Method and device for controlling power output during combustion in a pressurized fluidized bed (1). Energy developed is taken out by heat transfer surfaces (21, 22) and a gas turbine (26). Heat is utilized in a steam turbine (24, 25). The heat transfer surfaces comprise a high pressure section (7) with one evaporator (21) and a low pressure section (8) with one or more intermediate superheaters (22). In case of changes in the power output, the bed depth of the fluidized bed is varied, whereby heat transfer surfaces included in the evaporator are exposed or covered by the bed and production of high pressure steam, evaporation power, is controlled. Heat taken from the fluidized bed is controlled by controlling the temperature difference in between the bed and low pressure steam flowing in the intermediate superheaters. High pressure steam, produced in the evaporator is superheated in a heat exchanger (23) arranged outside the bed by low pressure steam from the intermediate superheaters before it is expanded in a high pressure steam turbine (25).
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Method and device for controlling the power output during combustion in a fluidized bed

The invention relates to the control of the power output during combustion of fuel in a fluidized bed in which energy is recovered with heat transfer surfaces, arranged close to the fluidized bed, which are traversed by a liquid or gaseous heat transfer medium.

The invention is particularly valuable in power plants with combustion in a pressurized fluidized bed, PFBC (Pressurized Fluidized Bed Combustion) plants, where energy is recovered with a gas turbine and a steam turbine in combination. In such a plant the invention makes possible a more rapid change of the power output, an increase of the gas temperature at partial load, and control of the power balance between gas turbine and steam turbine during operation.

BACKGROUND ART

During combustion of fuels in a fluidized bed, the power output is usually controlled by changing the bed depth. With conventional fluidized bed boilers for the production and superheating of steam, which is expanded in a steam turbine, the control of the bed depth in case of changes of the power output entails the transportation of large quantities of bed material back and forth to the fluidized bed. These large material flows require a complicated transport systems involving, inter alia, intermediate storage containers for bed material. In addition, the considerable bed depth adjustments and the associated material flows as well as the exposure of large heat transfer surfaces result in a slow control and in the temperature of the flue gases falling in case of partial load, which is reflected in inferior environmental performance.

If the fluidized bed is pressurized, that is, is included in a plant for combustion in a pressurized fluidized bed, a
PFBC (Pressurized Fluidized Bed Combustion) plant, in which
energy is recovered also from the hot pressurized flue gases
by means of gas turbines, conventional control of the power
output with bed depth adjustments also results in the
5 efficiency of the plant decreasing with decreasing flue gas
temperature as well as in considerable difficulties in
adjusting the power balance between the steam and gas tur-
bines during operation.

10 SUMMARY OF THE INVENTION

The heat transfer surfaces included in the fluidized bed
boiler are arranged in a high pressure section, comprising
an evaporator and a possible superheater, as well as a low
15 pressure section, with one or more intermediate super-
heaters. In the fluidized bed, the heat transfer surfaces
are arranged, according to the invention, such that, in case
of a change of the bed depth, substantially heat transfer
surfaces included in the evaporator are exposed from or
covered by the fluidized bed whereas heat transfer surfaces
included in the intermediate superheater are substantially
located in the fluidized bed irrespective of the power
output. A fluidized bed boiler designed and arranged
according to the invention and with evaporation and
20 superheating of steam carried out according to the invention
requires a considerably smaller change of the bed depth in
case of a corresponding change of the power output than a
conventionally arranged fluidized bed boiler. In addition,
with a fluidized bed boiler according to the invention, a
direct control of the evaporation power is obtained by
changes of the bed depth.

By concentrating the evaporator substantially to the upper
part of the fluidized bed in this way, a direct and rapid
30 control of the evaporation power upon a change of the bed
depth is obtained. In addition, at a given change of the
power output, a considerably smaller change of the bed depth
is needed in a plant with the evaporator arranged according
to the invention than in a plant with a conventionally arranged evaporator. In addition, the flue gas temperature is not changed to the same extent as a result of changes in the power output.

