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(54) **A RECOVERY BOILER, FUEL FEEDING MEANS AND A METHOD FOR FEEDING BLACK LIQUOR AND AIR TO REDUCE NITROGEN OXIDE EMISSIONS**

(57) The invention relates to a recovery boiler comprising a set of black liquor feed pipes in the first combustion zone (I), and primary air nozzles below the set of black liquor feed pipes. The recovery boiler comprises an air feed channel above at least part of the length of at least one black liquor feed pipe for supplying combustion air for volatile matter into the first combustion zone

(I) along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe. The present invention further relates to fuel feeding means for a recovery boiler and a method for feeding black liquor and air to a recovery boiler to reduce nitrogen oxide emissions.

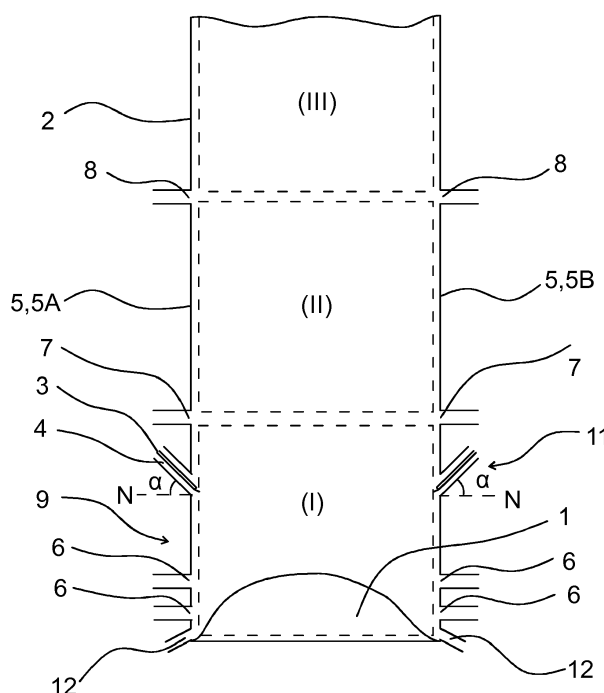


Fig. 1

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a recovery boiler having reduced nitrogen oxide emissions. The present invention further relates to fuel feeding means for a recovery boiler and a method for feeding black liquor and air to a recovery boiler.

BACKGROUND OF THE INVENTION

[0002] Recovery boilers are used in the Kraft process of pulping for combustion of black liquor. Black liquor is an aqueous solution comprising organic and inorganic chemicals which formed as a by-product in pulping process. The purpose of the process is to regenerate black liquor into active cooking chemical with the aid of heat and reducing conditions.

[0003] Before combustion in a recovery boiler, black liquor is normally concentrated until the dry matter content is approximately 65 to 85 %. Several simultaneous processes occur in a recovery boiler. Combustion of compounds originating from wood produces heat which is used to produce high pressure steam. The steam is used to generate electricity in a turbine. In addition, heat is produced when chemicals contained in black liquor react in a recovery boiler. Reduction of inorganic sulfur compounds in a char bed located at the lower part of the furnace produces chemical smelt which exits the furnace through smelt removal spouts. The regenerated sulfur and sodium compounds of black liquor are returned into the process.

[0004] A typical recovery furnace comprises black liquor feed pipes at a height of 6 to 7 meters from the bottom to the furnace for supplying black liquor into the furnace. The number of black liquor feed pipes is between four and twenty. Black liquor feed pipes comprise black liquor spray nozzles for distributing black liquor spray into the boiler furnace. The black liquor spray nozzles atomize the black liquor into droplets of a size of 0.5 to 5 mm. The black liquor droplets go through a series of processes involving drying, pyrolysis, char gasification and combustion. The solid char residue that remains after pyrolysis is burned mostly in the char bed at the bottom of the furnace. The formation of black liquor spray is controlled by the choice of a suitable black liquor spray nozzle. The purpose of the black liquor nozzle is to control the droplet size and to efficiently distribute the liquor spray in to the boiler furnace. Typical nozzle types include swirlcone nozzle, V-type nozzle and splash plate nozzle.

[0005] Primary air is typically supplied from all four furnace walls at a height of one meter and secondary air at a height of two meters from the bottom of the furnace. Typically, 65 to 85 % of combustion air is supplied below the black liquor feed pipes. Tertiary air is typically supplied at a height of eight meters from two furnace walls. Primary air is used to achieve optimal combustion of

black liquor and to control the shape of the char bed located at the lower part of the furnace. The purpose of secondary air is to control combustion processes in the upper part of the furnace and to combust the pyrolysis gases and carbon monoxide. Secondary air is also used to control the shape of the char bed. The purpose of tertiary air is to finalize the combustion process. In addition to three-level air system, multilevel air system and vertical air systems have been used.

[0006] Smelt removal spouts are typically located at the bottom of the furnace on the sides of the furnace walls. The smelt removal spouts direct the chemical smelt produced in combustion out of the furnace.

[0007] Combustion and charring take place in the char bed located at the bottom of the furnace. The height of the char bed is typically about two meters from the bottom of the furnace. The height and shape of the char bed is controlled with the aid of primary and secondary air.

[0008] Currently, combustion of black liquor in recovery boilers has the following requirements: stable combustion in the char bed located in the lower part of the furnace and controlling of the shape and size of the char bed, reducing conditions in the char bed, minimization of carryover of black liquor particles to the upper parts of the furnace, minimization of sulfur emissions and minimization of nitrogen oxide emissions.

[0009] Recovery boilers produce various emissions, such as sulfur dioxides, total reduced sulfur compounds, nitrogen oxides, hydrochloric acid, heavy metals, volatile organic compounds and polycyclic aromatic hydrocarbons. The emissions have been reduced by designing more advanced boilers and air systems. There is, however, a need to reduce nitrogen oxide emissions of recovery boilers. Nitrogen oxide emission limits for recovery boilers are about to get stricter in the near future and it is likely that the new nitrogen oxide emission limit for recovery boilers will be in the range of 120 to 200 mg/Nm³. A nitrogen oxide emission limit of 120 mg/Nm³ would be rather strict and would possibly require, in addition to methods of combustion technology, post-combustion nitrogen oxide control technologies such as Selective Non-catalytic Reduction (SNCR) process.

[0010] Fouling of heat transfer surfaces causes major problems in recovery boilers. Part of the black liquor spray particles may be entrained in the air and flue gas streams and carried to the upper part of the furnace. The black liquor particles burn in the flue gases, and the carryover particles carried by the flue gas stream are stratified on the heat transfer surfaces thereby causing fouling and corrosion of the heat transfer surfaces and preventing flue gas flow. It would be desirable to increase the temperature of steam in superheaters in order to acquire more electricity in a turbine. However, due to carryover of black liquor particles, the temperature of the steam cannot be increased. Carryover is especially formed if strong upflow jets are formed inside the furnace. Upflow jets are formed when two streams of high velocity collide. There is thus a need to invent new ways to reduce fouling

and corrosion of superheaters.

[0011] EP 0761871 A1 describes a kraft recovery boiler furnace in which air is introduced into the furnace through quarternary air injection ports located in the furnace in the vicinity of or at approximately the same elevation as the black liquor injection guns. Injection site combustion zone is defined surrounding the black liquor guns. In this zone, the quarternary air supports efficient combustion of the combustible gases driven from the drying black liquor droplets without entraining solid particles. The solution improves mixing and combustion, but does not direct the black liquor particles down into the char bed. Also, no reduction in nitrogen oxide emission is described.

THE PURPOSE OF THE INVENTION

[0012] The purpose of the invention is to provide a recovery boiler in which carryover of black liquor particles to the upper parts of the furnace is reduced. The purpose is also to reduce nitrogen oxide emissions.

SUMMARY

[0013] The present invention relates to a recovery boiler comprising a boiler furnace comprising vertical furnace walls and a first combustion zone (I), a set of black liquor feed pipes on at least one furnace wall in the first combustion zone (I) for supplying black liquor into the boiler furnace, and primary air nozzles on at least one furnace wall below the set of black liquor feed pipes for supplying primary air into the first combustion zone (I).

[0014] The recovery boiler comprises an air feed channel above at least part of the length of at least one black liquor feed pipe of the set of black liquor feed pipes for supplying combustion air for volatile matter into the first combustion zone (I) along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe.

[0015] The present further invention relates to a recovery boiler comprising a boiler furnace comprising vertical furnace walls and a first combustion zone (I), a set of black liquor feed pipes on at least one furnace wall in the first combustion zone (I) for supplying black liquor into the boiler furnace, and primary air nozzles on at least one furnace wall below the set of black liquor feed pipes for supplying primary air into the first combustion zone (I).

[0016] The recovery boiler comprises an air feed channel around at least part of the length of at least one black liquor feed pipe of the set of black liquor feed pipes and surrounding the at least one black liquor feed pipe on its all sides for supplying combustion air for volatile matter into the first combustion zone (I) along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe such that the supply of combustion air for volatile matter surrounds the black liquor

supply.

[0017] The present invention further relates to fuel feeding means for a recovery boiler comprising a boiler furnace comprising vertical furnace walls. The fuel feeding means comprises a set of black liquor feed pipes on at least one furnace wall for supplying black liquor into the boiler furnace. The fuel feeding means comprises an air feed channel above at least part of the length of at least one black liquor feed pipe of the set of black liquor feed pipes for supplying combustion air for volatile matter into the boiler furnace along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe.

