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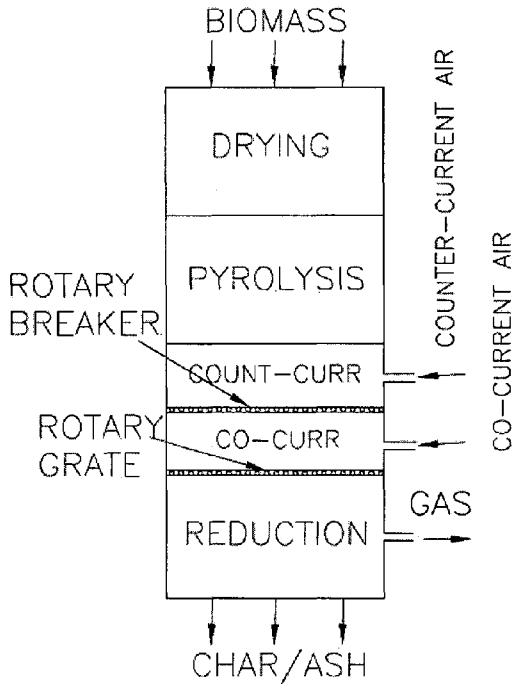
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(54) Title: MULTI-CONDITION THERMOCHEMICAL GAS REACTOR



(57) Abstract: The gas reactor comprises a drying zone (6), carbonisation zone (7) and pyrolysis zone (8) for preparing biomass feedstock for gasification. The biomass feedstock for gasification enters the counter-current gasification zone (15) and a co-current gasification zone (17) after passing through drying zone (6), carbonisation zone (7) and Pyrolysis zone (8) of the gas reactor. The gas reactor is constructed to operate in a combined mode or in a selected mode of counter-current gasification and co-current gasification. A breaker shaft assembly (16) with shaft arrangements (30) and paddle breakers (31) are placed in between the counter-current gasification zone (15) and co-current gasification zone (17). Rotating grates (22) and screw conveyer assembly (12) are placed below the co-current gasification zone (17) to discharge the ash produced in the gas reactor. The thermochemical gas reactor works under diverse conditions with regards to feed, shape, size, moisture levels, bulk density and operated on all types of bio-mass to convert them to a tar free gas by removing ash and particulate in the proficient manner.

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MULTI-CONDITION THERMOCHEMICAL GAS REACTOR

FIELD OF INVENTION

The present invention relates to gas reactors, and more particularly to an improved thermochemical biomass gas reactor for efficient conversion of biomass materials into usable heat energy, by incorporating the combined modes and operational advantages of counter-current and co-current gasification.

BACKGROUND OF THE INVENTION

The depletion of non-renewable petroleum energy resources has caused increased interest in renewable biomass energy resources. The potential energy contained in wood residues and other biomasses are the attractive possibilities for reducing our dependence on fossil fuels. Further, the environment-friendly power generation through renewable sources of energy is the need of the hour in consideration to the conventional power generation systems.

Gasification is an established technology for power generation where the process facilitates to overcome many of the limitations of the conventional combustion systems with highest efficiency which converts solid fuels into a clean gas that can be used in a 100% Gas Engine mode for power generation. The conventional power generation is mostly concentrated and centralized. Realizing the heavy power transmission loss, a policy of Distributed Power Generation system was formulated. In "Distributed Decentralized Power Generation Scheme, many small-scale gasifier based Power Plants are encouraged against the demand. The steam generation from the waste heat recovery and process optimisation apart from power generation from gas with enhanced efficiency abets in plummeting the all-scale processing factory's steam consumption in radical approach.

The fast depletion of the fossil fuel and the potential energy in crop residues, wood residues, and biomass crops seed the importance of non-conventional energy and power generation using the non-conventional energy. Gas reactors are usually classified as counter-current, co-current, or side-draft (cross-current) reactors. Fig. 1 and 2 shows the counter current sand co-current gasification for the thermochemical gas reactors in accordance to the prior art of the invention. In the counter-current gas reactors, air is blown or drawn up through a grate supporting the feedstock, and the producer gas passes up through the combustion zone and the unburned fuel and out an exit at the top for energy consumption. Co-current gas reactors, on the other hand, force the producer gas down through the combustion area by means of air pressure or air suction to an exit for use as energy consumption.

Co-current gas reactors were developed in an effort to reduce tar content in gas used to power internal combustion engines. In conventional co-current systems, the air enters through peripheral jets directed toward the center of the airtight cylindrical fuel and combustion chamber just above a funnel-shaped or conical bottom to initiate gasification. As the feedstock is devolatilized by combustion and heat, it shrinks into pieces of carbon or char which accumulate in a conical bottom and are supported on a grate below the throat. The char forms a red-hot bed which reduces CO_2 to combustible CO and also cracks the tars into stable gases. This gas can be cleaned and cooled for use in an engine to generate power by mitigating emissions compared over conventional route. One of the most common techniques of providing a conversion of biomass material to gas involves the use a dumping of the material into container which has a grate near the bottom. The material is mixed with combustible air which is force-fed and the burning product produces the gas which is pumped away from the source. The purpose of the grate is to provide a surface which allows for a complete burn up of the product and the removal of the ash away from the combustion area so that the heat is not wasted on completely combusted material.

The US4452611 discusses about co-current channel gasifier for the efficient conversion of biomass materials to generate heat energy, which includes two generally triangularly shaped air ducts positioned longitudinally across an enclosed housing defining a combustion chamber. The air ducts have sloping sides which downwardly converge towards one another to define a open-bottom V-shaped channel, the sloping sides primarily supporting the biomass fuel which will be combusted to derive producer gas. The air ducts are hollow and are in fluid communication with a high pressure air source at one end, and with the gasification chamber through air jet openings near their apexes. The high pressure air exits out through the air jet openings placed along the top edges of the air ducts which provides primary air for gasification of the biomass in the channels. The producer gas passes down between the channels and horizontally to an exit.

However these convention gas reactors works under either counter current gasification or co current gasification and when processing the feedstock results a substantial high ash and tar content. In particular when processing the feedstock at higher temperatures and pressures, the operation of the gasification process becomes more difficult. Further, these reactors cannot be adapted to produce heat and power for all scales of industries to meet the energy requirements. Moreover the above discussed reactors requires feedstock in a specified powdered form or small particulate form of biomass for gasification, and are unable to gasify the large pieces of biomass materials to produce usable heat energy and to suit all levels of industries.

