 DIRECT-FIRED PRESSURIZED CONTINUOUS COKING

A gasification apparatus includes a gasifier and structure for introducing fuel into the gasifier. A temperature sensor array is arranged vertically on the gasifier for measuring a temperature profile in the gasifier. The temperature profile can be used to determine the rate at which fuel is introduced into the gasifier.

FIG 1


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CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/280,506, filed on November 5, 2009 and U.S. Provisional Application No. ____________, filed on October 19, 2010, both of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] This invention relates generally to pyrolysis gasification.

[0003] Coking processes other than in batch ovens have not been very successful. Batch ovens clearly dominate, but have duration times in the range of 14-30 hours, depending on the difficulty in driving off coal volatiles.

[0004] Continuous direct or indirect fired bulk fed rotating kilns have also been used to pyrolysize wastes, but not successfully. They are awkward and slow and result in unwanted liquid products. The wet gas in such kilns makes cleaning cumbersome and expensive, and they are not pressurized. This method was tried on garbage but was expensive to build and maintain. It has since been refined to a higher level of technology in smaller systems, but is it is still not high pressurized and is still little used.

[0005] Pulverized entrained flow is very fast, taking only seconds. But it is preferred instead to go all the way with 100% gasification, generally for petrochemical production from the gas with slagging ash rejection, i.e., there is no reason to stop pressurized entrained flow gasification at pyrolysis temperatures.
For granular solids, processing direct heating by fluidizing or re-circulating hot sand has been tried, and is as fast as an ½ hour to complete pyrolysis. But these processes are mainly suitable for producing a gas, and are not useful for coke or carbon production. And due to the energy intensiveness and wear from fluidization or re-circulation of sand, they are not in widespread use.

There are miscellaneous indirect heated processes such as large horizontal screws, which have been tried, but are not used in coking coal production.

Another method is the direct-heat plasma torch type, but the torches become a high maintenance/cost item and are expensively electric fired. Also their claims as a suitable pyrolysis process have not been substantiated according to a recent engineering report that has been made public.

In addition, there is significant value added in turning biomass or coal or mixtures thereof into liquid fuels and electricity using a once-through Fischer Tropsch (FT) process. Capital and operating costs to do this, however, have heretofore been excessive when including gasifier, gas cleaning, FT reactor, and electricity generation using tail gases. If atmospheric gasifier based, the gas has to be cooled and cleaned with large volumes for the gases, thus excessively large equipment makes it costly to build and operate. If pressurized gasifiers are used, they tend to be heavy and expensive fully refractory lined energy intensive O2 blown, the O2 alone taking up to 15% of the energy generated. Their high temperature O2 operation results in more CO2 in the gas and requires more gas cooling using steam or water addition, thus more moisture in the gas and the necessity to fully cool and quench the gas to remove this excess water. While some heat is recovered from this process, still more energy loses result. To help make back these losses, this type FT system tends to use more expensive and
efficient cobalt catalysts. But these are also more prone to poisoning and do not inherently push the needed CO shift reaction to H2 as do iron catalysts, thus they require a separate shift reaction apparatus resulting in even more energy losses.

[0010] Thus, there is a need for an improved coking process. There is also a need for a simpler and more cost-effective FT process to make oil and electricity from biomass and coal at whatever ratio the designer selects for each.

SUMMARY OF THE INVENTION

[0011] One embodiment of the present invention provides a coking gasifier using bulk-fed direct-fired pressurized continuous pyrolysis suitable for feeding all manner of carbonaceous materials such as coal, waste tires, and biomass of all kinds to produce coke or carbon and dry gas for IGCC power or petrochemical operations. There are no liquids rejected, just high-quality gas and coke or carbon solids, and done with high productivity and thermal efficiency. The gasses are totally contained during processing so fugitive gas emissions are nil from the pressurized once-through gas flow and gases would generally be directed to an IGCC gas turbine system. The coking gasifier has an upper pressurized combustion chamber that is uniform flow fed carbon material from top mounted duplex lock hoppers. By setting a coke discharge rate, the pyrolysis zones are controlled by a vertical sensor array and initial and final temperature measurement to control the fire amount, and inlet temperature profile and exit gas temperatures of the coking process.

[0012] Many vertical vibrating rods with small spacing, say about 10 inches square, within the mass cross section create many passageways for uniform fast heating kinetics and devolitization to speedup coking and enhance hardening. Coke fines can likely be recycled into the feed to re-bond into hardened coke
product. Or with an extra production step, remanufactured into activated carbon, which can double the value of the carbon produced.

[0013] The coking gasifier has a unique rotating and undercutting helical plate for shearing and unloading the carbonaceous materials, such as coke.

