(54) Title: SUPPLY DEVICE FOR A COMBUSTION CHAMBER

(57) Abstract: The present invention relates to a tubular supply device (1) for supplying solid particles (2) and a carrier fluid (3) to a combustion chamber in a heat generating plant, said supply device having a first end (5), a second end and a longitudinal axis and comprising: a tube (8, 9); an opening (13) through the tube at the first end; and a supply pipe (15), a first end (16) of the pipe being proximal to the first end of the supply device and having an opening (17) defining an outlet of the pipe, and a second end (18) of the pipe being distal to the first end of the supply device, having an opening (19) defining an inlet of the pipe and being connected to an inside surface of the tube, the supply pipe defining a curved flow channel (20) within the tube wherein the flow channel at the outlet of the pipe has a direction towards the opening through the tube which is at an angle (a) to the longitudinal axis of the supply device.
SUPPLY DEVICE FOR A COMBUSTION CHAMBER

TECHNICAL FIELD
The invention relates to a method and a supply device for supplying a fluid and/or solid particles to a combustion chamber.

BACKGROUND
Generally, heat generating plants, such as boilers, incinerator furnaces and technically corresponding apparatuses are designed to combust or burn different kinds of fuels. Depending on the type of fuel being combusted or burnt, different kinds of hazardous gases and/or particles maybe formed or released. The amount of these hazardous gases and/or particles depends, among other things, on how well or completely the fuel is being combusted or burnt. This in turn depends on e.g. the temperature of the grate and the combustion chamber, the amount of available air and other substances that are present to be used by the combustion process and so on. In order to improve the combustion and in order to minimise the pollution/emission caused by the hazardous gases and/or particles, different kinds of supply devices for supplying fluid to an internal combustion chamber of a heat generating plant have been devised.

Supply devices for supplying fluid to an internal combustion chamber of a heat generating plant, such as a boiler, an incinerator furnace and technically corresponding apparatus are known from SE 9201747-4 publication number 502 188 and SE 9304038-4 publication number 502 283 both in the same name of ECOMB and their foreign counterparts.

These known fluid supply devices provide comparatively low emission levels and great flexibility and enable adjustments to desired emission levels to be achieved quickly and reliably. This is attained by arranging a supply device comprising at least one tube to be inserted horizontally into the combustion chamber.
Said devices also simplify de-sooting and cleaning of the tubes included in the
device, a feature which also enhances the yield of the combustion and
vaporisation process respectively.

The devices also enable different fluids or solids to be supplied at different
points of time, through one or more of said tubes, so that a new optimal
operating point can be set in relation to the prevailing operating state of the
combustion chamber. A particular advantage afforded by the known supply
devices is that one or more tubes can be withdrawn while still enabling the
combustion or gasification process to continue with the use of the remaining
tubes.

Other types of supply devices are described in DE 306 765 (Bauer) and US
5,112,216 (Tenn) for example.

A supply device must be able to operate reliably over a long period of time in
a demanding environment. The tube that is inserted into the combustion
chamber, according to prior art, is subjected to high stresses as a result of the
high temperature and the corrosive environment that prevail.

In view of changing conditions within a combustion chamber, the optimal
place for injecting fluid or solid particles into the combustion gases of the
chamber by means of a supply device may vary over time. This has been
solved by using a plurality of tubes and/ or a plurality of injection holes in
each tube.

It is a general problem within the field that old heat generating plants are
often designed for fossil fuel combustion, which is less and less desirable in
view of environmental effects. Many plants are thus converted for using a
renewable or less harmful fuel source such as wood pellets, household waste
etc. However, such fuels often have a lower energy content why a larger
amount of fuel may need to be combusted in order for the plant to operate
efficiently. However, the combustion chambers are not so easily modified and
it maybe very expensive to demolish and rebuild large combustion chambers
to allow for a higher fuel supply.
SUMMARY

It is an objective of the present invention to provide an improved method and supply device for injecting/ emitting a solid fuel into a combustion chamber.

According to an aspect of the present invention, there is provided a tubular supply device for supplying solid particles and a carrier fluid to a combustion chamber in a heat generating plant, said supply device having a first end, a second end and a longitudinal axis and comprising: an outer tube forming an outer lateral surface of the supply device; an inner tube positioned inside the outer tube such that an axial space is formed surrounding the inner tube between said inner tube and the outer tube; coolant connectors at the second end of the supply device and configured for being inlet and outlet, respectively, of a cooling medium allowed to circulate in the axial space of the supply device between the inner tube and the outer tube; a connector located at the second end of the supply device configured for connecting a supply-line for supply of the solid particles into the inner tube; an opening through the outer tube and the inner tube at the first end of the supply device; a supply pipe, a first end of the pipe being proximal to the first end of the supply device and having an opening defining an outlet of the pipe, and a second end of the pipe being distal to the first end of the supply device, having an opening defining an inlet of the pipe and being connected to an inside surface of the inner tube, the supply pipe defining a curved flow channel within the inner tube wherein the flow channel at the outlet of the pipe has a direction towards the opening through the tubes which is at an angle to the longitudinal axis of the supply device, the pipe not extending outside of the outer tube.

