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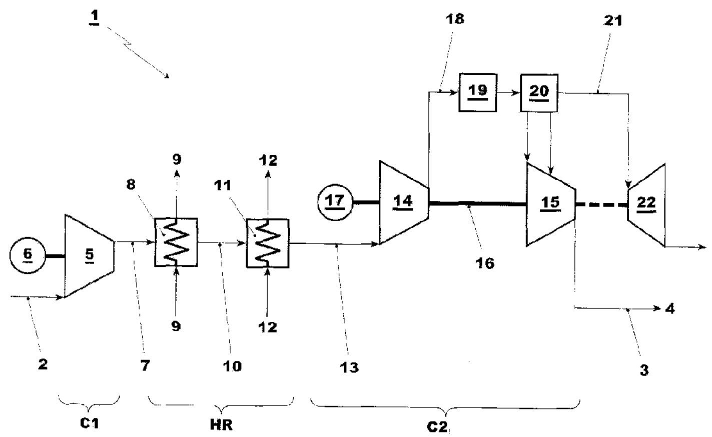

FIG. 1

(57) Abstract: A power plant for the generation of electrical energy with a system (1) for processing flue gases resulting from a combustion of fossil fuels comprises, according to the invention, an adiabatic compressor (5) for a first low-pressure compression of the flue gases and a second multi-stage, low-pressure flue gas compression system (14) and a multi-stage, high-pressure CO_2 compression system (15), where both the low-pressure flue gas compression system and the high-pressure CO_2 compression systems are combined in one single machine (C2) and are arranged on one common shaft (16) driven by one common driver (17). A heat exchanger (8) facilitates an improved recovery of heat resulting from the cooling of the adiabatically compressed flue gases. The invention allows an improvement of the overall power efficiency of a power plant integrated with this processing system as well as a reduction of investment cost.

WO 2011/006862 A2

System for gas processing

Technical Field

The present invention relates to systems for processing gas resulting from fossil fuel fired power plants for the generation of electric energy. It relates in particular to a system for gas processing to purify such gas in order to facilitate the transport and storage of carbon dioxide.

Background Art

In view of reducing the emission of the greenhouse gas carbon dioxide (CO2) into the atmosphere, the flue gases of fossil fuel fired power plants for the generation of electrical energy are typically equipped with so-called CO2-capture systems. CO2 gases contained in the flue gases is first separated, then compressed, dried, and cooled and thus conditioned for permanent storage or a further use such as enhanced oil recovery. For safe transport, storage or further use, the CO2 is required to have certain qualities. For example, for enhanced oil recovery the gas is to have a CO2 concentration of at least 95%, a temperature of less than 50°C and a pressure of 13.8 Mpa. Flue gases from fossil fuel fired power plants comprise not only CO2 but also a number of further contaminants such as water vapor, oxygen, nitrogen, argon, as well as SO3, SO2, NO, NO2, which must be removed in order to fulfill the environmental regulations and requirements for transport and storage of CO2. All of these contaminants and the CO2 itself can appear in various concentrations depending on the type of fossil fuel, combustion parameters, and combustor design. The percentage of CO2 contained in the flue gases can range from 4% in the case of combustion of gases for a gas turbine to 60% -90% in the case of a coal fired boiler with air separation unit providing additional oxygen to the combustion process. The removal of contaminants from flue gases is not limited by technical barriers but rather by the additional cost and energy requirements and subsequent reduction in the overall power plant efficiency.

Minish M. Shah, “Oxyfuel combustion for CO2 capture from pulverized coal boilers”, GHGT-7, Vancouver, 2004, discloses an example of a system for handling the flue gases resulting from a fossil fuel fired boiler. The system includes a recycle line for a portion of the flue gas to be returned to the coal-fired boiler together with oxygen from an air separation unit. The flue gas is led through a filter for removal of ash and dust, such as a fabric filter or electrostatic precipitator, furthermore through a flue gas desulphurization unit for the removal of SOx and finally through a gas processing unit for CO2 purification and compression. This unit comprises a system for removal of incondensable gases such as O2, N2, and Ar, a dehydration system for removal of water vapor, and a series of compression and cooling systems. These include a first low-pressure compression systems of the non-purified flue gases and a high-pressure compression system of the purified CO2, each with coolers integrated.

