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(71) Applicant: Boliden Aktiebolag
Box 5508
S-114 85 Stockholm(SE)

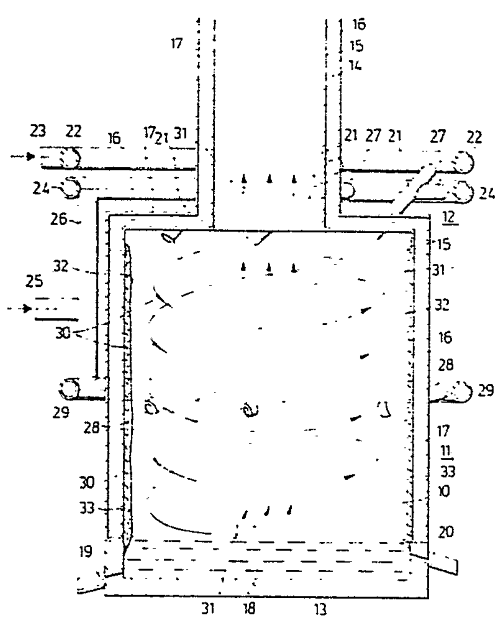
(72) Inventor: Hellestam, Carl-Johan Sigvard
Drottninggatan 153
S-252 33 Helsingborg(SE)

(72) Inventor: Elvander, Hans Ivar
Halalid 15
S-252 40 Helsingborg(SE)

(74) Representative: Lundin, Björn-Eric et al,
Boliden Aktiebolag Box 5508
S-114 85 Stockholm(SE)

(54) A gasification process.

(57) In the manufacture of fuel gas or synthesis gas by partially combusting carbonaceous fuel, preferably solid carbonaceous fuel having a high content of non-combustible constituents, finely divided fuel is injected into a shaft-like reactor chamber (10) and is combusted partially while moving down through the reactor chamber, to form a fuel gas or synthesis gas which is removed from the reactor chamber at the upper part (12) thereof, while simultaneously melting non-combustible constituents of the fuel, the resultant melt being taken out of the reactor chamber at the bottom part (13) thereof. A layer (32) of molten material which covers the wall (11) of the reactor chamber and moves downwardly along the wall is sustained by maintaining a selected temperature for substantially instantaneous melting of the non-combustible constituents of the fuel, and by selecting the directions in which the fuel is injected into the reactor chamber so that at least a substantial part of the fuel or the non-combustible constituents contained therein is brought into contact with the wall (11) of the reactor chamber or the layer (32) on said wall during movement down through the shaft. The wall of the reactor chamber is kept cooled in order to maintain thereon, between the wall and the molten layer (32), a frozen coating (33) formed by the non-combustible constituents of the fuel and protecting against slag attack and overheating.



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A GASIFICATION PROCESS

The present invention relates to a process for manufacturing fuel gas or synthesis gas by partially combusting carbonaceous fuel, preferably solid carbonaceous fuel having a high content of non-combustible constituents, such as in particular ash-rich coal, shales and carbon-containing residues obtained when working-up coal, comprising injecting fuel in a finely divided form into a shaft-like reactor chamber and partially combusting said fuel during movement down through said chamber, to form a fuel gas or synthesis gas during melting of the non-combustible constituents of the fuel, and removing the melt formed from the bottom part of the reactor chamber.

Known processes for manufacturing fuel gas or synthesis gas, said processes including inter alia the Koppers-Totzek-process, the Shell-Koppers-process, the Texaco-process, the C-E-process and the Otto-Saarberg-process, are encumbered with serious deficiences and limitations. Thus, it is necessary to use a very finely-divided fuel having a relatively low ash content if acceptable results with respect to gas production are to be obtained with the very short resident time available to the fuel in the reactor chamber, and if the problems relating to dust and slag are to be solved in an acceptable manner.

Consequently, the object of the present invention is to provide a novel and useful process of the aforementioned kind, in which said deficiencies and limitations are at least substantially eliminated.

