1850, or from about 280 ppm to about 370 ppm.

CO₂ is one of several greenhouse gases in the atmosphere. Greenhouse gases have absorption bands in the frequency area typical for the black body radiation from the surface of the earth, and will thus function as an isolating blanket around the earth which retains the earth's radiant heat loss to the space. The greenhouse effect is vital to the life on earth as we know it, since the total greenhouse effect raises the global mean temperature in the troposphere by approx. 30 °C to a comfortable global mean temperature of about +15 °C. However, there is an increasing concern that if the humans continue to discharge huge amounts of greenhouse gases into atmosphere, the earth's heat balance may be sufficiently displaced to induce possibly dangerous climatic changes such as substantial melt down of glaciers, increased sea levels, altered precipitation patterns, more extreme weather, etc. This concern is based on many recent discoveries in climate research, and has led to official statements from several leading scientific societies of the world warning that if we who live today do not reduce or at least ends the increase of our greenhouse gas discharges, we will probably seriously alter the climate for the
coming generations. This message is finding more and more accept in the public opinion in many countries, and it is therefore expected that there will be introduced further regulations of discharge of greenhouse gases in near future.

Our long use of fossil fuels as the dominant energy carrier have resulted in that most of present infrastructure in the world for energy supply are based on this energy carrier. Thus it will be in practical terms literally impossible to substitute this infrastructure with a non-fossil fuel based alternative immediately on a short term. Nor will it be economical feasible, especially not when taking into consideration the rather huge remaining reservoirs of coal, oil and natural gas in the world. This means that any realistic expectation of shortcoming cuts in greenhouse gas discharges should include implementing technology that may be retrofitted to existing infrastructure for capturing and disposing the CO₂ produced during combustion of carbonaceous fuels.

Prior art

One proposed method for disposal of large quantities of CO₂ is injecting it into underground deep saline aquifers, which are porous rock formations filled with salty water. It is also suggested to inject CO₂ as pressurizing agent in producing oil fields or in depleted reservoirs, or to inject it at great sea depth. The concept of capturing and subsequent injection of CO₂ gas into earth formations or deep sea water is considered to be an economically viable solution for process industry, thermal power plants and other facilities that produces large volumes of CO₂.

A mature and well proven technology for large scale capturing and separating CO₂ out of a gas phase is scrubbing the gas-phase by passing it through an absorbent, usually an amine dissolved in water. This technology is presently considered to be the best available technology, and has found long use in several industries with need for removing CO₂ from a gas phase, including cleaning flue gases from thermal power plants, removal of CO₂ from natural gas, removal of CO₂ from the process line during production of NH₃ etc.

CO₂ capture plants by absorption usually includes an absorption column, often denoted scrubber or absorber, that captures the CO₂ and a desorption column, often denoted stripper, for regenerating the absorbent and releasing the captured CO₂. Both absorber and stripper are usually vertically oriented enabling to obtain a counter flow between the liquid and the gas phase in order to exchange the CO₂ between the liquid and gas phases. There may be employed more than one absorber columns and one or more stripping columns for each absorber, depending on the volume flow of gas that needs to be handled.

The absorber functions as follows: The absorbent binds CO₂ in a weak chemical bonding at moderate temperatures. By introducing the absorbent dissolved in a
liquid solvent (usually water) in the upper section and simultaneously introduce a
gas-phase that is to be stripped for CO₂ at the lower section of an absorber column,
the absorbent liquid will flow downwards and the gas-phase will rise upwards in a
counter flow through the column, and thus obtain that the absorbent phase becomes
enriched and the gas-phase correspondingly depleted for CO₂ on their way through
the absorber column. When the gas-phase reaches the top of the absorber column it
will usually be depleted most of its CO₂ content, and may be vented out in the
atmosphere or sent to further treatment. The CO₂ enriched liquid absorbent phase is
taken out at the lower section of the absorber column and then sent to the stripper
(the desorption column(s)) for regeneration.