Therefore, it is desirable to provide an improved gas reactor having operational advantages of counter-current and co-current gasification which narrates to a multi-condition acceptable advanced thermochemical gas reactor and accept any size, shape and type of feedstock, and suit various level of industries, and produce useable heat energy.

OBJECT OF THE INVENTION

The main object of the present invention is to provide an improved gas reactor having combined or selected operation modes of counter current and co current gasification modes to produce tar free gas.

Another object of the present invention is to provide a gas reactor which gasify the large pieces of biomass materials and produce usable heat energy to suit all levels of industries.

Another object of the present invention is to provide an improved gasifier having compact modular design to accommodate a wide variety of energy demands for the single size product unit and producing required energy output.

Yet another object of the present invention is to produce heat and power at all levels of industries such as small, medium, large and very large scales with multi-condition acceptability.

Further object of the present invention is to provide a gas reactor producing usable heat energy which can be scaled up to the of end users demand.

Further object of the present invention is to produce heat and power at all levels of industries from multi-flexible conditions.

A still further object of the invention is to combine the use of a pre-heater that is self-sustained to give greater gasification efficiency and to allow the use of a moist fuel.

Further object of the invention is to provide a tar-free gas even with extreme conditions of the feedstock properties.

SUMMARY OF THE INVENTION

The present invention which achieves the objectives relates to a gasification system comprising a stratified counter-current gasification assisted co-current type gasifier operating simultaneously on both modes. The gasification system includes a hopper at the top of the reactor, a top slide door and a bottom slide door arranged with the hopper for ascertaining a leak proof environment inside the gas reactor. An inspection door is provided above the drying zone and this inspection door arrangement enables for maintenance process of the gas reactor and easy access for troubleshooting and inspections. The gas reactor has drying zone, carbonization zone and pyrolysis zone. The hopper is placed above the drying zone with motorized slide valves for feedstock through conveyor system. The feedstock for gasification enters the gasification zone after passing through drying zone and Pyrolysis zone of the gas reactor.

The gas reactor is designed to utilize the sensible heat which enhances the process of drying, torrefaction and carbonization and pyrolysis of the feedstock for gasification before entering the gasification zones. The gas reactor comprises of counter current gasification zone and co-current gasification zone. The torrefied carbonized and pyrolyzed feedstock first enters the counter-current gasification zone. The counter-current gasification zone is made with single rows of nozzles arrangements distributed uniformly along the length of the reactor. This counter-current gasification zone is constructed in such a way that, the counter-current air distribution systems and the counter-current fire ignition ports are placed uniformly along the periphery of the reactor. The air from the blower for counter-current gasification enters the zone through counter-current air nozzles having combination of circular and rectangular slot openings. A breaker shaft assembly with shaft arrangement and paddle breakers are placed in between the counter-current zone and the co-current zone. The breaker shaft assembly breaks the larger sized carbonized product to smaller size reduction.

The torrefied carbonized and pyrolyzed feedstock then enters the co-current gasification zones with single cyclonic reduction for complete gasification conversion and further reduction to tar-free gases. The co-current gasification zones has a capsule type co-current central buffer chambers with baffles welded on both sides of the reactor along the length of the reactor above the rotating grates for preventing the load of feedstock on the gasification zones. The arrangement of co-current nozzles distribution are made in such a way that the co-current gasification zones is made with multiple rows of side nozzles arrangements distributed uniformly and peripherally all along the length of the reactor. The air from the blower for gasification enters the co-current gasification zones through co-current air nozzles with circular and rectangular slot openings combination. The gasification system is fully insulated by a special surface lining methodology to achieve maximum thermal efficiency on hot gas condition as well as cold gas efficiency with tar-free gas.

Air is introduced into the gasification zone through a manifold along the entire length of the active zone of the reactor supplies sensible heat to be fed through the feedstock material in order to remove the extreme moisture up to 50% before it is fed to the gas reactor. The air which is supplied through the manifold operates in such a manner that the combustion takes place in a co-current environment which prevents the residue and by-products from collecting on the walls of the vessel and completely burns off these products and converts them to hydrocarbon molecules which become part of the fuel. The produced gas from the gas reactor passes through multi cyclone ash separator followed by immersion type venturi scrubber for gas cleaning, vertical column damper with dry filter and finally passing through coarse and fine filters. The cleaned and cooled gases are passed through a buffer tanks and uniformly distributed for power generation. The Counter-current and Co-current gasification air distribution system renders uniform air supply all along the length of the reactor for improved combustion.

The gas reactor is fully insulated by a special surface lining methodology to achieve maximum thermal efficiency on hot gas condition as well as cold gas efficiency with tar-free gas. The pressure drop across the rotary grates with adjustable options based on size feedstock for gasification can be uniformly maintained during operation which will help to gasify small particles and pellets also. The load above the cyclonic reduction zone is totally minimised by incorporation of circular and capsule type air distribution ducts and breaker shafts assembly with shaft arrangement and paddle breakers.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawings wherein the showings are for the purpose of illustrating a preferred embodiment of the invention only, and not for the purpose of limiting the same.

Fig. 1 shows a schematic diagram of counter current gasification for a thermochemical biomass gas reactor, in accordance to the prior art of the invention.

Fig. 2 shows a schematic diagram of co-current gasification for a thermochemical biomass gas reactor, in accordance to the prior art of the invention.

Fig. 3 shows a schematic diagram of counter current assisted co-current gasification for a thermochemical biomass gas reactor, in accordance to the exemplary embodiment of the present invention.

Fig. 4 shows an illustration of a thermochemical biomass gas reactor constructed for tar free gasification, in accordance to the exemplary embodiment of the present invention.

Fig. 5 shows another view of the thermochemical biomass gas reactor, in accordance to the present invention.

Fig. 6 shows the gas reactor having counter-current gasification zone and co-current gasification zone, in accordance to the present invention.

Fig. 7 shows another view of the gas reactor showing the air nozzles and air distribution system, in accordance to the present invention.

Fig. 8 shows left hand side and right hand side views of the air nozzle distribution plate for the gas reactor, in accordance to the present invention.

Fig. 9 shows the breaker shaft having paddle breaker for the gas reactor, in accordance to the present invention.

Fig. 10 shows the rotary grate assembly for the gas reactor, in accordance to the present invention.

DETAILED DESCRIPTION

The present invention relates to a gas reactor which operates on counter-current assisted co-current gasification to generate tar free gas. Fig. 3 shows a schematic diagram of counter current assisted co-current gasification for a thermochemical biomass gas reactor, in accordance to the exemplary embodiment of the present invention. The gas reactor provides efficient conversion of biomass materials into usable heat energy, by incorporating the combined modes and operational advantages of counter-current and co-current gasification. The gasification system works as a stratified counter-current gasification assisted co-current type gasifier operating simultaneously on both the modes.

