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<p>(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</p> <p>(71) Applicant: Alstom Technology Ltd 5400 Baden (CH)</p> <p>(72) Inventors: • Enault, Christian 92260 Fontenay aux Roses (FR)</p>	<p>• Dreisler, Philippe 78140 Vélizy (FR)</p> <p>• Gauville, Pierre 91370 VERRIERES LE BUISSON (FR)</p> <p>(74) Representative: Pesce, Michele et al ALSTOM Technology Ltd CHTI Intellectual Property Brown Boveri Str. 7/664/2 5401 Baden (CH)</p>
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(54) **Circulating fluidized bed boiler device**

(57) The invention relates to a boiler device (1) comprising:
- a circulating fluidized bed boiler (5), in which a combustion is used for producing steam,
- a high pressure turbine (2) in which enters the steam produced in the boiler (5),

- a middle pressure turbine (3) in which is supplied steam from the high pressure turbine (2),
characterized in that the device (1) further comprises a heat exchanger for transferring heat from steam flowing upstream the high pressure turbine (2) to steam flowing between the high pressure turbine (2) and the middle pressure turbine (3).

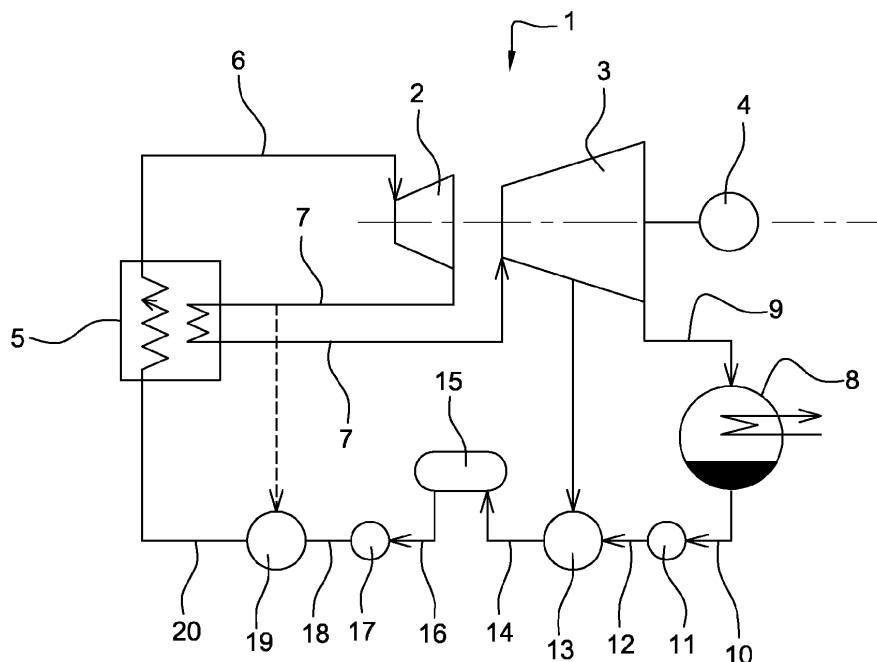


Fig. 1

Description

[0001] The present invention is related to a circulating fluidized bed (CFB) boiler device, including a reactor where the solid particles are fluidized and where chemical reactions and/or combustion reactions can take place. The circulating fluidized regime enhances the mixing of particles along with potential exothermic or endothermic chemical reactions.

[0002] The furnace of a conventional fluidized bed boiler is defined by four external side walls, a bottom and a roof and potentially inner walls to ensure the sealing with the outside if multiple fluidizing grates are used. All the walls constitute an ash-tight enclosure in which the solid particles including the fuel material are fluidized. The furnace enclosure is usually made of gastight panels formed of thin tubes. The heat released from the combustion of fuel is transferred to the water or steam flowing inside the tubes and also allowing the tubes to be cooled.

