(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 December 2005 (08.12.2005)

PCT

(10) International Publication Number
WO 2005/116524 A1

(51) International Patent Classification[7]: F23G 5/00, 5/20, 5/027, 5/32

(21) International Application Number: PCT/GB2005/001768

(22) International Filing Date: 10 May 2005 (10.05.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0411643.0 25 May 2004 (25.05.2004) GB
0500620.0 13 January 2005 (13.01.2005) GB

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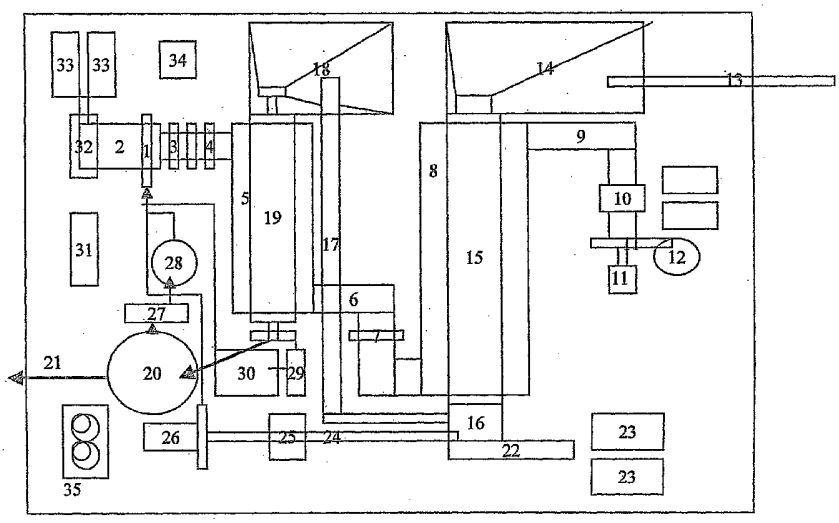
(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ,*

[Continued on next page]

(54) Title: IMPROVED GASIFIER



(57) Abstract: An apparatus and process for converting carbonaceous or other material with calorific value into high quality gas preferably to fuel a reciprocating gas engine for the generation of electricity. Wet fuel is delivered via conveyer (13) to fuel hopper (14). From the hopper the fuel is fed into the dryer (15) by a screw feeder. The dried fuel then is checked for size via a trammel (16) where the correctly sized fuel passes through and the oversized fuel goes onto the reject conveyer (22) where it is delivered for shredding. The correct sized dry fuel is transported via a conveyer (17). The fuel is then fed via a feed system, to avoid the ingress of air, into the gasifier (19) provided with an innovative internal vane configuration. The gas is cooled and cleaned in the gas quench unit (20).

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CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*
— *of inventorship (Rule 4.17(iv)) for US only*

Published:
— *with international search report*
— *with amended claims*

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IMPROVED GASIFIER

The present invention relates to an apparatus and process for the gasification of any carbonaceous or other material of useable calorific value to produce a high quality gas preferably to fuel a reciprocating gas engine for the generation of electricity

Sources of traditional fossil fuels and hydrocarbons have a finite life and there is ever growing pressure from environmental groups, as well as government authorities, to clean up the planet. There is also international pressure to suppress noxious emissions that are causing climate change. Waste to energy systems are known, but mainly rely upon incineration with high capital cost and production of large quantities of dirty ash, and are increasingly becoming unacceptable.

The present invention provides an efficient solution, at a relatively modest capital cost. The system provides significant improvements to well known, long established technology, with the advantage of allowing a modular and adaptable system to be custom built to suit the composition and quantity of the waste supply. The design has low maintenance costs and beats by a substantial margin all emission targets set by international and domestic treaties and agreements. A wide range of fuels can be processed including, but not limited to, forestry waste, municipal waste after removal of metals, food waste including factory processing waste, sewage, animal waste and rubber tyres.

The process is one of continuous flow. The waste is dried and metals, if present, are extracted. Any plastics, glass etc can also be removed although this is not essential. The waste is then graded, with the oversize material being shredded and re-introduced. The fuel thus produced is then injected into an unique anaerobic gasifier and gasified at about 800°C. The gas is cooled and filtered to remove contaminants before being fed into gas engines or gas turbines for power generation. The solid residues from the gasifier together with any oils and tars are then introduced into a secondary gasifier to produce further gas and heat for use in the cycle. The minimal residues are converted to an inert vitrified slag for use in the construction industry. Hence the full process has no unusable residues.