Fig. 4 and 5 shows views of a thermochemical biomass gas reactor constructed for tar free gasification, in accordance to the exemplary embodiment of the present invention. The gasification system includes a hopper (2) at the top of the reactor, a top slide door (3) and a bottom slide door (4) arranged with the hopper for ascertaining a leak proof environment inside the gas reactor. An inspection door (5) is provided above the drying zone (6) and this inspection door arrangement enables for maintenance process of the gas reactor and easy access for troubleshooting and inspections. The gas reactor has drying zone (6), carbonization zone (7) and pyrolysis zone (8). The hopper (2) is placed above the drying zone (6) with motorized slide valves for feedstock through a conveyor system. The feedstock for gasification enters the gasification zone after passing through the drying zone (6) and Pyrolysis zone (8) of the gas reactor.

The feedstock for gasification is conveyed to the hopper (2) through a conveying device from ground level and the hopper gets closed with a top slide door (3) by motorized or pneumatic or hydraulic mechanism based operation on the top after filling the chamber. The bottom slide door (4) is opened after ensuring the closing of top slide door (3). The conveying arrangements are made to ensure uniform charging of feedstock into the gas reactor which prevents feedstock load on the counter-current and co-current gasification zones and the rotary grate assembly (22). The top slide door (3) and the bottom slide door arrangement (4) of the hopper (2) enables leak proof environment inside the gas reactor which is operating under pressure mode.

Inspection door arrangements (5) are provided with the gas reactor (1), one above the drying zone (6) and another at reduction zone (11). The inspection door arrangements allows for ease of maintenance and easy access for troubleshooting inspections. The gas reactor operates on suction mode for initial start up ignition of charcoal on the counter-current (15) and co-current gasification zones (17) through suction mode for few minutes and changed to

pressure mode operation thereafter. The gas reactor is designed to utilize the sensible heat of the process which sequentially enhances the process of drying (6), torrefaction and carbonization (7) and pyrolysis (8) of the feedstock for gasification before entering the gasification zones. The shell of the gas reactor (1) is designed and constructed using Mild Steel (MS) and Stainless Steel (SS) sheet with required thickness on civil foundations or structures or platform (9). The gas reactor comprises of counter current and co-current gasification zone.

Ribs (28) are provided to support rectangular flange (27) for strengthening the reactor shell (1) during operation and easy dismantling during cleaning and maintenance. The bottom section of the gas reactor accelerates the gas flow so that the char and ash particles will more likely deposit at the ash collection in conical ash pit with gas cyclonic deflector (11) for better settlement of larger particulates through the gas outlet duct (29). The ash collected will be removed from the bottom of the gas reactor using a screw conveyer assembly (12) regulated using a rotary valve (13) for maintaining dry seal below gasification zone. This leak proof arrangement helps discharge the ash continuously from the reactor under dry seal arrangement.

Fig. 6 and 7 shows various views of the gas reactor having counter-current gasification zone and co-current gasification zone, in accordance to the present invention. The torrefied carbonized (7) and pyrolyzed (8) feedstock first enters the counter-current gasification zone (15). The counter-current gasification zone (15) is made with single row of nozzle arrangements (14) distributed uniformly along the length of the gas reactor (1). This counter-current gasification zone (15) is constructed in such a way that, the counter-current air distribution systems (25) and the counter-current fire ignition ports (24) are placed uniformly along the periphery of the reactor (1). Fig. 8 shows various views of the air nozzle distribution plate for the gas reactor, in accordance to the present invention. The arrangement of co-current nozzles (23) distribution are made in such a way that

the co-current gasification zones (17) is made with multiple rows of side nozzles (23) arrangements distributed uniformly and peripherally all along the length of the reactor. The air from the blower for gasification enters the co-current gasification zones (17) through co-current air nozzles with circular and rectangular slot openings combination (23).

The air from the blower for counter-current gasification enters the zone (15) through counter-current air nozzles with circular and rectangular slot openings combination (14). The opposing plurality of nozzles plates are placed such that the nozzles do not face each other throughout the periphery of the reaction zones. The co-current gasification zone (17) are designed in such a way that the co-current air distribution systems (26) and the co-current fire ignition ports (21) are placed uniformly all along the periphery of the smooth-edged rectangular reactor (1).

The feedstock for gasification enters the counter-current gasification zone (15) after passing through drying (6) and Pyrolysis (8) zones of the gas reactor to utilize the sensible heat of the process which sequentially enhances the process of drying (6), torrefaction and carbonisation (7) and pyrolysis (8) of the feedstock for gasification before entering the gasification zones (17). The counter-current gasification zone (15) is made with single rows of nozzles (14) arrangements distributed uniformly all along the length of the reactor.

In addition to the side nozzles (14), counter-current central ducts (18) with baffles are placed along the length of the counter-current gasification zone (15) with single row of counter-current central duct nozzles (14) arrangements focusing side wards. This counter-current gasification zone (15) is constructed in such a way that the counter-current air distribution systems (25) and the counter-current fire ignition ports (24) are placed uniformly all along the periphery of the gas reactor (1).

The air from the blower for counter-current gasification enters the gasification zone (15) through counter-current air nozzles with circular and rectangular slot openings combination (14). Charcoal is filled for initial ignition start up inside the counter-current gasification zone (15) above the counter-current nozzles level (14). These arrangements ensure consistent bed porosity and uniform counter-current gasification zone (15) height throughout the operation of the gas reactor.

Fig. 9 shows the breaker shaft having paddle breaker for the gas reactor, in accordance to the present invention. The breaker shaft assembly (16) with shaft arrangement (30) and paddle breakers (31) is incorporated in between the counter-current (15) and co-current (17) gasification zones which are highly effective in breaking the larger sized carbonized product to smaller size. The torrefied carbonized (7) and pyrolyzed (8) feedstock then enters the co-current gasification zones (17) with single cyclonic reduction (11) for complete gasification conversion and further reduction to tar-free gases. The co-current gasification zones (17) has capsule type co-current central buffer chambers (18) with baffles welded on both sides of the reactor along the length of the reactor above the rotating grates (22) for preventing the load of feedstock on the gasification zones (17).

