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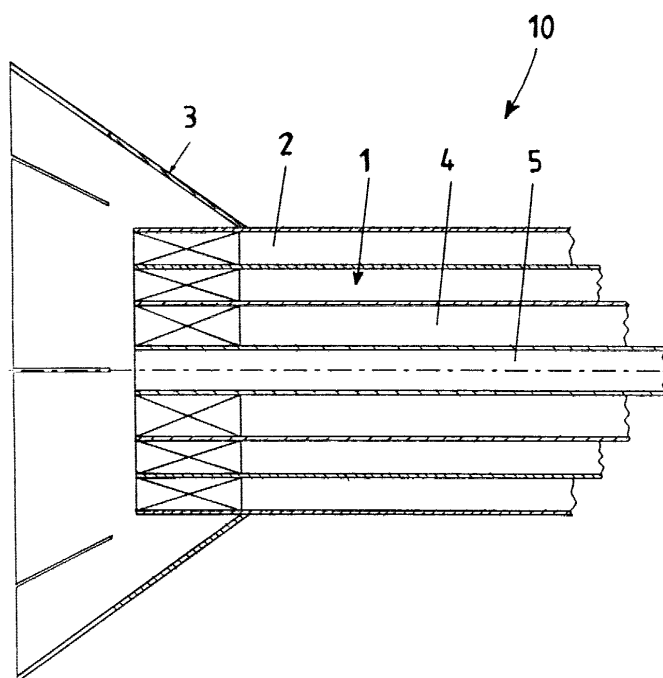
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(54) **Device for injecting solid fuels in atomised form into a cement kiln**

(57) A device (10) for injecting solid fuels in atomised form into a cement kiln (12) is installed at the mouth of a burner (11), and comprises a nozzle for liquid fuels (5), a first pipe (4), coaxial to the nozzle of liquid fuels (5), and an annular piping (1), for injecting the solid fuel in atomised form. In such device (10), the annular piping (1) is divided into a plurality of sectors (1a, 1b) converg-

ing towards the burner mouth, so as to allow the formation of alternate rich solid fuel flows, and poor solid fuel flows. The device (10) also exhibits an outside baffle (3) for addressing the primary and secondary air flows, maintaining them sufficiently separate for controlling the first stages of the combustion process relating to the NO_x formation.

Fig.2



Description

[0001] The object of the present invention is a device for injecting solid fuels into a cement kiln.

[0002] The device object of the invention is suitably designed for burners operating with both two fuels (solid and liquid fuels), and with three fuels (gaseous, liquid and solid fuels), in particular with different combinations of the three fossil fuels.

[0003] A possible solid fuel for such kilns is, for example, atomised coal.

[0004] It is well known that nitric oxides are the most important gaseous pollutants produced during the combustion and emitted by the exhausted smokes to the environment in the different industrial production processes.

[0005] In a cement kiln, the high temperatures of secondary air produce equally high flame temperatures since they are necessary for an effective transfer of the heat to the material being baked.

[0006] As a consequence, all of this produces high NO_x concentrations, due to the involved thermal process and to the total conversion of the nitrogen bound to the fuel.

[0007] Without going to the heart of the different (thermal, fuel and prompt) mechanisms of formation of the NO_x, it is useful to note that the main formation of NO_x depends on the fuel, on its nitrogen content, on the air excess, of the air pre-heating, on the flame temperature, and in cement kilns, on other typical parameters of the production process.

[0008] For this reason, the simple manipulation of the combustion process does not always produce the desired results in the NO_x control.

[0009] From a generic point of view, in a specific cement kiln characterised by a high thermal input and high temperature of the comburent air, the thermal NO_x are usually prevalent also as a consequence of the confinement of the flames; however, fuel NO_x cannot be neglected.

[0010] Besides the extremely complex mechanism of NO_x formation, it must be kept into account that the particular different air/fuel ratios needed for the NO_x control, which are normally realised with multi-circuit burners, can only be obtained close to the burner mouth, and they do not always totally concern the first fuel de-volatilisation stage.

[0011] Moreover, the air distribution and at first the aerodynamics along the burner axis affect the fuel fire point. Generally speaking, the sooner the ignition, the lower the NO_x concentration, due to the reduced axial moment needed for the combustion process.