The desorption column functions as follows: The weak chemical bonding between
the absorbent and CO₂ will break at elevated temperatures, such that the CO₂-
enriched liquid absorbent solution from the absorber may be regenerated (depleted
for absorbed CO₂) by introducing it at an appropriate elevated temperature in the
upper section of the desorption column and simultaneously introduce additional heat
(usually provided by hot steam) in the lower section of the desorption column. Then
the absorbent be heated sufficiently to release the absorbed CO₂ and thus become
regenerated as absorbent on its way through the desorption column. The released
CO₂ will form gas bubbles and rise up to the top of the desorption column where it
may be collected for further processing as more or less pure CO₂ gas. The
regenerated absorbent solution is taken out at the lower section of the desorption
column, cooled to moderate temperatures and then reintroduced in the upper section
of the absorption column(s) of the absorber for being used in a new cycle as CO₂
absorbent.

For amine based absorbents, the most commonly employed CO₂ capturing method,
the moderate temperatures are usually 40-50 °C in the absorber column and the
elevated temperatures in the stripping column are usually 100-130 °C. The major
disadvantage with amine absorption is the relatively huge temperature difference
between the adsorption and desorption phases. Even though much of this
temperature elevation and lowering of the amine solution may be obtained by heat
exchanging the cold enriched amine solution from the absorber with the hot
regenerated amine solution exiting the stripper, there is still a substantial need for
heat energy to strip the amine solution in the stripper. This heat energy is usually
obtained by heat exchanging the amine solution in the stripper with hot steam of
130-140 °C. The energy consumption in amine scrubber plants is partially electrical
energy for running pumps for forcing amine solution, steam and cooling water
through the plant, and energy associated with providing hot steam of about 130 —
140 °C. The latter constitutes nearly all of the energy consumption in amine
scrubber plants.
In cases where the CO₂ generating process plant includes a steam system, it is in principle possible to integrate this steam system with the CO₂ capturing and separation process for providing the hot steam required by the stripping columns. This will substantially reduce the energy loss of the combined CO₂ generating and CO₂ capturing and separating process. However, due to the relatively high temperature of the steam required to strip the absorbent, the heat recovery steam generator of most conventional CO₂ generating process plants needs to be substantially rebuilt in order to provide steam at these temperatures. This makes it impossible to retrofit CO₂ capturing equipment to existing CO₂ generating plants without shutting down the entire plant and reconstructing of the heat recovery steam generator. Another disadvantage is that the primary process of the plant, the CO₂ generating process will be less efficient since energy in the form of hot steam is extracted to be used in the stripping column (but the entire process including CO₂ capturing will be more efficient). In addition to this, an integrated primary CO₂ generating process and CO₂ capturing process means that both processes must be operated as one process, meaning less flexibility and lower on-line factor for the entire complex as compared to the CO₂ generating process alone. These consequences are considered sufficiently detrimental that it is better to pay the penalty of reduced energy efficiency and instead provide the hot steam required by the stripping columns from an external process.

The penalty, the loss of energy efficiency by operating the primary CO₂ generating process and the CO₂ capturing process as two separate processes is substantial. For example, for the present NGCC plants (thermal power plants fuelled by natural gas), the overall net electrical energy yield will be lowered from approx. 58% without CO₂ capturing to about 48-50% when using amine scrubbing. There is thus a substantial loss of energy associated with capturing the greenhouse gas discharges from combustion gases, and a corresponding need for more efficient ways of performing CO₂ capturing of the combustion gases.

Objectives of the invention

The main objective of this invention is to provide a method and plant for reducing the energy costs associated with capturing and separation of CO₂ in flue gases by use of conventional gas scrubbing technique.

A further objective is to provide a method and plant for capturing and separating CO₂ from flue gases that may easily be retrofitted to existing CO₂ generating processes or plants.

A further objective is to obtain a method and plant for capturing and separating CO₂ from flue gases that may be run independently of the CO₂ generating process.
The objectives of the invention may be obtained by a method and plant characterised by the features given in the following description of the invention and/or in the appended patent claims.

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Figure 1 shows a schematic view of a preferred embodiment in the form of an installation for producing electric energy with CO₂ capture according to the invention.