Fig. 10 shows the rotary grate assembly for the gas reactor, in accordance to the present invention. The rotary grates (22) with horizontal rods assembly (32) operating on rotating shaft arrangements (33) are placed externally below the co-current throat which discharges the ash uniformly preventing clinker formation and bed pressure drop and thus improving the gasification efficiency. The rotating grates (22) are provided with adjustable options based on size feedstock for gasification at low speed rotation which directly supports the gasification zone (17) and made capable of letting ash fall through without excessive loss of fuel conversion. In addition, the grates are used to control

reactor pressure drop and to maintain the augmented gas production rate. The air from the blower for counter-current gasification enters the counter current gasification zone (15) through counter-current air nozzles with circular and rectangular slot openings combination (14). The gasification system is fully insulated by a special surface lining (20) to achieve maximum thermal efficiency on hot gas condition as well as cold gas efficiency with tar-free gas.

In operation, charcoal is filled for initial ignition start up inside the counter-current and co current gasification zones (15, 17) above the nozzles level. The small cross sectional area enables radial uniform temperatures, and uniform air distribution. The feedstock for gasification is conveyed to the hopper (2) through suitable conveying device from ground level and the hopper gets closed with a top slide door (3) by motorized or pneumatic or hydraulic mechanism based operation on the top after filling the chamber. The bottom slide door (4) is opened after ensuring the closing of top slide door (3). The feedstock for gasification enters the counter-current gasification zone (15) after passing through drying (6) and Pyrolysis (8) zones. The gas reactor operates on suction mode for initial start up ignition of charcoal on the counter-current (15) and co-current gasification zones (17) through suction mode for few minutes and changed to pressure mode operation.

The air introduced into the gasification zone (17) through a manifold along the entire length of the active zone of the reactor supplies sensible heat to be fed through the feedstock material in order to remove the extreme moisture up to 50% before it is fed to the gas reactor. The air which is supplied through the manifold operates in such a manner that the combustion takes place in a co-current environment (17) which prevents the residue and by-products from collecting on the walls of the vessel and completely burns off these products and converts them to hydrocarbon molecules which become part of the fuel.

The torrefied carbonised (7) and pyrolyzed (8) feedstock enters the multi-bed co-current gasification zones (17) with single cyclonic reduction (11) for complete gasification conversion and further reduction to tar-free gases. Capsule type co-current central ducts (18) with baffles are welded on both sides of the reactor along the length of the reactor above the rotating grates (22) that aids in preventing the load of feedstock on the gasification zones (17).

The arrangement of co-current nozzles (23) distribution are made in such a way that the co-current gasification zones (17) is made with multiple rows of side nozzles (23) arrangements distributed uniformly and peripherally all along the length of the reactor. In addition to the side nozzles (23), rectangular pipe with capsule type insulation on the co-current central ducts (18) with baffles are placed along the length of the co-current gasification zones (17) with multiple rows of co-current central duct nozzles (23) arrangements.

The char and ash are removed by the rotating paddle breakers (16), grate (22) and rotary valve (13) fitted below the reduction zone. This minimizes the chances of clinker formation in the char ash bed or combustion of the generated producer gas below the reduction zone itself. The Counter-current and Co-current gasification air distribution system renders uniform air supply all along the length of the reactor for improved combustion.

The producer gas is passed to the cleaning and cooling devices followed by series of filters and buffer tanks. The produced gas from the gas reactor is passed through multi cyclone ash separator (10) followed by immersion type venturi scrubber for gas cleaning, vertical column damper with dry filter and finally passed through coarse and fine filters. The cleaned and cooled gases are passed through buffer tanks for usage.

The interior of the gas reactor shell inner surface is lined with multi-composition layers of firecrete grade, glass powder, wood ash, refractory brick powder and whytheat-A (90% Alumina) dense castable to a suitable thickness. The exterior of the shell is lined glass wool (20), ceramic blanket supported by chicken mesh enclosed in an aluminium cladding. The gas reactor is fully insulated by this special surface lining methodology to achieve maximum thermal efficiency on hot gas condition as well as cold gas efficiency with tar-free gas. The pressure drop across the rotary grates with adjustable options based on size feedstock for gasification can be uniformly maintained during operation to gasify small particles and pellets.

The design of the gas reactor is flexible to scale-up for any rated capacity. The length, width and height of the rector can be scaled up to any proportions. The shell of the gas reactor is constructed using Mild Steel (MS) and Stainless Steel (SS) sheet with suitable thickness. The MS/SS plate is either rectangular type or rolled in bending machine on four sides to have a single joint welding. This instigates production cost and time reduction, and augments the feedstock and pyrolyzed products to flow freely downwards in stratified reactor avoiding edge losses and prevents clinker formation on sharp edges.

The gas reactor according to the present invention allows for sustained gasification at ambient temperature regimes and even at extreme temperatures below 8°C also without any pre-heating process. The rating capacity with feedstock can be doubled while using wood chips or pellets. The gas reactor can also works under pressure below 600 mm of water column. The load above the cyclonic reduction zone is totally minimised by incorporation of circular and capsule type air distribution ducts and breaker shafts assembly with shaft arrangement and paddle breakers. This helps in efficient agitation of char bed avoiding void spaces and clinker formation.

The gas reactor can be a square, rectangular, smooth-edged rectangular or smooth edged square shape which can be operated on all types of firewood, coal, refused derived fuel, rubber waste, leather waste, coconut husk, coconut shell, coconut fronds, mango seed and any powdery bio-fuel or agro-wastes in bailed, briquetted or pellet form that generates tar free gas while removing ash and particulate in the proficient manner.

The improved gas reactor can handle high bulk density or low bulk density feed materials like leafy/powdery feedstock e.g. sugarcane trash and bagasse, and other agro-waste materials in bailed or briquetted forms. This reactor operates on stratified counter-current assisted co-current gasification mode operating slightly above atmospheric pressure for flexible rating with multi-bed gasification and single cyclonic reduction bed. The gasification zone temperatures are maintained above 1400°C and above to achieve tar-free gas.

The gas reactor can accommodate any type of feedstock feed on very larger size (from 50mm of length X 50mm of diameter to 1200mm of length X 300mm of diameter) even with higher bulk density (from 350 to 1500 kg/m^3) that is highly comparable over woody feedstock (i.e., around 400kg/ m^3) and powdery feedstock (i.e., around 60 kg/ m3) and acceptable even with large woods and long sticks with higher moisture (up to 50%) acceptability.

The foregoing description is a specific embodiment of the present invention. It should be appreciated that this embodiment is described for purpose of illustration only, and that numerous alterations and modifications may be practiced by those skilled in the art without departing from the spirit and scope of the invention. It is intended that all such modifications and alterations be included insofar as they come within the scope of the invention as claimed or the equivalents thereof.

