(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 030 099 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
20.07.2022 Bulletin 2022/29

(21) Application number: **21216208.5**

(22) Date of filing: **21.12.2021**

(51) International Patent Classification (IPC):
F22B 1/18 *(2006.01)* ***F22G 7/14*** *(2006.01)*
F22B 35/00 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F22B 1/1869; F22B 35/00; F22G 7/14

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **22.12.2020 BE 202005962**

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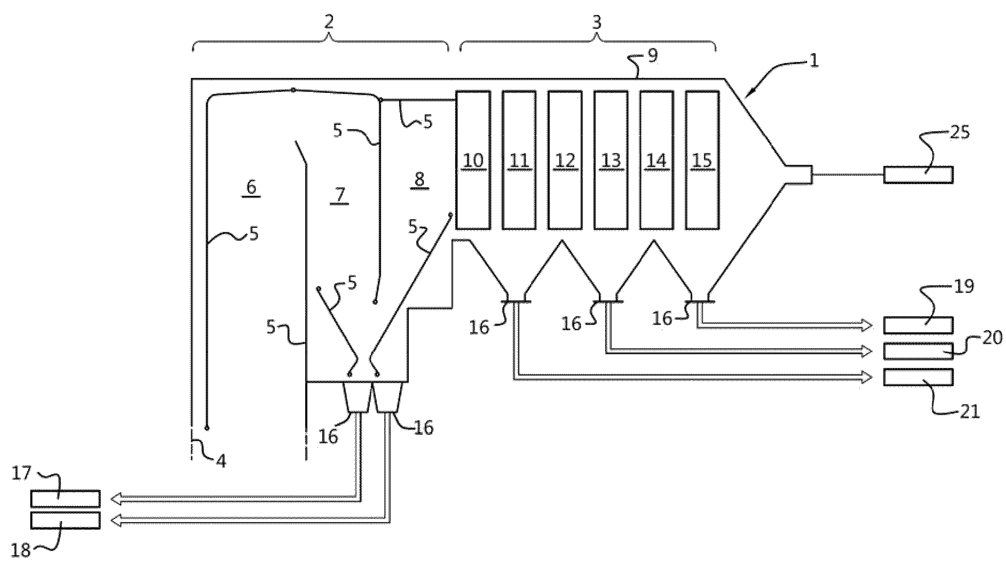
(54) METHOD AND DEVICE FOR ENERGY RECOVERY AFTER COMBUSTION OF SOLID COMBUSTIBLE MATERIAL

(57) The invention relates to a method for energy recovery after combustion of solid combustible material, for example solid waste material. In the method, the cooling of flue gas, which flue gas is obtained by combustion of solid combustible material, is carried out in two steps, wherein in a first step the flue gas is cooled to a temperature of 620 to 680 °C via radiant heat transfer and in a second step the flue gas is further cooled by convection heat transfer with water to a temperature of at most 250°C, through which convection heat transfer a heating of water to saturated steam and subsequently to superheated steam is also carried out, which superheated steam is used as such for energy-demanding processes and/or is used for converting the superheated steam into electricity.

The invention also relates to a device for energy recovery after combustion of solid combustible material.

Fig. 1



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Description

TECHNICAL FIELD

[0001] The invention relates to a method and a device for energy recovery after combustion of solid combustible material.

PRIOR ART

[0002] Hot flue gas is obtained by burning solid combustible material, for example combustible waste material. The flue gas must subsequently be purified to comply with emission guidelines. The energy represented by the hot flue gas does not have to be lost. By performing certain actions, this energy can be recovered to carry out other processes. One of these operations is the generation of steam which can be used further as such or which can be used, for example, for the production of electricity.