The gasifier consists of a substantially horizontal, cylindrical reactor which rotates slowly within a refractory lined furnace vessel. The waste material is indirectly heated in an oxygen free atmosphere. The gas produced, after cooling and cleaning, can be used to generate "green" electricity via a gas engine or gas turbine. Thermal energy produced also has profitable uses.

The main feature of the design is the provision of an innovatory internal vane arrangement which allows homogeneous distribution of the feed material over a large area of the retort. This exposes it quickly to the heat without the need for rapid tumbling and agitation that is used in competing processes. Furthermore "cold spots" are avoided, thus increasing the plant's ability to produce gas of a consistently good quality.

As a result of the internal configuration, the design is also an improvement on the conventional rotating reactor design because it permits the use of a more compact unit. A slight increase in diameter allows the use of a shorter vessel. Thermal analysis confirms that the system provides the correct rate of heating needed to generate good quality gas. The refractory lining acts as a good heat sink and gives the required temperature stability.

The design is robust and has the advantage that, whilst innovative, it draws on proven engineering principles and also avoids the problems associated with other systems that incorporate high speed moving parts.

By way of example only, a specific embodiment of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic view of a gasification plant in accordance with the present invention.

Figure 2 is a longitudinal section of the gasifier.

Figure 3 is a cross-section of the gasifier kiln.

Figure 4 is a diagrammatic view of the secondary gasifier showing the principal flow patterns. The dotted lines are not structural. They show flow boundaries.

Referring to figure 1, wet fuel is delivered via conveyer 13 to fuel hopper 14. From the hopper the fuel is fed into the dryer 15 by a screw feeder. The fuel rolls around the dryer and is heated to evaporate off the moisture. The drying process also serves to sterilize the fuel feed. The dried fuel is then graded for size via a trommel 16 where the correctly sized fuel passes through and the oversized fuel goes onto the reject conveyer 22 where it is delivered to a reject skip 23 for further processing.

The correct sized dry fuel is transported via a conveyer 17, along with the fuel that did not require drying. Both fuels are stored in the dry fuel hopper 18.

The shredding of oversized dry fuel is carried out by selected equipment suitable for the material to be shredded (eg. tyres, dry industrial waste). On completion the material is carried by a separate conveyor and dropped onto conveyor 17. Oils and other liquid fuels are stored in tanks and pumped into the gasifier 19 or bio oil storage tank 28 to fuel a secondary gasifier depending on the fuel combinations being processed and the respective heat balance.

The fuel is then fed via an elaborate purged feed system, to avoid the ingress of air, into the gasifier 19 where it is heated to separate the gas from the solid char. The gas is cooled in the gas quench unit 20 where it is also cleaned. The gas is then compressed and stored in a gas storage unit. Then it is used to fuel a gas engine to generate electricity.

The char is quenched in a water trough then fed by a screw conveyer to a dryer 29 then stored in a hopper 30. Oils and tars that are carried over with the gas are removed by an extraction unit 27 and stored in storage vessel 28. From storage the oils are used as a fuel along with the char via burners 1 to fuel the secondary gasifier 2. The combustion air used in the secondary gasifier is taken from the dryer. This air is dried in 25 by the forced draft fan 26

then sent to the combusters1. Any slag that is produced in the secondary gasifier pours out from the secondary gasifier as a vitrified slag into a trough 32 where it is removed into skips 33.

The hot gases from the secondary gasifier are treated to reduce NOx by NOx suppression system 3. The temperature is then controlled at 4 before heating the gasifier 5. Having heated the gasifier the hot gases are guided via ducts 6 to a further stage of temperature control 7. From there they heat the dryer before being guided via duct 9 to a filter 10 that collects any dust allowing the clean exhaust to pas to the chimney 12 via an Induced draft fan 11.

The preferred plant equipment is further described in the following sections.

The process takes any carbonaceous material, wood, plastic etc with a size less than 16mm. Gas quality is initially determined by the overall temperature and subsequently by the gas temperature and gas residence time in the gasifier. By a process of rapid heating in the absence of air in the rotary kiln gasifier, the sorted waste is gasified to produce significant quantities of gas fuel. To maintain the safety and integrity of the gasifier a pressure release system is needed to enable the swift release of gas. As the gas will be at a high temperature its release into the atmosphere will cause it to self ignite. Thus this emergency release will be directed through a low-pressure flare immediately above the gasifier. A nitrogen purge system ensures safe operation during start up and shutdown.

Wet fuel is transported, by conveyor, to a storage hopper that has a volumetric capacity for 3 hours at maximum output. The fuel is fed by gravity into a screw feeder then into the dryer. This allows for control of the feed rate into the dryer. This unit will improve the energy efficiency of the overall process by using waste heat to drive off moisture.

