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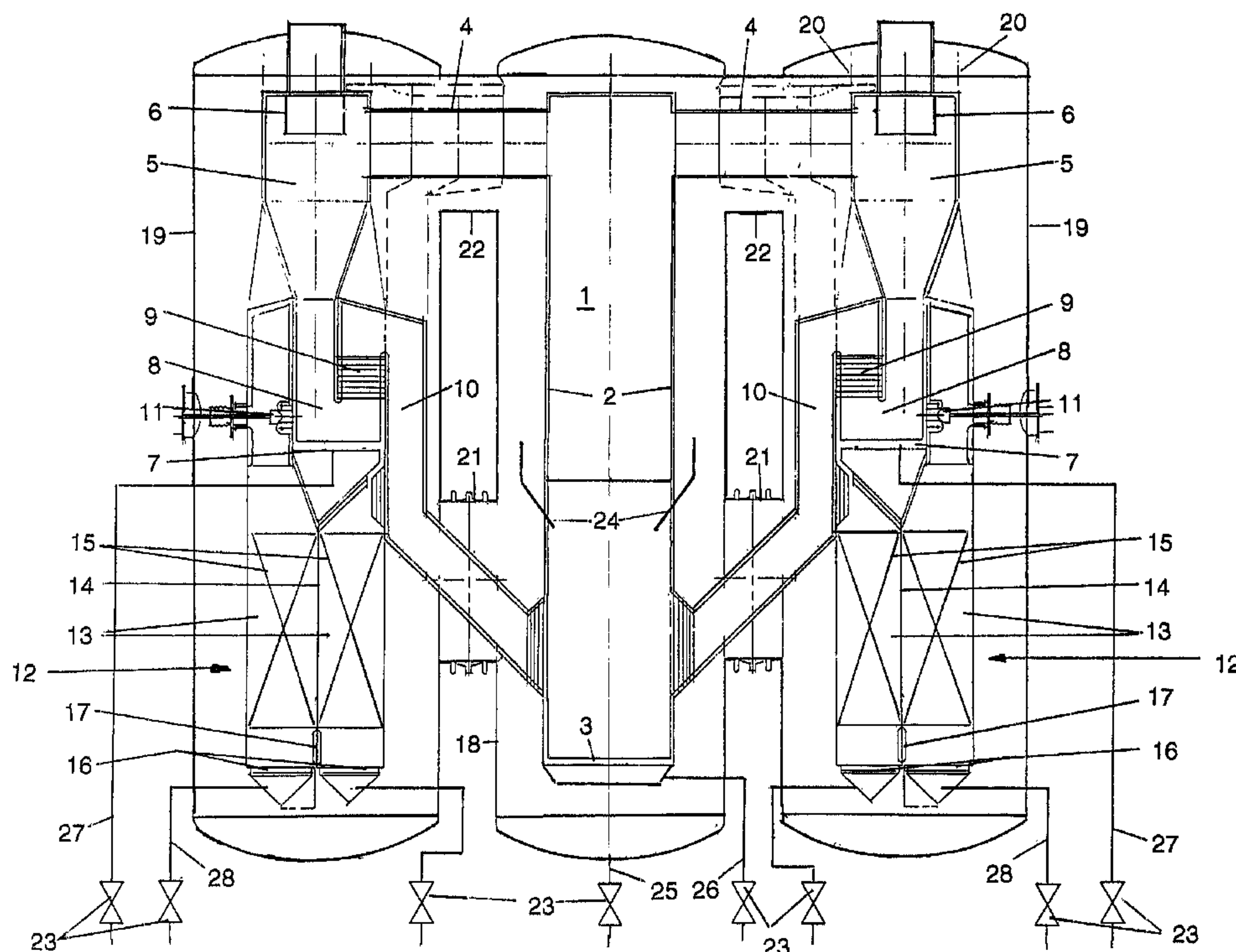
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(54) Titre : CHAUDIERE A COMBUSTION SUR LIT FLUIDISE PRESSURISE CIRCULANT

(54) Title: BOILER WITH PRESSURIZED CIRCULATING FLUIDIZED BED FIRING



(57) **Abrégé/Abstract:**

A continuously operated boiler heated with a pressurized circulating fluidized bed firing consists of a fluidized bed burner chamber and one or more cyclone separators connected in series after the fluidized bed burner chamber and on the flue gas side. A fluidized bed cooler is connected in series after each cyclone separator which cooler is connected by way of a dip pot with the solids output of the cyclone separator on one hand and with the fluidized bed burner chamber on the other hand. A return conduit is connected with the dip pot which opens into the fluidized bed burner chamber. Pressure vessels house the fluidized bed burner chamber, the cyclone separator and the fluidized bed cooler. The fluidized bed cooler, the cyclone separator and the dip pot are thereby combined into a unit which is housed in the common pressure vessel.

