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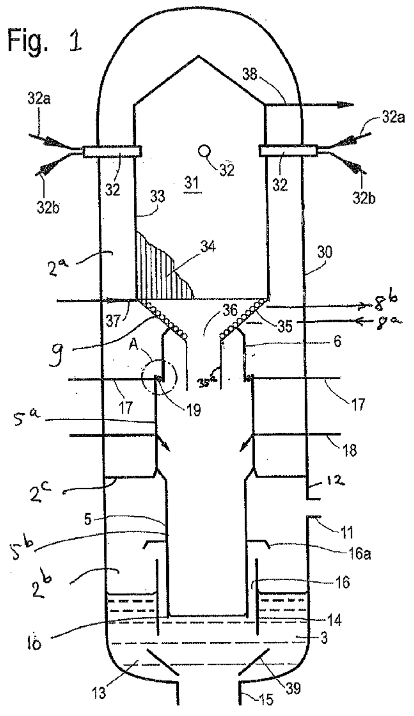
(54) Title: REACTOR FOR PREPARING SYNGAS

Fig. 1



(57) Abstract: Reactor vessel for preparing a syngas comprising a tubular syngas collection chamber, a quench chamber and a dipleg connecting the syngas collection chamber with the quench chamber, wherein the syngas collection chamber is connected to the dipleg via a slag tap, comprising of a frusto-conical part starting from the lower end of the tubular wall of the syngas collection chamber and diverging to an opening fluidly connected to the interior of the dipleg, wherein the diameter of said opening is smaller than the diameter of the dipleg, and wherein the frusto-conical part comprises one or more conduits having in inlet for cooling medium and an outlet for used cooling medium wherein the slag tap also comprises of a first tubular part connected to the opening of the frusto- conical part and extending in the direction of the dipleg, wherein a second tubular part is connected to the frusto-conical part or to the tubular part and extending in the direction of the dipleg and having a diameter smaller than the diameter of the diptube and larger than the diameter of the opening of the frusto-conical part and wherein the second tubular part is spaced away from the dipleg to provide an annular space and wherein in said annular space a discharge conduit for liquid water is present having a liquid water discharge opening located such to direct the liquid water along the inner wall of the diptube, and wherein at least half of the vertical length of the first tubular part extends below the liquid water discharge opening.

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REACTOR FOR PREPARING SYNGAS

The invention is directed to a reactor for preparing syngas comprising a syngas collection chamber and a quench chamber. The syngas outlet of the syngas collection chamber is fluidly connected with the quench chamber via a tubular diptube.

Such a reactor is described in US-A-4828578. This publication describes a gasification reactor having a reaction chamber provided with a burner wherein a fuel and oxidant are partially oxidized using oxygen gas to produce a hot gaseous product. The hot gases are passed via a constricted throat to be cooled in a liquid bath located below the reaction chamber. A diptube guides the hot gases into the bath.

When such a reactor is used to gasify ash containing feedstocks slag may block the constricted throat. To avoid such blockage one will have to continuously operate the reactor at a more elevated gasification temperature than the temperature at which one would ideally operate from an efficiency point of view.

The present invention aims to provide an improved reactor, which can be operated closer to the optimal gasification temperature while minimizing the risk for blockage by slag.

This is achieved by the following reactor vessel. Reactor vessel for preparing a syngas comprising a tubular syngas collection chamber, a quench chamber and a dipleg connecting the syngas collection chamber with the quench chamber,

wherein the syngas collection chamber is connected to the dipleg via a slag tap, comprising of a frusto-conical part starting from the lower end of the tubular wall of the syngas collection chamber and diverging to an opening fluidly connected to the interior of the dipleg,

wherein the diameter of said opening is smaller than the diameter of the dipleg,

wherein the frusto-conical part comprises one or more conduits having an inlet for cooling medium and an outlet for used cooling medium,

wherein the slag tap also comprises of a first tubular part connected to the opening of the frusto-conical part and extending in the direction of the dipleg,

wherein a second tubular part is connected to the frusto-conical part or to the tubular part and extending in the direction of the dipleg and having a diameter smaller than the diameter of the diptube and larger than the diameter of the opening of the frusto-conical part and wherein the second tubular part is spaced away from the dipleg to provide an annular space and wherein in said annular space a discharge conduit for liquid water is present having a liquid water discharge opening located such to direct the liquid water along the inner wall of the diptube, and

wherein at least half of the vertical length of the first tubular part extends below the liquid water discharge opening.