[0003] For example, US4882903A discloses a combined cycle waste-to-energy plant used to thermally convert municipal and industrial solid waste into substantially complete combustion products and use the heat of combustion to produce steam and/or electrical energy. The plant comprises a building envelope with a waste receiving area, a waste fuel separation and processing area, an incinerator and an area for heat recovery and power generation. Processed waste fuel is delivered to a series of incinerators by an automated conveyor and hopper system, and the waste fuel is burned in the incinerators by hot exhaust gas delivered thereto from one or more combustion turbines located outside the building and drivingly connected to electrical generators. Inlet air to the turbines is drawn in along with the building to maintain the interior at a negative pressure, thereby preventing waste odors and pathogens from escaping from the building. The hot exhaust gas from the combustion turbine delivered to the incinerators is passed through a superheater, and a portion of the exhaust gas exiting the superheater is passed through a waste heat boiler. Hot combustion gas discharged from each of the incinerators is passed through an associated combustion heat recovery boiler. Gas heat recovered in the superheater and the various boilers is used to produce steam which drives a steam turbine which is drivingly connected to an electrical generator. A portion of the steam generated may also be used for process purposes.

[0004] US4882903A shows the problem that the utilization of the heat of combustion for the production of steam and/or electric power can be further improved.

[0005] The present invention aims to find a solution to at least the above-mentioned problem.

SUMMARY OF THE INVENTION

[0006] In a first aspect, the invention relates to a method for energy recovery after combustion of solid combustible material, for example solid waste material, according to claim 1. Preferred embodiments of the method are set out in claims 2 to 7.

[0007] In a second aspect, the invention relates to a device for energy recovery after combustion of solid combustible material, for example solid waste material, according to claim 8. Preferred embodiments of the device are set out in claims 9 to 13.

DESCRIPTION OF THE FIGURES

[0008]

Fig. 1 is a schematic representation of flue gas side components of a steam boiler according to preferred embodiments of the invention.

Fig. 2 is a schematic representation of water/steam side components of a steam boiler according to preferred embodiments of the invention.

Fig. 3 shows a schematic representation of a device for energy recovery after combustion of solid combustible material according to preferred embodiments of the invention.

DETAILED DESCRIPTION

[0009] Quoting numerical intervals by endpoints comprises all integers, fractions and/or real numbers between the endpoints, these endpoints included.

[0010] In a first aspect, the invention relates to a method for energy recovery after combustion of solid combustible material, for example solid waste material, according to claim 1.

[0011] The specific cooling of the flue gas in the two steps according to claim 1 ensures an efficient and smooth cooling of the flue gas and at the same time provides energy in an optimum manner for heating water to saturated steam and subsequently to superheated steam.

[0012] Preferably, the flue gas obtained by combustion of the solid combustible material initially has a temperature of at least 850°C. According to preferred embodiments of the method according to the first aspect of the invention, in the first step the flue gas is cooled via radiant heat transfer to a temperature of from 630 to 670°C, more preferably from 640 to 660°C and most preferably from 645 to 655°C.

[0013] According to a preferred embodiment, the cooling of the flue gas via radiant heat transfer is carried out by means of one or more evaporator panels.

[0014] Preferably, a flue gas cooled in this way is discharged to a flue gas cleaning device for cleaning the flue gas.

[0015] Preferred embodiments of the method are set out in claims 2 to 7.

[0016] The preferred embodiment of the method as described in claim 2 has the effect that such temperatures are very suitable for discharging the flue gas and for presenting the flue gas to a flue gas cleaning device. In a more preferred embodiment of the method according to claim 2, the flue gas is cooled to a temperature of from 220 to 240°C and even more preferably from 225 to 235°C.

[0017] The preferred embodiment of the method as described in claim 3 has the effect that superheated steam with such temperature and pressure values is optimally suited to be used as such or to be used for electricity production. In a more preferred embodiment of the method as set forth in claim 3, the saturated steam is heated to superheated steam having a temperature of 390 to 410°C, and more preferably from 395 to 405°C, and with an absolute pressure of 33 bar to 47 bar, more preferably from 36 bar to 44 bar and even more preferably from 38 bar to 40 bar.

[0018] The preferred embodiment of the method as described in claim 4 has the effect that, via a space-saving arrangement of the radiant heat transfer means, the flue gas can still cool over a large surface area of the radiant heat transfer means in a specific space.