**Principal description of the invention**

The invention is based on the realisation that the steam required to run the desorption process may be obtained by a second CO₂ generating process with a steam system tuned to supplying the necessary thermal energy. Thus a process plant according to the invention will comprise three sections:

- a primary CO₂ generating process that serves as the main product supplier,
- a CO₂ capturing and separating section of CO₂ from the flue gases in the primary and secondary CO₂ generating processes based on an absorption and desorption process, respectively, and
- a second CO₂ generating process which serves as a second product supplier and which has a steam system tuned to deliver the required steam for running the desorption process of the CO₂ capturing and separating section.

As used herein, the term "flue gas" means any post-process gas containing CO₂, including for example exhaust gas, discharge gas, process gas etc. The term "CO₂ capturing and separating section" or "scrubber plant" shall mean any plant or process section where CO₂ in a flue gas is captured by absorption by an absorbent and then separated into a substantially pure CO₂ gas phase by desorption of the absorbent.

This specific combination provides a benefit in that the primary CO₂ generating process may be operated independently of the remaining process sections in the plant, CO₂ capturing and separating section and secondary product supplier. The only link between the primary product producing section and the remaining two sections is a pipeline that transfers the flue gases from the primary CO₂ generating process to the absorption process of the CO₂ capturing and separating section. This allows operating and optimising the primary product producing section in the conventional manner that existing plants are operated; focusing on optimised energy efficiency in the primary product supplying process. In addition, the inventive combination may easily be retrofitted to existing CO₂ generating processes.

These benefits are similar to those obtained by the conventional solution where the steam needed to run the desorption process is provided by an external source (not by the steam system of the primary CO₂ generating process). However, the
inventive combination has a major advantage over prior art in that the implementation of a second product supplying process as steam supplier to the CO₂ capturing and separating section will increase the product output from the plant without increasing the need for external energy to run the absorption process section accordingly. Further, the waste heat from the secondary product supplying process may be fully utilised in the desorption process of the CO₂ capturing and separating section. Thus the energy efficiency of the plant is substantially increased and the penalty for implementing CO₂ capturing and separation is correspondingly reduced.

A further advantage may be obtained by using flue gas from the primary CO₂ generating process as oxygen supply for the secondary CO₂ generating process. In this case, the secondary CO₂ generating process may be run without significantly increase in the flue gas volumes in the plant, such that the absorption section of the CO₂ capturing and separating section may be scaled for the flue gas volumes from the primary CO₂ generating process only. This allows an easy retrofitting of the secondary CO₂ generating process into existing plants with CO₂ capturing and separating sections. Some CO₂ generating processes, for instance gas turbines use atmospheric air as oxygen supply and produce flue gases with only a few percent CO₂. Thus, only a fraction of the oxygen in the fresh air will be consumed in the primary CO₂ generating process, such that the flue gas contains sufficient oxygen to be used in a second CO₂ generating process. The flues gases from a modern natural gas combined cycle (NGCC) thermal power plant is about 3-4 %, meaning that the flue gas will contain about 13-15 % O₂ which is sufficient for a second combustion process.

In a further aspect of the invention, there may also be obtained recovery and reuse of heat that otherwise would be lost to the surroundings by implementing heat pump(s). Examples of suitable heat sources are condensed water in the stripping column, overhead from the desorption process, residual heat in the flue gases from the second CO₂ producing process, etc. The heat pump may be driven by the steam delivered by the steam system of the second CO₂ generating process. It is also possible to design the steam system of the second CO₂ generating process such that it provides steam for driving back-pressure driven turbines that runs the CO₂ compressor, fans and pumps etc. of the entire plant. This will reduce the need for internal consumption of electric energy in the plant, and thus further increase the energy efficiency for the entire process. The latter aspect requires a careful design of the steam system, boiler and superheater of the second CO₂ generating process.

List of figures
Figure 1 is a schematic diagram showing a first preferred embodiment of the invention.
Figure 2 is a schematic diagram showing a second preferred embodiment of the invention.
Preferred embodiments of the invention

The invention will be described in more detail under reference to preferred embodiments of the invention. The preferred embodiments should however not be considered as a limitation of the invention.

