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Kuczynski et al.

(54) **FUEL PREPARATION APPARATUS AND METHOD**

(71) Applicant: **DOOSAN BABCOCK LIMITED**, Crawley, Sussex (GB)

(72) Inventors: **Konrad Jerzy Kuczynski**, Renfrew (GB); **Agnieszka Magdalena Kuczynska**, Renfrew (GB)

(73) Assignee: **DOOSAN BABCOCK LIMITED**, Crawley, Sussex (GB)

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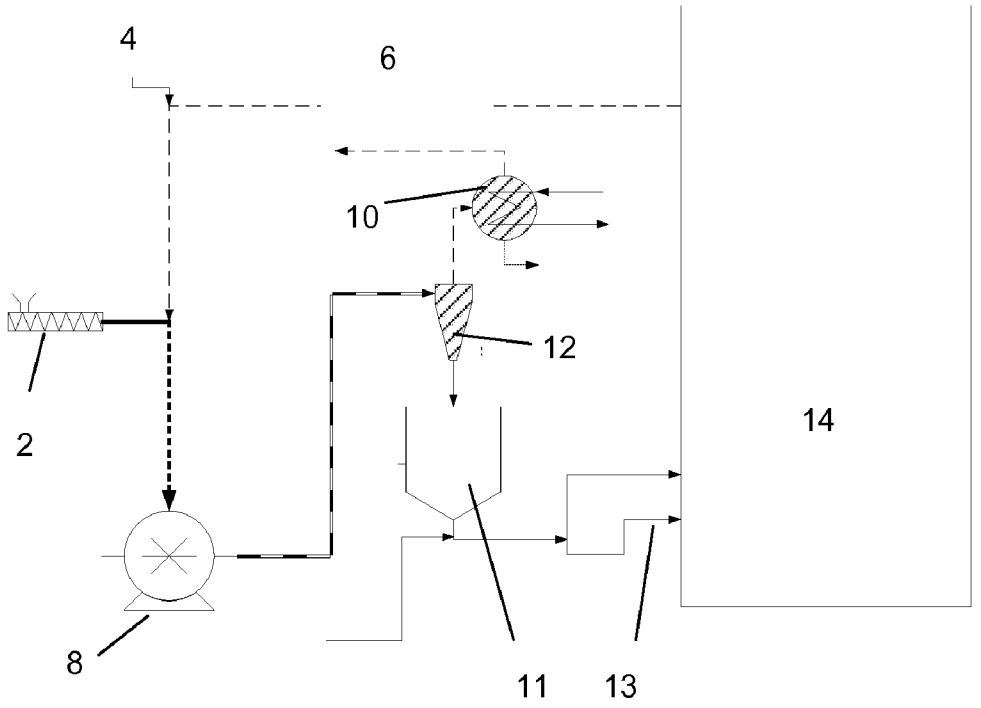
(57) **ABSTRACT**

An apparatus and method for fuel preparation for example by milling and drying to produce a pulverous fuel supply are described. The apparatus includes a fuel preparation unit adapted to receive a mixture of fuel and a gas and to prepare the fuel for combustion in a pulverous state; an output conduit defining an output flow path for a mixture of pulverous fuel and gas from the fuel preparation unit; a phase separator disposed to receive the mixture from the output conduit and to separate the mixture into a gas phase comprising at least a major part of the gas from the mixture and a fuel phase comprising the pulverous fuel; a gas phase conduit defining a flow path for the gas phase from the separator; a heat exchanger preferably being a process fluid heat exchanger such as a feed water heat recovery heat exchanger fluidly connected to the gas phase conduit and adapted to receive and dry the gas phase. The method applies the principles embodied in the apparatus.