To this end there is proposed in accordance with the invention a process of the kind mentioned in the introduction which is further characterized by maintaining in said reactor chamber a temperature which is selected for substantially instantaneous melting of the non-combustible constituents of the fuel, injecting the fuel and oxygen-gas or oxygen-enriched air through nozzles located at the upper part of the reactor chamber and directed obliquely downwardly and tangentially to imaginary horizontal circles having a diameter which is smaller than the smallest cross-sectional dimensions of the reactor chamber, to cause at least a substantial part of the fuel or its non-combustible constituents, during passage of the supplied and formed gas and the fuel suspended therein downwards in a helical path along the wall of the reactor chamber, to be brought into contact with said wall along substantially the whole height thereof, thereby forming and maintaining a molten layer covering and flowing down along said wall to the bottom part of the reactor chamber, cooling the reactor chamber wall for maintaining thereon between said wall and said molten layer, a frozen coating formed by non-combustible constituents of the fuel, causing said gas to turn at the bottom portion of the reactor chamber and pass upwardly in the centre portion of the reactor chamber, and removing the upwardly flowing gas through the top of the reactor chamber. In the molten layer caused to run down the wall of the reactor chamber in accordance with the invention, said molten layer comprising mainly molten slag obtained from the non-combustible constituents of the fuel, there is formed favourable reaction conditions for gasifying coal and carbonaceous combustible substances in the coarser fuel particles which, when coming into contact with the molten layer running down said wall, adhere to said layer and accompany said layer relatively slowly towards the bottom part of the reactor chamber. Because of the different physical properties of the particles in relation to the inorganic slag mass, said different physical properties being primarily a different density and different surface properties, the particles tend to collect on the surface of the slag layer facing the interior of the reactor chamber, where they are exposed to the hot combustion gases.

The partial combustion is effected with oxygen-gas or oxygen-enriched air, whereat high combustion temperatures, which promote the gasification of the fuel, and a rich fuel gas or synthesis gas can be obtained. Suitably, at least part of the gas sustaining said partial combustion is utilized as a carrier gas for injecting the finely divided fuel into the reactor chamber, thereby avoiding in an advantageous manner dilution of the resultant fuel gas or synthesis gas with a foreign carrier gas.

In order to enable the reactor chamber to be utilized effectively along the whole of its height, at least a part of the gas sustaining said partial combustion may suitably be introduced into the reactor chamber at a level located beneath the level at which the fuel is injected into said chamber.

A desired, relatively long gasification reaction time is obtained in accordance with the invention due to the fact that the fuel and the oxygen gas or oxygen-enriched air is injected through nozzles which are directed obliquely downwardly and tangentially to imaginary horizontal circles in the shaft-like reactor chamber having a diameter which is smaller than the smallest cross-sectional dimensions of the reactor chamber. A particularly favourable pattern of gas flow is obtained in the reactor chamber when applying this method of procedure, since both the supplied and the formed gas and the fuel suspended therein are first forced downwards in a helical path along the wall of the reactor chamber, to then turn and pass vertically upwardly in the centre of said chamber. During the rotary and downward movement of the gas suspension along the wall of the reactor chamber, solid and molten particles are caused to move towards the wall of the reactor chamber, whereat large particles will contact the slag layer high up on said wall and smaller particles lower down on the wall, whereat those particles which have already melted and the melt obtained by melting meltable material present in said solid particles form and maintain the molten slag covering the wall of the reactor chamber. As beforementioned, at the bottom of the reactor chamber the gas is forced to turn upwardly in the centre of the reactor chamber, whereat small particles still suspended in the gas stream continue downwardly and can be caught by a slag bath formed in the bottom part of the reactor chamber. In this way, the flow of gas passing upwardly through the centre of the reactor chamber is substantially clean of dust particles. The manner in which the gas flows through the reactor chamber makes possible an intensive exchange of heat between the downwardly passing gas and the upwardly passing gas. This enables a high temperature to be obtained throughout the whole of the reaction volume, which accelerates the gasification reactions and provides for rapid ignition of the reaction mass immediately adjacent the injection or supply nozzles. The practically dust-free gas in the centre of the reactor chamber also provides good heat-penetration conditions. Slag which runs down into the slag bath becomes very hot as a result of heat radiation, and becomes more liquid as a result thereof.