ABSTRACT

A continuously operated boiler heated with a pressurized circulating fluidized bed firing consists of a fluidized bed burner chamber and one or more cyclone separators connected in series after the fluidized bed burner chamber and on the flue gas side. A fluidized bed cooler is connected in series after each cyclone separator which cooler is connected by way of a dip pot with the solids output of the cyclone separator on one hand and with the fluidized bed burner chamber on the other hand. A return conduit is connected with the dip pot which opens into the fluidized bed burner chamber. Pressure vessels house the fluidized bed burner chamber, the cyclone separator and the fluidized bed cooler. The fluidized bed cooler, the cyclone separator and the dip pot are thereby combined into a unit which is housed in the common pressure vessel.

BOILER WITH PRESSURIZED CIRCULATING FLUIDIZED BED FIRING

The invention relates to boilers and more particularly to boilers with pressurized, circulating fluidized bed firing which are part of a combined gas-steam power plant.

Boilers of this type are known, wherein the flue gases produced in the fluidized bed fire box are transported to the gas turbine after cleaning of the hot gas at the temperature of the fluidized bed of 800 to 1000°C. In the combined process, the advantageous combustion and emission properties of a circulating fluidized bed firing, which operates at high pressure, and the special heat uptake distribution from the cooling of the flue gas and solids in the boiler can be combined with the gas turbine operation for optimal energy use. Boilers of this type, apart from the fluidized bed burner chamber, generally include a hot flue gas cleaning arrangement such as one or more cyclone separators for the removal of solids and a flue gas cooling arrangement for the harnessing of the heat energy stored in the flue gas.

It is an object of the invention to advantageously coordinate the individual reaction and heat exchanger components of the boiler.

This object is achieved in a known steam boiler by combining the cooling arrangement and the hot gas cleaning arrangement into one unit which is placed in a common pressure vessel.

Accordingly, the invention provides a boiler with pressurized, circulating fluidized bed firing, comprising a fluidized bed burner chamber; at least one cyclone separator connected by a connecting conduit on the flue gas side to and in series after the fluidized bed burner chamber; a fluidized bed cooler respectively connected in series to each cyclone separator, the cooler being connected on the one hand by way of a dip pot with a solids output of the cyclone separator and on the other hand with the fluidized bed burner chamber; a return flow

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conduit connected to the dip pot and discharging into the fluidized bed burner chamber, and at least one pressure vessel housing the fluidized bed burner chamber, the cyclone separator and the fluidized bed cooler, wherein the fluidized bed cooler, the dip pot and the cyclone separator are combined into one unit and placed in a common pressure vessel.

In another aspect of the invention, there is provided a steam generator with pressurized, circulating fluidized bed firing, comprising: a fluidized bed burner chamber; at least one cyclone connected to a flue gas side of said fluidized bed burner chamber through a connecting conduit; said cyclone having a solids output; a fluidized bed cooler connected behind said cyclone; a dip pot connected to said solids output of said cyclone and to said fluidized bed cooler; a return flow conduit connected to said dip pot and entering into said fluidized bed burner chamber; a plurality of pressure vessels, one of said pressure vessels housing said fluidized bed burner chamber; said fluidized bed cooler, said dip pot, and said cyclone being combined into a unit, said unit being housed in another of said pressure vessels; a gas turbine system with a compressor connected to an intermediate space between said unit and the respective pressure vessel and between said fluidized bed burner chamber and the respective pressure vessel, said intermediate space being subjected to air over pressure from said gas turbine system; ducts connecting said pressure vessels; said connecting conduit being positioned between said fluidized bed burner chamber and said cyclone as well as said return flow conduit from said dip pot and said fluidized bed cooler and leading to said fluidized bed burner chamber being passed through said ducts.