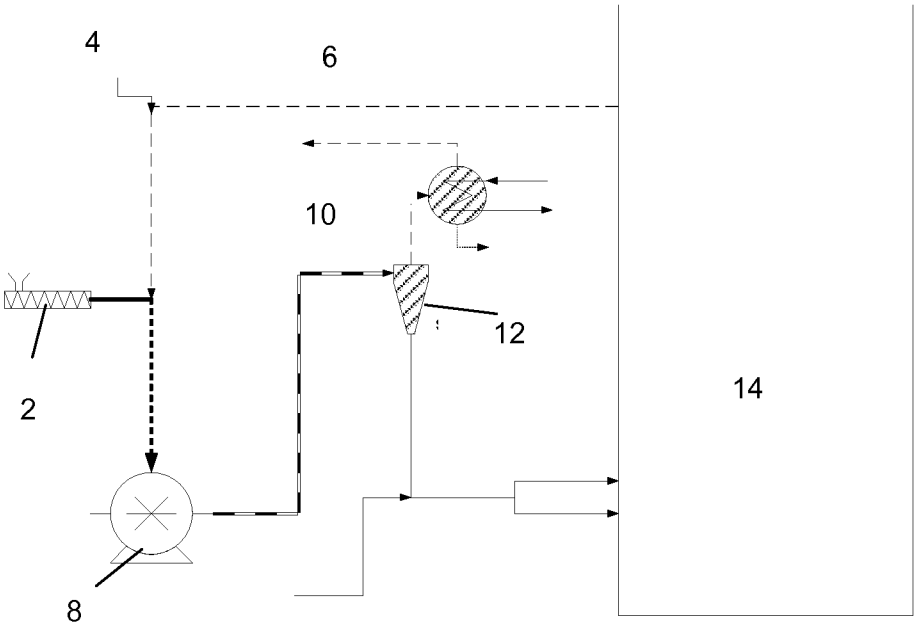


Figure 1

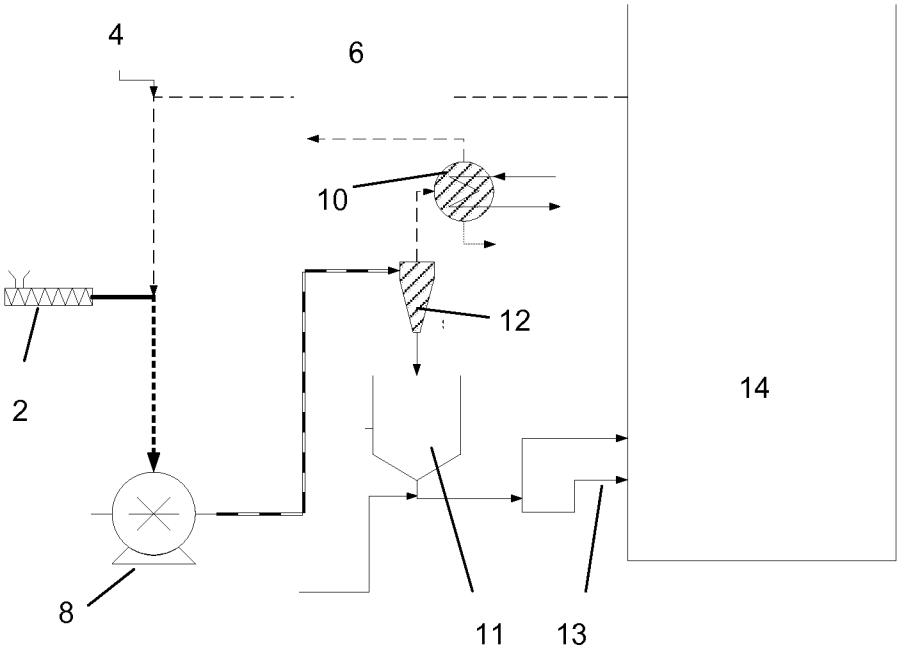


Figure 2

FUEL PREPARATION APPARATUS AND METHOD

[0001] The invention relates to a fuel preparation process used on power plants for the preparation for example by milling and drying of pulverous fuel and in particular carbonaceous fuel such as pulverised coal and to an apparatus embodying the process. The invention is in particular applied in the context of milling and drying of pulverous fuel for supply as a fuel source to a thermal power plant. The invention is in particular applied to the process for fuel milling and drying for lignite power plants or biomass power plants. Additionally the invention is relevant to waste to energy plants.

