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(54) Apparatus and method of gasification using ozone

(57) Known gasification processes suffer from the disadvantage that fuel loads are not fully converted into synthesis gases. Inefficient gasification results in a low yield of synthesis gases and therefore a product that is high in volume but low in caloric power. Accordingly, there is provided a process of gasification and a gasification apparatus (100) comprising a secondary reactor circuit wherein the secondary reactor circuit comprises a flow control device (21) for regulating an amount of ozone provided to the reactor (7). Recirculation of synthesis gases is also provided.

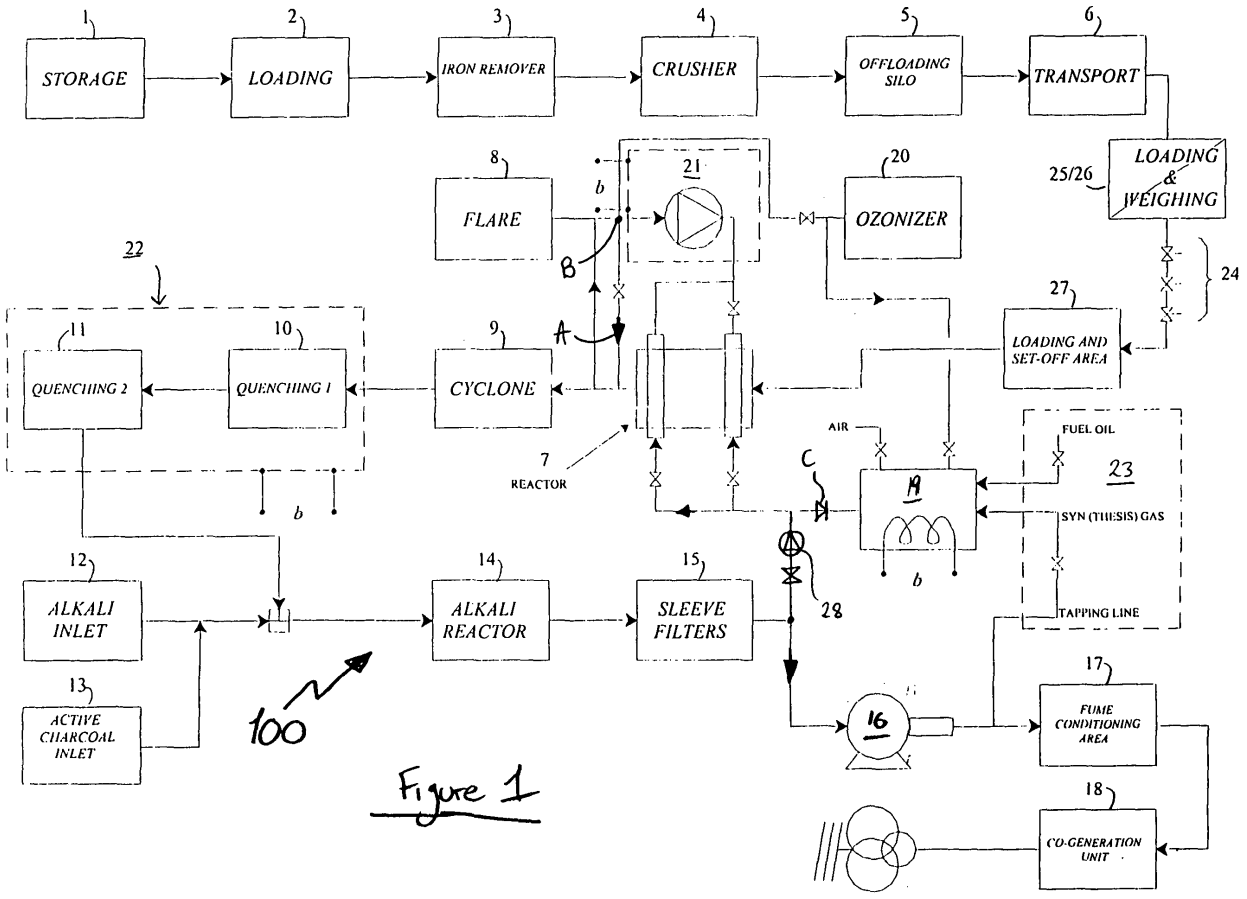


Figure 1

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Description

[0001] The present invention relates, in general, to the conversion of combustible matter in solid or liquid fuels to fuel gases by a process known as gasification. In particular, the present invention relates to a gasification apparatus and a process of gasification for the treatment of aromatic chains and of substances rich in caloric power.