Applicants found that by providing the claimed frusto-conical part it is possible to predict blockage by slag by measuring the temperature of the used cooling water or steam make in the conduits of the frusto-conical part. Typically a decrease in temperature of the used cooling water or a decrease in steam make is indicative for a growing layer of slag. Thus one can operate closer to the optimal gasification temperature, while simultaneously being able to monitor the slag layer thickness.

The invention and its preferred embodiments will be further described by means of the following figures.

Figure 1 is a reactor according to the invention.

Figure 1a shows an alternative design for a section of the reactor of Figure 1.

Figure 2 is a side-view of a preferred embodiment for detail A of Figure 1.

Figure 3 is a top view of detail A of Figure 2.

Syngas has the meaning of a mixture comprising carbon monoxide and hydrogen. The syngas is preferably prepared by gasification of an ash comprising carbonaceous feedstock, such as for example coal, petroleum coke, biomass and deasphalted tar sands residues. The coal may be lignite, bituminous coal, sub-bituminous coal, anthracite coal and brown coal. The syngas as present in the syngas collection chamber may have a temperature ranging from 600 to 1500 °C and have a pressure of between 2 and 10 MPa. The syngas is preferably cooled, in the vessel according the present invention, to below a temperature, which is 50 °C higher than the saturation temperature of the gas composition. More preferably the syngas is cooled to below a temperature, which is 20 °C higher than the saturation temperature of the gas composition.

Figure 1 shows a reactor vessel 30 comprising a tubular syngas collection chamber 31, a quench chamber 3. Dipleg 5 connects the syngas collection chamber 31 with the quench chamber 3. The syngas collection chamber 31 is connected to the dipleg 5 via a slag tap 9, comprising of a frusto-conical part 35 starting from the lower end of the tubular wall of the syngas collection chamber 31 and diverging to an opening 36. The opening 36 fluidly connects the interior of the syngas collection chamber 31 to the interior of the dipleg 5. The diameter of opening 36 is smaller than the diameter of the dipleg 5. If the dipleg 5 has varying diameters the largest diameter is meant. The frusto-conical part 35 comprises one or more conduits having in inlet 8a for cooling medium and an outlet 8b for used cooling medium.

The tubular syngas collection chamber 31 is provided with 4 horizontally firing burners 32. The number of burners may suitably be from 1 to 8 burners. To said burners the carbonaceous feedstock and an oxygen containing gas are provided via conduits 32a and 32b. The wall 33 of the syngas collection chamber 31 is preferably an arrangement of interconnected parallel arranged tubes 34 resulting in a substantially gas-tight tubular wall 33. Only part of the tubes are drawn in Figure 1. The tubes 34 run from a lower arranged cooling water distributor 37 to a higher arranged header 38. The burners 32 are arranged in Figure 1 as described in for example WO-A-2008110592, which publication is incorporated by reference. The burners or burner may alternatively be directed downwardly as for example described in WO-A-2008065184 or in US-A-2007079554. In use a layer of liquid slag will be present on the interior of wall 33. This slag will flow downwards, via slag tap 9 and diptube 5 and will be discharged from the reactor via outlet 15.

In use the reactor vessel 30 is vertically oriented as shown in the Figure 1. References to vertical, horizontal, top, bottom, lower and upper relate to this orientation. Said terms are used to help better understand the invention but are by no means intended to limit the scope of the claims to a vessel having said orientation.

The syngas collection chamber 31 and the diptube 5 have a smaller diameter than the reactor vessel 30 resulting in an upper annular space 2a between said chamber 31 and the wall of reactor vessel 30 and a lower annular space 2b between the diptube 5 and the wall of reactor vessel 31. Annular space 2a and 2b are preferably gas tight separated by sealing 2c to avoid ingress of ash particles from space 2b into space 2a.

Preferably the slag tap 9 also comprises of a tubular part 35a connected to the opening 36 of the frusto-conical part 35 and extending in the direction of the dipleg 5. This part 35a is preferred because it will guide slag downwards into the diptube 5 and into the water bath 13 where the slag solidifies. In water bath 13 the solidified slag particles are guided by means of an inverted frusto-conical part 39 to outlet 15.