We Claim:

1. A thermochemical gas reactor comprises,

a drying zone (6), carbonisation zone (7) and pyrolysis zone (8) for preparing biomass feedstock for gasification, such that the sensible heat of the preheating process enable drying (6), torrefaction and carbonisation (7) and pyrolysis (8) of the biomass feedstock;

a counter-current gasification zone (15) and a co-current gasification zone (17) for thermochemical reaction and gasification of biomass feedstock, wherein the gas reactor (1) is constructed to operate in a combined mode or in a selected mode of counter-current gasification and co-current gasification;

wherein the biomass feedstock for gasification enters the counter-current gasification zone (15) and a co-current gasification zone (17) for thermochemical reaction and gasification of biomass feedstock after passing through drying zone (6), carbonisation zone (7) and Pyrolysis zone (8) of the gas reactor.

2. The gas reactor as claimed in claim 1, wherein a breaker shaft assembly (16) with shaft arrangements (30) and paddle breakers (31) are placed in between the counter-current gasification zone (15) and co-current gasification zone (17).

3. The gas reactor as claimed in claim 1, wherein co-current air distribution system (26) and co-current fire ignition ports (21) are placed along the periphery of the reactor (1).

4. The gas reactor as claimed in claim 1, wherein rotating grates (22) and screw conveyer assembly (12) are placed below the co-current gasification zone (17) to discharge the ash produced in the gas reactor.

5. The gas reactor as claimed in claim 1, wherein rotary grates (22) has horizontal rods assembly (32) operating on rotating shaft arrangements (33), and the rotating grates (22) has adjustable rotation speed options based on the size feedstock for gasification.

6. The gas reactor as claimed in claim 7, wherein a hopper (2) is placed above the drying zone (6) with motorized slide valves for passing the biomass feedstock through a conveyor system.

7. The gas reactor as claimed in claim 1, wherein the gas reactor (1) is square, rectangular, smooth-edged rectangular or smooth edged square in shape, and is constructed using Mild Steel (MS) and Stainless Steel (SS) sheet with suitable thickness.

8. The gas reactor as claimed in claim 1, wherein the gas reactor is operated on firewood, coal, coconut husk, coconut shell, coconut fronds, mango seed and powdered bio-fuel and agro-wastes in bailed, briquetted and pellet form, and the oxidizing agent (Air) inlet temperature for sustained gasification can be achieved at ambient temperature regimes and even at extreme temperatures below 8°C also without any pre-heating process.

9. The gas reactor as claimed in claim 1, wherein the reactor operates on stratified counter-current assisted co-current gasification mode operating slightly above atmospheric pressure for flexible rating with multi-bed gasification (17) and single cyclonic reduction bed (11).

10. A biomass gasification system including the gas reactor as claimed in any one of the preceding claims.

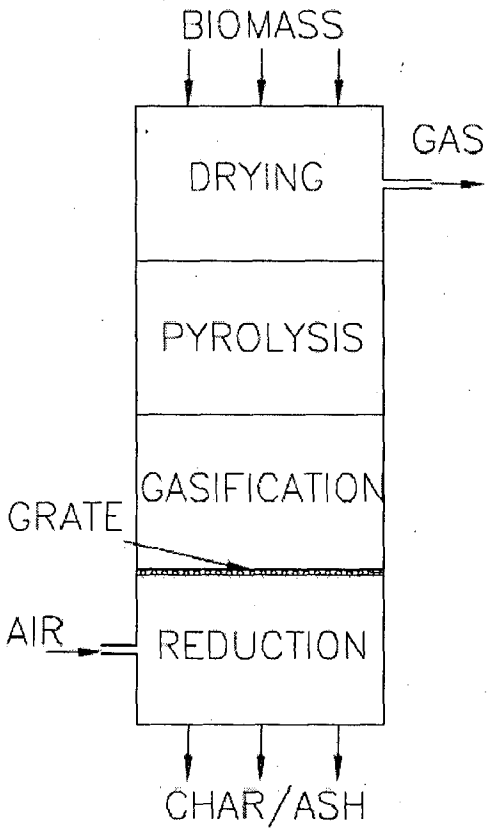


Fig. 1

(Prior art)

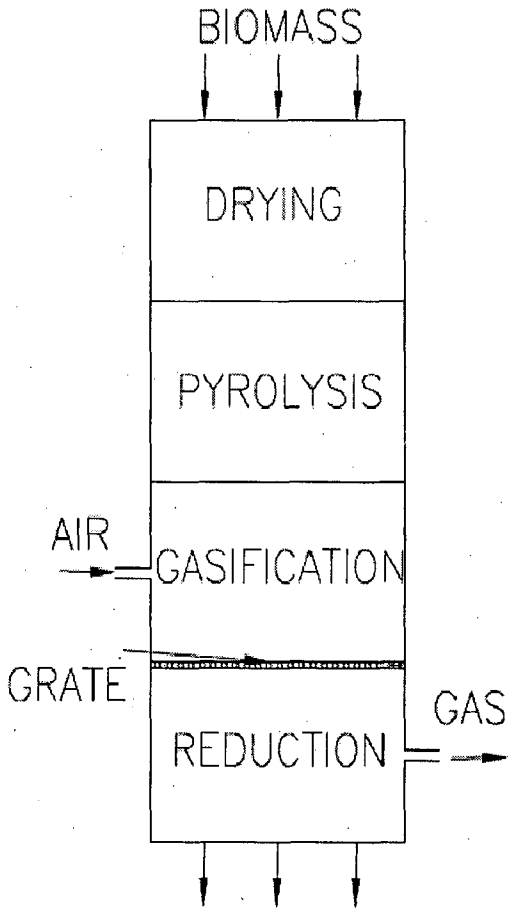


Fig. 2

(Prior art)

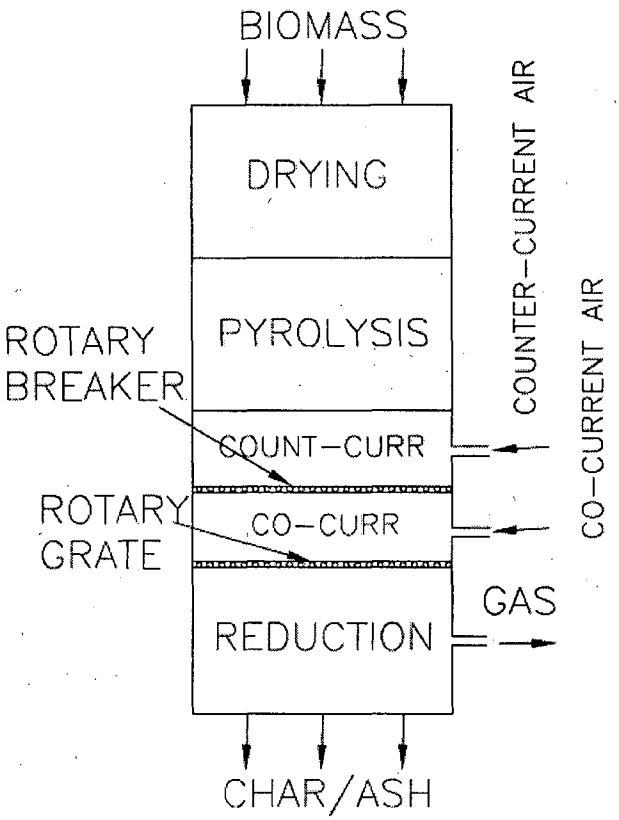


Fig. 3

(Present invention)