According to another aspect of the present invention, there is provided a supply device assembly for supplying solid particles and a carrier fluid to a combustion chamber in a heat generating plant, said combustion chamber being delimited at least one wall, the assembly comprising: the tubular supply device of any preceding claim, the supply device extending, led by its first end, into the combustion chamber through a through hole in the wall of
the combustion chamber; a displacing device in mesh with the supply device for axial displacement of the tube through the hole in the chamber wall; a supply line connected to the connector for supply of the solid particles, the supply line providing a flow channel between the inner tube and a supply source of the solid particles.

According to another aspect of the present invention, there is provided a method of supplying solid particles and a carrier fluid to a combustion chamber in a heat generating plant, said combustion chamber being delimited at least one wall, the method comprising: providing a tubular supply device extending, led by a first end of said supply device, into the combustion chamber through a through hole in the wall of the combustion chamber; circulating a cooling medium in an axial space formed between an inner tube and an outer tube forming an outer lateral surface of the supply device; supplying a flow of solid particles from a supply source into the inner tube at a second end of the supply device; supplying a flow of a carrier fluid into the inner tube at the second end of the supply device such that the solid particles are carried by the carrier fluid in the inner tube from the second end of the supply device towards the first end of the supply device along a longitudinal axis of said supply device; allowing the flow of carrier fluid carrying the solid particles to enter a supply pipe defining a curved flow channel inside the inner tube, whereby the flow direction is changed; and emitting the flow of carrier fluid carrying the solid particles from an end outlet of the supply pipe, through an opening through the outer tube and the inner tube at the first end of the supply device and into the combustion chamber at an angle to the longitudinal axis of the supply device.

It is an advantage of the present invention that a supply pipe is used which defines a curved flow channel within the tubular supply device. The inlet of the pipe is connected to the inside surface of the inner tube, whereby at least a part of the solid particles and carrier fluid flowing within the inner tube is forced into the supply pipe via the inlet. After having entered the supply pipe via the inlet, the flow of particles and carrier fluid is guided through the
curved flow channel, changing the direction of the flow such that when the flow is injected into the combustion chamber through the outlet of the supply pipe, the flow will be at an angle to the longitudinal axis of the tubular supply device. Thus, by means of the present invention, the solid particles flowing through the inner tube can be redirected and emitted into the combustion chamber in a desired direction to reach a desired location within the combustion chamber.

Further, by the supply pipe not extending outside of the outer tube, the first end of the supply pipe is less affected by the harsh (hot and corrosive) environment in the combustion chamber. Also, the first end of the supply pipe does not form a projection extending beyond the tubular form of the supply device, whereby said first end does not interfere with e.g. axial movement of the tubular supply device through a through hole of a wall of the combustion chamber for inserting or removing the supply device from the combustion chamber. The ability of redirecting the flow thus does not interfere with the ability of axial displacement of the supply device.

Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of "first", "second" etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The invention is now described, by way of example, with reference to the accompanying drawings, in which:
Fig 1 is a schematic side view of an embodiment of a supply device of the present invention, when the supply device is inserted into a combustion chamber through a hole in a wall of the combustion chamber (the wall shown in section).

Fig 2 is a partial schematic side view in longitudinal section of an embodiment of a supply device of the present invention.

Fig 3 is a partial schematic side view in longitudinal section of another embodiment of a supply device of the present invention.

Fig 4 is a partial schematic side view in longitudinal section of another embodiment of a supply device of the present invention.

DETAILED DESCRIPTION

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

The term "tube" or "tubular" is intended to denote a hollow substantially cylindrical structure being delimited by a lateral surface and first and second end surfaces. The lateral surface is substantially parallel to the central longitudinal axis of the tube, whereas the respective end surfaces are substantially not parallel to the central longitudinal axis of the tube but intersects the central longitudinal axis of the tube. The tube has a first end with the first end surface, and a second end with the second end surface. Conveniently, the first and second ends do not include any of the lateral surface. When the tube is inserted into the combustion chamber, the first end may be regarded as an inner end since it extends, is inserted, into the combustion chamber, whereas the second end may be regarded as an outer
end since it extends through an outer wall of the combustion chamber, such
that the second end is in or outside said outer wall. The apertures discussed
herein are thus apertures through one of these surfaces. The second end
surface, i.e. the surface of the second end of the tube, may, depending on the
design of the tube, more or less substantially consist of an aperture. The tube
maybe a substantially circular tube, i.e. have a substantially circular cross-
section perpendicular to the central longitudinal axis, but other shapes are
also contemplated, such as a square or rectangular tube.