[0018] The present invention further relates to fuel feeding means for a recovery boiler comprising a boiler furnace comprising vertical furnace walls. The fuel feeding means comprises a set of black liquor feed pipes on at least one furnace wall for supplying black liquor into the boiler furnace. The fuel feeding means comprises an air feed channel around at least part of the length of at least one black liquor feed pipe of the set of black liquor feed pipes and surrounding the at least one black liquor feed pipe on its all sides for supplying combustion air for volatile matter into the boiler furnace along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe such that the supply of combustion air for volatile matter surrounds the black liquor supply.

[0019] The present invention further relates to a method for feeding black liquor and air to a recovery boiler burning black liquor, the recovery boiler comprising a boiler furnace comprising a first combustion zone (I) and vertical furnace walls, in which method air needed for burning the black liquor is supplied in stages into the boiler furnace. The method comprises:

- supplying the black liquor into the first combustion zone (I) through a set of black liquor feed pipes located on at least one furnace wall,
- supplying primary air into the first combustion zone (I) through primary air nozzles located below the set of black liquor feed pipes for causing substoichiometric combustion of the black liquor in the first combustion zone (I),
- supplying combustion air for volatile matter into the first combustion zone (I) along with the black liquor supply in the direction of the length of the black liquor feed pipe.

[0020] The present invention further relates to a method for feeding black liquor and air to a recovery boiler burning black liquor, the recovery boiler comprising a boiler furnace comprising a first combustion zone (I) and vertical furnace walls, in which method air needed for burning the black liquor is supplied in stages into the boiler furnace. The method comprises:

- supplying the black liquor into the first combustion

- zone (I) through a set of black liquor feed pipes located on at least one furnace wall,
- supplying primary air into the first combustion zone (I) through primary air nozzles located below the set of black liquor feed pipes for causing substoichiometric combustion of the black liquor in the first combustion zone (I),
- supplying combustion air for volatile matter into the first combustion zone (I) along with the black liquor supply in the direction of the length of the black liquor feed pipe such that the supply of combustion air for volatile matter surrounds the black liquor supply on all sides.

[0021] In one embodiment the air feed channel at least partly surrounds the at least one black liquor feed pipe such that the supply of combustion air for volatile matter at least partly surrounds the black liquor supply.

[0022] In one embodiment the combustion air for volatile matter is supplied into the first combustion zone (I) through an air feed channel arranged above at least part of the length of at least one black liquor feed pipe of the set of black liquor feed pipes. In one embodiment, the air feed channel at least partly surrounds the at least one black liquor feed pipe.

[0023] In one embodiment, the supply of combustion air for volatile matter at least partly surrounds the black liquor supply. In one embodiment, the supply of combustion air for volatile matter surrounds the black liquor supply on all sides.

[0024] In one embodiment the combustion air for volatile matter is supplied into the first combustion zone (I) through an air feed channel arranged around at least part of the length of at least one black liquor feed pipe of the set of black liquor feed pipes and surrounding the at least one black liquor feed pipe on its all sides.

[0025] When the black liquor particles supplied to the furnace dry, they swell and lose weight, which makes them more easily carried to the upper part of the furnace. Black liquor particles carried to the upper part of the furnace cause superheater fouling. The particles may also escape out of the furnace together with the flue gases, thereby causing loss of black liquor. When combustion air for volatile matter is supplied into the first combustion zone (I) above the black liquor supply, or at least partly surrounding or surrounding the black liquor supply, the black liquor is efficiently directed into the char bed. Carryover of black liquor particles to the upper part of the furnace is reduced. As a consequence, fouling of the heat transfer surfaces and losses of black liquor raw material are reduced.

[0026] According to the invention, the air feed channel is arranged above the black liquor feed pipe for supplying combustion air for volatile matter along with the black liquor supply in the direction of the length of the black liquor feed pipe. The air feed channel may also be arranged above and on both sides of the black liquor feed pipe.

[0027] The air feed channel is arranged to supply a continuous curtain of combustion air for volatile matter. The continuous curtain of combustion air for volatile matter prevents escape of black liquor particles to the upper part of the furnace through the curtain. The combustion air for volatile matter directs the black liquor into the char bed. The air feed channel is arranged to supply combustion air for volatile matter such that it directs the black liquor into the char bed. The combustion air for volatile matter prevents escape of black liquor particles to the upper part of the furnace. Combustion air for volatile matter supplied along with the black liquor is also efficiently mixed with the black liquor, thus causing efficient combustion of the black liquor.

[0028] In one embodiment, the air feed channel at least partly surrounds the at least one black liquor feed pipe, i.e. the air feed channel is arranged around at least part of the black liquor feed pipe. In one embodiment, the outlet of the air feed channel is arranged around at least part of the outlet of the black liquor feed pipe. In one embodiment, the air feed channel is arranged above the black liquor feed pipe, and not extending to the sides of the black liquor feed pipe.

[0029] In one embodiment, the air feed channel is curved or angular. In one embodiment, the air feed channel extends around at least part of the black liquor feed pipe.

[0030] In one embodiment, the supply of combustion air for volatile matter at least partly surrounds the black liquor supply. In one embodiment, the supply of combustion air for volatile matter does not extend to the sides of the black liquor supply.

[0031] In one embodiment, the air feed channel surrounds the at least one black liquor feed pipe by at least 45 degrees. In other words, the air feed channel extends around the black liquor feed pipe by 45 degrees. In one embodiment, the air feed channel surrounds the at least one black liquor feed pipe by at least 90 or 180 or 270 degrees. In one embodiment, the air feed channel surrounds the at least one black liquor feed pipe by 360 degrees. That is, the air feed channel surrounds the at least one black liquor feed pipe on all sides. In one embodiment, the outlet of the air feed channel surrounds the outlet of the at least one black liquor feed pipe by at least 45 degrees. In one embodiment, the outlet of the air feed channel surrounds the outlet of the at least one black liquor feed pipe by at least 90 or 180 or 270 degrees. In one embodiment, the outlet of the air feed channel surrounds the outlet of the at least one black liquor feed pipe by 360 degrees. That is, the outlet of the air feed channel surrounds the outlet of the at least one black liquor feed pipe on all sides.

[0032] In one embodiment, the air feed channel surrounds the at least one black liquor feed pipe symmetrically on both sides of the black liquor feed pipe. In one embodiment, the outlet of the air feed channel surrounds the outlet of the at least one black liquor feed pipe symmetrically on both sides of the outlet of the black liquor

feed pipe. In one embodiment, the air feed channel or its outlet extends to an equal distance on both sides of the black liquor feed pipe or its outlet.

[0033] In one embodiment, the cross-section of the air feed channel is U-shaped. The U-shape opens downwards. In one embodiment, the air feed channel is a spout opening downwards. In one embodiment, the cross-section of the air feed channel is a rectangle. In one embodiment, the cross-section of the air feed channel is a circle. The cross-section of the air feed channel may be of any shape suitable for supplying combustion air such that it directs the black liquor into the char bed.

[0034] The air feed channel is arranged to provide a continuous supply of combustion air for volatile matter. The air feed channel may be a uniform channel. The air feed channel may consist of separate air feed channels arranged contiguous with each other. No space is left between the separate air feed channels to prevent black liquor from escaping through the supply of combustion air for volatile matter into the upper parts of the boiler.

[0035] In one embodiment, the air feed channel and the at least one black liquor feed pipe are contiguous with each other. Hence, no vertical or horizontal space is left in between the air feed channel and the black liquor feed pipe. In one embodiment, the air feed channel is arranged at a vertical distance from the at least one black liquor feed pipe. In one embodiment, the air feed channel is arranged at a horizontal distance from the at least one black liquor feed pipe. In one embodiment, the vertical distance between the air feed channel and the black liquor feed pipe is 0 - 50 centimeters. In one embodiment, the vertical distance between the air feed channel and the black liquor feed pipe is 0 - 30 centimeters. In one embodiment, the vertical distance between the air feed channel and the black liquor feed pipe is 0 centimeters.

[0036] The outlet of the air feed channel is broader than the outlet of the at least one black liquor feed pipe. In one embodiment, the outlet of the air feed channel is at least two times broader than the outlet of the at least one black liquor feed pipe. In one embodiment, the outlet of the air feed channel is at least three times broader than the outlet of the at least one black liquor feed pipe. In one embodiment, the outlet of the air feed channel is at least five times broader than the outlet of the at least one black liquor feed pipe. In one embodiment, the outlet of the air feed channel is 2 - 15 or 2 - 10 or 4 - 15 or 4 - 10 or 4 - 8 or 7 - 14 times broader than the outlet of the at least one black liquor feed pipe.

[0037] In one embodiment, the width of the outlet of the air feed channel is 0.2 - 1.5 meters. In one embodiment, the width of the outlet of the air feed channel is 0.4 - 1.0 meters. In one embodiment, the width of the outlet of the air feed channel is 40 - 60 centimeters.

[0038] The size, shape and dimensions of the air feed channel as well as its vertical and horizontal distance from the black liquor feed pipe are affected by the velocities of the black liquor and the combustion air for volatile matter together with the manufacturing process of the air

feed channel and the arrangement of individual components inside the recovery boiler.

[0039] In one embodiment, the supply of combustion air for volatile matter fully surrounds the black liquor supply. Combustion air for volatile matter forms a curtain of combustion air around the black liquor flow. The curtain of combustion air for volatile matter directs the black liquor flow into the char bed and prevents escape of black liquor particles to the upper part of the furnace. Combustion air for volatile matter supplied along with the black liquor is also efficiently mixed with the black liquor, thus causing efficient combustion of the black liquor.