The presence of part 35a is advantageous because one then avoids slag particles to foul a water discharge conduit 19 which will be described in more detail below. If such a tubular part 35a would not be present small slag particles may be carried to a circular opening 19 by recirculating gas. By having a tubular part of sufficient length such recirculation in the region of opening 19 is avoided. Preferably the length of 35a is such that the lower end terminates at or below the opening 19. Even more preferably the lower end terminates below the opening 19, wherein at least half of the vertical length of the tubular part 35a extends below opening 19.

Preferably at the end of the diptube 5 which is nearest to the syngas collection chamber 31 means for introducing water are present, more preferably such means is a circular opening 19 for introducing water, fluidly connected to a water supply line 17. Such means preferably have an outflow opening for liquid water directed such that, in use, a film of water is achieved along the inner wall of the diptube 5.

Figure 1 also shows a preferred next tubular part 6 as connected to the frusto-conical part 35 or to the optional tubular part 35a and extending in the direction of the dipleg 5. The next tubular part 6 has a diameter smaller than the diameter of the diptube 5 at its upper end. This diameter of part 6 is larger than the diameter of the opening 36 of the frusto-conical part 35. The next tubular part 6 is preferably spaced away from the dipleg 5 to provide a circular opening 19 for introducing water.

Preferably the frusto-conical part 35 is directly connected to a cooling supply conduit and directly connected to a cooling discharge conduit. By having a cooling system for the frusto-conical part 35 which is separate from for example the optional cooling system for the wall of the syngas collection chamber 31 it is even more easy to measure the local heat transfer and predict if slag tap blockage may occur.

Preferably the tubular part 35a comprises one or more conduits having in inlet for cooling medium and an outlet for used cooling medium. More preferably the tubular part 35a is directly connected to a cooling supply conduit and directly connected to a cooling discharge conduit. By having a cooling system for the tubular part 35a which is separate from for example the cooling system for the frusto-conical part 35 or the optional cooling system for the wall of the syngas collection chamber 31 it is even more easy to measure the local heat transfer and predict if slag tap blockage may occur.

The frusto-conical part 35 and the optional tubular part 35a and 35b comprise one or more conduits, through which in use boiling cooling water or sub-cooled cooling water, flows. The design of the conduits of parts 35, 35a and 35b may vary and may be for example spirally formed, parallel formed, comprising multiple U-turns or combinations.

Preferably the temperature of the used cooling water or steam make of these parts 35 and 35a are measured to predict the thickness of the local slag layer on these parts. This is especially advantageous if the gasification process is run at temperatures, which would be beneficial for creating a sufficiently thick slag layer for a specific feedstock, such as low ash containing feedstocks like certain biomass feeds and tar sand residues. Or in situations where a coal feedstock comprises components that have a high melting point. The danger of such an operations is that accumulating slag may block opening 36. By measuring the temperature of the cooling water or the steam make one can predict when such a slag accumulation occurs and adjust the process conditions to avoid such a blockage.

The invention is thus also directed to avoid slag blockage in a reactor according to the present invention, by (i) measuring the temperature of the cooling water as it is discharged from the conduit(s) of the frusto-conical part or from the tubular part or by measuring the steam make in the conduit(s) of the frusto-conical part or from the tubular part, (ii) predict if a slag blockage could occur based on these measurements and (iii) adjust the process conditions if necessary to avoid such a blockage.

Typically a decrease in temperature of the used cooling water or a decrease in steam make are indicative for a growing layer of slag. The process is typically adjusted by increasing the gasification temperature in the reaction chamber such that the slag will become more fluid and consequently a reduction in thickness of the slag layer on parts 35 and 35a will result. The reactor is preferably provided with means to measure the above cooling water temperature or steam make, means to predict of slag blockage may occur based on said measurements and control means to adjust the gasification conditions to avoid slag blockage. The supply and discharge conduits for this cooling water are not shown in Figure 1.