The preferred embodiments of the invention relates to conventional thermal power plants known as NGCC plants which are fuelled on natural gas. Due to vast known reserves of natural gas, many such power plants are build and operated today, and many more will be build in the coming years. It is thus important from a climatic point of view to implement these, both existing and projected power plants with CO₂ capturing. The preferred embodiments of the invention employs NGCC thermal power plants as both the primary and secondary CO₂ generating process. The CO₂ capturing is provided by a conventional amine based scrubbing plant comprising one or more absorption and desorption columns.

First preferred embodiment

The first preferred embodiment has implemented a heat pump for recovery of the heat loss from the desorption column(s), residual heat of the flue gas from the second CO₂ producing process, and steam driven turbines in the plant. By this combination of more or less known features, the first preferred embodiment of the invention is able to cut the penalty in energy efficiency due to CO₂ capturing by at least 50 %, and thus substantially improve operational expenditures of NGCC plants with CO₂ capturing.

The first preferred embodiment of the invention is schematically presented in Figure 1. The primary conventional NGCC thermal power plant is given as items 1 to 6 in the Figure, where numeral 1 is the primary electric power generator, 2 is the steam turbines (shown schematically as one, but comprises high, intermediate and low pressure steam turbines), 3 is the primary gas turbine, 4 is the heat recovery steam generator, 5 is the flue gas chimney, 6 is the condensate circulation loop comprising a condenser and a circulation pump. A list of all reference numbers is attached at the end of the description. The NGCC thermal power plant is a conventional plant well known to a skilled person in the art and needs no further description. The primary NGCC plant is operated in a conventional manner aimed at maximum net energy efficiency (approx. 58 %), meaning that the heat recovery steam generator 4 is operated for minimizing the heat loss to the cooling water through condenser 6 such that it holds about 20 - 40 °C. The only modification is that due to the CO₂ capturing, the flue gases in the chimney 5 is collected and sent via a flue gas pipeline 7 and flue gas fan 8 to the CO₂ handling plant. The natural gas is fed to the primary gas turbine 3 via a pipeline 31.

The CO₂ capturing is provided by a conventional amine based capturing plant, comprising one or more absorption and desorption columns for capturing and
separating the CO₂ in the flue gas, respectively. The construction, functionality and scaling of amine based scrubber plants are well known to a skilled person in the art, and need no further description. Figure 1 shows one absorption column 9 and one stripping column 13, but the number of and dimensioning of these columns are as mentioned dependent upon the flue gas volumes and the flue gas CO₂ concentration.

The remaining constituents of conventional CO₂ capturing plants are an exit 10 for purified flue gas, a pipeline 12a with pump for circulating the enriched amine solution from the absorption column(s) to the desorption column(s), and a pipeline 12b with pump for circulating the regenerated amine solution from the desorption to the absorption column(s), one or more heat exchangers 11 for heat exchanging the cold enriched amine solution in pipeline 12a with the hot regenerated amine solution in the pipeline 12b, a pipeline 24 for supplying hot steam to the desorption column(s) and an outlet pipeline 14 for stripped CO₂. The temperature in the desorption column(s) 13 has to be limited to avoid degradation of the absorbent.

The suitable temperature range for regeneration of the absorbent will depend on the chemicals used, typically between 100 and 160 °C, preferably between 110 and 150 °C, and most preferably between 120 and 130 °C. This corresponds to condensation of steam between 1 and 6 bars absolute. The steam consumption for the regeneration will be above 1 tonne steam/tonne CO₂ captured, typical values are 1.3 to 1.6 tonne steam/tonne CO₂.

All items presented so far are conventional technique for NGCC thermal power plants with CO₂ capturing. The invention is related to the implementation of a second gas turbine 27 fed with the flue gas from the primary main gas turbine 3 as oxygen supply, and where a second steam generating system or boiler 26 provides the steam for the desorption column(s) 13 and optionally heat pump(s) and back-pressure turbines. The second gas turbine may be connected to the NGCC power plant and CO₂ capturing section as follows: The flue gas pipeline 7 is branched such that a part stream is led via pipeline 35 to the second gas turbine 27. The natural gas supplying pipeline 31 is also branched to feed the second gas turbine 27. The flue gases from the second gas turbine are led via pipeline 29 with fan to pipeline 7 downstream of the connection point with pipeline 30. In this way, the second gas turbine may produce electricity via generator 28 without significantly increasing the flue gas volumes in the plant without need for up-scaling the absorption column(s). However, the concentration of CO₂ in the flue gas entering the CO₂ absorber will be increased, which may lead to a need for increased stripping capacity.