[0002] The process aims to improve the standard/conventional process for the preparation for example by milling and drying of coal for coal power plants.

[0003] The process aims to improve the standard/conventional process for fuel preparation and drying applied for biomass power plants.

[0004] The process aims to improve the standard/conventional process for fuel preparation for waste to energy power plants.

[0005] In one conventional approach the mill dries the coal and then the product is directly transported to the combustion furnace. There are two significant disadvantages that are present, if the mills (for example fan-beater mills) are used for processing lignite, that impact significantly the power plant process efficiency.

[0006] Firstly, in such a conventional process the mill dries the fuel and then the product is directly transported to the combustion furnace. This approach is proven in the industry. However it has reduced process efficiency because of the water vapour that has been created by drying the fuel and passed to the combustion furnace. This vapour increases the Induced Draft (ID) fan power required to extract the flue gas from the furnace and pass it to the chimney. Secondly, the heat consumed by moisture evaporation is irreversibly lost.

[0007] In another conventional approach the fuel processed by the mill is held in intermediate storage silo, from which it is transported to the furnace. In this process arrangement the water vapour does not enter the furnace, and therefore the plant efficiency is increased, however the heat consumed by the mill for drying the fuel is still lost.

[0008] Current efforts to improve lignite plant efficiency are focused on pre-drying the coal, and removing the moisture prior to its introduction to the milling system. Therefore the plant efficiency is increased by maximum amount at the expense of significant investment in the drying system. Such systems are present on the market and are tested on various full size power plants across the world (i.e. WTA or DryFining process with fluidized bed dryers). The known processes based on fluidised bed dryers require an additional milling stage to prepare the coal, otherwise the fluidised phenomenon will not be achieved. This further increases the capital investment of the system.

[0009] The invention seeks to provide a process methodology that addresses initial problems and potentially increases plant efficiency whilst limiting and ideally avoiding the use of capital expensive pre-drying technology.

[0010] In accordance with the invention in a first aspect, a method of preparation of a fuel to produce a pulverous fuel supply, in particular for supply as fuel to a steam generator such as a boiler for example of a thermal power plant comprises the steps of:

[0011] supplying a mixture of fuel and a gas to a fuel preparation unit adapted to prepare the fuel for combustion in a pulverous sate;

[0012] outputting from the fuel preparation unit a mixture of pulverous fuel and gas;

[0013] separating the mixture into a gas phase comprising at least a major part of the gas output and a fuel phase comprising the pulverous fuel;

[0014] passing the gas phase to a heat exchanger preferably being a process fluid heat exchanger such as a feed water heat recovery heat exchanger to dry the gas phase.

[0015] The fuel preparation unit is preferably a fuel pulveriser such as a mill adapted to receive a mixture of fuel and a gas and to mill the fuel to a pulverous state. The apparatus in such case is therefore a method of milling and drying of a fuel to produce a pulverous fuel supply, in particular for supply as fuel to a steam generator such as a boiler for example of a thermal power plant comprises the steps of:

[0016] supplying a mixture of fuel and a gas to a mill;

[0017] outputting from the mill a mixture of pulverous fuel and gas;

[0018] separating the mixture into a gas phase comprising at least a major part of the gas output from the mill and a fuel phase comprising the pulverous fuel;

[0019] passing the gas phase to a process fluid heat exchanger such as a feed water heat recovery heat exchanger to dry the gas phase.

[0020] In accordance with the invention in a second aspect, an apparatus for the preparation of fuel for example by milling and drying to produce a pulverous fuel supply, in particular for supply as fuel to a steam generator such as a boiler for example of a thermal power plant comprises:

[0021] a fuel preparation unit adapted to receive a mixture of fuel and a gas and to prepare the fuel for combustion in a pulverous state;

[0022] an output conduit defining an output flow path for a mixture of pulverous fuel and gas from the fuel preparation unit;

[0023] a phase separator disposed to receive the mixture from the output conduit and to separate the mixture into a gas phase comprising at least a major part of the gas from the mixture and a fuel phase comprising the pulverous fuel;

[0024] a gas phase conduit defining a flow path for the gas phase from the separator;

[0025] a heat exchanger preferably being a process fluid heat exchanger such as a feed water heat recovery heat exchanger fluidly connected to the gas phase conduit and adapted to receive and dry the gas phase.