The wall of the reactor chamber is kept cooled, in order to maintain on said wall, between the wall and the molten layer thereon, a congealed or frozen coating formed by the non-combustible constituents of the fuel and protecting the wall against slag attack and overheating. In this respect there is preferably used an unlined metallic reactor wall having a cooling jacket through which a coolant is passed. In this way the reactor is self-lining, thereby advantageously avoiding costs and work involved with lining the reactor.

The layer of slag on the wall of the reactor chamber is heat-insulating and contributes therewith to maintaining the desired high reaction temperature in the reactor. For the purpose of maintaining a slag layer of desired thickness there is preferably used, when carrying out the gasification method according to the invention, a fuel which contains, or which can be caused to contain by means of additives, at least 40 percent by weight non-combustible constituents. Thus, when carrying out the method according to the invention high contents of ash-forming or slag-forming constituents in the fuel, for example to 70-80 percent by weight, are an advantage. This is in direct contrast to the case with the known gasifaciation methods recited in the introduction, in which there must be used relatively pure and expensive fuels, the ash content of which in each particular case should not exceed 40 percent by weight.

In accordance with the invention, the additives used for maintaining in the raw material charged to the reactor chamber a sufficient quantity of non-combustible constituents for forming and sustaining the slag layer on the wall of the reactor chamber, and for optional optimization of the composition of said constituents, include one or more materials taken from the group: lime, limestone, alkali compounds, iron compounds, suitably in the form of pyrites or pyrrhotites, silicates, quartz and parts of non-combustible constituents previously removed from the reactor chamber.

The fuel charged to the reactor chamber may contain sulphur, for example organically bound to carbon compounds in the form of inorganically bound sulphide or sulphate. Steam can to advantage be charged to the reactor chamber, suitably as a carrier gas for the fuel, in order to cause said sulphur to pass practically completely into the formed fuel gas in the form of hydrogen sulphide or carbonyl sulphide,these compounds being readily removable from the fuel gas and readily convertible to elementary sulphur.

When the fuel and optional additives charged to the reactor chamber contains iron compounds, the reduction conditions in the lower part of the reactor chamber can, in accordance with the invention, be advantageously so adapted that the iron compounds are reduced to iron,which is collected and discharged from the bottom part of the reactor chamber together with or separate from remaining constituents of said melt.

In this respect the gasification process can be combined with the manufacture of iron, for example by including in the raw material charged to the reactor chamber slag-forming additives in the form of iron pyrites or other iron-containing material, for example iron-containing shales or other poor, iron-containing materials able to provide the desired amount of slag and the desired slag composition in the reactor chamber. Additional heat for the reduction process and, if desired, for melting purposes may be supplied electrically or electro-inductively to a lower portion of the reactor by means of electrodes or induction coils.

The invention will now be described in more detail with reference to a vertical-sectional view of a reactor illustrated schematically in the accompanying drawing, which reactor can be used to advantage when carrying out the method according to the invention.

The gasifying reactor has a shaft-like reactor chamber 10 in the form of an upright cylinder whose diameter is approximately the same as its height. The reactor chamber 10 is bounded by a peripheral wall 11, an upper part 12 and a bottom part 13. Connected to the upper part 12 is a gas-outlet shaft 14. The wall 11, the upper part 12 and the shaft 14 have metallic walls 15 which face towards the interior of the chamber 10 and the shaft 14 respectively and which are surrounded by an outer shell 16. A suitable coolant, for example water and/or steam, is circulated in a space 17 between the walls 15 and the shell 16 in a manner not specifically described, so as to keep the walls 15 at a relatively low temperature. The reactor walls and shaft walls, comprising walls 15 and the shell 16, and the upper part 12 may suitably be formed of gas-impermeable panels obtained by welding together boiler tubes extending adjacent to one another.

