



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
**05.07.2023 Bulletin 2023/27**

(51) International Patent Classification (IPC):  
**F23C 10/26** <sup>(2006.01)</sup> **F23G 5/30** <sup>(2006.01)</sup>  
**F23C 10/18** <sup>(2006.01)</sup>

(21) Application number: **21218369.3**

(52) Cooperative Patent Classification (CPC):  
**F23G 5/30; F23C 10/18; F23C 10/26**

(22) Date of filing: **30.12.2021**

(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**

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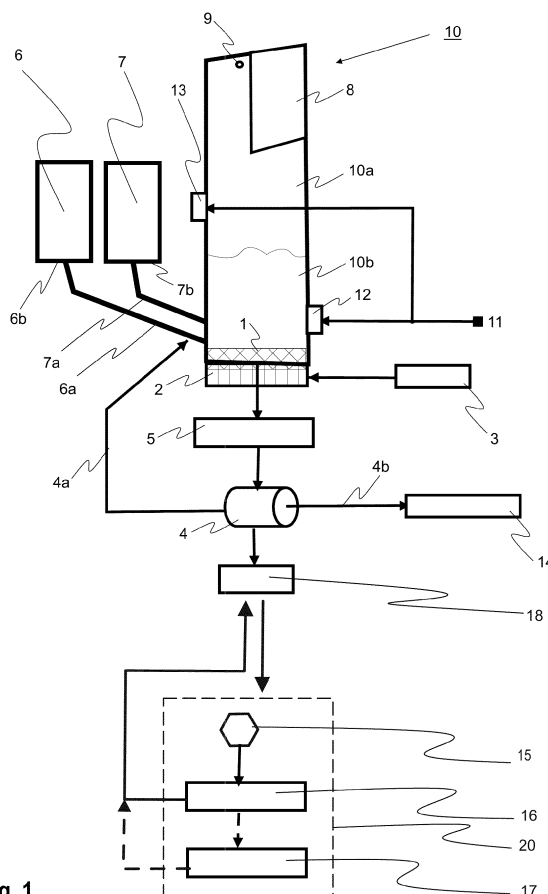
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Remarks:  
Amended claims in accordance with Rule 137(2) EPC.

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(54) **METHOD OF OPERATING A FLUIDIZED BED BOILER AND BOILER PLANT**

(57) The method uses a fluidized bed boiler (10), which has a furnace (10a). In the method, the furnace is heated to operating temperature, a fluidized bed (1) is formed in the furnace from bed material (6), which has a target grain size, determined operating temperature for the fuel (7) to be burned is maintained in the furnace by burning fuel in the furnace, and bed material in the fluidized bed boiler is circulated by removing bed material from the furnace, by dividing the removed bed material by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size, and by returning at least part of the first share into the furnace. Before the bed material is returned to the furnace, at least part of the bed material removed from the furnace is regenerated by detaching impurities and/or ash from the surface of the bed material grains, the regenerated bed material is divided by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size, and at least part of said first share is returned into the furnace. The boiler plant comprises a fluidized bed boiler, which has a furnace, means for generating a fluidized bed in the furnace and circulation means for removing bed material from the furnace and returning it to the furnace. The boiler plant additionally comprises regenerating means for regenerating the bed material removed from the furnace before the bed material is returned to the furnace.



**Fig. 1**

## Description

[0001] The invention relates to a method for operating a fluidized bed boiler, where the fluidized bed boiler has a furnace, in which method the furnace is heated to operating temperature, a fluidized bed is formed in the furnace from bed material, which has a target grain size, determined operating temperature for the fuel to be burned is maintained in the furnace by burning fuel in the furnace, and bed material is circulated by removing bed material from the furnace, by dividing the removed bed material by sieving into a first share, where the bed material grains have a target grain size, and a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size, and by returning at least part of said first share into the furnace. The invention also relates to a boiler plant.

## Prior art

[0002] Fluidized bed combustion has become one of the most important methods for producing energy from solid fuels in an environmentally friendly manner. Boiler plants based on fluidized bed combustion technique are generally called fluidized bed boilers or fluidized layer boilers. Fluidized bed combustion is especially well suited for fuels, the burning of which is difficult in conventional boiler plants. In fluidized bed combustion the combustion reactions mainly occur in a thick fluidized bed floated by an air stream, where the fuel comes into contact with hot bed material, which intensifies the heat transfer and stabilizes the combustion event. Advantages of the method are inexpensive sulphur removal, minor emissions of  $\text{NO}_x$  and unburned particles and a possibility to use different, also low quality and varying quality fuels. Fluidized bed combustion is especially suited for fuels used in forest industry, which are among others bark, chips, peat and various sludges. Due to the pressurized air required by the fluidized bed, the technique has a large intrinsic need for operating power.

[0003] Fluidized bed combustion can be implemented in boiler plants either as layer or circulation fluidization. In layer fluidization the grains of the fluidized bed material remain in the fluidized bed and in circulation fluidization the bed material particles pass out of the furnace. Circulation fluidization requires a cyclone at the back of the furnace, with which the material particles are separated and returned back into the furnace. Layer fluidization is better suited than circulation fluidization for wet fuels and/or fuels with a low temperature value. Additionally, it is a more inexpensive technique and enables easier boiler changes.

[0004] In layer fluidization, the temperature of the fluidized bed is low (750-950 °C), so that the ash does not soften. Softened or melted ash binds the bed material, whereby fluidization no longer works. The diameter of bed material grains used in layer fluidization is typically in the range of 1-3 mm and the height of the fluidized bed

is 0,5-1,0 meters. The main part of the generated ash passes along with the flue gas out as fly ash. Due to this, a fluidized bed boiler usually has efficient flue gas cleaners. Bottom ash flowing under the fluidized bed is removed with shut-off feeders.

[0005] Fuel is fed in layer fluidization into the fluidized bed. Combustion air is generally fed in several stages. Primary combustion air, which also functions as fluidization air, is fed from below the fluidization bed. The second and third air feed are on top of the fluidized bed, at a height of 1,5-4,0 metres from the bottom grate.