[0019] The preferred embodiment of the method as described in claim 5 has the effect of thus further cooling the flue gas optimally since the flue gas sequentially passes each of the adjacent convection heat transfer means. Preferably, in said convection heat transfer means, water is used as coolant.

[0020] The preferred embodiment of the method as described in claim 6 has the effect that a gradual heating of the water to saturated steam and subsequently to superheated steam can thus take place.

[0021] The preferred embodiment of the method as described in claim 7 has the effect of thus avoiding accumulation of ash, since an accumulation of ash has a negative effect on cooling of the flue gas by radiant or convection heat transfer over time.

[0022] In a second aspect, the invention relates to a device for energy recovery after combustion of solid combustible material, for example solid waste material, according to claim 8.

[0023] The arrangement of the evaporator panels, economizers, evaporators and superheaters according to claim 8 allows the flue gas to give off a maximum of its heat to heat water to saturated steam and then to superheated steam, wherein a compact arrangement of the steam boiler is also made possible.

[0024] Preferably, in use, the steam boiler is connected at the level of the radiant heat transfer means to an incinerator in which solid combustible material is burned in use.

[0025] Preferred embodiments of the device are set out in claims 9 to 13.

[0026] The preferred embodiment of the device as described in claim 9 has the effect that the steam consumer, e.g., an industrial processing plant that at least partly obtains energy from steam, can immediately use the superheated steam to perform work.

[0027] The preferred embodiment of the device as described in claim 10 has the effect that the steam conditioning stations can condition the superheated steam as desired and subsequently use the conditioned steam for certain desired applications.

[0028] The preferred embodiment of the device as described in claim 11 has the effect that the superheated steam can lose its energy via the steam turbine bypass valve when the steam turbine is not in operation or suddenly breaks down. This is of great importance because of safety considerations.

[0029] The preferred embodiment of the device as described in claim 12 has the effect that any excess superheated steam can thus be expanded.

[0030] The preferred embodiment of the device as described in claim 13 has the effect that the steam can thus be post-treated in an optimum manner.

[0031] In what follows, the invention is described by way of non limiting drawings illustrating the invention, and which are not intended to and should not be interpreted as limiting the scope of the invention.

DETAILED DESCRIPTION OF THE FIGURES

[0032] Fig. 1 is a schematic representation of flue gas side components of a steam boiler according to preferred embodiments of the invention. Fig. 2 is a schematic representation of water/steam side components of a steam boiler according to preferred embodiments of the invention. Fig. 3 shows a schematic representation of a device for energy recovery after combustion of solid combustible material according to preferred embodiments of the invention. For advantages and technical effects of elements described below in the detailed description of the drawings, reference is made to the advantages and technical effects of corresponding elements described above in the detailed description.

[0033] The flue gas side components of the steam boiler 1 as shown in Fig. 1 comprises radiant heat transfer means 2 and convection heat transfer means 3 arranged inside the steam boiler 1. The radiant heat transfer means 2 are connected to an incinerator 4, and the convection heat transfer means 3 are in turn connected to the radiant heat transfer means 2. The radiant heat transfer means 2 are thus arranged to receive hot flue gases, which hot flue gases are obtained by combustion of solid combustible material, preferably solid waste material, in the incinerator 4.

[0034] The radiant heat transfer means 2 comprise walls 5 constructed from evaporator panels 5. These walls 5 are arranged such that three standing radiation chambers 6-8 are formed, and in particular in the direction from the incinerator 4 to the convection heat transfer means 3, a first 6, second 7 and a third standing radiation chamber 8. When the hot flue gases leave the incinerator 4, they have a high temperature of at least 800°C and preferably of at least 850°C. By successively flowing through said first 6, second 7 and third standing radiation chambers 8, which can also be called a vertical draft, the gases are cooled by radiant heat transfer with the walls 5 to a temperature of 645 to 655°C.