For the compression, such systems comprise for example two multistage centrifugal compressors, a low-pressure compressor and a high-pressure compressor and apparatuses for dehydration and cryogenic removal of inert gases arranged between the low- and high-pressure compressors. The multistage centrifugal compressors have intercoolers following each compressor stage in order to minimize the power consumption of the compression. The multistage centrifugal compression typically includes 4-6 compression stages. Because of the large number of compressor stages, the low-pressure and high-pressure compressors are each arranged on independent shafts with a separate driver. The heat resulting from the intercoolers is low-level heat of 70-80°C, which is typically not recovered but instead dissipated in the cooling water system of the power plant. The cryogenic system for removal of inert gases generates an inert gas flow under pressure, which is typically expanded in a suitable turbine, which in turn drives a generator or is arranged to provide a part of the mechanical power for driving a compressor.

2010272630 01 Oct 2015

Furthermore, Bin Xu, R.A. Stobbs, Vince White, R.A. Wall, "Future CO2 Capture Technology for the Canadian Market", Department for Business Enterprises & Regulatory reform, Report No. COAL R309, BERR//Pub, URN 07/1251, March 2007, discloses on pages 124-129 a system for processing the flue gases including dehydration, compression, cooling, and cryogenic processing. The compressors used are adiabatic compressors, which allow an improvement in terms of power consumption and cooling requirements.

US 6,301,927 discloses a method of separating CO_2 from a feed gas by means of autorefrigeration, where the feed gas is first compressed and expanded in a turbine. The CO_2 contained in the feed gas is then liquefied and separated from its gaseous components in a vapor-liquid-separator.

US 4,977,745 discloses a method for recovering low purity CO_2 from flue gas including compressing flue gas and directing it through a water wash and a dryer and finally to a CO_2 separation unit.

US 7,416,716 discloses a method and apparatus for purifying carbon dioxide, in particular for the removal of SO_2 and NOx from CO_2 flue gas resulting from a coal fired combustion process. For this, the flue gas or raw CO_2 gas is compressed to an elevated pressure by means of a compression train with intercoolers for the cooling of the compressed gas, where some of the compression is performed adiabatically. The compressed gas containing water vapor, O_2, SOx, and NOx is then led into a gas/liquid contact device for washing the gaseous CO_2 with water for the removal of SOx and NOx.

Summary of Invention

In view of the described background art, it would be desirable to provide a system for processing flue gases from a fossil fuel fired power plant for the generation of electrical energy.

2010272630 01 Oct 2015

According to an aspect of the invention, there is provided a system for processing flue gases from a fossil fuel fired power plant for the generation of electrical energy comprising:

an adiabatic compressor for a first low-pressure compression of the flue gas;

a second low-pressure compression system having one or more stages and one or more coolers; and

a high-pressure compression system having several stages and one or more coolers, where both the second low-pressure compression system and the high-pressure compression system are combined in one single machine, arranged on one common shaft, and driven by one common driver,

wherein the adiabatic compressor is configured to compress the flue gas to a discharge pressure in the range from 5 bar abs to 9 bar abs.

Preferably, the system further comprises a unit for cryogenic purification of the flue gases by removal of inert gases from the flue gas, where the unit for cryogenic purification is arranged downstream of the second low-pressure compression system and upstream of the high-pressure compression system.

Preferably, the system further comprises a dehydration unit arranged downstream of the second low-pressure compression system.

Preferably, the system comprises two low-pressure compressor stages and four to six high-pressure compressor stages arranged on one single shaft.

Preferably, the system further comprises a heat exchanger arranged downstream from the adiabatic compressor.

Preferably, the system further comprises a heat exchanger configured for heat exchange with a water flow system for heat recovery.

2010272630 01 Oct 2015

Preferably, the system further comprises a heat exchanger configured for heat exchange with a water flow system for heat recovery, wherein the water flow system is part of a water/steam cycle of a steam turbine power plant.

Preferably, the system further comprises a heat exchanger configured for heat exchange with a water flow system for heat recovery, wherein the water flow system is connected to a condensate extraction pump.