[0002] Gasification is the conversion of a solid or liquid fuel load to a lower molecular weight gaseous fuel having a lower carbon to hydrogen ratio than the fuel load. The main reactions involved in gasification provide synthesis gases such as hydrocarbons, carbon monoxide CO, hydrogen H_2 and methane CH_4.

[0003] It is known to obtain such synthesis gases using an installation having a primary reactor circuit comprising a reactor maintained at an appropriate temperature and pressure. A fuel load is injected into the reactor causing the molecular bonds of the fuel load to rupture and produce synthesis gases. The synthesis gases flow through the remainder of the installation where they can be collected and used for other energy generation purposes.

[0004] Known processes of gasification suffer from the disadvantage that the fuel loads are not fully converted into synthesis gases. Inefficient gasification results in a low yield of synthesis gases which comprise low levels of hydrocarbons, CO, H_2 and CH_4 and therefore a product which is high in volume but low in caloric power.

[0005] According to a first aspect of the present invention, there is provided a gasification apparatus comprising a primary reactor circuit including a thermal generator for heating a reactor to a temperature for initiating gasification of a fuel load, the reactor having an input stage for receiving the fuel load and an output stage for expelling synthesis gases, characterised in that the reactor is provided with a secondary reactor circuit, wherein the secondary reactor circuit comprises a flow control device for regulating an amount of ozone provided to the reactor.

[0006] Gasification is therefore increased in efficiency when compared to the prior art. The injection of ozone within the reactor enables a reduction in the quantity of nitrites and nitrates ($NO[DVX1]_x$) owing to the absence of air in the gasification process. The injection of ozone also provides a synthesis gas that features a high concentration of caloric power. A volume quantity of synthesis gas at least four times lower than what is obtained with a normal gasification circuit can be achieved, i.e., a gas richer in caloric power in the same proportion.

[0007] Preferably, the reactor comprises a pair of toroidal gas circulation chambers disposed around the periphery of the reactor. Very preferably, the toroidal gas circulation chambers comprise holes for allowing a flow of gas to the reactor.

[0008] At the input stage, a valve group may provide a plurality of interception chambers for substantially reducing an amount of air associated with the fuel load such that gasification can occur within a substantially ozone atmosphere within the reactor.

[0009] Preferably, the apparatus further comprises a cleaning stage coupled to the output stage of the reactor. The cleaning stage may comprise a quenching stage coupled to an alkali reactor for reducing an acid content of the expelled synthesis gases. The alkali reactor may use an additive-reactant lime/soda milk for reducing the acid content.

[0010] The apparatus preferably comprises a pump coupled to the cleaning stage and to the input stage of the reactor for recirculating a portion of the expelled synthesis gases and thereby returning the expelled synthesis gases to the reactor. Synthesis gases are therefore provided by introducing an innovative system of recirculation of the gases within the primary circuit of the main reactor. A non-return valve may be disposed between the thermal generator and the reactor to substantially prevent the thermal generator from receiving expelled synthesis gases returned to the input stage of the reactor. Preferably, an extractor fan is coupled to the output stage of the reactor, the velocity of the extractor fan being capable of controlling the rate of expulsion of synthesis gases from the reactor.

[0011] According to a second aspect of the present invention, there is provided a process of gasification comprising: heating a reactor to a temperature for initiating gasification of a fuel load by a thermal generator; injecting a fuel load into the reactor; expelling synthesis gases from the reactor; the process characterised by regulating an amount of ozone provided to the reactor.