[0006] Conventionally, natural sand is used as bed material in the fluidized bed. Natural sand contains as main components quartz and other silicates. Especially quartz has a strong tendency to react with alkali metals contained in the fuel, such as potassium and sodium. Alkali metals form, when reacting with quartz, a sticky alkali melt on the surface of the quartz particle, which causes sintering of the bed sand.

[0007] Alkali metals from wood affect the behaviour of bed material in fluidized bed combustion. Especially in combustion of wood chips, alkali metals, alkaline earth metals and compounds containing phosphor stick around the sand particles used as bed material. These compounds agglomerate bed material grains to each other and increase the size of the grains. Thus, when burning only wood, sintering of the fluidized bed can become a problem. Large agglomerates may even clog combustion air nozzles coming into the bed, whereby the entire fluidized bed boiler stops functioning.

[0008] The above-described sintering phenomenon disturbs the operation of the fluidized bed and may lead to sintering of the entire fluidized bed and as a result thereof to the shutdown of the fluidized bed boiler. The aim is to prevent this problem by replacing the used bed sand during use. Used bed sand waste, which can no longer be reused, is generated in combustion plants, depending on the size of the plant, typically 5-20 tons per day. Even if the bed sand was replaced often, shutdowns caused by sintering of the fluidized bed cannot be completely avoided. Additionally, if wood-based fuel is used, which contains less ash than for example peat does, then more bed material is needed to replace the sand exiting the process.

[0009] Publication F1128502 B describes a method for operating a fluidized bed boiler and a fluidized bed boiler, where crystallized, quartz free blast furnace slag is used as fluidized bed material. Bed material exiting the fluidized bed in connection with ash removal is continuously sieved and blast furnace slag particles with a suitable size are returned from the sieving back into the fluidized bed of the fluidized bed boiler. Blast furnace slag particles separated in the sieving, which are too small and too large and sintered from the quartz, are removed from the process along with the ash. Even though this as such functional solution can significantly reduce the need for replacing the bed material, the amount of bed material to be replaced is still large.

## Object of the invention

**[0010]** The object of the invention is to introduce a new method for operating a fluidized bed boiler and a boiler plant, with which problems and disadvantages related to methods and boiler plants according to prior art can be reduced.

**[0011]** The objects of the invention are obtained with a method and a boiler plant, which are characterized in what is presented in the independent claims. Some advantageous embodiments of the invention are presented in the dependent claims.

## Brief summary of the invention

**[0012]** The invention relates to a method for operating a fluidized bed boiler, where the fluidized bed boiler has a furnace. In the method, the furnace is heated to operating temperature, a fluidized bed is formed in the furnace from bed material, which has a target grain size, determined operating temperature for the fuel to be burned is maintained in the furnace by burning fuel in the furnace, and bed material in the fluidized bed boiler is circulated by removing bed material from the furnace, by dividing the removed bed material by sieving into a first share, where the bed material grains have a target grain size, and a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size, and by returning at least part of said first share into the furnace. The method is characterized in that before the bed material is returned to the furnace, at least part of the bed material removed from the furnace is regenerated by detaching impurities and/or ash from the surface of the bed material grains, the regenerated bed material is divided by sieving into a first share, where the bed material grains have a target grain size, and a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size, and at least part of said first share is returned into the furnace.

**[0013]** In one advantageous embodiment of the method according to the invention, before the bed material is regenerated, bed material grains with a grain size that is larger or smaller than the target grain size are separated from the bed material removed from the furnace by pre-sieving. In this embodiment, only the part of the bed material removed from the furnace, the grain size of which is in accordance with the target grain size of the bed material, is regenerated.

**[0014]** In a second advantageous embodiment of the method according to the invention, the bed material to be regenerated is transferred from the fluidized bed boiler to a regenerating plant at a distance therefrom, the fluidized bed material is regenerated in said regenerating plant and the regenerated bed material is returned from the regenerating plant to the fluidized bed boiler. The distance between the fluidized bed boiler and the regenerating plant can be several kilometres, whereby the transportation of the bed material to the regenerating

plant and back to the fluidized bed boiler can be done with trucks.

**[0015]** In a third advantageous embodiment of the method according to the invention, bed material is regenerated by grinding and wearing the surface of the bed material grains mechanically. Advantageously, the surface of the bed material grains is ground or worn by milling the bed material in a mill, especially in a centrifugal mill, a ball mill or the like.

**[0016]** In a fourth advantageous embodiment of the method according to the invention, before the regenerated bed material is returned to the furnace, the amount of impurities contained in the regenerated bed material is determined. The impurities are mainly slag layers detached from the surface of the bed material grains in connection with the regenerating, the grain size of which is the same as the target grains size of the bed material grains, whereby the slag layers are not separated from the bed material grains by sieving. The amount of impurities is advantageously determined by taking sample batches from the regenerated bed material and analysing said sample batches chemically.

**[0017]** In still another advantageous embodiment of the method according to the invention, an upper limit value is determined for the impurities contained in the bed material and the regenerated bed material is returned to the furnace only if the amount of impurities in the regenerated bed material is below said upper limit value.

**[0018]** In still another advantageous embodiment of the method according to the invention, the impurities comprise chemical elements, which include at least silicon, sodium and potassium, and the upper limit value for the chemical element content in the regenerated bed material is set as the chemical element content of virgin bed material plus an allowed growth rate. Advantageously, the allowed growth rate for silicon content is set at 3 %, the allowed growth rate for sodium content is set at 0.5 %, the allowed growth rate for potassium content is set at 0.5 % and the sum of the allowed growth rates for the content of other chemical elements than the ones mentioned is set at 6 %.