The heat content in the flue gases from the second gas turbine 27 are taken out in a second steam boiler 26 that produces heated steam to the stripping column(s) 13. To achieve a thermal efficiency as high as possible, the steam boiler 26 in the preferred embodiment is designed for the highest steam pressure and temperature required by the downstream consumers. As the CO₂ capture plant produces CO₂ at close to
atmospheric pressure, a CO₂ compressor 16 is required for delivery to the recipient 34. The CO₂ capture plant also calls for large flue gas fans, 8 and 29, these are also driven by the steam in back pressure turbines in this preferred embodiment. The second steam boiler 26 must hence be designed for supply of steam at a pressure and temperature high enough to give the required compression energy in back pressure turbines, 17, 18 and 20. The steam from these turbines is supplied to the desorption column(s) 13 in the CO₂ capture plant through pipeline 23. Typical temperature and pressure required in this case is steam in the area of 50 - 150 bar and 400 - 600 °C from the second steam boiler 26. After passing the back-pressure turbines, the temperature and pressure of the steam are reduced to about 3 bar and 130-140°C before entering the desorption column(s) via pipeline 23.

Regeneration of the absorbent is carried out at temperatures at approx. 100 °C. Hence energy that would be lost to the cooling water in the overhead condenser 15a may be utilised. In the preferred embodiment of the invention, this is done by circulating water from a heat pump vacuum vessel 21 via a pipeline 22 with pump through the first part of an overhead condenser 15a. Another available heat source is the condensate from the steam supply to the stripping column(s) 13. This condensate is flashed through a pressure control valve 33 to the vacuum vessel 21. The pressure in the vacuum vessel 21 is kept at a low value by a steam compressor 19 which transfers the flash steam from the vacuum vessel 21 to the steam header 23 leading to the stripping column(s) 13. The steam system will also have to be equipped with condensate injection pipes for control of the steam temperatures as required. The steam compressor 19 (heat pump) is preferably driven by a back pressure turbine 20. The function of the heat pump is to lift the energy from one temperature level to a higher temperature level at which the energy can be utilized. The advantages are obvious when a part of this energy, as indicated on Figure 1, is collected from the overhead condenser 15a where the energy otherwise would have been discarded to the cooling water. Also other sources of heat at suitable temperature levels may be included, such as flue gas discharged from the second boiler 26.

The intention with the heat pump is hence to reduce the need for energy from the boiler 26 to run the desorption process. Typical values of the various steam and water streams in the heat pump are: Steam that exits the desorption column(s) has a temperature of about 90 - 110 °C. The vacuum vessel 21 contains water and saturated steam at about 60 - 70 °C. Water fed from the vacuum vessel 21 via pipeline 25 to steam boiler 26 has a temperature of about 60 - 70 °C, condensate from the steam supply of the desorption column(s) 13 flows via pipeline 33 and pressure control valve has a temperature of approx. 130 °C, condensate extracted from the vacuum vessel 21 at about 60 - 70 °C is passed through overhead
condenser 15 a via pipeline 22, and lifted to a higher temperature before entering the vacuum vessel 21 via pipeline 32.

A CO₂ capture plant with heat pump may need steam in the order of 100 bars and 500 °C for driving the back pressure turbines 17, 18 and 20. This means that still higher value energy is available in an energy plant with efficient combustion of natural gas. This invention therefore includes a gas turbine 27 with a power generator 28 for utilization of this high value energy for the production of electric power.

In this way, the first preferred embodiment of the invention combines several techniques in a way that optimizes the energy supply to the CO₂ capturing section. These techniques are:

1. Generation of steam at high pressure and temperature for driving the back pressure turbines, and thereafter providing heat for running the desorption process.
2. Heat recovery through heat pump.
3. Recovery of high value energy through gas turbine with power generation.
4. Use of oxygen containing flue gas as combustion air.