Preferably, the adiabatic compressor is configured for a discharge pressure of the flue gases of a pressure in the range from 7 bar abs to 9 bar abs. Above this pressure range the adiabatic compression would require more power consumption than the compression in an intercooled centrifugal compressor. With this discharge pressure the temperature at the discharge of the adiabatic compressor may be in the range from 170 to 280°C. This may allow an efficient heat recovery for instance by heating condensates from the power plant steam/water cycle through the use of a dedicated heat exchanger. After the heat recovery, the flue gas may be at a temperature of about 50°C. It may then be further cooled in a second exchanger, where heat is dissipated. It may then be compressed to 30 to 40 bar abs by two stages of the second low-pressure flue gas compressor, a centrifugal compressor with intercoolers. These two stages can be easily combined with the high-pressure CO_2 compressor having 4 to 6 stages, for instance by the use of one integral gear compressor with 6 to 8 stages. The adiabatic compressor facilitates an improved recovery of the heat resulting from the cooling of the compressed flue gas. This can further improve the overall efficiency of a power plant integrated with this type of flue gas processing system. A further advantage of the power plant according to the invention is in that the number of flue gas compressors, these being adiabatic and centrifugal, may remain constant compared to power plants of the prior art having only centrifugal compressors.

Preferably, the adiabatic and low-pressure compression system are configured such that the ratio of the discharge pressure of the adiabatic compressor to the

2010272630 01 Oct 2015

discharge pressure of the first stage of the low-pressure compression system is in a range from 1.5 to 2.5.

Preferably, the system further comprises a first line for low-pressure purified CO_2 gas which leads from a cryogenic purification unit to a first inlet of the high-pressure compression system, and a second line for medium-pressure purified CO_2 gas which leads from the cryogenic purification unit to an intermediate stage of the high-pressure compression system.

Preferably, the system further comprises a system for the removal or reduction of SOx and NOx arranged either in a low-pressure flue gas treatment system upstream of the systems for flue gas compression or after the adiabatic compressor.

Preferably, the system further comprises a power plant fired by gas, coal, oxyfired coal, or a gas turbine power plant with a facility for post-combustion CO_2-capture.

The power plant with the post-combustion flue gas processing system according to the invention allows, due to the integration of an adiabatic compressor, a reduction of the total power consumption necessary for the flue gas compression. Furthermore, the adiabatic compressor without intercoolers allows a recovery of the heat from the flue gas and its use in the power plant or in a system connected with the power plant such as an industrial consumer or other consumer requiring heat. Thereby, required heat, for example for feedwater preheating, that would otherwise be extracted from the power plant can now be drawn from the compressed flue gases. The system according to the invention therefore seeks to facilitate an improvement in the overall efficiency of the power plant thus integrated with the flue gas processing system, however without an increase in number of compressor machines.

Additionally, a flue gas processing system according to the invention may allow a reduction in the initial investment cost for the system. The system may comprise two compression machines with two drivers and two shafts, i.e. the adiabatic, flue

2010272630 01 Oct 2015

gas compressor on one hand and the combination of second low- pressure flue gas compressor with high-pressure CO_2 multi-stage compressor, on the other hand. In spite of the addition of an adiabatic compressor, the system's total number of machines may still be the same. Finally, a combination of the second low-pressure flue gas compressor and high-pressure CO_2 compressor into one machine may result not only in a reduction in investment cost but also allows space efficiency in the power plant construction.

In a further particular embodiment of the invention, the flue gas processing system comprises one or more heat exchangers for cooling of the flue gas downstream from the adiabatic compressor, where the heat exchanger(s) is/are configured for heat exchange with a water flow that can be part of the water/steam cycle of a power plant or any other water flow system for heat recovery within the power plant or in a system connected with the power plant. For this embodiment, the adiabatic flue gas compressor is configured for a discharge pressure of the flue gases of a selected pressure range. This pressure range is selected for example in consideration of an optimal heat recovery in connection with the water/steam cycle of the power plant, an optimally minimized power consumption of the adiabatic compressor, and the integration of the low- and high-pressure compression stages downstream from the adiabatic flue gas compressor.

Comprises/comprising and grammatical variations thereof when used in this specification are to be taken to specify the presence of stated features, integers, steps or components or groups thereof, but do not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Brief Description of the Drawings

Figure 1 shows a diagram of an embodiment of a flue gas processing system according to the invention that may be integrated in a power plant for the generation of electricity.

2010272630 01 Oct 2015

Best Modes for Carrying out the Invention

Figure 1 shows a flue gas processing system 1 for the processing of flue gases resulting from a fossil fuel fired power plant. The power plant itself is not shown save for a line 2 directing the flue gas resulting from the combustion of fossil fuels for the generation of a working medium to drive a turbine. The processing system 1 comprises essentially a flue gas line 2, directing flue gases to a first compressor system C1, heat recovery system HR, a second compressor system C2, all

THE NEXT PAGE IS PAGE 8.

arranged in series in the sequence mentioned, and a CO2-line 3 for directing the separated CO2 to a facility for further use. The flue gas line 2 leads from a power plant to the first compressor system C1, which comprises an adiabatic flue gas compressor 5. The heat recovery system HR comprises heat exchangers for the cooling of the compressed flue gases released by the compressor C1 and transfer of heat from the flue gases to the power plant. The second compressor system C2 comprises a combined multi-stage and intercooled compressor system for the low-pressure compression of flue gases and the high-pressure compression of purified CO2. Finally, the line 3 leads purified and compressed CO2 away from the system 1 to a further system 4 for transport, storage or further use of the CO2 such as enhanced oil recovery.