The diptube 5 is open to the interior of the reactor vessel 30 at its lower end 10. This lower end 10 is located away from the syngas collection chamber 31 and in fluid communication with a gas outlet 11 as present in the vessel wall 12. The diptube is partly submerged in a water bath 13. Around the lower end of the diptube 5 a draft tube 14 is present to direct the syngas upwardly in the annular space 16 formed between draft tube 14 and diptube 5. At the upper discharge end of the annular space 16 deflector plate 16a is present to provide a rough separation between entrained water droplets and the quenched syngas. Deflector plate 16a preferably extends from the outer wall of the diptube 5.

The lower part 5b of the diptube 5 preferably has a smaller diameter than the upper part 5a as shown in Figure 1. This is advantageous because the layer of water in the lower end will increase and because the annular area for the water bath 13 will increase. This is advantageous because it enables one to use a more optimized, smaller, diameter for reactor vessel 30. The ratio of the diameter of the upper part to the diameter of the lower part is preferably between 1.25:1 and 2:1.

Figure 1 also shows preferred water spray nozzles 18 located in the diptube 5 to spray droplets of water into the syngas as it flows downwardly through the diptube 5. The nozzles 18 are preferably sufficiently spaced away in a vertical direction from the opening 19 to ensure that any non-evaporated water droplets as sprayed into the flow of syngas will contact a wetted wall of the diptube 5. Applicants have found that if such droplets would hit a non-wetted wall ash may deposit, thereby forming a very difficult to remove layer of fouling. In an embodiment with a diptube 5 having a smaller diameter lower part 5b as discussed above it is preferred that the nozzles 18 are positioned in the larger diameter part 5a. More residence time is achieved by the larger diameter resulting in that the water as injected has sufficient time to evaporate.

In Figure 1a a preferred embodiment for tubular part 35a is shown, wherein the lower end of tubular part 35a is fixed by a plane 35b extending to the lower end of the next tubular part 6. This design is advantageous because less stagnant zones are present where solid ash particles can accumulate.

Figure 2 shows detail A of Figure 1 for a preferred embodiment of opening 19. Figure 2 shows that the next tubular part 6 terminates at a point within the space enclosed by the diptube 5 such that an annular space 20 is formed between the next tubular part 6 and the diptube 5. In the annular space 20 a discharge conduit 19' for a liquid water is present having a discharge opening 21 located such to direct the liquid water 22 along the inner wall of the diptube 5. Conduit 19' and tubular part 6 are preferably not fixed to each other and more preferably horizontally spaced away from each other. This is advantageous because this allows both parts to move relative to each other. This avoids, when the vessel is used, thermal stress as both parts will typically have a different thermal expansion. The gap 19a as formed between conduit 19' and part 6 will allow gas to flow from the syngas collection chamber 2 to the space 2a between the wall of the chamber 2 and the wall of vessel 1. This is advantageous because it results in pressure equalization between said two spaces. The discharge conduit 19' preferably runs in a closed circle along the periphery of the tubular part 6 and has a slit like opening 21 as the discharge opening located at the point where the discharge conduit 19' and the inner wall of the diptube 5 meet. In use, liquid water 22 will then be discharged along the entire inner circumference of the wall of the diptube 5. As shown conduit 19' does not have discharge openings to direct water into the flow of syngas, which is discharged via syngas outlet 4.

Figure 2 also shows that the discharge conduit 19' is suitably fluidly connected to a circular supply conduit 23. Said supply conduit 23 runs along the periphery of the discharge conduit 19'. Both conduits 19' and 23 are fluidly connected by numerous openings 24 along said periphery. Alternatively, not shown in Figure 2 and 3, is an embodiment wherein the discharge conduit 19' is directly fluidly connected to one or more supply lines 17 for liquid water under an angle with the radius of the closed circle, such that in use a flow of liquid water results in the supply conduit.

Preferably the discharge conduit 19′ or conduit 23 are connected to a vent. This vent is intended to remove gas, which may accumulate in said conduits. The ventline is preferably routed internally in the vessel 1 through the sealing 2c to be fluidly connected to annular space 2b. The lower pressure in said space 2b forms the driving force for the vent. The size of the vent line, for example by sizing an orifice in said ventline, is chosen such that a minimum required flow is allowed, possibly also carrying a small amount of water together with the vented gas into the annular space 2b. Preferably conduit 19′ is provided with a vent as shown in Figure 2, wherein the discharge conduit 19′ has an extending part 26 located away from the discharge opening 21, which extending part 26 is fluidly connected to a vent conduit 27.