The upper end of the shaft 14 discharges into an apparatus for purifying fuel gas or synthesis gas departing through the gas-outlet shaft 14 and for recovering physical heat from said gas, which gas is generated in a manner hereinafter described. This apparatus may comprise for example, a boiler and one or more cyclones. The bottom part 13 comprises a collecting part for melt 18 formed during the manufacture of said gas, and is provided with one or more outlets, as shown at 19 and 20, for discharging molten material from the reactor chamber 10, either continuously or intermittently.

The reference 21 identifies a plurality of nozzles or tuyers, which extend from a common distribution line 22 extending around the shaft 14, obliquely downwardly through the upper part 12 of the reactor and into the reactor chamber 10, whereat the tuyers 21 are inclined so that they also have a direction component which is tangential to an imaginary horizontal circle in the reactor chamber 10, the diameter of said imaginary circle being smaller than the diameter of said chamber. A supply line 23 discharges into the distribution line 22 and serves to conduct finely divided carbonaceous fuel suspended in a carrier gas, and optionally additives accompanying the fuel, into the line 22, from where the fuel is conveyed through the tuyers 21 and injected into the reactor chamber 10. The reference 24 identifies a further distribution line which extends around the shaft 14 and which supplies oxygen-containing gas via lines 25 and 26 and delivers said gas to the tuyers 21 through lines 27. The reactor is also provided to advantage with a ring of nozzles or tuyers 28, each of which extends from a distribution line 29 passing around the reactor, through the wall 11 of the reactor chamber 10 and into said chamber. In the illustrated embodiment, the line 29 is connected to the line 25 via the line 26, so that oxygen-containing gas is supplied to the reactor chamber through tuyers 28. As with the tuyers 21, the tuyers 28 extend obliquely downwardly and tangentially to an imaginary horizontal circle whose diameter is smaller than the diameter of the reactor chamber 10, so that material and gas injected through the tuyers 21, 28 is caused to move obliquely downwardly in a helical movement path, as shown by the arrows 30, the path taken by said gas and said material turning at the surface of the melt 18 located in the bottom part 13 of the reactor chamber 10, and from there passing upwardly centrally through the reactor chamber 10 and the shaft 14, as shown by the arrows 31.

When manufacturing fuel gas or synthesis gas while using the illustrated reactor there is injected into the reactor chamber 10 through the tuyers 21 a raw material in the form of a finely divided carbonaceous fuel having a high content of non-combustible constituents, together with oxygen-enriched air or commercial oxygen gas, and preferably also steam in a quantity sufficient to convert any sulphur compounds present in the raw material to hydrogen sulphide or carbonyl sulphide. At the same time, oxygen-containing gas is injected through the tuyers 28. As a result of the described design of the reactor chamber 10 and the positioning of the tuyers 21, 28 there is obtained the flow pattern indicated by the arrows 30, 31. The fuel-gas suspension is ignited, and the ratio between the fuel and the oxygen-containing gas sustaining the combustion process is adapted so that there is obtained in front of each of the outlet orifices of respective tuyers 21 a hot flame having a temperature of about 2000°C. In this way, the inorganic constituents of the fuel are rapidly caused to melt, whereat particles of coal and ash are thrown by centrifugal force towards the wall 11 of the reactor chamber, said wall having a lower temperature as a result of the aforementioned cooling. Molten particles close to the wall congeal or freeze into a hard mass, forming a coating 33 of frozen slag which lines the wall 11 of the reactor chamber 10. At locations more remote from the inner wall 15 of the reactor, said mass converts into a semi-molten or doughy state and forms on the side facing the interior of the reactor space 10 a downwardly running layer 32 of molten slag, which is collected in the form of a slag bath 18 at the bottom part 13 of the reactor. The layer 32 is sustained by newly arriving molten ash particles.