[0014] Also included, to enable feeding many kinds of carbonaceous materials that pyrolyze quickly, is an optional dischargeable ceramic stone grate mass to support the final phase of pyrolysis, or even downdraft gasification reductions. The stone depth can be nuclear gage sensed and controlled and discharged with the carbon, and screened out and recirculated with the upper lock hopper carbonaceous feed.

[0015] The lower coke discharge hopper has large diameter discharge valves with a cooled expanding bubble-tight seal to accommodate discharging large pieces of coke such as needed in steel making.

[0016] The high quality pressurized gas exits through the unloader opening with the coke and discharges from a side mounted pipe in the truncated cone section between the unloader and upper discharge valve and can be used for petrochemicals or efficient IGCC power system.

[0017] Advantages of this embodiment include:

1. Continuous speed controlled lock hoppers to provide for a very uniform feed and process control of the once-through gas and gravity down-flow of material for complete pyrolysus under intense pressure and heat (gas turbine pressures). Operating at a 15 to one typical gas turbine pressure ratio, the coal heat penetration will be faster, and after filtering and
cleaning, the hot gas can be fed directly to a gas turbine IGCC power system or into petrochemical processes.

2. There are no unwanted liquids with this process, just high quality coke or carbon and a dry gas easily hot gas filtered for other uses, and since pyrolysis gases are totally contained throughout the whole process, there are nil fugitive gases releases.

3. The gasifier is pressurized by bleed compressor air off a gas turbine to a direct firing blast in an upper combustion chamber feeding very hot gases down though numerous vertical passageways created by vertical vibrating rods to increase the productivity of coking (devolitization), estimated to be a 2-3 hour process whereas indirect heated modern horizontal coking ovens can take 14-30 hours. Only enough blast as needed to heat and devolitize the coal is used, which is controlled by temperature and flow data from the gasifier.

4. It has thorough computer control over the process by firing and end gas temperature sensors and a vertical temperature sensing array of about 32-thermocouples computer scanned to determine the vertical coking temperature profile to determine if the established coke discharge rate is excessive, which will detract from coke hardness and quality.

5. It has a rugged helical undercutting unloader to continuously and uniformly discharge large chunks of coke than can be used in steel making.
6. So the gasifier can process a wide variety of carbonaceous material other than coal for coke, to support the carbon fines of this material at the end of pyrolysis, the coke unloader zone can be comprised of a level controlled layer of ceramic stones of irregular shape mixed with feed material, the stones accumulating atop the unloader helix to be screened out later to recirculate with the feed. The stones can be irregular shaped to create a maximum space for granular carbon produced which will minimize the recirculation rate. Thus, there is no possibility of the grate plugging as its constantly being replenished and level measured with a surface nuclear gage.

7. There's an efficient and cost effective lower lock hopper to discharge pressurized material to atmosphere with large diameter discharge bubble-tight sliding gate valves with expanding seals capable of high temperatures, and designed to accommodate large sized coked coal for steel making. The smaller upper feed lock hopper valves can be convention dome valves with bubble tight expanding seals, and/or lapped, flat steel slide valves that also have minimal gas leakage.

[0018] Another embodiment of the present invention uses a pressurized compact cross-draft slagging fast-starting gasifier that is primarily water-walled and that has an insulated refractory in the lower burn zone, and operates at much lower temperatures than O2 blown systems. Also, being fully water-walled cooled enables inexpensive and much higher R-value insulation to be applied to
its outside surface, minimizing Btu losses. It's highly desirable to insure coal ash and clinkers are discharged under automatic control in a way that enables the gasifier to operate in a temperature zone that produces a high Btu gas, or, minimizes energy leaving as heat. A lower temperature operating gasifier is desirable while at the same time sintering the ash and clinkers as slag. A 450-psi operating pressure also minimizes system volume and footprint and integrates the gasifier to needed FT and gas turbine pressures. Air-blown also eliminates costly O2 PSA apparatus.

[0019] This embodiment’s unique two-step filtering enables hot gas cleaning at full pressure and temperature as the gas has already been cleaned of ash and carbon particulates with a cyclone, which are recycled back into the gasifier. This minimizes particulates to the agitated bed reactor that removes remaining sulfur and acid gases not removed by dolomite in the gasifier by using low cost quicklime and crushed limestone to form final mass products such as gypsum.

[0020] Because it has nitrogen gas passing through the process (air blown), the fixed bed FT reactor has to be larger in proportion, but then it is less sensitive to over-heating, and there is more iron catalyst surface area to react CO into hydrogen (the shift reaction), as well as make oil.