That something is at the first or second end of the supply device, such as the
opening thorough the tubes being at the first end of the supply device or the
displacing device meshing with or engaging the supply device at its second
end, implies that it is on/in the end surface or on/in the lateral surface but in
close proximity of, or adjacent to, the end surface and at least closer to that
(first or second) end surface than to the other (first or second) end surface of
the supply device.

The tubular supply device maybe of any size, but it maybe convenient to use
an outer tube which has a longitudinal length of less than 10 m, such as less
than 5 m, in order to reduce the lateral stress on the tube, especially if the
supply device is inserted substantially horizontally into the combustion
chamber. The diameter of the outer tube may also be of any size, but it may
be convenient to use a tube with a diameter of less than 250 mm, such as less
than 200 mm, less than 150 mm, less than 120 mm or less than 100 mm, in
order to reduce the weight of the supply device to make it more easy to
handle and move, axially and/or rotationally around its longitudinal axis.

Another advantage with using a smaller supply device is that less cooling may
be needed of the tube, since the tube takes up heat in relation to its surface
area.

Only one supply device maybe used in a combustion chamber, but it may
also be convenient to use a plurality of supply devices, e.g. substantially
parallel to each other, at different positions in the combustion chamber. The
supply devices may then co-operate with each other to provide optimal
supply of the fluid and solid particles in the combustion chamber, e.g.
improved mixture of the fluid and solid particles with the atmosphere in the
combustion chamber and/ or improved coverage of the combustion chamber
volume by being able to supply the fluid and solid particles at more different
positions in the combustion chamber.

The supply device may be inserted into the combustion chamber in any
direction. It may be convenient to insert the supply device vertically, e.g.
hanging through the top wall (ceiling/roof) of the combustion chamber in
order to reduce the lateral stresses on the supply device and the mounting of
the supply device in the chamber wall, and/ or on the displacing device. On
the other hand it maybe convenient to insert the supply device horizontally,
e.g. through a side wall of the combustion chamber. Depending on the design
on the combustion chamber, it may be easier to reach the place within the
combustion chamber where it is desired to supply the fluid and solid particles
in the combustion chamber with a horizontal supply device. A vertically
inserted supply device may need to be much longer and heavier in order to
reach the same position in the combustion chamber as a substantially smaller
horizontally inserted supply device.

The supply device maybe provided with means for supplying a cooling agent
to said supply device. This has the advantage that the tube can operate for
long periods of time in a very hot environment.

The displacing device or means for displacing said supply device maybe
arranged so as to permit rotation of the supply device around its longitudinal
axis.

The supply device may further be associated with a cleaning means, e.g.
mechanically by means of steel pins or brushes, or pneumatically by means of
blowing air or steam for cleaning the outer tube during its axial inward
and/or outward movement in the combustion chamber. As the outer tube is
subjected to a combustion process, particles, such as e.g. soot, will eventually
be formed on the tube and also at the opening and pipe outlet. The tube will
at some point in time need to be withdrawn from the combustion chamber to be cleaned. By this arrangement, the supply device is cleaned swiftly and can be re-inserted immediately after cleaning.

In some embodiments, the opening is through a lateral surface of the inner and outer tubes. In this way the direction of the particle flow may be conveniently altered to e.g. about 90° in relation to the axial flow within the inner tube. The flow can e.g. be directed downwards, towards the hearth from a horizontally positioned supply device in a combustion chamber. In other embodiments, however, the opening is in the end surface of the first end of the device, e.g. allowing the particles to be more easily injected forwards along the longitudinal axis whereby the supply device may extend a shorter length into the combustion chamber, allowing the device to be made smaller and reducing the gravitational strain on a horizontally extending tubular supply device.

In some embodiments, the outlet opening of the pipe has a diameter which is less than 80%, e.g. less than 50%, of a diameter of the inner tube. This implies that the supply pipe may have a substantially smaller cross section than the inner tube, allowing the pipe to form the curved flow channel within the inner tube. The supply pipe may have a substantially uniform cross section between its inlet and outlet, although allowing for some deviations for allowing the pipe to curve. Also, the inner tube may have a uniform cross section/diameter, at least along the part of the inner tube surrounding the supply pipe.