[0012] Preferably, the process comprises quenching the expelled synthesis gases; reducing an acid content of the expelled synthesis gases. Preferably, the process includes recirculating a portion of the expelled synthesis gases for returning the expelled synthesis gases to the reactor. Preferably, the process provides for reducing an amount of air associated with the fuel load such that gasification can occur within a substantially ozone atmosphere within the reactor.

[0013] Embodiments of the present invention will now be described by way of further example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a gasification apparatus according to an embodiment of the present invention;
Figure 2 is a schematic diagram of a reactor according to the embodiment of the present invention; and
Figure 3 is a schematic diagram of the reactor of Figure 2 along line A-A.

[0014] Referring to Figure 1, an embodiment of the present invention comprises a gasification apparatus 100 having an input stage including a storage funnel 1 and a loading funnel 2 for storing and loading a fuel load. The fuel load can comprise a mixture of paper, paperboard, plastics, cloth and wood distributed to provide an average caloric power of approximately 17.000 KJ/kg. The chem-

ical composition of the mixture can be stated as C = 50%, N_2 = 1.3%, H_2 = 6.6%, Cl = 0.1 - 0.8%, O_2 = 21.9 - 25%, and S = 0.1 - 0.3%; the remainder being water and ash.

[0015] The input stage may also include, depending upon the fuel load to be treated, an iron remover device 3 and a crusher 4. An offloading silo 5 is provided together with a transport means 6. The transport means 6 is as short in length as possible and operates, in conjunction with a loading area 25, as a dosage/weighing mechanism 26.

[0016] A valve group 24 providing a plurality of interception chambers is provided between the loading area 25 and a loading and set-off area 27. The loading and set-off area 27 is coupled to an input stage of a reactor 7. The reactor 7 belongs to a primary reactor circuit also including a thermal generator, such as a hot-air generator 19. The reactor 7 is provided with a secondary reactor circuit having a control valve or pump 21 coupled to the reactor 7 and to an ozone (O_3) generator 20. A safety flare 8 is provided as protection for the primary reactor circuit so as to give synthesis gas produced by the reactor 7 an escape route in the event of a problem of the gaseous distillation apparatus 100. The safety flare 8 is capable of handling the entire flow of gas produced by the reactor 7, and is autonomous in terms of its electric start-up circuit.

[0017] The gasification apparatus 100 further comprises a cleaning stage. The cleaning stage includes a first quenching stage 10 and a second quenching stage 11 connected to the output stage of the reactor 7 by way of a centrifugal cyclone 9. An energy recovery system 22 for returning heat to the hot-air generator circuit 19 and also to the secondary reactor circuit 21 is provided at the first and second quenching stage 10, 11. The energy recovery system 22 returns heat to the hot-air generator circuit 19 and the secondary reactor circuit 21 by way of inlets designated by reference numeral *b.*

[0018] An alkali inlet 12 and an active charcoal inlet 13 are further provided at an output of the second quenching stage 11 in addition to an alkali reactor 14 and a plurality of sleeve filters 15. A pump 28 and valve mechanism is coupled to the output of the sleeve filters 15 and also to the input of the circulation chambers 50, 52 of the reactor 7 for the return of synthesis gases. An extractor fan 16 of, for example, a centrifugal type with a scirocco-blade fan, is coupled to the output of the sleeve filters 15. A fume conditioning area 17 is coupled to an output of the extractor fan 16 and an electric co-generation unit 18 for which the use of endothermal motors connected via a feed unit to variable-rated-voltage alternators is coupled to the fume conditioning area 17.

[0019] Referring to Figure 2, the reactor 7 according to an embodiment of the present invention comprises a reactor body having, at one end, the input stage for receiving the fuel load from the loading and set-off area 27 and, at another end, the output stage for expelling synthesis gases to the centrifugal cyclone 9. A first toroidal shaped circulation chamber 50 and a second toroidal shaped circulation chamber 52 surround the reactor body towards each end of the reactor body. As best seen in Figure 3, a view of the reactor 7 taken along a line A-A of Figure 2 illustrates the circulation chamber 50, 52 having a plurality of holes for receiving a controlled flow of gas from the pump 21 controlled secondary reactor circuit and the hot-air generator circuit 19.