[0021] There is a low-pressure drop though the whole system, and being well insulated, energy losses are low enabling this invention to approach the generally accepted 70% efficiency ceiling for FT. With woody biomass, this process could yield to 75% of the net Btu energy as oil and 25% as electricity. Some of the electricity generated from tail gases and excess steam is fed back to a motor powered compressor to drive gasification and gas though the system. Either a gas turbine or diesel engine system enables the facility to be located off utility lines.

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Advantages of this embodiment include:

1. A fast starting water walled air-blown cross-draft gasifier has a stirred fuel levelizer and hot bed agitators and integrated lower heating plate to produce slag from clinkers, then flowing into a quench bath, such plate activated by a wall mounted temperature sensor-strip. This controlled slag unloading of ash enables a broader gasifier operating temperature range to maximize gas Btu content while economically recycling ash as slag, effectively eliminating its environmental effects, including the need to land fill ash, while maximizing its value as an aggregate material at nominal extra energy cost of about 50 cents per ton of high ash coal.

2. For final removal of sulfur and acid gases not removed by adding dolomite to the gasifier coal feed, a low cost pressurized hot gas cleaning of a cyclone pre-filtering removes carbon particulate, recycling it back to gasification enabling a follow-on simple stirred hot gas reactor to clean away the remainder, and also remove trace tars. The gas passes on to a hot gas candle filter to remove the reaction mass products prior to gas cooling.

3. A once-through FT reactor filled with least cost iron catalyst operating at about 450 psig and 400 F react the hot gas to oil, and power is made by engines from FT tail gases.
4. The tail gas engine to generate power is speed controlled to match tail gas production to engine volume using electronic frequency control to maintain 60-cycle power.

DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 is a partial elevation sectional view of one embodiment of a direct-fired pressurized continuous coking gasifier.

[0024] FIG. 2 is a partial elevation of a sliding coke discharge valve from the direct-fired pressurized continuous coking gasifier of FIG. 1.

[0025] FIG. 3 is a partial elevation sectional view of another embodiment of a pyrolysis gasifier.

DETAILED DESCRIPTION OF THE INVENTION

[0026] Referring to FIG 1, one embodiment of a direct-fired pressurized continuous coking gasification apparatus 1 is shown. A startup sequence for this apparatus 1 is filling a gasifier 4 with coal and then starting the gas turbine (not shown) with natural gas, which brings the IGCC power system on line. The compressed air bleed 24 from the turbine starts the gasifier top fire in pressurized combustion space 22. In terms of economics, because of the medium Btu quality of pyrolysis gas 8, once treated for impurities and filtered, it is high enough in Btu's to work in just about any gas turbine built today. For example, an efficient five (5) MW gas turbine in an IGCC power cycle would need the gas from about 410-tons/day coals feeding the coking gasifier and could produce up to 165 MWH a day of electricity in IGCC combined cycle. At expected new-nuclear power wholesale rates or $100 MWH, that's about $16,000 a day in power revenue. In the startup, gasifier syngas 8 would be flared until suitably hot to
pass the hot gas filter without tars plugging it (they stay in vapor form). A computer controller (not shown) then ramps up the transition from natural gas to gasifier syngas, while simultaneously discharging coke from the gasifier and feeding fresh coal 3 from the pressurized upper lock hoppers 2. The fire in combustion space 22 and the temperature control system will maintain the needed maximum temperature profile measured by temperature sensor array 21 to maintain production, which means the gasifier is sized volumetrically to achieve the needed coking time and gas production rate that matches the syngas 8 gas to power the gas turbine, i.e. it's the gas turbine and power production that is the limiting condition for system production of coke and that sets the volumetric design of gasifier 4; everything follows from that, including gas cleaning and gas filter size (both not shown as they are part of the power island system). Once the gasifier 4 starts up, it doesn't shut down until a scheduled shutdown.

[0027] Note that in this coking gasifier apparatus 1, fugitive emissions are nil as gases are always enclosed inside the system until they leave as exhaust from a gas turbine or petrochemical system. And since the coking process is now a gasifier, it is generally not classified as an emissions device, thus avoiding the usual criteria associated with an emissions device. It is instead the gas turbine that is judged on emissions. NOx is the primary emissions concern, which is already pre-approved with the turbine by the pre-tests of the gas turbine manufacturer, and which is not related to gasifier 4, as turbine emissions are entirely a function of the turbine combustion design and controls, and not the gasifier. Thus, permitting for coking or general pyrolysis applications with this technology as applied to gas turbines should be greatly simplified.

[0028] Again referring to FIG. 1, coking gasifier apparatus 1 is comprised of a duplex set of continuously feeding top lock hoppers 2 feeding coal or carbonaceous material 3, into level controlled gasifier 4 whereby coke 5 is
unloaded into receiving lock hopper 6, by undercutting unloader helix 7 and whereby all gas 8 generated leaves through transition piece 9 to a typical IGCC power system, not shown.