In a further aspect of the invention, there is provided a steam generator with pressurized, circulating fluidized bed firing, comprising: a fluidized bed burner chamber; at least one cyclone connected to a flue gas side of said fluidized bed burner chamber through a connecting conduit; said cyclone having a solids output; a fluidized bed cooler connected

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behind said cyclone; a dip pot connected to said solids output of said cyclone and to said fluidized bed cooler; a return flow conduit connected to said dip pot and entering into said fluidized bed burner chamber; a plurality of pressure vessels, one of said pressure vessels housing said fluidized bed burner chamber, said fluidized bed cooler, said dip pot, and said cyclone being combined into a unit, said unit being housed in another of said pressure vessels; said unit being suspended in said other pressure vessel; said fluidized bed cooler having an output end connected to said return flow conduit; said return flow conduit being connected to said dip pot and to said output end of said fluidized bed cooler; walls of tubes welded gas-tight together and defining said fluidized bed cooler, said cyclone, said dip pot, said return flow conduit, said connecting conduit, and said fluidized bed burner chamber; a common water-steam circuit operated under continuous flow and connected to said walls of tubes arranged in series with respect to said water-steam circuit; said walls of tubes being connected directly free of intermediate collectors positioned therebetween; said walls of tubes arranged so that tubes with downward flow are adjacent tubes with upward flow; ducts connecting said pressure vessels, said connecting conduit being positioned in said ducts; said connecting conduit and said return flow conduit comprise walls of tubes and forming a connection between said walls of tubes inside said pressure vessels; secondary air nozzles opening into said fluidized bed burner chamber and open to an intermediate space between an inner wall of said one pressure vessel and wall of tubes of said fluidized bed burner chamber; return flow blocking means in said nozzles; said fluidized bed burner chamber, said dip pot, and said fluidized bed cooler having a respective nozzle floor with separate air supply conduits respectively; a gas turbine system with a compressor connected to an intermediate space between said units and the respective pressure vessel and between said fluidized bed burner chamber and the respective pressure vessel, said intermediate space being subjected to air over pressure from said gas turbine system.

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In a further aspect of the invention, there is provided a steam generator with pressurized, circulating fluidized bed firing, comprising: a fluidized bed burner chamber, at least one cyclone connected to a flue gas side of said fluidized bed burner chamber through a connecting conduit; said cyclone having a solids output; a fluidized bed cooler connected behind said cyclone; a dip pot connected to said solids output of said cyclone and to said fluidized bed cooler; a return flow conduit connected to said dip pot and entering into said fluidized bed burner chamber; a plurality of pressure vessels, one of said pressure vessels housing said fluidized bed burner chamber; said fluidized bed cooler, said dip pot, and said cyclone being combined into a unit, said unit being housed in another of said pressure vessels; said unit being suspended in said other pressure vessel; said fluidized bed cooler having an output end connected to said return flow conduit; said return flow conduit being connected to said dip pot and to said output end of said fluidized bed cooler; walls of tubes welded gas-tight together and defining said fluidized bed cooler, said cyclone, said dip pot, said return flow conduit, said connecting conduit, and said fluidized bed burner chamber; a common water-steam circuit operated under continuous flow and connected to said walls of tubes arranged in series with respect to said water-steam circuit; said walls of tubes being connected directly; said walls of tubes arranged so that tubes with downward flow are adjacent tubes with upward flow; ducts connecting said pressure vessels, said connecting conduit being positioned in said ducts; said pressure vessels being connected through ducts enclosing said connecting duct and said return flow duct; said connecting duct and said return flow duct forming the connection between said walls of tubes arranged within said pressure vessels.

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The invention provides a boiler arrangement with relatively low space and material requirements. Furthermore, in the arrangement of the invention, the characteristics of a low pollution combustion reaction, including unavoidable tolerances, are considered independently from a process point of view. They are also considered independent of the individually different characteristics of the solids transport and the heat exchange and the also unavoidable associated tolerances. This results in an especially flexible arrangement which is stable over wide load ranges and can be operated for any selected steam parameter. A further advantage is the favourable exploitability of extreme steam parameters by using highly alloyed materials at moderate intake temperatures and in especially small amounts. The current operational limits observed with boilers of known construction operated with flexible fuels, which limits result from the load capacity of the pipe walls surrounding the burner chamber and their material specifications, thereby no longer exist.

A preferred embodiment of the boiler in accordance with the invention is shown in the drawing and will be further described in the following by way of example only. The drawing schematically illustrates a boiler arrangement.