A fluidized bed boiler arranged such that the flow of a heat transfer medium through the boiler is varied to control the mean temperature difference between the fluidized bed and the heat transfer medium, and hence also the heat taken from the bed, requires a considerably smaller bed depth change for a certain change in the energy output than a conventional boiler. This gives a rapid control and a small change of the flue gas temperature, which in turn improves the environmental performance, for example the possibilities of nitrogen oxide reduction. Further, if the fluidized bed is part of a power plant with combustion in a pressurized fluidized bed where energy is also recovered from the pressurized flue gases with gas turbines, the possibilities of adjusting, in operation, the power balance between the steam and gas sides are also improved.

The flow through the boiler is suitably varied as a heat transfer medium to a varying degree is bypassed the boiler. In this way, the temperature of the heat transfer medium is changed and hence also the temperature difference between the fluidized bed and the medium and consequently the heat taken out by the heat transfer medium from the fluidized bed.

With a fluidized bed boiler comprising an evaporator, a superheater and an intermediate superheater, and according to the invention supplemented by at least one external heat exchanger in which high pressure steam from the evaporator is superheated by hot steam of a lower pressure from the intermediate superheater, low pressure steam, and in which according to the invention the temperature difference between the fluidized bed and a medium flowing in the intermediate superheater, low pressure steam, is controlled
through bypasses and recirculation in the circuit for low pressure steam, a rapid control of the power output is obtained.

5 The evaporator is supplied with feedwater which is evaporated to high pressure steam. Before the high pressure steam is expanded in a high pressure steam turbine, its energy contents are further increased by superheating it, according to the invention, in at least one heat exchanger located outside the fluidized bed. The heat for the superheating of high pressure steam is taken from steam of lower pressure which has been superheated in at least one intermediate superheater arranged in the fluidized bed.

15 The intermediate superheater is supplied with steam of low pressure, preferably a sub-quantity of the steam expanded in the high pressure steam turbine, which is greatly superheated. Through a bypass duct arranged outside the fluidized bed, an additional sub-quantity of the steam expanded in the high pressure steam turbine is bypassed the intermediate superheater. The superheated low pressure steam and the low pressure steam, which by means of the bypass duct is conducted past the superheater, are mixed downstream of the intermediate superheater and supplied to at least one heat exchanger arranged outside the fluidized bed, the cooling medium of which is high pressure steam, before the energy is recovered from the low pressure steam through expansion in a low pressure steam turbine. By superheating low pressure steam, by the possibility to bypass the intermediate superheater and by designing the intermediate superheaters of high temperature resistant material, the low pressure steam may be superheated to a temperature very close to the temperature of the fluidized bed. In this way, the possibility of changing the mean temperature difference between fluidized bed and low pressure steam, and hence the possibility of controlling power transferred to the intermediate superheater in
relation to a conventionally designed fluidized bed boiler, are increased.

The temperature of the low pressure steam is controlled by varying the percentage of steam conducted past intermediate superheaters.

The flue gas temperature is not changed to the same extent with changed power output in a fluidized bed,

- with the heat transfer surfaces arranged according to the invention,
- with superheating of high pressure steam according to the invention, and
- with control of the mean temperature difference between fluidized bed and low pressure steam according to the invention,

as in a fluidized bed with a conventionally arranged fluidized bed boiler, which means, if the fluidized bed is part of a power plant with combustion in a pressurized fluidized bed and where energy is recovered with a gas turbine from the hot, pressurized flue gas,

- that the efficiency is increased, and
- that the possibilities of achieving improved environmental performance are increased.

The invention also greatly improves the possibilities of control of the power balance between the steam and gas turbines.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in greater detail with reference to Figure 1.
Figure 1 shows a fluidized bed boiler arranged in a power plant for combustion in a pressurized fluidized bed, a PFBC - Pressurized Fluidized Bed Combustion - plant, which according to the invention has been arranged in a high pressure section with an evaporator which is connected to a high pressure steam turbine and a low pressure section with one or more intermediate superheaters which is or are connected to external heat exchangers for superheating of the high pressure steam, with possibilities of bypassing of the intermediate superheater before the low pressure steam is finally expanded in a low pressure steam turbine.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention as applied to combustion in a fluidized bed, included in a plant with combustion in a pressurized fluidized bed, a PFBC plant, is illustrated in Figure 1. Heat transfer surfaces 21, 22 for recovery of energy developed during the combustion are arranged in the fluidized bed 1, in the walls of the bed vessel 5 surrounding the fluidized bed 1, in the freeboard 6 above the fluidized bed 1 or in flue gas ducts 29 provided downstream of the fluidized bed 1.