[0026] The fuel preparation unit is preferably a fuel pulveriser such as a mill adapted to receive a mixture of fuel and a gas and to mill the fuel to a pulverous state. The apparatus in such case is therefore an apparatus for milling and drying of a fuel to produce a pulverous fuel supply, in particular for supply as fuel to a steam generator such as a boiler for example of a thermal power plant comprises:

[0027] a mill adapted to receive a mixture of fuel and a gas and to mill the fuel to a pulverous state;

[0028] a mill output conduit defining an output flow path for a mixture of pulverous fuel and gas from the mill;

[0029] a phase separator to separating the mixture into a gas phase comprising at least a major part of the gas output from the mill and a fuel phase comprising the pulverous fuel;

[0030] a gas phase conduit defining a flow path for the gas phase from the separator;

[0031] a process fluid heat exchanger such as a feed water heat recovery heat exchanger fluidly connected to the gas phase conduit to receive and dry the gas phase.

[0032] The apparatus of the second aspect of the invention is an apparatus to implement the process of the first aspect, and preferred embodiments of each aspect will be understood from the following discussion.

[0033] The gas phase is used for example to dry and/or transport and/or facilitate the storage of the combined fuel and gas phase. The gas phase becomes laden with water vapour. The invention separates at least a major part of the water vapour laden gas phase that has been created by the milling and drying and/or transport and/or storage of the fuel. The water vapour is not passed to the combustion furnace. This avoids the penalty of increased ID fan power demand. The invention uses a heat exchanger preferably being a process fluid heat exchanger such as a feed water heat recovery heat exchanger downstream of the phase separator to effect condensation of vapour moisture. Latent heat consumed by the drying process is in the preferred case recovered and transferred to a process fluid for recovery of sensible heat for use in an industrial process, and in particular is used to preheat feed water. This further increases the process efficiency.

[0034] In the preferred case the invention is applied to a combined milling and drying apparatus and method for the milling and drying of coal of high moisture content, and examples are discussed hereinbelow in such a context. However the skilled person will appreciate that this invention can be applied to both coal milling and drying systems and other milling/fuel preparation and drying systems presenting similar problems so that the increase of efficiency of a power cycle can be achieved without dedicated pre-drying facility and the examples will be interpreted and the principles of the invention understood accordingly.

[0035] In an example combined milling and drying apparatus and method the milled fuel is dried by a gas supplied in mixture with the fuel to be milled. Preferably the gas is at elevated temperature above ambient. It may be a mixture of optionally preheated air and flue gas from a combustion chamber. In such case in the method the step of supplying a mixture of fuel and a gas to a mill comprises the supply of a gas at elevated temperature and optionally the step of supplying a gas at elevated temperature comprises the supply of a mixture of optionally preheated air and flue gas from a combustion chamber, for example a combustion chamber of a steam generator.

[0036] Preferably an apparatus in accordance with the invention includes a fuel source and a gas source together configured to supply a mixture of fuel and gas to the mill. Preferably the gas source is adapted to supply a gas at elevated temperature. For example the gas source comprises a source of optionally preheated air and a supply of flue gas from a combustion chamber, for example a combustion chamber of a steam generator.

[0037] In accordance with the invention, at least a major part of the water vapour laden gas phase and of the water vapour laden gas output from the mill that has been created by the milling and drying process is diverted away as the gas phase supplied to the heat exchanger, which effects condensation of the water vapour and in the preferred case thereby recovers at least some of the latent heat from the drying and evaporation process. In a preferred case substantially all of the water vapour laden gas output is diverted away as the gas phase supplied to the heat exchanger. In a preferred case the phase separator is adapted to separate substantially all of the gas output from the mill into the gas phase.