**[0019]** In still another advantageous embodiment of the method according to the invention, crystallized, quartz free blast furnace slag is used as bed material. Advantageously, 0.5-1.5 mm is used as the target grain size for the bed material. Crystallized, quartz free blast furnace slag is blast furnace slag slowly cooled with the aid of air, which in accordance with its name has a crystalline structure. The properties of the crystallized, quartz free blast furnace slag include that it does not react with alkali metals in the fuel. The alkali in the fuel can thus only react with quartz-containing sand coming into the bed with the fuel, the amount of which sand is typically minor.

**[0020]** The boiler plant according to the invention comprises a fluidized bed boiler, a furnace, means for generating a fluidized bed in the furnace, which fluidized bed comprises a granular bed material, which has a target

grain size, a container for bed material, input means for feeding bed material from the container to the furnace, a fuel container for fuel, fuel input means for feeding fuel from the fuel container to the furnace, circulation means for removing bed material from the furnace and returning it to the furnace, which circulation means comprise a sieve for dividing the bed material removed from the furnace into a first share to be returned to the furnace, where the bed material grains have a target grain size, and a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size. The boiler plant is characterized in that it additionally comprises regenerating means for regenerating the bed material removed from the furnace before the bed material is returned to the furnace, which regenerating means are arranged to regenerate the bed material removed from the furnace by detaching impurities and/or ash from the surface of the bed material grains, to divide the regenerated bed material by sieving into a first share, where the bed material grains have a target grain size, and a second share, where the grain size of the bed material grains is larger or smaller than the target grain size.

**[0021]** In one advantageous embodiment of the boiler plant according to the invention, said regenerating means comprise grinding means or a mill, such as a centrifugal mill or a ball mill, for mechanical treatment of the surface of the bed material grains.

**[0022]** In a second advantageous embodiment of the boiler plant according to the invention, said regenerating means further comprise analysing means for analysing the amount of impurities contained in the regenerated bed material.

**[0023]** In still another advantageous embodiment of the boiler plant according to the invention, the bed material of the fluidized bed comprises crystallized, quartz free blast furnace slag.

**[0024]** In still another advantageous embodiment of the boiler plant according to the invention, the target grain size of the bed material is 0.5-1.5 mm.

**[0025]** In still another advantageous embodiment of the boiler plant according to the invention, said regenerating means are arranged in a separate regenerating plant at a distance from the fluidized bed boiler.

**[0026]** An advantage of the method and fluidized bed boiler according to the invention is that the invention significantly reduces the need for replacing the bed material.

**[0027]** An additional advantage of the invention is that the reduction in need for replacing the fluidized bed proportionally also saves transportation, handling, waste costs and also waste tax costs.

### Brief description of the drawings

**[0028]** In the following, the invention will be described in detail. In the description, reference is made to the enclosed drawings, in which

figure 1 shows as an example some functional main

components of a fluidized bed boiler according to the invention, and

figure 2 shows as an example the functional main phases of the fluidized bed combustion process according to the invention.

### Detailed description of the invention

**[0029]** Figure 1 shows as an example a fluidized bed boiler 10 belonging to a boiler plant according to the invention, in which fluidized bed 1 crystallized, quartz free blast furnace slag is used as the bed material 6. The fluidized bed boiler 10 shown in figure 1 comprises a furnace 10a, a superheater 8 and input means 12 and 13 for feeding auxiliary fuel 11 into the furnace. The auxiliary fuel can be for example oil or natural gas.

**[0030]** The fluidized bed boiler 10 also comprises a fuel container 7b for solid fuel 7 and fuel input means 7a leading from the fuel container 7b to the furnace 10a, such as for example an input pipe or a screw conveyor. For example tree bark, wood, wood dust, wood chips, peat, glulam waste, plywood borders and various sludges can be used as solid fuel.

**[0031]** Quartz particles contained in the used solid fuel 7 have a strong tendency to react with alkali metals contained in the fuel, such as potassium and sodium. Alkali metals form, when reacting with quartz, a sticky alkali melt on the surface of the quartz particle, which causes slag formation, i.e. sintering of the bed material. The fluidized bed boiler 10 according to the invention uses crystalline, quartz free blast furnace slag as bed material, which however is sintered significantly less than bed sand conventionally used in fluidized bed boilers.

**[0032]** The weight of the fluidized bed 1 is typically 15-50 tons. The fluidized bed 1 is lifted off the bottom of the furnace 10a via a nozzle arrangement 2 with a strong air flow available from one or more fans 3.

**[0033]** In the fluidized bed boiler 10 according to the invention, the crystallized, quartz free blast furnace slag 6 used as bed material is transferred from the container 6b via a bed material transfer pipe 6a to the lower part of the furnace 10a to form a fluidized bed 1 before the fluidized bed boiler is started.

**[0034]** Ash generated from the solid fuel 7 in the furnace 10a during combustion is removed from the furnace 10a with ash removal means 5, such as for example shut-off feeders or with the aid of a downpipe and a screw conveyor. The same ash removal means 5 are used to remove also used bed material 6 from the furnace.

**[0035]** The bed material removed from the furnace 10a in the fluidized bed boiler 10 belonging to the boiler plant according to the invention is led little by little to the sieve 4. The sieve 4 sorts this material into fractions of different sized bed material grains. The target grain size for the bed material grains is advantageously 0.5-1.5 mm, but also other targets grain sizes are possible. Ash and fine bed material grains, the grain size of which is smaller than the target grain size, are guided from the sieve 4 to

a removal platform 14 with transfer means 4b. In the same way, coarse bed material grains, the grain size of which is larger than the target grain size, i.e. larger than 1.5, are guided with the transfer means 4b to the removal platform 14. The transfer means can for example comprise a screw or belt conveyor. After the fine and coarse bed material grains have been removed, the remaining target grain sized usable bed material is returned to the furnace.

**[0036]** In the boiler plant 10 according to the invention, the entire material of the fluidized bed 1 is circulated through the sieve 4 and regenerating apparatus 20 once every 2-4 days. Thus, the fluidized bed boiler 10 does not need to be shut down due to the circulation of the ash and fluidized bed material.