Of a combined gas-steam power plant, only the boiler is shown. The boiler is heated by way of a circulating fluidized bed firing and includes a fluidized bed burner chamber 1. The fluidized bed burner chamber 1 is defined by the walls 2 of tubes which are surrounding the chamber and are welded

together gas-tight. The cross section of the fluidized bed burner chamber 1 is downwardly conically tapered in the lower part and along two opposing walls which are not shown in the drawing. The tube walls 2 of the fluidized bed chamber 1 are ceramically coated especially in the lower highly solids-enriched part in order to prevent wear of the tubes. However, the upper part of the fluidized bed burner chamber 1 which is less loaded with solids can also be provided with a ceramic coating with advantageous heat transfer characteristics to protect it against wear by the solids. No heat exchange surfaces are provided within the fluidized bed burner chamber 1. The fluidized bed burner chamber 1 is downwardly closed by a nozzle floor 3. One or more connecting conduits 4 which respectively lead to a cyclone separator 5 are connected to the fluidized bed burner chamber 1. In the cyclone separator 5, the suspended solids are separated from the flue gas. The solids-free flue gas is guided to a hot gas filter through a dip conduit 6 of the cyclone separator 5. Subsequently, the hot gas is guided, without cooling, to the not illustrated gas turbine installation.

The solid's output of the cyclone separator 5 opens into a dip pot 8 provided with a nozzle floor 7. The dip pot 8 principally operates as a syphon and as a solids return flow check valve to prevent a short circuit on the flue gas side between the fluidized bed burner chamber 1 and the cyclone separator 5. The open side of the dip pot 8 is provided with an overflow gate and connected to a return conduit 10. The return conduit 10 discharges into the fluidized bed burner chamber 1.

The dip pot 8 is provided with an opening for the removal of a portion of the main solids return flow which opening is closable by a control member 11. The control member 11 can be an externally operable lancet-shaped valve provided with ceramic or metallic wear and heat protection. However, an overflow with gate can be used which is pneumatically operated

with combustion air and the overflow edge of which can be horizontal or slanted. The control of the pneumatic air flow can be continuous, intermittent or pulsed. The height of the overflow edge can be fixed or variably adjustable relative to the height of the overflow of the dip pot 8.

The secondary solids flow which is divided out from the dip pot 8 by way of the control element 11 is guided to fluidized bed cooler 12 which is positioned below the dip pot 8. The fluidized bed cooler 12 includes several chambers 13 which are separated by a separation wall 14. Each chamber 13 of the fluidized bed cooler 12 houses one heat exchanger bundle 15. A nozzle floor is provided below each chamber 13 through which air is blown for fluidizing the solids contents of the chamber 13. The nozzle floors of the chambers 13 can be supplied with fluidizing air from the same or separate sources. In the illustrated case, two chambers 13 are positioned side by side. Especially at higher throughput, the chambers 13 can also be positioned one above the other. The flow of the solids through the chambers 13 can be upward or downward. The chambers 13 of the illustrated fluidized bed coolers 12 are connected to each other below the heat exchanger bundles 15 and through an opening 17 in the separation wall 14. In this way, a downward flow is induced in the first chamber 13 exposed to the solids and an upward flow in the chamber 13 subsequently exposed to the same solids. It is also possible to guide a partial solids stream downward and to directly guide a make up solids stream to the subsequent chambers 13 by appropriately selecting the height of the gate in the separation wall 14 between the chambers 13.

The output end of the chamber exposed last is connected to the return conduit 10. In this way, the solids as well as the fluidizing air are guided from the fluidized bed cooler 12 and the dip pot 8 through the return conduit 10 and into the fluidized bed burner chamber 1. The solids transported from the fluidized bed burner chamber 1 into the cyclone separator

5 are used as heat carrier from which heat is extracted in the fluidizing bed cooler 12 with the help of the fluidizing air which is a portion of the combustion air. The solids thereby develop a high heat transition capacity whereby large amounts of heat can be transferred with the smallest heat transfer surfaces. After the heat transfer, the cooled solids stream is fully or partly mixed with the uncooled solids return stream and returned to the fluidized bed burner chamber 1. The cyclone separator 5, the dip pot 8, the fluidized bed cooler 12, the connecting conduit 4 and the return flow conduit 10 are defined by the walls of gas tight welded together tubes, just as the fluidized bed burner chamber 1. The tube walls are made of planar pipe panels and form a polygon whereby the lowest number of corners is 4. The tube walls are protected against unacceptable deformation by appropriate external reinforcing bands.