In the dryer, the fuel will be dried to water content of less than 8%, dependent on the inlet water burden, though if this rises above 40% then the "dried" fuel moisture content may rise above 8% whilst the system stabilizes.

The dryer is a rotating kiln type dryer with internal fins to increase the heating surface area and to keep the fuel moving. Dryer temperature is controlled to maintain a fuel temperature of around 125'C to 140'C so as to minimize premature pyrolysis of the waste. The dryer is designed for fuel temperatures of 240'C. Temperature control is by dilution air added to the hot exhaust gases from the gasifier. These are thermally controlled to supply the required temperature to the dryer.

The dryer runs at a constant speed and the control variables are wet fuel feed rate and heating temperature. The fuel dwell time in the dryer is controlled by the incline of the dryer and is pre-set to 20 minutes. The dryer exhaust gases then pass through a ceramic fabric filter for removal of particulates. An Induced air fan draws the exhaust gases through the dryer and filter. The end of the dryer has a trommel that rejects the fuel of a size greater than 5/8 of an inch. The correctly sized fuel travels to the dry fuel hopper and the rejects fall into a skip.

The wet air from the dryer is drawn off. This air is then dried through cooling to provide dry air to the forced draft fan. The water collected is used as part of the secondary gasifier de NOx system

The dry fuel is stored in the dry fuel hopper above the gasifier. It has a 3-hour supply of fuel at maximum load. By gravity the fuel falls into one of 2 sets of hydraulically actuated ram loaders, where waste is charged incrementally to the gasifier. Each loader is phased, one filling whilst the other is feeding the gasifier. A purpose designed feeding mechanism has been provided which ensures a positive seal between the gasifier and atmosphere, purge entrained air from the fuel and positively feed the fuel to the gasifier.

Based on the principles previously outlined, the gasifier is a rotary kiln consisting of a rotating, slightly inclined metal shell or tube, which progressively transports the fuel along its length, and is contained within a refractory lined static metal shell. The exhaust gas from the secondary gasifier external to the kiln heats the tube.

A quench system cools the gas, and a gas clean up plant then ensures that the gas is suitably cleaned of contamination. An effluent plant neutralizes the effluent streams from the gas clean up system. The function of the gas clean up plant is to remove the contaminants from the gas stream. Cleaning is required to prevent contaminants from causing a problem within the downstream equipment such as rapid clogging of filters and corrosion of gas engine internals etc.

The particulates are removed by physical separation, whilst the halides and sulphurous compounds are removed by chemical reaction. The plant also includes a polishing filter to remove trace compounds including dioxins, furans and heavy metals.

Gas and minimal liquid products exit the gasifier in the gaseous phase and pass through a quenching spray that reduces the gas temperature and saturates the gas to its adiabatic condition. This allows condensation of the oils and tars and performs a degree of solids removal.

Owing to the expected levels of condensable tars and oils it was decided that a wet quench would be more prudent. The condensates of the volatile hydrocarbons are collected and removed regularly to the bio oil storage tank. Operational experience will determine the actual frequency.

The design requires a use of chemicals based on the normal expected levels of contaminants. This is very much dependent on the composition of the waste.

A gas compressor is situated before the carbon filters to ensure that the gas is drawn through the gas clean-up plant and is of sufficient pressure to pass through the carbon filter and then feed the gas engine and also to achieve the gas storage compressor's inlet pressure.

Liquors are collected from the plant and delivered into a liquor holding tank. These will include the blow down from the char quench system and spent materials from the scrubbing stage. The effluent will include chlorine, fluorine, sulphur and hydrogen sulphide contaminants, which are oxidised at stabilized pH levels by the addition of sodium hydroxide and sodium hypochlorite. The liquors are then injected into the secondary gasifier.

Chlorine compounds, a precursor to the formation of dioxins and furans, are expected to be present in the gas. However, their formation in the gasification process will be minimal owing to the absence of significant quantities of oxygen Nevertheless, provision is made in the gas clean up plant to remove chlorine compounds.

The transition time of the fuel from initial entry to ash removal is determined by the angle of inclination, the speed of rotation being pre-set. The angle of inclination can be adjusted manually. The gasifier is designed to heat up the fuel as quickly as possible to the pyrolysis temperatures in order to minimize carbon in the ash. The temperature of the gas will initially be determined by the temperature of the fuel when the gas is given off, and subsequently by heat gained by the gas from the shell and from the ash being tumbled by the gasifier.