[0035] The convection heat transfer means 3 comprise convection screens 10-15, arranged in a row, hanging from an upper wall 9 of the steam boiler 1. Starting from the radiant heat transfer means 2, the convection screens 10 to 15 thus suspended comprise successively a first evaporator 10, a second superheater 11, a first superheater 12, a second evaporator 13, a first economizer 14 and a second economizer 15. The reason for the mutual arrangement of the convection screens 10-15 is elucidated below in the discussion of Fig. 2. After flowing past the successive convection screens 10-15, which is also called a horizontal draft, the flue gases are cooled to a temperature of 210 to 250°C. The flue gases are subsequently collected by a flue gas cleaning device 25 for cleaning the flue gases.

[0036] As discussed above in the description of Fig. 1, the hot flue gases entering the steam boiler 1 are forced to pass through four so-called drafts along which they are cooled. Part of the dust that is entrained with the flue gases will precipitate out of the flue gases due to the many bends. However, some of the dust sticks to parts of the radiant heat transfer means 2 and convection heat transfer means 3. The cooling capacity of the steam boiler 1 hereby decreases because an insulating layer is formed on said parts, as it were. For this reason, the exit temperature of steam (see further in the description of Fig. 2) at start-up is 210°C but can gradually increase to 250°C. Means can be provided for cleaning the dust so that the accumulation of dust on said parts is avoided.

[0037] Dust falling on the bottom 16 of the steam boiler 1 is also called "boiler dust". Boiler dust falling on the bottom 16 under the radiant heat transfer means 2 is collected and discharged by screw conveyors 17, 18. Boiler dust falling under the convection heat transfer means 3 to the bottom 16 is collected and discharged by chain conveyors 19-21. The resulting boiler dust streams are therefore preferably discharged together over a crusher (not shown in Fig. 1) to boiler dust storage silos (not shown in Fig. 1).

[0038] In Fig. 2 flows of water/steam through the various convection screens 10-15 (see Fig. 1) are shown. For simplicity of presentation, in Fig. 2 certain parts of the steam boiler 1 are not or only partly shown. The water/steam flows are indicated by arrows. Fig. 2 further shows a boiler drum 22 as an additional water/steam side component. In the second 15 and first economizers 14, water or condensate is preheated before going to the boiler drum 22. At the same time, these economizers 14, 15 on the flue gas side ensure a final cooling of the flue gases. In the second 13 and first 10 evaporators, preheated condensate from the boiler drum 22 is converted to saturated steam which flows back to the boiler drum 22. The saturated steam from the boiler drum 22 is then passed through the first 12 and second 11 superheaters which convert the saturated steam to superheated steam. In order to control the temperature of the superheated steam from 395 to 405°C, a water injector is provided between the first 12 and second superheater 11 for injecting water. The superheated steam (absolute pressure from 38 bar to 40 bar, 395 to 405°C) is collected in a steam header 24 which carries the steam to a steam turbine 28 and a steam consumer 29 (see Fig. 3).

[0039] Fig. 3, in particular, shows a schematic representation of a device for energy recovery after combustion of solid combustible material according to preferred embodiments of the invention, wherein three such steam boilers as discussed above for Figs. 1-2 are arranged. The water/steam flows are indicated in Fig. 3 by arrows. The superheated steam from three steam boilers 1, 26, 27, for example a combined produced 160 to 170 tons/hour of superheated steam of 40 bar absolute pressure and 400°C, comes together in a joint steam header 24 which is substantially a pipeline. The steam is distributed to various consumers via the steam header. According to the embodiment shown in Fig. 3, these consumers are:

- a steam turbine 28 (e.g., about 90 tons/hr. of superheated steam);
- steam export to a steam consumer 29 for use of the superheated steam as such (e.g., 45 tons/hour of superheated steam);
- first 30 and second steam conditioning stations 31 (e.g., 10 tons/hour of superheated steam); and
- the remaining superheated steam is expanded in a bypass valve 32.

[0040] For example, the steam turbine 28 produces about 21.5 MW of electrical power. After the steam turbine 28, obtained expanded steam is condensed in a first air-cooled condenser 33.