[0003] Air is introduced into the furnace to fluidize the solid particles and also brings the needed oxygen for combustion. Two air streams can be used. Primary air is mostly used to fluidize the particles, flows through the fluidizing grate which constitutes the bottom of the furnace. Secondary air is the additional air required for a complete combustion and is introduced through several ports located over the external side walls and/or inner walls if the bottom part of the furnace comprises a dual fluidizing grate and whose shape can be described like a pant leg.

[0004] Additional heating surfaces are located in the furnace and/or in external devices placed outside the furnace. External devices, for instance fluidized bed heat exchangers (FBHE), are supplied with hot circulating solids which are captured by the cyclones and return to the furnace either directly via multiple ducts or through devices where heat exchangers are installed, which allow the heat released by the combustion to circulating solids to be transferred to water or steam system. Other additional heat exchangers are located on the flue gas path and constitute the heat recovery boiler. The flue gas is usually cooled from 800-950°C which is the temperature at the furnace exit up to 300-350°C before entering the air pre-heater.

[0005] When increasing the thermal capacity of the boiler for power generation, water and steam cycles are changed to improve the overall thermal efficiency of the power plant. The first step was to develop a single reheat system. The steam at a high pressure (HP) turbine exhaust goes through one or multiple heat exchangers of the boiler in order to be reheated up to high temperature before feeding a middle pressure - low pressure (MP - LP) turbine. This basic process flow diagram has been used with a wide range of steam parameters, i.e. operating pressures and steam temperatures. Nowadays, steam temperatures up to 600°C along with a 300 bar operating pressure at the boiler outlet are the standard parameters for the biggest power plants.

[0006] Whatever the steam parameters, two subsequent operating conditions have some impact on the overall thermal efficiency of the power plant. The spray water injection for controlling the final reheat steam temperature at the rated temperature leads to a decay of gross plant heat rate by typically 0.2% when the spray water flow increases by 1% of the main steam flow. The pressure drop of the reheat system from the HP turbine exhaust up to the MP turbine inlet also impacts the gross plant heat rate. The pressure drop is usually closed to 8 to 10% of the steam pressure at the HP turbine exhaust. When increasing the pressure drop from 8 to 10% the gross plant heat rate increases by 0.2%.

[0007] Focusing on these two drivers the boiler makers have developed several arrangements in order to reduce as far as possible both parameters on an economic basis. Several arrangements were developed to reach no spray water such as a split back-pass, an external device such as a FBHE or a steam by-pass. In the first configuration, the split back-pass is equipped with a control damper for balancing the flue gas between two separate paths. The flue gas is then modulated in the path where the reheat heat exchangers are located so as to achieve a zero spray water flow. This system is sometimes not commercially agreed by customers because of the risk of fast wearing of control damper system with high ash coal.

[0008] In the case of an external device, one or several reheat heat exchangers are installed into the external devices. The heat pick-up and so the final steam temperature are controlled by changing the solid flow through the external device. The control of the solid flow may be fulfilled with a control valve or by any other system. All these systems require an appropriate steam pressure drop to allow a safe and cost-effective material selection. Steam by-pass is also used but can lead to a high pressure drop if some deviation in operating conditions happens.

[0009] Thus, an object of the present invention is to provide a circulating fluidized bed boiler device as to solve the above- described problems.

[0010] The object mentioned above is accomplished by a boiler device comprising:

- a circulating fluidized bed boiler, in which a combustion is used for producing steam,
- a high pressure turbine in which enters the steam produced in the boiler,
- a middle pressure turbine in which is supplied steam from the high pressure turbine.

[0011] The device according to the invention further comprises a heat exchanger for transferring heat from steam flowing upstream the high pressure turbine to steam flowing between the high pressure turbine and the middle pressure turbine.

[0012] Thus, by controlling the amount of heat transferred from the high pressure steam to the low pressure steam, it is possible to control the temperature of the

steam at the inlet of the middle pressure turbine without any water injection and with a low pressure drop between the HP turbine exhaust and the MP turbine inlet.

[0013] The device can comprise controlling means for controlling the steam flow entering the heat exchanger.