Solid ash or char residue from the gasifier is deposited into a water-cooled receiver to reduce the temperature. The char is then ground and transported via a screw conveyor into the char storage hopper. From here the char will be collected via bottom silo empting rotary valves through gravity and carried in the primary combustion air into a char combustor.

The char, carbon and ash, from the gasifier is used as the primary fuel in the secondary gasifier, together with the tar and oil collected during the gas quench process. Added to this will be any concentrated effluent and the dust from the filters. The non-combustibles are vitrified in the secondary gasifier to produce a slag. This vitrified slag is used in the construction industry.

A gas storage facility is also provided to smooth out variations in gas quality caused by changes in the waste stream. The storage tanks can also supply gas for short periods when the gasifier is not producing gas, for example during start-ups.

The gas is preferably fed into a gas engine, which drives an alternator to generate electrical power for export into the local grid network. The exhaust heat from the gas engines is added to the system to support the process.

The secondary gasifier is designed to form a molten slag from the ash products encapturing pollutants and to produce a vitrified slag.

The refractory-lined vessel is fired by multiple fuel burners that can operate on gas, fuel oil, Including the bio oils and tars and the char from the gasifier.

As the fuel is injected into the secondary gasifier it is gasified and as the gas burns progressively as it travels down through the secondary gasifier it is aerodynamically forced to rotate at high speed.

The secondary gasifier has a unique flow made up of two aerodynamic spirals, one inside the other. The outer spiral rotates downwards towards a vortex collector cone, and as the flames spin down the cone the rotation inverts into a vortex. This causes the remaining ash to eject into the molten pool that collects and finally drains into a water trough by gravity, leaving cleaned gases to spiral through the ultra high temperature central axis.

Centrifugal force retains the heavier un-gasified fuel with ash products and other matter around the periphery of the cylindrical chamber thus providing a longer gasification/burn time and thus reducing the emissions. This also cools the walls, which run at less than 900 °C for long refractory life. As the gases burn out and become rarefied at very high temperature they rotate towards the central outlet. Circling the flames back on themselves and blending layer upon layer achieves regenerative combustion, which increases the temperature on residence period to several times that of conventional burners.

Immediately after the secondary gasifier, a water and urea injection system reduces the temperature and NOx levels. This system consists of a urea concentrate holding tank and a mixing tank where the water from the combustion air dryer is delivered. The mixing tank is controlled to give the correct consistency of urea and water to minimize the NOx levels.

Whilst the invention has been described in detail in terms of a specific embodiment thereof, it will be apparent that various changes and modifications can be made by one skilled in the art without departing from the spirit and scope thereof.

CLAIMS

1: An apparatus and process for the treatment of material with a significant usable convertible calorific value comprising an externally heated rotary, approximately horizontal, un-pressurised internal cylindrical vessel within a static outer vessel with a feed mechanism for ingress of suitably sized fuel designed to ensure anaerobic conditions within the said inner vessel.

2: An apparatus as claimed in claim 1, wherein the longitudinal axes of the vessels are inclined at an angle in excess of 1% to the horizontal.

3: An apparatus as claimed in claim 2 in which the heating of the volume between the inner and outer vessels is achieved by hot gases produced in the process.

4: An apparatus as claimed in claim 3, in which the fuel material is indirectly heated to approximately 850 °C in an oxygen free atmosphere.

5: An apparatus as claimed in claim 4 in which the heating medium is supplied by the product of the process.

6: An apparatus as claimed in any one of claims 3 to 5 in which the internal rotary vessel is provided with internal longitudinal substantially parallel vanes.

7: An apparatus as claimed in claim 6 in which the said vanes are of a profile to restrict the fall of the material whilst providing an increased heated surface area.

8: An apparatus as claimed in claim 7 in which the vanes are substantially L shaped in cross section.

9: An apparatus as claimed in claim 8 in which the vanes are attached by means of bolts and interlocking mortises to allow for expansion and contraction whilst holding the vanes firmly in place.

10: An apparatus as claimed in any one of claims 1 to 9 in which the outer vessel is insulated with a heat retentive material.

11: An apparatus as claimed in any one of the previous claims including a gas quench system.

12: An apparatus as claimed in any one of the previous claims including a secondary gasifier.

13: An apparatus and process as claimed in claim 12 in which the secondary gasifier comprises two substantially concentric dynamic spirals induced by tangential introduction of fuel into a refractory lined vessel..

14: An apparatus as claimed in claim 13 in which the secondary gasifier is fuelled by char, oils and/or tar

15: An apparatus as claimed in claim 14 in which the secondary gasifier is fuelled principally by the product of the primary gasifier.