The circular supply conduit 23 of Figure 3 is suitably fluidly connected to one or more supply lines 17 for liquid water under an angle α, such that in use a flow of liquid water results in the supply conduit 23. Angle α is preferably between 0 and 45°, more preferably between 0 and 15°. The number of supply lines 17 may be at least 2. the maximum number will depend on the dimensions of for example the conduit 23. The separate supply lines 17 may be combined upstream and within the vessel 1 to limit the number of openings in the wall of vessel 1. The discharge end of supply line 17 is preferably provided with a nozzle to increase the velocity of the liquid water as it enters the supply conduit 23. This will increase the speed and turbulence of the water as it flows in conduit 23, thereby avoiding solids to accumulate and form deposits. The nozzle itself may an easy to replace part having a smaller outflow diameter than the diameter of the supply line 17.

The openings 24 preferably have an orientation under and angle β with the radius 25 of the closed circle, such that in use a flow of liquid water results in the discharge conduit 19' having the same direction has the flow in the supply conduit 23. Angle β is preferably between 45 and 90°.

Figure 3 also shows next tubular part 6 as an arrangement of interconnected parallel arranged tubes 28 resulting in a substantially gas-tight tubular wall 29.

CLAIMS

1. Reactor vessel for preparing a syngas comprising a tubular syngas collection chamber, a quench chamber and a dipleg connecting the syngas collection chamber with the quench chamber,

wherein the syngas collection chamber is connected to the dipleg via a slag tap, comprising of a frusto-conical part starting from the lower end of the tubular wall of the syngas collection chamber and diverging to an opening fluidly connected to the interior of the dipleg,

wherein the diameter of said opening is smaller than the diameter of the dipleg, and

wherein the frusto-conical part comprises one or more conduits having in inlet for cooling medium and an outlet for used cooling medium,

wherein the slag tap also comprises of a first tubular part connected to the opening of the frusto-conical part and extending in the direction of the dipleg,

wherein a second tubular part is connected to the frusto-conical part or to the tubular part and extending in the direction of the dipleg and having a diameter smaller than the diameter of the diptube and larger than the diameter of the opening of the frusto-conical part and wherein the second tubular part is spaced away from the dipleg to provide an annular space and wherein in said annular space a discharge conduit for liquid water is present having a liquid water discharge opening located such to direct the liquid water along the inner wall of the diptube, and wherein at least half of the vertical length of the first tubular part extends below the liquid water discharge opening.

2. Reactor according to claim 1, wherein the frusto-conical part is directly connected to a cooling supply conduit and directly connected to a cooling discharge conduit.