[0041] If the steam turbine 28 is not in operation or suddenly fails, the steam has to lose its energy in some other way. In that case, the steam is passed over a steam turbine bypass valve 34, which is connected to the steam turbine 28, which ensures a reduction of the pressure to, for example, 0.3 bar absolute pressure. At the same time, the steam is cooled by means of condensate injection. After the steam turbine bypass valve 34, the steam is fed into the first air-cooled condenser 33.

[0042] The second steam conditioning station 31 is constructed as a medium pressure (MP) station: the required pressure (e.g., 15 bar absolute pressure) is controlled by a reducing valve 49, the required temperature (e.g., 210°C) by injection with water from boiler feedwater pumps (not shown in Fig. 3). The second steam conditioning station 30 is constructed as a low pressure (LP) station: the required pressure (e.g., 5 bar absolute pressure) is controlled by a reducing valve 48, the required temperature (e.g., 160°C) by injection with condensate from condensate pumps and/or condensate injection pumps (not shown in Fig. 3). The remaining superheated steam is expanded in the bypass valve 32 and is then fed to a second air-cooled condenser 33.

[0043] The air-cooled condensers 33, 35 cool the steam from the steam turbine 28 and the steam turbine bypass valve 34 in the case of the first air-cooled condenser 33 and from the bypass valve 32 in the case of the second air-cooled condenser 35, whereby the steam condenses and condensate is formed which flows to the first condensate tank 36 and the second condensate tank 37, respectively, by the action of gravity.

[0044] The temperature of condensate (for example 46°C) determines the underpressure (for example 0.1 bar absolute pressure) in the first air-cooled condenser 33. For the second air-cooled condenser 35 these parameters are, for example, 70°C and 0.3 bar absolute pressure.

[0045] The first air-cooled condenser 33 comprises a first condensate separator 38 and a first air cooler 39. The steam to be condensed from the steam turbine 28 first enters the first condensate separator 38. The first condensate separator 38 functions as the lowest point, collecting point for the condensate formed, this in particular to protect the steam turbine 28 (low-pressure section) against backflowing liquid. This condensate is discharged by the action of gravity to the first condensate tank 36. From the first condensate separator 38 the steam goes to the first air cooler 39, the latter can be installed on a building's roof for practical reasons and for cooling reasons. Just after the first condensate separator 38, the steam from the steam turbine bypass valve 34 enters a main line and there is a balancing line (not shown in Fig. 3) from the first air cooler 39 to the first condensate tank 36. The first air cooler 39 consists of two main parts 42, 43. It is possible to take a part out of service at low capacity. Each part preferably consists of two identical modules, each provided with an adjustable fan (not shown in Fig. 3). The regulation of the first air cooler 39 takes into account the exit temperature of the various modules, the pressure at the entrance, temperature of the non-condensable gases and the outside temperature. In a similar manner, the second air-cooled condenser 35 comprises a second condensate separator 40 and a second air cooler 41. The second air cooler 41 comprises only one compartment and preferably comprises two or three controllable fans (not shown in Fig. 3).

[0046] The first 36 and second condensate tanks 37 collect all condensate flows from the steam circuit. The most important condensate flows are, of course, those from the air coolers 39, 41. The other streams come from the condensate separators 38, 40, but also from ejector condensers (not shown in Fig. 3), and condensate preheaters 46, 47. Condensate from the first 36 and second condensate tanks 37 is pumped to first 44 and second degassers 45, respectively, by condensate pumps (not shown in Fig. 3). Two desuperheating stations (not shown in Fig. 3) are also fed from the condensate tanks 36, 37 by means of condensate injection pumps (not shown in Fig. 3) which serve to desuperheat LP steam (for example with an absolute pressure of 5 bar) in a LP reducing valve 48 and vacuum steam (for example with an absolute pressure of 100 to 600 mbar) in the steam turbine bypass valve 34.