**[0037]** Deposits formed by alkali gasses in the fluidized bed boiler 10 are avoided by controlling the combustion temperature. When burning solid fuel 7, the fluidized bed 1 and the combustion zone 10b above it are advantageously kept at a temperature of 800-900 °C. The combustion zone 10b of the solid fuel 7 is close to the upper surface of the fluidized bed 1. The temperature of the combustion zone is guided to a selected temperature range advantageously with primary, secondary and tertiary combustion air nozzles and with the aid of circulating gas.

**[0038]** On the other hand, the surface temperature of the superheater 8 in the upper part of the furnace 10a is advantageously kept at a temperature below 750 °C. Thus, the alkali compounds in the solid fuel 7 crystallize in the fly ash exiting the fluidized bed boiler 10 and not on the surfaces of the superheater 8. The temperature of the upper part of the furnace 10a is measured with a temperature sensor 9. By preventing the alkali compounds from crystallizing on the surfaces of the superheater 8, the ability of the superheater to operate as a heat exchanger is improved.

**[0039]** During use of the fluidized bed boiler, situations regularly arise, where it is not appropriate to return all the material removed from the furnace back to the furnace directly after the sieving. Such a situation is for example when it is necessary to remove bed material from the furnace in order to reduce the thickness of the fluidized bed. In the same way, in connection with fluidized bed boiler downtime and service, the entire fluidized bed material can be removed from the furnace for the duration of the service or downtime. The used fluidized bed material removed from the furnace can be stored temporarily in an intermediate storage 18 close to the fluidized bed boiler.

**[0040]** In such situations, at least a part of the fluidized bed material removed from the furnace can be taken to a separate regenerating plant to be regenerated with the method according to the invention. The regenerating plant can be in the immediate vicinity of the fluidized bed boiler or it can be at a distance of several kilometres from the fluidized bed boiler. The regenerating plant can also be part of a completely other plant or factory and not a

part of the boiler plant, for example a fluidized bed material manufacturing plant. The regenerating plant has a regenerating apparatus 20 for regenerating used fluidized bed material.

**[0041]** The regenerating apparatus comprises a mill 15, into which the bed material grains to be regenerated are led. In the mill, mechanical grinding or wearing stress is directed at the surface of the bed material grains, which stress causes the sintered slag layers attached to the surface of the material grains to detach from the material grains. At the same time, ash attached to the grains detaches from the surface of the bed material grains. The mill can be a centrifugal mill, a ball mill or any other mill directing mechanical stress to the bed material grains. After the regenerating, the coarse bed material grains are led to a second sieve 16, where the particles which are smaller than the target grain size are separated from the regenerated bed material grains, which smaller particles contain ash and sintered slag particles. This waste fraction divided by sieving is moved aside to wait for transportation to a final repository.

**[0042]** The regenerated bed material, the grain size of which is in accordance with the target grain size, is transported from the regenerating plant back to the intermediate storage 18 in connection with the fluidized bed boiler, from where it is transferred to the furnace with circulation means belonging to the fluidized bed boiler. It is also possible to transfer the regenerated bed material to the container 6, where it is mixed with the unused bed material in the container and from where it is led along a transfer pipe to the furnace.

**[0043]** The regenerated bed material can contain slag particles detached from the bed material grains, which slag particles have a grain size in accordance with the target grain size, whereby they are not separated from the bed material by sieving. In order to control the amount of these impurities, the regenerating apparatus can comprise analysing means 17, with which the amount of impurities contained in the regenerated bed material is determined. The amount of impurities is determined by taking sample batches from the regenerated bed material and analysing said sample batches using chemical analysis. An upper limit value can be set for the impurities in the regenerated bed material and the bed material can be returned to the fluidized bed boiler only if the amount of impurities is below said upper limit value.

**[0044]** Typically, the impurities in the regenerated fluidized bed material comprise various chemical elements, which include at least silicon, sodium and potassium. In the method, the upper limit value for the content of chemical elements classified as impurities is obtained by determining the content of said chemical element in corresponding virgin bed material and adding an allowed content growth rate to this content. In the method according to the invention, the allowed growth rate for silicon content is advantageously set at 3 %, the allowed growth rate for sodium content is advantageously set at 0.5 %, and the allowed growth rate for potassium content is ad-

vantageously set at 0.5 %. Typically, the regenerated bed material contains, in addition to silicon, sodium and potassium, also other chemical elements classifiable as impurities. There can be several dozens of these other chemical elements, and they can be treated in the method as one group. In that case, an upper limit value is set for the sum of the content growth of this group of the other chemical elements, which upper limit value is advantageously 6 %.

**[0045]** Figure 2 shows as an exemplary flow chart the combustion event of the fluidized bed in a fluidized bed boiler 10 according to the invention.

**[0046]** In phase 20 the ramp-up of the fluidized bed boiler 10 is started by feeding bed material 6 into the bottom part of the furnace 10a. When the fluidized bed 1 is complete, input of auxiliary fuel 11 into the furnace is started. For example oil or natural gas can be used as auxiliary fuel 11. In order to ensure the combustion, air is also fed into the furnace to maintain the combustion. At the same time, the fans 3 detaching the fluidized bed 1 from the bottom of the fluidized bed boiler 10 are started.

**[0047]** In phase 21, the fluidized bed boiler 10 is heated by burning auxiliary fuel.

**[0048]** Phase 22 involves checking, if the temperature of the fluidized bed boiler 10 has risen above a certain threshold value. The fluidized bed boiler and the used solid fuel 7 determine the threshold temperature in question. The threshold temperature is advantageously in the range of 400-500 °C. If the temperature of the fluidized bed boiler 10 is below the set threshold temperature, the feeding of auxiliary fuel is continued in phase 21 in order to raise the temperature of the fluidized bed boiler 10.

**[0049]** If it is in phase 22 found that the temperature in the fluidized bed boiler 10 has reached the predetermined temperature threshold, then the method moves unto phase 23, where input of solid fuel 7 into the fluidized bed boiler 10 is started. For example tree bark, wood dust, wood chips, peat, glulam waste, plywood borders and various sludges can be used as solid fuel.