Flue gases are led to system 1 as shown via the line 2, where the flue gases can result for example from a coal-fired boiler, from a gas combustion chamber, or oxyfired coal-fired boiler. As such, they can contain CO2 gas of various concentrations, such as 4% or more in the case of a gas turbine power plant with or without flue gas recirculation, or up to 60-90% in the case of oxyfired coal burning boilers for steam turbine power plant. Following the boiler or combustion chamber, the flue gases may have been pre-treated in a filter such as an electrostatic precipitator or a fabric filter or any other process unit for the removal of sulphur. Furthermore, the flue gases may have been treated in an apparatus for the removal of NOx or mercury.

The flue gas line 2 carries the CO2-containing flue gas to the low-pressure, adiabatic flue gas compressor 5 driven by a driver 6 and configured to compress the flue gas to a discharge pressure of 5 to 20 bar abs. A minimized power consumption for the compression can be reached with a configuration for a discharge pressure of 5 to 8 bar abs, for example 7 bar abs. The adiabatic compressor 5 is configured for a compression to a discharge pressure of no more than 20 bar. Compression to a discharge pressure higher than this limit would increase the power consumption such that there would no longer be any benefits from the use of an adiabatic compressor. This is due to the fact that after a pressure of around 8 bar abs, the adiabatic (axial) power consumption becomes higher than that of an intercooled centrifugal compressor. After this pressure the benefit of having more efficient wheels in the axial machine is more than compensated by the increase of power consumption due to the gas temperature increase in the absence of intercooling. At the compressor discharge the compressed flue gas may have a temperature of ca. 200℃-280℃.

The optimum discharge pressure of the adiabatic compressor will be set by the minimization of power consumption, but also by additional parameters such as water/steam cycle integration, intermediate removal of SOx and NOx if any, as well as machine selection.

A line 7 leads from the discharge of the low-pressure flue gas compressor 5 to a first heat exchanger 8, through which the compressed and hot flue gases flow in counterflow to a flow of water or another cooling medium. The cooling medium is led from the heat exchanger 8 via line 9 to a system for heat recovery in a system within the power plant or in a system connected with the power plant. The adiabatic/axial flue gas compressor 5 allows the recovery of heat from the flue gases at a higher temperature (170-240℃) compared to the case if a centrifugal compressor were used instead in this position. This heat can be effectively used in the power plant. For example, in the embodiment shown, the heat recovery system is the water/steam cycle 9 of a steam turbine system. In a particular example, this water flow is connected to a feedwater preheater or to the condensate extraction pump. A part of the condensates can be heated directly by the flue gas, thus by-passing the low-pressure heaters. The steam consumption of the low-pressure heaters is reduced and, as a consequence, more steam is expanded in the cycle steam turbine and the plant can produce more electrical power. Due to the use of the adiabatic /axial flue gas compressor a gain of the net power output of the power plant of 0.5% to 1% can be achieved over the net output of a power plant having only centrifugal flue gas compressors. The power plant according to the invention achieves a greater output although having the same number of compressor machines as a power plant with only centrifugal compressors.

After having passed through the heat exchanger 8, the flue gases have a temperature of for example 50℃. On the flue gas side, the heat exchanger 8 is connected via a line 10 to a further heat exchanger or cooler 11, where the flue gases are further cooled to a temperature of for example 30°C. The heat resulting from this cooling is of low-grade and can be dissipated.