[0038] A particular virtue of the invention is that it is potentially applicable to a range of milling technologies. The method of the first aspect of the invention and the apparatus of the second aspect of the invention includes a milling step or apparatus in which the fuel is milled to a pulverous state for drying and supply for combustion or storage. Any suitable mill may be envisaged for use in accordance with the invention to mill the fuel to a pulverous state, for example including without limitation ball mills, horizontal and vertical roller mills, beater mills etc.

[0039] In a possible embodiment, the mill comprises a fan beater mill, for example comprising in familiar manner a housing for receiving fuel to be pulverised, a rotary milling shaft, a beater formation carried on the shaft to effect pulverising of fuel within the housing, and an impeller.

[0040] The mill in accordance with the invention may be adapted for direct or indirect supply of pulverous fuel to a combustion chamber, for example a combustion chamber for a steam generator such as a boiler for example of a thermal power plant.

[0041] The apparatus and method of the invention is in particular an apparatus and method for the processing of carbonaceous fuel having relatively high fuel moisture content prior to milling, for example at least 25%, for example for use in a combustion apparatus. The apparatus and method of the invention is in particular an apparatus and method for the processing of low-rank fuel, for example for use in a combustion apparatus. The invention in particular incorporates a carbonaceous fuel and for example low-rank fuel drying process and system.

[0042] Low-rank fuels are characterised by higher fuel moisture content (typically 25-60% or more). To avoid the inefficiencies inherent in combustion of fuel with a high moisture content, the low-rank fuel is milled to a pulverous state and dried. In a preferred case, moisture content may be reduced to around 10-20%.

[0043] The present invention relates to the processing by milling and drying, especially for combustion, of carbonaceous fuel having relatively high moisture content prior to milling, for example low-rank fuels, which term is used herein to refer to those fuels, including fuels sometimes called peat, lignites, brown coals or sub-bituminous coals, or biomass, which have a higher fuel moisture content (typically 25-60% or more) than bituminous coals. Thus, in the preferred case, the apparatus of the invention comprises a supply of such fuel for milling to pulverous form, and the method of the invention comprises the milling of such as required by the combustion furnace.

[0044] Additionally this invention may be applied to waste combustion plants.

[0045] In accordance with the invention a heat exchanger preferably being a process fluid heat exchanger is fluidly connected to the gas phase conduit downstream of the phase separator to receive and dry the gas phase. Latent heat consumed by the mill for drying or otherwise in the gas phase is recovered and transferred to heat the process fluid.

[0046] The process fluid may be a process liquid or air or other gases. The process liquid may be any liquid or combination of liquids useable for heat exchange, including water, ammonia, alcohols, hydrocarbons and the like. Preferably,

the process liquid is wholly or substantially water, optionally including one or more additives or other minor components known in the art.

[0047] The process fluid stream may be heated by any direct or indirect thermal exchange, method, device, unit or apparatus.

[0048] In a possible embodiment of the present invention, the process fluid is water and/or steam and is for example water and/or steam for/from a steam generator or boiler of a steam generating process. In a possible embodiment of the present invention, the process fluid is feedwater for a steam generator. Such a steam generator may be a boiler, optionally comprising one or more boilers, and optionally including an integral steam generator economiser known in the art.

[0049] Latent heat consumed by the mill for drying or otherwise in the gas phase is in this case recovered and used to preheat feed water by means of the heat exchanger.

[0050] Such feedwater may be provided directly or indirectly from a feedwater stream. Preferably, a portion of such a feedwater stream is provided as the process liquid for the system of the present invention. Such a portion may be provided as a slip stream of such a feedwater stream, such a slip stream generally being a minor portion of the full feedwater stream.

[0051] Thus in such a case the heat exchanger of the apparatus of the invention is preferably a process fluid heat exchanger and is for example a heat exchanger disposed to exchange heat with a process fluid and supply the same for use in an industrial process. In particular the heat exchanger is adapted to supply the process fluid to an industrial process in such manner as to make use of the sensible heat therein. For example the process fluid is feedwater for a steam generator and the the process fluid is supplied in such manner as to make use of the sensible heat recovered in the heat exchanger is effected in that the sensible heat recovered in the heat exchanger effects preheating of the feedwater.