[0040] When combustion air for volatile matter is supplied into the first combustion zone (I) along with the black liquor the temperature in the first combustion zone (I) is high. The fuel is made to ignite quickly and a major part of the volatile matter released from black liquor can be burnt before the second combustion zone (II). The amount of unburned black liquor is minimized and combustion of black liquor is more complete. Also, the dwell time of the black liquor in the furnace is increased and the combustion is easier to control.

[0041] In one embodiment, the black liquor feed pipe is arranged inside the air feed channel at a distance from the walls of the air feed channel such that airspace surrounds the black liquor feed pipe on all sides. In one embodiment, the black liquor feed pipe and the air feed channel are coaxial cylinders. In one embodiment, a separate air feed channel is arranged around the black liquor feed pipe. The air feed channel may comprise several separate air feed channels arranged around different sides of the black liquor feed pipe and together surrounding the black liquor feed pipe on all sides. The air feed channel may comprise means for directing the air flow, such as guide vanes. In one embodiment, the recovery boiler comprises an air feed channel around at least part of the length of each black liquor feed pipe of the set of black liquor feed pipes and surrounding each black liquor feed pipe on its all sides.

[0042] In one embodiment, black liquor feed pipes are located on two opposite furnace walls. In one embodiment, black liquor feed pipes are located on all four furnace walls. In one embodiment, the number of black liquor feed pipes is 4 to 20. The black liquor feed pipes may be located at several different heights on furnace walls so that the outlets of individual black liquor feed pipes are at different heights. In one embodiment, the height of the black liquor feed pipes from the bottom of the boiler furnace is 4 to 6 meters.

[0043] In one embodiment, the black liquor feed pipe comprises a black liquor spray nozzle for distributing black liquor spray into the boiler furnace. The black liquor spray nozzle may be of any conventional type, such as swirlcone nozzle, V-type nozzle and splash plate nozzle.

[0044] In one embodiment, the supply of combustion air for volatile matter and the black liquor supply are supplied in the same direction.

[0045] The current invention reduces nitrogen oxide

emissions by supplying combustion air for volatile matter into the first combustion zone (I), thus improving combustion of volatile matter released from black liquor in the pyrolysis reaction and reduction of nitrogen oxides in the furnace. In the presence of oxygen, the volatile matter released from the black liquor reacts into nitrogen monoxide. In substoichiometric conditions, the volatile matter is reduced to molecular nitrogen. The quantity of combustion air for volatile matter is adjusted so that the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is as high as possible, however, less than 1. Combustion of volatile matter in the first combustion zone (I) is thus as efficient as possible, but still takes place in substoichiometric conditions in relation to volatile matter. Combustion of volatile matter creates a high temperature, thereby maximizing the formation of hydrocarbon radicals from the black liquor. These hydrocarbon radicals take part in reducing nitrogen oxides to molecular nitrogen in an internal re-burning reaction.

[0046] Further, the current invention reduces the temperature of the flue gas at the furnace exit (Furnace Exit Gas Temperature, FEGT). As a consequence of supplying combustion air for volatile matter into the first combustion zone (I), volatile matter released from black liquor is burnt as low in the furnace as possible. As a result, most of the volatile matter can be burnt before the second combustion zone. Also, the black liquor particles are directed to the char bed and therefore do not escape to the upper parts of the furnace. Thus the temperature in the upper part of the furnace and of flue gases at the nose of the furnace is not excessively risen. Low FEGT decreases fouling of the heat transfer surfaces.

[0047] The first combustion zone (I) begins from the bottom of the boiler furnace and extends up to below the height level of secondary air nozzles. In one embodiment, the height of the primary air nozzles is one to two meters from the bottom of the boiler furnace. In one embodiment, primary air nozzles are located at several heights, e.g. at a height of both one and two meters from the bottom of the boiler furnace. In one embodiment, the number of primary air nozzles is 35. In one embodiment, the height of the secondary air nozzles is 2 to 6 meters from the height level of black liquor feed pipes. In one embodiment, the number of secondary air nozzles is 4 to 16. In one embodiment, primary air nozzles are located on all four furnace walls. In one embodiment, secondary air nozzles are located on all four furnace walls.

[0048] Primary air is set to flow from a suitable height and with such a velocity that the shape of the char bed is kept optimal. In addition to primary air, the shape of the char bed is controlled with the aid of combustion air for volatile matter supplied along with the black liquor supply.

[0049] In one embodiment the boiler furnace comprises a lower part, and the set of black liquor feed pipes is arranged to supply the black liquor in the direction of the lower part to form a char bed at the lower part of the boiler furnace. In one embodiment the boiler furnace comprises

a lower part, and the black liquor is supplied in the direction of the lower part to form a char bed at the lower part of the boiler furnace.

[0050] In one embodiment at least one black liquor feed pipe of the set of black liquor feed pipes is directed obliquely downwards and the angle α between the normal N of the at least one vertical furnace wall and the at least one black liquor feed pipe is 20 to 60 degrees. In one embodiment, all black liquor feed pipes of the set of black liquor feed pipes are directed obliquely downwards and the angle α between the normal N of the at least one vertical furnace wall and the black liquor feed pipes is 20 to 60 degrees. In one embodiment, all black liquor feed pipes having an air feed channel around at least part of the length of the black liquor feed pipe, wherein the air feed channel surrounds the black liquor feed pipes on all sides, are directed obliquely downwards and the angle α between the normal N of the at least one vertical furnace wall and the black liquor feed pipes is 20 to 60 degrees. In one embodiment the angle α is 30 to 60 degrees. In one embodiment the angle α is 40 to 50 degrees. In one embodiment the angle α is 45 degrees. The angle α is the angle between the central axis of the at least one black liquor feed pipe and the normal N of the at least one vertical furnace wall.

[0051] In one embodiment, the black liquor feed pipes are 4 to 6 meters above the bottom of the boiler furnace. The angle α and the height of the at least one black liquor feed pipe is adjusted so as to achieve optimal shape of the char bed and to prevent individual black liquor supplies and surrounding supplies of combustion air for volatile matter from colliding with each other. The angle α and height of the at least one black liquor feed pipe may differ from the angle and height of another black liquor feed pipe. In one embodiment, the at least one black liquor feed pipe is directed obliquely downwards for supplying the black liquor in the direction of the char bed.

[0052] In one embodiment, the angle between the normal N of the at least one vertical furnace wall and the air feed channel is equal to angle α . In one embodiment, the angle between the normal N of the at least one vertical furnace wall and the air feed channel is 20 to 60 degrees. In one embodiment, the angle between the normal N of the at least one vertical furnace wall and the air feed channel is 30 to 60 degrees. In one embodiment, the angle between the normal N of the at least one vertical furnace wall and the air feed channel is 40 to 50 degrees. In one embodiment, the angle between the normal N of the at least one vertical furnace wall and the air feed channel is 45 degrees.

[0053] In one embodiment at least one black liquor feed pipe of the set of black liquor feed pipes is arranged on a first furnace wall and at least one black liquor feed pipe of the set of black liquor feed pipes is arranged on a second furnace wall opposite the first furnace wall, and the at least one black liquor feed pipe on the first furnace wall and the at least one black liquor feed pipe on the second furnace wall are arranged in a staggered fashion

so that the at least one black liquor feed pipe on the first furnace wall is not directly opposite to the at least one black liquor feed pipe on the second furnace wall. In one embodiment the air feed channels on the first and the second furnace wall are arranged in a staggered fashion so that the air feed channel on the first furnace wall is not directly opposite to the air feed channel on the second furnace wall.

[0054] In order to prevent black liquor and air flows from colliding with furnace walls or with each other, the black liquor feed pipes and the air feed channels may also be arranged horizontally at an angle β to the normal N of the wall the pipe or channel is attached to. Said angle β may be, for instance, 5 degrees. In one embodiment, the at least one black liquor feed pipe of the set of black liquor feed pipes is arranged on a first furnace wall, and the at least one black liquor feed pipe nearest to a third furnace wall which is perpendicular to the first furnace wall is turned in the horizontal direction away from the third furnace wall such that the angle β between the normal N of the first furnace wall and the at least one black liquor feed pipe is 5 to 15 degrees. In one embodiment, the angle β is 5 to 10 degrees. In one embodiment, the angle β is 5 degrees.

[0055] When two streams of high velocity collide, strong upflow jets are easily formed. These upflow jets tend to catch black liquor particles and carry them to the upper part of the furnace thus causing superheater fouling. The black liquor feed pipes are arranged in such a way that the supplies of black liquor and combustion air for volatile matter do not collide with each other. This way, formation of upflow jets is reduced. Black liquor feed pipes may be located at different height levels from the bottom of the furnace.

[0056] The primary, secondary and tertiary air nozzles are arranged in such a way that the supplies of primary, secondary and tertiary air do not collide with each other. In one embodiment, primary air nozzles on the first and the second furnace wall are arranged in a staggered fashion so that primary air nozzles on the first furnace wall are not directly opposite to primary air nozzles on the second furnace wall. In one embodiment, secondary air nozzles on the first and the second furnace wall are arranged in a staggered fashion so that secondary air nozzles on the first furnace wall are not directly opposite to secondary air nozzles on the second furnace wall. In one embodiment, tertiary air nozzles on the first and the second furnace wall are arranged in a staggered fashion so that tertiary air nozzles on the first furnace wall are not directly opposite to tertiary air nozzles on the second furnace wall.