16: An apparatus as claimed in any of claims 12 to 14 7 in which the exhaust gas from the secondary gasifier is ducted to heat the primary gasifier which in turn provides a fuel source for the secondary gasifier.

17: An apparatus as claimed in claim 16 in which residual ash is ejected at the base of the secondary gasifier allowing cleaned gases to be extracted by the cyclonic flow.

18: An apparatus as claimed in any of claims 13 to 17 in which steam is injected into the secondary gasifier with the fuel.

19: An apparatus as claimed in any of claims 13 to 18 in which contaminated liquors are injected into the secondary gasifier for cleaning and purification.

20: An apparatus and process for the gasification of waste residues or any other fuel of significant calorific value constructed or adapted to operate substantially as described herein with reference to and as illustrated in the drawing.

AMENDED CLAIMS

[Received by the International Bureau on 21 September 2005 (21.09.2005): original claims 1-20 replaced by amended claims 1-15; (2 pages)]

1: A method for the treatment of material with a significant usable convertible calorific value including a primary gasifier comprising an externally heated rotary, slightly inclined to the horizontal, un-pressurised internal cylindrical vessel within a static outer vessel, with a purged feed mechanism for substantially axial ram injection of suitably sized fuel designed to ensure anaerobic conditions within the said inner vessel and to produce a gas used solely to fuel a gas engine or gas turbine.

2: A method as claimed in claim 1 in which the heating of the volume between the inner and outer vessels is achieved by hot gases produced in a later stage of the process.

3: A method as claimed in claim 2 in which the fuel material is indirectly heated to approximately 850 °C in an oxygen free atmosphere.

4: A method as claimed in claim 3 in which the heating medium is hot gas supplied by the high temperature gasification in a secondary gasifier of the char and other residues of the primary gasifier after removal of the pyrolysis gas produced in the primary gasifier.

5: A method as claimed in claim 4 in which the secondary gasifier is fuelled by residues from the primary gasifier and from the gas clean-up system after extraction of the gas from the primary gasifier.

6 A method as claimed in claim 5 in which the fuel introduced into the primary gasifier is dried in a rotary dryer and the hot air from the dryer is introduced into the secondary gasifier with the fuel.

7: A method as claimed in claim 5 or claim 6 in which the secondary gasifier is a single refractory lined vessel in which two substantially concentric dynamic helices are induced by tangential introduction of fuel, the inner helix rotating in an opposite direction from the outer helix in both vertical and circular motion.

8: A method as claimed in claim 7 in which there is no physical barrier between the inner and outer helices.

9: A method as claimed in claim 7 or claim 8 in which residual ash is ejected at the base of the secondary gasifier allowing cleaned gases to be extracted by the cyclonic flow.

10: A method as claimed in any of claims 4 to 9 in which steam is injected into the secondary gasifier with the fuel.

11: A method as claimed in any of claims 4 to 10 in which contaminated liquors are injected into the secondary gasifier for cleaning and purification.

12: Apparatus for carrying out the method of any one of the previous claims in which the internal rotary vessel of the primary gasifier is provided with internal longitudinal substantially parallel vanes of a profile to distribute the fuel and restrict its fall from the central axis, at the same time providing an increased heated surface area.

13: An apparatus as claimed in claim 12 in which the vanes are substantially L shaped in cross section and spaced in such a manner that a separating gap between the inner adjacent edges of the vanes is of a dimension to limit the free flow of fuel from the central axial space to the outer spaces adjacent to the surface of the rotary vessel in order to improve heat flow and prevent rapid tumbling and agitation of the fuel.

14: An apparatus as claimed in claim 13 in which the vanes are attached by means of bolts and interlocking mortises to allow for expansion and contraction whilst holding the vanes firmly in place.

15: An apparatus as claimed in any one of the previous claims including a cyclone for removal of excess liquid, a rotary dryer and a water and urea injection system.