The high temperature causes volatile constituents in the fuel, e.g. alkali compounds, to be rapidly gasified and imparts a high reaction ability to silica or acid silicates. In the case of reactors having brick linings this would result in much wear on the bricks, since it is impossible to find a high-refractory brick which is capable of resisting both condensing alkali compounds and aggressive acid silicates. The metallic reactor inner wall 15, on which the formed slag freezes, is free from all attack, however.

The slag layers 32, 33 on the reactor wall 11 form a heat insulator therefor and, in this way, contribute to maintaining a desired high reaction temperature in the reactor chamber 10 and result in relatively low vapour production in the space 17. For the purpose of achieving a sufficiently good heat-insulating effect, the formed slag should not be excessively liquid. For example, a slag which runs too freely down the reactor wall 11 will impair the heat economy of the reactor.

Favourable reaction conditions for gasifying coarse coal particles are formed in the running slag layer 32. Because of the different physical properties thereof in relation to the inorganic slag mass the coal particles have a tendency to collect on the inner surface of the liquid slag layer 32. In this way said particles are influenced by the constituents of the slag, primarily iron oxides present therein. The very high reaction temperature of the flame issuing from the tuyers 21 splits the pyrites present into FeS, which together with other iron compounds are converted to wüstite. The wüstite reacts in the liquid slag layer 32 with carbon to form iron and carbon monoxide while cooling.

When oxygen-containing gas is blown through the tuyers 28 the iron again reacts to form iron oxide, which is able to gasify further carbon. Thus, iron present in the slag promotes the reactions taking place when gasifying coal.

Large solid fuel particles are thrown against the slag layer 32 higher up in the reactor space 10, while smaller particles accompany the downwardly flowing gas stream and adhere to the slag layer 32 further down. Thus, the coarser coal particles in the downwardly flowing slag layer have more time to be gasified. This means that a very low carbon content can be obtained in the slag bath 18. Thus, there can also be used fuel which is not so finely ground as that required in other so-called flash reactors.

A thick slag layer on the wall of the reactor chamber has a significant energy content in the form of physical heat. This heat actively contributes to ensuring that heat-requiring reactions in the slag layer 32, above all the reaction between wüstite and carbon, take place quickly enough.

The slag particles are quickly cooled from the very high flame temperature down by some hundred degrees centigrade in the slag layer. In this way the amount of alkali which leaves the reactor together with the gas is reduced. Consequently, the alkali will be present in the slag to a larger extent than otherwise usual in flash reactors. In this way troublesome coatings of alkali in the exhaust gas system are avoided, thereby decreasing the risk of blockages. When the non-combustible constituents of the fuel form highly viscous slag, e.g. a slag having a high aluminium-oxide content requiring the addition of a fluxing agent, the amount of fluxing agent required is less than would otherwise be the case, since more alkali remains in the slag and improves its flowability.

At the bottom of the reactor chamber 10 the small particles accompanying the gas continue to move downwardly and are caught by the slag bath 18, where the remainder of the gas turns and passes upwardly in the manner indicated by the arrows 31. The gas flow passing upwardly in the centre of the reactor chamber 10 becomes, in this way, relatively free from dust particles. The manner in which the gas flows also enables intensive heat exchange between the downwardly flowing gas and the upwardly flowing gas. This enables a high temperature to be reached throughout the whole of the reaction volume, which accelerates the gasification reactions and provides rapid ignition of the reaction mass immediately adjacent the injection tuyers 21. The practically dust-free gas in the centre of the reactor chamber provides good heat-penetration conditions. The slag, which is cooled somewhat as it flows down the wall 11 of the reactor chamber and runs down into the slag bath 18, is again heated to high temperatures by heat-radiation and made more liquid. Surplus slag is tapped from the bottom part 13 through one of the outlets 19 and 20, and is passed, for example, to a cooling and granulating plant. By selecting suitable reduction conditions, the iron compounds accompanying the fuel can be reduced to iron in the lower part of the slag layer 32, whereat said iron is collected beneath the slag bath 18 and may be tapped off separately through the outlet 19. The fuel gas or synthesis gas formed by incomplete combustion of carbonaceous fuel in the reactor chamber 10 is, as beforementioned, very pure and is discharged through the shaft 14 to a collecting or consuming station, subsequent to recovering heat and separating dust from said gas.