To compensate the high gas counter pressure of the gas turbine, the individual components of the boiler are housed in separate, cylindrical pressure vessels with preferably vertical axes. A first pressure vessel 18 encloses the fluidized bed burner chamber 1. A further pressure vessel 19 houses respectively a cyclone separator 5 with the dip pot 8 positioned therebelow and the fluidized bed cooler 12. The cyclone separator 5, the dip pot 8 and the fluidized bed cooler 12 are combined into a unit which is suspended in the respective pressure vessel 19 by way of anchors 20.

The cylindrical pressure vessels 18, 19 are connected by cylindrical ducts 21, 22 having horizontal or inclined axes. Positioned within these ducts 21, 22 are the pipe-shaped connecting conduits 4 and return conduits 10 for the fluid and solids transport from the fluidized bed burner chamber 1 to the other components and *vice versa*. These pipe shaped conduits 4, 10 at the same time provide the connection between the pipe systems positioned in the individual pressure vessels 18, 19.

The intermediate space between the pressure vessels 18, 19 and the components positioned therein, which are surrounded by the gas tight tube walls, is kept at a slight over-pressure relative to the gas operating pressure in the interior of the components. This over-pressure is produced by blowing blocking air from the gas turbine compressor of the associated gas turbine installation into the intermediate space by way of an air conduit 25 and through a control valve 23. The blocking air at the same time serves as secondary air for the fluidized bed firing. Secondary air nozzles 24 are provided for this purpose penetrate the tube walls 2 in the upper part of the fluidized bed burner chamber 1, are open to the intermediate space and are respectively provided with a return flow check valve arrangement (not illustrated). The over pressure is adjusted by way of the secondary air nozzles 24 and preferably self-regulating because of the dynamic resistance of the fluidized bed burner chamber 1. In special circumstances, the over pressure can be adjusted with the help of a regulating arrangement. The remaining air flows, such as the primary and fluidizing air for the fluidized bed burner chamber 1 and the fluidizing air for the dip pots 8 and the fluidized bed coolers 12 are necessarily guided to the individual nozzle floors 3, 7, 16 by way of separate air conduits 26, 27, 28 respectively.

On the water/steam side, the individual tubes of the tube walls are connected in series and are part of a common water/steam circuit. This water/steam circuit is operated with continuous flow according to the Benson principle. The serial connection in the water/steam circuit is carried out in such a way that the flow preferably passes first through the tube walls of one of the fluidized bed coolers 12 and the associated cyclone separator 5 with dip pot 8 and subsequently without intermediate collector through the connecting conduit 4 and the return conduit 10 which is positioned in the same pressure vessel 19. In this way, the water/steam mixture carrying pipe system is guided without additional connecting

conduits into the fluidized bed burner chamber 1. The second fluidized bed cooler-cyclone separator-group is connected in reverse series to the pipe system of the fluidized bed burner chamber with multiple upwards and downward flows. Thereafter follow the heat exchanger bundles 15 of the fluidized bed cooler 12, which are operated as further evaporators and as superheaters. The economizer is positioned in the exhaust heat vessel placed in series after the gas turbine.

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CLAIMS:

1. A steam generator with pressurized, circulating fluidized bed firing, comprising: a fluidized bed burner chamber; at least one cyclone connected to a flue gas side of said fluidized bed burner chamber through a connecting conduit; said cyclone having a solids output; a fluidized bed cooler connected behind said cyclone; a dip pot connected to said solids output of said cyclone and to said fluidized bed cooler; a return flow conduit connected to said dip pot and entering into said fluidized bed burner chamber; a plurality of pressure vessels, one of said pressure vessels housing said fluidized bed burner chamber; said fluidized bed cooler, said dip pot, and said cyclone being combined into a unit, said unit being housed in another of said pressure vessels; a gas turbine system with a compressor connected to an intermediate space between said unit and the respective pressure vessel and between said fluidized bed burner chamber and the respective pressure vessel, said intermediate space being subjected to air over pressure from said gas turbine system; ducts connecting said pressure vessels; said connecting conduit being positioned between said fluidized bed burner chamber and said cyclone as well as said return flow conduit from said dip pot and said fluidized bed cooler and leading to said fluidized bed burner chamber being passed through said ducts.