A line 13 leads from the cooler 11 to the combined compression system C2 driven by driver 17 and comprising a low-pressure flue gas compressor 14, a high-pressure CO_2 compressor 15 arranged on shaft 16 and driven by driver 17. The low-pressure flue gas compressor can have for example two stages of a centrifugal compressor with intercooler, whereas the high-pressure CO_2 compressor can have for example four to six stages with intercoolers. If the discharge pressure of the adiabatic compressor is lower, that is within the discharge pressure range given between 5 to 20 bar abs, the centrifugal low-pressure flue gas compressor can also have three instead of two stages. The flue gases, compressed to a pressure of for example 30 bars abs by the low-pressure compressor 14, are led via line 18 to a dehydration unit 19 and thereafter to a cryogenic unit 20. In the cryogenic unit, the flue gas is separated resulting in a purified CO_2 gas flow and a vent gas containing inert gases like nitrogen, oxygen and argon. The vent gas is sent via line 21 to an expander 22, which can be mounted on the same shaft 16 or mounted on an independent shaft. In the flue gas processing system according to the invention, the low-pressure flue gas compression system 14 and high-pressure CO_2 compression system 15 are arranged on the same shaft, whereas the low-pressure flue gas compression system is arranged up-stream of the cryogenic purification system and the high-pressure CO_2 compression system is arranged down-stream from the purification system.

The cryogenically purified flue gas, now containing mainly CO_2 of a concentration sufficient for transport and storage, is led from the unit 20 to the high-pressure compressor system 15 for further compression to a pressure of 110 bar abs, from where it is finally led via line 3 to a system 4 for further use of the CO_2. The cryogenic process can be optimized in that the purified CO_2-gas is fed in two separate flows to the compressor system 15 at two different pressures respectively, by which the compressor power consumption is minimized. One first low-pressure line feeds the purified CO_2 gas to the front inlet of the compressor system 15 and a second medium pressure line feeds the purified CO_2 gas to an intermediate stage of the compressor system 15.

Terms used in Figures

1	system for processing flue gases
2	flue gas line from power plant
3	line for purified CO2 gas
4	system for transport, storage or further use of purified CO2
5	adiabatic compressor
6	driver
7	flue gas line
8	heat exchanger
9	system for cooling medium
10	flue gas line
11	heat exchanger
12	system for cooling medium
13	flue gas line
14	low-pressure compressor for flue gas
15	high-pressure compressor for CO2 gas
16	shaft
17	driver for combined low- and high-pressure compressor
18	flue gas line
19	dehydration unit
20	cryogenic unit
21	line for inert gases
22	expander for vented inert gases
C1	adiabatic compressor
C2	combined compressor machine
HR	heat recovery system

2010272630 01 Oct 2015

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A system for processing flue gases from a fossil fuel fired power plant for the generation of electrical energy comprising:

an adiabatic compressor for a first low-pressure compression of the flue gas;

a second low-pressure compression system having one or more stages and one or more coolers; and

a high-pressure compression system having several stages and one or more coolers, where both the second low-pressure compression system and the high-pressure compression system are combined in one single machine, arranged on one common shaft, and driven by one common driver,

wherein the adiabatic compressor is configured to compress the flue gas to a discharge pressure in the range from 5 bar abs to 9 bar abs.

2. The system according to claim 1, further comprising a unit for cryogenic purification of the flue gases by removal of inert gases from the flue gas, where the unit for cryogenic purification is arranged downstream of the second low-pressure compression system and upstream of the high-pressure compression system.

3. The system according to either one of claims 1 or 2, further comprising a dehydration unit arranged downstream of the second low-pressure compression system.

4. The system according to any one of the previous claims, wherein the system comprises two low-pressure compressor stages and four to six high-pressure compressor stages arranged on one single shaft.

5. The system according to any one of the previous claims, further comprising a heat exchanger arranged downstream from the adiabatic compressor.

2010272630 01 Oct 2015

6. The system according to any one of claims 1 to 4, further comprising a heat exchanger configured for heat exchange with a water flow system for heat recovery.

7. The system according to any one of claims 1 to 4, further comprising a heat exchanger configured for heat exchange with a water flow system for heat recovery, wherein the water flow system is part of a water/steam cycle of a steam turbine power plant.

8. The system according to any one of claims 1 to 4, further comprising a heat exchanger configured for heat exchange with a water flow system for heat recovery, wherein the water flow system is connected to a condensate extraction pump.

9. The system according to any one of claims 1 to 8, wherein the adiabatic compressor is configured for a discharge pressure of the flue gases of a pressure in the range from 7 bar abs to 9 bar abs.

10. The system according to any one of the previous claims, wherein the adiabatic compressor and low-pressure compression system are configured such that the ratio of the discharge pressure of the adiabatic compressor to the discharge pressure of the first stage of the low-pressure compression system is in a range from 1.5 to 2.5.

11. The system according to any one of the previous claims, further comprising a first line for low-pressure purified CO_2 gas which leads from a cryogenic purification unit to a first inlet of the high-pressure compression system, and a second line for medium-pressure purified CO_2 gas which leads from the cryogenic purification unit to an intermediate stage of the high-pressure compression system.