[0052] By analogy in the method of the invention the heat exchanger is a process fluid heat exchanger and the method comprises supply of process fluid to the heat exchanger. In particular the heat exchanger is a heat exchanger disposed to exchange heat with a process fluid for use in an industrial process and the method comprises using the heat exchanger to effect condensation of the water vapour and thereby recover at least some of the latent heat from the drying process. Preferably the method comprises the further step of using the process fluid in an industrial process in such manner as to make use of the sensible heat recovered in the heat exchanger. In a particularly preferred case the process fluid is feedwater for a steam generator and the step of using the process fluid in such manner as to make use of the sensible heat recovered in the heat exchanger, effected in that the sensible heat recovered in the heat exchanger effects preheating of the feedwater.

[0053] The heat exchanger may be any suitable form of direct or indirect heat exchanger of familiar or bespoke design. The heat exchange is in the preferred case a process fluid heat exchanger from which sensible heat can be recovered for utilisation within an industrial process, and for example within a steam generation process. In a possible more complete aspect of the invention, the method comprises a method of milling and drying of a fuel to produce a pulverous fuel supply in accordance with the first aspect of the invention, and further comprises the additional step of supplying the fuel to a combustion apparatus. A combustion apparatus is for example a combustion chamber of a steam generator such as a boiler, for example comprising the boiler of a thermal power plant.

[0054] In a possible embodiment, the fuel phase is supplied directly to the burners. In another possible embodiment, the fuel phase is supplied indirectly for example via a storage silo.

[0055] In an alternative more complete aspect of the invention, the method comprises a method of milling and drying of a fuel to produce a pulverous fuel supply in accordance with the first aspect of the invention, and the further step of passing the dried fuel for storage.

[0056] The method comprises passing the gas phase to a heat exchanger preferably being a process fluid heat exchanger to dry the gas phase, and preferably further comprises using recovered sensible heat from the heat exchanger, for example as a means of heating a process fluid which may be a liquid, gas or mixture, in an additional industrial process. The additional industrial process is for example a process of operation of a thermal power plant. The process fluid in such a case is for example a process fluid which may be a liquid, gas or mixture used in the operation of a thermal power plant, and is for example feedwater or air.

[0057] By analogy, in accordance with a further more complete aspect of the invention, an apparatus is provided for milling and drying of a fuel to produce a pulverous fuel supply, which apparatus further comprises a combustion apparatus and a fuel supply conduit to supply the fuel phase comprising the pulverous fuel to the combustion apparatus. The combustion apparatus is for example the combustion chamber of a steam generator such as a boiler for example of a thermal power plant and the supply conduit is adapted to supply the fuel phase comprising the pulverous fuel to a combustion chamber within the steam generator. Optionally the supply conduit is configured to supply the fuel phase directly to one or more burners of the steam generator. Alternatively the supply conduit is configured to supply the fuel phase to a storage silo for example being a storage silo of an indirectly fired steam generator.

[0058] In accordance with an alternative further more complete aspect of the invention, an apparatus in accordance with any preceding claim further comprises a storage volume and a supply conduit to receive the fuel phase and supply the fuel phase to the storage volume.

[0059] The invention will now be described by way of example only with reference to FIGS. **1** and **2** of the accompanying drawings in which:

[0060] FIG. **1** is an example system for the supply of pulverous fuel directly to the burners for combustion in combustion furnace embodying the principles of the invention;

[0061] FIG. **2** is an example system for the indirect supply of pulverous fuel embodying the principles of the invention.

[0062] The following discussion considers processes applied in particular to a standard state of the art milling system such as a fan-beater mill used for processing fuel for combustion into pulverous form. It will be appreciated that this is an example only. FIG. **1** shows the supply of pulverous fuel directly to the burners of a combustion furnace and FIG. **2** shows the indirect supply of pulverous fuel to a combustion furnace. To the extent that features of the embodiment of the invention and of the milling system and combustion furnace are common, like reference numerals are used.