[0014] The controlling means can include a valve mounted on a pipe for routing the steam produced in the boiler into the heat exchanger and a valve mounted on a pipe for routing the steam produced in the boiler downstream the heat exchanger.

[0015] The device can comprise temperature controlling means for controlling the temperature of the steam at the inlet of the middle pressure turbine as a function of the heat transferred in the heat exchanger.

[0016] The steam exiting the high pressure turbine can be reheated in at least one reheater prior to being supplied to the middle pressure turbine.

[0017] The temperature of the steam flowing upstream the high pressure turbine (i.e. entering the heat exchanger) can be between 450 and 600°, preferably between 500 and 600°C, whereas the temperature of the steam located between the high pressure turbine and the middle pressure turbine (i.e. entering the heat exchanger) can be between 300 and 500°C, preferably between 300 and 450°C, between 300 and 400°C, between 400 and 500°C, between 400 and 450°C, or between 450 and 500°C.

[0018] The device preferably does not include any water injection means to control the reheat steam temperature.

[0019] Other features and advantages of the invention will become apparent from the following description of an embodiment of the invention given by way of a non-limiting example only, and with reference to the accompanying drawings, in which:

- Figure 1 is a schematic diagram of a device according to the invention, and
- Figure 2 is a partial view of the device.

[0020] In a typical steam turbine power plant, a steam generator such as a boiler produces steam which is provided to a high pressure (HP) turbine through a plurality of steam admission valves. Steam exiting the high pressure turbine is reheated in a conventional reheater prior to being supplied to a lower pressure turbine, the exhaust from which is conducted into a condenser where the exhaust steam is converted to water and supplied to the boiler to complete the cycle. A typical power utility system will employ one or more HP turbines, a medium pressure (MP) turbine and a low pressure (LP) turbine. The turbines are generally coupled to drive a synchronous electric power generator at constant speed for producing electric utility power which is transmitted over a transmission link to various users.

[0021] Figure 1 illustrates a simplified block diagram of a fossil-fired single reheat steam turbine generator unit, by way of example. The turbine system 1 includes

a plurality of turbines in the form of high pressure (HP) turbine 2, and at least one or more lower pressure turbines which, in the case of FIG. 1, include medium pressure (MP) and low pressure (LP) turbine 3. The turbines are connected to a common shaft to drive an electrical generator 4 which supplies power to a load such as an electrical grid network (not illustrated).

[0022] A steam generating system, that is a circulating fluidized bed boiler 5 operated by fossil fuel, generates steam which is heated to proper operating temperatures and conducted through a pipe 6 to the high pressure turbine 2, the flow of steam being governed by a set of steam admission valves.

[0023] Steam exiting the high pressure turbine 2 via the high pressure turbine exhaust outlet and steam pipe 7 is conducted to one or several reheaters R_{i-1} , R_i , R_{i+1} (as illustrated in Figure 2) and thereafter provided via the steam pipe 7 to the medium pressure turbine 3 for instance under control of valving arrangement. Thereafter, the exhaust from the MP-LP turbine 3 is provided to a condenser 8 via steam pipe 9 and converted to water. The water is provided back to the boiler 5 via the path including water pipe 10, low pressure pipe 11, water pipe 12, reheater 13, water pipe 14, boiler feed water container 15, water pipe 16, high pressure pump 17, water pipe 18, reheater 19 and water pipe 20. Although not illustrated, water treatment equipment is generally provided in the return line so as to maintain a precise chemical balance and a high degree of purity of the water.

[0024] As illustrated in Figure 2, the device according to the invention includes a heat exchanger $R_i S_{i+1}$ for exchanging heat between the steam located upstream the high pressure turbine and the steam located between the high pressure turbine and the middle pressure turbine.

[0025] S is the steam path of the heat exchanger $R_i S_{i+1}$ supplied with high steam pressure, i.e. with steam from the boiler and located upstream the high pressure turbine, whereas R is the steam path of the heat exchanger $R_i S_{i+1}$ supplied with low pressure, i.e. with steam from the high pressure turbine and located upstream the medium pressure turbine.