[0029] Upper lock hoppers are similar in design. Hopper 2 has top valve 10, and lower high temperature valve 12, which could be an Everlasting high temperature valve, and which are buffeted by a small but continuous air flow 13 to help cool the base of the valve, although air flow 13 can be purchased water cooled. Hoppers 2 and 6 have the usual sequencing controls. Upper hoppers 2 full levels are determined by sensor 14, which could be a rotary or vibrating type at this low temperature position. The Bindicator type rotating arm of high temperature level sensor 15 provides a sample-data continuous signal to determine drive speed control of unloader 16 for feed 3 to maintain fuel level 25 in the top zone of gasifier 4. Point level sensor 15 which would be made from non-corroding high temperature metals and cool air purged to withstand the high temperature combustion zone conditions, as would the rotating fuel leveling bar 17. When level 25 reaches a critically low level indicating hopper 2 is empty, the other lock hopper 18 takes over, and lock hopper filling feed conveyor 19 is switched to fill hopper 2 (switching apparatus for conveyor 19 not shown). Or, upper hoppers 2 can have a lower level sensor (not shown) to cause switchover to the alternate feed hopper. Whichever upper hoppers’ switching control method is used, the sample data continuous signal developed from point level sensor 15 controls the lock hopper 2 unloading speed for feed flow 3.

[0030] Based on the control algorithms for final gas temperature measured by sensor 20, vertical temperature sensor array 21 (generally comprised of about thirty two sensors), combustion zone 22 top temperature sensor 23 (generally type K thermocouple sensors), and burner blast 24 from the high-pressure bleed air rate of the gas turbine (not shown) determines the heat and gas flow rate 18
from cavity 22. The top of the carbonaceous fuel feed 3 can be the fuel source for this continuous fire within cavity 22 to meet pyrolysis gas heat flow needs 18 as determined by temperature sensors 20, 21, and 23 to heat the mass 25 to meet production rates set by unloader speed 7. If temperatures are too high, either the fire rate 24 reduces or the unloader rate is increased consistent with the pyrolysis time span needed for the material 25, but this is an optimization sequence determined by the control computer which is in part determined from past runs of the feed material in question. Mass 25 is comprised of fresh fuel zone 26, coal plastic and swelling zone 27, and lower hardening coking zone 28. The steel shell of gasifier 4, at least stainless steel lined, is insulated inside and cast refractory lined over this insulation and gasifier 4 is cooled outside by ½ pipe cooling and then outside insulated (all not shown but well understood in the art). The combustion cavity 22 is very hot, possibly reaching 2500 F, thus the leveling bar 17 driven by gear head 32 are all cooled though rotary joint 33 by circulating fluid flows 34. The final temperature of sensor 20 could be 1200 F, or a total gas temperature drop within the system of 1300 F in this example. To maximize fuel use efficiency to coke, the vertical profile measure of temperature sensor array 21 can determine the optimized decreasing temperature pattern and gas flow (energy level) 18 so that a minimum of coal is used to provide the excess energy over theoretical to heat the mass 25 to final temperature of sensor 20 to fully devolitize and harden mass 25.

[0031] To assure uniform gas flow 18 over the cross section of gasifier 4, passageways for gas flows 18 are created around rows of vibrating rods 35, whereby a row of rods 35 are agitated by one or more agitators 36 (cooled as needed) for each row. For example, the rods 35 in cross section of gasifier 4 represents the center row or maximum number of rods in a row, while rows about ten (10) inches apart on either side would be lower in number of rods to maintain a square spacing of ten (10) inches. As a comparison, indirect heated coking
ovens have spacing of just over two (2) feet between walls, which results in a
great deal of wasted energy and a long heating time of between fourteen (14) to
thirty (30) hours for coking. This apparatus's coking time is anticipated at two (2)
to three (3) hours at most, with the advantages of direct firing and the close
proximity of heat flow passageways noted created by the vibrating rods 35. The
agitators 36 are placed at the top within the fresh fuel zone 26 and above, but
near, the plastic zone 27 so that plastic zone 27 receives well-agitated
passageways around the rods 35. However, the cooled agitators 36 do not see
the full effect of the highest temperature measured by sensor 23.