[0012] As a consequence, there is a lower flame suction of secondary air at a high temperature and a reduced local mixing between such air and the coal casting.

[0013] In some burners, such effect is in competition with the action of the outside primary air flow, of the

swirled type (that is, a quickly rotating air flow) which tends to suck in flame the secondary air and to produce a faster thermal release in the area close to the burner mouth.

[0014] Thus, purpose of the present invention is that of realising a device which should allow solving the above disadvantages, thus optimising the combustion conditions.

[0015] A further purpose of the present invention is that of providing a burner which should be capable of guaranteeing an improved operation with respect to similar burners in terms of a further reduction of NO_x emissions.

[0016] These and other purposes are achieved by a device for injecting solid fuels in atomised form into a cement kiln, according to claim 1, to which reference shall be made for shortness.

[0017] Further features and advantages of the present invention shall appear more clearly from the following description and attached drawings, provided by way of an explicative and non-limiting example. In such drawings:

- Figure 1 shows a view of a burner provided with a nozzle for injecting atomised solid fuels, in particular in a cement kiln, wherein the device of the invention is applied to such nozzle;
- Figure 2 shows a longitudinal section of the device for injecting atomised liquid or solid fuels, according to the present invention, applied to the burner of figure 1;
- Figure 3 shows a front view of the device for injecting fuels of figure 2.

With particular reference to the mentioned figures, there is visible the device object of the invention, globally indicated with reference numeral 10;

- Figure 4 shows a longitudinal section of a second embodiment of the device according to the invention;
- Figure 5 is a graphic showing the nitrogen oxid and free line concentration, as a function of the oxygen percentage at the kiln back-end, both in the case of the burner according to the present invention and of the one according to the standard low NO_x design.

[0018] It is particularly adapted to be mounted on any burner, better if of the multi-circuit type, for limiting the production of nitrogen oxides (NO_x).

[0019] It is, as it will be better specified hereinafter, a nozzle exhibiting a suitable shape for the staged combustion of fossil fuels, both solid and liquid, which in particular uses the same construction solution as the installed burner, but adopts special construction solutions for the end portion of the primary air and fuel injection ducts.

[0020] The device for injecting atomised solid fuels according to the invention is designed to be installed at

the output mouth of a burner 11, coaxially to the central portion of the same burner 11.

[0021] Such central portion of burner 11 consists of a nozzle for liquid fuels 5, and of piping for injecting the solid fuel 1 and for injecting the inside air 4.

[0022] Figure 1 shows device 10 installed on burner 11, in turn inserted into a kiln 12 for clinker 13; there is also visible the coal injected by such burner 11.

[0023] With reference to figures 2 and 3, device 10 relating to the present invention thus comprises an annular piping 1, which is coaxial to the liquid fuel nozzle 5.

[0024] The annular piping 1 has the purpose of concentrating the solid fuel dust into physically separate flows with different transport air/fuel ratios.

[0025] In fact, the annular piping is divided into sectors 1a and 1b, which converge towards the mouth of burner 11 so as to allow the formation of alternate flows rich in solid fuel, and poor flows, as it shall be better illustrated in the following description.

[0026] Device 10 also exhibits a coaxial piping 2, outside the other coaxial piping, which has the purpose of shaping the flame, imparting the desired length to it, by confining the fuel flow and generating an effective and efficient inside recycle zone (which shall be indicated with the abbreviation IRZ in the following description).

[0027] The coaxial piping 2 can also be provided with a swirler for generating a rotational air flow.

[0028] Device 10 also exhibits an outside baffle 3 which actively helps to maintain the primary and secondary air flows as separate as necessary for preventing the re-entering of secondary air at high temperature in the IRZ.

[0029] The separation of primary and secondary air flows is sufficient for controlling the first stages of the combustion process relating to the NO_x formation.

[0030] The inclination angle of baffle 3 can vary in the range 0° and 60° with respect to the longitudinal axis of burner 11.

[0031] Moreover, the ratio between the greatest diameter of baffle 3 and the outside diameter of burner 11 varies in the range between 1.5 and 3.5.

[0032] As regards the length of baffle 3, it varies in the range between 100 mm and 800 mm, with respect to the profile of the mouth of burner 11, according to a plane passing through the axis of burner 11.

[0033] Inside, baffle 3 is a truncated cone realised and/or coated with refractory material of a suitable thickness, shape and union of the type used for coating burner 11.