[0020] In operation, plant start-up occurs through initial heating by way of a diesel-oil burner disposed within the hot-air generator 19 to bring the reactor 7 to between 300°C and 600°C which is an optimum temperature needed to cause an initial rupture of the molecular bonds of the fuel load to be processed.

[0021] The input flow of the fuel load into the reactor 7 is controlled at a loading and set-off area 27. The valve group 24, which provide the plurality of interception chambers, enable the fuel load which is located initially at atmospheric pressure to be passed to the primary reactor circuit at a desired pressure, for example, at a pressure slightly above atmospheric pressure in order to mitigate damaging air infiltrations from outside. Parcelisation of the service of the extractor fan 16 is also used to avoid any unnecessary intake of air during the loading cycle and the higher NO_x values that would follow.

[0022] An extracted synthesis gas velocity is controlled by the extractor fan 16, and through adjustment of the secondary reactor circuit and pump 21, the temperature of the reactor 7 can be raised to approximately 1,000°C and then allowed to drop to around 800-850°C with stoichiometry values of the reagent oxygen considerably below those needed for traditional combustion.

[0023] The adjustment of the volume of ozone to be conveyed to the circulation chambers 50, 52 of the reactor 7 by the ozone generator 20 is controlled by the pump 21 to optimize gasification. The pump 21 introduces ozone into the reactor in a quantity which is divided during operation between the hot-air generator 19 and the secondary reactor circuit. As a result, the total amount of ozone provided to the reactor 7 can approach that of an amount required for optimum gasification. Theory indicates that, for each 100 kg of fuel load, 7.6 kg of ozone is required to take the gasification to completion. Use of ozone in this way, favours the extraction of substances such as the light hydrocarbons, thus enhancing the (value of the) heating capacity of the synthesis gas while noticeably reducing their volume. The secondary reactor circuit and pump 21 therefore generate a recycling flow that guarantees a reduction of the oxygen left back in the primary reactor circuit after a first oxydation phase. Ozone is inserted so as to favour, after the first-phase reduction of the oxygen present in the initial product and the production of first-phase synthesis gases, the development of secondary reactions capable of extrapolating, from the initial aromatic-chain-rich product, gases with high levels of: light hydrocarbons, CO, H_2, and methane CH_4. Detail of the process flow is indicated by reference numeral A and reference numeral B indicates a nodal intersection point of ozone originating from the ozone

generator 20 and entering the pump 21.

[0024] Once the plant is operational, the initial burner is deactivated and by means of a gas tapping circuit downstream of the extractor fan 16 a portion of the thermal input 23 intended for the reactor is provided by a portion of the synthesis gas that is produced.

[0025] In the vicinity of reactor 7 it is preferable to proceed with a reaction conducted at a pressure as constant as possible and just barely above the atmospheric pressure in order to avoid damaging air infiltrations from the outside. The conditions can be controlled by accurate control of the velocity of the extractor fan 16 located at the end of the gas-line circuit.

[0026] For further security of the gasification apparatus, a system of pre-calibrated rupture disks (not shown) can also operate, and come into play in the event of abnormal positive pressures.

[0027] Synthesis gases output from the reactor 7 flow to the cleaning stage. Cleaning the synthesis gas occurs through the centrifugal cyclone 9 and the first and second quenching stages 10, 11 to abate the dust and the temperature generated during the reaction phase 7. Abatement occurs with heat recovery 22 (recovery to be conveyed back to the hot air generator circuit 19 and to the secondary reactor circuit). Recovery is performed to keep the temperature of the core of the reactor 7 high with the minimal energy input from the outside 23. To the same end, the entire synthesis gas transit circuit is insulated through to the area provided for the cleaning stage.

[0028] Control of the acidity of the synthesis gases is provided by "washing" the gas in the alkali reactor 14, i.e. a solution of water and additives is exposed to the gas and the resulting reaction products thus remain dissolved until a precipitate is obtained into a collection vat ready to be evacuated from the system. Additive-reactant lime or soda milk is normally used since they are strong absorbers of acid substances and good sulphur dioxide reducers and because beyond their chemical action they also exert a direct physical pull on the dusty particles that may have eluded the first and second quenching stages 11, 12.