In some embodiments, the outlet opening of the pipe has a diameter which is less than 80% of the diameter of the opening through the inner and outer tubes. This may allow for a gap to be formed between the supply pipe and the inner and outer tubes at the opening through said tubes. This gap may be advantageous for e.g. allowing access to the
inside of the inner tube e.g. for maintenance work or for removing or exchanging the supply pipe. Also or alternatively, the relatively smaller diameter of the supply pipe at its outlet may allow the pipe to be inclined to the opening through the tubes when extending through said opening (i.e. the pipe does not have to extend at a $90^\circ$ angle to the longitudinal axis when extending through the opening if the opening is through the lateral surfaces of the tubes.

In some embodiments, the outlet opening of the pipe has a diameter which is at least 3 cm or at least 5 cm. This relatively large outlet of the supply pipe allows a relatively large flow rate of the particles and carrier fluid, allowing a large amount of particles to be injected per time period. This is advantageous e.g. for efficient injection of particles as a primary or secondary fuel into the combustion chamber. Also, the pipe may have a substantially uniform diameter of at least 3 cm or at least 5 cm.

In some embodiments, the second end of the supply pipe is connected to the inside surface of the inner tube by means of a circumferential flange configured for forcing an axial flow in the inner tube, from the second end towards the first end of the supply device, into the pipe.

Thus, the pipe may conveniently be fixed to the flange and the circumferential flange may at the same time prevent the flow from passing beside the supply pipe and instead forcing the flow into the supply pipe. The flange may also comprise guiding parts which gradually reduces the diameter of the flow channel of the flow in the inner tube before entering the supply pipe. The flange may allow the supply pipe to be exchangeable. For instance, it may be convenient to be able to replace a supply pipe if it has been corroded or otherwise damaged, or if a supply pipe having a different curvature or diameter is desired. If the opening through the tubes is large enough, as discussed
above, the supply pipe may be replaced through said opening without the need to disassemble the supply device any further.

In some embodiments, the supply pipe comprises a flexible or jointed part, allowing the angle to the longitudinal axis to be adjusted. This may be in addition to or an alternative to switching between different supply pipes having different curvatures as mentioned above. The flexible or jointed part may further improve the ability of adapting to where in the combustion chamber the particles are injected/emitted by changing the injection direction. The pipe may be curved by the joint e.g. by hand when the supply device is under maintenance outside the chamber, or by means of mechanical externally operated means while the supply device is inserted into the chamber (e.g. a motor which mechanically bends and possibly holds the curvature of the pipe).

In some embodiments, the angle of the flow channel at the outlet of the pipe in relation to the longitudinal axis is between 0° and 90°, such as at least 30°, e.g. between 45° and 90°, e.g. if the opening is through a lateral surface of the inner and outer tubes. Thus, the flow direction of the particles is substantially altered in relation to its axial flow through the inner tube, by means of the supply pipe.

In some other embodiments, e.g. if the opening is through an end surface of the inner and outer tubes, the angle of the flow channel at the outlet of the supply pipe in relation to the longitudinal axis is between 0° and 45°, such as less than 30°. The angle may then be in any direction, e.g. upwards or downwards from a longitudinal direction of a horizontally mounted supply device.

Regardless of whether the opening is through a lateral or end surface, the angle may be towards a direction against the flow direction of the
gas in the combustion chamber, typically downward for a horizontally mounted supply device.

In some embodiments, the supply device is mounted through a through hole in a wall of the combustion chamber, e.g. a vertical wall if the device is inserted horizontally into the chamber, or a horizontal wall if the device is inserted vertically into the chamber e.g. hanging from the ceiling. In some embodiments, a displacing device is in mesh with the supply device for axial displacement of the tubular device through the hole in the chamber wall. By axial displacement, the position in the chamber to where the particles are injected/emitted (the terms injected and emitted are herein used interchangeably) may be controlled, and the tubular device may be removed to the outside of the chamber for maintenance etc. In some embodiments, the supply device may be axially displaced out from the combustion chamber when it is not in use, i.e. when it is not supplying solid particles into the combustion chamber. Additionally, the displacing device may be arranged for rotation of the tubular supply device, further increasing the control of to where the particles are injected.

In some embodiments, the supply device is associated with a particle analysing device arranged for measuring a particle size of the solid particles in a flow channel between the supply source and the pipe outlet. The particle size may e.g. be a number average particle size or a weight average particle size. The size of the particles may be relevant for to where in the chamber they should be injected, which may be controlled by different controlling parameters e.g. by the curvature of the supply pipe, the speed/pressure of the carrier fluid and/or the position (axial displacement and/or rotation) of the supply device in the chamber. E.g. a particulate fuel having a large particle size may travel further from the supply device before combusting than a fuel
having a smaller particle size. Associating the particle analysing device may e.g. allow any of the controlling parameters to be adjusted in view of continuous or periodic analysis of the particle size. This is relevant e.g. since the particle size can vary over time. For instance, larger particles have a tendency to move to the top of a supply source. In some embodiments, the supply device is associated with a control unit configured for controlling the angle between the direction of the pipe outlet and the longitudinal axis depending on the particle size measured by the particle analysing device. In some embodiments, the supply device is associated with a carrier fluid compression unit configured to adjust the pressure of the carrier fluid depending on the particle size measured by the particle analysing device.