[0026] In addition to the heat exchanger $R_i S_{i+1}$, the steam path S can include other heat exchangers $S_i S_{i+2}$, ... S_n and the steam path R can include other heat exchangers R_{i-1} , R_{i+1} , ... R_n .

[0027] The steam temperature at the outlet of the finishing hot reheater R_n is controlled by modulating the heat pick-up in the heat exchanger $R_i S_{i+1}$. The amount of the heat transferred is controlled by regulating the high-pressure steam flow through the S_{i+1} steam path with control valves Va, Vb. A valve Vb is mounted on a pipe for routing the steam produced in the boiler into the heat exchanger $R_i S_{i+1}$ and a valve Va is mounted on a pipe for routing the steam produced in the boiler downstream the heat exchanger

[0028] The pressure drop of the low pressure steam path R is constant whatever the opening of control valves.

[0029] The device preferably comprises temperature

controlling means for setting the temperature of the steam upstream the high pressure turbine to a value comprised between 500 and 600°C and for setting the temperature of the steam located between the high pressure turbine and the middle pressure turbine to a value comprised between 400 and 500°C. These specific temperature ranges and also the homogeneity of the temperature of the steam upstream the high pressure turbine make it possible to design the heat exchanger R_i, S_{i+1} with a very low pressure drop between the HP turbine exhaust and the MP turbine inlet.

[0030] The device according to the invention provides that no water spray is needed during continuous stable operation and that a low pressure drop is obtained despite possible deviations in the operating conditions.

Claims

1. A boiler device (1) comprising:
 - a circulating fluidized bed boiler (5), in which a combustion is used for producing steam,
 - a high pressure turbine (2) in which enters the steam produced in the boiler (5),
 - a middle pressure turbine (3) in which is supplied steam from the high pressure turbine (2),

characterized in that the device (1) further comprises a heat exchanger (R_i, S_{i+1}) for transferring heat from steam flowing upstream the high pressure turbine (2) to steam flowing between the high pressure turbine (2) and the middle pressure turbine (3) .
2. A device (1) according to claim 1, **characterized in that** it comprises controlling means for controlling the steam flow entering the heat exchanger (R_i, S_{i+1}).
3. A device (1) according to claim 2, **characterized in that** the controlling means include a valve (V_b) mounted on a pipe for routing the steam produced in the boiler into the heat exchanger (R_i, S_{i+1}) and a valve (V_a) mounted on a pipe for routing the steam produced in the boiler downstream the heat exchanger (R_i, S_{i+1}).
4. A device (1) according to claim 2 or 3, **characterized in that** it comprises temperature controlling means for controlling the temperature of the steam at the inlet of the middle pressure turbine (3) as a function of the heat transferred in the heat exchanger (R_i, S_{i+1}).
5. A device (1) according to any of claim 1 to 4, **characterized in that** the steam exiting the high pressure turbine (2) is reheated in at least one reheater prior to being supplied to the middle pressure turbine (3).

6. A device (1) according to any of claim 1 to 5, **characterized in that** the temperature of the steam flowing upstream the high pressure turbine (2) is between 500 and 600°C whereas the temperature of the steam located between the high pressure turbine (2) and the middle pressure turbine (3) is between 300 and 450°C.