The combination of these four techniques will give significantly lower CO₂ capture penalty than presently known energy supply systems, since the loss in overall thermal efficiency, i.e. the penalty for CO₂ capture, will be significantly reduced. A penalty as low as 5 percentage points or less can be achieved. The reason is that the optimized energy plant reaches a thermal efficiency above 90 %. The heat of condensation of steam, which is normally lost to the cooling water in for example a NGCC power plant, is utilized fully in the stripping column(s) 13 in the CO₂ capture plant. The only loss is in the flue gas through the fan 29 at the outlet of the energy plant.

The energy balance for the second gas turbine 27, generator 28 and the downstream boiler 26 may have to be established for each case individually. In some cases additional flexibility may be required. This flexibility can be achieved through the use of the following design tools:

1. Installation of additional gas burner(s) between the second gas turbine 27 and the boiler 26.
2. Cooling of the flue gas downstream the boiler 26 by an optional flue gas cooler 36, before the flue gas fan 29, through supply to a district heating grid or to supply the heat pump.

The invention includes the utilization of these two optional design tools when necessary.
Second preferred embodiment
The second preferred embodiment of the invention is presented in Figure 2, and is an alternative embodiment providing a larger electricity production. This embodiment is similar to the first preferred embodiment except that the heat pump comprising references 19, 20, 21, 22, 32, and 33 is replaced by a back pressure turbine 37 driving an electric power generator 38. The back pressure turbine will supply intermediate pressure steam through the pipeline 39 to the back pressure turbines 17 and 18.

With this alternative all the steam required by the CO₂ absorption process has to be generated in the boiler 26 at a high pressure of more than 100 bar, and expanded in the back pressure turbines 37, 17 and 18 before it enters the stripping column 13 through the supply line 23. A consequence of this alternative is that the flue gas cooler 36 and the overhead condenser 15a have to be supplied by cooling water.

The second preferred embodiment may be arranged in different ways: The back pressure steam turbine 37 may be installed on the same shaft as the gas turbine 27, and the electric power generators 28 and 38 combined into one unit. This combination will reduce the number of units at the cost of reduced flexibility of the system. The back pressure steam turbines 17, 18 and 37 may be arranged in parallel. Turbines 17 and 18 may be replaced by electric motors and all the high pressure steam expanded to low pressure through turbine 37 only. These options give room for optimization during engineering.

The invention has been described as two preferred embodiments comprising amine based flue gas scrubbing and two conventional gas-fuelled thermal power plants. However, the inventive idea may however also be implemented in many other types of CO₂ generating processes including, but not limited to coal fired power plants, petrochemical plants, cement kilns etc.

Some types of CO₂ generating processes will not be producing flue gases with sufficient oxygen content for use as combustion air, and oxygen may not be available; therefore this invention also covers the use of atmospheric air as combustion air for the second gas turbine 27. This gives an increase in the flue gas quantity to the CO₂ capture plant through the fan 29 and thereby somewhat lower overall thermal efficiency, but still the CO₂ capture penalty will be lower than with other known techniques. Alternatively, there may be added oxygen containing gases and if necessary, pure oxygen through an inlet 35. The second CO₂ generating process may be fuelled by other sources and other fuels than the primary CO₂ generating process. For example, in the case of using flue gas from the HRSG 4 as
combustion air directly to the second boiler 26 which is fuelled by an external fossil/combustible fuel, the second gas turbine 27 and the generator 28 may not be included in the energy plant design.