In some embodiments, a flame detector is mounted on the supply device inside the combustion chamber. The flame detector may e.g. be connected to the control unit and/or compression unit for regulating the particle emission in view of flame detection.

In some embodiments, the heated cooling medium exiting the supply device is used to pre-heat the carrier fluid before it enters the supply device, e.g. by means of a liquid-gas heat exchanger if the cooling medium is a liquid and the carrier fluid is a gas. Thus, energy which is lost from the combustion chamber due to the cooling of the supply device may be restored to the chamber by the carrier fluid.

In some embodiments, the solid particles are of a fuel for the combustion chamber. The particles may be a primary fuel, but it may be convenient to use the supply device of the present invention for adding a secondary fuel, complementing a primary fuel added at the bottom grate of the chamber. When the particles are a secondary fuel, the particles may be supplied counter current to the combustion gases from the upstream main combustion zone. The supply device may be
used when additional (secondary) fuel is useful for obtaining extra power/effect from the furnace, e.g. less than 50% additional power/fuel such as between 10 and 30% may be added by means of the supply device. The present invention may be used for upgrading a heat generating plant which is designed for fossil fuel combustion. If a more environmentally friendly primary fuel is used, such as wood pellets or household waste, the grate and combustion chamber may not be designed for the lower energy density of such a fuel, why the heat generating plant may not operate optimally. In such a case, the combustion chamber may easily be upgraded by making a through hole in one of its walls for insertion of the supply device of the present invention for supplying a particulate secondary fuel to the combustion chamber for combustion in the combustion gases from the primary fuel. This is a much simpler and cheaper upgrade than a more extensive upgrade for allowing more primary fuel to be combusted. The solid particles may e.g. be of a medium calorific fuel such as a non-fossil fuel e.g. a wood powder, or of a high calorific fuel such as a fossil fuel e.g. a plastics powder, or of a low calorific fuel such as sewage sludge, or of a mixture thereof.

Thus, in some embodiments, a primary fuel is combusted at the bottom of the combustion chamber and the solid particles are a secondary fuel emitted into combustion gases of the combustion chamber from the combustion of the primary fuel. In some embodiments, the solid particles are emitted in a direction which is at least partly counter current to the combustion gases. This may improve the combustion of the fuel particles.

In some embodiments, at least 100 kg/h, e.g. at least 500 kg/h or at least 1000 kg/h, of solid particles are emitted from the supply pipe.
This implies that a large amount of e.g. secondary fuel can be injected into the combustion chamber.

In some embodiments, the carrier fluid is air, recirculated flue gas, oxygen enriched air, oxygen, or a mixture thereof. If the carrier fluid comprises oxygen, the present device may additionally be designed to provide secondary oxygen to the combustion chamber for improved combustion.

Figure 1 is a schematic illustration of an embodiment of a supply device 1 of the present invention, when the supply device is inserted into a combustion chamber 4 through a hole 23 in a wall 24 of the combustion chamber. The supply device 1 has a first end 5 extending into the combustion chamber 4 and a second end 6 extending out of said chamber 4. The supply device 1 has a longitudinal axis 7 which is herein used for reference when discussing the present invention. The wall 24 may e.g. be a vertical or a horizontal wall of the combustion chamber 4. Coolant connectors 10 at the second end 6 of the device 1 provides an inlet and an outlet of cooling medium circulating in the supply device. A coolant supply pipe 25 guides cooling medium, e.g. water, from a coolant source 27, and a coolant recirculation pipe 26 guides the heated coolant from the supply device, e.g. back to the coolant source 27 to be cooled, possibly partly by heat exchanging with the carrier fluid before said fluid enters the supply device. A connector 11 for connecting a supply-line 12 for supply of the solid particles into the supply device from a particle supply source 28 is also positioned at the second end 6 of the device 1. The particles maybe transported through the supply line 12 by and in mixture with the carrier fluid, or the particles may be mixed with the carrier fluid at a later stage inside the supply device. An opening 13 through a later surface of the tubular supply device allows an outlet opening 17 of the supply pipe to emit the particles and carrier fluid into the chamber 4, e.g. at least partly counter currently with the combustion gases in the combustion chamber.
Figure 2 is a schematic illustration in longitudinal section of the first end 5 of an embodiment of the supply device 1. An outer tube 8 forms an outer lateral surface of the supply device and an inner tube 9 is positioned inside the outer tube such that an axial space 14 is formed surrounding the inner tube 9 between said inner tube and the outer tube 8. The axial space 14 is configured for allowing a cooling medium to flow there through. There is an opening 13 through the outer tube 8 and the inner tube 9 at the first end 5 of the supply device 1. A supply pipe 15 is positioned inside the inner tube 9. A first end 16 of the pipe 15 is proximal to the first end 5 of the supply device and has an opening 17 defining an outlet of the pipe 15, and a second end 18 of the pipe is distal to the first end 5 of the supply device. The second end 18 has an opening 19 defining an inlet of the pipe 15 and being connected to an inside surface of the inner tube 9. The supply pipe 15 defines a curved flow channel 20 within the inner tube 9 wherein the flow channel at the outlet 17 of the pipe 15 has a direction towards the opening 13 through the tubes 8 and 9 which is at an angle a to the longitudinal axis 7 of the supply device. In the embodiment of figure 2, the angle a is about 90° to emit the particles 2 in a direction perpendicular to the longitudinal axis 7 as indicated by the bold arrow at the outlet opening 17. The pipe 15 does not extend outside of the outer tube 8, but ends substantially in level with the outer tube 8. In the embodiment of figure 2, a particle supply pipe 22 extends inside and along the inner tube 9 for transporting the particles, possibly by means of and mixed with a part of the carrier fluid 3 within the supply device. The particles are then injected into the inner tube from the particle supply pipe (as indicated by the bold arrow) and mixed with the carrier fluid 3 flowing (as indicated by the broad arrows) beside the particle supply pipe 22 in the inner tube before the mixture enters the supply pipe 15 via its inlet 19. At its second end 18, the supply pipe 15 is fixed to the inner tube 9 by a circumferential flange 21.