[0029] For the purposes of recirculating the synthesis gases, controlled tapping by the pump 28 and valve mechanism can be performed after the sleeve filters 15 have filtered the synthesis gases. When it is desired to recirculate the gases, a control signal can be generated to open the valve mechanism and initiate the pump 28 to return a portion of the synthesis gases to the reactor 7. The purpose of the recirculation is to further reduce any residual level of oxygen remaining in circulation from the preceding gasification. A non-return valve C protects the hot-air generator 19 from unwanted return of gas.

[0030] Since the produced gases feature good heating capacity, they can be used by burning them directly in a boiler or by transferring them inside of an electric cogeneration unit 17, 18 for which the use of endothermal motors connected via a feed unit to variable-rated-voltage alternators can be realised.

[0031] The reactor 7, the pump 21 and the extractor fan 16 can be run by a Personal Computer (PC), a Programmable Logic Computer (PLC) and by a dedicated process-phase gas analyser to allow optimising the gas production in line with end user demand.

[0032] The aforegoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the present invention.

Claims

1. A gasification apparatus (100) comprising:

   a primary reactor circuit including a thermal generator (19) for heating a reactor (7) to a temperature for initiating gasification of a fuel load, the reactor (7) having an input stage for receiving the fuel load and an output stage for expelling synthesis gases,
   characterised in that the reactor (7) is provided with a secondary reactor circuit, wherein the secondary reactor circuit comprises a flow control device (21) for regulating an amount of ozone provided to the reactor (7).

2. An apparatus (100) as claimed in claim 1, wherein the reactor (7) comprises a toroidal gas circulation chamber (50) disposed around the periphery of the reactor (7).

3. An apparatus (100) as claimed in claim 2, wherein the toroidal gas circulation chamber (50) comprises holes for allowing a flow of gas to the reactor (7).

4. An apparatus (100) as claimed in any one of the preceding claims, further comprising, at the input stage, a valve group (24) providing a plurality of interception chambers for substantially reducing an amount of air associated with the fuel load such that gasification can occur within a substantially ozone atmosphere within the reactor (7).

5. An apparatus (100) as claimed in any one of the preceding claims, further comprising a cleaning stage coupled to the output stage of the reactor (7).

6. An apparatus as claimed in claim 5, wherein the cleaning stage comprises a quenching stage (10, 11) coupled to an alkali reactor (14) for reducing an acid content of the expelled synthesis gases.

7. An apparatus as claimed in claim 6, wherein the alkali reactor (14) uses an additive-reactant lime/soda milk for reducing the acid content.

8. An apparatus (100) as claimed in any one of claims

6 and 7, wherein a pump (28) is coupled to the cleaning stage and to the input stage of the reactor (7) for recirculating a portion of the expelled synthesis gases and thereby returning the expelled synthesis gases to the reactor (7).

9. An apparatus (100) as claimed in claim 8, wherein a non-return valve is disposed between the thermal generator (19) and the reactor (7) to substantially prevent the thermal generator (19) from receiving expelled synthesis gases returned to the input stage of the reactor (7).

10. An apparatus as claimed in any one of the preceding claims comprising an extractor fan (16) coupled to the output stage of the reactor (7), the velocity of the extractor fan (16) being capable of controlling the rate of expulsion of synthesis gases from the reactor (7).

11. A process of gasification comprising:

heating a reactor (7) to a temperature for initiating gasification of a fuel load by a thermal generator (19);
injecting a fuel load into the reactor (7);
expelling synthesis gases from the reactor (7);
the process **characterised by**
regulating an amount of ozone provided to the reactor (7).

12. A process as claimed in claim 11, comprising:

quenching the expelled synthesis gases;
reducing an acid content of the expelled synthesis gases.

13. A process as claimed in any one of claims 11 or 12 comprising:

recirculating a portion of the expelled synthesis gases for returning the expelled
synthesis gases to the reactor (7).