**[0050]** During the burning of solid fuel, phase 24 involves checking if the temperature in the furnace 10a has risen above 600 °C. If the temperature does not exceed 600 °C, the combustion adjustment process returns to phase 21.

**[0051]** The control of the combustion process of the fluidized bed boiler 10 turns the adjustment loop 21-24 for so long that it is in phase 24 found that the temperature of the fluidized bed boiler 10 exceeds 600 °C. Thus, in phase 25, the auxiliary fuel burners are shut off by ending the input of auxiliary fuel 11 into the furnace 10a.

**[0052]** When the temperature exceeds 600 °C in the fluidized bed boiler 10, the temperature of the fluidized bed 1 is in phase 26 raised to 800-900 °C by adjusting the input of solid fuel 7 and the amount of combustion air.

**[0053]** When the temperature of the fluidized bed 1 is adjusted to 800-900 °C, then in phase 27 the circulation of the bed material 6 is started via the sieve 4 and the regenerating apparatus 20 back to the fluidized bed 1.

The fluidized bed boiler 10 according to the invention advantageously uses crystalline, quartz free blast furnace slag as bed material. The target grain size for the blast furnace slag to be returned from the sieve 4 to the fluidized bed 1 is advantageously in the range of 0.5-1.5 mm. If necessary, virginal crystalline blast furnace slag 6 is, in addition to the regenerated and circulated bed material, added during the operation to the fluidized bed 1 from the bed material container 6b.

**[0054]** When the fluidized bed boiler 10 is in functional order, producing thermal energy, then in phase 28 removal of ash and bed material from the fluidized bed boiler 10 is advantageously started.

**[0055]** The material to be removed from the fluidized bed boiler 10 is guided in the fluidized bed combustion plant according to the invention to the sieve 4 in phase 29. The sieve 4 separates the material, advantageously into at least three fractions. The fine-grained material and ash is guided by the sieve 4 to the removal platform 14. In the same way, the sieve 4 guides coarse-grained sintered bed material to the removal platform (phase 31). The third fraction, which contains the bed material grains according to the target grain size, is led from the sieve 4 back to the fluidized bed.

**[0056]** In connection with fluidized bed boiler service or downtime, or when lightening the fluidized bed, the used and sieved fluidized bed material removed from the furnace can be stored in the intermediate storage 18 outside the furnace. In the method according to the invention, at least a part of this bed material removed from the furnace is transported from the intermediate storage to the regenerating apparatus 20 to be regenerated. After the regeneration, the bed material is transported back to the intermediate storage and transferred with bed material circulation means inside the furnace to the fluidized bed (phase 30).

**[0057]** In the description above, the fluidized bed material used in the fluidized bed boiler is crystallized, quartz free blast furnace slag. Even though this material is especially well suited for use in the invention, the invention is not limited to only this fluidized bed material. The fluidized bed material can thus be also some other granular slag material suitable as bed material. In the description above, the regenerating of bed material grains is done by grinding or wearing the surface of the bed material grains mechanically. The invention is however not limited only to mechanical regenerating of the bed material, but the impurities can be separated from the surface of the bed material grains also in other ways, for example chemically or using ultrasound.

**[0058]** Some advantageous embodiments of a method for operating a fluidized bed boiler and a fluidized bed boiler according to the invention have been described above. The invention is not limited to the solutions described above, but the inventive idea can be applied in numerous ways within the scope of the claims.

**List of reference numbers:****[0059]**

|     |                            |    |
|-----|----------------------------|----|
| 1   | fluidized bed              |    |
| 2   | nozzle arrangement         |    |
| 3   | fan                        |    |
| 4   | sieve                      |    |
| 4a  | return pipe                |    |
| 4b  | transfer means             | 10 |
| 5   | ash removal means          |    |
| 6   | bed material               |    |
| 6b  | container                  |    |
| 6a  | transfer pipe              |    |
| 7   | fuel                       | 15 |
| 7a  | fuel input means           |    |
| 7b  | fuel container             |    |
| 8   | superheater                |    |
| 10  | fluidized bed boiler       |    |
| 10a | furnace                    | 20 |
| 10b | combustion zone            |    |
| 11  | auxiliary fuel             |    |
| 12  | auxiliary fuel input means |    |
| 13  | auxiliary fuel input means |    |
| 14  | removal platform           | 25 |
| 15  | mill                       |    |
| 16  | second sieve               |    |
| 17  | analyzing means            |    |
| 18  | intermediate storage       |    |
| 20  | regenerating apparatus     | 30 |

**Claims**

1. A method for operating a fluidized bed boiler (10), which fluidized bed boiler (10) has a furnace (10a), in which method

- the furnace (10a) is heated to operating temperature,
- a fluidized bed (1) is formed in the furnace (10a) from bed material (6), which has a target grain size,
- determined operating temperature for the fuel to be burned is maintained in the furnace (10a) by burning fuel in the furnace (10a),
- bed material (6) is circulated

- by removing bed material (6) from the furnace (10a),
- by dividing the removed bed material (6) by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size and
- by returning at least part of said first share into the furnace (10a), **characterized in**

**that** before the bed material (6) is returned to the furnace (10a),

- at least part of the bed material (6) removed from the furnace (10a) is regenerated by detaching impurities and/or ash from the surface of the bed material grains,
- the regenerated bed material (6) is divided by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size and
- at least part of said first share is returned into the furnace (10a).

2. The method according to claim 1, **characterized in that**, before the bed material (6) is regenerated, bed material grains with a grain size that is larger or smaller than the target grain size are separated from the bed material removed from the furnace (10a) by pre-sieving.

3. The method according to claim 1 or 2, **characterized in that** the bed material (6) to be regenerated is transferred from the fluidized bed boiler (10) to a regenerating plant at a distance therefrom, the fluidized bed material (6) is regenerated in said regenerating plant and the regenerated bed material is returned from the regenerating plant to the fluidized bed boiler (10).