The CO₂ capture may be provided by all known and future CO₂ scrubbing plants using any known or future absorbent of CO₂, as long as the desorption column(s) employs hot steam as heat source.
List of reference numbers

1 Primary electric power generator
2 High, intermediate and low pressure steam turbines
3 Primary gas turbine
4 Heat recovery steam generator (HRSG)
5 Chimney
6 Condensate circulation loop
7 Flue gas pipeline
8 Flue gas fan
9 CO₂ absorption column(s)
10 Exit for treated flue gas
11 Heat exchangers for CO₂ absorption liquid
12a, 12b Pipelines for enriched and regenerated amine solution, respectively
13 CO₂ stripping column(s)
14 Outlet pipeline for CO₂
15a, 15b Overhead condenser and overhead receiver, respectively
16 CO₂ compressor
17 Back pressure steam turbine for CO₂ compressor
18 Back pressure steam turbines for flue gas fans 8 and 29
19 Compressor for the heat pump
20 Back pressure turbine for the heat pump
21 Heat pump vacuum vessel
22 Heat pump water circulating pump
23 Steam supply to 13
24 High pressure steam supply to back pressure steam turbines
25 Feed water supply pump for 26
26 Boiler of second energy plant section
27 Gas turbine of second energy plant section
28 Electric power generator of second energy plant section
29 Flue gas fan of second energy plant section
30 Pipeline for providing flue gas as combustion air to turbine 27
31 Pipeline for natural gas supply
32 Return pipeline to vacuum vessel 21
33 Control valve for the condensate from 13
34 Pressurized CO₂ to recipient
35 Optional oxygen supply
36 Optional flue gas cooler
37 Back pressure steam turbine for additional electric power generator
38 Additional electric power generator for energy plant section
39 Intermediate pressure steam supply to back pressure steam turbines
40
CLAIMS

1. Method for capturing CO₂ in flues gases from CO₂ generating processes, where
   - the flue gases are contacted with a CO₂ absorbent in at least one absorption column and then vented out into the atmosphere or sent to further processing,
   - the CO₂ enriched absorbent is sent to at least one desorption column heated by adequately tempered steam for regeneration of the absorbent, and
   - the released CO₂ in the at least one desorption column is collected and transferred to downstream process equipment for utilization and/or disposal, and where
   - there is employed at least a primary and secondary CO₂ generating process producing flue gas containing CO₂ which is sent to the at least one absorption column,
   characterised in that
   - the secondary CO₂ generating process is equipped with steam generation, and that
   the operation of the secondary CO₂ generating process is tuned to provide the adequately tempered steam required to run the desorption process in the at least one desorption columns.

2. Method according to claim 1, characterised in that the absorbent is one or more amines dissolved in water.

3. Method according to claim 2, characterised in that the steam supplied to the heat exchanger in the bottom of the desorption column(s) has a temperature between 100 and 160 °C, preferably between 110 and 150 °C, and most preferably between 120 and 130 °C, and that the pressure is between 1 and 6 bar absolute.

4. Method according to claim 1 - 3, characterised in that at least a part of the flue gas from the primary CO₂ generating process is utilised as oxygen source in the secondary CO₂ generating process

5. Method according to claim 1 - 3, characterised in that the heat loss in the plant is at least partially recovered by use of one or more heat-pumps and introduced into the desorption process.

6. Method according to claim 5, characterised in that one or more heat-pumps extracts heat from the overhead from the desorption process, residual heat in the flue gas from the secondary CO₂ generating process, and/or the condense water from the energy supply of the desorption process.

7. Method according to claim 5 or 6, characterised in that the compressor of the one or more heat-pumps is/are driven by
back-pressure steam turbines supplied by the steam system of the secondary CO₂ generating process.

8. Method according to claim 1 - 3, characterised in that the steam system of the secondary CO₂ generating process is tuned to deliver steam needed to drive back-pressure steam turbines for running pumps, compressors, fans etc. in the plant.

9. Method according to any of claims 1 - 3, characterised in that the primary and/or the secondary CO₂ generating process are one of thermal power plants fuelled with a carbonaceous fuel, petrochemical plants, cement kilns etc.