[0057] In one embodiment the air feed channel comprises an outlet and the cross-sectional area of the air feed channel at the outlet is arranged to be such that the velocity at which the combustion air for volatile matter is supplied is 5 to 40 m/s or 5 to 25 m/s. At this velocity range the combustion air for volatile matter directs the black liquor particles into the char bed but does not ag-

gressively crash into the char bed and cause mixing of the char bed. In one embodiment the air feed channel comprises an outlet and the cross-sectional area of the air feed channel at the outlet is arranged to be such that the velocity at which the combustion air for volatile matter is supplied is 5 to 25 m/s. In one embodiment the air feed channel comprises an outlet and the cross-sectional area of the air feed channel at the outlet is arranged to be such that the velocity at which the combustion air for volatile matter is supplied is 5 to 40 m/s. In one embodiment the air feed channel comprises an outlet and the cross-sectional area of the air feed channel at the outlet is arranged to be such that the velocity at which the combustion air for volatile matter is supplied is 20 to 40 m/s.

[0058] The velocity at which the combustion air for volatile matter is supplied means the velocity of the combustion air for volatile matter at the outlet of the air feed channel. The velocity of the air supply depends on the cross-section of the air feed channel at the outlet, i.e. the smaller the cross-section, the faster the flow. The velocity of combustion air for volatile matter is adjusted so as to efficiently direct the black liquor into the char bed and simultaneously preventing two flows from colliding. In addition to directing black liquor into the char bed, combustion air for volatile matter supplied along with the black liquor controls the shape of the char bed. The combustion air for volatile matter is set to flow at a velocity providing desired shape of the char bed.

[0059] In one embodiment, the cross-sectional area of the air feed channel at the outlet is arranged to be such that the velocity at which the combustion air for volatile matter is supplied is equal to or greater than the velocity at which the black liquor is supplied. The velocity at which the black liquor is supplied means the velocity the black liquor exits the black liquor spray nozzle and enters the boiler furnace. The velocity at which the black liquor is supplied is determined so that the black liquor flow does not collide with black liquor or air flows supplied from the opposite or adjacent furnace wall. In addition, the velocity at which the black liquor is supplied is such that black liquor particles do not escape to upper parts of the furnace through to the flow of combustion air for volatile matter supplied above the black liquor supply, or at least partly surrounding or surrounding the black liquor flow, and such that the black liquor particles are efficiently directed into the char bed by the combustion air for volatile matter. Taking into account the velocity at which combustion air for volatile matter is supplied, CFD calculations are used to determine variables concerning black liquor supply so that the black liquor particles do not escape from the black liquor flow directed to the char bed. Such variables include the type of black liquor spray nozzle, the velocity at which the black liquor particles exit the black liquor spray nozzle, the angle at which the black liquor particles exits the black liquor spray nozzle, and the size of the black liquor droplets. For a splash plate nozzle, the angle of the splash plate in relation to the black liquor feed pipe has to be taken into account. CFD

calculations are used to determine how much of the black liquor particles are directed into the char bed.

[0060] In one embodiment the velocity at which the combustion air for volatile matter is supplied is 5 to 40 m/s or 5 to 25 m/s. In one embodiment the velocity at which the combustion air for volatile matter is supplied is 5 to 40 m/s. In one embodiment the velocity at which the combustion air for volatile matter is supplied is 5 to 25 m/s. In one embodiment the velocity at which the combustion air for volatile matter is supplied is 20 to 40 m/s. In one embodiment the velocity at which the combustion air for volatile matter is supplied is 5 to 20 m/s. In one embodiment the velocity at which the combustion air for volatile matter is supplied is 5 to 15 m/s. In one embodiment the velocity at which the combustion air for volatile matter is supplied is 10 m/s. In one embodiment the velocity at which the combustion air for volatile matter is supplied is equal to or greater than the velocity at which the black liquor is supplied.

[0061] The amount of combustion air for volatile matter is determined by the amount of primary air supplied into the first combustion zone (I) so that the value of SR_{VOL} in the first combustion zone (I) is in the correct area. The velocity of the combustion air for volatile matter in the air feed channel is affected by the mass flow of air and the cross-section of the air feed channel.

[0062] In one embodiment the boiler furnace comprises a second combustion zone (II) located above the first combustion zone (I), and secondary air nozzles on at least on furnace wall above the set of black liquor feed pipes for supplying secondary air into the second combustion zone (II). In one embodiment the boiler furnace comprises a second combustion zone (II) located above the first combustion zone (I), and secondary air is supplied into the second combustion zone (II) through secondary air nozzles. The second combustion zone (II) begins from the height level of the secondary air nozzles and extends up to below the height level of tertiary air nozzles. The second combustion zone (II) is substoichiometric.

[0063] In one embodiment the air feed channel is connected to the secondary air for supplying secondary air at least as part of the combustion air for volatile matter. In one embodiment, the temperature of the combustion air for volatile matter is 150 to 250 °C. Secondary air is typically preheated in order to enhance combustion in the furnace. Due to the high temperature of combustion air for volatile matter, drying of the black liquor particles and subsequent pyrolysis begin immediately. Consequently, combustion of the black liquor begins earlier and is enhanced in the lower part of the furnace, thereby increasing the temperature in the lower part of the furnace. The time available for combustion is increased. When hot combustion air for volatile matter is used, the result of combustion is better. In one embodiment the combustion air for volatile matter comprises secondary air. In one embodiment the combustion air for volatile matter consists of secondary air. The amount of secondary air pro-

vided into the second combustion zone (II) through secondary air nozzles is decreased correspondingly.

[0064] The air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is in the substoichiometric area, i.e. below 1. In one embodiment the primary air nozzles and the air feed channel are arranged to supply primary air and combustion air for volatile matter in such an amount that the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is 0.9 - 1.0. In one embodiment the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is 0.9 - 1.0. In one embodiment the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is 0.95 - 1.0. Combustion air is supplied into the first combustion zone (I) as primary air through primary air nozzles and as combustion air for volatile matter through the air feed channel arranged above or around the black liquor feed pipe. Thus, primary air and combustion air for volatile matter together determine the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I).

[0065] When the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is 0.9 - 1.0, nitrogen oxides are efficiently reduced, whereby a major part of the black liquor's volatile matter will burn already in the first combustion zone (I). In addition to primary air, the first combustion zone (I) is supplied with combustion air for volatile matter which enhances nitrogen oxide reduction. The amount of primary air supplied into the first combustion zone (I) does not change as compared to conventional recovery boiler combustion. The total amount of combustion air in the first combustion zone (I) is increased by adding combustion air for volatile matter. Since SR_{VOL} is in substoichiometric area, combustion of volatile matter released from the black liquor in pyrolysis takes place in substoichiometric conditions in relation to volatile matter. In one embodiment, the air coefficient in relation to volatile matter is below 1, but as high as possible in order to enhance combustion of volatile matter in the first combustion zone (I). The higher the air coefficient SR_{VOL} in relation to volatile matter, the more quickly the volatile matter will burn, at the same time causing a high local temperature and forming a maximum quantity of hydrocarbon radicals, which are needed for the reduction of nitrogen oxides formed from the black liquor. Most of the volatile matter can be burnt in the first combustion zone (I) before the supply of secondary air. In one embodiment, the total air coefficient SR_{TOT} in the first combustion zone is substoichiometric.

[0066] The air coefficient or the stoichiometric ratio SR tells how much air must be used for the combustion in comparison with the theoretical (stoichiometric) volume of air needed for complete combustion of the fuel. In substoichiometric combustion, the air coefficient SR is under 1, and in superstoichiometric combustion the air coefficient SR is over 1. The first and second combustion zones (I,II) are substoichiometric. By substoichiometric combustion it is meant that the total air coefficient SR_{TOT} is

kept substoichiometric. The total air coefficient SR_{TOT} is kept superstoichiometric in the third combustion zone (III), in which the combustion is completed.

[0067] In one embodiment, 60 to 80 % of combustion air in the first combustion zone (I) consists of primary air and 20 to 40 % of combustion air in the first combustion zone consists of combustion air for volatile matter supplied along with the black liquor supply.

[0068] In one embodiment the primary air nozzles, the secondary air nozzles and the air feed channel are arranged to supply primary air, secondary air and combustion air for volatile matter in such an amount that the total air coefficient SR_{TOT} in the second combustion zone (II) is 0.75 - 0.85. In one embodiment the total air coefficient SR_{TOT} in the second combustion zone (II) is 0.75 - 0.85. In one embodiment the total air coefficient SR_{TOT} in the second combustion zone (II) is 0.8. Combustion air is supplied into the second combustion zone (II) as secondary air through secondary air nozzles. Thus, the amount of primary air and combustion air for volatile matter supplied into the first combustion zone (I), and secondary air supplied in the second combustion zone (II) together determine the total air coefficient SR_{TOT} in the second combustion zone (II). In one embodiment the secondary air nozzles are arranged to supply secondary air into the second combustion zone (II) in such an amount that the total air coefficient SR_{TOT} in the second combustion zone (II) is in the desired value.

[0069] In one embodiment the boiler furnace comprises a third combustion zone (III) located above the second combustion zone (II), and tertiary air nozzles on at least one furnace wall above the secondary air nozzles for supplying tertiary air into the third combustion zone (III), wherein the tertiary air nozzles are arranged to supply nitrogen oxide reductant into the third combustion zone (III) along with the tertiary air for reducing nitrogen oxides.