4. The method according to any of the claims 1-3, **characterized in that** bed material (6) is regenerated by grinding or wearing the surface of the bed material grains mechanically.

5. The method according to claim 4, **characterized in that** the surface of the bed material grains is ground or worn by milling the bed material (6) in a mill, advantageously a centrifugal mill, a ball mill or the like.

6. The method according to any of the claims 1-5, **characterized in that** before the regenerated bed material (6) is returned to the furnace (10a), the amount of impurities contained in the regenerated bed material (6) is determined.

7. The method according to claim 6, **characterized in that** the amount of impurities is determined by taking sample batches from the regenerated bed material and analysing said sample batches chemically.

8. The method according to claim 6 or 7, **characterized in that**

- before the regenerated bed material (6) is returned to the furnace (10a), an upper limit value

is set for impurities contained in the bed material (6) and

- the regenerated bed material is returned to the furnace (10a) only if the amount of impurities in the regenerated bed material (6) is below said upper limit value.

9. The method according to claim 8, **characterized in that** said impurities comprise chemical elements, which include at least silicon, sodium and potassium, and the upper limit value for the chemical element content in the regenerated bed material (6) is set as the chemical element content of corresponding virgin bed material (6) plus an allowed growth rate.

10. The method according to claim 9, **characterized in that** the allowed growth rate for silicon content is set at 3 %, the allowed growth rate for sodium content is set at 0.5 %, the allowed growth rate for potassium content is set at 0.5 % and the sum of the allowed growth rates for the content of other chemical elements than the ones mentioned is set at 6 %.

11. The method according to any of the claims 1-10, **characterized in that** crystallized, quartz free blast furnace slag is used as the bed material (6).

12. The method according to any of the claims 1-8, **characterized in that** 0.5-1.5 mm is used as the target grain size for the bed material (8).

13. A boiler plant, which comprises a fluidized bed boiler (10), which has

- a furnace (10a),  
- means (2, 3) for generating a fluidized bed (1) in the furnace (10a), which fluidized bed (1) comprises a granular bed material (6), which has a target grain size,

- a container (6b) for bed material (6),  
- input means for feeding bed material (6) from the container (6b) to the furnace (10a),  
- a fuel container (7b) for fuel (7),

- fuel input means (7a) for feeding fuel from the fuel container (7b) to the furnace (10a),  
- circulation means for removing bed material from the furnace (10a) and returning it to the furnace (10a), which circulation means comprise

- a sieve (4) for dividing the bed material removed from the furnace (10a) into a first share to be returned to the furnace (10a), where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size, **characterized in that** said boiler plant additionally comprises regenerating means (20) for regenerating the bed ma-

terial (6) removed from the furnace before the bed material (6) is returned to the furnace (10a), which regenerating means (20) are arranged to  
- regenerate the bed material (6) removed from the furnace (10a) by detaching impurities and/or ash from the surface of the bed material grains,  
- divide the regenerated bed material (6) by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size.

14. The boiler plant according to claim 13, **characterized in that** said regenerating means (20) comprise grinding means or a mill, such as a centrifugal mill or a ball mill, for mechanical treatment of the surface of the bed material grains.

15. The boiler plant according to claim 13 or 14, **characterized in that** said regenerating means (20) comprise analysing means for analysing the amount of impurities contained in the regenerated bed material (6).

16. The boiler plant according to any of the claims 13-15, **characterized in that** the bed material (6) of the fluidized bed (1) comprises crystallized, quartz free blast furnace slag.

17. The boiler plant according to any of the claims 13-16, **characterized in that** the target grain size for the bed material (6) of the fluidized bed (1) is 0.5-1.5 mm.

18. The boiler plant according to any of the claims 13-17, **characterized in that** said regenerating means are arranged in a separate regenerating plant at a distance from the fluidized bed boiler.

#### **Amended claims in accordance with Rule 137(2) EPC.**

1. A method for operating a fluidized bed boiler (10), which fluidized bed boiler (10) has a furnace (10a), in which method

- the furnace (10a) is heated to operating temperature,  
- a fluidized bed (1) is formed in the furnace (10a) from bed material (6), which has a target grain size,  
- determined operating temperature for the fuel to be burned is maintained in the furnace (10a) by burning fuel in the furnace (10a),  
- bed material (6) is circulated