[0047] Between the first condensate tank 36 and the first degasser 44, two condensate preheaters 46, 47 are arranged in series. Condensate preheating thus takes place in the formed cascade of two condensate preheaters 46, 47, which are substantially heat exchangers, where steam is condensed from the steam turbine's higher pressure tap and lower pressure tap (not shown in Fig. 3). The preheating is necessary to enable the degassing in the first degasser 44, since this requires the feedwater to boil. The feedwater should preferably be preheated to 140°C, so that a wall temperature in an economizer remains above the acid dewpoint. This is to avoid corrosion. The formed condensate flows stepwise from highest pressure to lowest pressure through a built-in supercooler (not shown in Fig. 3) to reduce flash steam generation.

[0048] Steam feeding to each condensate preheater 46, 47 is preferably constant. The temperature is preferably controlled by a level control of the condensate in each condensate preheater 46, 47. The level determines the heat transfer. The set point of the level control is adjusted according to the temperature of the feedwater. As the level rises, the temperature falls (and vice versa). At lower capacity (from 15% output) or with steam turbine bypass, the taps can no longer be used. These then close themselves. Only supersaturated steam is then used in the condensate preheater 47 which is connected to the first condensate tank 36.

[0049] Since the condensate preheaters 46, 47 connect to the steam turbine 28 (not shown in Fig. 3), measures are preferably taken to prevent the condensate from going to the steam turbine 28 in case of failure of the condensate preheaters 46, 47. For this purpose, the associated tap of the steam turbine 28 is closed in one of the condensate preheaters 46, 47 at a high level.

Claims

1. A method for energy recovery after combustion of solid combustible material, for example solid waste material, in which flue gas obtained by combustion of the solid combustible material with a temperature of at least 800 °C is converted into steam for use as such or for electricity production, by performing the following steps:

    - cooling the flue gas to a temperature not exceeding 250 °C by heat exchange with water, wherein the water is first heated to saturated steam and then the saturated steam is further heated to superheated steam, after which the flue gas is discharged;
    - using the superheated steam as such for energy-demanding processes and/or converting the superheated steam into electricity,

characterized in that the cooling of the flue gas is carried out in two steps, in which in a first step the flue gas is cooled to a temperature of 620 to 680 °C via radiant heat transfer and in a second step the flue gas is further cooled by convection heat transfer with water to a temperature of at most 250°C, through which convection heat transfer the heating of water to saturated steam and subsequently to superheated steam is also carried out.

2. The method according to claim 1, wherein the flue gas is cooled to a temperature of 210 to 245°C.

3. The method according to claim 1 or 2, wherein the saturated steam is heated to superheated steam having a temperature of 380 to 420°C and an absolute pressure of 30 bar to 50 bar.

4. The method according to any of claims 1 to 3, wherein, during radiant heat transfer, the flue gas is forced into a vertical flow by an arrangement of radiant heat transfer means (2), wherein said arrangement is such that the vertical flow is changed in its direction one or more times.

5. The method according to any of claims 1 to 4, wherein, during convection heat transfer, the flue gas is forced into a horizontal flow along convection heat transfer means (3) arranged side by side.

6. The method according to any of claims 1 to 5, wherein the heating of water by means of convection heat transfer to saturated steam and subsequently to superheated steam takes place at least partly in countercurrent to a flow of the flue gas.

7. The method according to any of claims 1 to 6, wherein the flue gas comprises ash released during cooling of the flue gas, and wherein the ash thus released is collected and removed.

8. A device for energy recovery after combustion of solid combustible material, for example of solid waste material, comprising a steam boiler (1), steam header (24) and a steam turbine (28), wherein in use within the steam boiler (1) radiant heat transfer means (2), convection heat transfer means (3) and a boiler drum (22) are provided, the radiant heat transfer means (2) comprising a plurality of evaporator panels (5) for cooling flue gas obtained through combustion of solid combustible material, the convection heat transfer means (3) comprising one or more economizers (14, 15), one or more evaporators (10, 13), and one or more superheaters (11, 12) for further cooling of the flue gas by convection heat transfer and for heating water from the boiler drum (22) to saturated steam and then to superheated steam, wherein the steam header (24) is arranged to distribute the superheated steam and is connected in use to the steam turbine (28) which in use converts the superheated steam into electricity, **characterized in that** the plurality of evaporator panels (5) are arranged in use so that they form two or more vertical walls that force the flue gas into a vertical flow during radiant heat transfer, and wherein in use the one or more economizers (14, 15), evaporators (10, 13) and superheaters (11, 12) are suspended side by side from an upper wall (9) of the steam boiler (1).