[0032] There are times when material 25 to be pyrolyzed won't be coal and
will be fast to devolitize in final zone 28 such that the granules of carbon
produced might fall though opening 32 within the base 37 supporting rotating
helix 7 driven by water-cooled variable speed gearhead drive 39. These same
conditions also occur with downdraft gasifiers that have a fine ash, so this
technique applies to downdraft gasifiers as well, such as wood sawdust that
cannot support the material (the reduction zone) in final zone 28 without a grate.
This optional feature of the invention creates a constantly replaced grate that
cannot plug, ideal for long term operations to eliminate plugging problems of
vibrated fixed grates with small particle resulting carbon from pyrolysis, or fine
ash particles from downdraft gasification, for example. Also, in coking or
downdraft gasification, the temperature profile of temperature sensor array 21
can be used to determine if the process is operating correctly, i.e. if the fire zone
in downdraft is in the correct position. If ash is building up too high, the
downdraft fire position it is shifting down by unloading faster by unloader 7. The
profile shape of temperature sensor array 21, including if the profile shift up or
down as in downdraft as noted, can provide the needed signal coking operations
in the same way, i.e. a final temperature occurring too near the lowest point in
final zone 28 would be reason to slow down production or increase heating by the control computer.

[0033] Stones 40 disposed in the bottom of the final zone 28 can be irregularly shaped to create a maximum space for granular carbon produced, and which will minimize the stone recirculation rate. Stones 40 prevent freefall though opening 32 as noted to accommodate a full size range of smaller carbonaceous materials. Stones 40 are level controlled to zone depth 41 whereby a low level nuclear sensor 42 can sense the density of stones 40 to feed back a signal to a separate feed rate apparatus for recirculated screened stones 40 (feed of stones 40 into hoppers 2 not shown) into lock hoppers 2. For some types of pyrolysis carbon 28, an air cooled rotary device of higher torque than 15 to cut though the ash or carbon material might also be acceptable as point level sensor 42, encountering a higher torque hence control signal from encountering stones 40, such torque sensing relay available and providing a closing contact for the control computer as drive motor power conditions change and the motor protected by a slip clutch if stones 40 stops rotation of the sensor piece rotating within material 28. Finer carbonaceous material 25 such as wood will pyrolysize much faster so the time constant for descending shapes 40 (not shown within the zones 26, 27, and 28) will be reasonable enough to make a feedback control of depth 41 from sensor 42 be stable without excessive variation in the depth 41 when there is steady state operation of apparatus 1.

[0034] Lower lock hopper 6 has high temperature bubble tight sliding gate valves 43 and 44, which achieve bubble tight operation from expanding seals, which collapse to open and close these valves when pressures are equalized above and below the closed slide. These seals have cooling means, which is fully described through the use of FIG. 2 along with other aspects of valve design and operation. Also, the expanding rubber seal tube of lower valve 44 is not
subject to direct heat from lock hopper 6 being filled with hot coke 33 as the top
surface of valve 44 can be pre-filled with a layer of water (maintained if needed)
from 45 to cool the upper side position of valve 44 prior to coke 5 again filling
lock hopper 6. Note the emptying sequence of hopper 6 is very fast, so little
discharge coke 5 accumulates atop the slide of valve 43 within the cavity of
transition piece 9 prior to reopening valve 43 to refill hopper 6. When hopper 6 is
discharged or emptied and valve 43 is thus closed, lock hopper 6 first has to be
vented before opening and discharging though valve 44 to suitable gas filtering
and treatment (not shown) as gas flow 46. Similarly, when hopper 6 is cycled,
prior to filling, its pressurized gas also has to be vented as gas flow 46. The
dumping level for hot coke 33 is shown by dotted line 48, as determined by high
level sensor 47, which is similar to sensor 15, but in this instance is a rotary
switch. Both sensors 15 and 47, described above as sensor 42, or like
Bindicator type rotary switch, but of a tougher design.

[0035] Referring to FIG 2, for welded large diameter valves 43 and 44 of FIG
1, the high-pressure outer casing of welded valve 43,44 is comprised of upper
diameter stub pipe 49 and lower diameter stub pipe 50. The outer casing is
further comprised of upper rectangular plate 51 and lower plate 52 with openings
51’ and 52’, and end plates 53 and 54. The cavity for the sealing tube 55 is
formed by inner and outer flat bar circular flat plate extensions 56 and 57
respectively, both attached to top plate 51. The molded extension above tube 55
is attached into a cavity 55’ cut into top plate 51. Rectangular sliding gate valve
plate 57’ is sealed bubble-tight by expanding circular flexible tube 55 with air
pressures 58 and 59 fed into tube 55, sealing between top plate 51 and the top of
sliding gate valve plate 57’. When sliding gate valve plate 57’ is open and the
tube 55 is partially collapsed (it can be held partially open with a spring coiled
inside when molded) with lower air pressure 58/59, cooled air can circulate under
pressure from one side of tube 55 say through air pressure 58, and out through
air pressure 59, preserving the life of sealing tube 55 from exposure to high temperatures when valve 43 is open and hopper 6 is refilling with hot coke as level 33. Or, there are other ways to preserve the integrity and long life of the expanding seal material of tube 55 (not shown) such as by spraying high pressure cooled air or water along the exposed surface of tube 55. Outside stiffeners for the top plate 51 and bottom plate 52 to achieve high-pressure capability are not shown. For large diameter valves, sliding gate valve plate 57' would need to be thick, and to save weight could be a steel shell of composite construction. Note the pressures above and below sliding gate valve plate 57' must be equalized and tube 55 partially collapsed prior to opening or closing sliding gate valve plate 57'. Doctor blade 60 mounted on ½ of the inside of member 56 diameter wipes excess material off the top of slide gate 57 for discharge into the gasifier space as it opens. The cavities of valve 43,44 can be kept clean inside by application of steam or other wash flows though multiple stems of flow 61 and 62, with the debris of flow 62 washed out though opening 63 (valves not shown). Sliding gate valve plate 57' can be designed to last over ½ million cycles, which is mainly due to the life of the operating cylinder (not shown) attached to rod 64 connected to the end of sliding gate valve plate 57' at junction 65. Rod 64 is provided with high pressure seal 66.