[0063] The proposed system is used in conjunction with the state of the art milling system such as a fan-beater mill. The

process incorporates the use of a feed water heat recovery heat exchanger to dry the gas phase of fan-beater mill product stream and thereby also to recover at least some of the latent heat input from the drying process.

[0064] Fuel for combustion, for example comprising a carbonaceous fuel of relatively high moisture content such as a lignite or other low-rank fuel, is delivered from a fuel supply **2** and combined with a hot gas stream comprising a mixture of cold or preheated air **4** and flue gas **6**. The mixture is supplied to a beater mill **8** to be milled into pulverous form suitable for combustion. The hot gases within the mill dry the fuel to a more suitable state for combustion. For example a moisture content of 25 to 60% is reduced to 5 to 10%. Water vapour from the fuel passes into the gas phase. However if the product of the mill is directly transported to the combustion furnace including the water vapour that has been created by drying the fuel this may reduce the process efficiency because the water vapour that has been created by drying the fuel is passed to the combustion furnace.

[0065] Instead, the stream that leaves the beater mill is first separated at the phase separator **12** into a pulverised and dried fuel phase, and a gas phase. Secondly, the gas phase is passed through a feed water heat exchanger **10** where the condensation of vapour moisture is carried out. This enables the plant to reduce the ID fan power demand, hence increase power plant energy sales. Additionally the process efficiency increases as the gas leaving the power plant will have less moisture and therefore a smaller heat capacity, what will result in less heat being lost through the chimney. Additionally the process efficiency increases as the latent heat consumed by the mill for drying is recovered and transferred to pre-heat the feed water. Importantly, this will reduce the fuel consumption while the power plant output will remain unchanged.

[0066] The pulverised fuel phase, substantially denuded of the gas and water vapour mixture, is passed to the burners **13** of a combustion furnace **14** of a steam generator. In FIG. **1** the pulverised fuel phase is supplied directly. FIG. **2** is an example system for the indirect supply of pulverous fuel to a silo **11** for onward supply to the burners **13** of a combustion chamber **14** of a steam generator. The steam generator may be on any suitable conventional or bespoke design.

[0067] The process calculation of the described solution, shows that assumed 50% latent heat recovery in the system the power plant net efficiency will increase by 2.65% p, and if 90% of heat recovery is achieved, the application of the invention will improve the net efficiency by 3.84% p. The amount of heat recovery is driven by the economic factors that influence the design to increase cost effectiveness of the system.

[0068] The dried fuel product separated from the gas phase in separator is passed directly to the burners for combustion in combustion furnace as presented on FIG. **1**, or is safely stored in intermediate storage device (i.e. silo) and then transferred to the burners for combustion as presented on FIG. **2**.

[0069] In another application current invention could be used to dry the raw fuel and store the product for transportation (i.e. shipping) and combustion on remote location.

1. An apparatus for preparation and drying of a fuel to produce a pulverous fuel supply comprising:

a fuel preparation unit adapted to receive a mixture of fuel and a gas and to prepare the fuel for combustion in a pulverous state;

an output conduit defining an output flow path for a mixture of pulverous fuel and gas from the fuel preparation unit;

a phase separator disposed to receive the mixture from the output conduit and to separate the mixture into a gas phase comprising at least a major part of the gas from the mixture and a fuel phase comprising the pulverous fuel;

a gas phase conduit defining a flow path for the gas phase from the separator;

a heat exchanger fluidly connected to the gas phase conduit to receive and dry the gas phase.

2. An apparatus in accordance with claim **1** wherein the fuel preparation unit is a mill adapted to receive a mixture of fuel and a gas and to mill the fuel to a pulverous state.

3. An apparatus in accordance with claim **1** wherein the heat exchanger is a process fluid heat exchanger.

4. An apparatus in accordance with claim **1** wherein the heat exchanger is a heat exchanger disposed to exchange heat with a process fluid and supply the same for use in an industrial process.

5. An apparatus in accordance with claim **4** wherein the heat exchanger is adapted to supply the process fluid to an industrial process in such manner as to make use of the sensible heat therein.