[0034] As regards the coaxial piping 4 into burner 11, it can be provided or not according to different aspects, such as the capacity of burner 11, the type of solid fuel, the number of fuels to be used, the need of changing the shape of flame 14, and else.

[0035] Such coaxial piping 4 can also be provided with swirler for better performing the functionalities it is intended for.

[0036] In particular, the swirler of coaxial piping 2 and

4 varies from 0° to 60° with respect to the longitudinal axis of the burner in the view plane of figure 3.

[0037] These axial or radial flows are controlled through devices capable of ensuring a variable ratio between the two moments, guaranteeing the control of the air mixing with the fuel, and changing the flows for the purpose of generating an effective IRZ of smokes produced by the combustion.

[0038] Going on to the more detailed examination of the annular piping 1, it can be noted that it consists of a group of at least 3 sectors (indicated with reference numeral 1a) converging towards the burner mouth, alternating with as many sectors, provided or not with swirler, and indicated with reference numeral 1b.

[0039] Such portion is sized so as to be arranged into an annulus coaxial to the burner axis and to the liquid fuel nozzle 5.

[0040] By way of an example, figure 2 shows a case with 4 sectors, provided with the coaxial piping 4.

[0041] In this way, the solid fuel dust is divided into various flows characterised by different local transport air/fuel ratios.

[0042] In fact, the transport air of the solid fuel dust feeds the device for injecting fuels with rich solid fuel flows at the periphery of the duct, and poor solid fuel flows at the centre.

[0043] The particular geometry of the annular piping 1 makes the rich flows enter directly into the free sectors 1a of the annular piping 1, whereas the poor ones flow - through swirler or not - into the other sectors 1b.

[0044] The result is the discretisation of the transport air + solid fuel flows, which flows are characterised by a different air/fuel ratio.

[0045] The composition of the two-phase mixture in the proximity of the burner mouth depends on the features of the mixing process set by the particular aerodynamics induced by the coal nozzle, and in particular generated by the geometry of the coaxial piping 2 and 4, if present.

[0046] Such composition is the base parameter for controlling NO_x , unburnt emissions, and the flame stability.

[0047] According to the present invention, with the proper combination of the annular piping 1 and of the coaxial piping 4, but above all thanks to their geometries that determine different effects on the air/solid fuel mixing, it is possible to define an optimum solution for the various requirements of different installations.

[0048] The outflow sectors of the transport air/solid fuel mixture are, at the input of device 10, substantially equivalent to 100% of the annular outlet section area, whereas the output section of the different flows varies from 100% to 50%, in function of the different industrial applications.

[0049] With such device or nozzle 10, after the optimisation of the combustion system according to the type of combustion used, it is possible to obtain NO_x reductions in the range of 50% with respect to traditional burn-

ers, while if applied to multi-circuit burners (which already are of the low NO_x type) it is possible to obtain further reductions in the range of 10-30% besides those already obtained by the original burner.

[0050] As an example the application afterwards reported, to be considered as a worst case from a viewpoint of NO_x reduction because it concerns the modification of an already low NO_x burner, the device (figure 4) in according to the present invention consists of:

- A fuel oil gun housed in the centre along the burner axis (5)
- A pipe co-axial the above fuel oil gun, formerly present in the original low NO_x burner design, inclusive of a swirler (4)
- A second pipe for feeding the pulverised coal, in this case exclusive of the separating vanes, co-axial at the above mentioned one and formerly existing in the original low NO_x burner design too (1)
- A third co-axial pipe, housing a swirler mounted around the coal pipe and characterised by the same angle of the inner one, in order to control the specific flame shape and to generate an effective internal re-circulation zone (IRZ) (2)
- An outer 25° divergent cone realised taking into account the current burner and kiln geometry; such a cone has been coated by a thick refractory material layer, the same applied for the burner body.

[0051] The performances of the modified burner in an oil - petcoke version according to the present invention has been compared with those of the standard low NO_x burner formerly installed on a 2400 tpd Lepol kiln.

[0052] The operating conditions were:

- Kiln production 2400 tpd
- Burner load 60 Gcal/h (72 % of total kiln heat input)
- Fuel nitrogen 1.6 - 1.7 %
- Secondary air temperature 900 - 1000 °C
- Primary air flow rate 12 - 13 %

[0053] Figure 5 shows the nitrogen oxide and free lime concentrations, as a function of the oxygen percentage at the kiln back-end, both in the case of the burner according to the present invention and of the one according to the standard low NO_x design.