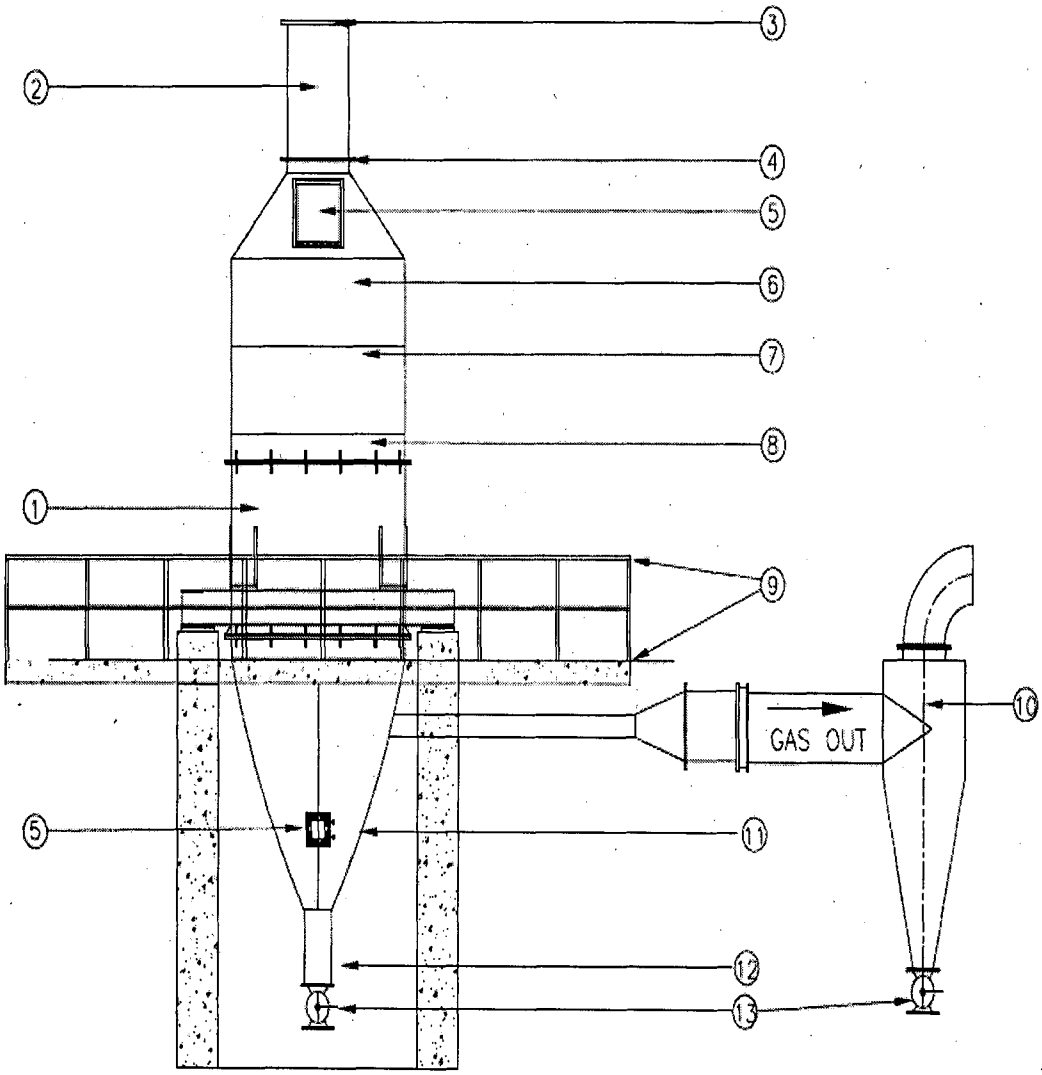


Fig. 4

(Present invention)