- by removing bed material (6) from the fur-



- nace (10a),  
 - by dividing the removed bed material (6) by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size and  
 - by returning at least part of said first share into the furnace (10a),  
 and before the bed material (6) is returned to the furnace (10a),  
 - at least part of the bed material (6) removed from the furnace (10a) is regenerated by detaching impurities and/or ash from the surface of the bed material grains,  
 - the regenerated bed material (6) is divided by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size and  
 - at least part of said first share is returned into the furnace (10a)  
**characterized in that**  
 - before the regenerated bed material (6) is returned to the furnace (10a), the amount of impurities contained in the regenerated bed material (6) is determined.
2. The method according to claim 1, **characterized in that**, before the bed material (6) is regenerated, bed material grains with a grain size that is larger or smaller than the target grain size are separated from the bed material removed from the furnace (10a) by pre-sieving.
3. The method according to claim 1 or 2, **characterized in that** the bed material (6) to be regenerated is transferred from the fluidized bed boiler (10) to a regenerating plant at a distance therefrom, the fluidized bed material (6) is regenerated in said regenerating plant and the regenerated bed material is returned from the regenerating plant to the fluidized bed boiler (10).
4. The method according to any of the claims 1-3, **characterized in that** bed material (6) is regenerated by grinding or wearing the surface of the bed material grains mechanically.
5. The method according to claim 4, **characterized in that** the surface of the bed material grains is ground or worn by milling the bed material (6) in a mill, advantageously a centrifugal mill, a ball mill or the like.
6. The method according to any of the claims 1 to 5, **characterized in that** the amount of impurities is determined by taking sample batches from the regenerated bed material and analysing said sample batches chemically.
7. The method according to any of the claims 1 to 6, **characterized in that**  
 - before the regenerated bed material (6) is returned to the furnace (10a), an upper limit value is set for impurities contained in the bed material (6) and  
 - the regenerated bed material is returned to the furnace (10a) only if the amount of impurities in the regenerated bed material (6) is below said upper limit value.
8. The method according to claim 7, **characterized in that** said impurities comprise chemical elements, which include at least silicon, sodium and potassium, and the upper limit value for the chemical element content in the regenerated bed material (6) is set as the chemical element content of corresponding virginal bed material (6) plus an allowed growth rate.
9. The method according to claim 8, **characterized in that** the allowed growth rate for silicon content is set at 3 %, the allowed growth rate for sodium content is set at 0.5 %, the allowed growth rate for potassium content is set at 0.5 % and the sum of the allowed growth rates for the content of other chemical elements than the ones mentioned is set at 6 %.
10. The method according to any of the claims 1-9, **characterized in that** crystallized, quartz free blast furnace slag is used as the bed material (6).
11. The method according to any of the claims 1-7, **characterized in that** 0.5-1.5 mm is used as the target grain size for the bed material (8).
12. A boiler plant, which comprises a fluidized bed boiler (10), which has  
 - a furnace (10a),  
 - means (2, 3) for generating a fluidized bed (1) in the furnace (10a), which fluidized bed (1) comprises a granular bed material (6), which has a target grain size,  
 - a container (6b) for bed material (6),  
 - input means for feeding bed material (6) from the container (6b) to the furnace (10a),  
 - a fuel container (7b) for fuel (7),  
 - fuel input means (7a) for feeding fuel from the fuel container (7b) to the furnace (10a),  
 - circulation means for removing bed material from the furnace (10a) and returning it to the furnace (10a), which circulation means comprise

- a sieve (4) for dividing the bed material removed from the furnace (10a) into a first share to be returned to the furnace (10a), where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size, which boiler plant additionally comprises regenerating means (20) for regenerating the bed material (6) removed from the furnace before the bed material (6) is returned to the furnace (10a), which regenerating means (20) are arranged to
  - regenerate the bed material (6) removed from the furnace (10a) by detaching impurities and/or ash from the surface of the bed material grains and to
  - divide the regenerated bed material (6) by sieving into a first share, where the bed material grains have a target grain size, and into a second share, where the bed material grains have a grain size which is larger or smaller than the target grain size **characterized in that** said regenerating means (20) further comprise analysing means for analysing the amount of impurities contained in the regenerated bed material (6) before the regenerated bed material (6) is returned to the furnace (10a).
- 13. The boiler plant according to claim 12, **characterized in that** said regenerating means (20) comprise grinding means or a mill, such as a centrifugal mill or a ball mill, for mechanical treatment of the surface of the bed material grains.
- 14. The boiler plant according to claim 12 or 13, **characterized in that** the bed material (6) of the fluidized bed (1) comprises crystallized, quartz free blast furnace slag.
- 15. The boiler plant according to any of the claims 12-14, **characterized in that** the target grain size for the bed material (6) of the fluidized bed (1) is 0.5-1.5 mm.
- 16. The boiler plant according to any of the claims 12-15, **characterized in that** said regenerating means are arranged in a separate regenerating plant at a distance from the fluidized bed boiler.

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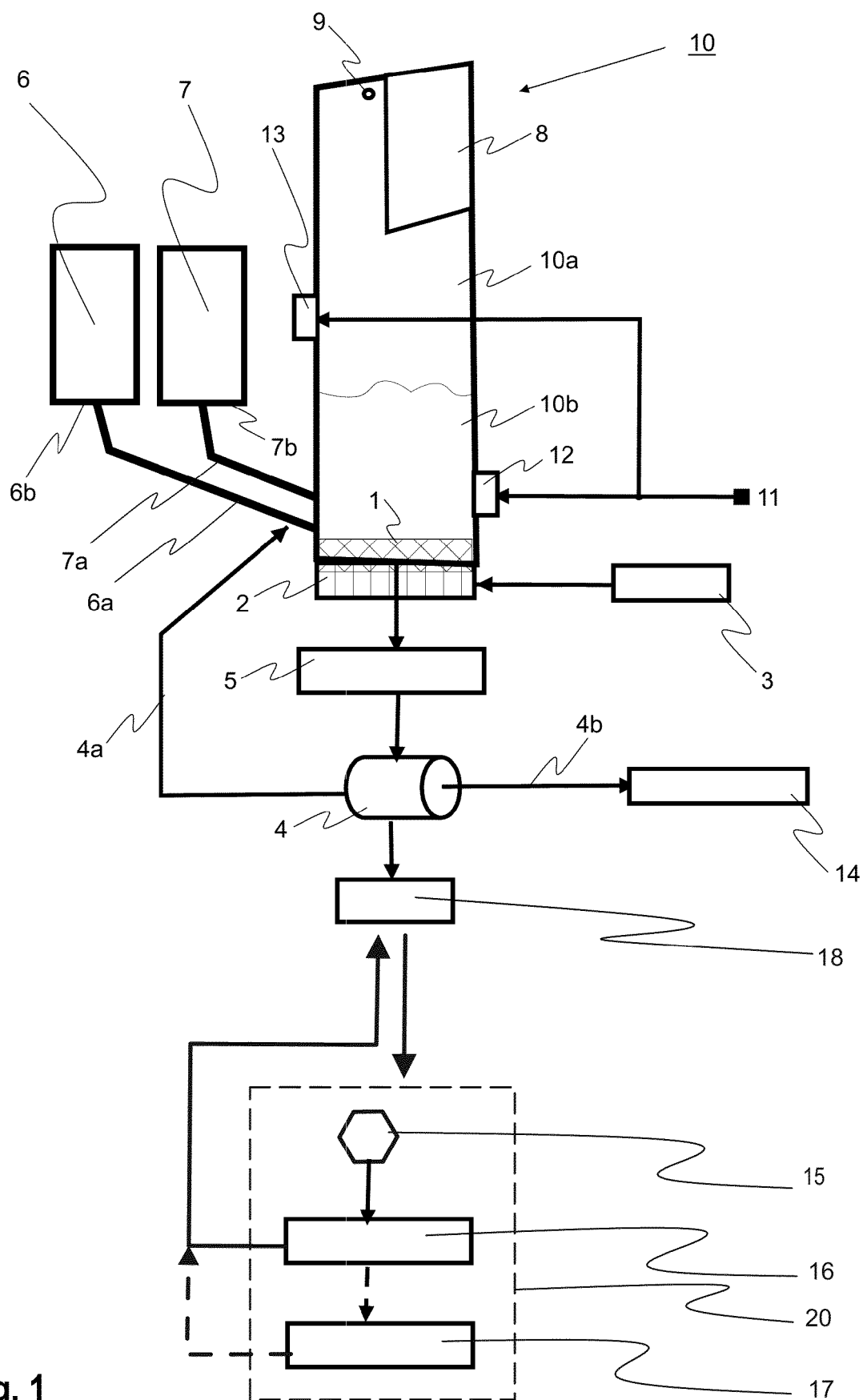