2010272630 01 Oct 2015

12. The system according to any one of the previous claims, further comprising a system for the removal or reduction of SOx and NOx arranged either in a low-pressure flue gas treatment system upstream of the systems for flue gas compression or after the adiabatic compressor.

13. The system according to any one of the previous claims, wherein the system is integrated with a power plant fired by gas, coal, oxyfired coal, or a gas turbine power plant with a facility for post-combustion CO_2-capture.

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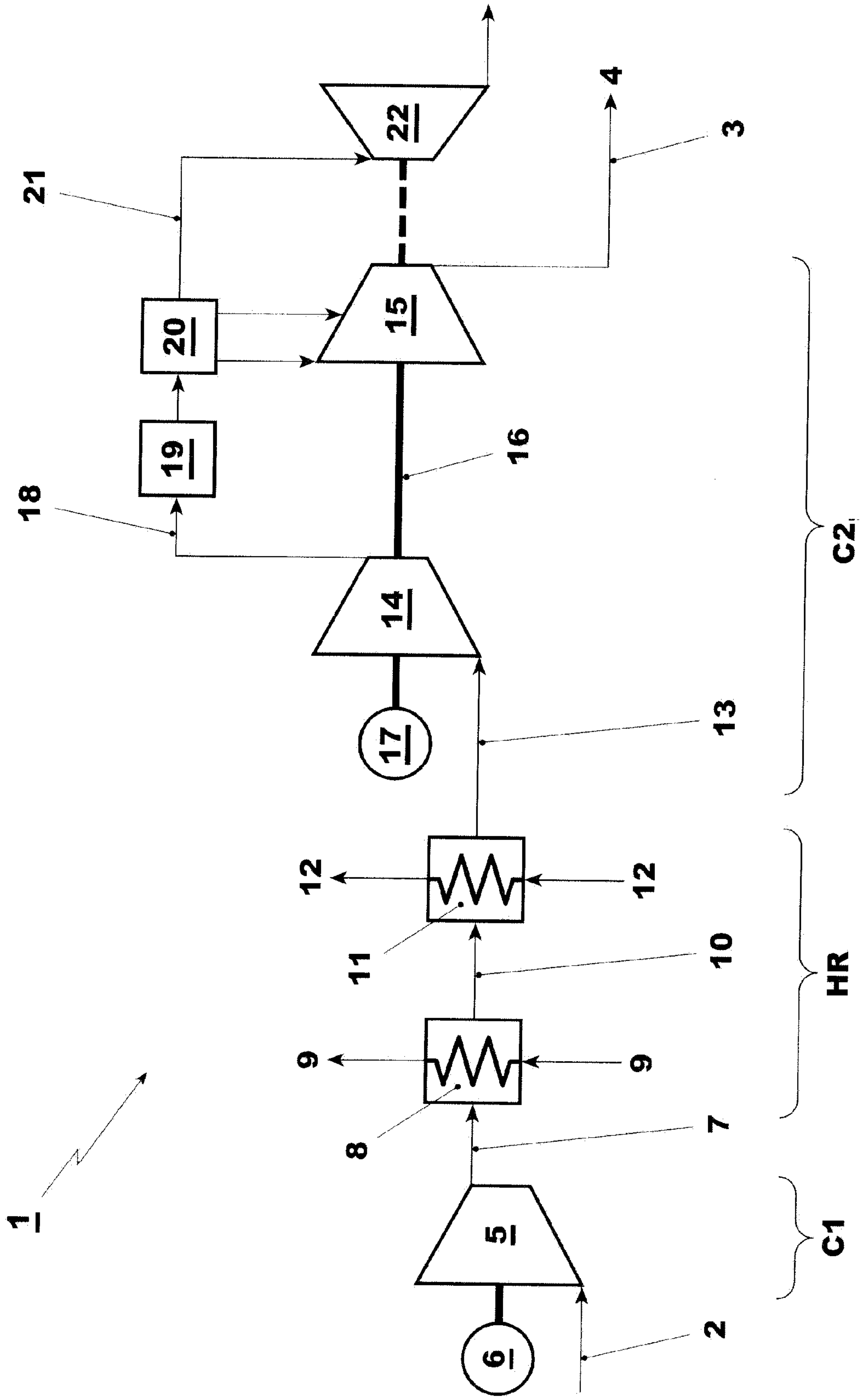

FIG. 1