9. The device according to claim 8, further comprising a steam extractor (29) for direct use of steam as such, wherein the steam header (24) is connected to the steam extractor (29) in use.

10. The device according to claim 8 or 9, further comprising one or more steam conditioning stations (30, 31) connected in use to the steam header (24).

11. The device according to any of claims 8 to 10, further comprising a steam turbine bypass valve (34) connected in use to the steam turbine (28).

12. The device according to any of claims 8 to 11, comprising an additional separate bypass valve (32) connected in use to the steam header (24).

13. The device according to any of claims 8 to 12, comprising one or more air-cooled condensers (33, 35), condensate tanks (36, 37) and degassers (44, 45), wherein in use, following said steam turbine bypass valve (34) and/or additional separate bypass valve (32) at least one air-cooled condenser (33, 35), condensate tank (36, 37) and degasser (44, 45) are sequentially arranged.

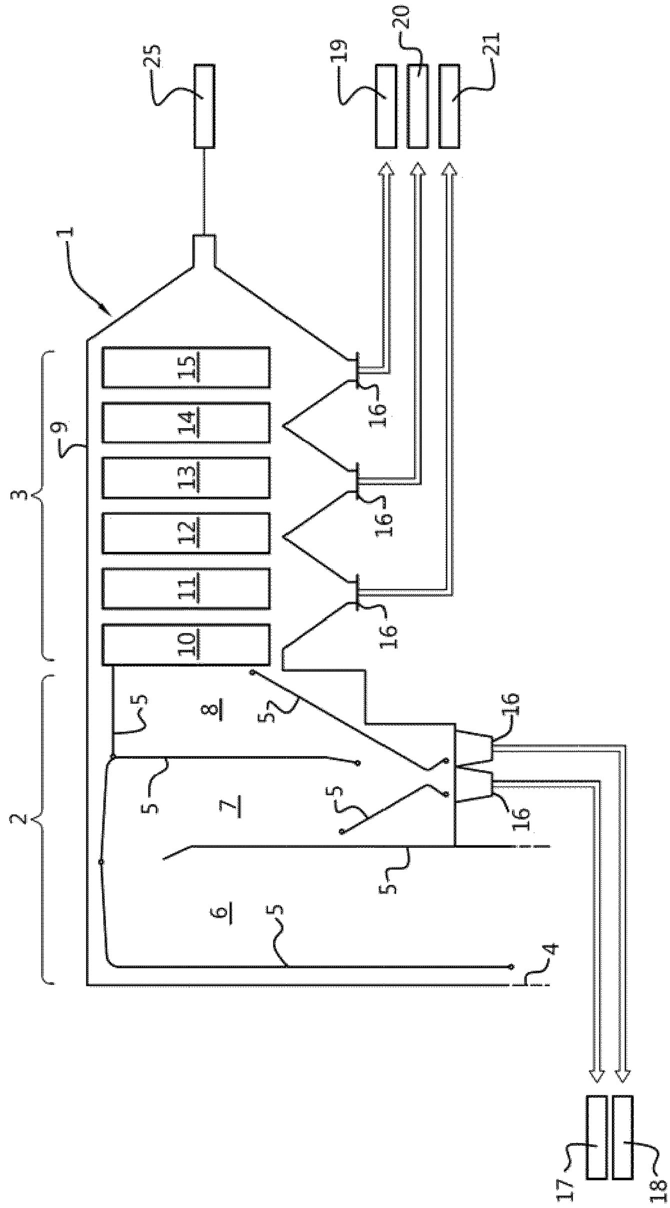
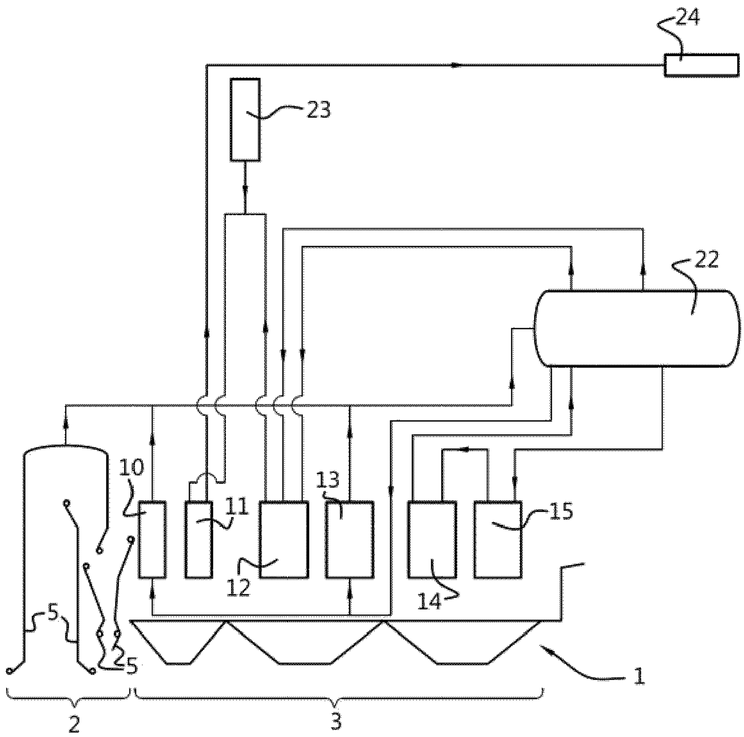