14. A processs as claimed in any one of claims 11 to 13 comprising:

reducing an amount of air associated with the fuel load such that gasification can
occur within a substantially ozone atmosphere within the reactor (7).

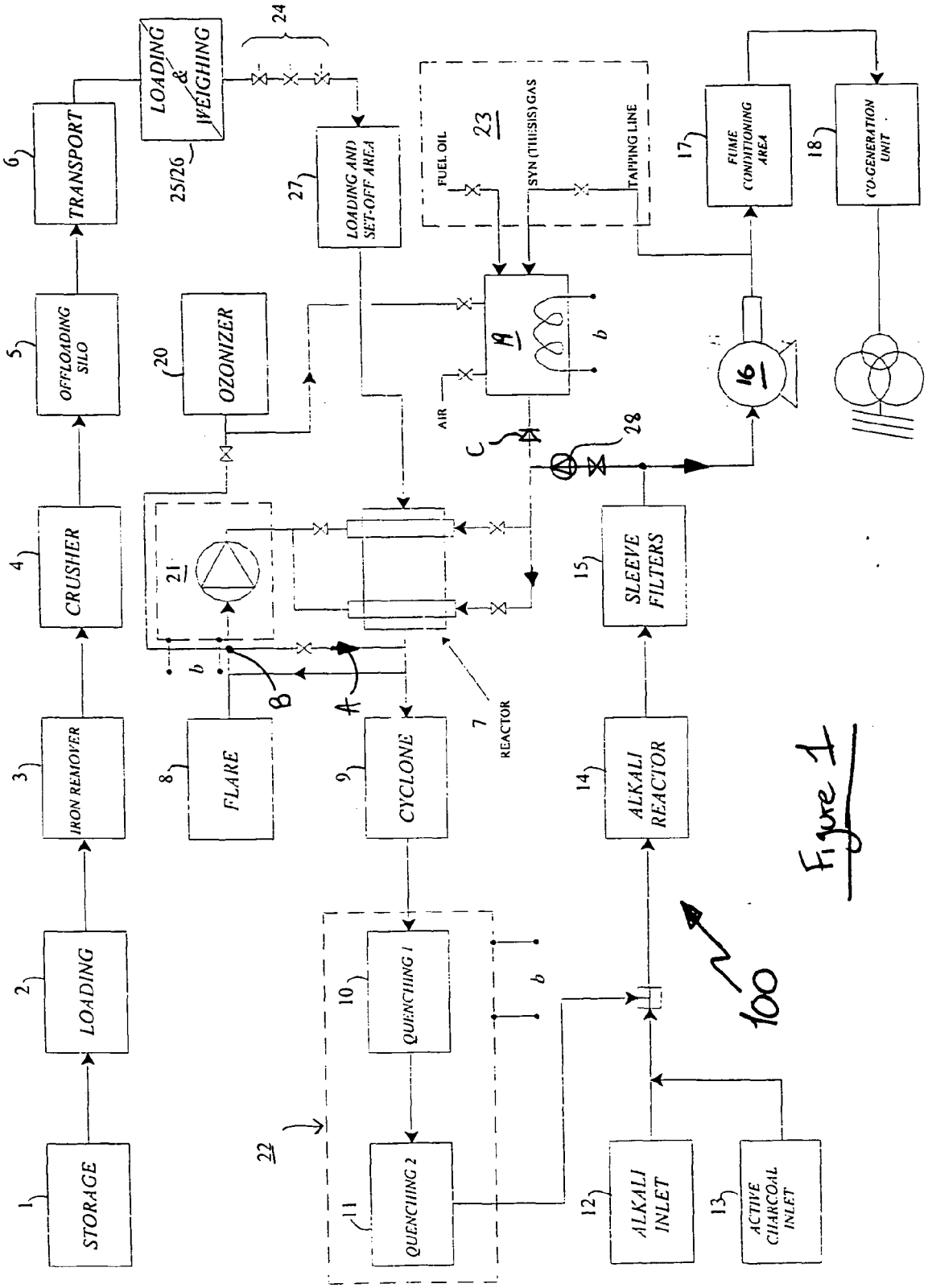

STORAGE
LOADING
IRON REMOVER
CRUSHER
OFFLOADING SILO
TRANSPORT
LOADING & WEIGHING
LOADING AND SET-OFF AREA
FUEL OIL
SYN (THESIS) GAS
TAPPING LINE
FUME CONDITIONING AREA
CO-GENERATION UNIT
OZONIZER
AIR
SLEEVE FILTERS
FLARE
CYCLONE
REACTOR
ALKALI REACTOR
QUENCHING 1
QUENCHING 2
ALKALI INLET
ACTIVE CHARCOAL INLET
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Figure 1