The oxidation potential in the gas mass in the reactor chamber 10 is regulated by the secondary oxygen charged through the tuyers 28. In this way a higher oxidation potential can be maintained adjacent the reactor chamber wall 11 thereby facilitating and accelerating the oxidation of coal particles and iron accompanying the slag layer 32 with favourable carbon transformation conditions as a result thereof.

As will be understood from the aforegoing, a slag layer 32 of suitable thickness is of great significance. In known powder reactors (flash gasifiers) a fuel having a low ash content is desired. To enable the advantages afforded by the described reactor to be utilized to the full the ash content of the fuel, however, should be high, preferably above 40%. If the fuel in its natural state does not have suitable properties, a slag former should be added, e.g. by admixing lime, limestone, alkali compounds or silicates and quartz. If the ash has a suitable composition but the ash content of the fuel is too low to obtain a satisfactory coating of slag on the wall 11 of the reactor chamber, discharged slag can be recycled. Because optimal functioning of the reactor requires a relatively large quantity of slag, it has been found particularly suitable for gasifying coal or coal residues having a very high ash content and shales. In this latter case, shales having an ash content of 70-80 percent have been found particularly suitable for gasification. The shale ash also contains about 5% iron and approximately an equal amount of alkali metals. It will be understood from the aforegoing, that this is an advantage in respect of the gasifying process, since it is possible during said process to utilize the reaction-promoting effect of the iron and alkali metals in this context to the maximum.

In the case of certain fuels having a low iron content, it is suitable to add iron. Since sulphur is normally present and it is necessary to recover hydrogen sulphide and carbonyl sulphide prior to using the fuel gas, the iron can advantageously be added in the form of pyrites or pyrrhotites, preferably of such quality as that obtained when purifying coal.

Since the presence of iron oxide in the liquid slag layer 32 on the wall 11 of the reactor chamber is advantageous from the aspect of gasifying the coal particles, it follows herefrom that it may be suitable to combine the manufacture of liquid raw iron and fuel gas in the reactor chamber 10. Thus, the method according to the invention is well suited for the manufacture of both crude iron and fuel gas having a high carbon monoxide content, from natural materials or mixtures of materials having a high content of iron oxide and/or iron sulphide and slag-rich coals.

Sulphur present in the raw materials, either organically bound with carbon compounds or present as inorganically bound sulphide or sulphate, can be caused to pass practically completely into the fuel gas in the form of hydrogen sulphide or carbonyl sulphide. These compounds can readily be recovered from the fuel gas and can be readily converted to elementary sulphur. Thus, the method according to the invention enables sulphur in iron raw-materials and carbon raw-materials, which as a rule must be considered a troublesome compound, to be readily converted to a valuable retailable product.

In order to obtain suitable fluidity properties of the slag it may be advantageous to mix the fuels. Thus, certain coal ashes are very rich in either alkali or lime. Such coals can be advantageously mixed with coals having acid ashes or with acid shales.

EXAMPLE

A gasification reactor of the kind illustrated in the drawing and able to gasify each year 900 kilotons of alun shale having a kerogen content of 22 percent by weight requires, for an operating time of 7900 hours per year and a gasifying temperature of 1550^{o}C, a reaction-chamber diameter of 4.5m and a reaction-chamber height of about 5m. The amount of oxygen gas consumed is 26500 m^3 (N)/h, of which 5000 m^3 (N)/h can be added at a location beneath the level at which the fuel is charged. The flux used may be burned lime in a quantity of 14 ton/h. In this way there is obtained the following production and process yields.