Fig. 1

Fig. 2



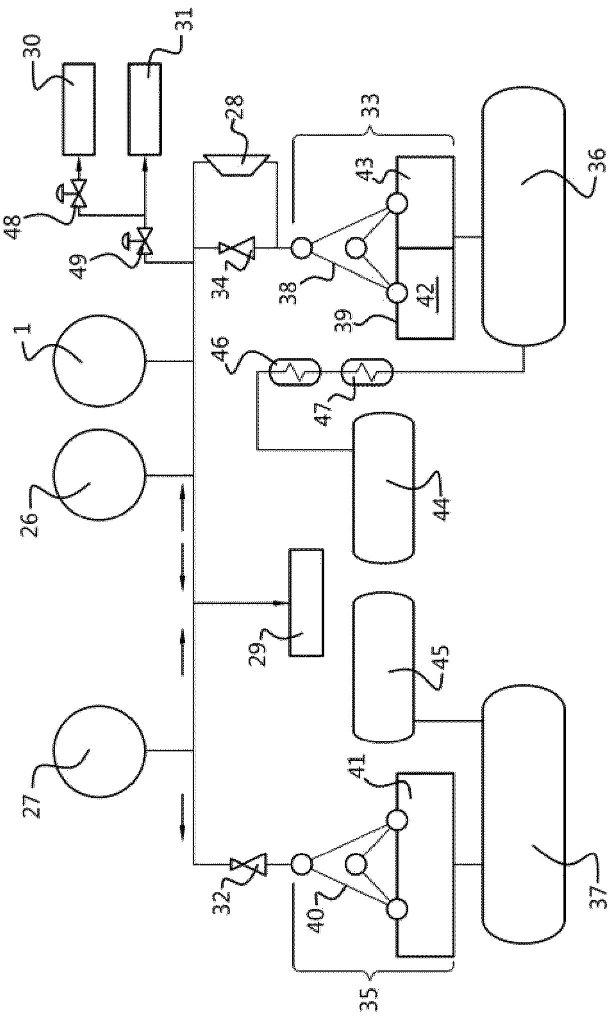


Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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