According to the invention, the heat transfer surfaces are arranged in a high pressure circuit 7 in the form of an evaporator 21 for the production of high pressure steam and possibly a superheater (not shown) and a low pressure circuit 8 in the form of one or more intermediate superheaters 22. The intermediate superheater 22 included in the low pressure circuit 8 is arranged in the fluidized bed 1 for superheating of low pressure steam. Heat taken out by means of the evaporator 21 and the intermediate superheater 22 is utilized in at least one steam turbine 24, 25 connected to the heat transfer surfaces 21, 22 whereas energy from the hot pressurized flue gases is recovered with at least one gas turbine 26 arranged in the flue gas duct 29. The gas turbine 26 drives a compressor 27 for pressu-
rization of the gas, preferably air, which is supplied to a pressure vessel 28 arranged around the bed vessel 5.

According to the invention, the flow of and the inlet temperature of the low pressure steam which is superheated in the intermediate superheater 22 are varied, heat taken out from the fluidized bed thus being controlled. The flow is varied by conducting the low pressure steam to a varying degree past the intermediate superheater 22, for example through a bypass duct 3 arranged outside the fluidized bed 1. The distribution of the flow between the intermediate superheater 2 and the bypass duct 3 is controlled by a valve 4. By superheating only steam of low pressure in the intermediate superheater 22 and designing the intermediate superheater 22 of high temperature resistant material, the low pressure steam may be superheated to temperatures close to the temperature of the fluidized bed 1. This increases the possibilities of controlling the output heat with the intermediate superheater 22, which in the low pressure section 8 is connected to at least one heat exchanger 23 arranged outside the fluidized bed 1, by bypassing the intermediate superheater 22 and the heat exchanger 23, respectively, to a varying degree. The low pressure steam superheated in the intermediate superheater 22 is used to superheat, in the heat exchanger 23, high pressure steam produced in the evaporator 21 before the low pressure steam is finally expanded in a low pressure steam turbine 24.

The high pressure steam superheated in the heat exchanger 23 is expanded in a high pressure steam turbine 25 and a subquantity of the low pressure steam thus obtained is suitably supplied to the low pressure circuit 8. By arranging the heat transfer surfaces in the fluidized bed 1, according to the invention, such that, in case of changes of the bed depth, the evaporator 21 is substantially exposed or covered by the fluidized bed 1, changes in the bed depth are immediately reflected by changes in the evaporation power. In this way, considerably smaller changes of the bed depth
are needed with the heat transfer surfaces 21, 22 arranged according to the invention, in relation to a conventional fluidized bed boiler, to achieve a certain change in the power output.

With the greatly improved possibilities of control of the evaporation power and of the output heat from the fluidized bed 1, according to the invention, valuable improvements in the control and operation of a PFBC plant are obtained, namely:

- A more rapid change of the power output since the need of bed depth changes and the associated transport of bed material are considerably reduced with the heat transfer surfaces 21, 22 arranged and connected according to the invention.

- The dependence of the flue gas temperature on the power output is considerably reduced by the reduction of the bed depth changes, and in this way the efficiency and environmental performance of the plant can be kept less dependent on the power output.