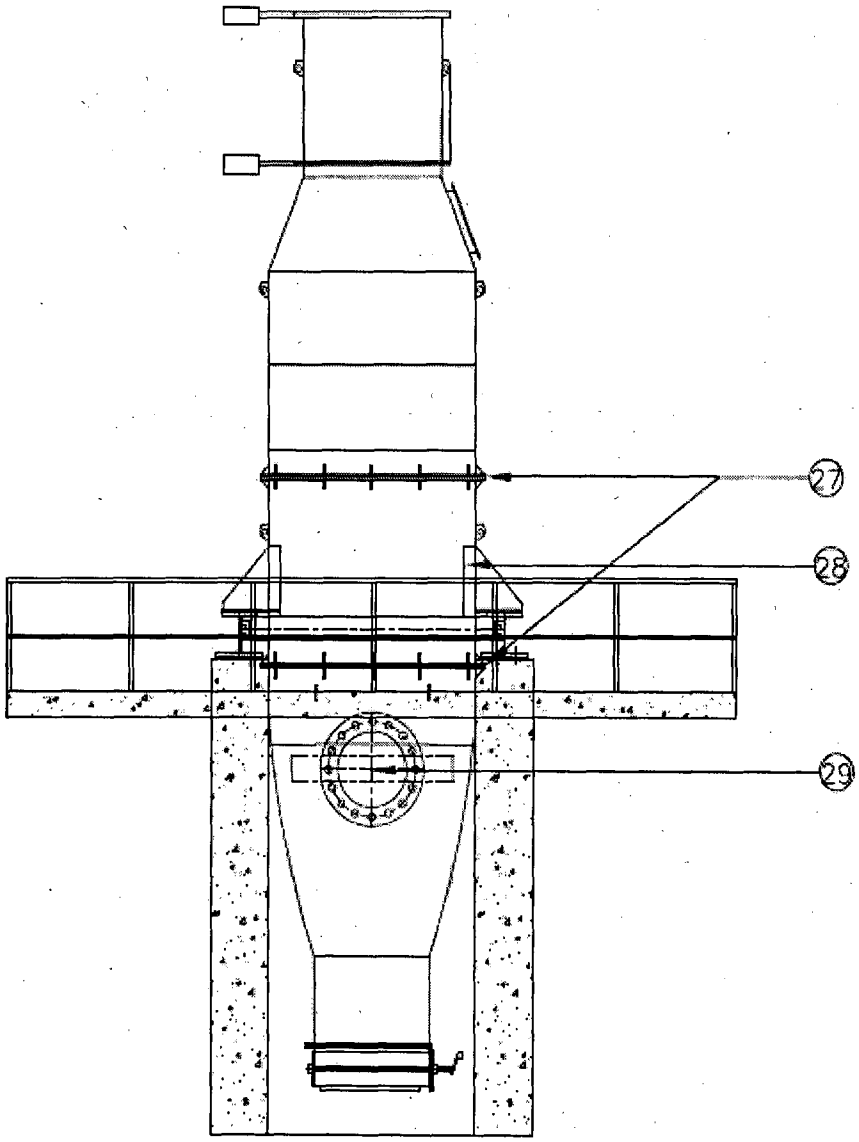


Fig. 5

(Present invention)

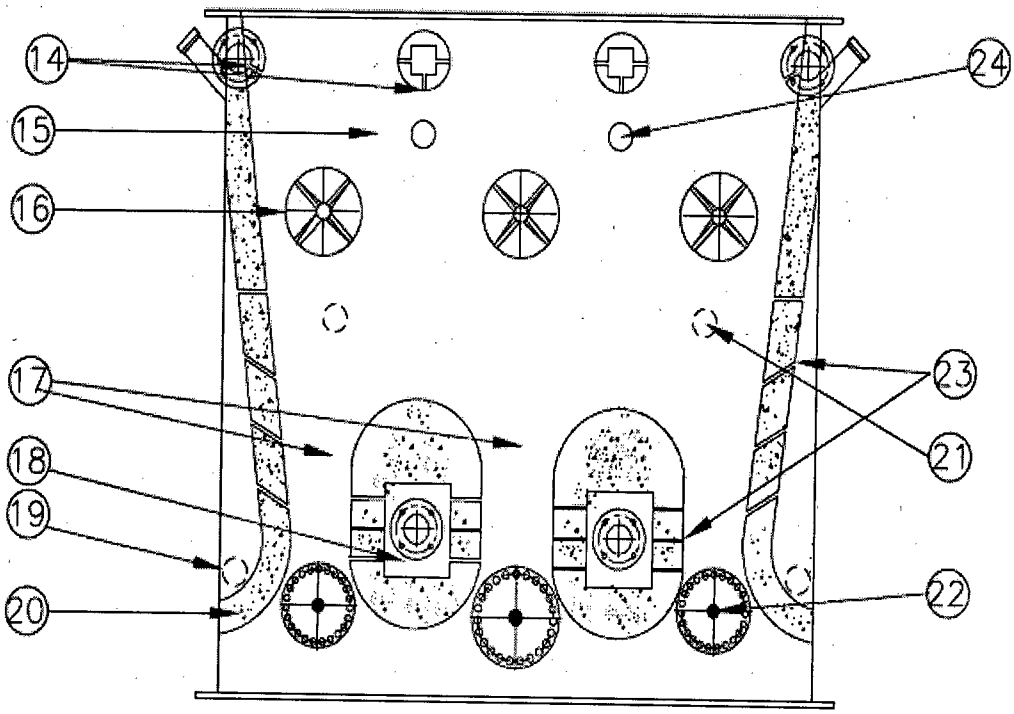


Fig. 6

(Present invention)

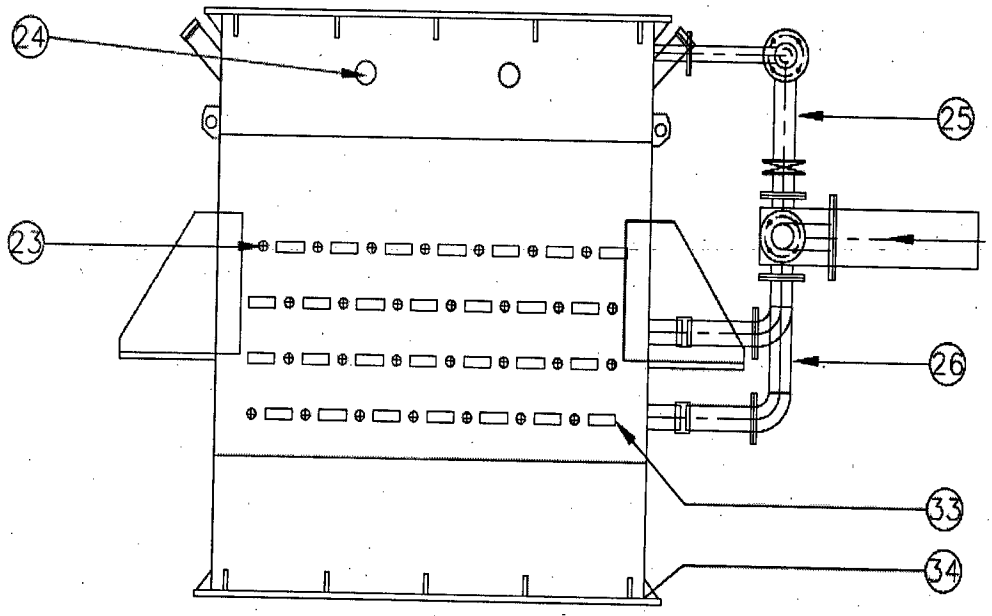


Fig. 7

(Present invention)