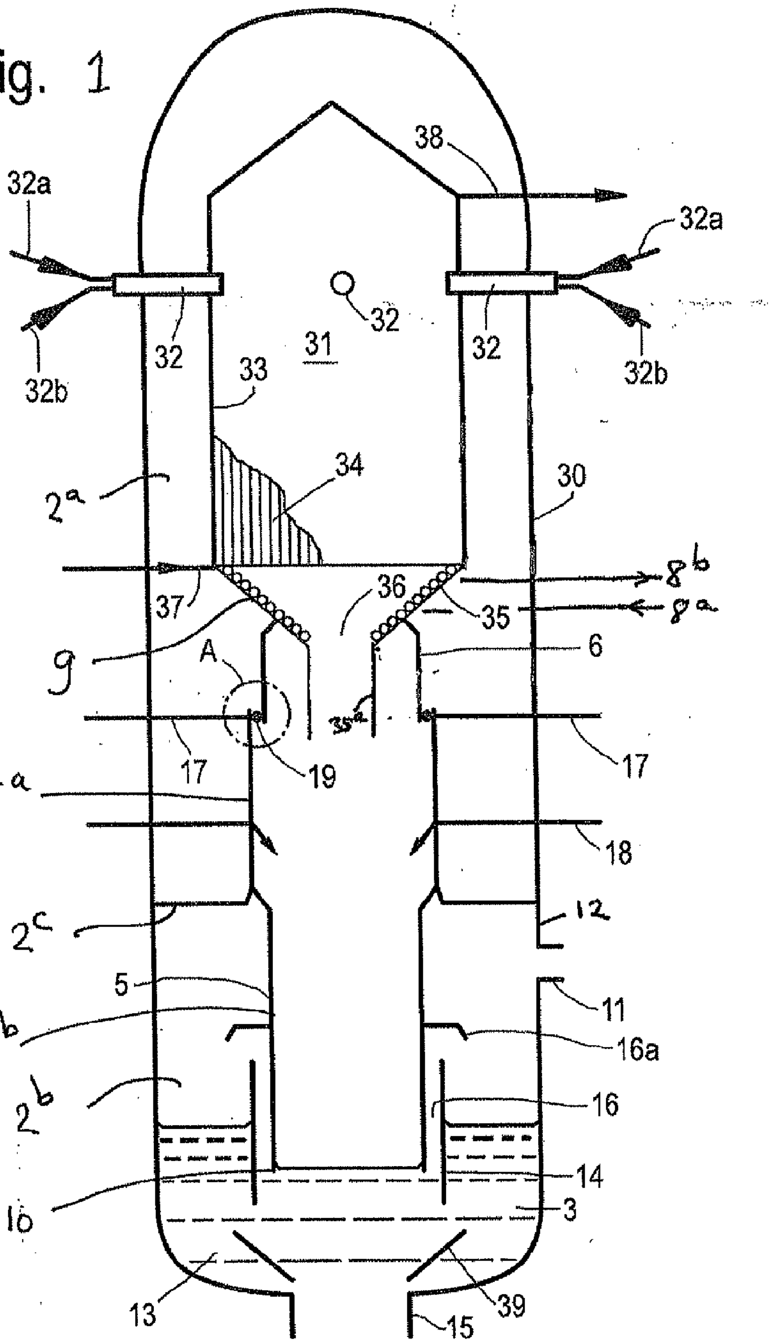
3. Reactor according to any one of claims 1-2, wherein the first tubular part comprises one or more conduits having an inlet for cooling medium and an outlet for used cooling medium.

4. Reactor according to any one of claims 1-2, wherein lower end of the first tubular part is fixed by a plane extending to the lower end of the second tubular part.

5. Reactor according to any one of claims 1-4, wherein one or more water spray nozzles are located in the diptube which, in use, spray droplets of water into a stream of syngas flowing downwardly through the diptube.

6. Reactor according to any one of claims 1-5, wherein the syngas collection chamber comprises of an arrangement of interconnected parallel arranged tubes resulting in a gas-tight tubular wall running from a distributor to a header, said distributor provided with a cooling water supply conduit and said header provided with a steam discharge conduit.

Fig. 1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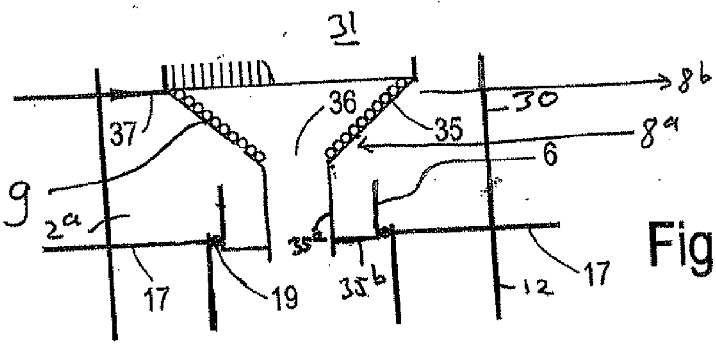

Fig. 1a

Fig.2

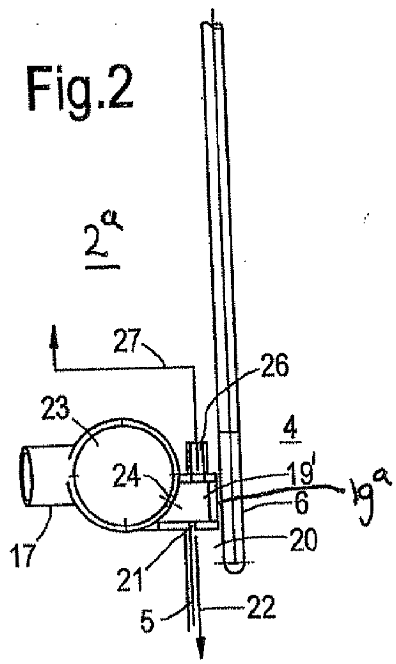

Fig.3