2. A steam generator as defined in claim 1, wherein walls of tubes welded gas-tight together define said fluidized bed burner chamber, said fluidized bed cooler, said cyclone, and said dip pot; said connecting conduit and said return flow conduit comprised of walls forming a connection between said walls of tubes welded gas-tight together.

3. A steam generator with pressurized, circulating fluidized bed firing, comprising: a fluidized bed burner chamber; at least one cyclone connected to a flue gas side

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of said fluidized bed burner chamber through a connecting conduit; said cyclone having a solids output; a fluidized bed cooler connected behind said cyclone; a dip pot connected to said solids output of said cyclone and to said fluidized bed cooler; a return flow conduit connected to said dip pot and entering into said fluidized bed burner chamber; a plurality of pressure vessels, one of said pressure vessels housing said fluidized bed burner chamber, said fluidized bed cooler, said dip pot, and said cyclone being combined into a unit, said unit being housed in another of said pressure vessels; said unit being suspended in said other pressure vessel; said fluidized bed cooler having an output end connected to said return flow conduit; said return flow conduit being connected to said dip pot and to said output end of said fluidized bed cooler; walls of tubes welded gas-tight together and defining said fluidized bed cooler, said cyclone, said dip pot, said return flow conduit, said connecting conduit, and said fluidized bed burner chamber; a common water-steam circuit operated under continuous flow and connected to said walls of tubes arranged in series with respect to said water-steam circuit; said walls of tubes being connected directly free of intermediate collectors positioned therebetween; said walls of tubes being arranged so that tubes with downward flow are adjacent tubes with upward flow; ducts connecting said pressure vessels, said connecting conduit being positioned in said ducts; said connecting conduit and said return flow conduit comprise walls of tubes and forming a connection between said walls of tubes inside said pressure vessels; secondary air nozzles opening into said fluidized bed burner chamber and open to an intermediate space between an inner wall of said one pressure vessel and wall of tubes of said fluidized bed burner chamber; return flow blocking means in said nozzles; said fluidized bed burner chamber, said dip pot, and said fluidized bed cooler having a respective nozzle floor with separate air supply conduits respectively; a gas turbine system with a compressor connected to an intermediate space

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between said units and the respective pressure vessel and between said fluidized bed burner chamber and the respective pressure vessel, said intermediate space being subjected to air over pressure from said gas turbine system.

4. A steam generator with pressurized, circulating fluidized bed firing, comprising: a fluidized bed burner chamber, at least one cyclone connected to a flue gas side of said fluidized bed burner chamber through a connecting conduit; said cyclone having a solids output; a fluidized bed cooler connected behind said cyclone; a dip pot connected to said solids output of said cyclone and to said fluidized bed cooler; a return flow conduit connected to said dip pot and entering into said fluidized bed burner chamber; a plurality of pressure vessels, one of said pressure vessels housing said fluidized bed burner chamber; said fluidized bed cooler, said dip pot, and said cyclone being combined into a unit, said unit being housed in another of said pressure vessels; said unit being suspended in said other pressure vessel; said fluidized bed cooler having an output end connected to said return flow conduit; said return flow conduit being connected to said dip pot and to said output end of said fluidized bed cooler; walls of tubes welded gas-tight together and defining said fluidized bed cooler, said cyclone, said dip pot, said return flow conduit, said connecting conduit, and said fluidized bed burner chamber; a common water-steam circuit operated under continuous flow and connected to said walls of tubes arranged in series with respect to said water-steam circuit; said walls of tubes being connected directly; said walls of tubes being arranged so that tubes with downward flow are adjacent tubes with upward flow; ducts connecting said pressure vessels, said connecting conduit being positioned in said ducts; said pressure vessels being connected through ducts enclosing said connecting duct and said return flow duct; said connecting duct and said return flow duct forming the connection

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between said walls of tubes arranged within said pressure vessels.