- The power balance between the gas and steam sides may be adjusted during operation.
1. A method of controlling the power output during combustion of fuel in a pressurized fluidized bed (1), wherein energy developed during the combustion is at least partially taken out as heat by means of heat transfer surfaces (21, 22) arranged in or downstream of the fluidized bed, wherein the heat transfer surfaces are traversed by liquid or gaseous medium and the output heat is utilized in at least one steam turbine (24, 25) connected to the heat transfer surfaces and the heat transfer surfaces are adapted to comprise a high pressure section (7) with at least one heat transfer surface in the form of an evaporator (21) as well as a low pressure section (8) with a heat transfer surface in the form of at least one intermediate superheater (22), wherein energy contained in the hot pressurized flue gases is recovered in at least one gas turbine (26) arranged in the flue gas paths downstream of the fluidized bed, and wherein, in case of changes in the power output, the bed depth of the fluidized bed is varied whereby the power balance between gas turbine and steam turbine is maintained by controlling the power taken out in the heat transfer surfaces, characterized in that, in case of a change of the bed depth as a result of a change in the power output, heat transfer surfaces included in the evaporator (21) are exposed from and covered by, respectively, the fluidized bed (1), whereby the production of high pressure steam, the evaporation power, is controlled, that at the same time heat taken out from the fluidized bed by means of the intermediate superheater (22) is controlled by controlling the mean temperature difference between the fluidized bed and a medium flowing in the intermediate superheater in the form of low pressure steam, and the low pressure steam is superheated, and that at the same time the temperature/energy contents of the high pressure steam are controlled by superheating high pressure steam, produced in the evaporator, by means of low pressure steam from the intermediate superheater in at least
one heat exchanger (23), arranged outside the fluidized bed (1), before it is expanded in a high pressure steam turbine (25).

2. A method according to claim 1, characterized in that heat taken out from the fluidized bed is controlled by dividing the steam expanded in the high pressure steam turbine (25), in the form of low pressure steam, after expansion into one sub-quantity which is supplied to the intermediate superheater (22) and one sub-quantity which is conducted past the intermediate superheater (22), the mean temperature difference between the fluidized bed and the low pressure steam being controlled and the low pressure steam being heated to a high temperature without the pressure being essentially changed, that said sub-quantities of low pressure steam are mixed downstream of the intermediate superheater and supplied to at least one heat exchanger (23), arranged outside the fluidized bed, for controlling the temperature of high pressure steam supplied to the high pressure steam turbine (25) before the low pressure steam is expanded in a low pressure steam turbine (24).

3. A device for control of the power output during combustion of fuel in a pressurized fluidized bed (1), wherein energy developed during the combustion is adapted, at least partially, to be taken out as heat with heat transfer surfaces (21, 22) arranged in or downstream of the fluidized bed, that the heat transfer surfaces are adapted to be traversed by a liquid or gaseous medium and the heat taken out is adapted to be utilized in at least one steam turbine (24, 25) connected to the heat transfer surfaces and the heat transfer surfaces are adapted to comprise a high pressure section (7) with at least one heat transfer surface in the form of an evaporator (21) as well as a low pressure section (8) with a heat transfer surface in the form of one or more intermediate superheaters (22), that at least one gas turbine (26) is arranged downstream of the fluidized bed, in a flue gas duct (29), for recovery of energy
contained in the hot pressurized flue gases, and wherein the bed depth of the fluidized bed is adapted to vary when controlling the power output and the power balance between gas turbine and steam turbine is adapted to be maintained by means of control of the power taken out in the heat transfer surfaces, characterized in that the evaporator (21) for production of high pressure steam is adapted, in case of changes of the bed depth, to be exposed or covered by the fluidized bed, whereby the production of high pressure steam is controlled, that the intermediate superheater (22) is included in a low pressure circuit (8) comprising the intermediate superheater, for superheating of low pressure steam, and at least one heat exchanger (23) arranged outside the fluidized bed, for superheating of high pressure steam, as well as at least one bypass duct (3) and at least one valve (4) for controlling the mean temperature difference between the fluidized bed and a medium flowing in the low pressure circuit, low pressure steam, thereby controlling the heat taken out from the fluidized bed, that the heat exchanger is adapted to control the energy contents/temperature of the high pressure steam produced in the evaporator by means of low pressure steam superheated in the intermediate superheater, before the high pressure steam is expanded in a high pressure steam turbine (25) arranged close to the heat exchanger.
INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER

According to international Patent Classification (IPC) or to both National Classification and IPC

IPC5: F 22 B 31/00

II. FIELDS SEARCHED

Classification System
IPC5

Minimum Documentation Searches
F 01 K; F 22 B

Classification Symbols

Documentation Searched other than Minimum Documentation

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SE, DK, FI, NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT

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IV. CERTIFICATION

Date of the Actual Completion of the International Search
15th May 1991

Date of Mailing of this International Search Report
1991 - 05 - 30

International Searching Authority

SWEDISH PATENT OFFICE

Signature of Authorized Officer

Anette Hall
ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. PCT/SE 91/00126

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