[0036] Referring to FIG. 3, an alternative approach to cross draft gasification is described. Such gasifiers have advantages of simplicity, fast starting and low cost. The gasifier of this embodiment removes clinkers using an electrically heated plate to melt and then quench the slag flowing through the plate tap hole. A vertical strip temperature recording profile controls when to melt ash and clinkers by the plate heating. This enables independent temperature operation of the gasifier to maximize H2 and CO production (gas Btu content) while minimizing gas temperature and CO2, thus minimizing heat and pollution to make more oil. The hot gas is also chemically cleaned of sulfur and acid gases.
and is then filtered and cooled before entering the Fischer Tropsch (FT) process to make oil and electricity. It is possible, however, to manipulate the ratio of oil and electricity produced by adjusting the catalyst volume in the Fischer Tropsch (FT) reactor.

[0037] The cross draft gasifier 1 of FIG. 3 has an on-off feed conveyor 2 to periodically fill lock hopper 3, which has bubble-tight type dome valves 4, the same type valves are used in the lower ash lock hopper 5 and filter lock hopper 6. Design and cycling operation of such hoppers is well known, including sequencing controls such as loading with flow from conveyor 2 under atmospheric conditions, and re-pressurizing hopper 3 before dumping the fuel into gasifier vessel 7. The fuel delivered by conveyor 2 can be coal, wood chips, hogged fuel or combination, and preferably under twenty percent moisture. Level sensor 8 determines the fill and dump cycle rate of lock hopper 3 to control filling to plus and minus a fixed amount around level 9. Stirrers 10 with drive 11 and extended shaft 12 have water cooling rotary joint 13 feeding a central pipe to 14 which delivers coolant water down to the bottom of shaft 12 back up the annulus so formed though a second exit opening in joint 13 (details not shown). Leveler bar 15 connected to drive shaft 12 maximizes the useful fuel volumes of vessel 7 while stirrer arms 10 prevent bridging as gravity cause the fuel to flow down to fire zone 16 and on down to ash and clinker zone 17.

[0038] Gasifying vessel 7 is double walled (not shown) with cooling liquid passing between. The liquid space of vessel 7 is filled with ceramic beads to transfer inner wall pressure to the outer wall (not shown). The outer wall absorbs the stress of the approximately 450-psig inner pressures and, since it is liquid cooled, it can be well insulated with low cost insulation on the outer wall of vessel 7. Gasifier steam and air/steam blast water-cooled nozzles 18 (more than one would typically surround the perimeter at a given elevation), and combines with
the small amount of recycle steam 19 from quenching operations of slag 20 in hopper 5. Other steam to nozzles 18 (not shown) for gasifying can come from several areas in the process and the compressed air is from a motorized compressor or tapped from the compressor of a gas turbine utilizing the tail gas from the invention, both sources not shown. Blast nozzles 18 create fire zone 16. Best practices would be an insulated reinforced cast refractory from burner area from blast nozzle 18 elevation down to the ash electrical ash melting plate typically having upper and lower plates 23 and 24, respectively, with electrical heating element 22 between them. This heats clinkers and ash to about 1300C, slagging temperature. A flux (not shown) such as dolomite is added to the fuel, which advantageously lowers molten temperature of slag 20, but which also aids in reacting out sulfur within the gasifier to be removed with slag 20. The life cycle of a MoSi2 or higher temperature electrical elements 22 can be very long lived if installed properly and under continuous operation as in this invention. The pressures on either side of plates 23 and 24 deflect these plate surfaces to a concave condition to efficiently press heating element 22 to the underside of hot top plate 23. To prevent heat loss from the underside plate 24, a dense insulating layer (not shown) is located between heating element 22 and plate 24. The electrical load to create molten slag 20 can be calculated considering the ash content of the fuel, specific heat of the slag, and heat-up temperature difference, and is economical at a cost of about $5/ton slag produced (about 50 cents per ton coal fuel). Once cooled, sintered slag 20 removed by lock hopper 5 is first shredded by grinder 25. The output 26 of hopper 5 is crushed, screened and used as aggregate in applications such as concrete, asphalt, rail ballast, roofing, shingle coating, and glass making. Thus, slagging ash and clinkers 17 enables the slag 20 to be sold at good value as opposed to paying toxic waste landfill rates for clinkers 17 as is.
The profile temperature of multiple sensors in strip 27 will determine if clinkers 17 have built up too high into fire zone 16, and will activate heating element 22 and rotation of stirrers 10 by drive 11. Lock hopper 5 runs to a water level 28 maintained by water level sensor 21, and grinder 25 deposits quenched slag 26 through the upper valve 29 of lock hopper 5. The sequencing operations of such lock hoppers 3, 5 and 6 are well known. An alternative for pressure letdown of the quenched slag 26 is a finer grinding by grinder 25 to feed slag 26 into a dewatering screw or pug mill (not shown) that can resist the pressure of vessel 7 to produce low moisture dewatered slag product ready for recycling as an aggregate.