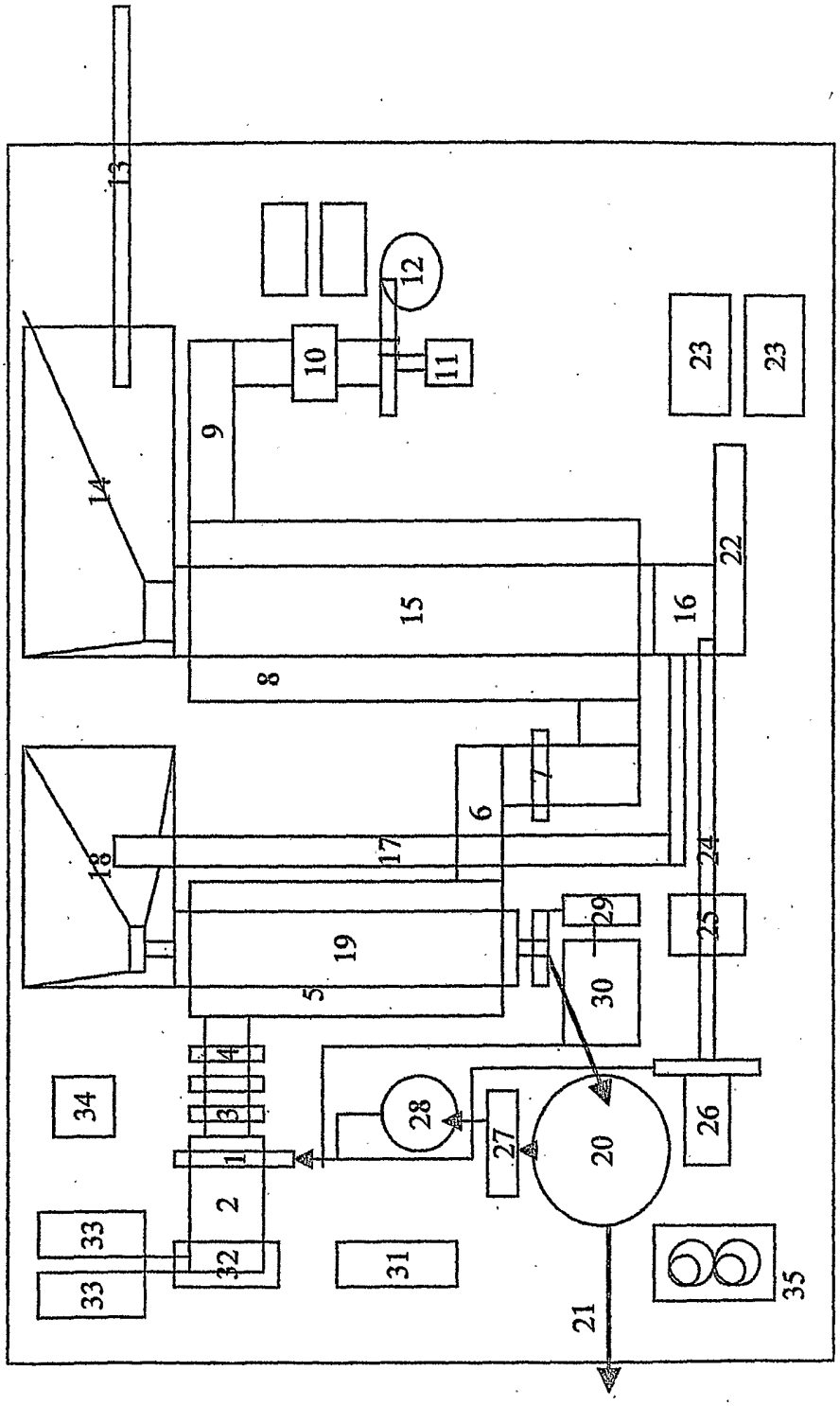
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Figure 1