[0070] In one embodiment the boiler furnace comprises a third combustion zone (III) located above the second combustion zone (II), and tertiary air is supplied into the third combustion zone (III) through tertiary air nozzles, and wherein nitrogen oxide reductant is supplied into the third combustion zone (III) along with the tertiary air through the tertiary air nozzles for reducing nitrogen oxides.

[0071] In one embodiment, the tertiary air nozzles are located 2 - 4 meters below the furnace nose. The third combustion zone (III) begins from the height level of the tertiary air nozzles and extends up to the height level of furnace nose.

[0072] In one embodiment the nitrogen oxide reductant comprises a water solution of ammonia, a water solution of urea or gaseous ammonia. In one embodiment the nitrogen oxide reductant consists of a water solution of ammonia, a water solution of urea or gaseous ammonia.

[0073] The nitrogen oxide reductant is often injected into the boiler furnace through separate nozzles installed on boiler walls. It is, however, challenging to achieve adequate penetration and distribution of the nitrogen oxide

reductant into the boiler furnace when the nitrogen oxide reductant is supplied through separate nozzles. Because of the viscosity of glue gases, efficient mixing is difficult to obtain. Undesired ammonia NH_3 and nitrous oxide N_2O are often formed due to inefficient distribution and mixing of the reductant in the flue gas stream. When nitrogen oxide reductant is supplied through tertiary air nozzles, homogeneous distribution and good penetration of the nitrogen oxide reductant in the boiler furnace is achieved. This may be achieved by installing nitrogen oxide reductant lances in the existing tertiary air openings. The lances may be equipped with air or pressure atomizing nozzles. In this case the nitrogen oxide reductant is efficiently distributed and mixed with the aid of combustion air into the whole cross-section of the boiler.

[0074] The temperature window for achieving an adequate nitrogen oxide reduction with a minimum NH_3 slip is narrow. The optimum temperature range for urea and ammonia is between about 950 and 1,100 °C. When the temperature is above this range, nitrogen oxides are formed. When the temperature is below this range, the reaction rate is slowed down causing ammonia slip. In the incorrect temperature range, nitrous oxide N_2O is formed.

[0075] When nitrogen oxide reductant is injected at the tertiary air level, there is a risk that the temperature of the flue gas at the injection level is above the allowable temperature of 1,100 °C and nitrogen oxide reduction is not sufficient. When conventional combustion technologies are used, the temperature at the height level of tertiary air nozzles is typically too high for injection of nitrogen oxide reductant. With the aid of the combustion technology according to the invention the temperature of the flue gas at the height level of the tertiary air nozzles is decreased. The invention thus enables injection of the nitrogen oxide reductant at the height level of tertiary air nozzles. Efficient nitrogen oxide reduction is achieved while keeping the undesired ammonia emissions below the allowable limits. Injection at the tertiary air level ensures longer dwell time of the nitrogen oxide reductant in the furnace, thereby allowing the nitrogen oxide reductant more time to react.

[0076] Several advantages are achieved by using the current invention. As a result of supplying combustion air for volatile matter into the first combustion zone along with the black liquor supply, combustion at the lower part of the furnace is improved. Black liquor droplets are more efficiently directed into the char bed, thereby avoiding the particles from being carried to the upper parts of the furnace. The loss of black liquor particles is reduced thereby reducing costs. Reduction of carryover also reduces fouling and corrosion of superheaters. In addition, nitrogen oxide emissions derived from black liquor are reduced. Boiler availability and efficiency is improved since maintenance intervals are extended. Further, operating costs are reduced.

[0077] The temperature of the flue gas at the furnace exit (FEGT) is reduced, since combustion takes place

lower in the furnace. Low FEGT reduces corrosion in the superheater area and fouling of heat transfer surfaces. Lower temperature in the upper part of the furnace allows supplying nitrogen oxide reductant through tertiary air nozzles. Nitrogen oxides can thus be further reduced with the aid of nitrogen oxide reductant without considerable ammonia emissions.

[0078] The embodiments of the invention described hereinbefore may be used in any combination with each other. Several of the embodiments may be combined together to form a further embodiment of the invention. A recovery boiler, fuel feeding means or a method to which the invention is related, may comprise at least one of the embodiments of the invention described hereinbefore.

BRIEF DESCRIPTION OF THE DRAWINGS

[0079] The accompanying drawings, which are included to provide a further understanding of the invention and constitute a part of this specification, illustrate embodiments of the invention and together with the description help to explain the principles of the invention. In the drawings:

Figure 1 is a schematic sectional front view of the furnace of a recovery boiler according to one embodiment of the invention,

Figure 2 is a schematic sectional view of the fuel feeding means according to one embodiment of the invention.

Figure 3 is a schematic sectional view of the horizontal cross-section of the boiler furnace according to one embodiment at the level of black liquor feed pipes.

Figures 4a-4e show the outlets of the black liquor feed pipe and the air feed channel from inside the recovery boiler according to a first, second, third, fourth and fifth embodiment.

DETAILED DESCRIPTION

[0080] Figure 1 is a schematic sectional front view of a recovery boiler. The figure is a basic view of the boiler and it is not intended to present the recovery boiler on its correct scale.

[0081] The recovery boiler of figure 1 comprises a boiler furnace 2 comprising vertical furnace walls 5. Furnace walls 5A and 5B are located opposite each other.

[0082] Black liquor is supplied into the first combustion zone (I) through fuel feeding means 11 presented in detail in figure 2. The fuel feeding means 11 comprises a black liquor feed pipe 3 and an air feed channel 4. The black liquor feed pipe 3 is directed obliquely downwards to direct black liquor into a char bed 1 located at the lower part 9 of the boiler furnace 2. An acute angle α is formed between the black liquor feed pipe 3 and the normal N of the furnace wall 5. The angle α is between 20 and 60°. The black liquor feed pipes 3 are typically located at a

height of 4 to 6 meters from the bottom of the boiler furnace 2. Typically, there are black liquor feed pipes 3 on all four walls. The total number of black liquor feed pipes 3 in a typical recovery boiler is between four and twenty.

[0083] Combustion air for volatile matter is supplied into the first combustion zone (I) along with the black liquor supply through the air feed channel 4 arranged around the black liquor feed pipe 3. The combustion air for volatile matter forms a curtain of air around the black liquor supply which directs the black liquor into the char bed 1, thereby preventing escape of black liquor particles to the upper parts of the boiler furnace 2. Although in figure 1 the air feed channel 4 is arranged around the black liquor feed pipe 3, it may also be arranged only above the black liquor feed pipe 3 or only partly surrounding the black liquor feed pipe 3. Different constructions of air feed channels 4 are illustrated in figures 4a to 4e. The air feed channel 4 may be connected to secondary air in order to supply secondary air as combustion air for volatile matter. The amount of secondary air is decreased correspondingly.

[0084] In the lower part 9 of the boiler furnace 2 there is a char bed 1 wherein combustion and charring of black liquor take place. The shape and size of the char bed 1 is controlled by adjusting the supply of primary air and combustion air for volatile matter supplied along with the black liquor. This may be done by adjusting the supply height, supply angle and velocity of said air supplies.

[0085] The combustion residue, i.e. smelt is removed from the boiler furnace 2 through smelt removal spouts 12 located at the bottom of the boiler furnace into a dissolving tank (not presented). The bottom of the furnace may be inclined in order to direct the smelt into the smelt outlet spouts 12.

[0086] Air is supplied into the boiler furnace 2 through primary air nozzles 6, secondary air nozzles 7 and tertiary air nozzles 8. In addition, air is supplied into the boiler furnace 2 through the air feed channel 4 arranged around the black liquor feed pipe 3. In a recovery boiler according to figure 1, primary air nozzles are located below the black liquor feed pipes 3 at two different heights from the bottom of the boiler furnace 2, i.e. approximately at a height of one meter and two meters. The secondary air nozzles 6 are located at a height of two to six meters above the black liquor feed pipes 3. The tertiary air nozzles 8 are located at a height of two to four meters below the furnace nose (not presented).

[0087] A recovery boiler typically comprises several primary air nozzles 6, e.g. 35, on each furnace wall 5. The number of secondary air nozzles 7 on each furnace wall 5 is typically 4 to 16. Tertiary air nozzles 8 are typically located on the rear and front wall of the boiler, each comprising typically 3 to 8 tertiary air nozzles 8. To prevent unwanted upflow jets from forming, the air nozzles 6, 7, 8 may be located in a staggered fashion so that no air nozzle is located directly opposite to another air nozzle.

[0088] The recovery boiler comprises three combus-

tion zones. The space confined between the height level of primary air nozzles 6 and the secondary air nozzles 7, which space begins from the bottom of the boiler furnace 2 and extends up to below the height level of secondary air nozzles 7, forms a first combustion zone (I). The space confined between the secondary air nozzles 7 and the tertiary air nozzles 8, which space begins from the height level of the secondary air nozzles 7 and extends up to below the height level of tertiary air nozzles 8, forms a second combustion zone (II). The third combustion zone (III) begins from the height level of tertiary nozzles 8 and extends up to the height level of furnace nose.

[0089] The first (I) combustion zone is substoichiometric. The air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is 0.9 - 1.0. Into the first combustion zone (I), primary air is supplied through primary air nozzles 6 and combustion air for volatile matter is supplied through the air feed channel 4 arranged around the black liquor feed pipe 3. The total amount of primary air and combustion air for volatile matter is arranged to be such that the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is at the desired value. A larger supply of air into the first combustion zone (I) will result in high temperatures in the first combustion zone (I). When air is supplied into the furnace 2 along with the black liquor supply, the black liquor is made to ignite quickly and a major part of the black liquor's volatile matter can be burnt before the second combustion zone (II).