Figure 3 is a schematic illustration in longitudinal section of the first end 5 of another embodiment of the supply device 1. An outer tube 8 forms an outer lateral surface of the supply device and an inner tube 9 is positioned inside
the outer tube such that an axial space 14 is formed surrounding the inner tube 9 between said inner tube and the outer tube 8. The axial space 14 is configured for allowing a cooling medium to flow there through. There is an opening 13 through the outer tube 8 and the inner tube 9 at the first end 5 of the supply device 1. A supply pipe 15 is positioned inside the inner tube 9. A first end 16 of the pipe 15 is proximal to the first end 5 of the supply device and has an opening 17 defining an outlet of the pipe 15, and a second end 18 of the pipe is distal to the first end 5 of the supply device. The second end 18 has an opening 19 defining an inlet of the pipe 15 and being connected to an inside surface of the inner tube 9. The supply pipe 15 defines a curved flow channel 20 within the inner tube 9 wherein the flow channel at the outlet 17 of the pipe 15 has a direction towards the opening 13 through the tubes 8 and 9 which is at an angle a to the longitudinal axis 7 of the supply device. In the embodiment of figure 3, the angle a is about 45° to emit the particles 2 in a direction which is not perpendicular to the longitudinal axis 7, as indicated by the bold arrow at the outlet opening 17. The pipe 15 does not extend outside of the outer tube 8, but ends substantially in level with the outer tube 8. In the embodiment of figure 3, a particle supply pipe 22 is not used. Rather, the particles 2 and carrier fluid 3 are mixed with each other upon entering the inner tube via the connector 11. At its second end 18, the supply pipe 15 is fixed to the inner tube 9 by a circumferential flange 21 including guides for guiding the flow of particles and carrier fluid into the pipe 15.

Figure 4 is a schematic illustration in longitudinal section of the first end 5 of another embodiment of the supply device 1. An outer tube 8 forms an outer lateral surface of the supply device and an inner tube 9 is positioned inside the outer tube such that an axial space 14 is formed surrounding the inner tube 9 between said inner tube and the outer tube 8. The axial space 14 is configured for allowing a cooling medium to flow there through. There is an opening 13 through the end wall of the outer tube 8 and the inner tube 9 at the first end 5 of the supply device 1. A supply pipe 15 is positioned inside the inner tube 9. A first end 16 of the pipe 15 is proximal to the first end 5 of the supply device and has an opening 17 defining an outlet of the pipe 15, and a
second end 18 of the pipe is distal to the first end 5 of the supply device. The second end 18 has an opening 19 defining an inlet of the pipe 15 and being connected to an inside surface of the inner tube 9. The supply pipe 15 defines a curved flow channel 20 within the inner tube 9 wherein the flow channel at the outlet 17 of the pipe 15 has a direction towards the opening 13 through the tubes 8 and 9 which is at an angle a to the longitudinal axis 7 of the supply device. In the embodiment of figure 4, the angle a is about 30° to emit the particles 2 in a direction which is not perpendicular to the longitudinal axis 7, as indicated by the bold arrow at the outlet opening 17. The opening 13 is through an end wall of the inner and outer tubes, as opposed to through a lateral wall as in the embodiments of figures 1, 2 and 3. The pipe 15 does not extend outside of the outer tube 8, but ends substantially in level with the outer tube 8. In the embodiment of figure 4, a particle supply pipe 22 is not used. Rather, the particles 2 and carrier fluid 3 are mixed with each other upon entering the inner tube via the connector 11. At its second end 18, the supply pipe 15 is fixed to the inner tube 9 by a circumferential flange 21 including guides for guiding the flow of particles and carrier fluid into the pipe 15.