<u>Production</u>

Crude gas		63100 m^3 (N)/h
	Analysis: CO_2	16.9 percent by weight
	CO	40.6 " "
	H_2	12.4 " "
	H_2S	7.3 " "
	H_2O	21.3 " "
	N_2	1.5 " "
		100.0 " "
Slag		94 tons per hr

<u>Process yield</u>

Chemical heat content of the gas	55.7 %
Energy content of high pressure steam produced in reactor and steam generator	18.3 %
Physical heat in slag (about 70% recoverable)	19.9 %
Chemical heat in slag, metallic iron	2.8 %
Heat losses	3.3 %
	100.0 %

The method according to the invention is not restricted to the illustrated and described embodiment, but can be modified within the scope of the following claims.

CLAIMS:-

1. A process for manufacturing fuel gas or synthesis gas by partially combusting carbonaceous fuel, preferably solid carbonaceous fuel having a high content of non-combustible constituents, such as in particular ash-rich coal, shales and carbon-containing residues from coal enrichment processes, comprising injecting fuel in a finely divided form into a shaft-like reactor chamber and partially combusting said fuel during movement down through said chamber to form a fuel gas or synthesis gas during melting of the non-combustible constituents of the fuel, and removing the melt formed from the bottom part of the reactor chamber, characterized by

maintaining in said reactor chamber a temperature which is selected for substantially instantaneous melting of the non-combustible constituents of the fuel,

injecting the fuel and oxygen-gas or oxygen-enriched air through nozzles located at the upper part of the reactor chamber and directed obliquely downwardly and tangentially to imaginary horizontal circles having a diameter which is smaller than the smallest cross-sectional dimensions of the reactor chamber, to cause at least a substantial part of the fuel or its non-combustible constituents, during passage of the supplied and formed gas and the fuel suspended therein downwards in a helical path along the wall of the reactor chamber, to be brought into contact with said wall along substantially the whole height thereof, thereby forming and maintaining a molten layer covering and flowing down along said wall to the bottom part of the reactor chamber,

cooling the reactor chamber wall for maintaining thereon, between said wall and said molten layer, a frozen coating formed by non-combustible constituents of the fuel,

causing said gas to turn at the bottom portion of the reactor chamber and pass upwardly in the centre portion of the reactor chamber, and

removing the upwardly flowing gas through the top of the reactor chamber.

2. A method according to claim 1, characterized by utilizing at least part of the gas sustaining said partial combustion as a carrier gas for injecting the finely divided fuel into the reactor chamber.

3. A method according to claim 1 or claim 2, characterized by introducing at least part of the gas sustaining said partial combustion into the reactor chamber at a level located beneath the level at which the fuel is injected into said chamber.

4. A method according to any one of claims 1 - 3, characterized by using an unlined metallic reactor wall having a cooling jacket through which a coolant is passed.