6. An apparatus in accordance with claim **4** wherein the process fluid is feedwater for a steam generator.

7. An apparatus in accordance with claim **1** wherein the phase separator is adapted to separate substantially all of the gas output from the mill is separated into the gas phase,

8. An apparatus in accordance with claim **1** further comprising a fuel source and a gas source together configured to supply a mixture of fuel and gas to the mill.

9. An apparatus in accordance with claim **8** wherein the gas source supplies a gas at elevated temperature.

10. An apparatus in accordance with claim **9** wherein the gas source comprises a source of optionally preheated air and a supply of flue gas from a combustion chamber.

11. An apparatus in accordance with claim **8** wherein fuel source comprises a supply of a low-rank fuel with a moisture content of at least 25% on average.

12. An apparatus in accordance with claim **1** further comprising a storage volume and a supply conduit to receive the fuel phase and supply the fuel phase to the storage volume.

13. An apparatus in accordance with claim **1** further comprising a steam generator and a supply conduit to receive the fuel phase and supply the fuel phase to the steam generator.

14. An apparatus in accordance with claim **13** wherein the supply conduit is configured to supply the fuel phase directly to one or more burners of the steam generator.

15. An apparatus in accordance with claim **14** wherein the supply conduit is configured to supply the fuel phase to a storage silo of a steam generator.

16. A method of preparation of a fuel to produce a pulverous fuel supply comprising the steps of:

supplying a mixture of fuel and a gas to a fuel preparation unit adapted to prepare the fuel for combustion in a pulverous sate;

outputting from the fuel preparation unit a mixture of pulverous fuel and gas;

separating the mixture into a gas phase comprising at least a major part of the gas output and a fuel phase comprising the pulverous fuel;

passing the gas phase to a heat exchanger to dry the gas phase.

17. A method in accordance with claim **16** applied as a method of milling and drying of a fuel to produce a pulverous

fuel supply, in that the fuel preparation unit is a mill applied to receive a mixture of fuel and a gas and to mill the fuel to a pulverous state.

18. A method in accordance with claim **16** wherein the heat exchanger is a process fluid heat exchanger.

19. A method in accordance with claim **16** wherein the heat exchanger is a heat exchanger disposed to exchange heat with a process fluid for use in an industrial process and the method comprises using the heat exchanger to effect condensation of the water vapour and thereby recover at least some of the latent heat from the drying process.

20. A method in accordance with claim **19** comprising the further step of using the process fluid in an industrial process in such manner as to make use of the sensible heat recovered in the heat exchanger.

21. A method in accordance with claim **20** wherein the process fluid is feedwater for a steam generator and the step of using the process fluid in such manner as to make use of the sensible heat recovered in the heat exchanger in that the sensible heat recovered in the heat exchanger effects preheating of the feedwater.

22. A method in accordance with claim **16** wherein substantially all of the water vapour laden gas output from the mill is separated into the gas phase and diverted away to the heat exchanger.

23. A method in accordance with claim **16** wherein the step of supplying a mixture of fuel and a gas to a mill comprises the supply of a gas at elevated temperature.

24. A method in accordance with claim **23** wherein the step of supplying a gas at elevated temperature comprises the supply of a mixture of optionally preheated air and flue gas from a combustion chamber.

25. A method in accordance with claim **16** wherein the step of supplying a mixture of fuel and a gas to a mill comprises the supply of a low-rank fuel with a moisture content of at least 25%.

26. A method in accordance with claim **16** comprising a method of producing a pulverous fuel supply for a steam generator such as a boiler for example of a thermal power plant.

27. A method in accordance with claim **26** further comprising the additional step of supplying the fuel phase to the steam generator.

28. A method in accordance with claim **27** further comprising the additional step of supplying the fuel phase directly to one or more burners of the steam generator.

29. A method in accordance with claim **28** further comprising the additional step of supplying the fuel phase to a storage silo of a steam generator.

30. A method in accordance with claim **16** comprising the further step of passing the fuel phase for storage.

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