According to another embodiment of the present invention, there is provided a tubular supply device (1) for supplying solid particles (2) and a carrier fluid (3) to a combustion chamber in a heat generating plant, said supply device having a first end (5), a second end and a longitudinal axis and comprising: a tube (8, 9); an opening (13) through the tube at the first end; and a supply pipe (15), a first end (16) of the pipe being proximal to the first end of the supply device and having an opening (17) defining an outlet of the pipe, and a second end (18) of the pipe being distal to the first end of the supply device, having an opening (19) defining an inlet of the pipe and being connected to an inside surface of the tube, the supply pipe defining a curved flow channel (20) within the tube wherein the flow channel at the outlet of the pipe has a direction towards the opening through the tube which is at an angle (a) to the longitudinal axis of the supply device. In some embodiments, the tube comprises an outer tube (8) forming an outer lateral surface of the supply
device; and an inner tube (9) positioned inside the outer tube such that an axial space (14) is formed surrounding the inner tube (9) between said inner tube and the outer tube (8). In some embodiments, the supply device (1) further comprises coolant connectors (10) at the second end (6) of the supply device and configured for being inlet and outlet, respectively, of a cooling medium allowed to circulate in the axial space (14) of the supply device between the inner tube (9) and the outer tube (8). In some embodiments, the supply device (1) further comprises a connector (11) located at the second end (6) of the supply device configured for connecting a supply-line (12) for supply of the solid particles (2) into the inner tube (9). In some embodiments, the supply pipe (15) does not extend outside of the outer surface of the tube (8).

The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.
CLAIMS

1. A tubular supply device (1) for supplying solid particles (2) and a carrier fluid (3) to a combustion chamber (4) in a heat generating plant, said supply device having a first end (5), a second end (6) and a longitudinal axis (7) and comprising:

an outer tube (8) forming an outer lateral surface of the supply device;

an inner tube (9) positioned inside the outer tube such that an axial space (14) is formed surrounding the inner tube (9) between said inner tube and the outer tube (8);

coolant connectors (10) at the second end (6) of the supply device and configured for being inlet and outlet, respectively, of a cooling medium allowed to circulate in the axial space (14) of the supply device between the inner tube (9) and the outer tube (8);

a connector (11) located at the second end (6) of the supply device configured for connecting a supply-line (12) for supply of the solid particles (2) into the inner tube (9);

an opening (13) through the outer tube (8) and the inner tube (9) at the first end (5) of the supply device (1); and

a supply pipe (15), a first end (16) of the pipe being proximal to the first end (5) of the supply device and having an opening (17) defining an outlet of the pipe (15), and a second end (18) of the pipe being distal to the first end (5) of the supply device (1), having an opening (19) defining an inlet of the pipe (15) and being connected to an inside surface of the inner tube (9), the supply pipe (15) defining a curved flow channel (20) within the inner tube wherein the flow channel at the outlet (17) of the pipe has a direction towards the opening (13) through the tubes (8, 9) which is at an angle (a) to the longitudinal axis (7) of the supply device, the pipe not extending outside of the outer tube (8).
2. The supply device of claim 1, wherein the opening is through a lateral surface of the inner and outer tubes.

3. The supply device of claim 1 or 2, wherein the outlet opening of the pipe has a diameter which is less than 80%, e.g. less than 50%, of a diameter of the inner tube.

4. The supply device of any preceding claim, wherein the outlet opening of the pipe has a diameter which is less than 80% of the diameter of the opening through the inner and outer tubes.

5. The supply device of any preceding claim, wherein the outlet opening of the pipe has a diameter which is at least 3 cm or at least 5 cm.

6. The supply device of any preceding claim, wherein the second end of the supply pipe is connected to the inside surface of the inner tube by means of a circumferential flange (21) configured for forcing an axial flow in the inner tube, from the second end towards the first end of the supply device, into the pipe.

7. The supply device of any preceding claim, wherein the supply pipe comprises a flexible or jointed part, allowing the angle to the longitudinal axis to be adjusted.

8. The supply device of any preceding claim, wherein the angle of the flow channel at the outlet of the pipe in relation to the longitudinal axis is at least 30°, e.g. between 45° and 90°.