10. Method according to claim 4, characterised in that the primary CO₂ generating process is a NGCC plant.

11. Plant for utilising a carbonaceous raw material with CO₂ capturing of the flue gases, where the plant comprises
   - at least a primary and a secondary CO₂ generating process section,
   - means for collecting the flue gases from the at least one primary and secondary CO₂ generating process sections,
   - at least one absorption column for absorbing the CO₂ in the collected flue gas onto an absorbent,
   - an outlet from the at least one absorption column for ventilating the cleaned flue gas into the atmosphere,
   - at least one desorption column for regenerating the absorbent by heating the absorbent with adequately tempered steam,
   - means for collecting the released CO₂ gas in the at least one desorption column, and
   - means for transferring the collected CO₂ gas to downstream process equipment for utilization and/or disposal,

   characterised in that
   - the secondary CO₂ generating process is equipped with steam generation tuned to provide at least a part of the adequately tempered steam required for running the desorption process in the at least one desorption columns.

12. Plant according to claim 11, characterised in that the flue outlet from the primary CO₂ generating process is branched such that at least a part of the flue gases from the primary CO₂ generating process is utilised as oxygen source in the secondary CO₂ generating process.

13. Plant according to claim 11 or 12, characterised in that the absorbent is one or more amines dissolved in water.

14. Plant according to any of claim 13, characterised in that the boiler 26 is tuned to provide steam to the heat exchanger in
the bottom of the desorption column(s) 13 at a temperature between 100 and 160 °C, preferably between 110 and 150 °C, and most preferably between 120 and 130 °C, and a pressure between 1 and 6 bar absolute.

15. Plant according to claim 11 - 14, characterised in that the plant also comprises at least one heat-pump (19, 21) in order to at least partially recover the heat loss in the plant.

16. Plant according to claim 15, characterised in that at the at least one heat-pump (19, 21) extracts heat from the overhead (15a) from the desorption process, residual heat in the flue gas (36) from the secondary CO₂ generating process, and/or the condense water from the energy supply (23) of the desorption process.

17. Plant according to claim 11 - 14, characterised in that the plant also comprises one or more steam driven back-pressure turbines (17, 18, 20) for running one or more fans (8, 29), and/or one or more of compressors (16, 19) in the plant.

18. Plant according to claim 17, characterised in that the steam system of the secondary CO₂ generating process is tuned to deliver steam needed to drive the at least one back-pressure steam turbines (17, 18, 20).

19. Plant according to claim 18, characterised in that the steam system of the secondary CO₂ generating process is tuned to deliver steam to a back-pressure steam turbine (37) connected to an electric generator (38).

20. Plant according to claim 19, characterised in that the steam system of the secondary CO₂ generating process is tuned to deliver steam to a back-pressure steam turbine (18) driving fans (8, 29) and a back-pressure steam turbine (17) driving compressor (16) in addition to the back-pressure steam turbine (37) connected to the electric generator (38).

21. Plant according to any of claims 11 - 18, characterised in that the primary and/or the secondary CO₂ generating process sections are one of fossil fuelled thermal power plants, petrochemical plants, cement kilns etc.

22. Plant according to claim 19, characterised in that the primary CO₂ generating process sections is a conventional NGCC plant.
A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D53/14 B01D53/62

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D F23J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>WO 00/57990 A (CHRISTENSEN PROCESS CONSULTING [NO]; CHRISTENSEN TOR [NO]) 5 October 2000 (2000-10-05) page 8, lines 1,28-33 page 9, lines 1-3,22-26; figure 6; examples 5,6</td>
<td>1,2,4,9, 11-13, 18,19,21</td>
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<td>US 4 364 915 A (PROCTOR RUSSELL C) 21 December 1982 (1982-12-21) column 3, lines 63-65 column 5, lines 34-37 column 6, lines 1-8,35-40 column 7, lines 37-46 column 10, lines 21-25,35-37 column 11, line 65 - column 12, line 5; figure</td>
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Further documents are listed in the continuation of Box C

See patent family annex

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Date of the actual completion of the international search

25 January 2007

Date of mailing of the international search report

01/02/2007

Name and mailing address of the ISA/
European Patent Office, P B 5818 Patentlaan 2 NL - 2280 HV Rijswijk
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Focante, Francesca
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<td>WO 2006/043820 A (NORSK HYDRO AS [NO]; AASEN KNUT INGVAR [NO]; EIMER DAG ARNE [NO]) 27 April 2006 (2006-04-27) page 9, lines 19-21; figure 1 page 11, lines 1-22; claims 1,12-14; figure 1</td>
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