[0054] From the tests performed the following results have been obtained:

- At 3 % oxygen a further 25 % NO_x reduction with respect to the values measured burning 100 % petcoke using the formerly installed low NO_x burner

- In this conditions (figure 6) no worsening of the combustion efficiency has been proven from a viewpoint of CO and SO₂ emissions measured at the stack

- 5 • The possibility of running the kiln at a lower excess air measured at the kiln back-end
- Similar behaviour burning 100 % fuel oil
- 10 • The ability to obtain concentric combustion (fuel oil + petcoke) in the range of the possible variations in the ratio of the two fuels
- The ability to combine the burner with any type of fuel oil atomisers
- 15 • The preservation of clinker quality and free lime concentrations obtained usually before the burner modification
- 20 • The possibility to run the kiln at lower speeds due to a different but more homogeneous temperature field into the kiln resulting in a more even internal shell coating
- 25 • A consequent lower kiln motor power absorption on account of which a reduction of the maintenance time and costs is expected.

30 **[0055]** The features of the device for injecting solid fuels in atomised form into a cement kiln - object of the present invention - as well as its advantages, are evident from the above description.

[0056] The following remarks are intended to better highlighting such advantages.

[0057] Based on what said above, a deep change of the aerodynamics at the output from the burner mouth has been realised, which was necessary for an effective reduction of the NO_x produced by the combustion in a clinker kiln.

[0058] Thus, an effective and efficient flame internal recycle zone (IRZ) has been realised for keeping the temperature peaks under control, for reducing the time of permanence of the fuel into the air at a high temperature and producing a reducing zone or, which is the same - an excess of fuel into the ignition zone.

[0059] As a consequence, it must be repeated that in burners where solid fuels are used, the geometry of the burner mouth (coal nozzle) has a primary importance for controlling the combustion and thus, the NO_x production. In particular, oxygen poor areas and fuel rich areas have been formed in the combustion zone, thus reducing the time of permanence of the fuel in the oxygen rich areas and preventing an excessive IRZ close to the burner mouth from producing local overheating phenomena which may damage the same burner.

[0060] Finally, it is clear that several changes can be made to the device for injecting solid fuels in atomised

form into a cement kiln, object of the present invention, without departing from the novelty principles of the inventive idea.

[0061] In the practical embodiment of the invention, the materials, shapes and sizes of the illustrated details can be of any type according to the requirements, and the same can be replaced with other technically equivalent details.

Claims

1. Device (10) for injecting solid fuels in atomised form into a cement kiln (12), where the above device (10) is installed at the mouth of a burner (11), and comprises at least one nozzle for liquid or gaseous fuels (5), and an annular piping (1), for injecting the above solid fuel in atomised form, **characterised in that** the above annular piping (1) is divided into a plurality of sectors (1a, 1b) converging towards the above burner mouth (11), so as to allow the formation of alternate flows, some of which are rich solid fuel flows, and others are poor solid fuel flows, and in that it is provided with an outside baffle (3) for addressing the primary and secondary air flows, maintaining them sufficiently separate for controlling the first stages of the combustion process relating to the NO_x formation. 5
2. Device (10) according to claim 1, **characterised in that** it exhibits at least one first coaxial piping (4) for the injection of internal air. 10
3. Device (10) according to claim 2, **characterised in that** the above first coaxial piping (4) exhibits means for providing rotation to the air. 15
4. Device (10) according to claim 1, **characterised in that** the above sectors (1b) exhibit means for providing rotation to the air. 20
5. Device (10) according to claim 1, **characterised in that** the inclination angle of the above baffle (3) is comprised between 0° and 60° with respect to the longitudinal axis of the burner (11). 25
6. Device (10) according to claim 1, **characterised in that** the ratio between the greatest diameter of the above baffle (3) and the outside diameter of the burner (11) varies in the interval 1.5 and 3.5. 30
7. Device (10) according to claim 6, **characterised in that** the length of the above baffle (3) varies in the range 100 mm and 800 mm with respect to the profile of the burner mouth according to a plane that is orthogonal to the axis of the above burner. 35
8. Device (10) according to claim 1, **characterised in** 40

that the inside of the above baffle (3) is a truncated cone realised and/or coated with a refractory material of a suitable thickness, shape and union similar to that used for coating the burner.