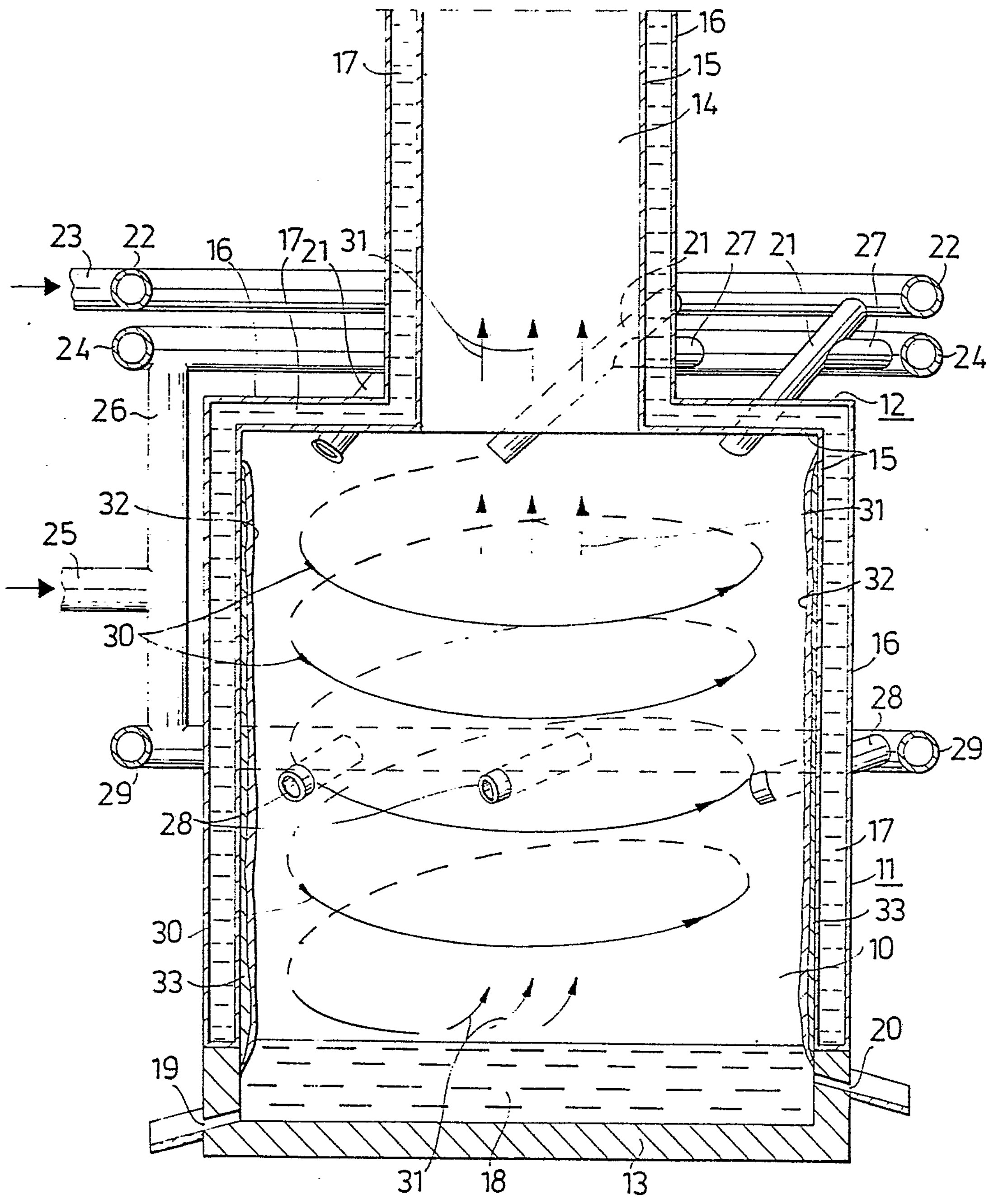
5. A method according to any one of claims 1 - 4, characterized by using a fuel which contains or which, by means of additives, is caused to contain at least 40% by weight non-combustible constituents.

6. A method according to claim 5, characterized by using for maintaining a sufficient quantity of non-combustible constituents and for optionally optimizing the composition of said constituents, additives which include one or more materials taken from the group lime, limestone, alkali compounds, iron compounds, suitably in the form of pyrites or pyrrhotites, silicates, quartz and parts of non-combustible constituents previously removed from the reactor chamber.

7. A method according to any one of claims 1 - 6, characterized by charging steam to the reactor chamber, suitably as a carrier gas for the fuel.

8. A method according to any one of claims 1 - 7, characterized by reducing iron compounds accompanying the fuel to iron by correspondingly adapting the reduction conditions in

the lower part of the reactor chamber, said iron being collected and discharged from the bottom part of said reactor chamber together with, or separate from, remaining constituents of said melt.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