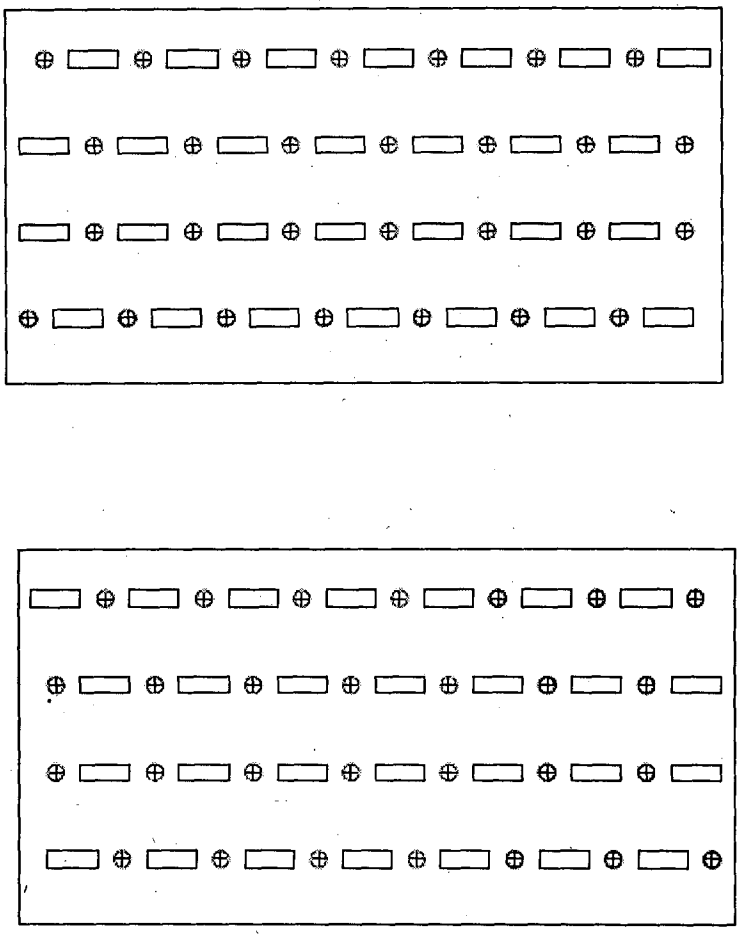


Fig. 8

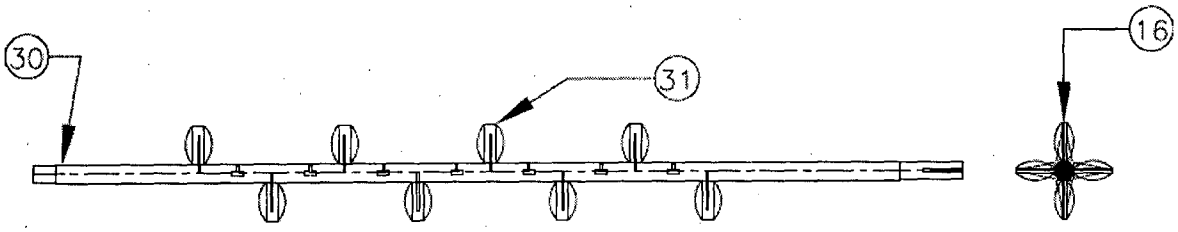


Fig. 9

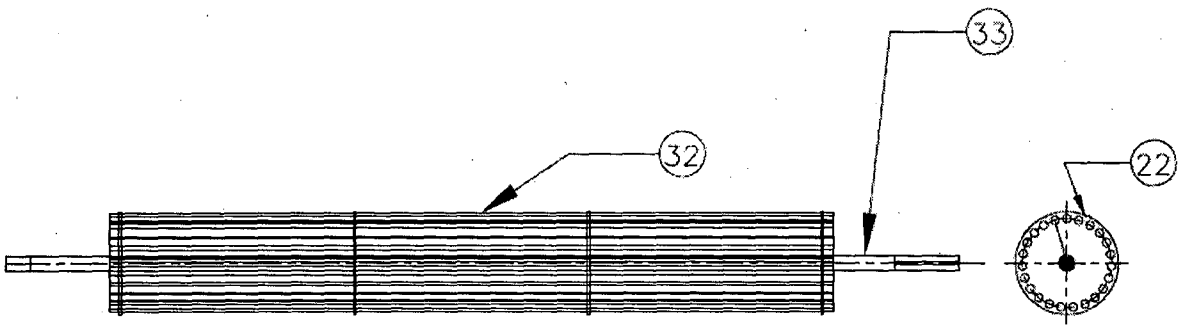


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2013/000172

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10J3/26 C10J3/40 C10J3/32
ADD.

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)
C10J

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 practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/46332 A2 (LUTEREK JANUSZ FRANCISZEK [ZA] LUTEREK JANUSZ FRANCISZEK [ZA]; HAHN HA) 13 June 2002 (2002-06-13)	1,3,4, 6-10
Y	figures 1-19 page 20, lines 20-25	2,5

X	WO 2007/102032 A2 (ELEFSINIOTIS LAMPROS [GR]) 13 September 2007 (2007-09-13) figures 1-3	1

X	DE 197 18 184 A1 (INST UMWELTTECHNOLOGIE UND UMW [DE] INST EN UND UMWELTTECHNIK E V [DE]) 5 November 1998 (1998-11-05) figure 1	1

X	DE 26 38 183 A1 (VANSLYKE WILLIAM J) 9 March 1978 (1978-03-09) figure 1	1

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 August 2013	05/09/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lachmann, Richard

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IN2013/000172

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 32 39 624 A1 (KIENER PYROLYSE [DE]) 26 April 1984 (1984-04-26) figures 1-7	1
Y	US 5 607 487 A (TAYLOR LELAND T [US]) 4 March 1997 (1997-03-04) figure 3	2
Y	DE 197 34 343 A1 (WACKERMANN VOLKER DIPL FORSTWI [DE]) 11 February 1999 (1999-02-11) figure 1	5

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2013/000172

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 1-10(partially)
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 1-10(partially)

Present claim 1 relates to an extremely large number of possible apparatus. Support and disclosure in the sense of Article 6 and 5 PCT is to be found however for only a very small proportion of the apparatus claimed, see pages 5 and 6 of the description, in particular the existence of a co-current and a counter-current zone within the same reactor vessel.

The formulation of claim 1 can be read as though the reactor could possibly be constructed such that it operates only counter-currently or only co-currently. It seems clear from the description however, that the reactor has to be able to be operated in co-current mode, in counter-current modeand in in a mode of operation having a co-current zone and a counter-current zone at the same time. The non-compliance with the substantive provisions is to such an extent, that the search was performed taking into consideration the non-compliance in determining the extent of the search of claim 1 (PCT Guidelines 9.19 and 9.23).

The search of claim 1 was restricted to those claimed apparatus which appear to be supported:

The reactor has to be able to be operated in co-current mode, in counter-current mode and in in a mode of operation having a co-current zone and a counter-current zone at the same time.

Because of the functional nature of claim 1 this claim is still very broad. The applicant should bear in mind that the functional features such as the respective zones do not translate into actual technical features. The claim is therefore read as a reactor suitable to have the mentioned zones and suitable to be operated in all three modes.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IN2013/000172

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0246332 A2	13-06-2002	AU 2028802 A	18-06-2002
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