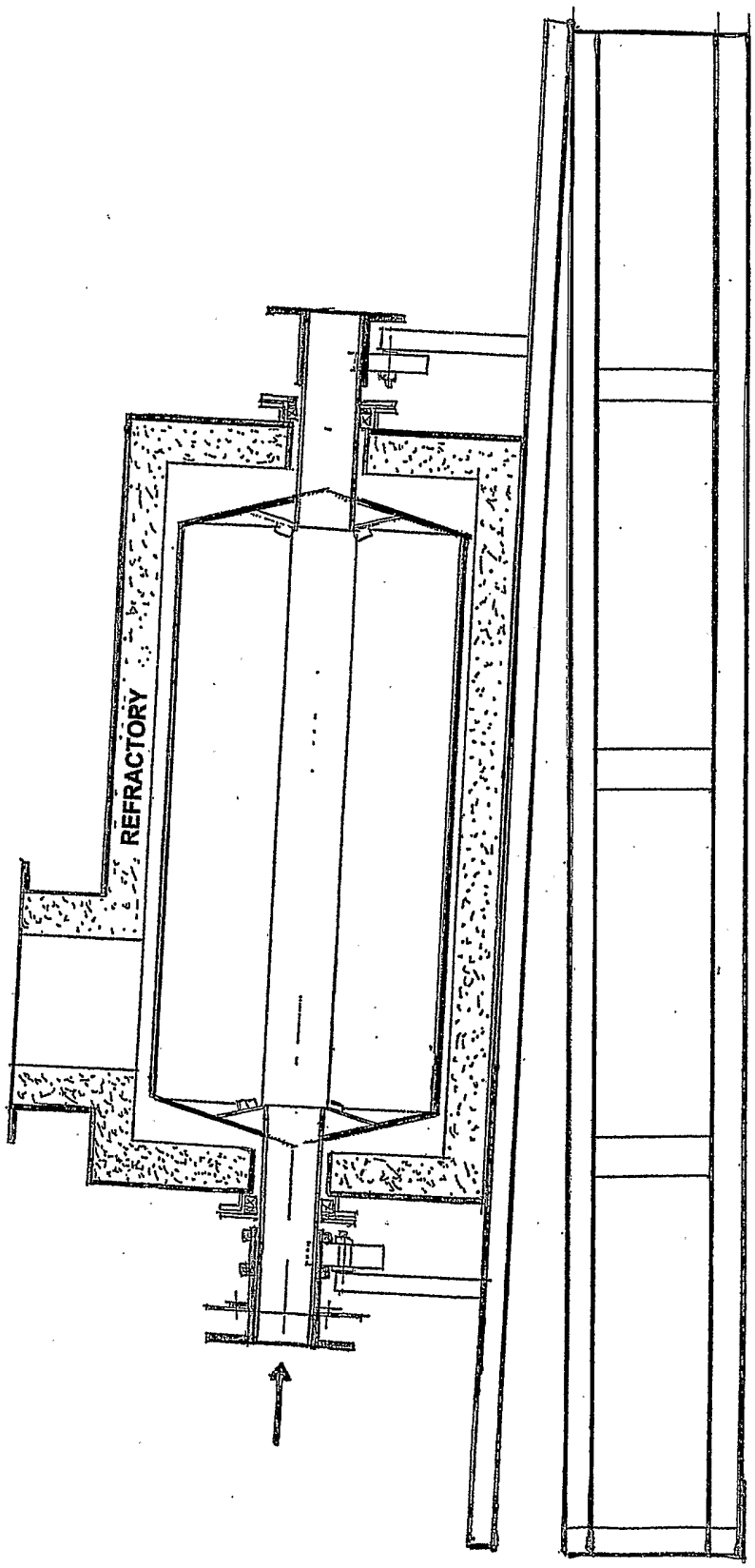

Figure 2

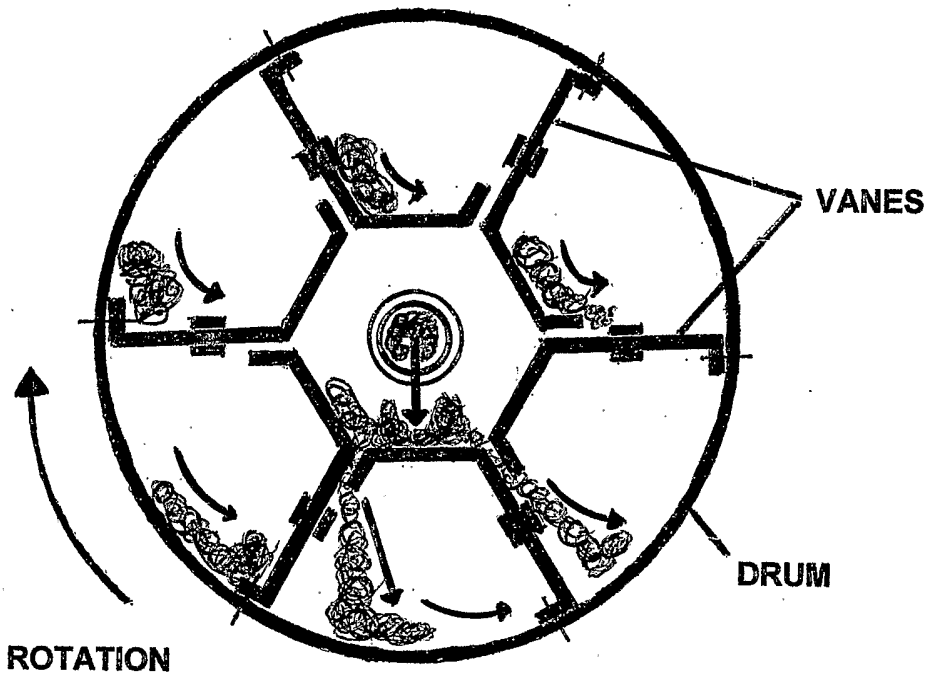

Figure 3

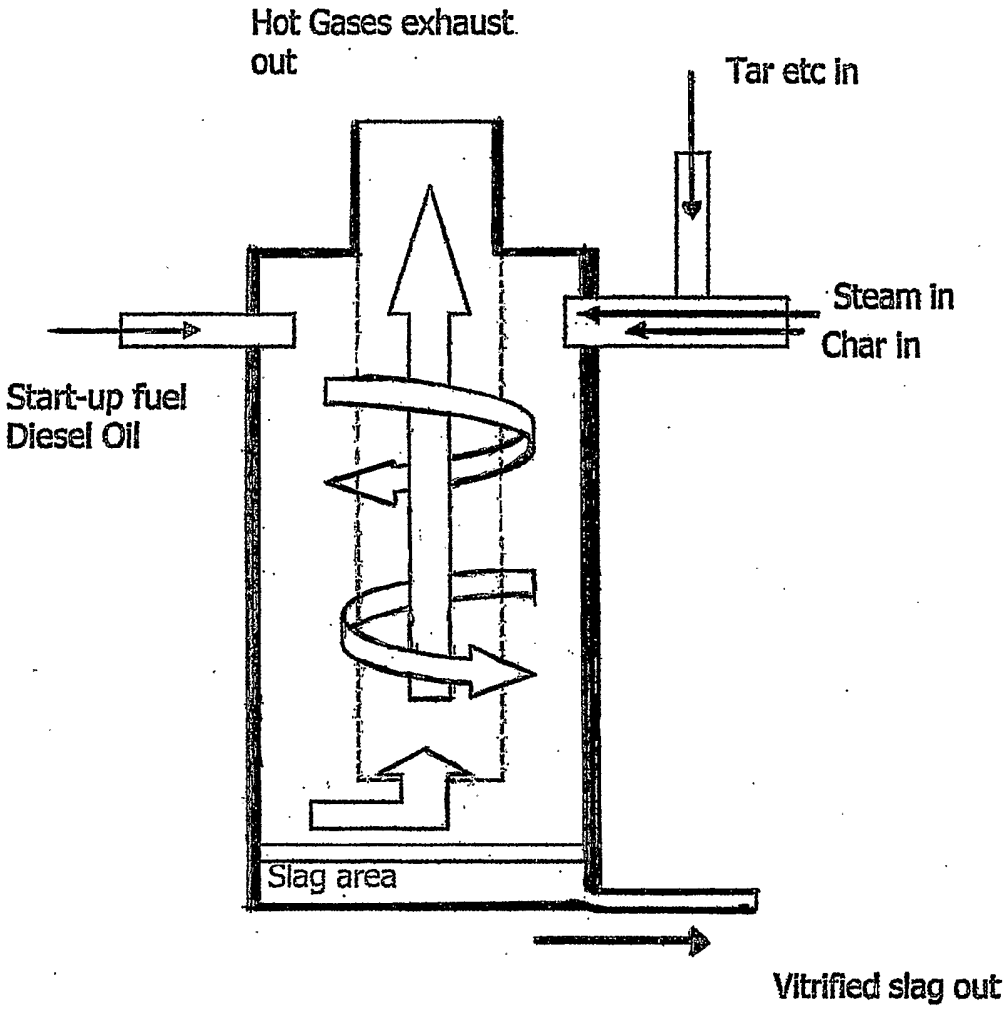
Hot Gases exhaust out
Tar etc in
Steam in
Char in
Start-up fuel
Diesel Oil
Slag area
Vitrified slag out

Figure 4

INTERNATIONAL SEARCH REPORT

PCT/GB2005/001768

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F23G5/00 F23G5/20 F23G5/027 F23G5/32

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F23G

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 6 178 899 B1 (KANEKO MASAKI ET AL) 30 January 2001 (2001-01-30) the whole document	1-5,11, 12 6-8
X	US 6 018 090 A (SCHMIDT ET AL) 25 January 2000 (2000-01-25) column 4, line 30 - line 67 column 5, line 34 - line 44	1-3,11, 12
X	US 6 270 630 B1 (XING LI) 7 August 2001 (2001-08-07) column 5, line 66 - column 6, line 67 column 7, line 28 - line 30; figure 1; example 2	1,3, 10-12
X	EP 0 908 672 A (EBARA CORPORATION) 14 April 1999 (1999-04-14) paragraphs '0007! - '0010!; figure 4	1,12-16

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2005	10/08/2005

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

PCT/GB2005/001768

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 110 430 A (SWISHER, JR. ET AL) 29 August 2000 (2000-08-29)	1
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