[0090] The second combustion zone (II) is substoichiometric. The total air coefficient SR_{TOT} in the second combustion zone (II) is 0.75 - 0.85. The combustion air supplied into the second combustion zone (II) includes secondary air supplied through secondary air nozzles 7. Into the second combustion zone (II), secondary air is supplied through the secondary air nozzles 7, to be mixed together with a flue gas flow rising upwards from the first combustion zone (I) and containing non-combusted gases and particles deriving from the black liquor, which gases and particles will be further combusted in the second combustion zone (II). The amount of secondary air supplied in the second combustion zone (II) is arranged to be such that the total air coefficient SR_{TOT} in the second combustion zone (II) is at the desired value.

[0091] The burning of the black liquor continues further in a third combustion zone (III) which is superstoichiometric. Into the third combustion zone (III), tertiary air is supplied through tertiary air nozzles 8. In the third combustion zone (III), the total air coefficient SR_{TOT} is about 1.15.

[0092] The reduction to molecular nitrogen of nitrogen oxides formed from the black liquor is carried out mainly in two stages. In the first substoichiometric combustion zone (I) a major part of the volatile matter of the black liquor and a part of the carbonization residue are burnt. This takes place in conditions which are substoichiometric as regards the air coefficient SR_{VOL} in relation to the

volatile matter of the fuel, whereby a lot of hydrocarbon radicals will result. In the second combustion zone (II), combustion air is supplied into the furnace from the secondary air nozzles 7 so much that substoichiometric combustion conditions are maintained, whereby the total air coefficient SR_{TOT} in the second combustion zone (II) is in a range of 0.75 - 0.85.

[0093] The solution according to the invention aims at optimizing the combustion of the black liquor's volatile matter in the two first substoichiometric combustion zones (I) and (II) of the furnace. The solution changes the air distribution in the boiler, so that the air coefficient in relation to volatile matter is as high as possible at as low a level as possible in the furnace and for as long a time as possible before the secondary air level.

[0094] Figure 2 shows a schematic sectional view of the fuel feeding means 11 according to one embodiment of the invention. The fuel feeding means 11 comprises a black liquor feed pipe 3 and an air feed channel 4. The black liquor feed pipe comprises a black liquor spray nozzle 14, e.g. a splash plate nozzle, for distributing black liquor spray into the boiler furnace 2.

[0095] The black liquor feed pipe 3 is directed obliquely downwards to direct black liquor into a char bed 1. An acute angle α is formed between the black liquor feed pipe 3 and the normal N of the furnace wall 5. The angle α is 20 - 60°. The height and the angle α of the black liquor feed pipes 3 are determined so as to prevent individual black liquor and air supplies from colliding with each other and subsequent formation of strong upflow jets.

[0096] The air feed channel 4 comprises an outlet 10 for supplying combustion air for volatile matter into the boiler furnace 2. The black liquor feed pipe 3 comprises an outlet 13 for supplying black liquor into the boiler furnace 2. The velocity of the black liquor and air supplies at the outlet 10, 13 is adjusted by conventional means to be such that individual streams of black liquor and air do not collide to streams supplied from other furnace walls 5. The cross-sectional area of the air feed channel at the outlet 10 is such that the velocity of the combustion air for volatile matter is 5 to 25 m/s. The velocity at which the combustion air for volatile matter is supplied is equal to or greater than the velocity at which the black liquor is supplied. The velocity of the black liquor supply at the outlet 13 refers to the velocity at which the black liquor exits the black liquor spray nozzle 14.

[0097] In the embodiment according to figure 2, the black liquor feed pipe 3 is arranged inside the air feed channel 4 so that the air feed channel 4 surrounds the black liquor feed pipe on all sides. Combustion air for volatile matter is supplied in the direction of the black liquor feed pipe 3 through the air feed channel 4 arranged around the black liquor feed pipe 3. Black liquor and combustion air for volatile matter are efficiently mixed, thereby accelerating ignition. The combustion air for volatile matter forms a curtain of air around the black liquor supply which directs the black liquor into the char bed 1. Escape

of black liquor particles to the upper parts of the boiler furnace 2 is thus reduced.

[0098] Figure 3 shows a schematic sectional view of the horizontal cross-section of the boiler furnace 2 at the level of black liquor feed pipes 3. The boiler furnace 2 comprises a first wall 5A and a second wall 5B, which located is opposite the first wall 5A. The fuel feeding means 11 comprising black liquor feed pipes 3 and the surrounding air feed channels 4 (not shown) are arranged on opposite furnace walls 5A, 5B such that individual black liquor and air streams do not collide. The fuel feeding means 11 on the first and second furnace walls 5A, 5B are arranged in a staggered fashion so that the fuel feeding means 11 arranged on opposite furnace 5A, 5B walls are not directly opposite each other. Also, the fuel feeding means near the adjacent wall are directed so that black liquor and air supplied from adjacent walls do not collide. In figure 3, two fuel feeding means 11 on adjacent walls are horizontally arranged at an angle β to the normal N of the wall so as to prevent black liquor and air supplied from adjacent walls from colliding. The angle β may be, for instance, 5 degrees. This helps in avoiding strong upflow jets easily formed when two streams collide. These upflow jets tend to catch black liquor particles and carry them to the upper part of the furnace thus causing superheater fouling and corrosion.

[0099] The fuel feeding means 11 may be located at one or more heights from the bottom of the boiler furnace 2. Any of the fuel feeding means 11 may be arranged in an angle in a horizontal direction for preventing the supplies of black liquor and combustion air for volatile matter from colliding each other or furnace walls 5.

[0100] Figures 4a-4e show the outlets 10, 13 of the black liquor feed pipe 3 and the air feed channel 4 from inside the recovery boiler according to a first, second, third, fourth and fifth embodiment. The cross-section and the dimensions of the air feed channel 4 may be of any shape, e.g. rectangular, U-shaped or round as long as the combustion air for volatile matter directs the black liquor into the char bed. Although the cross-section of the outlet 13 of the black liquor feed pipe 3 in figures 4a to 4e is circular, it may be of any other suitable shape. The air feed channel 4 may be one continuous air feed channel 4 or consist of several separate air feed channels 4 contiguous with each other.

[0101] In figures 4a and 4b, the air feed channel 4 is arranged above the black liquor feed pipe 3 and does not extend to the sides of the black liquor feed pipe 3. In figures 4a and 4b, the cross-section of the outlet 10 of the air feed channel 4 is rectangular. In figure 4a, the outlet 10 of the air feed channel 4 is directly above the outlet 13 of the black liquor feed pipe 3, leaving no vertical space between the outlet 10 of the air feed channel 4 and the outlet 13 of the black liquor feed pipe 3. In figure 4b, the outlet 10 of the air feed channel 4 is arranged at a vertical distance from the outlet 13 of the black liquor feed pipe 3.

[0102] In figures 4c to 4e, the air feed channel 4 is

arranged around the black liquor feed pipe 3 such that it extends to both sides of the black liquor feed pipe 3. The air feed channel 4 surrounds the black liquor feed pipe 3 by the angle γ . In figures 4c, 4d and 4e, the air feed channel 4 surrounds the black liquor feed pipe 3 by approximately 180, 270 or 360 degrees, respectively. The angle γ may be of any other value, as long as the combustion air for volatile matter directs the black liquor into the char bed. The angle γ is affected by the shape of the outlet 10 of the air feed channel 4 and by the distance of the outlet 10 of the air feed channel 4 from the outlet 13 of the black liquor feed pipe 3.

[0103] In figures 4c and 4d the cross-section of the outlet 10 of the air feed channel 4 is U-shaped. In figure 4c, the air feed channel consists of three separate air feed channels having a rectangular cross-section and arranged contiguous with each other. The separate air feed channels 4 are arranged so as to leave no space between the outlets 10 of the adjacent air feed channels 4 thereby preventing escape of black liquor particles through the supply of combustion air for volatile matter. In figure 4d the air feed channel 4 is a uniform air feed channel 4 having a U-shaped cross-section and extending downwards on both sides of the black liquor feed pipe 3.

[0104] The width of the outlet 10 of the air feed channel 4 is greater than the width of the outlet 13 of the black liquor feed pipe 3. In figures 4a to 4d the width of the outlet 10 of the air feed channel 4 is four to five times greater than the width of the outlet 13 of the black liquor feed pipe 3. The width of the outlet 10 of the air feed channel 4 as compared to the width of the outlet 13 of the black liquor feed pipe 3 may be of any other value as long as black liquor is directed by the combustion air for volatile matter into the char bed.

[0105] In figure 4e the black liquor feed pipe 3 is arranged inside the air feed channel 4 such that the air feed channel 4 surrounds the black liquor feed pipe 3 on all sides. The cross-section of the outlet of the air feed channel 4 is circular, but it may be of any other shape. The air feed channel 4 surrounds the black liquor feed pipe by 360 degrees.

[0106] The shape and width of the outlet 10 of the air feed channel 4 and the vertical and horizontal distance of the outlet 10 of the air feed channel 4 from the outlet 13 of the black liquor feed pipe 3 are sized based on the velocity of the black liquor and the combustion air for volatile matter. In addition, the manufacturing process of the air feed channel 4 and the arrangement of individual components inside the recovery boiler have an effect on the dimensions of the outlet 10 of the air feed channel 4 and its distance from the outlet 13 of the black liquor feed pipe 3.

[0107] It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not limited to the examples described above, instead they may vary within

the scope of the claims.