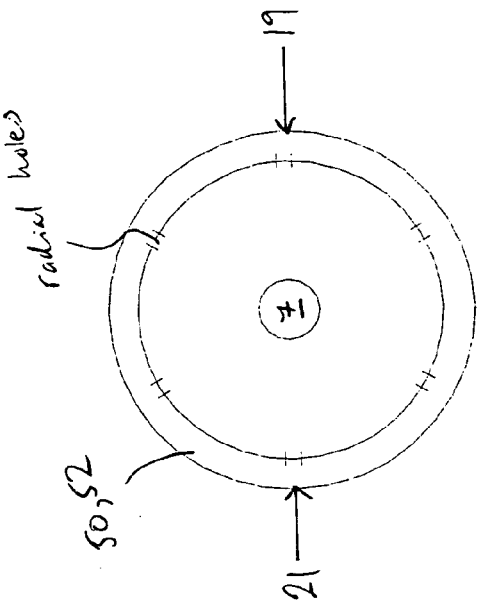


Figure 3

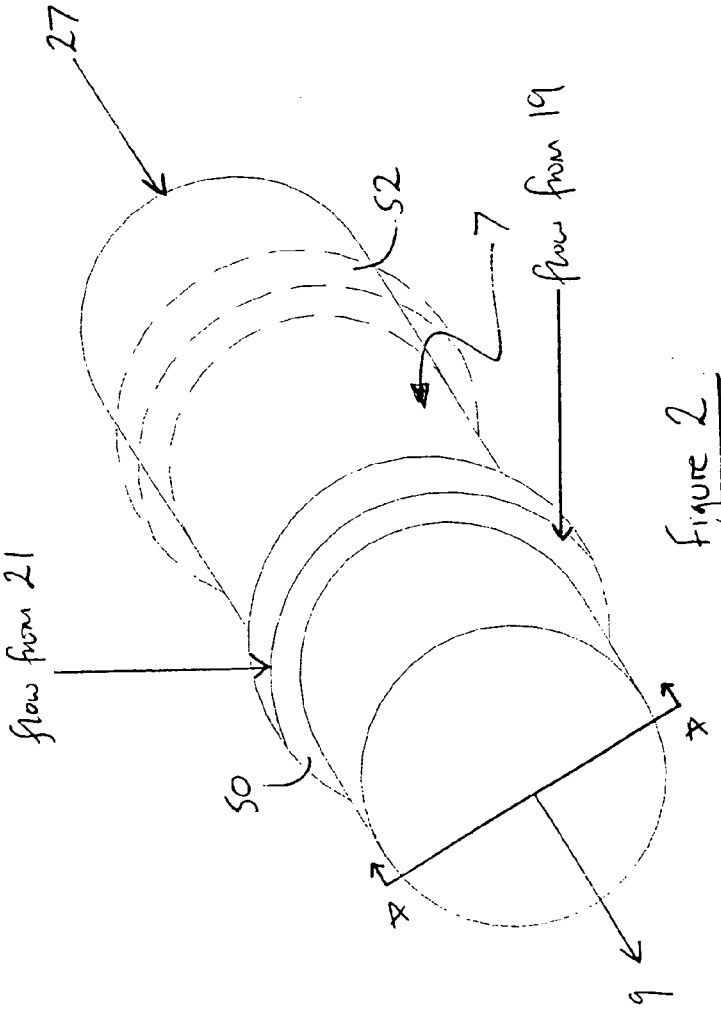


Figure 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 25 7863

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 June 2005	Lapeyrere, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 25 7863

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