9. Device (10) according to claim 1, **characterised in that** the swirler of the coaxial piping (2, 4) varies from 0° to 60° with respect to the longitudinal axis of the burner. 45
10. Device (10) according to any one of the previous claims, **characterised in that** the outflow sectors of the transport air/solid fuel mixture are, at the input of the above device (10), substantially equivalent to 100% of the annular outlet section area, whereas the output section of said annular portion varies from 100% to 50%, in function of the different industrial applications. 50
11. Device according to claim 1, **characterised in that** the proper combination of all its parts allows effectively obtaining the alternation of poor and rich fuel zones directly in the flame (14) of a single burner (11). 55

Fig.1

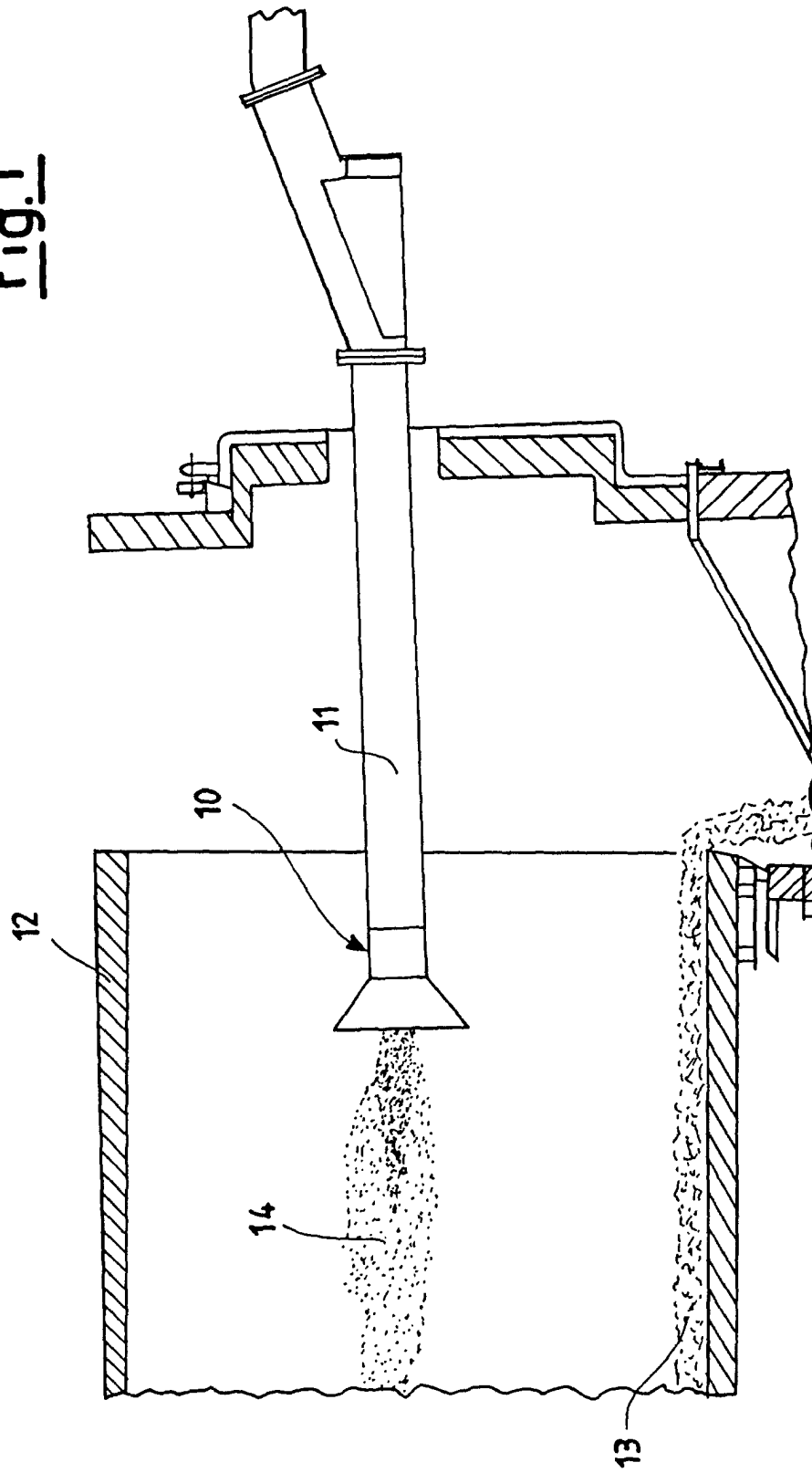


Fig.2

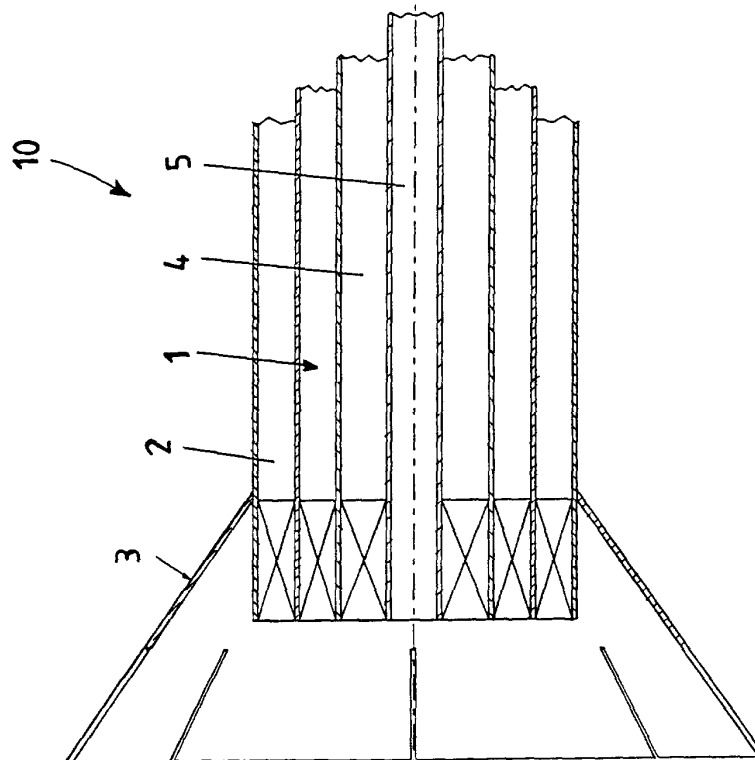
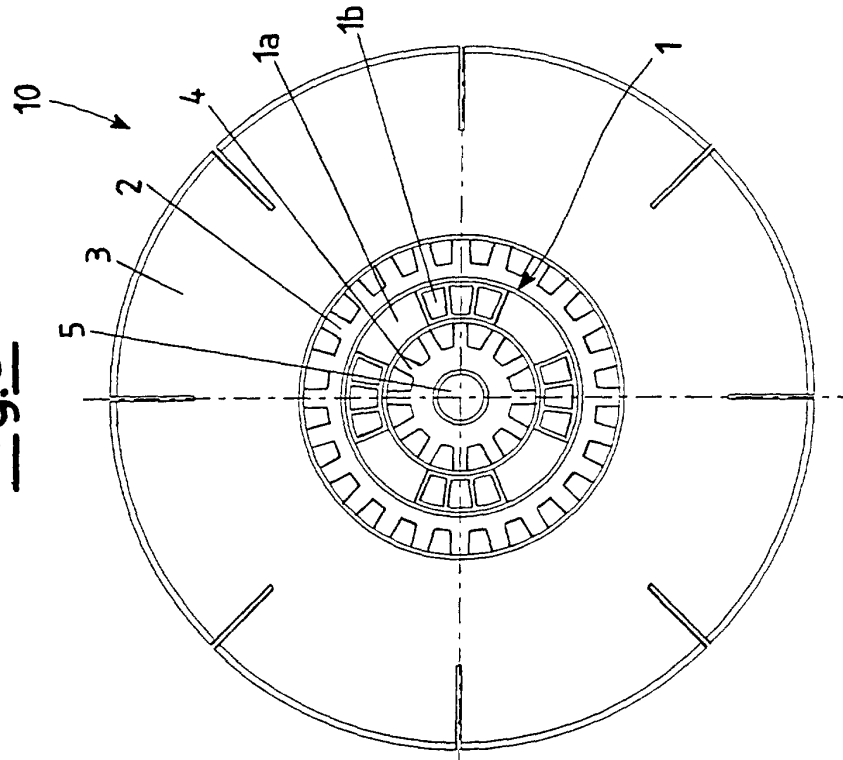