Claims

1. A recovery boiler comprising a boiler furnace (2) comprising vertical furnace walls (5) and a first combustion zone (I),
a set of black liquor feed pipes (3) on at least one furnace wall (5) in the first combustion zone (I) for supplying black liquor into the boiler furnace (2),
primary air nozzles (6) on at least one furnace wall (5) below the set of black liquor feed pipes (3) for supplying primary air into the first combustion zone (I),
characterized in that
the recovery boiler comprises an air feed channel (4) above at least part of the length of at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) for supplying combustion air for volatile matter into the first combustion zone (I) along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe (3).
2. The recovery boiler according to claim 1, **characterized in that** the air feed channel (4) at least partly surrounds the at least one black liquor feed pipe (3) such that the supply of combustion air for volatile matter at least partly surrounds the black liquor supply.
3. The recovery boiler according to claim 1 or 2, **characterized in that** the air feed channel (4) surrounds the at least one black liquor feed pipe (3) by at least 45 degrees.
4. The recovery boiler according to any of claims 1 to 3, **characterized in that** the recovery boiler comprises an air feed channel (4) around at least part of the length of at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) and surrounding the at least one black liquor feed pipe (3) on its all sides for supplying combustion air for volatile matter into the first combustion zone (I) along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe (3) such that the supply of combustion air for volatile matter surrounds the black liquor supply.
5. The recovery boiler according to any of claims 1 to 4, **characterized in that** the boiler furnace (2) comprises a lower part (9), and the set of black liquor feed pipes (3) is arranged to supply the black liquor in the direction of the lower part (9) to form a char bed (1) at the lower part (9) of the boiler furnace (2).
6. The recovery boiler according to any of claims 1 or 5, **characterized in that** at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) is directed obliquely downwards and the angle α between the normal N of the at least one vertical furnace wall (5) and the at least one black liquor feed pipe (3) is 20 to 60 degrees.
7. The recovery boiler according to any of claims 1 to 6, **characterized in that** at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) is arranged on a first furnace wall (5A) and at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) is arranged on a second furnace wall (5B) opposite the first furnace wall (5A), and the at least one black liquor feed pipe (3) on the first furnace wall (5A) and the at least one black liquor feed pipe (3) on the second furnace wall (5B) are arranged in a staggered fashion so that the at least one black liquor feed pipe (3) on the first furnace wall (5A) is not directly opposite to the at least one black liquor feed pipe (3) on the second furnace wall (5B).
8. The recovery boiler according to any of claims 1 to 7, **characterized in that** the air feed channel (4) comprises an outlet (10) and the cross-sectional area of the air feed channel (4) at the outlet (10) is arranged to be such that the velocity at which the combustion air for volatile matter is supplied is 5 to 40 m/s or 5 to 25 m/s.
9. Fuel feeding means for a recovery boiler comprising a boiler furnace (2) comprising vertical furnace walls (5), wherein the fuel feeding means comprises a set of black liquor feed pipes (3) on at least one furnace wall (5) for supplying black liquor into the boiler furnace (2), **characterized in that** the fuel feeding means comprises an air feed channel (4) above at least part of the length of at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) for supplying combustion air for volatile matter into the boiler furnace (2) along with the black liquor supply in the direction of the length of the at least one black liquor feed pipe (3).
10. The fuel feeding means according to claim 9, **characterized in that** the air feed channel (4) at least partly surrounds the at least one black liquor feed pipe (3) such that the supply of combustion air for volatile matter at least partly surrounds the black liquor supply.
11. The fuel feeding means according to claim 9 or 10, **characterized in that** the fuel feeding means comprises an air feed channel (4) around at least part of the length of at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) and surrounding the at least one black liquor feed pipe (3) on its all sides for supplying combustion air for volatile matter into the boiler furnace (2) along with the black

liquor supply in the direction of the length of the at least one black liquor feed pipe (3) such that the supply of combustion air for volatile matter surrounds the black liquor supply.

12. The fuel feeding means according to any of claims 9 to 11, **characterized in that** the boiler furnace (2) comprises a lower part (9), and the set of black liquor feed pipes (3) is arranged to supply the black liquor in the direction of the lower part (9) to form a char bed (1) at the lower part (9) of the boiler furnace (2).

13. The fuel feeding means according to any of claims 9 to 12, **characterized in that** at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) is directed obliquely downwards and the angle α between the normal N of the at least one vertical furnace wall (5) and the at least one black liquor feed pipe (3) is 20 to 60 degrees.

14. A method for feeding black liquor and air to a recovery boiler burning black liquor, the recovery boiler comprising a boiler furnace (2) comprising a first combustion zone (I) and vertical furnace walls (5), in which method air needed for burning the black liquor is supplied in stages into the boiler furnace (2), and which method comprises:

- supplying the black liquor into the first combustion zone (I) through a set of black liquor feed pipes (3) located on at least one furnace wall (5),
- supplying primary air into the first combustion zone (I) through primary air nozzles (6) located below the set of black liquor feed pipes (3) for causing substoichiometric combustion of the black liquor in the first combustion zone (I),

characterized in that

- the method comprises supplying combustion air for volatile matter into the first combustion zone (I) along with the black liquor supply in the direction of the length of the black liquor feed pipe (3).

15. The method according to claim 14, **characterized in that** the combustion air for volatile matter is supplied into the first combustion zone (I) through an air feed channel (4) arranged above at least part of the length of at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3).

16. The method according to claim 14 or 15, **characterized in that** the combustion air for volatile matter is supplied into the first combustion zone (I) through an air feed channel (4) arranged around at least part of the length of at least one black liquor feed pipe (3) of the set of black liquor feed pipes (3) and surround-

ing the at least one black liquor feed pipe (3) on its all sides.

17. The method according to any of claims 14 to 16, **characterized in that** the velocity at which the combustion air for volatile matter is supplied is 5 to 40 m/s or 5 to 25 m/s.

18. The method according to any of claims 14 to 17, **characterized in that** the air coefficient in relation to volatile matter SR_{VOL} in the first combustion zone (I) is 0.9 - 1.0.

19. The method according to any of claims 14 to 18, **characterized in that** the total air coefficient SR_{TOT} in the second combustion zone (II) is 0.75 - 0.85.