5. A steam generator as defined in claim 4, wherein said ducts are horizontal.

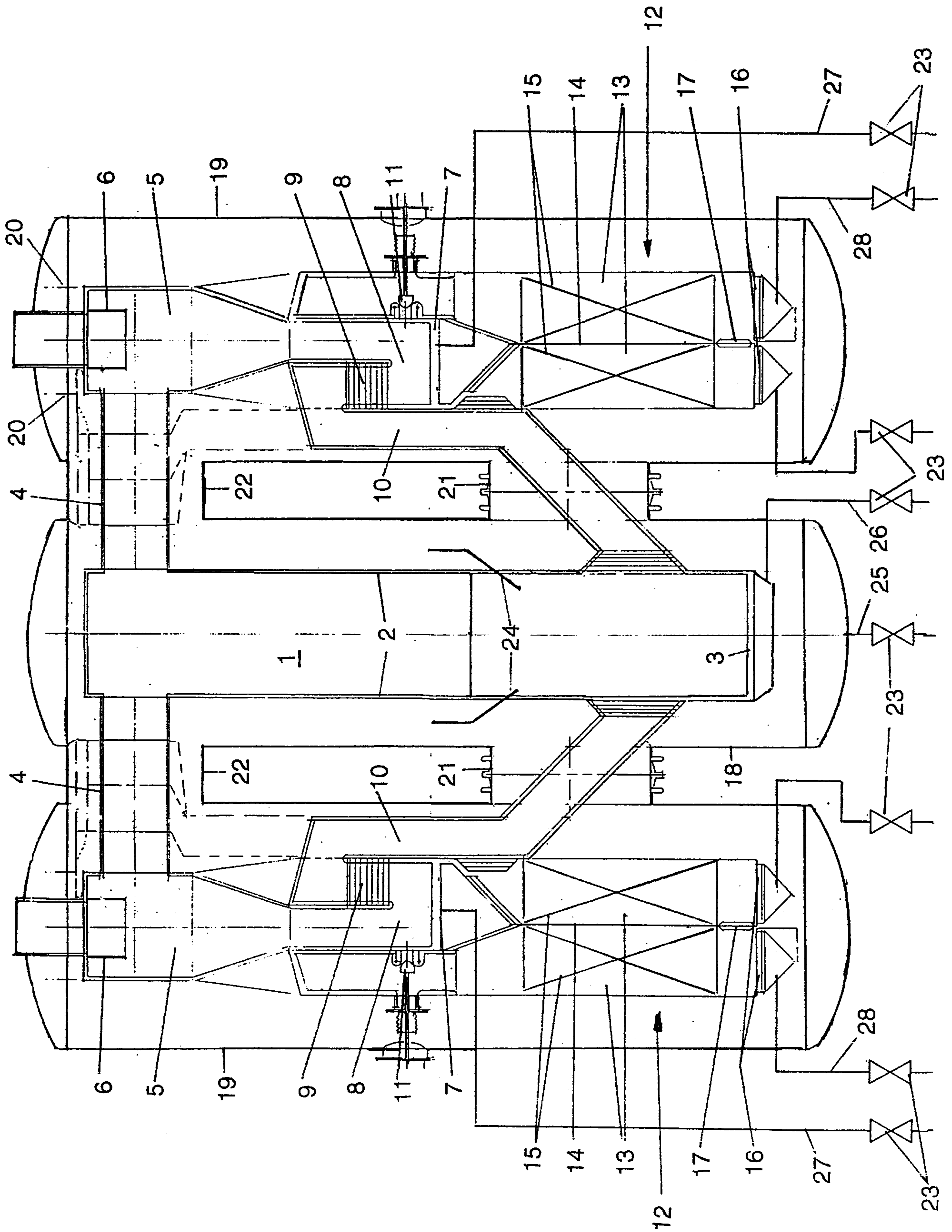
6. A steam generator as defined in claim 4, wherein said ducts are inclined.

7. A steam generator as defined in any one of claims 4 to 6, including secondary air nozzles opening into said fluidized bed burner chamber and open to an intermediate space between an inner wall of said one pressure vessel and said wall of tubes of said fluidized bed burner chamber; and return flow blocking means in said nozzles.

8. A steam generator as defined in any one of claims 4 to 7, wherein said fluidized bed burner chamber, said dip pot and said fluidized bed cooler have a respective nozzle floor with separate air supply conduits respectively.

9. A steam generator as defined in any one of claims 4 to 8, including a gas turbine system with a compressor connected to an intermediate space between said unit and the respective pressure vessel and between said fluidized bed burner chamber and the respective pressure vessel, said intermediate space being subjected to air over pressure from said gas turbine system.

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