Fig. 1

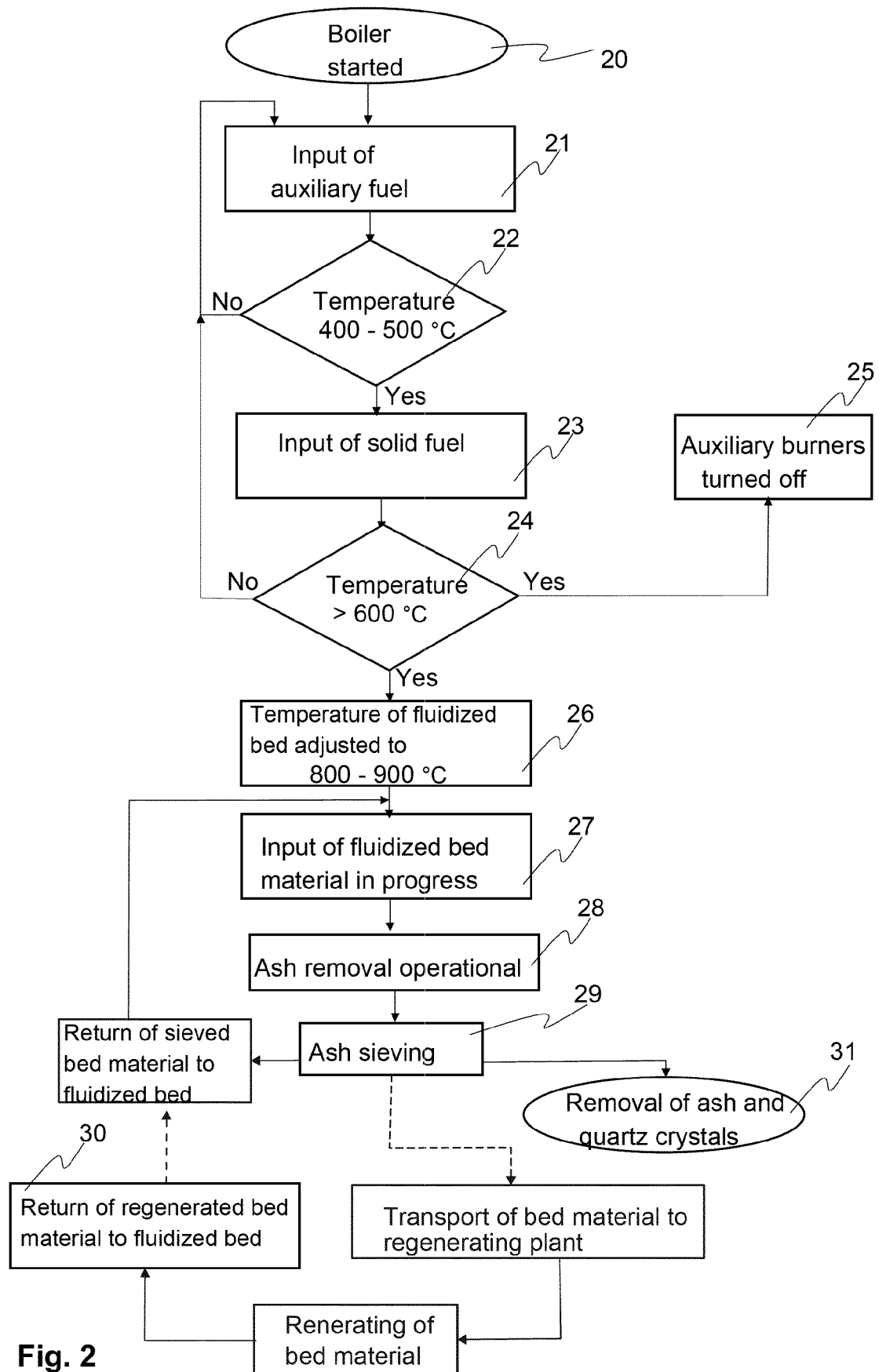


Fig. 2



## EUROPEAN SEARCH REPORT

Application Number

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| The present search report has been drawn up for all claims                                                                                                                                                              |                                                                                                                                                                   |                                                                                                                                                                                                                                                                                       |                                            |
| Place of search                                                                                                                                                                                                         |                                                                                                                                                                   | Date of completion of the search                                                                                                                                                                                                                                                      | Examiner                                   |
| Munich                                                                                                                                                                                                                  |                                                                                                                                                                   | 5 July 2022                                                                                                                                                                                                                                                                           | Rudolf, Andreas                            |
| CATEGORY OF CITED DOCUMENTS                                                                                                                                                                                             |                                                                                                                                                                   |                                                                                                                                                                                                                                                                                       |                                            |
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