In gasifier 7, inclined plate 30 creates a void space 31 to collect gas to exit as flow 32 and is maintained at the proper temperature and composition by the ratio of steam to air in the blast 18 and amount of blast and as measured and controlled by input from gas temperature sensor 33 to the main controller (not shown), such that gas 34 feeding the Fischer Tropsch (FT) reactor 35 content is optimized by flue gas sensor 36 monitoring the resulting moisture and gas constituents such as CO and CO2 of gas 34, with sensor data (from sensor 36) fed to the control computer. The controller (not shown) objective is to maximize CO and minimize CO2 and excess steam in the final gas 34, while limiting temperature to an acceptable level for chemical gas cleaning and hot gas candle filtering 37 operations. More steam cools the gas 32 and less air maximizes CO, i.e., CO2 is controlled to about 3%. Measurement data from sensor 36 can optimize steam and air ratios (measurements not shown) blast flow rates of blast 18 so final gas temperature (measured by sensor 33) is optimized to produce a rich gas (maximized Btu content) at varying loads, and the control algorithms to do this are well known and related to gasification chemical reactions.
Referring to gas cleaning, gas 32 enters cyclone 38 to pre-clean it of particulates before reacting out remaining sulfur and acid gases (not removed in the gasifier by dolomite addition to the fuel) in reactor 39. However, prior to passing gas through cyclone 38 at startup, vent and flare burner 40 is opened to burn off low temperature gases with the aid of a pilot igniter (not shown) and until all process elements are heated to normal operating temperatures. In operation, cyclone 38 periodic injector and valve assembly 41 injects cyclone waste ash and carbon through pipe 42 into blast nozzle 18 (dotted line indicates pipe 42 passing down and around gasifier 7), or as an independent flow injection contiguous with nozzle 18 (inlet not shown). The injection frequency of gas 32 can be level controlled from the bottom of cyclone 38, or cycling of assembly 41 set to exceed the maximum possible accumulation of ash in cyclone 38.

Pre-cleaned gas 43 is piped into reactor 39 combining with reactants 44 and 45 dispensed by feeders 46 and 47, respectively. Typically reactant 44 is quick lime and reactant 45 is crushed calcium carbonate. The reactants 44 and 45 are combined in conduit 50 and fed into reactor 39 to form the bed mass 51. The reactor 39 includes stirring bar 52 with drive 53. Quick lime 44 is well known to react out sulfur and acid gases, and the calcium carbonate 45 also reacts out sulfur as gypsum mass product within the temperature range of gas 43. Also, in addition to removing acid gases and sulfur, the hot limestone bed 51 also removes trace tars in the gas 43 before leaving with reactant waste products 54 from bed 51 to enter the candle filter 37. Bed 51 is maintained at about eighteen inches deep or as needed for complete reaction of sulfur to gypsum and is replenished by feeder 47 as needed based on level sensor 49. The rate of feed of quick lime 44 and other reactants needed is calculated based on flows and acid concentration and other contaminates in gas 34 measured by sensor 36, whereby the feedback signal of gas analyzer 36 to the computer controller can optimize or minimize the feed rate of reactant 44 over time. Bed 51 is supported
by pinhole grate 55 and passes the chemically cleaned gas and waste mass products into the base of candle filter 37 by center pipe 56, which is collected by the individual candle filters 57. Waste 54 is rejected via lock hopper 6 as determined by sensor 58. The candle filtered and now chemically and particulate cleaned gas 59 enters gas cooler 60 and leaves as gas 34 controlled at about 400 degrees F, coolant not shown.