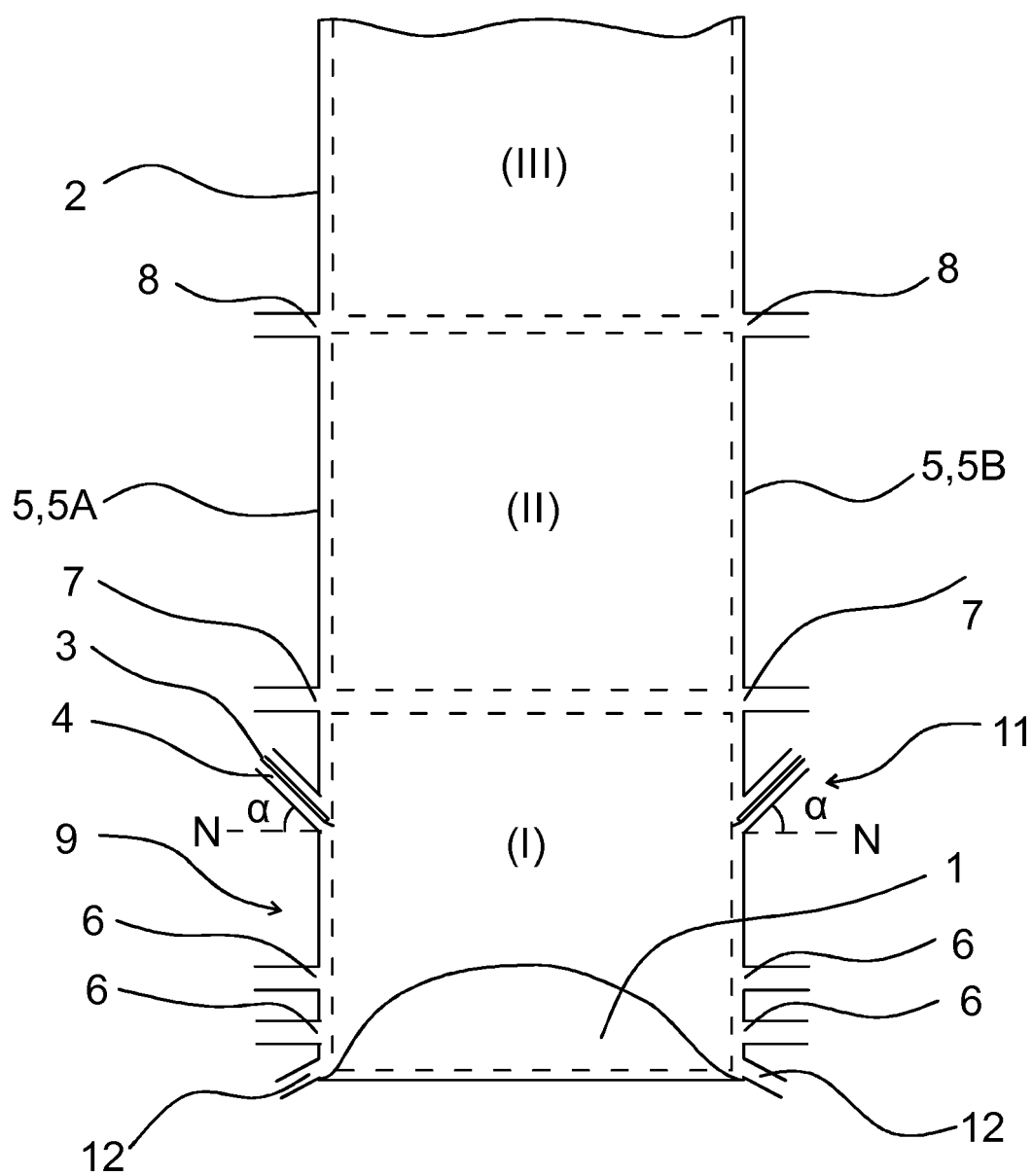


Fig. 1

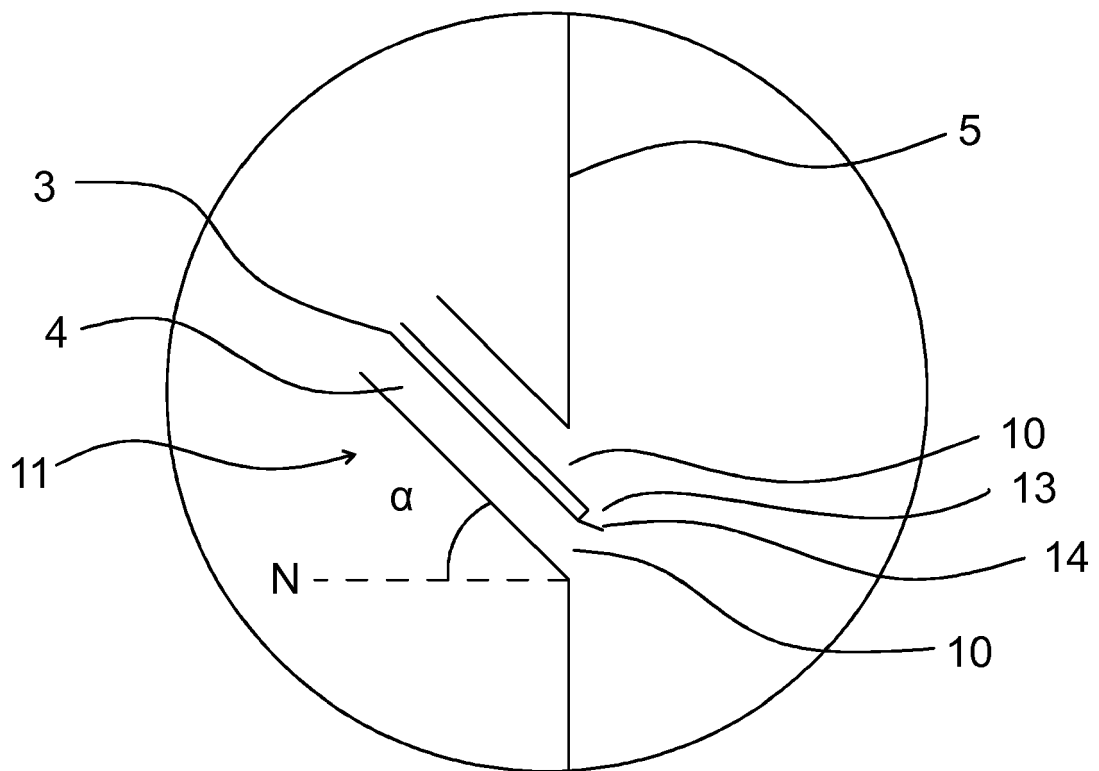


Fig. 2

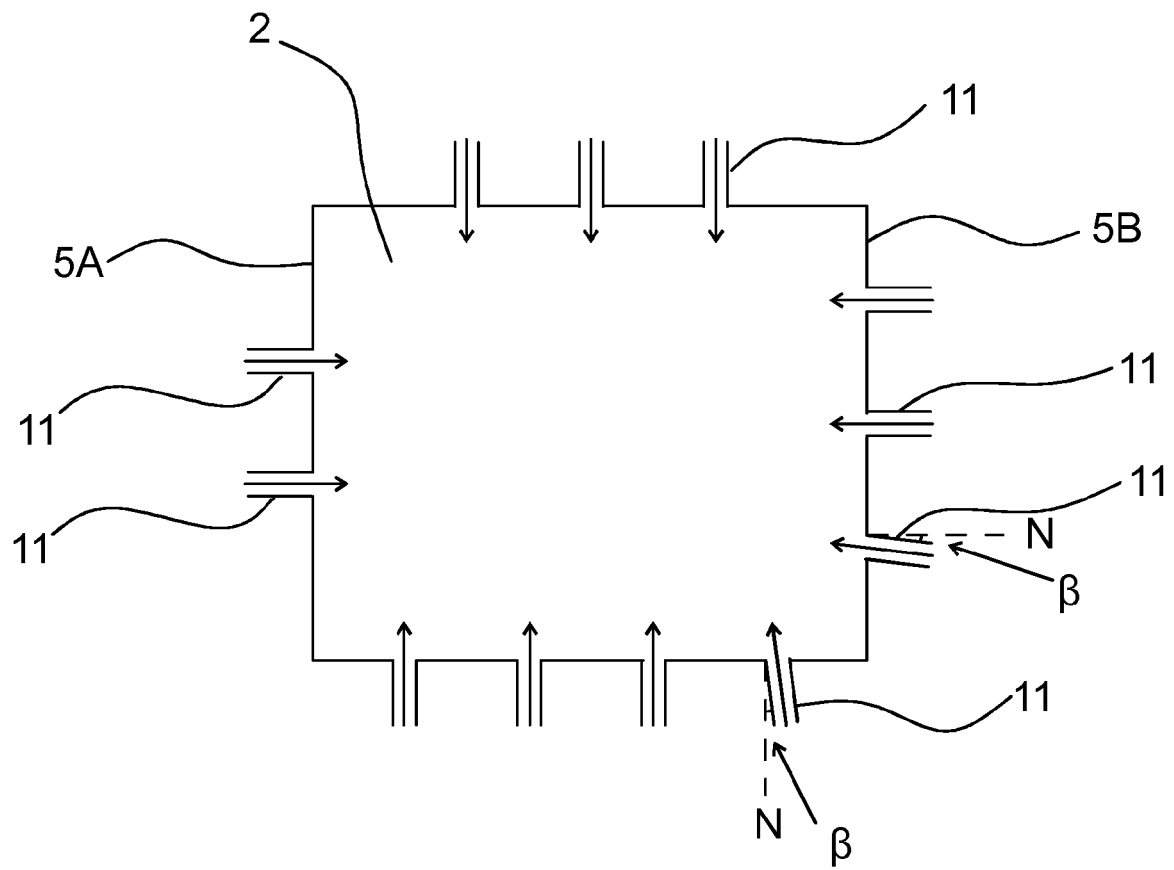


Fig.3

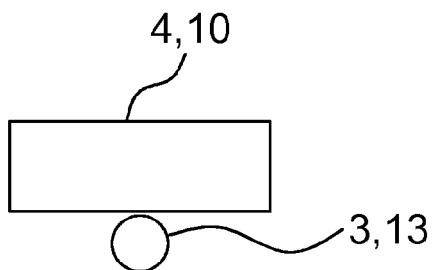


Fig.4a

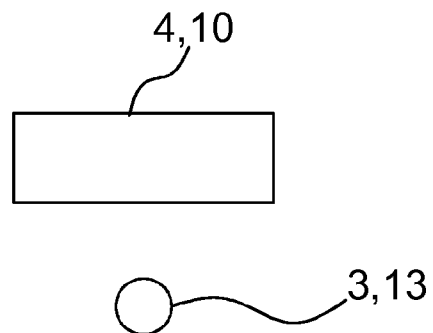


Fig.4b

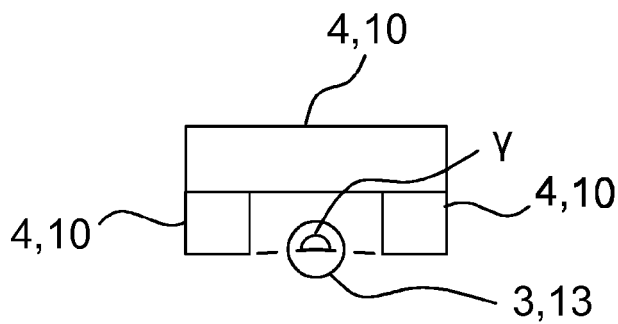


Fig.4c

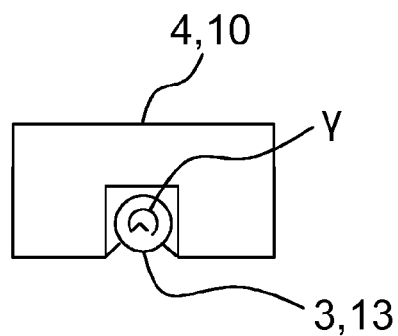


Fig.4d

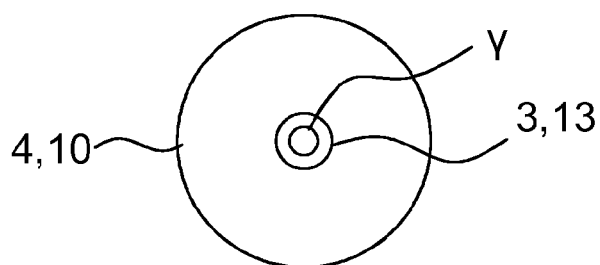


Fig.4e



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Place of search Munich		Date of completion of the search 29 August 2016	Examiner Karlsson, Lennart
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