Fig.3



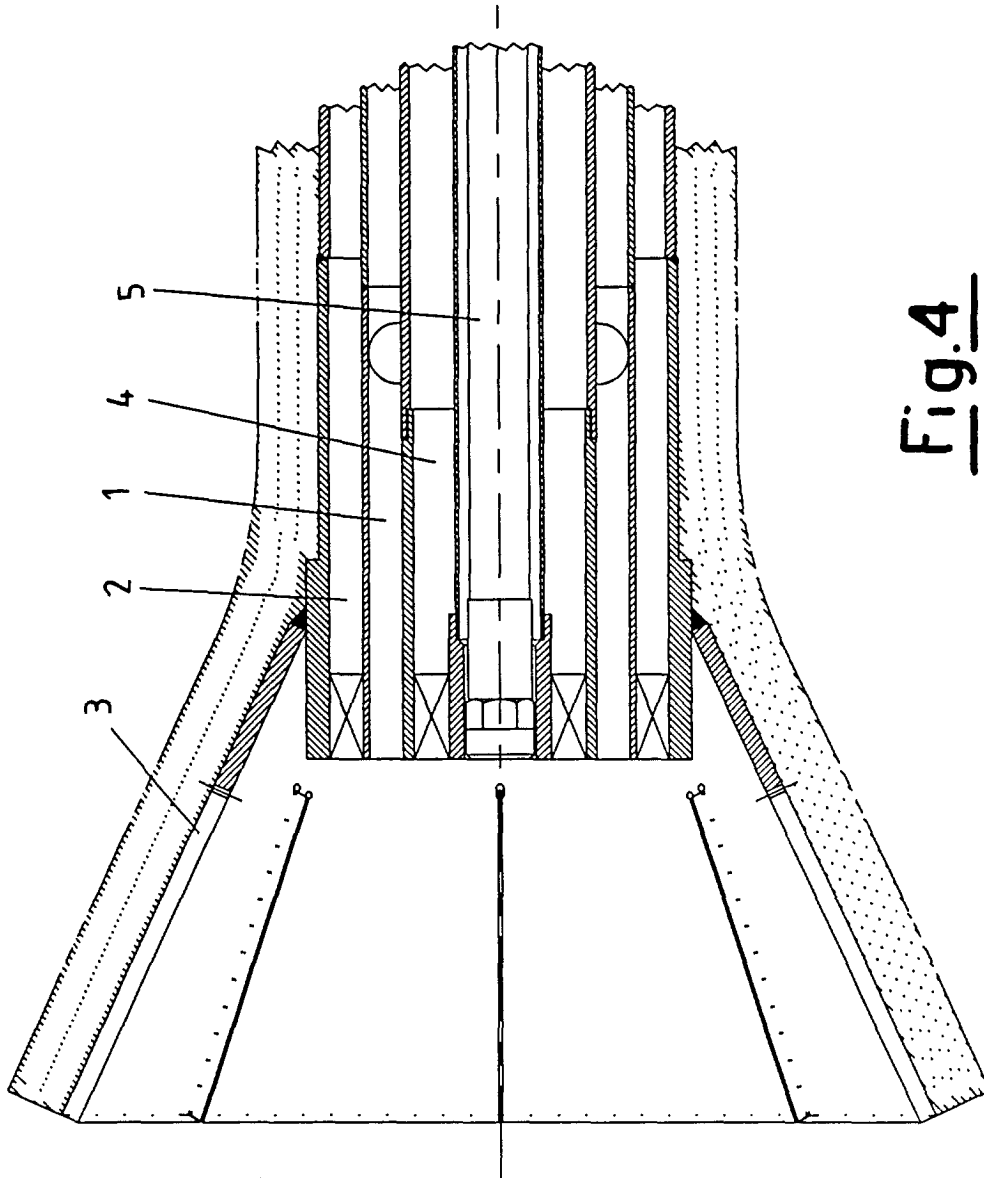


Fig.5

- 2400 tpd LEPOL KILN -
100 % petcoke - 60 Gcal/h