9. A supply device assembly for supplying solid particles and a carrier fluid to a combustion chamber in a heat generating plant, said combustion chamber being delimited at least one wall, the assembly comprising:
the tubular supply device of any preceding claim, the supply device extending, led by its first end, into the combustion chamber through a through hole in the wall of the combustion chamber;

a displacing device in mesh with the supply device for axial displacement of the tubular device through the hole in the chamber wall;

a supply line connected to the connector for supply of the solid particles, the supply line providing a flow channel between the inner tube and a supply source of the solid particles.

10. The assembly of claim 9, further comprising a particle analysing device arranged for measuring a particle size of the solid particles in a flow channel between the supply source and the pipe outlet.

11. The assembly of claim 10, further comprising a control unit configured for controlling the angle between the direction of the pipe outlet and the longitudinal axis depending on the particle size measured by the particle analysing device.

12. The assembly of claim 10 or 11, further comprising a carrier fluid compression unit configured to adjust the pressure of the carrier fluid depending on the particle size measured by the particle analysing device.

13. The assembly of any claim 9-12, further comprising a flame detector mounted on the supply device inside the combustion chamber.

14. A method of supplying solid particles and a carrier fluid to a combustion chamber in a heat generating plant, said combustion chamber being delimited at least one wall, the method comprising:
providing a tubular supply device extending, led by a first end of said supply device, into the combustion chamber through a through hole in the wall of the combustion chamber;

circulating a cooling medium in an axial space formed between an inner tube and an outer tube forming an outer lateral surface of the supply device;

supplying a flow of solid particles from a supply source into the inner tube at a second end of the supply device;

supplying a flow of a carrier fluid into the inner tube at the second end of the supply device such that the solid particles are carried by the carrier fluid in the inner tube from the second end of the supply device towards the first end of the supply device along a longitudinal axis of said supply device;

allowing the flow of carrier fluid carrying the solid particles to enter a supply pipe defining a curved flow channel inside the inner tube, whereby the flow direction is changed; and

emitting the flow of carrier fluid carrying the solid particles from an end outlet of the supply pipe, through an opening through the outer tube and the inner tube at the first end of the supply device and into the combustion chamber at an angle to the longitudinal axis of the supply device.

15. The method of claim 14, wherein the solid particles are of a medium calorific fuel such as a non-fossil fuel e.g. a wood powder, or of a high calorific fuel such as a fossil fuel e.g. a plastics powder, or of a low calorific fuel such as sewage sludge, or of a mixture thereof.

16. The method of claim 14 or 15, wherein at least 100 kg/h, e.g. at least 500 kg/h or at least 1000 kg/h, of solid particles are emitted from the supply pipe.
17. The method of any claim 14-16, wherein the carrier fluid is air, recirculated flue gas, oxygen enriched air, oxygen, or a mixture thereof.

18. The method of any claim 14-17, wherein a primary fuel is combusted at the bottom of the combustion chamber and the solid particles are a secondary fuel emitted into combustion gases of the combustion chamber from the combustion of the primary fuel.

19. The method of claim 18, wherein the solid particles are emitted in a direction which is at least partly counter current to the combustion gases.

20. The method of claim 18 or 19, wherein the solid particles are of a secondary fuel increasing the power of the heat generating plant with less than 50%, e.g. between 10% and 30%, in addition to the primary fuel.

21. The method of any claim 14-20, further comprising:

measuring a particle size of the solid particles in a flow channel between the supply source and the pipe outlet;

adjusting the angle at which the flow is emitted by changing the curved flow channel of the supply pipe based on the measured particle size; and/or

adjusting the pressure, and thus velocity, of the carrier fluid based on the measured particle size.
**INTERNATIONAL SEARCH REPORT**

**International application No.**
PCT/SE2013/051185

### A. CLASSIFICATION OF SUBJECT MATTER

*IPCI see extra sheet*

According to International Patent Classification (IPC) or to both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

**IPC:** F23C, F23D, F23J, F23K, F23L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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* Further documents are listed in the continuation of Box C.  

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**&** document member of the same patent family

**Date of the actual completion of the international search**

07-02-2014

**Date of mailing of the international search report**

10-02-2014

**Name and mailing address of the ISA/SE**

Patent- och registreringsverket
Box 5055
S-750 22 STOCKHOLM
Facsimile No. +46 8 666 02 86

**Authorized officer**

Claes Weyde

**Telephone No.** +46 8 782 25 00

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## INTERNATIONAL SEARCH REPORT

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Form PCT/ISA/210 (continuation of second sheet) (July 2009)
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International Patent Classification (IPC)

F23D 74/53 (2006.01)
F23J 7/00 (2006.01)
F23J 15/00 (2006.01)
F23K 3/02 (2006.01)
F23L 7/00 (2006.01)
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