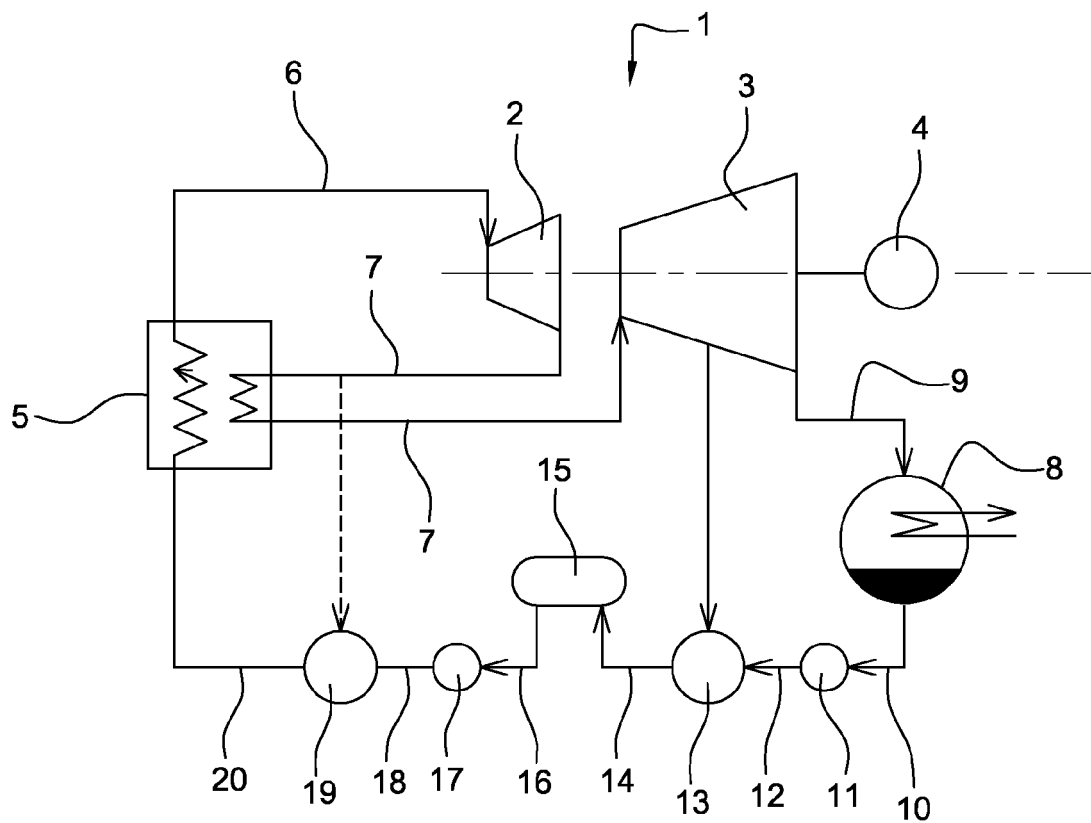


Fig. 1

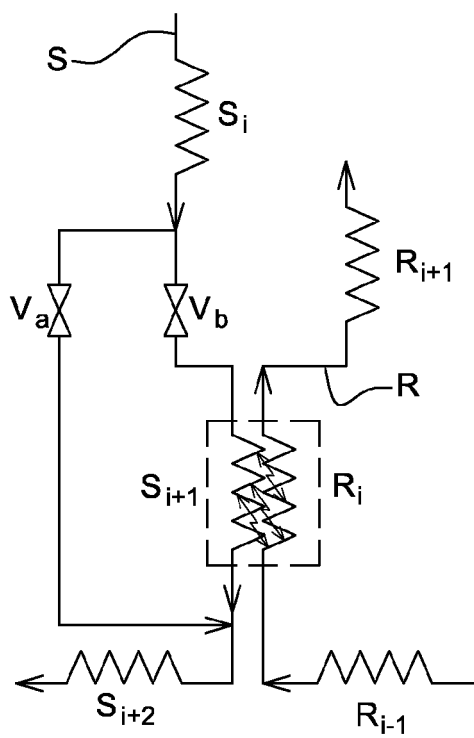


Fig. 2



EUROPEAN SEARCH REPORT

Application Number
EP 12 16 1881

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A	* page 2, line 7 - line 86; claims; figures *	2-4	

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A	* page 6, line 24 - page 18, line 13; claims; figures 2,3; examples; tables * * abstract *	2-4	
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 March 2013	Examiner Zerf, Georges
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 March 2013	Examiner Zerf, Georges
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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