[0043] The fixed bed Fischer Tropsch (FT) system is of standard fix bed design. Gas 34 enters the top of fixed bed FT reactor 35 and passes down though tube section 61 that are filled with a typical iron based catalyst to optimize H2 production from CO in gas 34. The water and steam aspects for controlling the temperature of reactions in tube section 61 are not shown but are well known in the art. The oily mixture 62 is throttle discharged by valve 63 based on level sensor 64. Tail hot gas 65 is fed directly to close-coupled engine 66 through backpressure valve 67, which maintains the needed pressure on FT reactor 35 regardless of the blast rate 18. The volume of gas 65 volume passing into engine 66 need not be held constant to balance gas flow 65 supplied to meet the gas volume needs of engine 66 as electronics enable a constant generator frequency to be maintained at a varying speeds of engine 66 to achieve a balanced flow. Thus, to provide maximum flexibility in operations, whether engine 66 is a turbine or diesel, it is preferred that an electric powered compressor (not shown) feed the pressurized air as blast 18. There is excess steam in the process, which can be fed back into the combustor of the gas turbine, or into a steam turbine to enhance power output 68 while reducing turbine NOx emissions in exhaust 69. Thus if steam flow (not shown) is fed back into the gas turbine combustor, it maximizes power 68 from the tail gas and steam generated overall at minimum cost. Water makeup to the turbine and gasifier, steam lines, and all other related apparatus needed for operations are not shown but are well understood in the art. The final stack gases 69 will need
no further cleaning as this was accomplished in gasifier 7 and in the gas cleaning system described previously.

[0044] While specific embodiments of the present invention have been described, it should be noted that various modifications thereto can be made without departing from the spirit and scope of the invention as defined in the appended claims.
WHAT IS CLAIMED IS:

1. A gasification apparatus comprising:
   a gasifier;
   means for introducing fuel into said gasifier; and
   a temperature sensor array arranged vertically on said gasifier for measuring a temperature profile in said gasifier, whereby said temperature profile determines the rate at which fuel is introduced into said gasifier.

2. The gasification apparatus of claim 1 further comprising a plurality of vibrating rods disposed in said gasifier and arranged to define gas passageways therein, and one or more agitators for agitating said vibrating rods.

3. The gasification apparatus of claim 2 further comprising means for cooling said one or more agitators.

4. The gasification apparatus of claim 1 wherein said means for introducing fuel into said gasifier comprises pressurized two lock hoppers mounted above said gasifier.

5. The gasification apparatus of claim 4 wherein each of said lock hoppers includes an inlet valve, an outlet valve and a variable speed controlled unloader.

6. The gasification apparatus of claim 1 further comprising means for discharging coke from said gasifier.

7. The gasification apparatus of claim 6 wherein said temperature profile determines the rate at which coke is discharged from said gasifier.
8. The gasification apparatus of claim 6 wherein said means for discharging coke from said gasifier includes a lock hopper mounted below said gasifier.

9. The gasification apparatus of claim 8 further comprising a variable speed unloader located in said gasifier for unloading coke into said lock hopper.

10. The gasification apparatus of claim 8 wherein said lock hopper includes an inlet valve and an outlet valve.

11. The gasification apparatus of claim 10 wherein each of said inlet valve and said outlet valve includes an expanding seal.

12. The gasification apparatus of claim 11 further comprising means for cooling said expanding seals.

13. The gasification apparatus of claim 1 further comprising a layer of stones disposed in said gasifier for supporting material therein.

14. The gasification apparatus of claim 13 further comprising means for sensing stone level in said gasifier to control recirculation rate.

15. The gasification apparatus of claim 13 wherein said stones are irregularly shaped to create a maximum space for granular material.

16. The gasification apparatus of claim 1 wherein said gasifier defines a combustion zone, whereby said temperature profile determines if said combustion zone is in a correct position in said gasifier.

17. The gasification apparatus of claim 16 said temperature profile is used to control said combustion zone by setting a coke or ash discharge rate.
18. The gasification apparatus of claim 1 wherein said temperature profile determines an optimized decreasing temperature pattern and gas flow to maximize fuel use efficiency.

19. The gasification apparatus of claim 1 further comprising means for cleaning gas discharged by said gasifier.

20. The gasification apparatus of claim 19 further comprising a Fischer Tropsch reactor for processing gas cleaned by said means for cleaning gas discharged by said gasifier.